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REPORT

Dredge Plume Modelling Assessment

Geraldton Port Maximisation Project (PMaxP)

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A5 Capital Dredging Source Term Development – New Tug Harbour

Glossary

Term	Definition
ADCP	Acoustic Doppler Current Profiler
AHD	Australian Height Datum - A common national plane of level corresponding approximately to mean sea level
ARI	Average Recurrence Interval; relates to the probability of occurrence of a design event
Astronomical tidal ranges	Variations in sea level caused by the gravitational forces exerted by the moon and the sun
AUSWAVE	Numerical wave prediction system
Barometric	The measurement of atmosphere pressure
Barotropic	A type of hydrodynamic model that assumes uniform density in the water column
Bathymetry	The study and mapping of the seafloor's topography
Berth/boat pens	Locations where ships may be moored
BHD	Backhoe Dredge
Calibration	The process by which the results of a computer model are brought to agreement with observed data
Capital dredging	The removal and relocation of the natural and previously undisturbed seabed
CD	Chart Datum, common datum for navigation charts - 0.55m below AHD in the Geraldton coastal region. Typically Lowest Astronomical Tide
Coriolis forcing	The effect of the Earth's rotation on moving water
CSD	Cutter Suction Dredge
Diffraction	The bending and spreading of waves
Discharge	The rate of flow of water measured in terms of volume per unit time
Discretisation	The process of transforming continuous variables or functions into discrete counterparts
DoWC	Distributed over water column
Draghead	The part of a dredging vessel that is lowered to the seabed to collect sediment
Dredge plume	Cloud of suspended sediment and debris that forms as a result of dredging activities
Dredging	Underwater excavation
Eddy	A circular movement of water
EIA	Environmental Impact Assessment
Equidistant distribution	Arrangement of points such that they are all equally spaced

ERA5 hindcast	Historical reanalysis data from the European Centre for Medium-Range Weather Forecasts (ECMWF)
FBH	Fishing Boat Harbour
GDA	Geocentric Datum of Australia
H_s	Significant wave height, defined as the average of the highest one-third of wave heights in a wave record
Hydrodynamics	The study of the motion of fluids
In-situ	On site
LAT	Lowest Astronomical Tide
Local sea	A sea state consisting of waves generated by local wind (as opposed to offshore swell)
Longshore currents	Ocean currents that move parallel to the shore
LRE	Long Reach Excavator
Maintenance dredging	The process of removing naturally accumulated sediment to restore the port/channel to its original design depth
MEQMMP	Marine Environmental Quality Management and Monitoring Plan
Metocean conditions	Meteorological and oceanographic conditions, such as waves, currents, and tides.
Micro-tidal	Areas identified as having a small tidal range (0–2 m)
MIKE21 SW	Model that simulates nearshore wave conditions
MIKE3 MT	Model that simulates the advection and dispersion of dredge plumes
Model domain	The geographical area covered by the model
MSL	Mean Sea Level
MWPA	Mid West Ports Authority
Neap tide	Tide with the smallest range in a fortnightly cycle. Neap tides occur when the sun and moon occur at right angles relative to the earth (the gravitational effects of the moon and sun act in opposition on the ocean)
OTR	Other than rock
PMaxP	Port Maximisation Project
Propwash	The turbulent water flow created by a vessel's propeller
PSD	Particle Size Distribution
Reclamation site	An area where dredged material is deposited to create new land
Refraction	The change in direction of waves as they move from deep water to shallow water
Semi-diurnal	A twice-daily variation, for example, two high waters per day
SHB	Split Hopper Barge

Shoaling	Waves that increase in height and decrease in wavelength as they move from deeper water to shallower water
Sigma layers	Vertical layers in a hydrodynamic model that adjust their thickness with the rise and fall of the tide
SSC	Suspended Sediment Concentration
Swell	Regular, long-crested waves generated in a distant storm that have dispersed across the ocean
Temperate carbonate	Carbonate sediments and environments in temperate regions, such as the temperate shelf in southern and southwestern Australia
Tides	The regular rise and fall in sea level in response to the gravitational attraction of the Sun, Moon and Earth
Tombolo	Narrow strip of sand or shingle that connects to an island
T_p	Mean peak wave period
TSHD	Trailer Suction Hopper Dredge
Validation	The process of testing the calibrated model against independent data to confirm its accuracy.

Executive Summary

Introduction

Geraldton Port (the Port), operated by the Mid West Ports Authority (MWPA), is one of Western Australia's most diverse ports catering for a range of products. MWPA is proposing a Port Maximisation Project (PMaxP), which is a major infrastructure project that will modernise and improve the Geraldton Port by maximising the utilisation and operability of the port facilities. PMaxP includes dredging and reclamation to provide additional berths and will progress in stages.

The proposed construction and dredging activities at Geraldton Port are part of the PMaxP. The construction elements (dredge activities) relevant to this assessment will take place at the following locations:

- New Berth 1
  - Maintenance dredging
  - Capital dredging
- Berth 6
  - Capital dredging
- New tug harbour
  - Capital dredging
- Berth 8/Berth 9
  - Capital dredging

This report has been prepared to inform the environmental impact assessment (EIA) and development of supporting technical management plans, as part of the Part IV EP Act approvals process for the PMaxP and support the EIA for the project. The EIA will be prepared to accompany the application for approval of the project, and address the environmental assessment requirements.

The potential impact as a result of the proposed maintenance and capital dredging activities at Geraldton Port was assessed utilising the following calibrated and validated numerical hydrodynamic and wave modelling tools, and suspended sediment transport tool (informed by the calibrated and validated hydrodynamic and wave modelling tools):

1. Wave modelling (using the MIKE21 Spectral Wave module);
2. Hydrodynamic (flow) modelling (using the MIKE21 and MIKE3 Flexible Mesh - Hydrodynamic module); and
3. Suspended sediment transport modelling (using the MIKE3 Mud Transport module).

Establishing both a calibrated and validated wave model and hydrodynamic model, and thereby an appropriate representation of currents in the Geraldton Port area, is critical in providing a sound basis for the suspended sediment transport modelling and simulation of the advection and dispersion of dredge plumes.

Wave Model

A calibrated and validated spectral wave model was developed to simulate nearshore wave conditions at Geraldton Port. The dataset used for the study includes offshore hindcast wind and wave data (ERA5), nearshore measured wave data, tidal level (from IHO), and bathymetric data.

Calibration was conducted at three wave measurement stations, with a focus on optimising the breaking parameter and bottom friction coefficients. These parameters are crucial for accurately modelling wave

transformation in fringing reef environments like Geraldton. The calibrated settings were subsequently validated at four additional wave measurement stations, showing a good agreement between measured and simulated wave parameters. The findings confirm that the spectral wave model configuration is suitable for reliably simulating wave conditions at Geraldton.

Hydrodynamic Model
A hydrodynamic model was developed, calibrated and validated to simulate the flow field at the Geraldton Port. The model performance was examined against measured data at three different locations. The flow field in this area is influenced by complex interactions between wave, tidal, and wind processes. Although the model cannot fully capture all of these natural processes, it effectively simulated the flow field, and the modelled currents near the bed, at mid-depth, and in the surface layer align well with the measurements. Therefore, the model is considered fit-for-purpose to provide the basis of the dredge plume model.

Dredge Plume Model
In order to assess potential impacts resulting from the dredging activities, numerical modelling has been carried out to represent the potential fate of sediments released into the water column through dredging. The modelling simulates the dispersal of suspended sediments by ambient currents as well as the subsequent deposition of sediment suspended by dredging. The modelling simulates sediment suspended by dredging, and therefore shows the impact dredging has on water quality (suspended solids concentration). Ambient suspended sediment concentration (SSC) and associated sedimentation were not simulated, however an assessment of (limited) available measured turbidity data in the vicinity of Geraldton Port was undertaken. The disposal of the dredged material is not a relevant consideration in the dredge plume modelling presented here.

The numerical modelling of suspended sediment plumes generated as part of the proposed dredging activities to modernise and improve Geraldton is divided into three scenarios:

- Scenario 1: Maintenance dredging at the new Berth 1;
- Scenario 2: Capital dredging at Berths 1, 6 and 8, as well as Berth 1 and Berth 6 only; and
- Scenario 3: Capital dredging at the New Tug Harbour (NTH).

MWPA have indicated that maintenance dredging at Berth 1 (Scenario 1) and capital dredging at the NTH (Scenario 3) will take place by means of a trailer suction hopper dredge (TSHD). In order to minimise the environmental impact of Scenario 2 (with the longest duration), RHDHV and an appointed dredge expert have proposed undertaking capital dredging at Berths 1, 6 and 8 by means of a backhoe dredge (BHD). The plume modelling of the three scenarios has been based on these equipment assumptions.

MWPA have indicated that the months in which dredging of the scenarios will commence are best indicators at this stage, as follows:

- Scenario 1: January (2026) – dredge duration approx. three (3) days;
- Scenario 2: April start (2026 or 2027) - dredge duration approx. 32 weeks; and
- Scenario 3: May (2027) - dredge duration approx. seven (7) days.

Laboratory Settling Velocity Investigations
Settling velocity is an input parameter required for the numerical modelling and it varies depending on site-specific parameters of the sediment/rock and water. Rather than adopting values calculated empirically or from published literature, the settling velocity was established from a laboratory investigation of the actual material to be dredged (refer **Appendix A1**).

Ambient Suspended Sediment Conditions

The ambient suspended sediment concentration for the Geraldton Port region is of particular relevance to this project due to the project's dredging requirements and the potential for influence on sensitive ecological habitats. An ambient model was set up for this investigation, however reproducing background SSC in a model environment at Geraldton has proven to be very challenging. As a result, it was decided to exclude modelled ambient SSC from this assessment.

Limited turbidity (which is typically used as an indicator of SSC) and TSS data is available from various sources and was reviewed and assessed (refer the Baseline Turbidity/TSS Data Review memo in **Appendix A2**) in order to gain an insight into ambient SSC conditions.

Turbidity data collected within Champion Bay, in the vicinity of the proposed dredging and modelled dredge plume, was used for the analysis herein.

The 2024 continuous turbidity monitoring dataset was adopted for locations within Champion Bay and considered adequate for the purposes of developing a baseline. A statistical summary of turbidity and TSS results for the 10-hour rolling average and daily (24-hr) average results is provided (among other output) which generally shows low baseline turbidity/TSS (median TSS in the order of 2mg/L) if not influenced by the breakout of the Chapman River.

Model Output

A range of outputs have been prepared for the above dredge scenarios, presenting excess sedimentation and SSC due to dredging. The modelled SSC is excess SSC above the ambient (or background) concentration.

Percentile maps

The SSC model results due to dredging have been processed to calculate the spatial percentile exceedance maps over the:

- duration of the dredging (Scenario 1, 2 and 3); and
- duration of dredging + one week (Scenario 1 and 3 - due to their short durations the percentile maps may look different for a time after dredging has ceased, due to the way the dredge plumes advect and disperse).

The following percentile maps have been produced:

- 50th percentile, showing the SSC value that is predicted to be exceeded for 50 per cent of the time during the dredging, or 84 hours in a week; and
- 95th percentile, showing the SSC value that is predicted to be exceeded for five per cent of the time during the dredging, or 8.4 hours in a week.

Time-series

Time-series plots of the dredging SSC provide an understanding of the relative influence of the SSC from dredging on water quality. The following locations were identified within the study area to provide a greater resolution as to the influence of dredged material on water quality:

- Alongshore up to approximately 20km north of the project site;
- At nominated sensitive receptor (seagrass) locations;
- On arcs emanating from the various dredge locations; and
- Near local areas of interest (Town Beach, Batavia Coast Marina).

Impact maps

For the purpose of this assessment, critical 'impact' maps for sedimentation and SSC as a result of dredging have been prepared for Scenarios 1, 2 and 3 based on guidelines provided in EPA (2016):

- Zone of influence/moderate impact/high impact for sedimentation; and
- Zone of influence/moderate impact/high impact for SSC.

This output showed the following:

- Scenario 1 (Berth 1 maintenance dredging – duration approx. 3 days)
  - The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berth 1 maintenance dredge area and is within the project development envelope; and
  - Impact due to SSC is limited to a 'zone of influence'.
- Scenario 2 (Berths 1, 6 and 8 capital dredging – duration approx. 32 weeks)
  - The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berths 1, 6 and 8 capital dredge areas and is within the project development envelope; and
  - The zone of high impact due to SSC is confined within Geraldton Port area. Town Beach and the Batavia Coast Marina are zones of moderate impact.
- Scenario 3 (New Tug Harbour capital dredging – duration approx. 7 days)
  - Impact due to sedimentation is limited to a small 'zone of influence' inside the New Tug Harbour; and
  - Impact due to SSC is limited to a 'zone of influence'.

It is noted that the ZoHI includes the direct disturbance (dredge) footprint, in addition to the ZoHI areas due to sedimentation and SSC.

1 Introduction

1.1 Background

Geraldton Port (the Port), operated by the Mid West Ports Authority (MWPA), is one of Western Australia's most diverse ports catering for a range of products. MWPA is proposing a Port Maximisation Project (PMaxP), which is a major infrastructure project that will modernise and improve the Geraldton Port by maximising the utilisation and operability of the port facilities. Geraldton Port will play an important role in enabling emerging industries, new customers with a diverse product mix, and significant growth forecasted within the Mid West region, over the next decade (MWPA, 2024).

1.2 Project Location

Geraldton is located on the Western Australian coastline around 400km north of Perth. The study area considered in the present modelling study extends approximately 150km along the coastline north and 125km south of the Port (refer **Figure 1-1**).

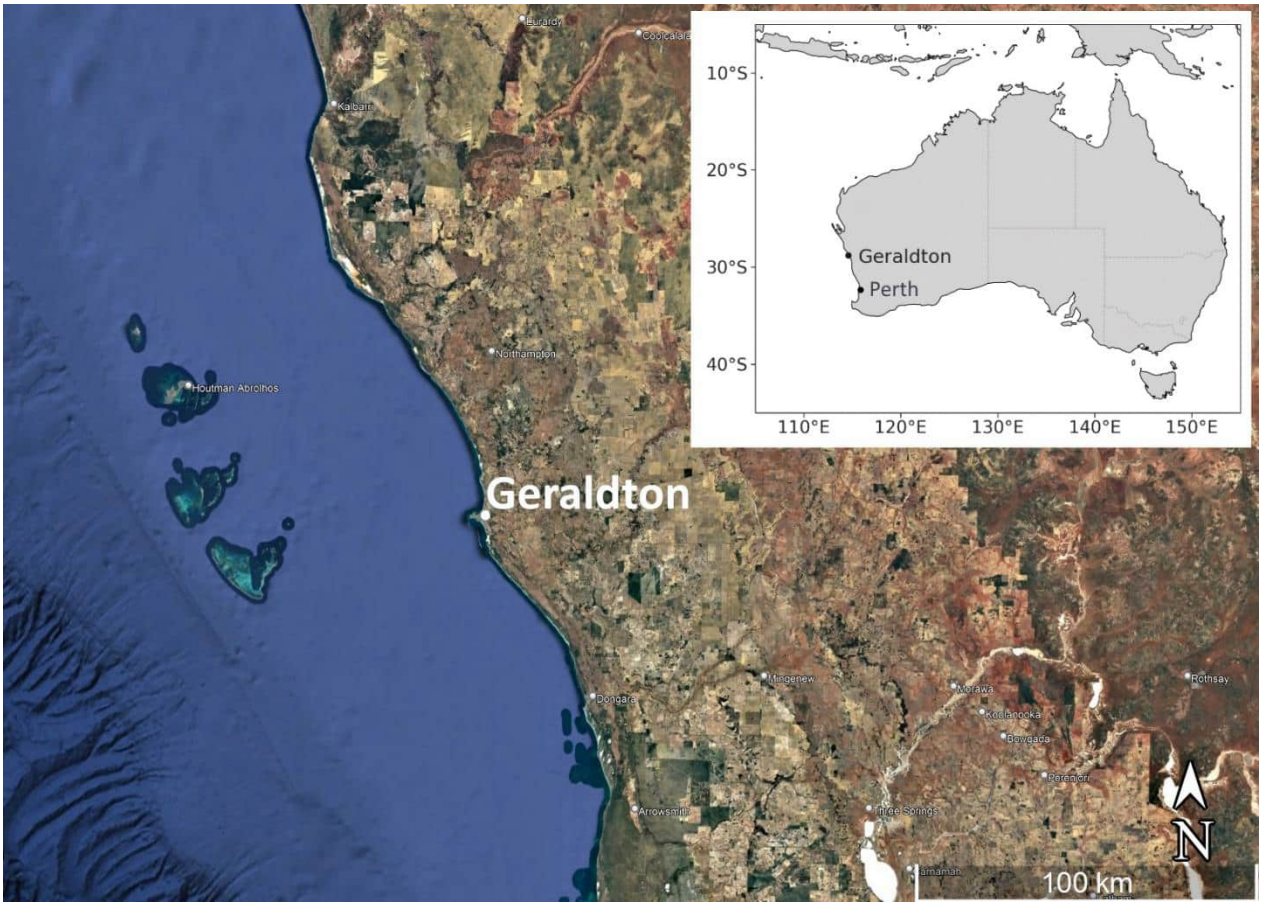


Figure 1-1: Project location

1.3 The Project

PMaxP includes staged dredging and reclamation to provide additional berths. The environmental approvals process is currently underway for PMaxP upgrade works for (new) Berth 1, the new tug facility

and Berth 6. While the delivery of Berth 8/Berth 9 is not part of the PMaxP construction scope, environmental approvals will also assess the opportunities for future construction of Berth 8/Berth 9 (MWPA, 2024). It is noted that Berth 8/Berth 9 will be referred to as Berth 8 from this point onward.

An EIA is an orderly and systematic process to evaluate a proposal (including its alternatives) and its effects on the environment. In Western Australia (WA), an EIA is regulated under Part IV of the *Environmental Protection Act 1986* (EP Act). The PMaxP proposal footprint and development envelope details are presented in **Figure 1-2**.

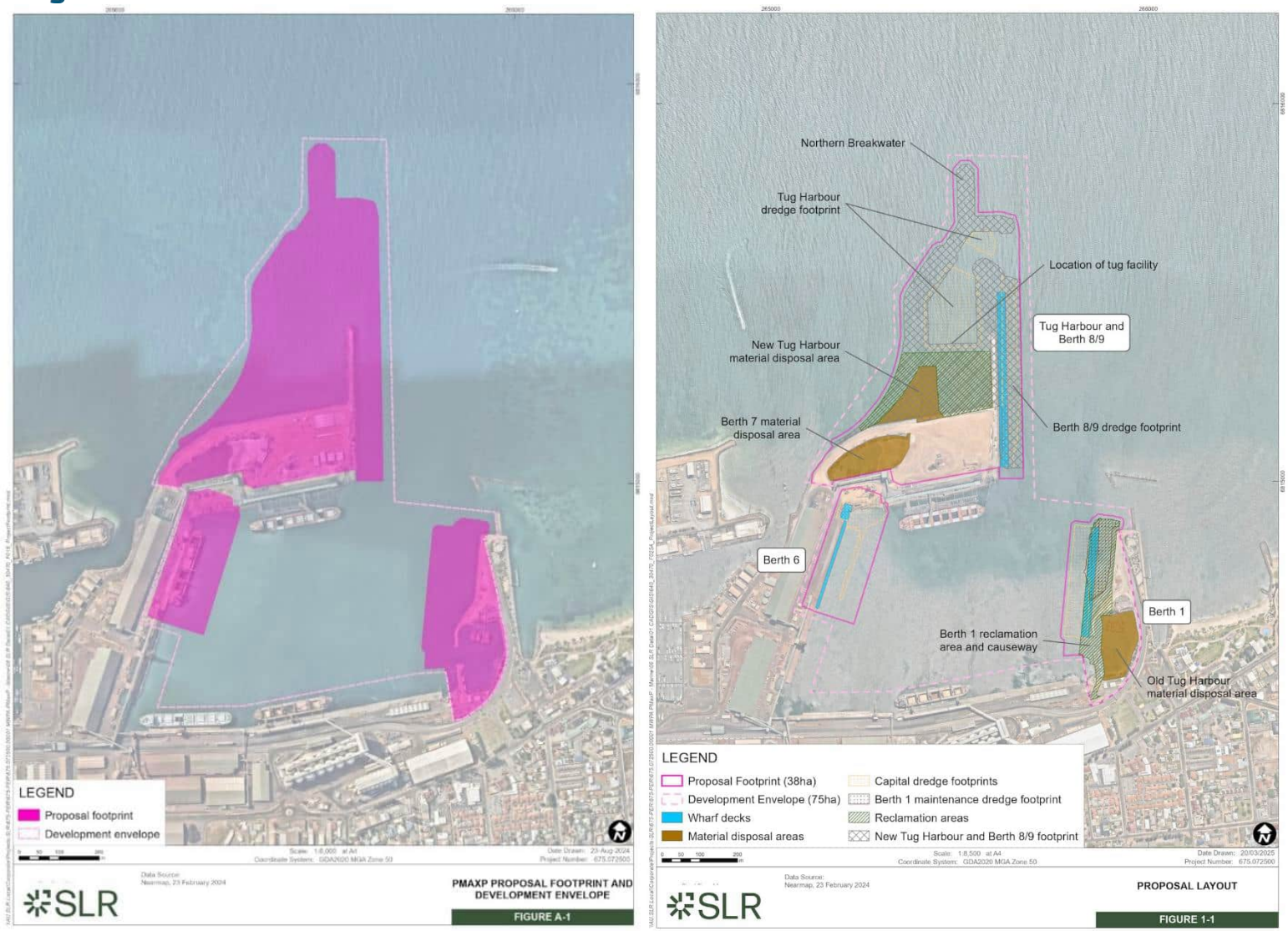


Figure 1-2: PMaxP proposal details (source: SLR, 2021)

1.4 Key Dredging Activities

The proposed dredging activities at Geraldton Port are part of the PMaxP project (refer **Section 1.1**). The proposed expansion of Geraldton Port to accommodate the new tug harbour and Berth 8/Berth 9, comprising rock revetments and marine construction works, is presented in **Figure 1-3**. The construction elements (dredge activities) relevant to this assessment will take place at the following locations:

- New Berth 1 (refer **Figure 1-4** – left pane)
  - Maintenance dredging
  - Capital dredging
- Berth 6 (**Figure 1-4** – centre)
  - Capital dredging
- New tug harbour (**Figure 1-4** – right); and
  - Capital dredging
- Berth 8 (**Figure 1-4** – right)
  - Capital dredging

The Berth 1 maintenance dredging will be completed prior to commencement of construction of the proposed expansion of Geraldton Port (refer **Figure 1-3**). All capital dredging will occur post the construction of the new tug harbour seawall of Geraldton Port.

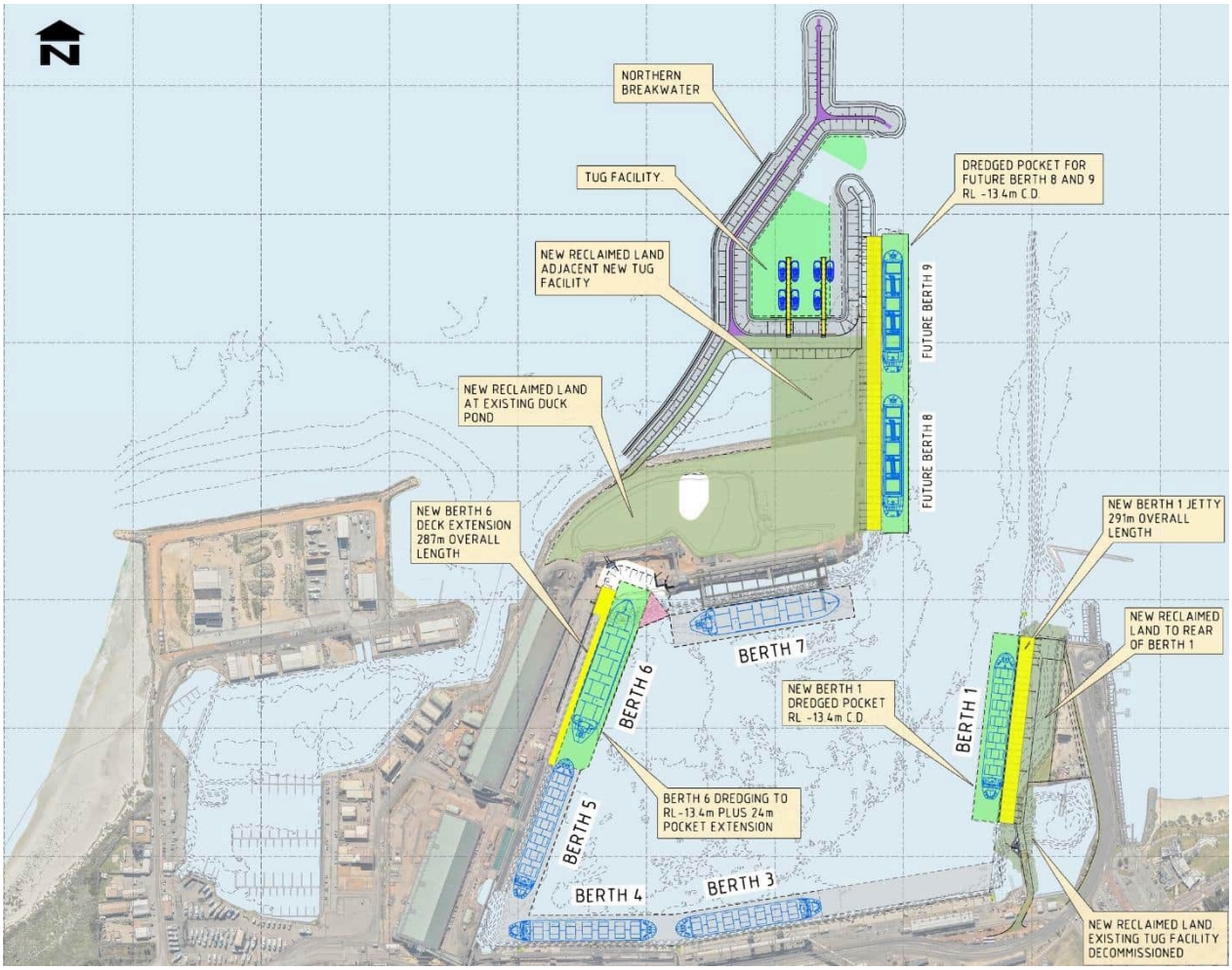


Figure 1-3: Proposed PMaxP works



Figure 1-4: Proposed berths (black outlines) and dredging works (capital in white, maintenance in grey) at new berth 1 (left pane), berth 6 (centre) and new tug harbour/berth 8 (right)

1.5 Purpose of this Report

This report has been prepared to describe the characteristics of plumes that could be generated due to the dredging activities required as part of the PMaxP and inform the development of the Marine Environmental Quality Management and Monitoring Plan (MEQMMP) as part of the Part IV EP Act approvals process for the PMaxP and support the EIA for the project. The EIA will be prepared to accompany the application for approval of the project, and address the environmental assessment requirements.

This report specifies impacts to specific water quality parameters associated with dredge requirements for PMaxP. It provides:

- a description of the existing marine environment based on available information and recently collected, project specific, hydrodynamic, wave and water quality data;
- a summary of the establishment and calibration of the two-dimensional (2D) and three-dimensional (3D) numerical models used in the impact assessment;
- a summary of the dredging methodology and assumptions as they relate to the dredge plume modelling; and
- results of the predictive modelling undertaken to assess potential impacts of dredging on SSC in the Geraldton Port area for the following activities:
    - maintenance dredging at Berth 1; and
    - sequential capital dredging at Berth 1 and Berth 6;
    - sequential capital dredging at Berth 1, Berth 6 and Berth 8; and
    - capital dredging at the New Tug Harbour.

1.6 Report Structure

The report herein is set out as follows:

- **Section 2** describes the existing environment (e.g., wind and wave climate);
- **Section 3** outlines the overall modelling approach utilised in this study;
- **Section 4** summarises the wave model developed to provide wave-driven currents for sediment plume transport;
- **Section 5** summarises the hydrodynamic model developed to provide conditions for sediment plume transport;
- **Section 6** details the dredge plume modelling and presents methodology, results and key observations for the simulation of the representative dredge programmes that involve a combination of maintenance and capital dredging at Geraldton Port as part of PMaxP;
- **Section 7** provides a summary and conclusion; and
- **Section 8** presents the references utilised in this report.

2 Description of the Existing Environment

2.1 Site Description

Geraldton Port (refer **Figure 2-1**), located 400km north of Perth, enables the facilitation of trade for the Mid West region, exporting a variety of products including iron ore, grains, mineral sands, non-mineral sands and mineral concentrates. The Port also imports fuel, fertiliser and break-bulk cargo.



Figure 2-1: Aerial view of Geraldton Port

MWPA operates seven commercial berths and associated marine assets including the harbour basin and channel, as well as the Geraldton Fishing Boat Harbour (FBH). Berths 1 to 6 are owned, operated, and maintained by MWPA. Berth 7 and the ship loading infrastructure are owned, operated, and maintained by Karara Mining. Further details of each berth are as follows:

- Berth 1 and Berth 2 are accessed by naval vessels, fuel bunkering, and other assorted vessels for mooring;
- Berth 3 ship loading infrastructure is owned, operated, and maintained by Co-Operative Bulk Handling (CBH) for the export of grain. CBH also owns and operates a train unloader within the Rail Terminal. Berth 3 is also accessed from time to time for cruise ship visits;
- Berth 4 and Berth 5 and ship loaders are owned, operated, and maintained by MWPA. These berths are primarily utilised for the export of iron ore, industrial minerals, mineral concentrates, and mineral sands.
- Berth 6 is accessed for fertiliser, minerals, fuel imports, cruise ship visits, mineral exports and break-bulk cargo; and
- Berth 7 is accessed for the export of iron ore.

In addition, MWPA manages Geraldton's Fishing Boat Harbour supporting the region's largest fishing industry (primarily western rock lobster) and is home to Geraldton's boat building and maintenance precinct.

2.2 Bathymetry

Reef System

The shoreline within the study area is protected by the Point Moore reef system and extensive limestone platforms that exist along the shoreline in most areas (an impression of the reef system from a 2015 chart is shown in **Figure 2-2**). This stretch of the shoreline is disrupted by outcrops of limestone reef close to or adjacent to the shore (M P Rogers, 2015)

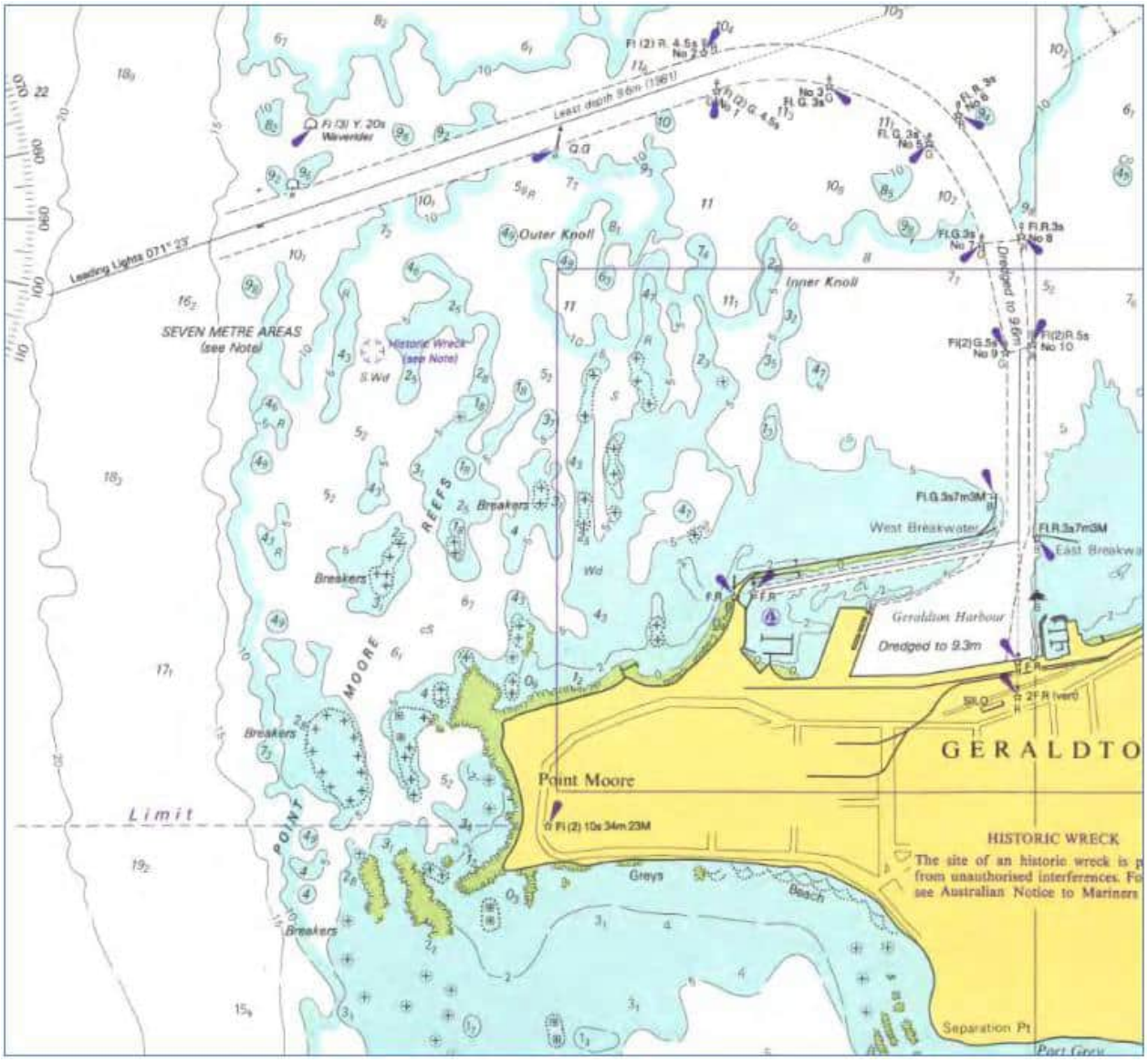


Figure 2-2: Impression of the reef system (in blue) for the Geraldton area – port layout not representative of current configuration (source: M P Rogers, 2015)

2.2.1 Level Datum

All elevations in this study are in metres and referenced to the Australian Height Datum (AHD), unless noted otherwise. AHD is approximately equivalent to Mean Sea Level (MSL) at present. MSL is 0.55 metres above Lowest Astronomical Tide (LAT).

2.2.2 Surveys

For the wider Geraldton area, the bathymetry data from the 2020 RHDHV wave transformation modelling study (RHDHV, 2020), conducted as part of the Geraldton Coastal Processes Study (RHDHV, 2023a, 2023b) was utilised. More recent (and hence more representative) bathymetric data in the immediate vicinity of the project site was obtained from Oceanum (refer **Section 4.3.4**). An overview of the bathymetry in the Geraldton area is presented in **Figure 2-3**. Important features include the reef system as described above, providing a degree of protection from waves, as well as the shipping channel for Geraldton Port.

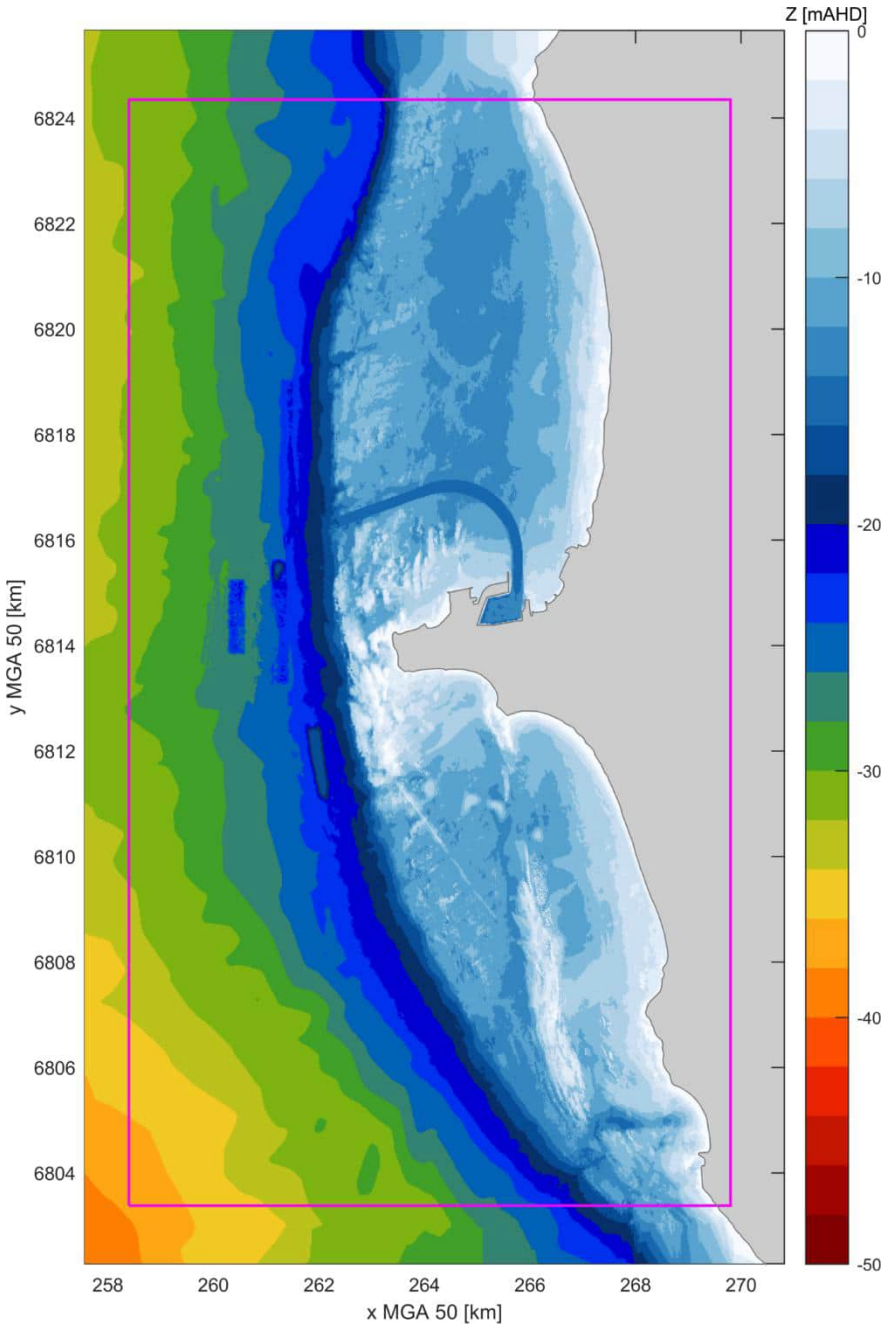


Figure 2-3: Bathymetry in the Geraldton area (RHDHV, 2024b)

2.3 Metocean Conditions

Geraldton is part of a micro-tidal swell wave dominated coast, at the northernmost extreme of temperate carbonate production in the marine waters of Western Australia. Geraldton experiences a Mediterranean-type climate and on rare occasions, more likely in late summer or early autumn, a tropical cyclone can affect the coast as it tracks in a southerly direction.

2.3.1 Water Levels

Astronomical tidal planes at Geraldton Port (refer **Section 5.3.1** for location) are shown in **Table 2-1**. The tidal range is typically approximately 0.8 m during spring tides (MLLW to MHHW) and 0.4 m during neap tides (MHLW to MLHW), making the coast micro-tidal. Owing to the relatively small tidal range, low barometric pressure and wind effects can cause storm surges such that water levels exceed one metre above the predicted astronomical tide level during storm events. The highest recorded water level of 2.1m CD or 1.5m AHD in 1970 was associated with Tropical Cyclone Glynis.

Table 2-1: Tidal levels at Geraldton. Note: Australian Height Datum (AHD) is 0.55m above Chart Datum (CD) at Geraldton

Tidal Plane	Elevation (m CD)	Elevation (m AHD)
HAT	1.2	0.6
MHHW	1.0	0.4
MLHW	0.8	0.2
MSL	0.6	0.0
MHLW	0.4	-0.2
MLLW	0.2	-0.4
LAT	0.0	-0.6

The time series of daily and monthly-average total and residual water levels at Geraldton Port over the period 2008 to 2019 are shown in **Figure 2-4** and **Figure 2-5**. Seasonal changes in total water level suggest a seasonal component to the astronomical tide that affects mean water level on a monthly basis. Residual water levels suggest both seasonal and longer-term variations in monthly averages.

In addition to the astronomical tide, a number of other non-astronomical processes can influence water levels in the Geraldton region:

- During storm events, low barometric pressure and wind effects can cause surges to exceed one metre above the astronomical tide level;
- Sea level oscillations along the Western Australian coastline with periods in the range of 10 to 40 minutes are caused by resonance of local waters in the basin between the shoreline and a submerged reef chain located approximately 5km from the shore. Hydrodynamic modelling of the sea level oscillations indicates the presence of oscillating currents near the coast (Allison *et al*., 1980); and
- The Western Australia coast is at risk from tsunamis, the most recent event was the Sumatran Tsunami (26th December 2004). During this event, Geraldton experienced the largest impact to water levels, with residual tidal amplitudes up to 1.5m registered. This combined with a peak tide resulted in a water level 0.6 m greater than had previously been recorded. At the northern suburbs

of Geraldton (Bluff Point and Drummond Cove) the corrected tsunami run-up estimates were between 1.4 and 1.9m.

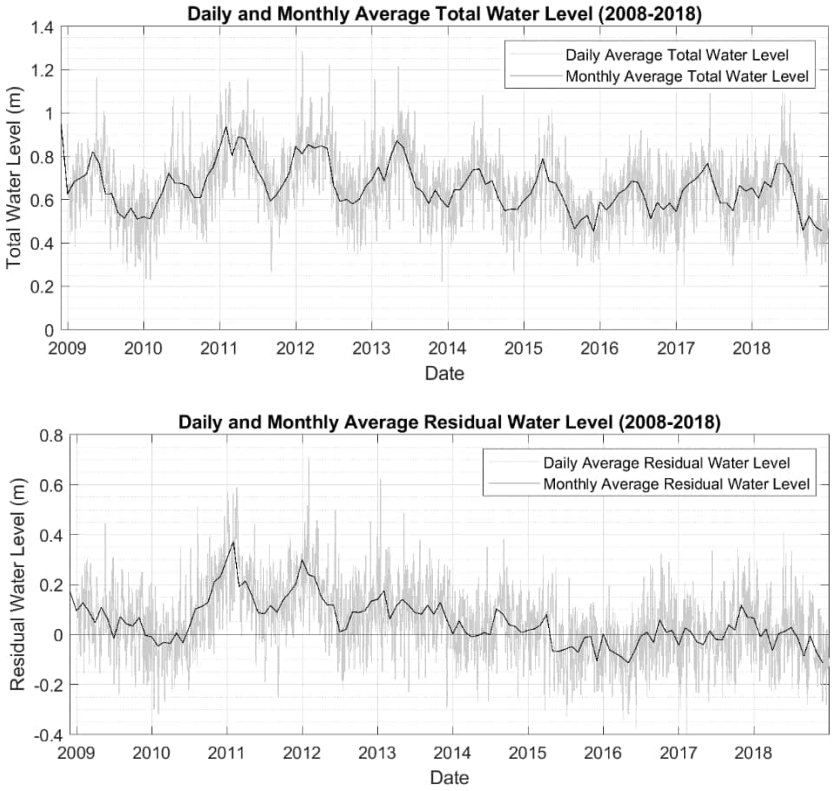


Figure 2-4: Time series of total (tidal and non-tidal processes measured with respect to Chart Datum – top pane) and residual (non-tidal processes only – bottom pane) water levels as measured at Geraldton Port tide gauge (2008 – 2019)

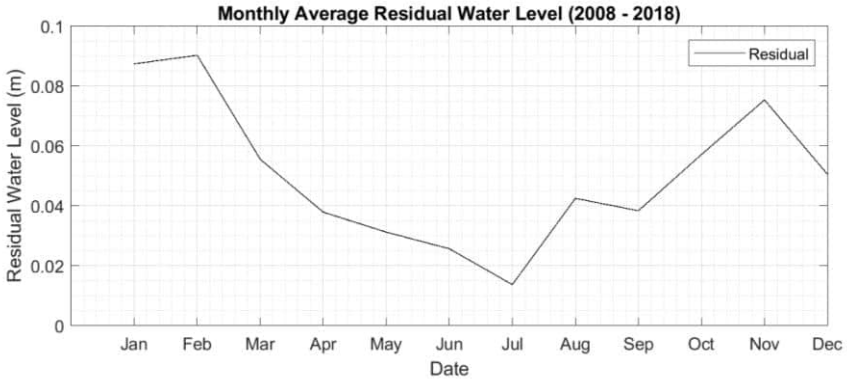


Figure 2-5: Monthly-average residual water levels during the calendar year at Geraldton tide gauge (2008 – 2018)

2.3.2 Wind

Approximately 20 years of Geraldton Port wind data (February 2004 to September 2023) was provided by MWPA from their weather station located at the offshore end of the navigation channel (Outer Channel or Beacon 1). The wind data was processed to help improve an understanding of the wind climate. A wind rose of wind speed and direction and joint frequency table are shown in **Figure 2-6** and **Table 2-2**, respectively.

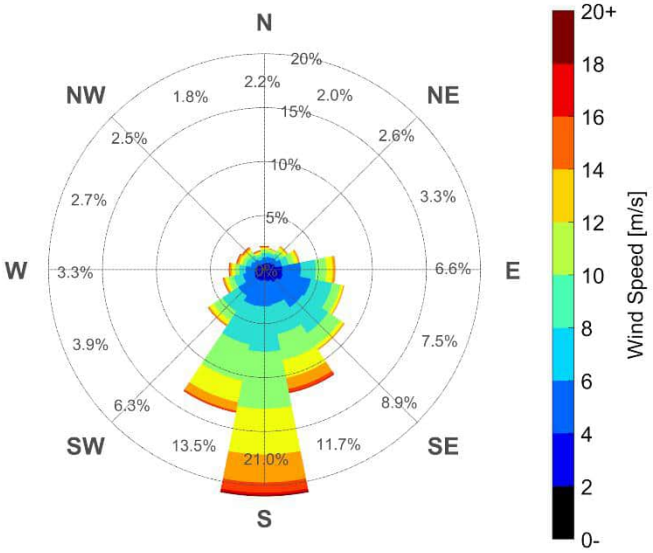


Figure 2-6: Wind rose for wind speed and direction at Geraldton Outer Channel (Beacon 1). Numbers on the radial axis show the % frequency of occurrence

The wind rose and joint frequency table show that southerly winds occur the most frequently and are also the strongest, winds from this direction occur at least twice as often as winds from any other direction. Winds from the south-south-west through to the east occur for approximately 70% of the time, with wind speeds only exceeding 14 m/s for less than 2% of the time for that sector.

The wind roses showing seasonal wind conditions (**Figure 2-7**) demonstrate that winds from the south dominate in the spring, summer and autumn, while in Winter winds from the east to south-east dominate in terms of duration while winds from the west to north dominate in terms of speeds.

Table 2-2: Joint frequency table of wind speed (m/s) against direction at Geraldton Outer Channel

		Wind Direction [degTN]																	
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		
Wind Speed [m/s]	0-2	0.15%	0.16%	0.20%	0.24%	0.26%	0.22%	0.18%	0.15%	0.15%	0.16%	0.20%	0.17%	0.17%	0.16%	0.15%	0.14%	2.85%	100.00%
	2-4	0.43%	0.48%	0.61%	0.78%	1.38%	1.52%	1.21%	0.96%	0.84%	0.90%	0.90%	0.78%	0.69%	0.51%	0.45%	0.38%	12.82%	97.15%
	4-6	0.53%	0.58%	0.53%	0.63%	1.71%	2.65%	2.81%	2.19%	2.41%	2.38%	1.82%	1.09%	0.87%	0.62%	0.53%	0.43%	21.79%	84.33%
	6-8	0.43%	0.35%	0.43%	0.64%	1.40%	2.00%	2.89%	2.80%	4.20%	3.62%	1.77%	0.86%	0.61%	0.47%	0.48%	0.33%	23.28%	62.54%
	8-10	0.29%	0.24%	0.41%	0.51%	0.98%	0.78%	1.37%	2.45%	5.28%	3.42%	0.99%	0.51%	0.40%	0.38%	0.38%	0.24%	18.63%	39.26%
	10-12	0.19%	0.11%	0.28%	0.37%	0.61%	0.28%	0.35%	1.70%	4.25%	2.05%	0.45%	0.31%	0.31%	0.26%	0.26%	0.15%	11.93%	20.63%
	12-14	0.10%	0.05%	0.12%	0.14%	0.20%	0.07%	0.10%	1.03%	2.59%	0.81%	0.15%	0.15%	0.17%	0.19%	0.16%	0.10%	6.15%	8.70%
	14-16	0.05%	0.02%	0.01%	0.02%	0.03%	0.01%	0.02%	0.33%	0.95%	0.16%	0.03%	0.05%	0.07%	0.07%	0.07%	0.04%	1.92%	2.55%
	16-18	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.21%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.42%	0.63%
	18-20	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.14%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.21%	0.21%
		2.20%	2.01%	2.61%	3.33%	6.57%	7.54%	8.95%	11.67%	21.02%	13.52%	6.32%	3.93%	3.31%	2.67%	2.51%	1.84%		

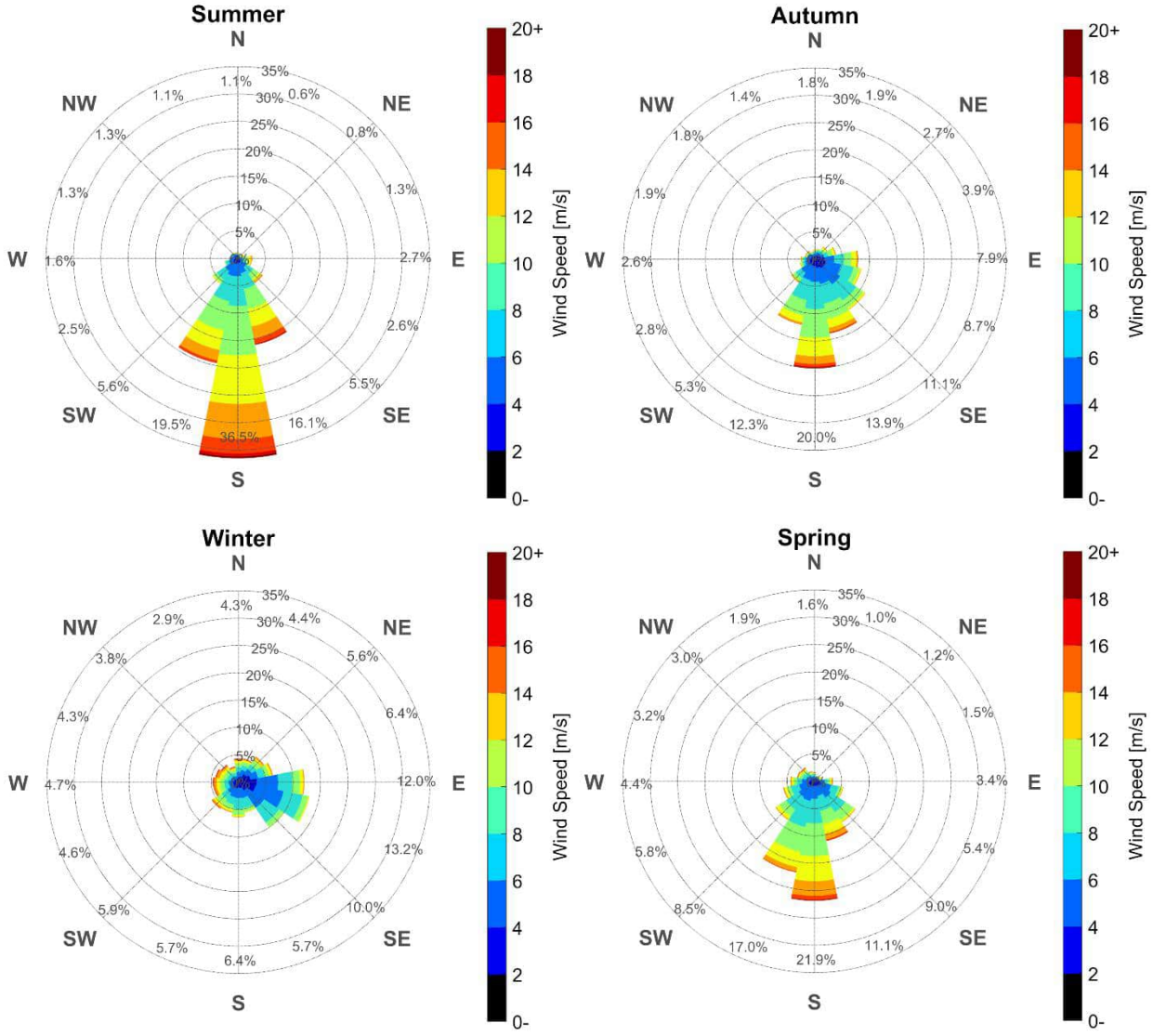


Figure 2-7: Seasonal wind roses for speed and direction at Geraldton Outer Channel. Numbers on the radial axis show the % frequency of occurrence

2.3.3 Currents

Depth-averaged currents at the Geraldton outer channel Beacon 1 (refer **Section 4.3** for location) are shown below for both the total current (**Figure 2-8**) and the residual current after the removal of tidal components (**Figure 2-9**). Currents are predominantly flowing northward (current directions refer to the direction towards which the current is flowing). Non-tidal residual currents are strongly correlated to wind speed and direction which occur mostly from the south (refer **Section 2.3.2**). The currents display a seasonal variation as shown in **Figure 2-10**. The currents are predominantly towards the NNE in summer, autumn and spring with a shift to a typically quite strong SSW current in late Autumn and through winter. **Figure 2-11** provides a sample of typical analysed data indicating the strength of the correlation between wind speed and direction and non-tidal residual currents. This means that currents, other than due to the tide, are largely driven by wind.

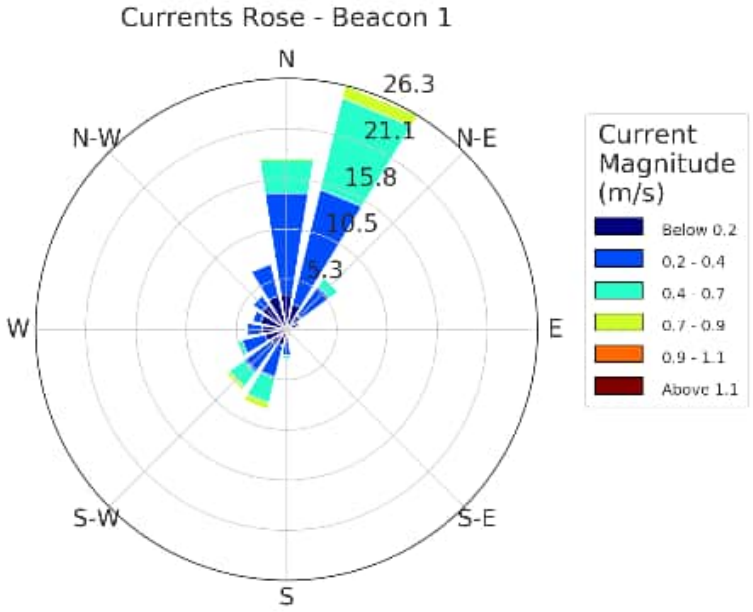


Figure 2-8: Depth-averaged currents (including tide) at Beacon 1 (2008 – 2018). Numbers on the radial axis show the % frequency of occurrence

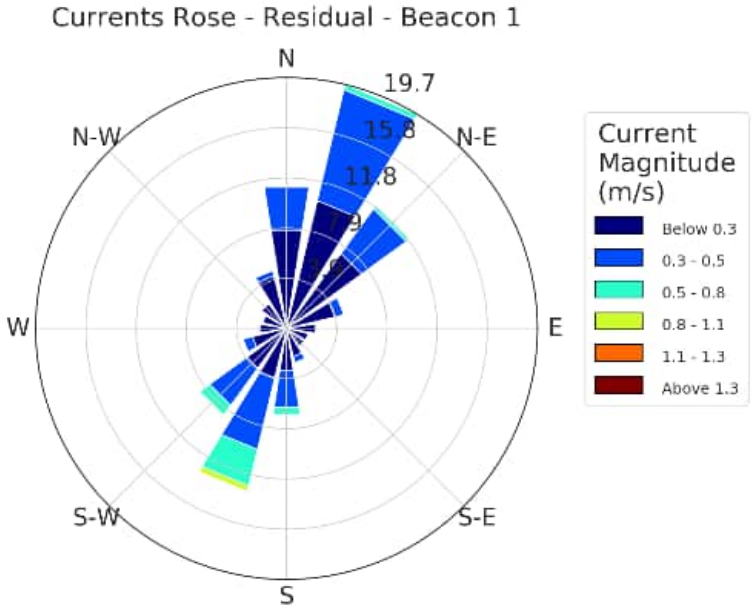


Figure 2-9: Depth-averaged residual current (excluding tide) at Beacon 1 (2008 – 2018). Numbers on the radial axis show the % frequency of occurrence

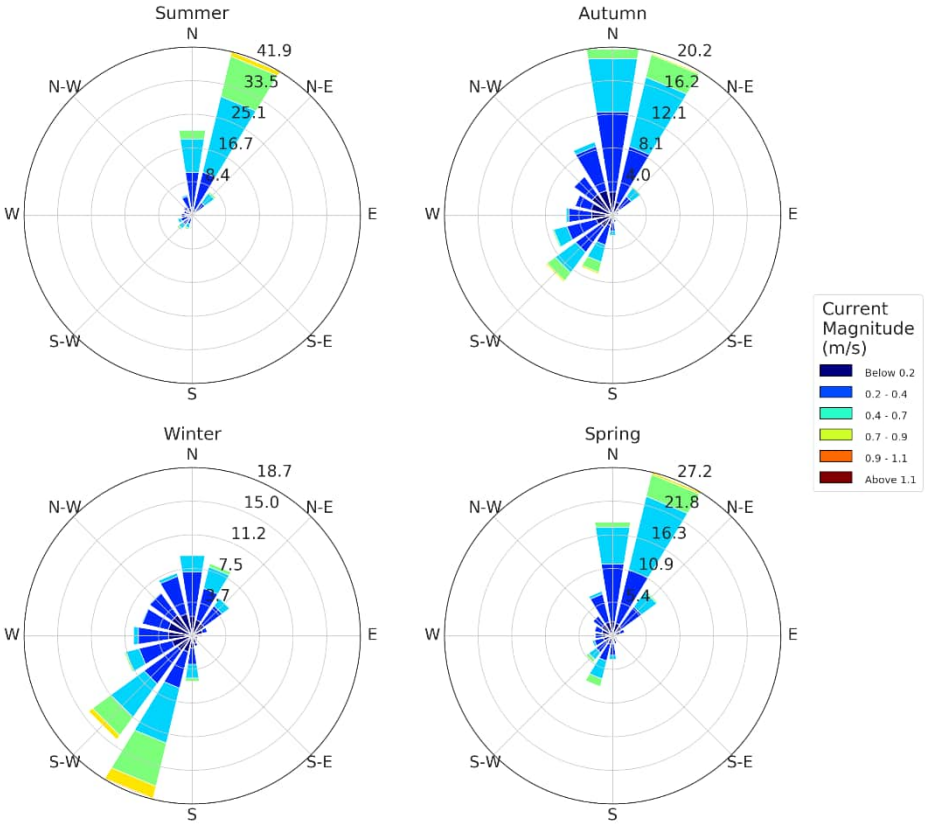


Figure 2-10: Seasonal currents at Beacon 1 (2008 – 2018). Numbers on the radial axis show the % frequency of occurrence

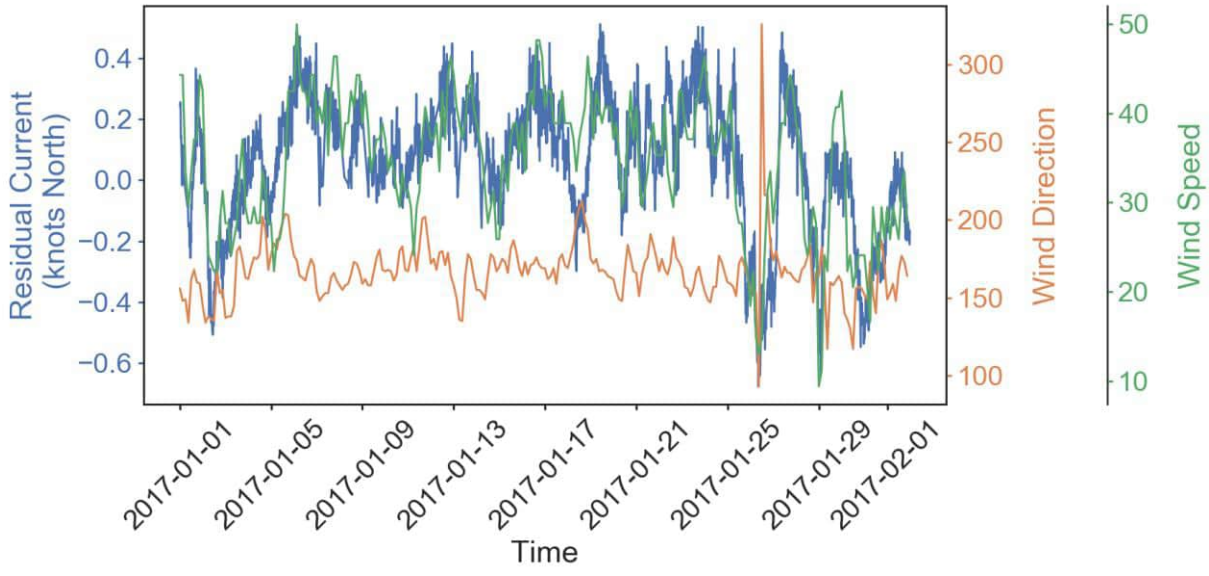


Figure 2-11: Correlation of current and wind for a period of time in 2017

2.3.4 Waves

2.3.4.1 Deepwater

The west coast of Australia is exposed to a combination of local wind waves and swell waves that are generated in the Indian and Southern Oceans. In the Southern Oceans, intense low-pressure systems regularly travel in an easterly direction around the latitudes north of the Antarctic. These systems create high wave energy events that collide with the west coast of Australia. Winter cold front and low-pressure systems, closer to the Geraldton coast, can set-up westerly to north-westerly fetches to create local sea waves.

Furthermore, during the Australian summer tropical cyclones regularly propagate across the Indian Ocean towards and along the Australian west coast. Although cyclones can generate significant wave and storm surge (elevated water levels), these occur infrequently and only make up a small component of the overall storm wave climate. Historically, the cyclones predominantly form in the Indian Ocean along the higher latitudes of Australia and move southwards along the mid-west coast towards Geraldton.

A wave rose of deepwater swell wave conditions (from AUSWAVE model hindcast results) are presented in **Figure 2-12** for a location offshore of Geraldton. The offshore wave climate consists primarily of waves from a SW to SSW direction with a mean deepwater significant wave height (H_s) of 2.9 m and mean peak period (T_p) of 13.7 seconds.

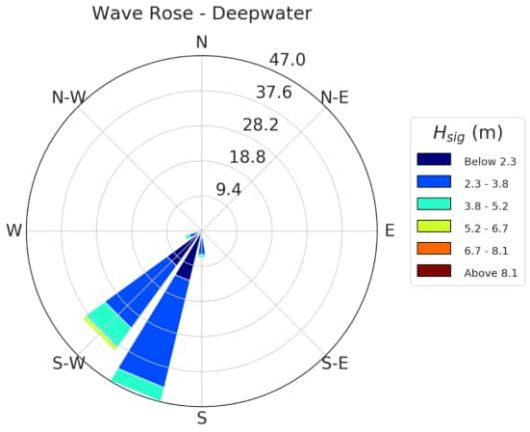


Figure 2-12: Deepwater significant swell wave height rose (1986 – 2019). Numbers on the radial axis show the % frequency of occurrence

Examination of seasonality in the offshore wave data shows that the most energetic months are observed to be during winter and spring (refer **Figure 2-13**). Over the longer timescales the data from the AUSWAVE model indicates that the wave climate exhibits natural variability (refer **Figure 2-14** and **Figure 2-15**). Associated with the higher wave energy is a shift to a more westerly swell (refer **Figure 2-15**). Both a seasonal signal and interannual variability are evident. In particular, the periods 1986-1992 and 2013-2020 exhibited a higher amount of energy than the intervening years, with generally larger significant wave heights and longer wave periods.

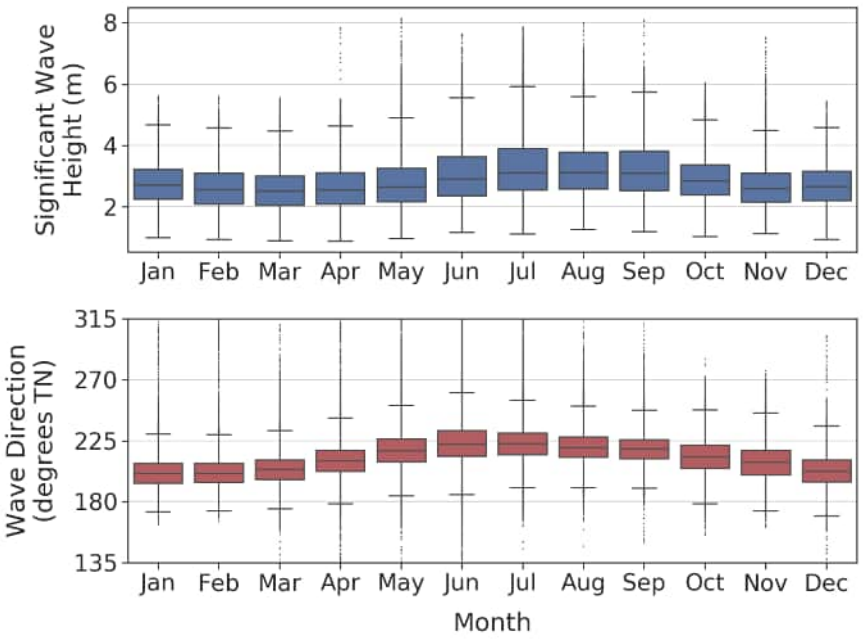


Figure 2-13: Seasonal changes in monthly deepwater average wave height and direction (AUSWAVE – 1986 to 2019)

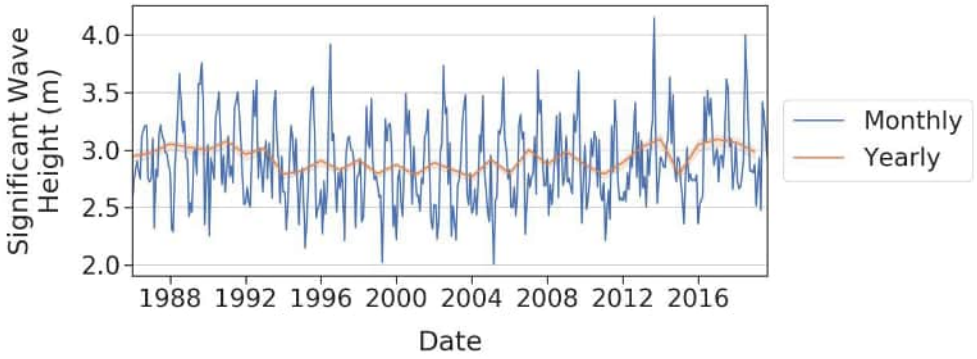


Figure 2-14: Deepwater significant wave height timeseries (AUSWAVE - 1986 to 2019)

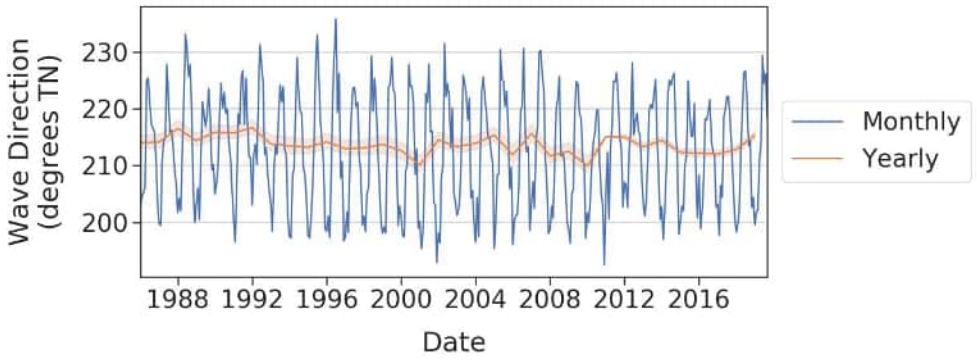


Figure 2-15: Deepwater significant wave direction timeseries (AUSWAVE - 1986 to 2019)

It is important to note that incident deepwater waves in the Geraldton region undergo a significant transformation as they propagate towards the shoreline, with the complex bathymetry causing shadowing, refraction, diffraction and shoaling. The deepwater data should be considered alongside the corresponding measurements closer to shore.

2.3.4.2 Nearshore

The nearshore wave climate at Geraldton is characterised by swell predominating over locally generated wind waves. Summer (December, January and February) is the calmest season with average H_s of 1.0 – 2.2 m, reaching up to 3.0 m, and winter (June, July and August) is the most energetic season with average H_s of 1.0 – 2.8 m and reaching up to 3.9 m. Typical wave periods (T_p) are around 12.5 s in summer and 14 s in winter.

Offshore wave conditions are affected by the various offshore reefs, which cause; reef face reflections, depth induced breaking, diffraction through the reef gaps, and refraction and shoaling due to variability in the seabed depth. These effects can create calm regions in the leeward areas resulting in the formation of tombolo's. However, breaks in the reef allow higher wave energy to reach the coast.

Geraldton Outer Channel

Nearshore wave conditions measured at Geraldton Port 'Beacon 1' consist of swell waves generated far offshore by weather systems in the Southern and Indian Oceans, and locally generated wind waves (or 'sea'), generated by the strong prevailing south-south-westerly winds.

The 'total' wave climate is a result of the local wind waves superimposed on swell. The seasonal variation of swell, sea, and total wave conditions are shown in **Figure 2-16**, **Figure 2-17** and **Figure 2-18**, respectively, at Beacon 1. The 'total' wave climate is overwhelmingly a function of the swell wave climate.

Wind waves show more seasonal variability, occurring generally from the SW in summer and a combination of SW and WSW in winter. These directions reflect the seasonal wind climate and the available fetch over which local wind waves can be generated.

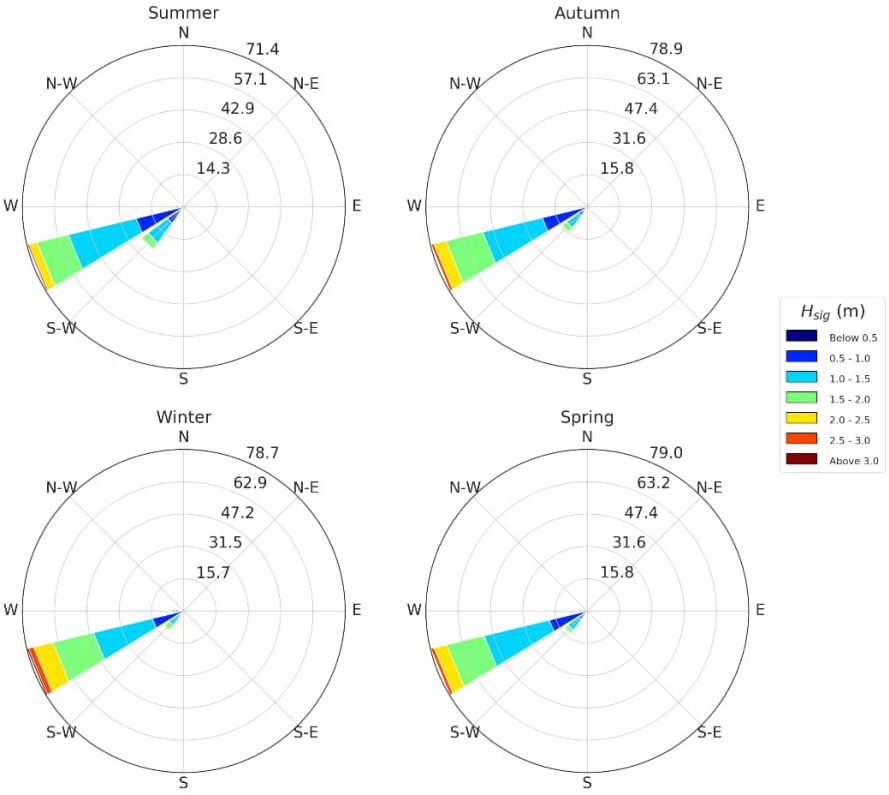


Figure 2-16: Seasonal variations in swell wave height at Beacon 1. Numbers on the radial axis show the % frequency of occurrence

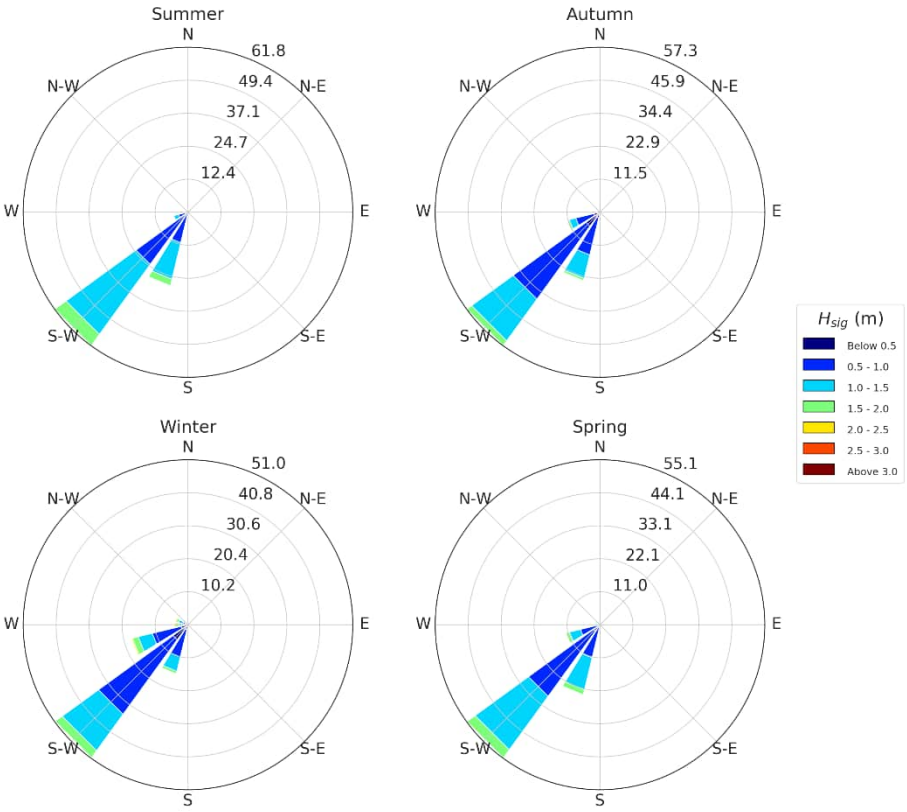


Figure 2-17: Seasonal roses of wind wave height at Beacon 1. Numbers on the radial axis show the % frequency of occurrence

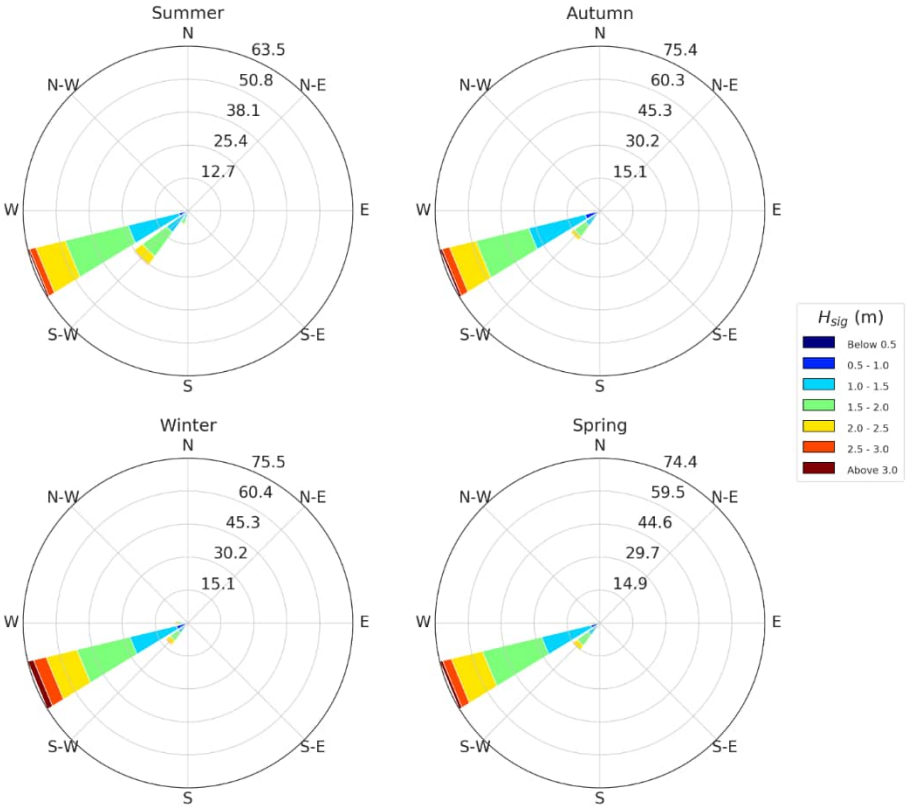


Figure 2-18: Seasonal total wave height roses at Beacon 1. Numbers on the radial axis show the % frequency of occurrence

2.4 Suspended Sediment

The ambient SSC for Geraldton Port, Champion Bay and beyond is of particular relevance to this project due to the projects dredging requirements and the potential for influence upon sensitive ecological habitats. Limited (ambient) turbidity measured in Nephelometric Turbidity Units or NTU (which is typically used as an indicator of SSC) and TSS data is available from various sources and was reviewed and assessed. This data includes episodic turbidity depth profiles (limited to two monitoring events to determine baseline conditions (pre-dredging) within Champion Bay) and TSS samples collected during the Geraldton Port maintenance dredging in 2021. This campaign further comprised collection of continuous turbidity data, however this was limited to one location within Geraldton Port (Berth 6).

Further continuous turbidity data is currently being measured as part of the MWPA MEQMMP and PMaxP baseline data collection program at four locations in Champions Bay. This data is further discussed and analysed in **Section 6.4** for the purposes of developing a baseline (although it is noted the record length is insufficient for reliable long-term statistics). The analyses show that typical ambient turbidity in Champion Bay is generally (median values) low (in the order of up to a few NTU). A-typical conditions may occur for a period of time post the breakout of the Chapman River (which is episodic) and median turbidity increases significantly, with turbidity peaks in the order of 100-200NTU. Further details of the analyses are provided in **Section 6.4**.

3 Modelling Approach

The potential impact on water quality as a result of the proposed maintenance and capital dredging activities at Geraldton Port was assessed utilising the following calibrated and validated numerical hydrodynamic and wave modelling tools, and suspended sediment transport tool (informed by the calibrated and validated hydrodynamic and wave modelling tools):

1. Wave modelling (using the MIKE21 Spectral Wave module);
2. Hydrodynamic (flow) modelling (using the MIKE21 and MIKE3 Flexible Mesh - Hydrodynamic module); and
3. Suspended sediment transport modelling (using the MIKE3 Mud Transport module).

Establishing both a calibrated and validated wave model and hydrodynamic model, and thereby an appropriate representation of currents in the Geraldton Port area, is critical in providing a sound basis for the suspended sediment transport modelling and simulation of the advection and dispersion of dredge plumes.

3.1 Spectral Wave Model

Nearshore wave conditions in the vicinity of the project site were simulated utilising the MIKE21 SW model. MIKE21 SW simulates wave propagation and transformation and provides simulations of wind-generated waves and swell, providing forecasts of wave conditions in the nearshore Geraldton area.

A spectral wave model was set up and calibrated and validated against measured wave data. This model was driven by (refer **Section 4** for further details):

- time-varying tidal water level;
- hindcast wind speed and direction; and
- hindcast significant wave height, peak wave period and mean wave direction applied to the offshore north, west, and south model boundaries.

3.2 Hydrodynamic Flow Model

A hydrodynamic model to simulate three-dimensional (3D) flow in the vicinity of the project site was calibrated and validated using the MIKE21 and MIKE3 Flow Model (FM) – Hydrodynamic (HD) module. The MIKE21/3 FM HD module is a three-dimensional (3D), flexible mesh, finite volume model that solves the basic fluid dynamic equations used to describe the movement of the water (currents), the distribution of temperature and salinity, and water level. The system is based on the numerical solution of the 3D incompressible Reynolds averaged Navier-Stokes equations invoking assumptions of Boussinesq and hydrostatic pressure. The model consists of continuity, momentum, temperature, salinity and density equations, and includes a turbulent closure scheme. Turbulent mixing (turbulence) is modelled using an eddy viscosity concept described separately for vertical and horizontal transport.

The 3D model allows for the distinction of the vertical discretisation of the water column, as well as for mimicking the introduction of sediment sources at different depths as realistically as possible, depending on the dredge equipment being used. The hydrodynamic model was forced with (refer **Section 5** for further details):

- astronomical water levels varying along the model boundary and time; and
- measured wind forcing from nearby recording station Beacon 1.

3.3 Suspended Sediment Transport Model

The advection and dispersion of dredge plumes were modelled utilising the MIKE3 Mud Transport (MT) module. The MIKE3 MT module calculates erosion, transport and deposition of fine-grained sediments (fines) and utilises the current information based on the spectral wave and hydrodynamic model output. The MIKE3 MT model provides an estimate of the excess or 'above ambient' suspended sediment concentration (SSC) due to the dredging activity.

A suspended sediment transport model was set up and was driven by:

- Wave radiation stresses and spectral wave output from the MIKE21 SW model (refer **Section 3.1** and **Section 4**), where appropriate; and
- Hydrodynamic (flow) information from the MIKE3 FM HD model (refer **Section 3.2** and **Section 5**).

The introduction of fines into the water column due to the action of dredging, discharging of dredged material, as well as due to the dredge equipment itself (i.e., scour due to propellor wash – where appropriate) was simulated by incorporating sediment sources or sediment fluxes into the model. These fluxes were estimated by an appointed dredging expert and based on, for example, dredge strategy, dredge equipment, and geotechnical information, etc. Further details are provided in **Section 6**.

3.4 Coordinate system, vertical datum and conventions

The models were developed in the Geocentric Datum of Australia (GDA) 2020 and Map Grid of Australia (MGA), Zone 50. The Australian Height Datum (AHD) is used as the vertical datum. All flow simulation results are presented in this coordinate system. The time reference in the numerical model is aligned with Coordinated Universal Time (UTC)+00. All units in this report, unless stated otherwise, are in accordance with the International System of Units (SI units). Current directions refer to the direction towards which the current is flowing. The current direction is always given as bearings (degrees clockwise from North). For example, a current direction of 90° means that the current is flowing eastward. Wave and wind directions are defined according to the nautical convention, that is, the direction from which the wave/wind is coming relative to the true north. A wave with a direction of 0° is a wave coming from the north, and a wave with a direction of 90° is a wave coming from the east.

4 Wave Modelling

4.1 Introduction

This section describes the modelling activities undertaken to calibrate and validate a spectral wave model, developed to simulate nearshore wave conditions at Geraldton Port. The methodology, wave model setting, model calibration and model validation are discussed in the following sections.

4.2 Model Extent and Resolution

To derive the wave conditions at the study area, the MIKE21 SW model was used. The model domain is presented in **Figure 4-1**. The local mesh is illustrated in **Figure 4-2**. The model boundary is extended to the offshore wave hindcast data point (29.50S,114.00E). The dimensions of the grid cell are approximately 8-14.5 km at the offshore area and 25-50m at the project site. The model domain and grid resolution of the model are considered appropriate to properly capture the characteristics of the study area.

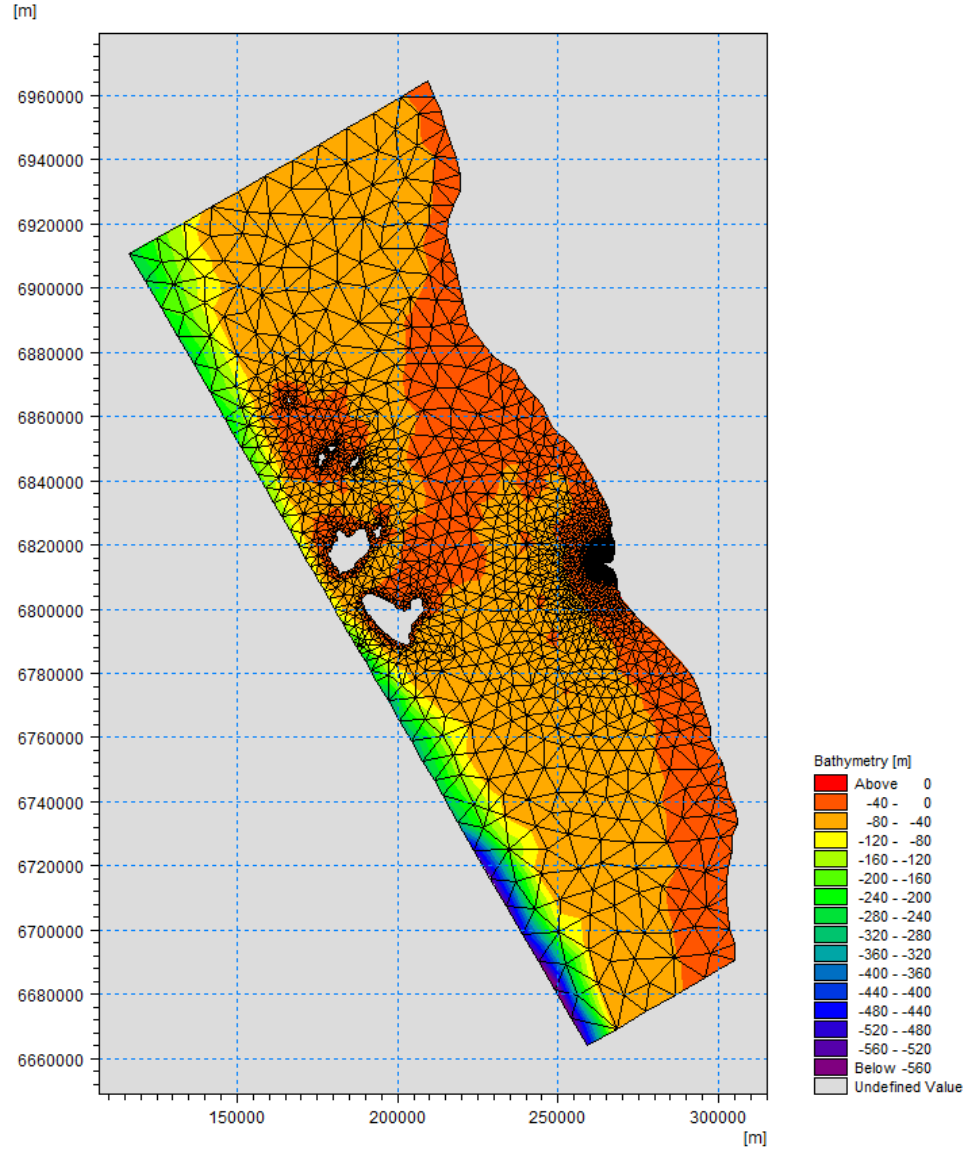


Figure 4-1: Model extent and bathymetry (m AHD)

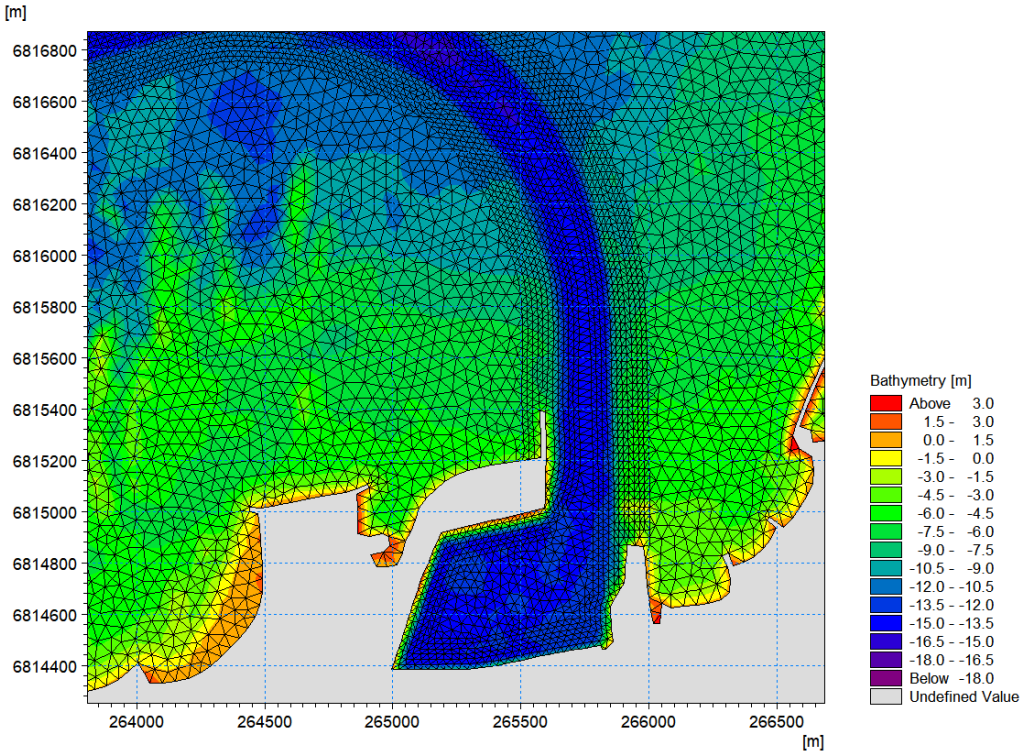


Figure 4-2: A close-up view of the MIKE21SW computational mesh

4.3 Data used

This section presents the data used for the wave calibration, comprising in-situ measured wave data, boundary wave and wind data, tidal water level, and bathymetry data. The data locations are shown in **Figure 4-3.**

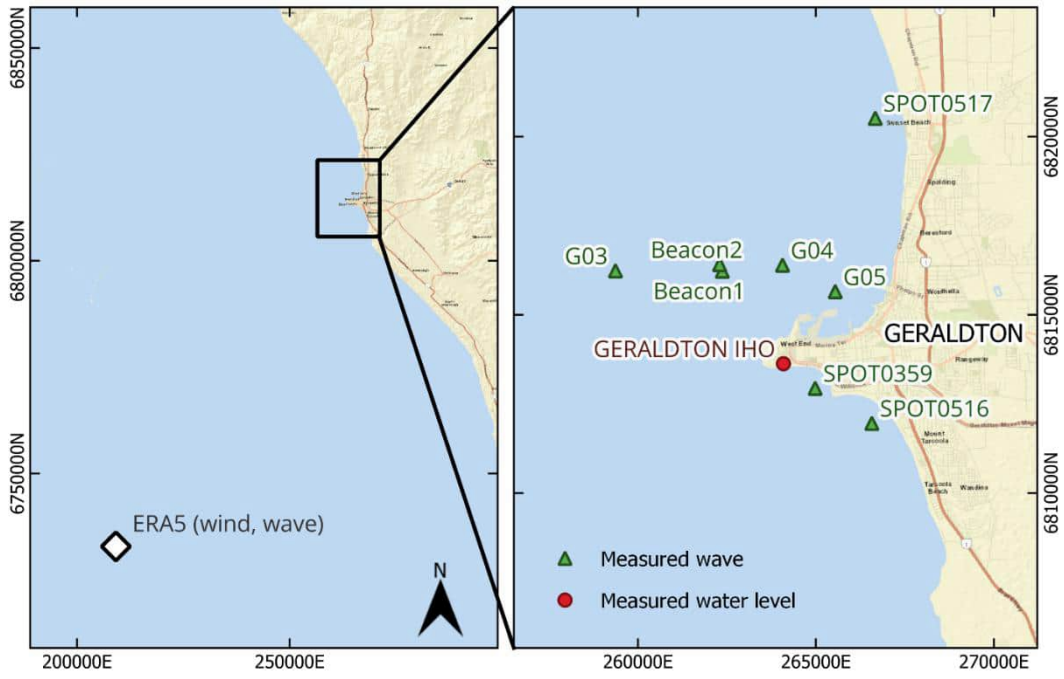


Figure 4-3: Indication of data locations

4.3.1 In-situ measured wave data

The measured wave data available for model calibration and validation purposes is listed in **Table 4-1** and a location map is provided in **Figure 4-3**.

Table 4-1: Wave data locations used for model calibration and validation

Station	X (m) GDA2020/ MGA zone 50	Y (m) GDA2020/ MGA zone 50	Time
G03	259,368.70	6,816,236.00	December 1983 to January 1985
G04	264,060.60	6,816,394.30	December 1983 to January 1985
G05	265,541.20	6,815,653.60	December 1983 to December 1984
Beacon 1	262,369.00	6,816,227.00	March 1999 to August 2019
SPOT0359	264,977.70	6,812,937.70	July 2020 to August 2020
SPOT0516	266,570.20	6,811,955.20	January 2020 to March 2020
SPOT0517	266,665.90	6,820,516.30	July 2020 to August 2020

4.3.2 Boundary wave and wind data

In this section, ERA5 hindcast data **Invalid source specified.**, the fifth generation ECMWF atmospheric reanalysis of the global climate, are briefly analysed to demonstrate offshore wind and wave conditions. The spatial resolution of the data is 0.25°x0.25° (for atmosphere) and 0.5°x0.5° (for ocean waves). As the dominant wave and wind directions are mainly from the south and southwest sector, the grid point at 29.50S, 114.00E with the location shown in **Figure 4-3** was chosen as the offshore data point. The scatter plot of the significant wave heights versus peak wave periods of total waves from 1/1/1940 to 1/1/2024 is shown in **Figure 4-4**. Significant wave heights of up to 8.6 m have been modelled with the associated peak wave periods estimated to be 13.6 s.

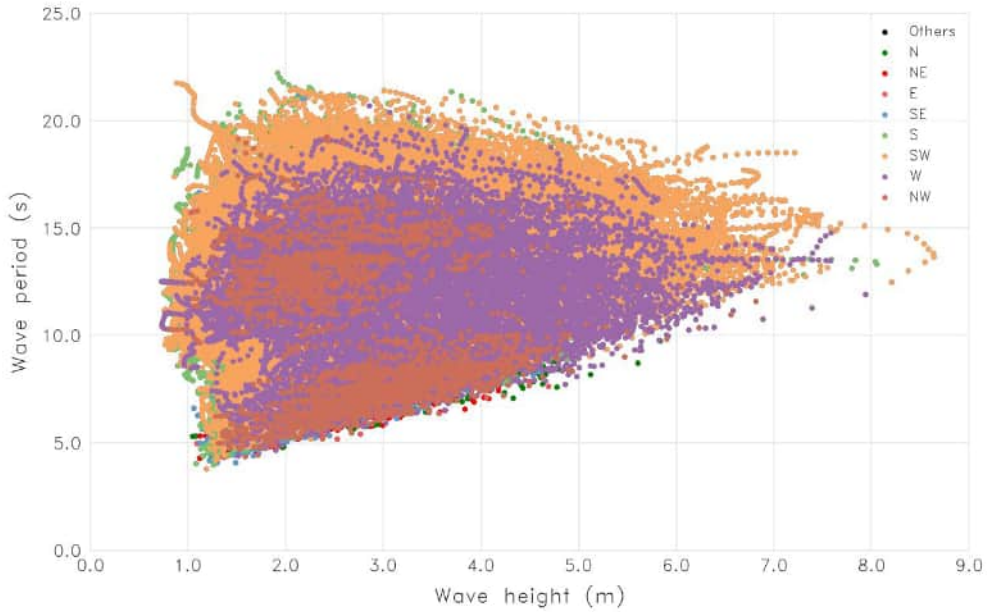


Figure 4-4: Significant wave heights versus peak wave period at location 29.5^{0}S,114.0^{0}E (based on ERA5 hindcast data from 1/1/1940 to 1/1/2024)

Seasonal wave roses are presented in **Figure 4-5** for grid point 29.50S,1140E based on ERA5 hindcast data from 01/01/1940 to 1/1/2024. Over the entire year, the predominant wave directions are SSW (41.0%), SW (36.7%), S (11.6%) and WSW (7.0%). From May to October (wet season), the predominant wave direction is from SW (51.3%), SSW (27.2%), WSW (12.1%) and S (3.8%). From November to April (dry season), the predominant wave direction is from SSW (55.0%), SW (21.9%), S (19.6%) and WSW (1.9%).

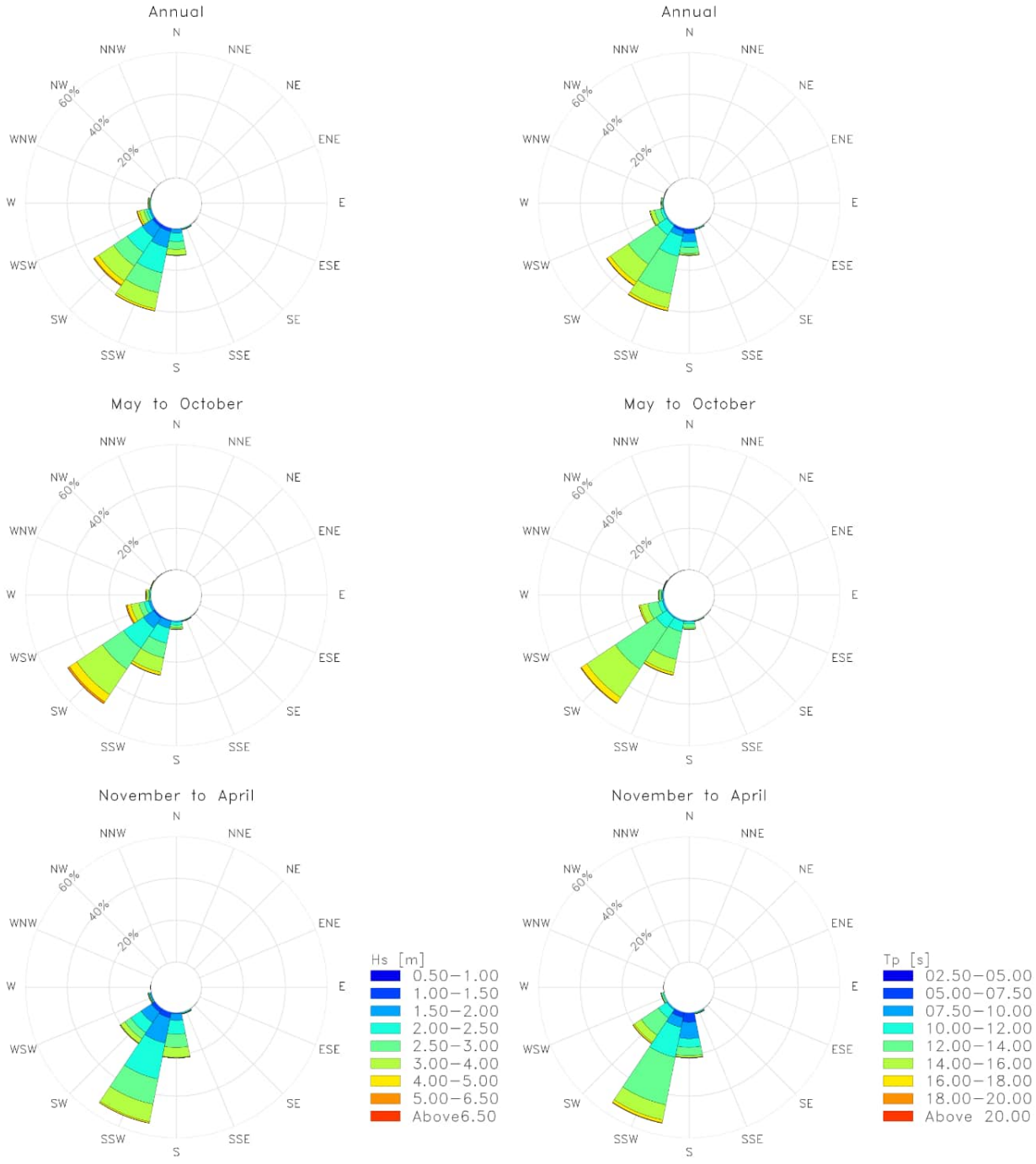


Figure 4-5: Seasonal wave roses at grid point 29.5^{0}S,114.0^{0}E (based on ERA5 hindcast data from 1/1/1940 to 1/1/2024)

Seasonal wind roses are presented in **Figure 4-6** for grid point 29.50S,1140E based on ERA5 hindcast data from 01/01/1979 to 31/12/2019. Over the entire year, dominant wind directions are SSE (21.2%), S (20.7%), SE (9.5%) and SSW (9.1%). During the summer/dry period (October to April), dominant wind directions are from S (29.4%), SSE (28.6).

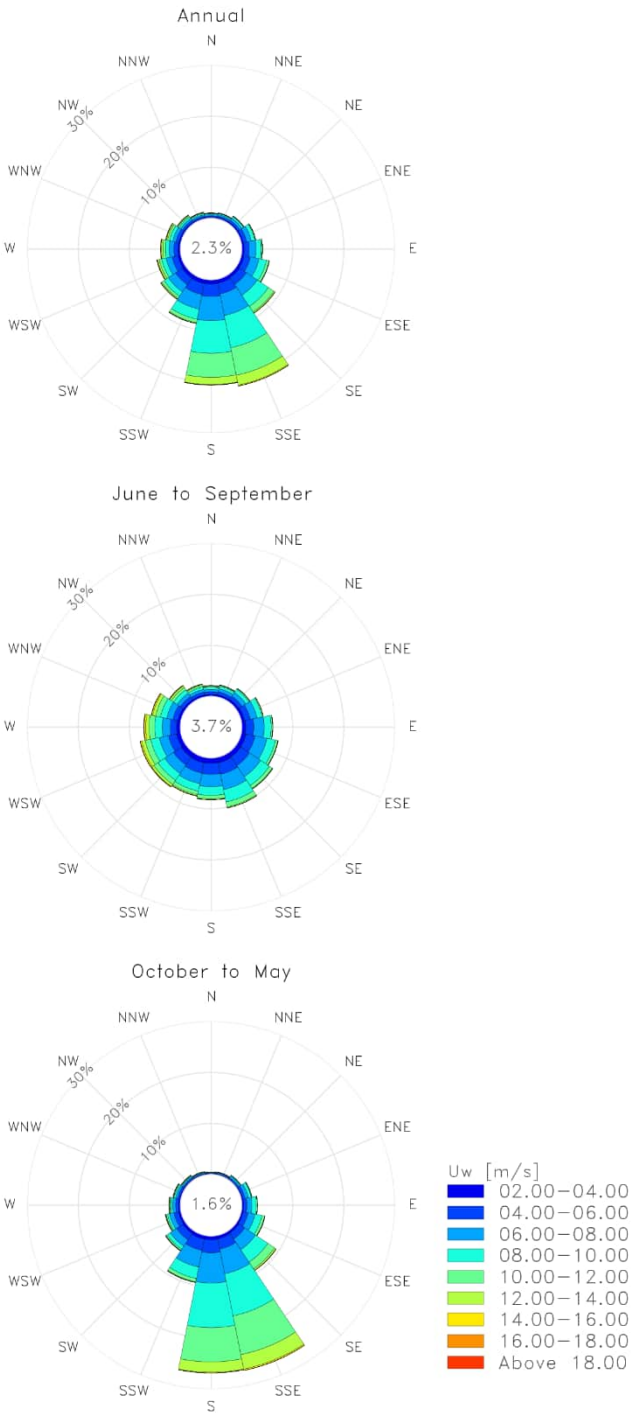


Figure 4-6: Seasonal wind roses at grid point 29.5^{0}S,114.0^{0}E (based on ERA5 hindcast data from 1/1/1940 to 1/1/2024)

4.3.3 Water Level

Water level variations were obtained from the Geraldton IHO station with the location shown in **Figure 4-3**. The station is located at 28.7833ºS, 114.5833ºE with 53 available tidal constituents. The data are suitable for providing water level inputs for the wave transformation modelling.

4.3.4 Bathymetry Data

The more recent bathymetric data at the project site was obtained from Oceanum. The extent of the 'Oceanum' dataset is depicted by a dashed box in **Figure 4-7**. For the wider area, the bathymetry data from the 2020 RHDHV wave modelling study (RHDHV, 2020) was utilised.

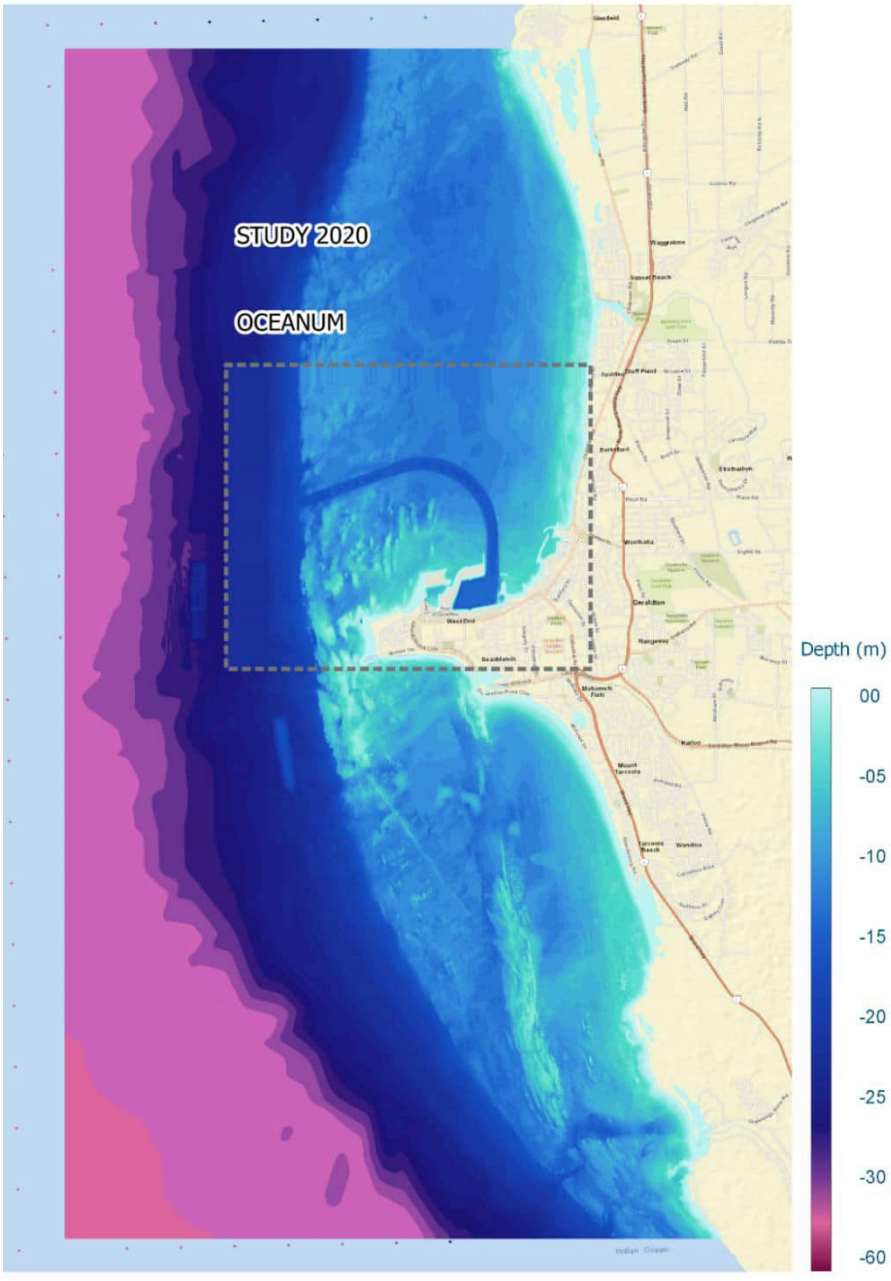


Figure 4-7: Combined OCEANUM and bathymetry from the previous study of RHDHV 2020 ***Invalid source specified.***

4.4 Boundary Conditions and Forcings

The following boundary conditions and forcings have been used in the model:

1. Time-varying tidal water level obtained at IHO Geraldton tidal station;
2. ERA5 hindcast wind speed and direction extracted at 29.50S,1140E. Over the entire year, the dominant wind directions are S and SSE, respectively; and
3. Significant wave height (Hm0), peak wave period (Tp) and mean wave direction (MWD) at grid point 29.5°S, 114°E were extracted from the ERA5 hindcast model. This same offshore time series of wave parameters was assigned to all three offshore boundaries north, west, and south.

4.5 Model Calibration and Validation

Model calibration is the process of setting physically realistic values for model parameters so that the model reproduces observed values to the desired level of accuracy. After the calibration, model validation is needed to ensure that the model setting is able to accurately represent the actual physical processes using data collected over a different time period to that adopted for model calibration.

4.5.1 Model Settings

The model settings and the selected computational mesh are the results of the calibration process. The model settings are summarized in the **Table 4-2**.

Table 4-2: Spectral wave model settings

Parameters		Value
Equations	Fully spectral formulation	-
	Quasi-stationary formulation	-
Spectral discretisation	Frequency discretisation	logarithmic
		30 frequencies
		0.035 minimum frequency
		1.1 frequency factor
	Directional discretisation	360 degrees rose 72 number of directions
	No separation of wind sea and swell	-
Water level	Varying in time, constant in domain	IHO Geraldton tidal station
Wind forcing	Varying in time, constant in domain	ERA5 hindcast data
Energy transfer	quadruplet-wave interaction	-
Wave breaking	Specified gamma	0.5
Bottom friction	Nikuradse roughness, kn	0.15
White capping	Dissipation coefficient	4.5
Structure	No structure	-

4.5.2 Simulation Periods

The following periods have been chosen for the calibration and validation of the wave model:

Calibration period
(18 July 1984 to 17 August 1984): For calibration purposes, measured and simulated wave results of the total waves at G3, G4, and G5 were compared from 18 July to 17 August 1984.

Validation period
For this study, the validation process was done for the measured wave data at Beacon 1 (from 15 August 2018 to 14 September 2018), and at SPOT0359, SPOT0516, and SPOT0517 (from 1 July 2020 to 31 July 2020).

4.5.3 Calibration Results

Comparisons of measured and simulated waves at G03, G04, and G05 from 18 July 1984 to 17 August 1984 were undertaken as shown in **Figure 4-8**, **Figure 4-9** and **Figure 4-10**. The simulated wave heights and periods generated by the MIKE21 SW model exhibited overall good agreement with the corresponding observational wave data. The patterns of peak and trough values were consistent. The value of wave breaking, and bottom friction parameters were 0.5 and 0.15 respectively.

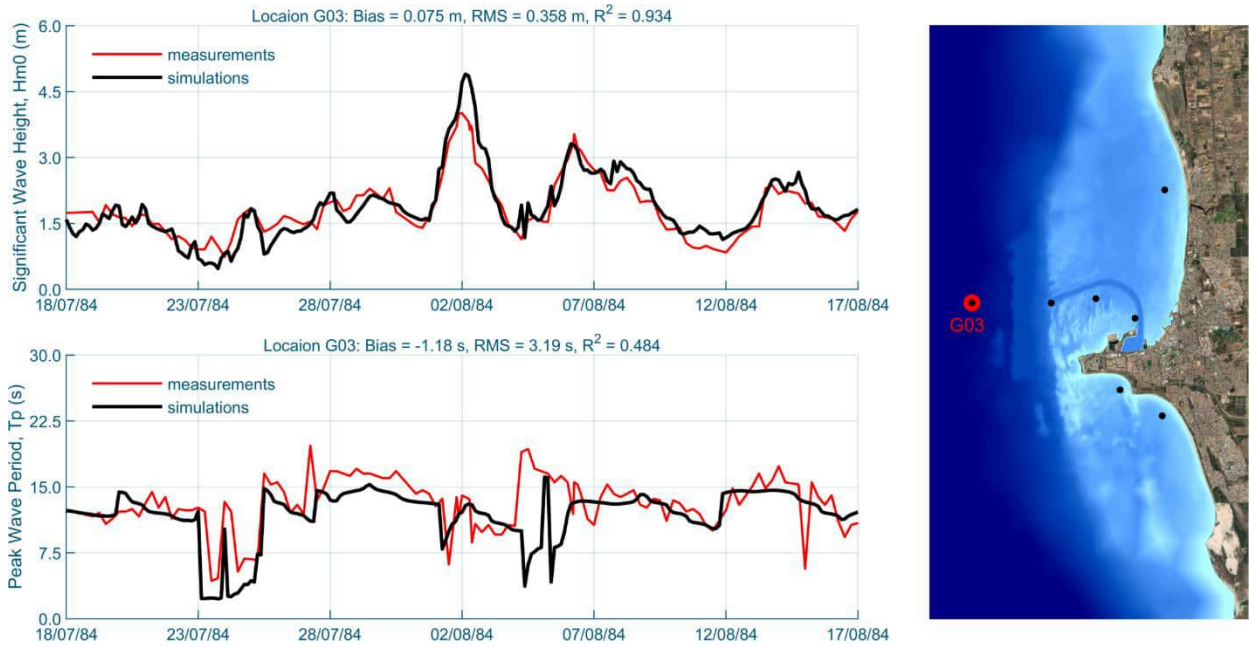


Figure 4-8: Comparison of measured and simulated significant wave height and peak wave period of total waves at G03

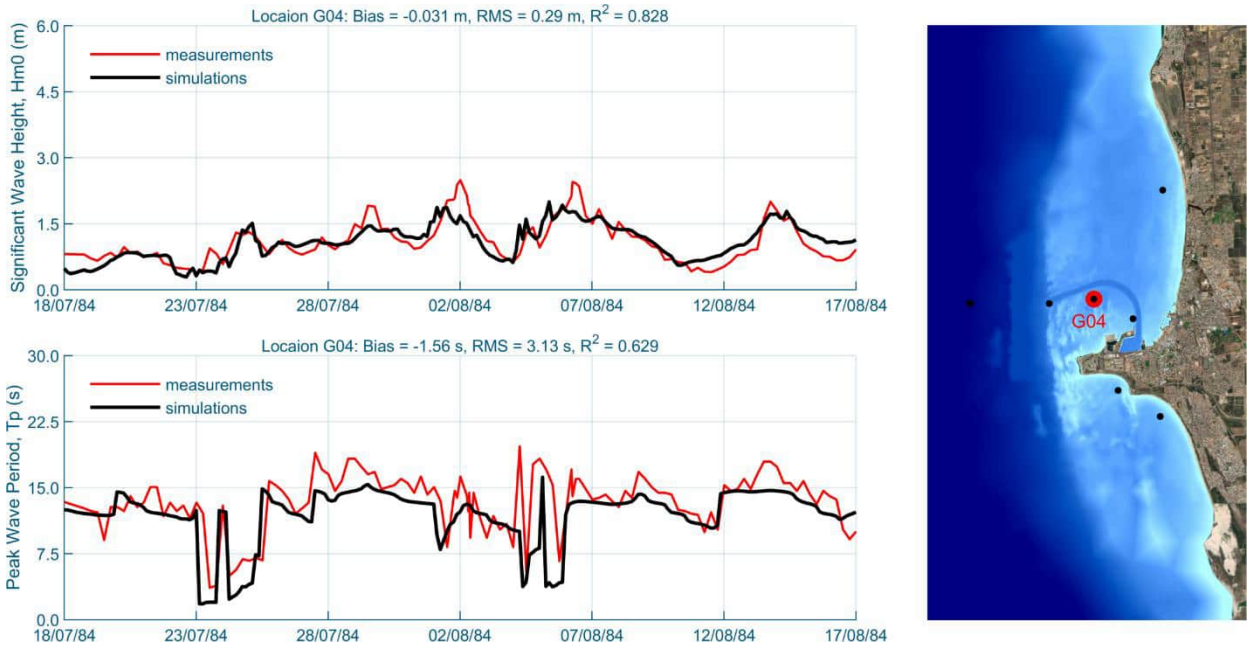


Figure 4-9: Comparison of measured and simulated significant wave height and peak wave period of total waves at G04

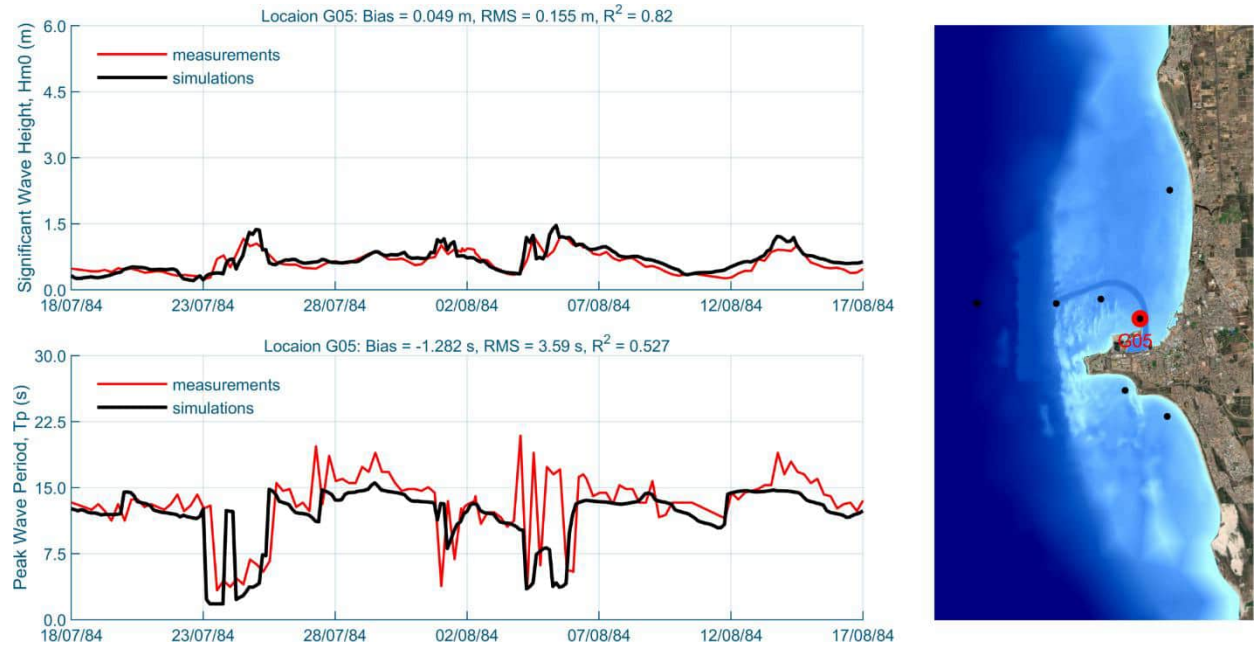


Figure 4-10: Comparison of measured and simulated significant wave height and peak wave period of total waves at G05

It can be seen that both measured and simulated data indicate that the high waves approaching the site decrease significantly from G3 (deep water) to G4, and then to G5 in the shallow zone, as the waves begin to break in the shallow water. This trend is further illustrated in **Figure 4-11**.

The calibration results show that the simulated wave heights and periods aligned well with measurements at G03, G04, and G05 and suggest the selected model settings and computational mesh are sufficient to provide good results. To make sure that the model performs well, the wave model is further validated with measurements at Beacon 1 and SPOT Buoys and presented in **Section 4.5.4**.

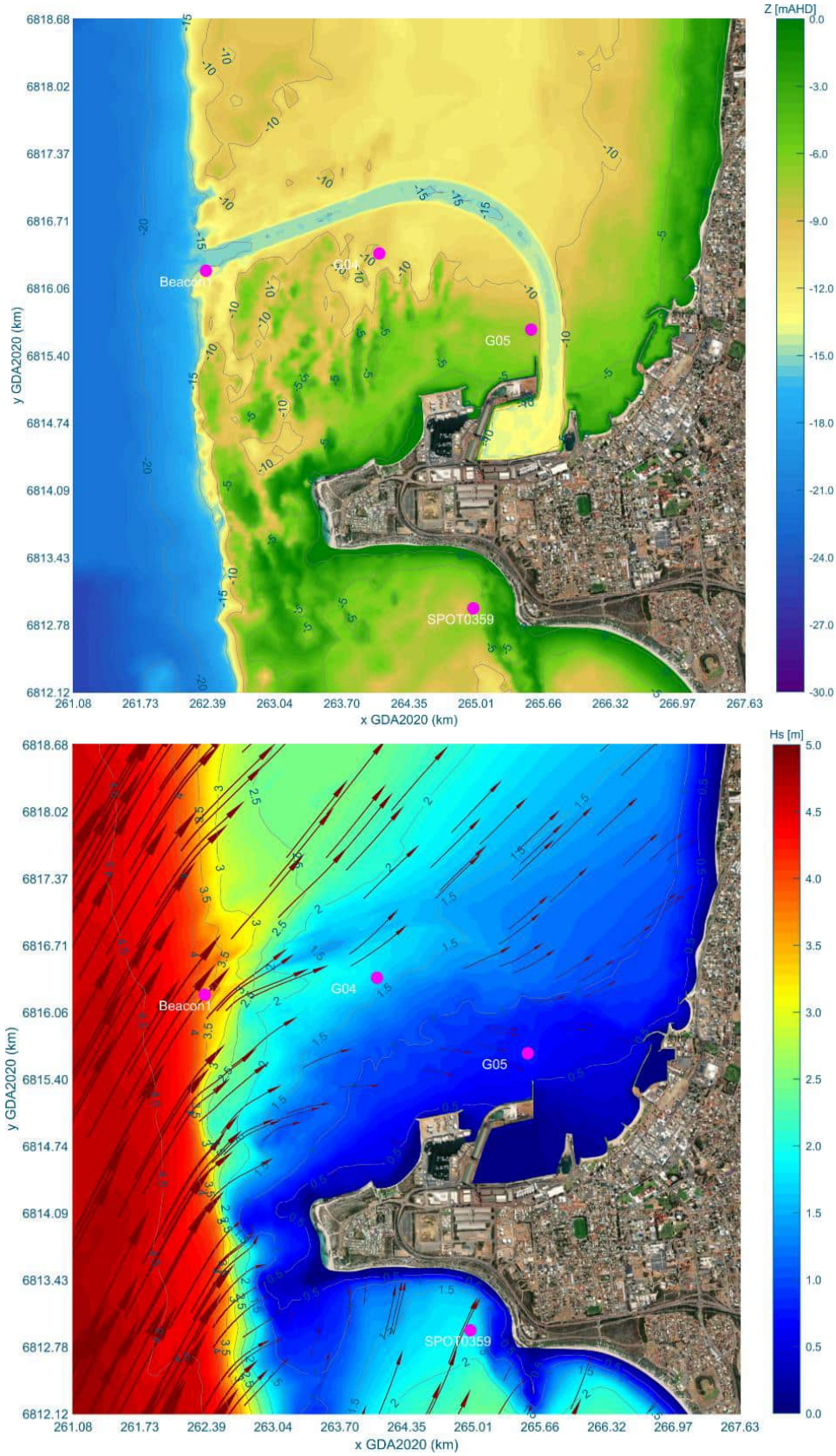


Figure 4-11: Model bathymetry (top pane) and example modelled spatial variation of the wave field as it approaches the shallow reef zone (bottom pane)

4.5.4 Validation Results

The validation results are presented in **Figure 4-12** to **Figure 4-15**.

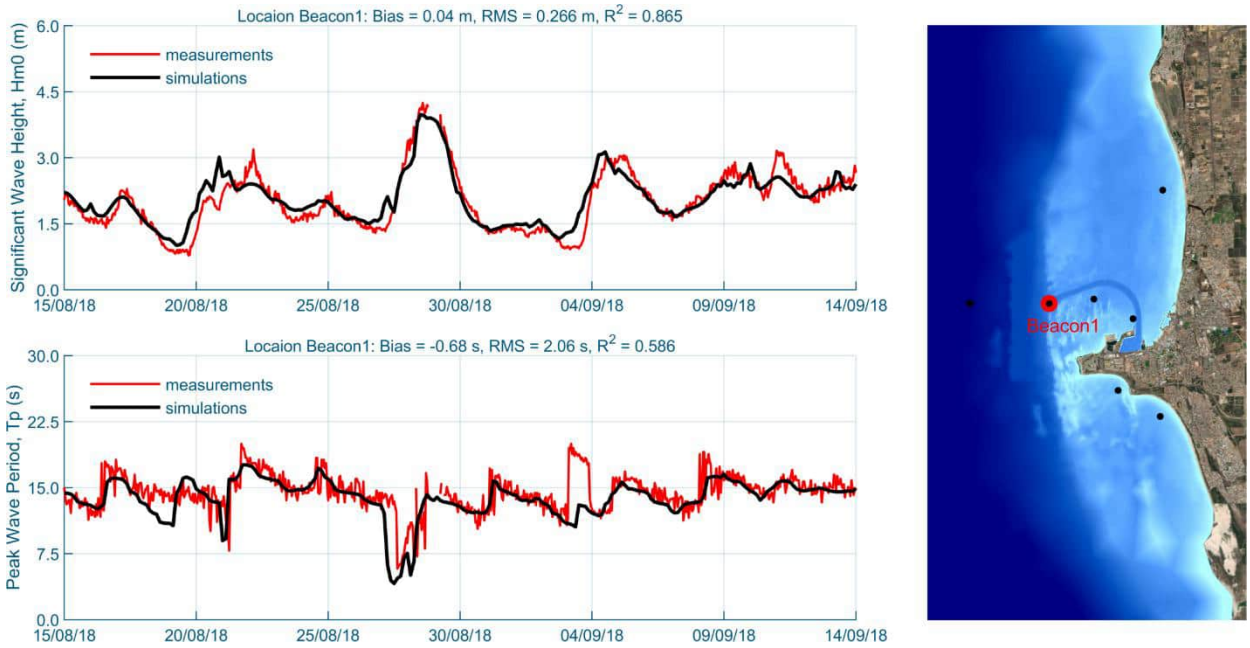


Figure 4-12: Comparison of measured and simulated significant wave height and peak wave period of total waves at Beacon

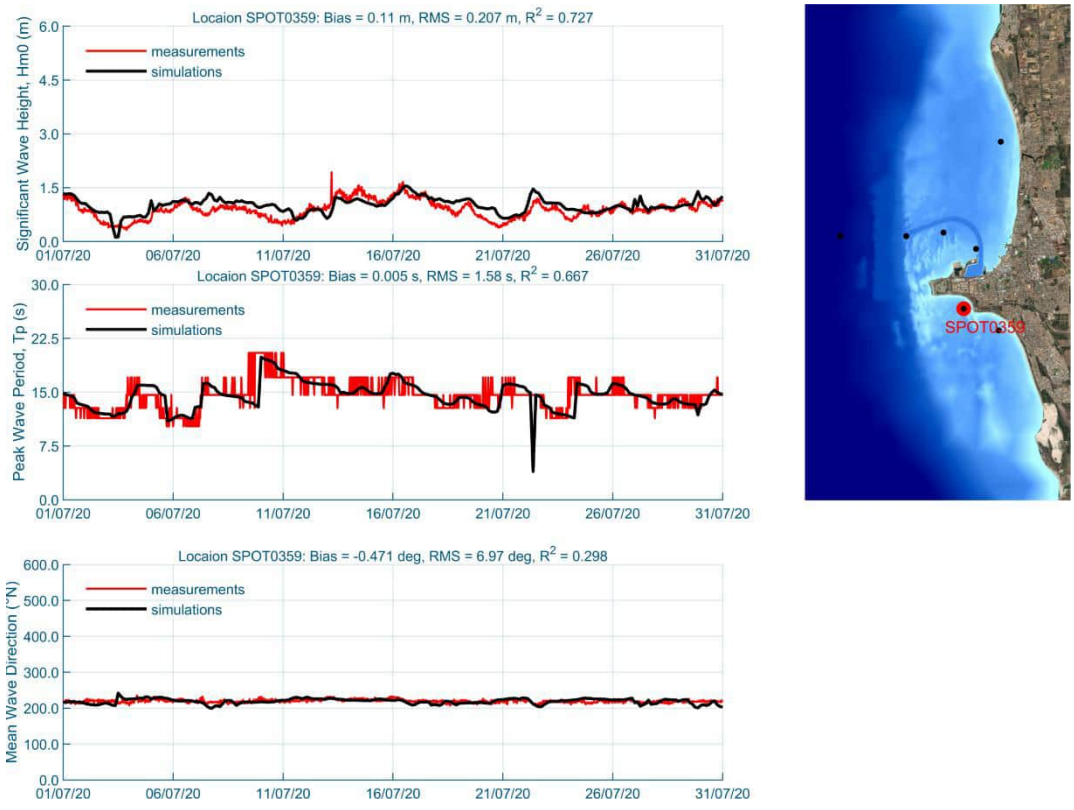


Figure 4-13: Comparison of measured and simulated significant wave height and peak wave period of total waves at SPOT0359

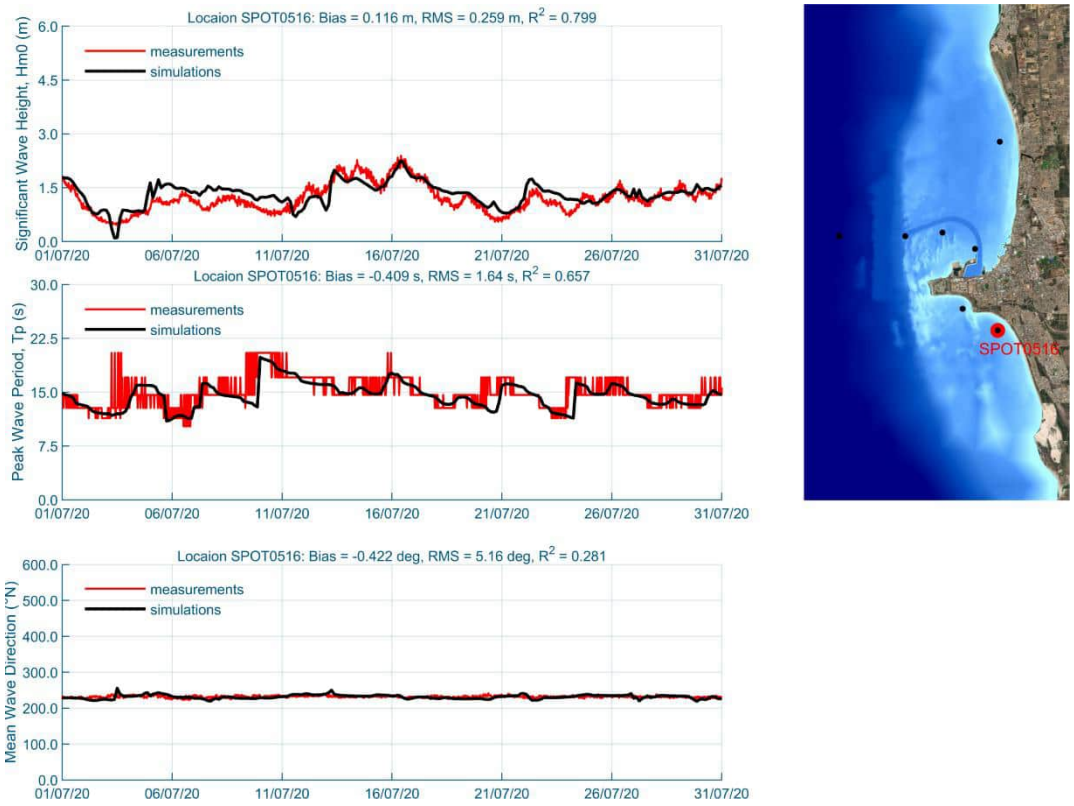


Figure 4-14: Comparison of measured and simulated significant wave height and peak wave period of total waves at SPOT0516

The validation results at location SPOT0517 indicate a slight overestimation of wave heights. The cause of this overestimation is unclear, but one possible explanation is a discrepancy between the reported coordinates and the actual location of the buoys. Given the significant spatial variability in wave conditions around the SPOT0517 area, even small errors in data location may lead to this overestimation. However, the model's good performance at nearby stations, such as SPOT0359 and SPOT0516, suggests that the model input (including hindcast wind and wave data) and model settings are likely to be appropriate.

It is observed that the reported location of SPOT0517 is farther offshore compared to SPOT0539 and SPOT0516. However, if SPOT0517 is hypothetically positioned closer to the shore, similar to the other two spot buoys, the wave validation results show a significant improvement, as illustrated in **Figure 4-16**.

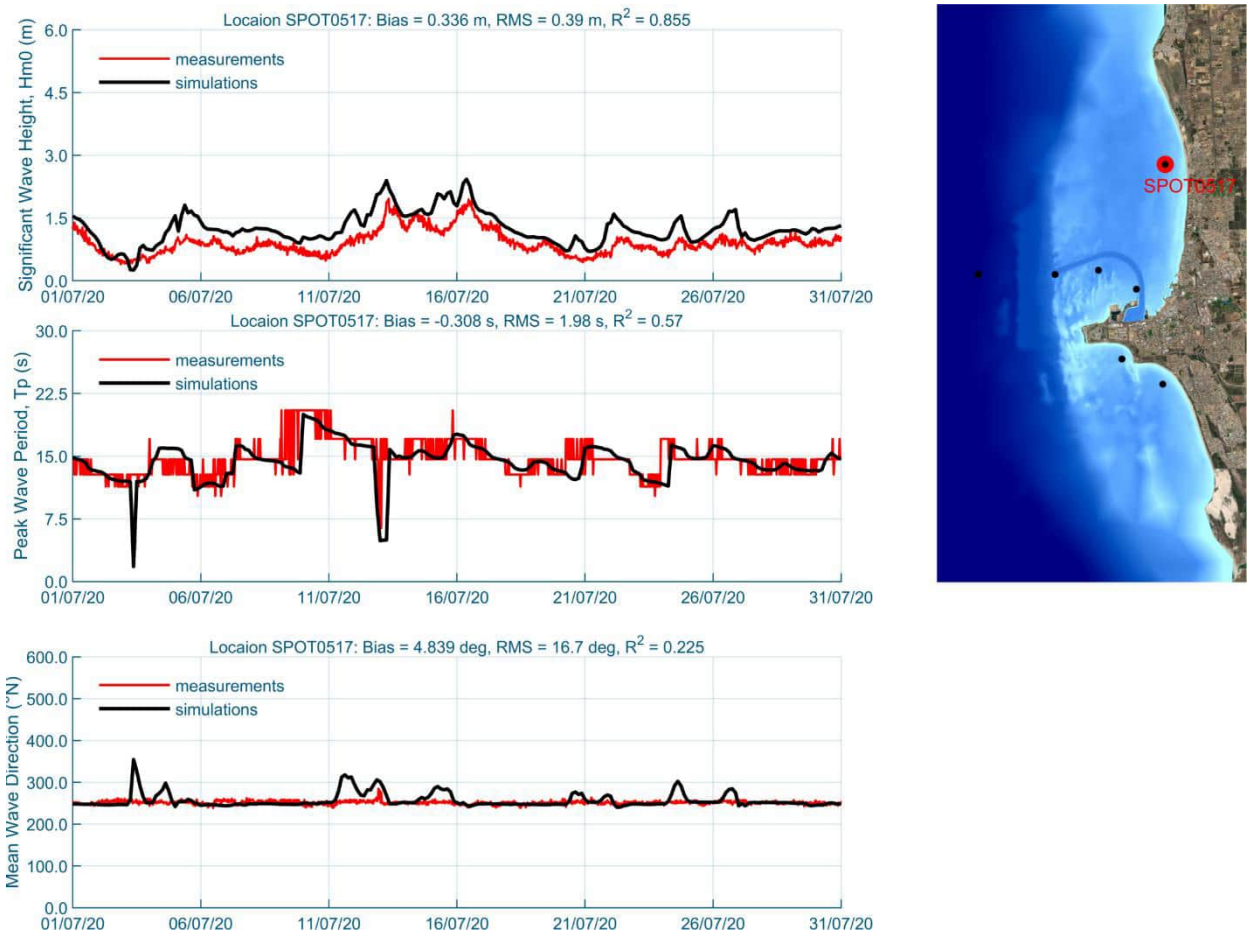


Figure 4-15: Comparison of measured and simulated significant wave height and peak wave period of total waves at SPOT0517

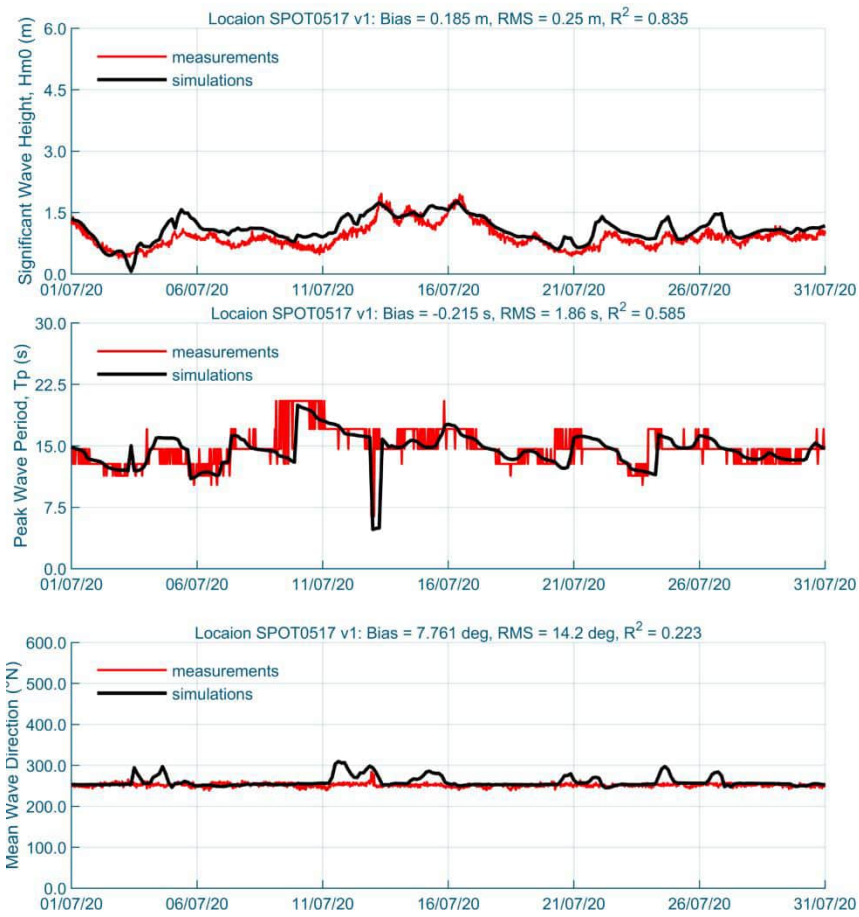




Figure 4-16: Comparison of measured and simulated significant wave height and peak wave period of total waves at SPOT0517 v1 (move the output point SPOT0517 closer to the shore, equidistant from the shore as for the other two spot buoys)

4.6 Summary

This section described the development, calibration, and validation of a MIKE21 SW spectral wave model to simulate nearshore wave conditions at the study area. The dataset used for the study included offshore hindcast wind and wave data (ERA5), nearshore measured wave data, tidal level (from IHO), and bathymetric data.

Calibration was conducted at three wave measurement stations, with a focus on optimising the breaking parameter and bottom friction coefficients. These parameters are crucial for accurately modelling wave transformation in fringing reef environments like Geraldton. The calibration yielded values of 0.5 for the breaking parameter and 0.15 for the bottom friction coefficient.

These calibrated settings were subsequently validated at four additional wave measurement stations, showing a good agreement between measured and simulated wave parameters. The findings confirm that this model configuration is suitable for reliably simulating wave conditions at Geraldton.

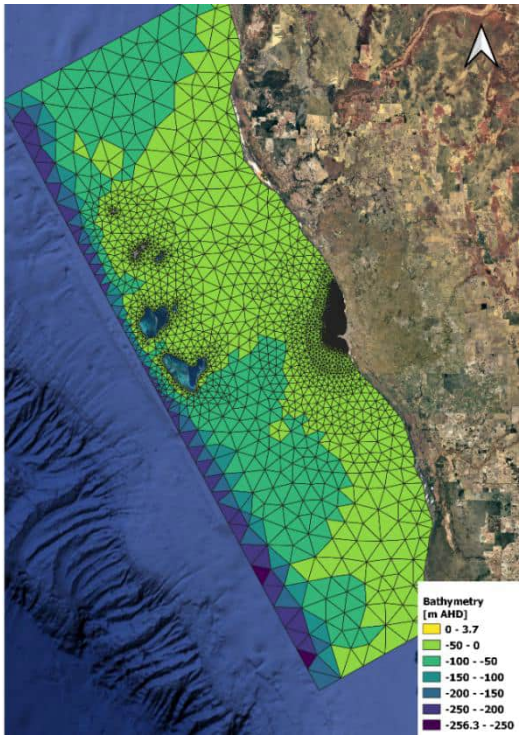
5 Hydrodynamic Modelling

5.1 Introduction

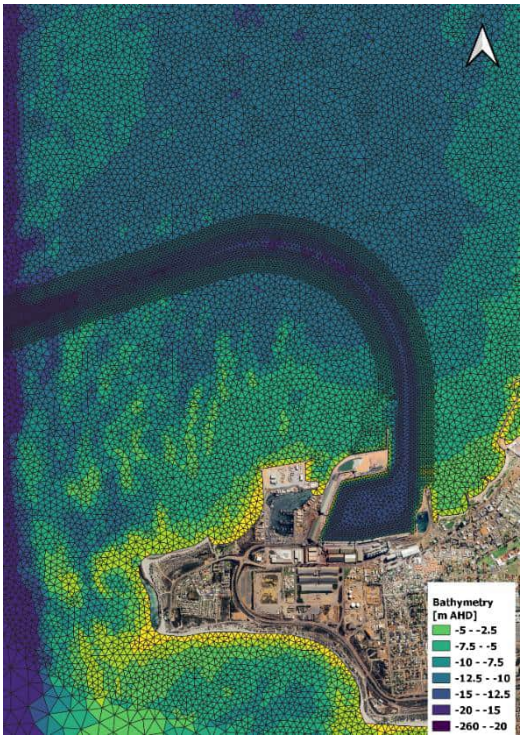
In this section, the development, calibration, and validation of the hydrodynamic (flow) model is presented. A three-dimensional (3D) hydrodynamic model was developed using MIKE-21/3 HD flexible mesh (FM). The 3D model allows for the distinction of the vertical discretisation of the water column, as well as for mimicking the introduction of sediment sources as realistically as possible at different depths, depending on the dredge equipment being used (e.g., a near-bed source, a surface source, or distributed evenly over the water column). In the vertical domain, five sigma layers with equidistant distribution were adopted which adjusts the vertical layer thickness with the rise and fall of the tide.

5.2 Model Extent and Resolution

The foundation of the HD model is a computational model network (or model geometry) that is designed using flexible mesh. **Figure 5-1** displays the mesh extent and resolution. The model domain is consistent with the wave model domain and extends approximately 130 kilometres (km) to the south and 160 km to the north of the project site. In the cross-shore direction, the model extends 70 km offshore, where the water depth reaches below -250 m. The HD mesh has a higher resolution than the wave model mesh and contains approximately twice as many elements as the wave mesh. The HD mesh resolution varies from 5 km in the offshore region to 30 m near the project site. The fine resolution near the project site enables the mesh to capture bathymetric features such as the navigation channel and reefs and also resolve the local flow patterns in these regions. This detailed bathymetry is maintained near the project site, while a coarser resolution is used offshore to ensure reasonable computational time. The same bathymetry data discussed in **Section 4.3.4** was used.



(a) *Extent and resolution of the 3D HD mesh*



(b) *A close-up view of the mesh representing the project site*

Figure 5-1: Computation grid adopted in the 3D HD model

5.3 Data used

5.3.1 In-situ Measured Current Data

The current and water level measurements used for model calibration and validation are summarised in **Table 5-1** whereas the location of the stations is shown in **Figure 5-2**. Beacon 1 is located at the entrance of the navigation channel at a depth of -14 m AHD while Beacon 17 is located in the proximity of the Geraldton Port entrance (at a depth of -9 m AHD). The ADCP data from Beacon 1 spans approximately 20 years while the data at Beacon 17 is available over 5 years. The data are not continuous and include several gaps. Also, some periods appear to be erroneous and are not used. The data show that the peak current speeds at both locations are in a range of 0.3 to 0.4 m/s with Beacon 17 experiencing slightly lower current speeds.

Table 5-1: Current and water level data locations used for model calibration and validation

Station	Data type	X (m) GDA2020/MGA zone 50	Y (m) GDA2020/MGA zone 50	Time
Beacon 1	Current	262371.6	6816219.3	Feb 2004 to 21 Jul 2024 The data contains significant gaps in several years and appears erroneous during certain periods. Therefore, only the data periods considered reasonable were used for calibration and validation.
Beacon 17	Current	265620.4	6815820.2	23 Feb 2005 to 27 Nov 2010 The data contains large gaps during 2006 and 2008. The data during 2009 and 2010 appears to be erroneous.
Sunset Beach	Current	266606.7	6819936.3	21 Oct 2021 to 28 Nov 2021
Geraldton Harbour	Water level	265782.7	6814509.4	31 Jan 2008 to 31 Dec 2018



Figure 5-2: Indication of current and water level data locations

5.3.2 Wind

In addition to tides, winds also influence hydrodynamic flows and exhibit seasonality. Wind was included as time-varying across the model domain (constant in space). Hindcast wind data were obtained from the ERA5 model (Hersbach *et al*., 2020) and measured wind data from Beacon 1. A review and analysis of Beacon 1 measured wind data was carried out to guide the selection of representative periods.

Approximately 20 years of wind data (February 2004 to September 2023) was provided by MWPA from their weather station located at the offshore end of their navigation channel (Outer Channel or Beacon 1). The wind data was processed to help improve understanding of the wind climate, a joint frequency table and wind rose of wind speed and direction are shown in **Table 5-2** and **Figure 5-3**.

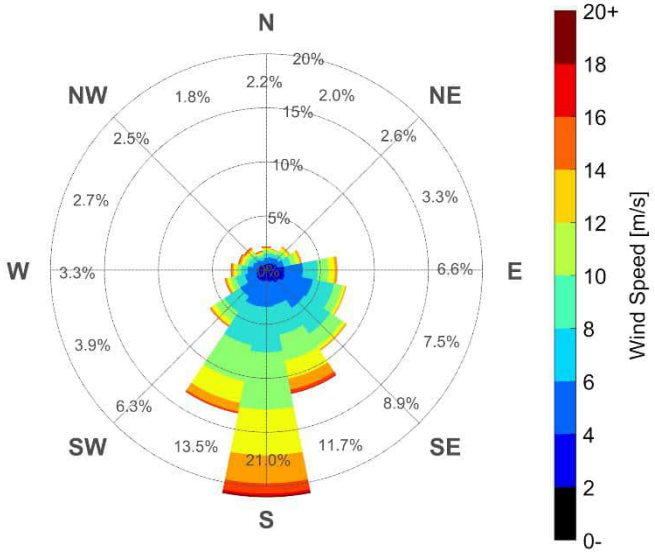


Figure 5-3: Wind rose for wind speed and direction at Geraldton Outer Channel (Beacon 1). Numbers on the radial axis show the % frequency of occurrence

These shows that southerly winds occur the most frequently and are also the strongest, winds from this direction occur at least twice as often as from any other direction. Winds from the south-south-west through to the east occur for approximately 70% of the time, with wind speeds only exceeding 14 m/s for less than 2% of the time.

The wind roses showing seasonal wind conditions (**Figure 5-4**) demonstrate that winds from the south dominate in the Spring, Summer and Autumn, while in Winter winds from the east to south-east dominate in terms of duration while winds from the west to north dominate in terms of speeds).

Table 5-2: Joint frequency table of wind speed (m/s) against direction at Geraldton Outer Channel

		Wind Direction [degTN]																	
		N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW		
Wind Speed [m/s]	0-2	0.15%	0.16%	0.20%	0.24%	0.26%	0.22%	0.18%	0.15%	0.15%	0.16%	0.20%	0.17%	0.17%	0.16%	0.15%	0.14%	2.85%	100.00%
	2-4	0.43%	0.48%	0.61%	0.78%	1.38%	1.52%	1.21%	0.96%	0.84%	0.90%	0.90%	0.78%	0.69%	0.51%	0.45%	0.38%	12.82%	97.15%
	4-6	0.53%	0.58%	0.53%	0.63%	1.71%	2.65%	2.81%	2.19%	2.41%	2.38%	1.82%	1.09%	0.87%	0.62%	0.53%	0.43%	21.79%	84.33%
	6-8	0.43%	0.35%	0.43%	0.64%	1.40%	2.00%	2.89%	2.80%	4.20%	3.62%	1.77%	0.86%	0.61%	0.47%	0.48%	0.33%	23.28%	62.54%
	8-10	0.29%	0.24%	0.41%	0.51%	0.98%	0.78%	1.37%	2.45%	5.28%	3.42%	0.99%	0.51%	0.40%	0.38%	0.38%	0.24%	18.63%	39.26%
	10-12	0.19%	0.11%	0.28%	0.37%	0.61%	0.28%	0.35%	1.70%	4.25%	2.05%	0.45%	0.31%	0.31%	0.26%	0.26%	0.15%	11.93%	20.63%
	12-14	0.10%	0.05%	0.12%	0.14%	0.20%	0.07%	0.10%	1.03%	2.59%	0.81%	0.15%	0.15%	0.17%	0.19%	0.16%	0.10%	6.15%	8.70%
	14-16	0.05%	0.02%	0.01%	0.02%	0.03%	0.01%	0.02%	0.33%	0.95%	0.16%	0.03%	0.05%	0.07%	0.07%	0.07%	0.04%	1.92%	2.55%
	16-18	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.05%	0.21%	0.02%	0.01%	0.01%	0.02%	0.02%	0.02%	0.02%	0.42%	0.63%
	18-20	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.14%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.01%	0.21%	0.21%
		2.20%	2.01%	2.61%	3.33%	6.57%	7.54%	8.95%	11.67%	21.02%	13.52%	6.32%	3.93%	3.31%	2.67%	2.51%	1.84%		

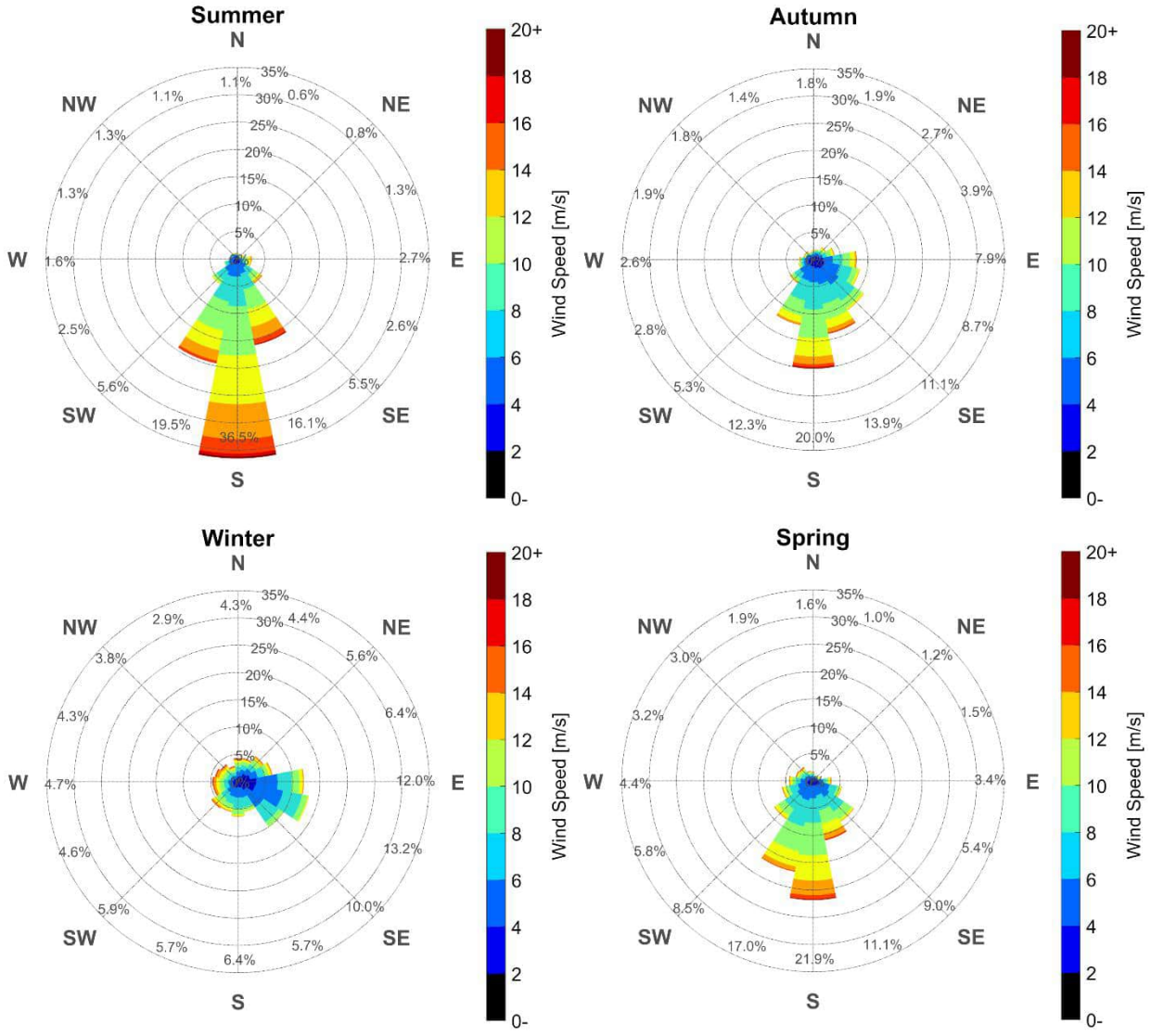


Figure 5-4: Seasonal wind roses for speed and direction at Geraldton Outer Channel. Numbers on the radial axis show the % frequency of occurrence

5.4 Boundary Conditions and Forcings

Open boundary conditions

The hydrodynamic model is forced with astronomical water levels varying along the model boundary over time. The water levels are extracted along each boundary from the 0.25° resolution grid Global Tide Model (DTU10). Tidal water levels derived from the DTU10 represent the major 10 constituents in the tidal spectra including semidiurnal constituents M2, S2, K2, N2, the diurnal constituents S1, K1, O1, P1, Q1, and the shallow water constituent M4.

Wind forcing

The flow field in the project area is dominated by wind-induced currents. Therefore, implementing wind data that is representative of the wind condition within the region is of high importance. Wind measurements at Beacon 1 station are available from February 2004 to September 2023 (see **Figure 5-2** for location) and provide a valuable source for the inclusion of wind forcing in the HD model. To ensure the continuity of the wind input during simulation periods, any gaps within the time series are filled with the corresponding ERA5 hindcasted data extracted from the closest point to Beacon 1.

5.5 Model Calibration and Validation

5.5.1 Model Settings

Vertical layers

A set of sensitivity tests was conducted to choose the appropriate vertical discretisation (i.e., the number of vertical layers). Based on the test results, 5 vertical layers were found sufficient as the model's performance does not change with a further increase in vertical resolution.

Bed roughness height

The model was tested for a range of spatially constant bed roughness heights to evaluate model sensitivity to bottom friction and to adjust the roughness height accordingly. The model did not demonstrate significant sensitivity to the roughness height. A roughness height of 0.05 m was selected as it provided the optimal representation of the water level and the current speed at the project site.

Initial conditions

Spatially varying water depths and velocities were used as initial conditions for the 3D hydrodynamic model. These were created by running the model over a 10-day period prior to the calibration and validation period to ensure the model had sufficient warm-up.

Wind friction

The model is forced by wind measurements available at Beacon 1. Sensitivity tests indicated that the measured wind at Beacon 1 yielded better model results than the ERA5 hindcast wind. However, note that the gaps present in the measured time series at Beacon 1 were filled using the ERA5 data. A series of sensitivity tests were conducted to identify the wind friction coefficient that best matched the modelled currents with measurements. Following this testing a constant wind friction coefficient equal to 0.0008 was adopted.

Wave radiation stresses

In order to account for wave-induced currents, the wave radiation stresses should be included in the HD model. The wave radiation stresses were generated by the calibrated and validated wave model (refer to **Section 4**). Sensitivity tests showed that including wave radiation stresses resulted in significantly large

currents that are inconsistent with the measurements. The model setup does not include calibration parameters to adjust wave-induced currents. Excluding wave radiation stresses, the model results showed acceptable agreement with the measured data. Therefore, wave radiation stresses were not included in the model.

The settings adopted in the HD model are summarised in **Table 5-3**.

Table 5-3: Adopted hydrodynamic model settings

Parameters		Description
Boundary conditions		DTU10 tide level
Equation		Shallow Water Equations
Solution Technique	Time integration	Low Order, Fast algorithm
	Space discretisation	Low Order, Fast algorithm
	Minimum timestep	0.01 s
	Maximum time	600 s
	Critical CFL number	0.8
Depth Correction type		No depth correction
Vertical discretisation		5 sigma layers
Flood and dry	Drying Depth	0.005 m
	Wetting Depth	0.1 m
Density type		Barotropic
Eddy Viscosity		Smagorinsky formulation, constant: 0.28
Bed Resistance		Roughness height, constant value = 0.05m
Coriolis Forcing		Varying in domain
Wind forcing		Measured wind at Beacon 1 (time-varying and constant in domain)
Wind friction		0.0008
Wave radiation		Not included
Initial conditions		Spatially varying water depth and velocities (HD model output)

5.5.2 Simulation periods

Wind-induced currents play an important role in the hydrodynamics of the project site. As discussed in **Section 5.3.2**, Geraldton's wind climate shows a clear seasonal pattern, with strong southerly winds prevailing during the summer and less significant wind events in winter, mostly from the east. Therefore, it is essential to select calibration and validation periods that reflect distinct wind conditions. However, the availability and accuracy of the measured data are limitations to this matter. Note that the modelled currents are compared with measurements at near-bed, mid-depth, and near-surface. The following calibration and validation periods were selected based on the available current measurements and wind variability:

Calibration period

To ensure a comprehensive assessment, two distinct calibration periods were selected based on the availability of measured data. This approach guarantees that current measurements are available from at least two locations during one period, and from at least one current station along with water level measurements during another period.

A period of 12 days starting from 07/04/2005 to 19/04/2005 was chosen for the first calibration period where ADCP measurements are available for both Beacon 1 and Beacon 17 (see **Figure 5-2** for locations). This period coincides with relatively strong southerly winds (up to 13 m/s) mostly from the south (see **Figure 5-5**).

The second calibration period was chosen from 17 November 2012 to 3 December 2012. During this period, ADCP measurements are available at Beacon 1 while water level measurements are available at Geraldton Harbour. This summer period includes multiple periods with strong winds (wind speeds up to 18 m/s) from the south and the west.

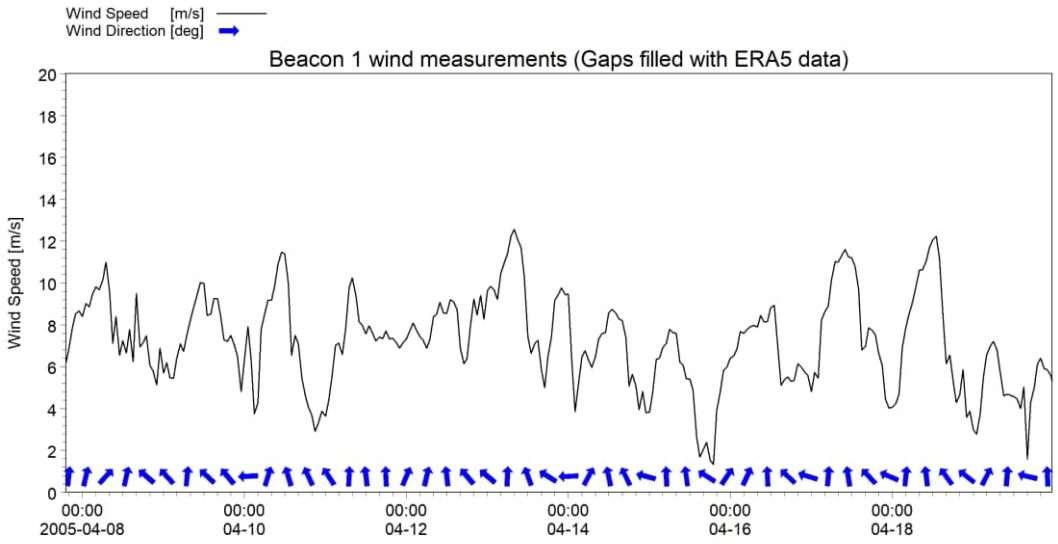


Figure 5-5: Measured 10-minute wind speed and wind direction at Beacon 1 during the first calibration period

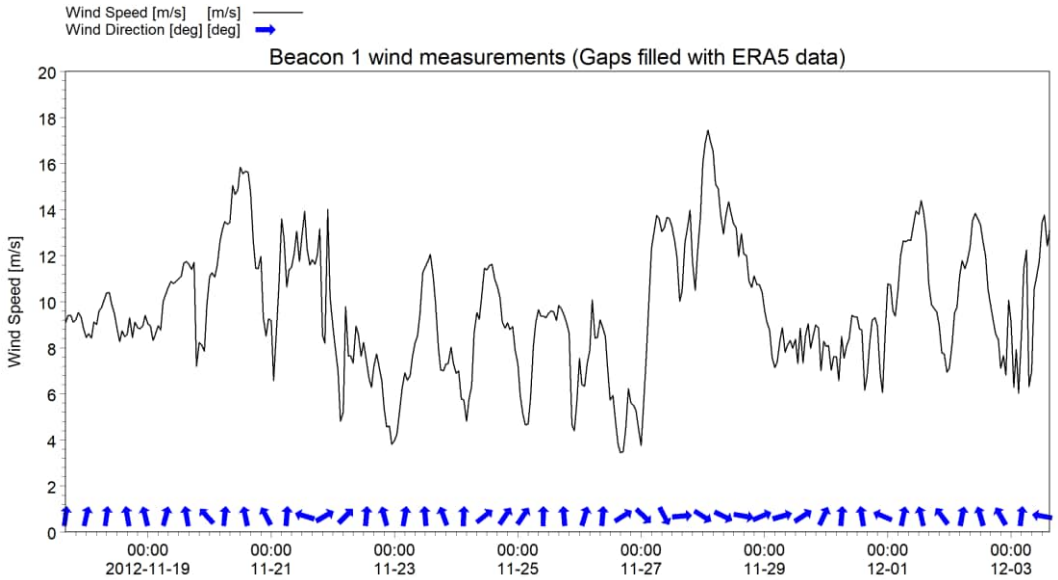


Figure 5-6: Measured 10-minute wind speed and wind direction at Beacon 1 during the second calibration period

Validation period

Two validation periods were selected:

- 25/10/2005 to 10/11/2005: As depicted in **Figure 5-7**, this period during the spring exhibits greater variation in both wind speed and wind direction compared to the calibration period. Although the southerly winds are still dominant, there are instances where the wind blows from other directions (i.e., west, north and east). For this validation period, the model results are compared against current measurements at Beacon 1; and

- 10/10/2021 to 21/10/2021: Current measurements are available at Sunset Beach (see **Figure 5-2** for location) from 21/10/2021 to 28/11/2021. Therefore, the second validation period is selected to ensure that the model can be validated against more recent data and a different location. This period includes a strong wind event (from 19 Oct to 21 Oct), mainly blowing from the west with wind speeds as high as approximately 17 m/s.

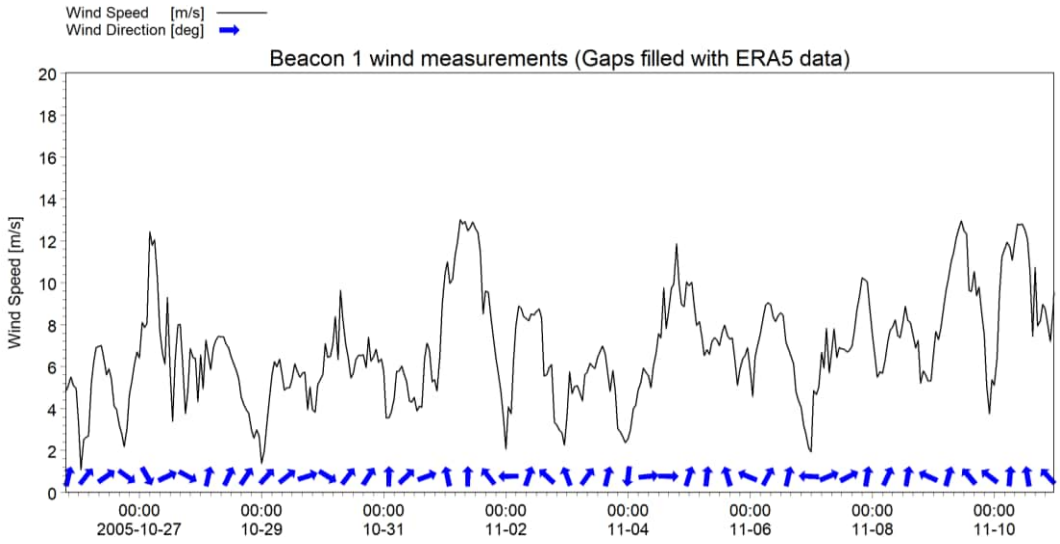


Figure 5-7: Measured 10-minute wind speed and wind direction at Beacon 1 during the first validation period (25/10/2005 to 10/11/2005)

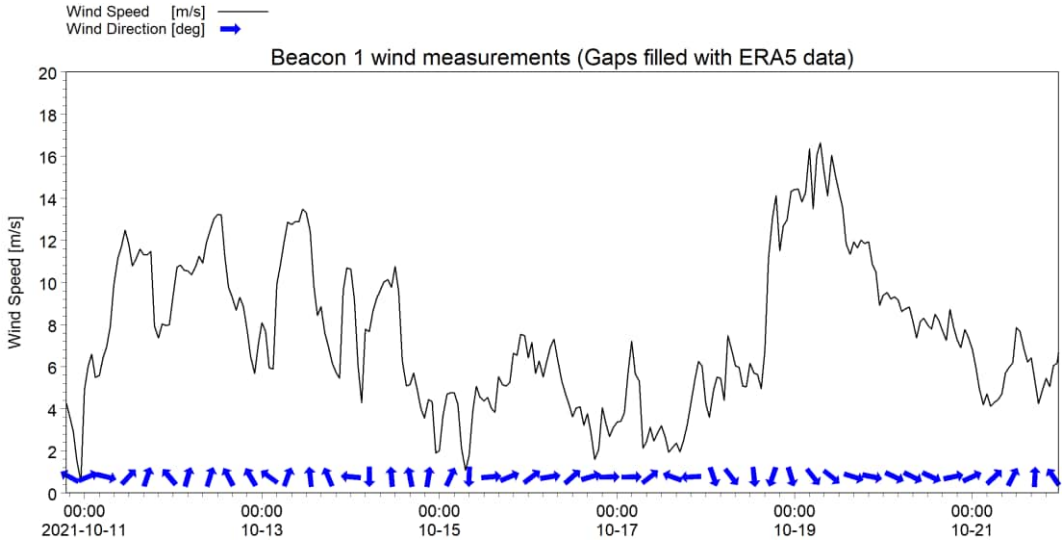


Figure 5-8: Measured 10-minutewind speed and wind direction at Beacon 1 during the second validation period (10/10/2021 to 21/10/2021)

5.5.3 Calibration Results

Modelled and measured current speeds and directions at near-bed, mid-depth and near-surface at Beacon1 during the first calibration period are presented in **Figure 5-9** and **Figure 5-10**, respectively. **Figure 5-11** and **Figure 5-12** depict the modelled current speeds and directions at Beacon 17 for the same period. The water level measurements at Geraldton Harbour are not available for this period. The model results show a reasonable agreement with the measurements and the model has been able to capture peak currents relatively well. The modelled current speed and direction at Beacon 1 for the second calibration period are presented in **Figure 5-13** and **Figure 5-14**, respectively. Note that measurements at Beacon 17 are not available for this period. The plots show that the model is typically able to provide a good representation of the measured currents at Beacon 1. The plots also demonstrate the model's capability to provide a good representation of the variability in the measured current speed and direction through the water column.

Figure 5-15 presents the modelled water level against measurements at Geraldton Harbour. During some periods, the modelled water levels agree reasonably with the measurements, while in other periods, the model underpredicts the variation in water levels. As the model includes the process of local winds, this shows that the variability in the measured water levels is also due to other processes such as atmospheric pressure and potentially regional wind processes which are not included in the model. Given that the objective of the hydrodynamic model is to simulate the local flow conditions (which are not influenced by surges), it is not necessary for the hydrodynamic model to accurately represent the total water levels (astronomical tide + surge) provided it is able to represent astronomical tide and currents (mainly wind-driven).

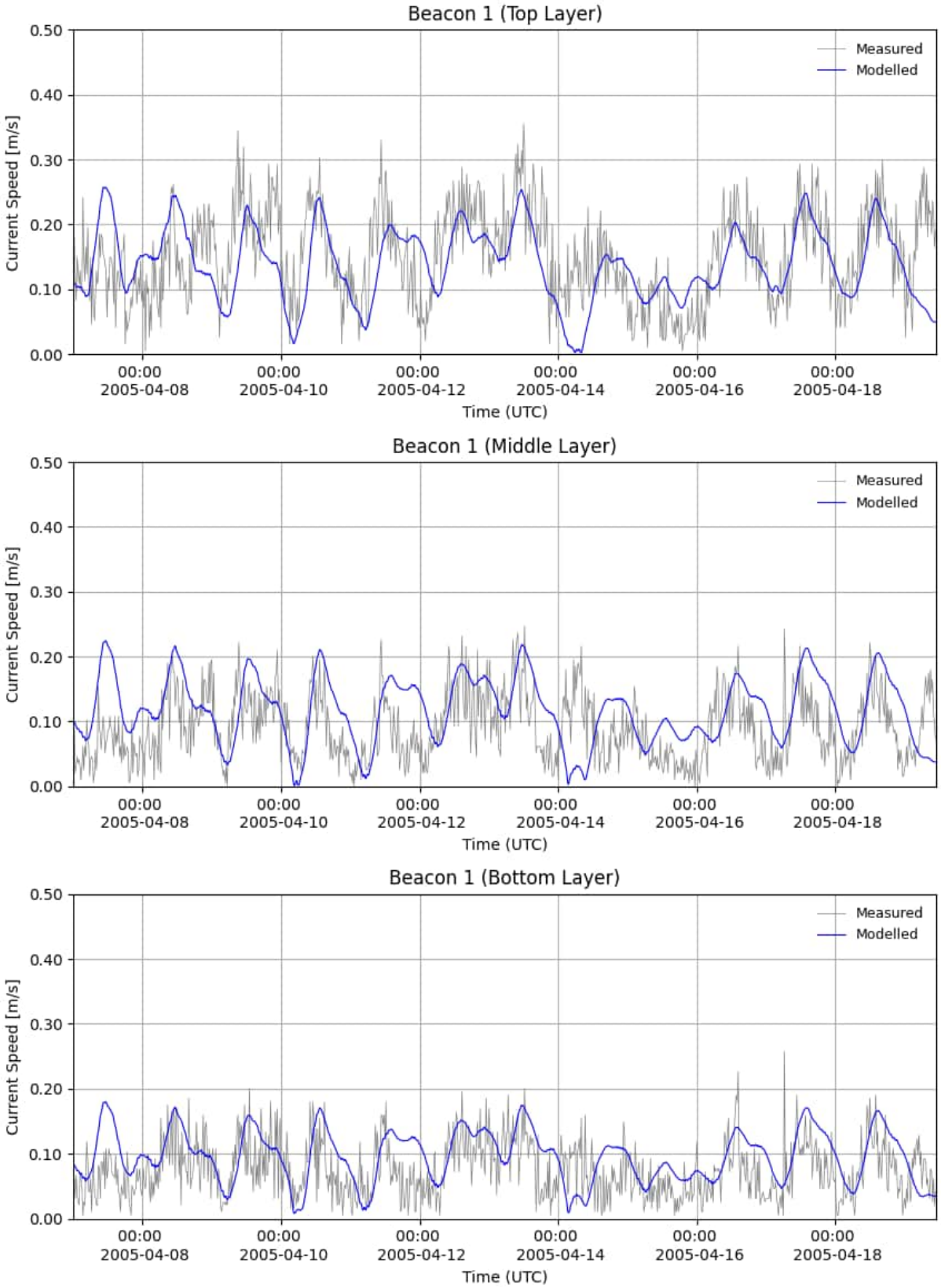


Figure 5-9: Modelled and measured current speed at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

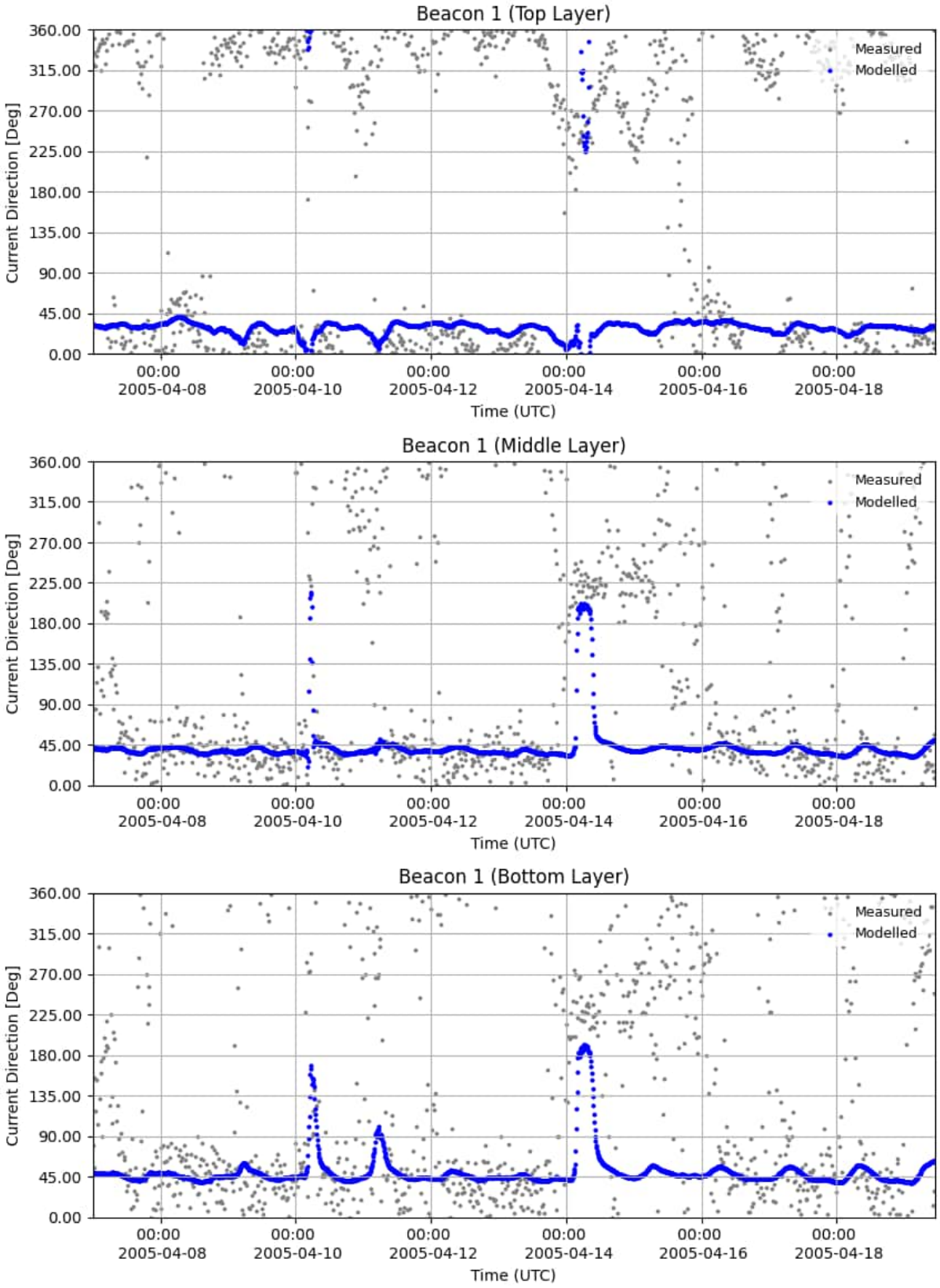


Figure 5-10: Modelled and measured current direction at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

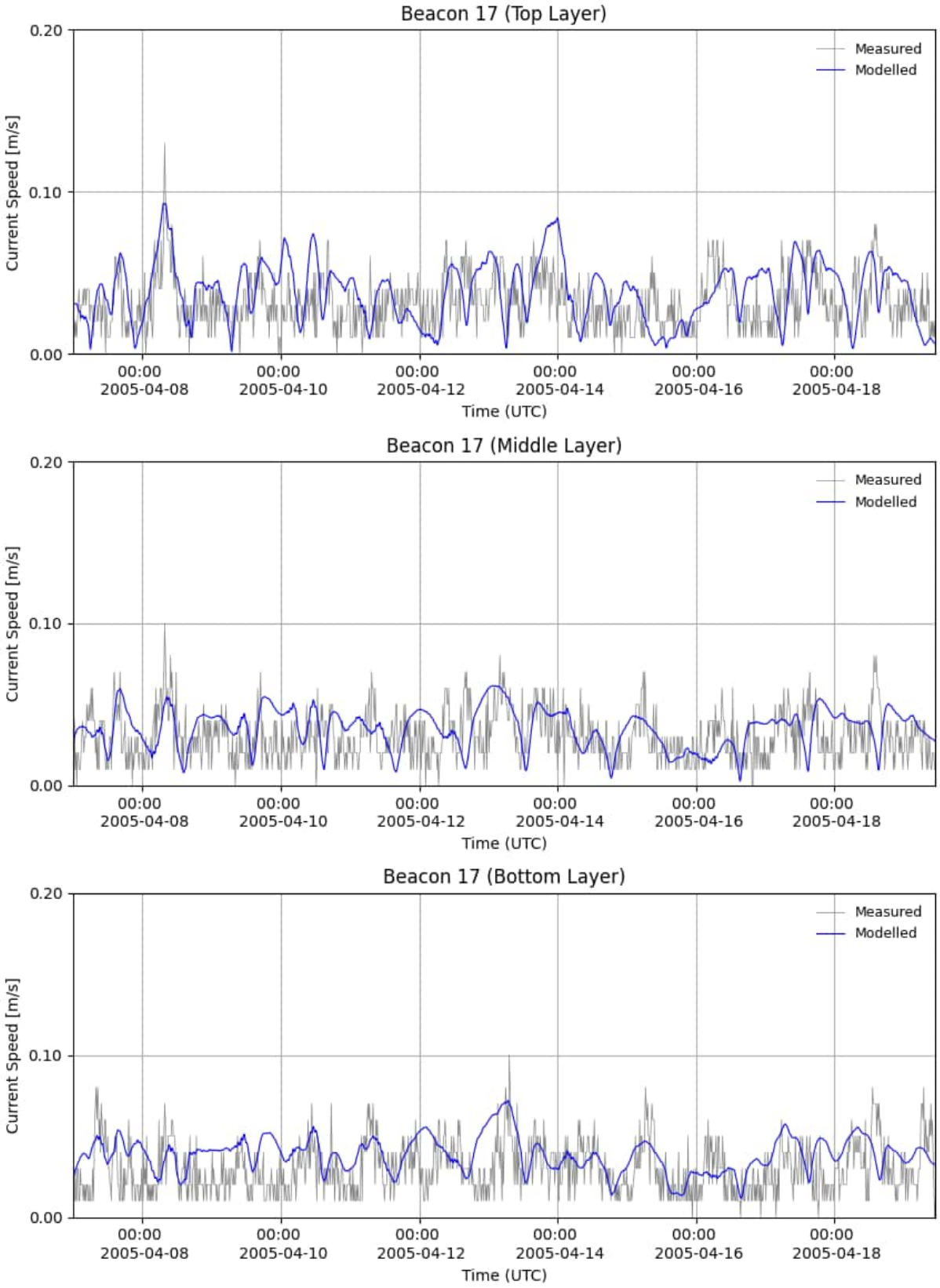


Figure 5-11: Modelled and measured current speed at Beacon 17: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

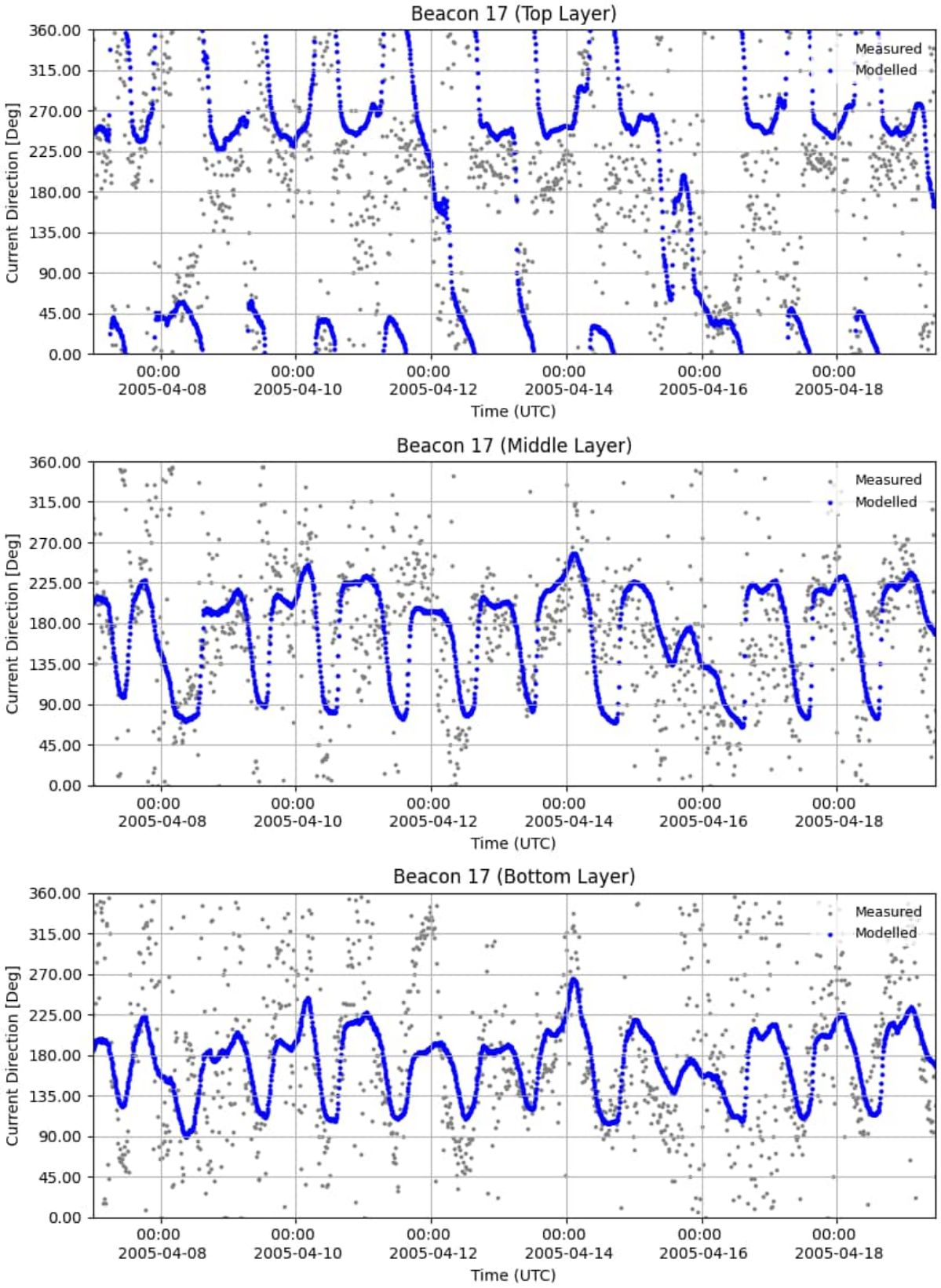


Figure 5-12: Modelled and measured current direction at Beacon 17: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

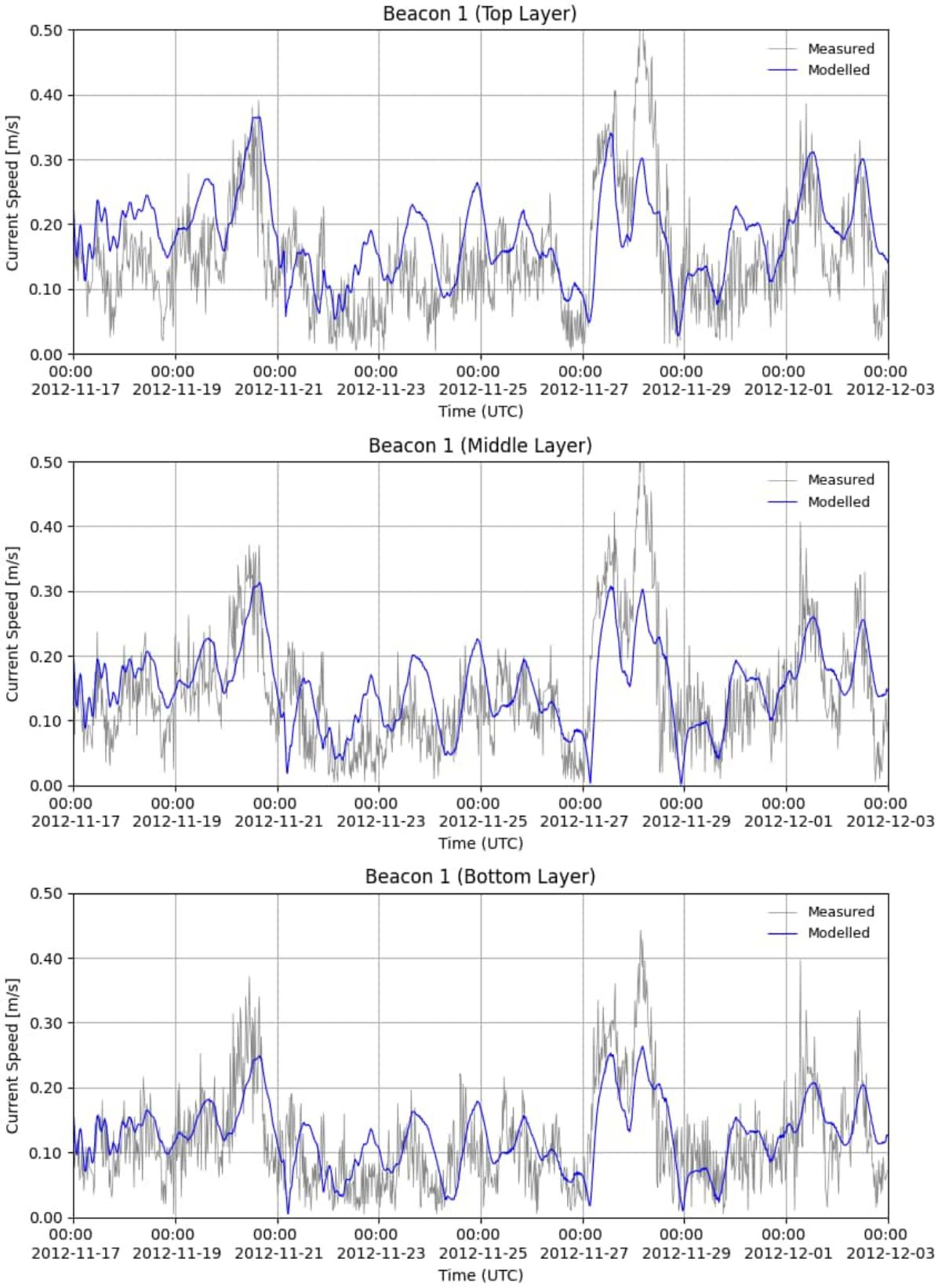


Figure 5-13: Modelled and measured current speed at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

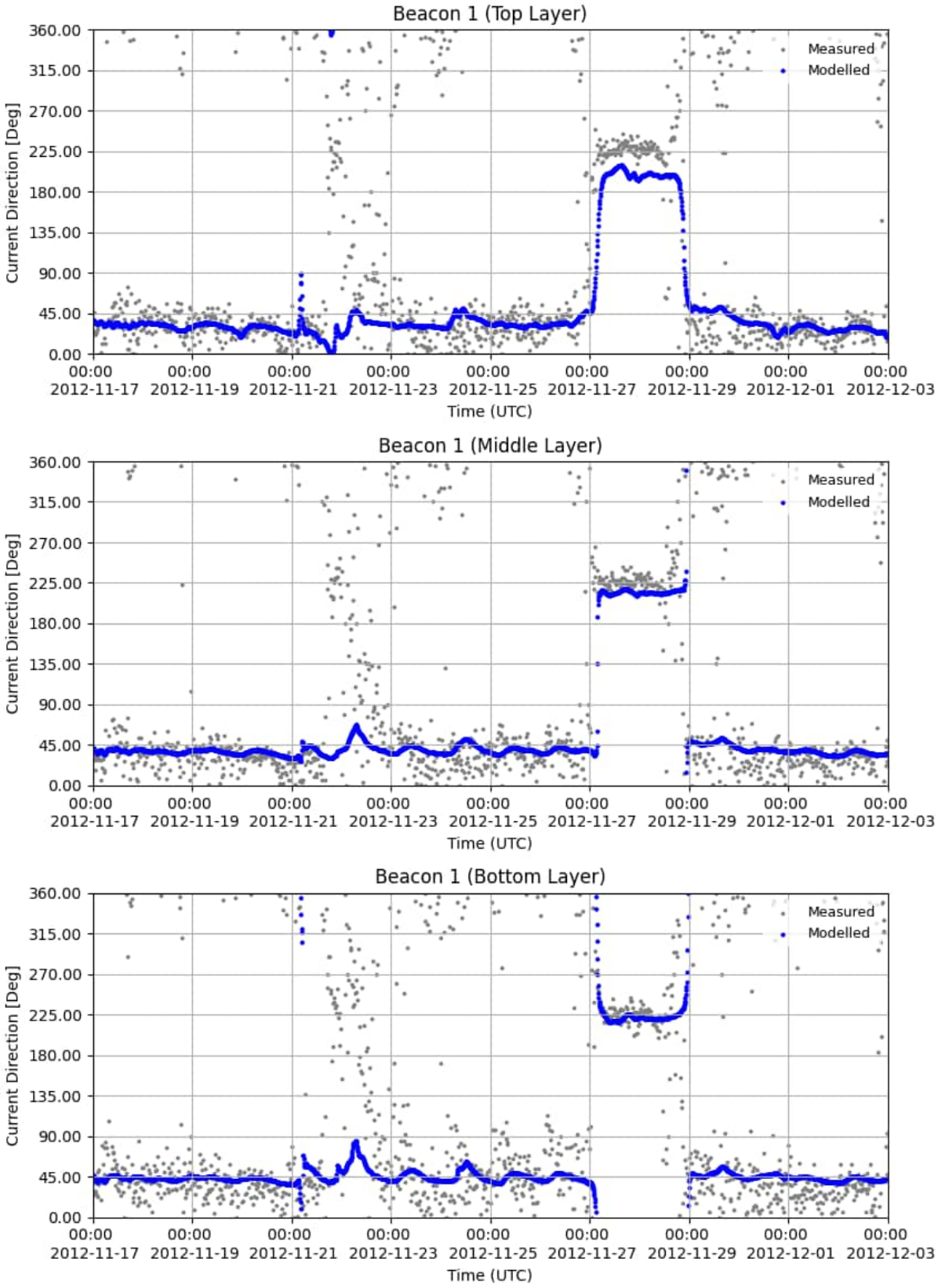


Figure 5-14: Modelled and measured current direction at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

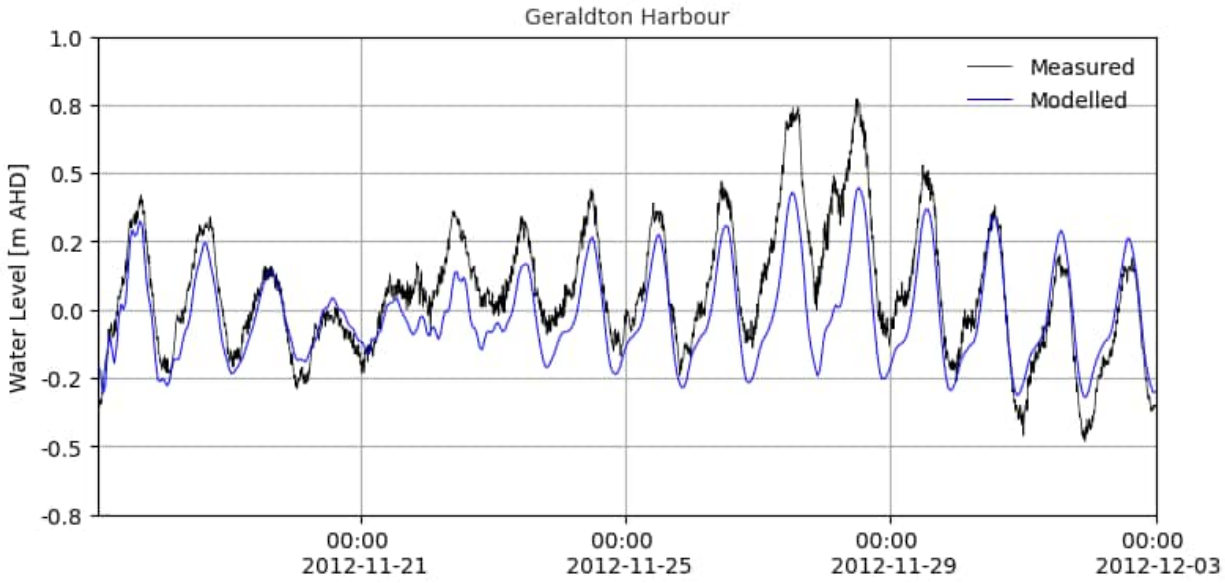


Figure 5-15: Modelled and measured water level at Geraldton Harbour

5.5.4 Validation Results

Figure 5-16 and **Figure 5-17** depict the comparison of the modelled and measured current speeds at Beacon 1 near-bed, mid-depth and near-surface. The modelled currents are consistent and show good agreement with the measurements in all three layers. The model was further validated against more recent measurements at Sunset Beach (refer to **Figure 5-2** for location). The model reproduced the current velocities at all three layers (i.e., near-surface, mid-depth and near-bed) with reasonable agreement during the strong wind event (19 October to 21 October 2005).

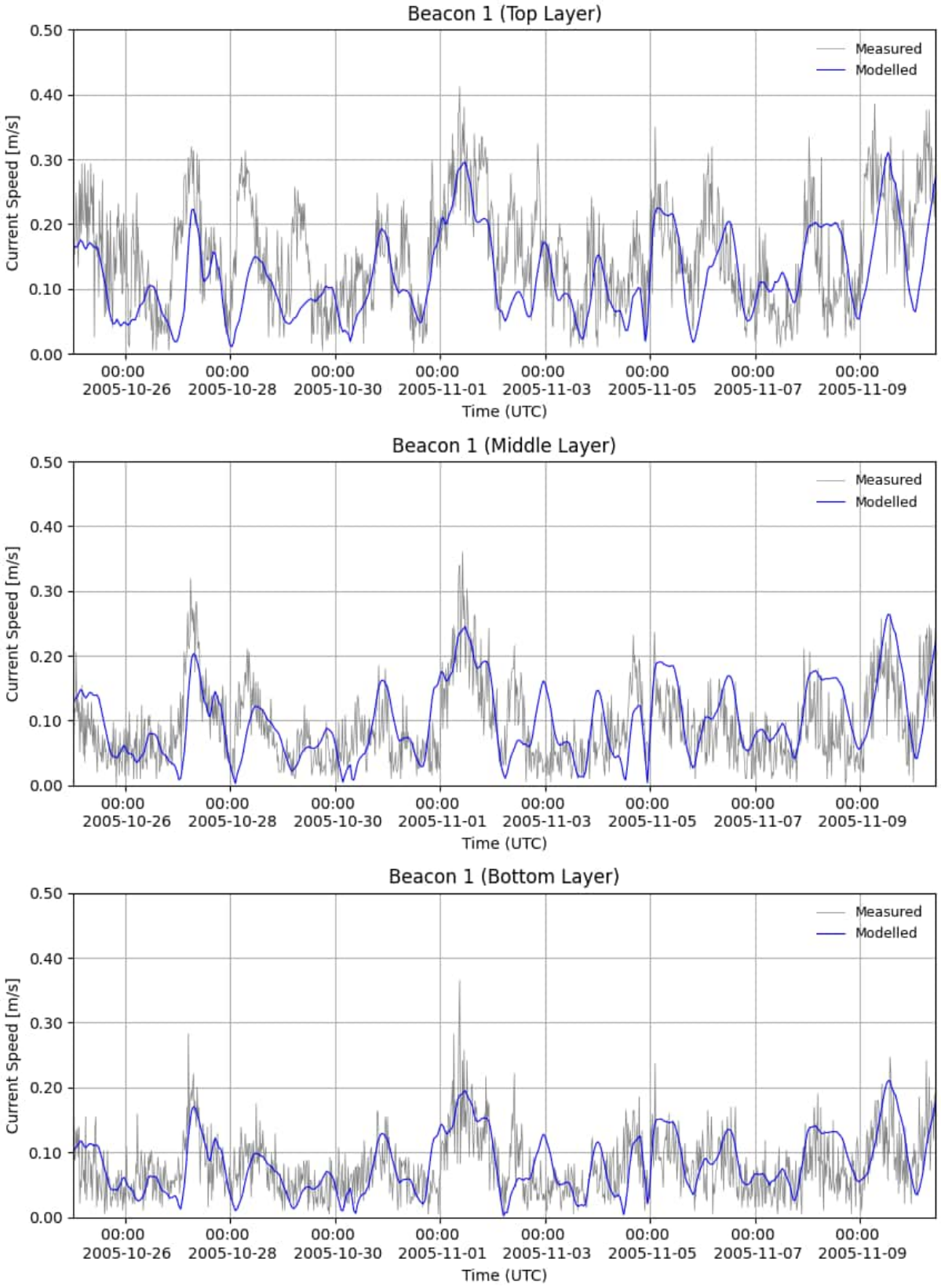


Figure 5-16: Modelled and measured current speed at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

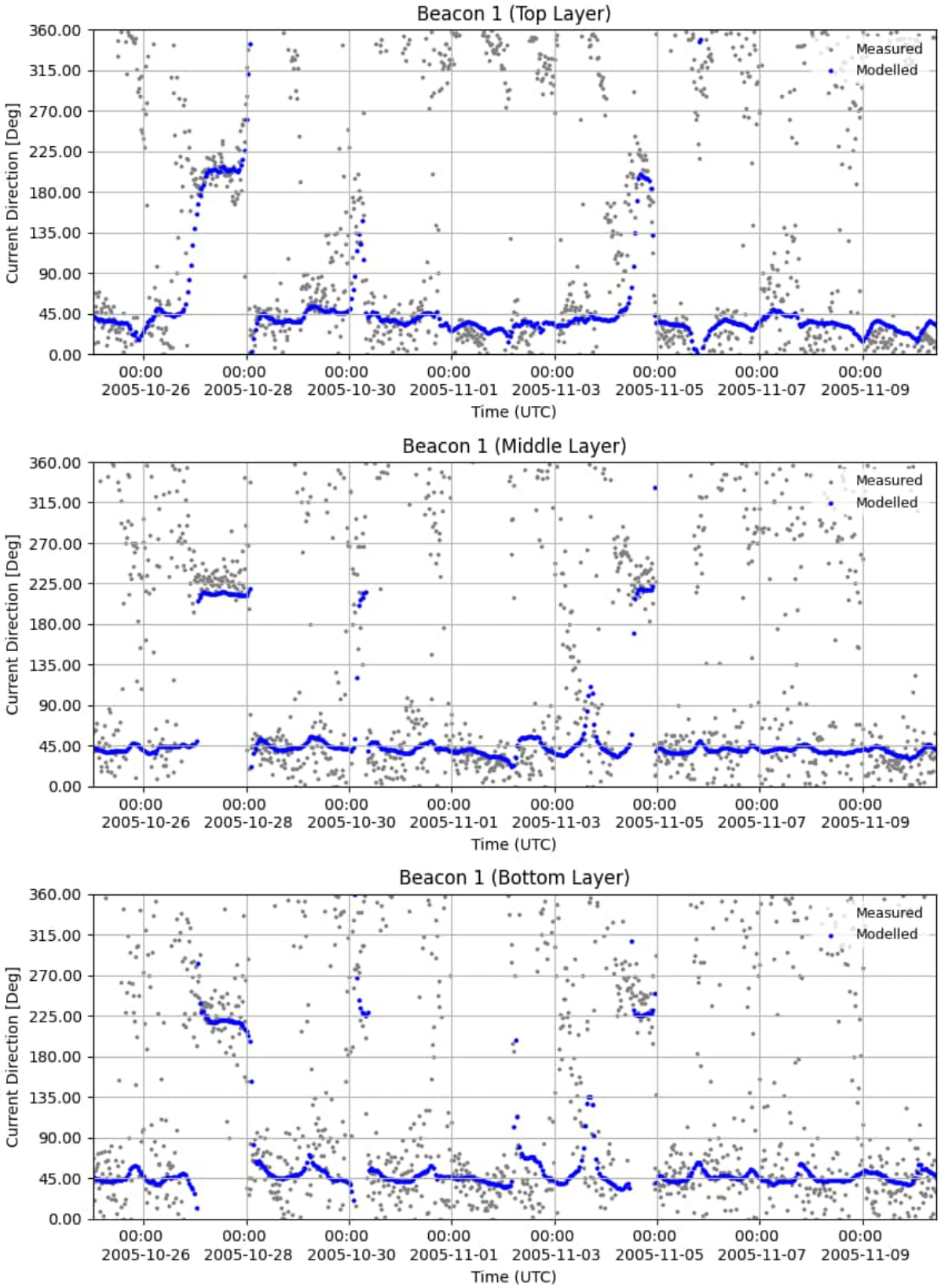


Figure 5-17: Modelled and measured current direction at Beacon 1: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

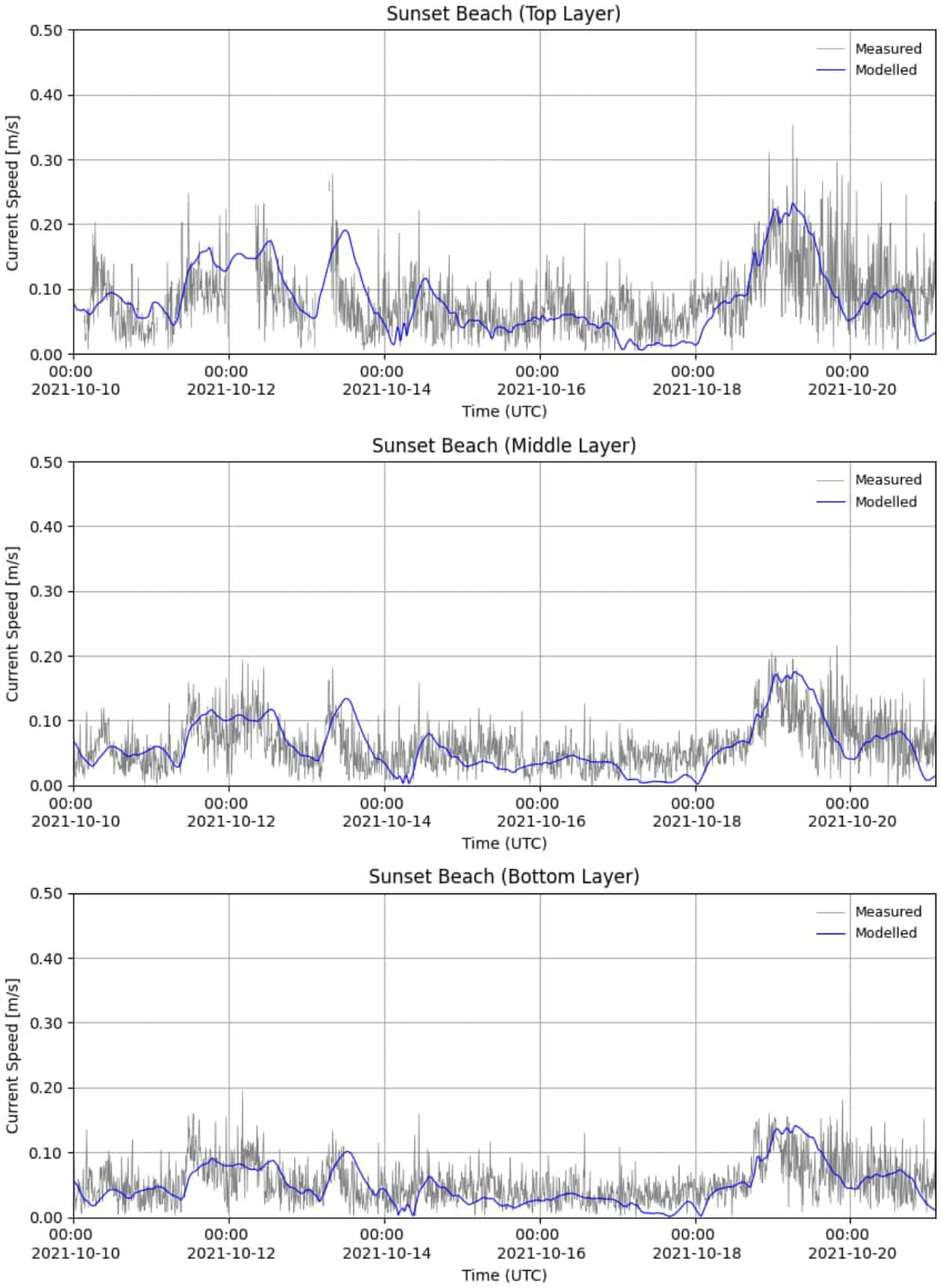


Figure 5-18: Modelled and measured current speed at Sunset Beach: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

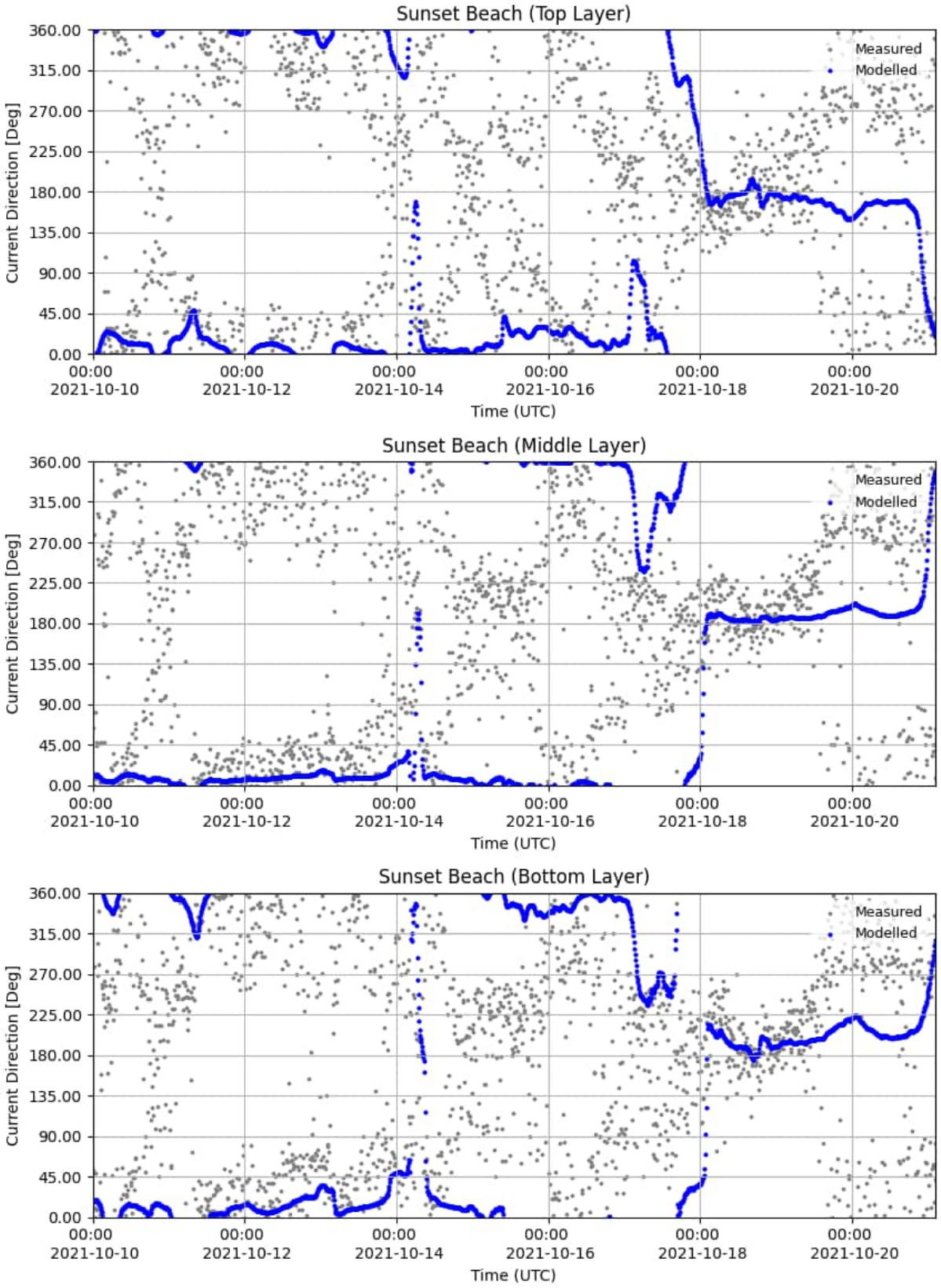


Figure 5-19: Modelled and measured current direction at Sunset Beach: near-surface (top plot), mid-depth (middle plot) and near-bed (bottom plot)

5.6 Summary

A hydrodynamic model was developed, calibrated and validated to simulate the flow field at the Geraldton Port. The model performance was examined against measured data at three different locations including Beacon 1, Beacon 17 and Sunset Beach. The flow field in this area is influenced by complex interactions between wave, tidal, and wind processes. Although the model cannot fully capture all of these natural processes, it effectively simulated the flow field, and the modelled currents near the bed, at mid-depth, and in the surface layer align well with the measurements. Therefore, the model is considered fit-for-purpose to provide the basis of the dredge plume model.

6 Dredge Plume Modelling

6.1 Introduction

The modernisation and improvement of Geraldton Port requires dredging activities to be undertaken. In order to assess potential impacts resulting from these dredging activities, numerical modelling has been carried out to represent the potential fate of sediments released into the water column through dredging. The modelling simulates the dispersal of suspended sediments by ambient currents as well as the subsequent deposition of sediment suspended by dredging. The modelling simulates sediment suspended by dredging, and therefore shows the impact dredging has on water quality (suspended solids concentration). Ambient suspended sediment concentration (SSC) and associated sedimentation are not simulated, however an assessment of (limited) available measured turbidity data in the vicinity of Geraldton Port was undertaken (refer **Section 6.4**). The disposal of the dredged material is not a relevant consideration in the dredge plume modelling presented here.

In order to represent the dredging activities in the numerical model, it is necessary to define the quantity, characteristics, location, duration and frequency of the material released into the water column. RHDHV in consultation with an appointed dredging expert have developed a dredging strategy, enabling a realistic representation of the actual dredging works. The amount of material which would become suspended in the water column during the dredging activities is referred to as the source term.

The modelled source terms are dependent on a number of parameters which relate to several aspects and processes, including the fines content of the material to be dredged, and the breakup of the dredge material under mechanical action and hydraulic transport. Other factors, including dredger efficiency, production rates and cycle times also feed into the magnitude of the source term.

6.2 Methodology

6.2.1 Dredge Scenarios

The numerical modelling of suspended sediment plumes generated as part of the proposed dredging activities to modernise and improve Geraldton is divided into three scenarios (refer **Section 1.4** for the key construction activities):

- Scenario 1: Maintenance dredging at the new Berth 1;
- Scenario 2: Capital dredging at Berths 1, 6 and 8, as well as Berth 1 and Berth 6 only; and
- Scenario 3: Capital dredging at the New Tug Harbour (NTH).

The approximate duration of the dredging works for each scenario is as follows:

- Scenario 1: 2 days and 17 hours;
- Scenario 2:
    - Berth 1: 2.08 weeks
    - Berth 6: 15.73 weeks
    - Berth 8: 14.25 weeks
- Scenario 3: 0.97 week.

As outlined in **Section 1.4**, Scenario 1 (Berth 1 maintenance dredging) will be completed prior to commencement of construction of the proposed expansion of Geraldton Port. The existing tug facility (refer **Figure 1-3**) near the proposed Berth 1 will still be in existence at the time of maintenance dredging. Scenario 2 (Berths 1, 6 and 8 capital dredging) and Scenario 3 (NTH capital dredging) both occur post the

construction of the proposed expansion of Geraldton Port (the existing tug facility will be closed off prior to commencement of capital dredging). This has been reflected in the bathymetry included in the numerical models.

6.2.2 Dredge Equipment

MWPA have indicated that maintenance dredging at Berth 1 (Scenario 1) and capital dredging at the NTH (Scenario 3) will take place by means of a trailer suction hopper dredge (TSHD). In order to minimise the environmental impact of Scenario 2 (with the longest duration), RHDHV and an appointed dredge expert have proposed undertaking capital dredging at Berths 1, 6 and 8 by means of a backhoe dredge (BHD). The plume modelling of the three scenarios has been based on these equipment assumptions.

It is noted that the application of any silt curtains has not been taken into account. It is common practice to install silt curtains around the BHD (also referred to as moon pools), however this has not been modelled (which is conservative).

6.2.3 Dredge Simulation Periods

6.2.3.1 Model Simulation Periods

MWPA have indicated that the months in which dredging of the scenarios will commence are best indicators at this stage, as follows:

- Scenario 1: January (2026) – dredge duration approx. three (3) days;
- Scenario 2: April start (2026 or 2027) - dredge duration approx. 32 weeks; and
- Scenario 3: May (2027) - dredge duration approx. seven (7) days.

While dredging is projected to occur in 2026 and 2027 (refer **Figure 6-1**), alternative years had to be nominated for numerical modelling, primarily given the need for actual measured wind data. The years 2005 (Scenarios 2 and 3) and 2009 (Scenario 1) were selected on the basis of the available calibration and validation periods (refer **Section 5** – providing additional confidence in the model) and available measured data. In combination with the dredge durations outlined in **Section 6.2.1**, the dredge simulation periods are as presented in **Table 6-1**. It is noted that Scenario 3 has been simulated in both May and April (2005), due to the a-typical metocean conditions in May 2005 (refer **Section 6.2.3.2**).

Rev 8			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Dredge																
Berth 1 Maint Dredge Pocket																
Berth 1 Capital Dredge																
Berth 6 Marine																
Berth 8/9																
Tug Harbour (Nxt Port Maint Dredge)																
Construction																
Tug Harbour Seawalls / Breakwaters																
- Outer Wall				*Core & filter construction (seawall will be functional in this phase)*					Armour placement							
- Inner Wall (extension of existing)									*Core & Filter construction*				Armour placement			
- Toe Stabilisation (Inside Tug harbour)																
Tug Harbour Piling (40 Piles)																
B1 Causeway & Revetment																
B1 Piling (#120 piles)																
B1 Structural (Deck Install)																
B6 Piling - #120 *(including Sheet Piles - Land side 60m)*																
B6 Structural																
B2 Berth Demolition																
B8 Piling																
B8 Structural																

Figure 6-1: Proposed PMaxP construction schedule

Table 6-1: Dredge scenarios simulation periods

Scenario	Sub-scenario	Model start	Dredging start	Dredge duration	Dredge end	Model end
Scenario 1		03/01/2009 3:30	03/01/2009 3:30	2d17hrs	05/01/2009 20:00	17/01/2009 21:30
Scenario 2	Berth 1 and 6 only	01/04/2005 0:00	01/04/2005 0:00	17.81 wks	03/08/2005 16:00	11/12/2005 0:00
	Berth 1, 6 and 8	01/04/2005 0:00	01/04/2005 0:00	32.06 wks	11/11/2005 10:00	11/12/2005 0:00
Scenario 3	April	01/04/2005 0:00	02/04/2005 0:00	0.97 wks	08/04/2005 19:00	27/04/2005 6:00
	May	03/05/2005 17:00	03/05/2005 17:45	0.97 wks	10/05/2005 12:45	29/05/2005 23:00

6.2.3.2 Metocean Conditions

The metocean conditions during simulation of the above scenarios are presented in **Figure 6-2** to **Figure 6-5**. Metocean conditions are of particular importance to Scenario 1 and Scenario 3 given their relatively short durations (approximately 3 and 7 days, respectively) and as a result the increased likelihood that conditions during dredging are not typical for the season. This is not relevant for Scenario 2 given the long duration of dredging (>32 weeks) and conditions are likely to be representative of typical conditions for that period (hence time-series of water level and wind for Scenario 2 are not presented).

As alluded to in **Section 6.2.1**, metocean conditions during the selected model period (May 2005) for Scenario 3 are not considered typical and an additional case was simulated in April 2005 (compare the two right-most panes of **Figure 6-2**, as well as **Figure 6-4** and **Figure 6-5**).

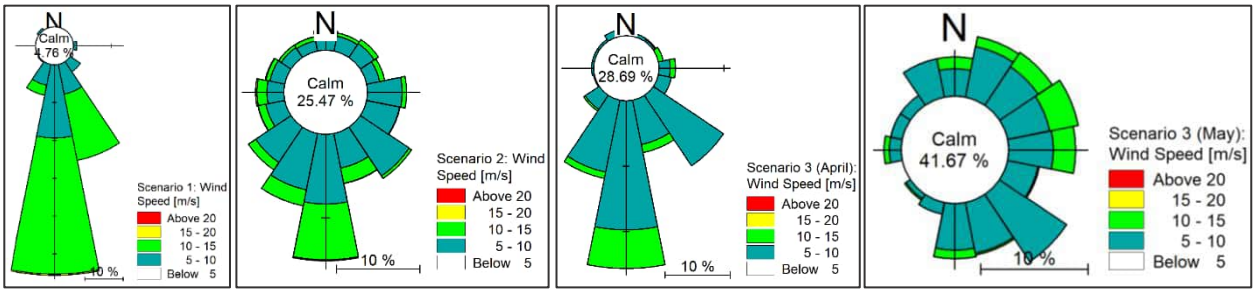


Figure 6-2: Wind roses during simulation of (from left to right) Scenario 1, Scenario 2, Scenario 3 (April) and Scenario 3 (May)

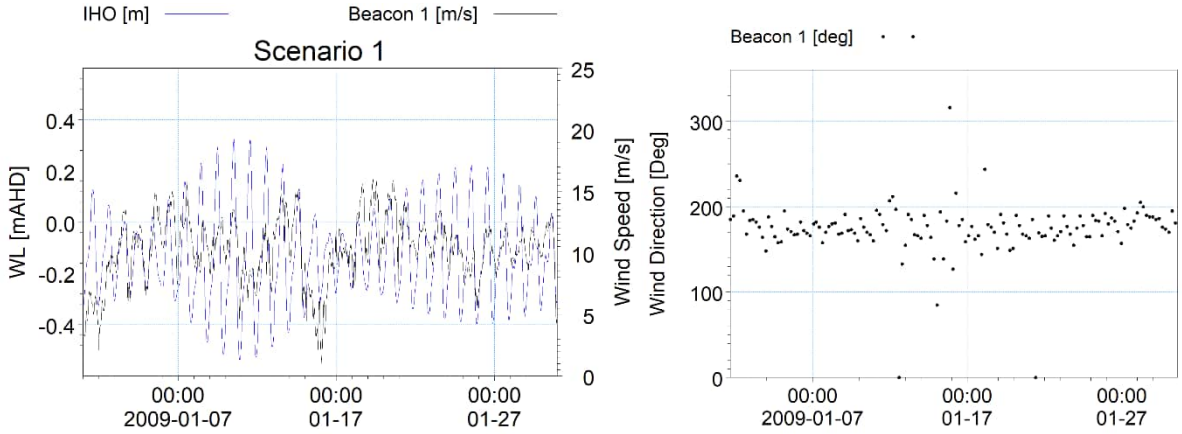


Figure 6-3: Scenario 1 simulation metocean conditions (water level, wind speed and wind direction)

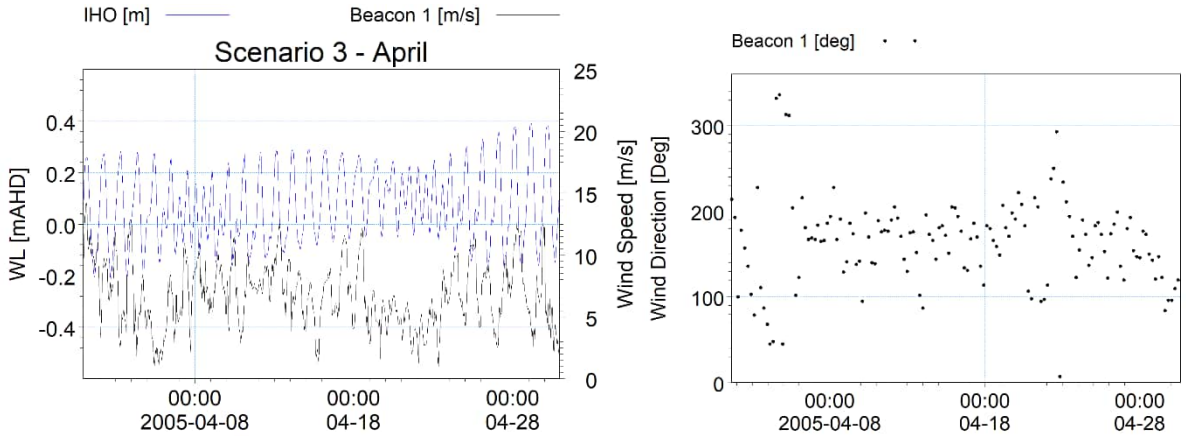


Figure 6-4: Scenario 3 simulation metocean conditions (water level, wind speed and wind direction) - April

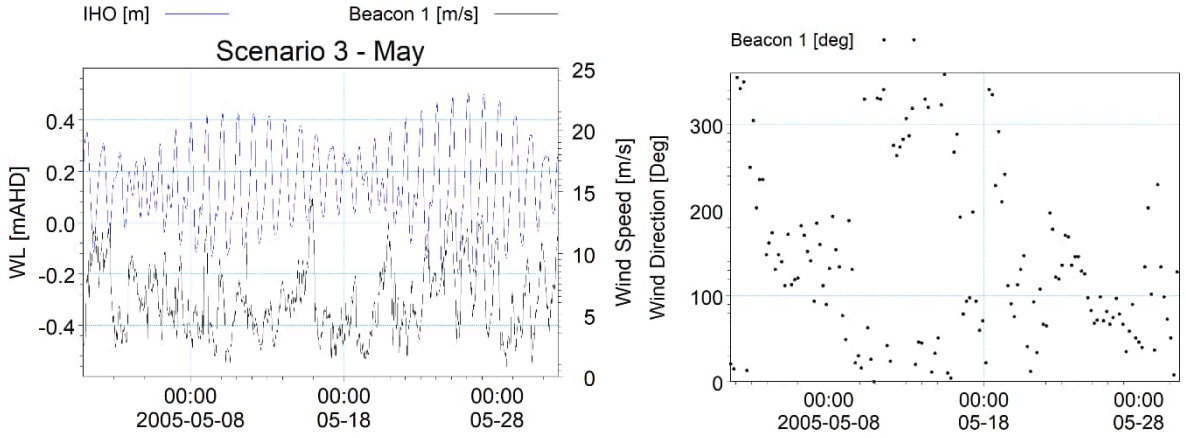


Figure 6-5: Scenario 3 simulation metocean conditions (water level, wind speed and wind direction) - May

6.2.4 Model Settings

A suite of numerical models has been developed including wave, hydrodynamic (HD) and mud transport (MT) models (as outlined in **Section 3**) to assess the impact of dredging on water quality. The HD model accounts for tide-induced currents and wind-driven currents from local wind conditions. The MT model was

run in a decoupled mode using the pre-run hydrodynamic outputs. The MT model also includes the wave field in terms of significant wave height (H_s), peak wave period (T_P) and peak wave direction (D_P). The development, calibration and validation of the wave and HD models are presented in **Section 4** and **Section 5**, respectively. The settings adopted in the MT model to estimate dredge-induced SSC are summarised in **Table 6-2**.

Table 6-2: Mud transport (MT) model settings for representing dredge-induced SSC

Settings	Parameter	Description				
Solution technique	Time integration/Space discretisation	High order/High order				
Water column properties	No of fractions	5				
	Fractions	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay
	Grain size (µm)	67.5	50.0	30.0	11.0	1.0
	Settling velocity (m/s)	9.787e-4	5.500e-4	2.100e-4	3.520e-5	1.200e-6
	No of bed layers	1				
	Flocculation	Not included*				
	Critical shear stress for deposition	0.05 N/m^2				
Bed parameters	Critical bed shear stress for erosion	0.1 N/m^2				
	Erosion coefficient	5e-05 kg/m^2/s				
	Power of erosion	8.3				
	Bed density	180 kg/m^3				
Dispersion	Horizontal/Vertical dispersion	Scaled eddy viscosity (Hor.=1, Ver.=1)				
Initial conditions	Initial TSS	Zero for both fractions (given that only excess SSC is modelled)				
	Initial bed thickness	Zero bed thickness (existing bed thickness is highly variable and unknown)				
Boundary conditions	TSS	0 mg/L				

** Refer **Section 6.3** for further details on the exclusion of flocculation*

It is noted that the model allows for the suspended sediment to be deposited and re-suspended again. A critical bed shear stress for deposition equal to 0.05 N/m^2 was defined, as per **Table 6-2**. As long as the bed shear stress is below this value, suspended sediment will deposit.

Critical bed shear stress for erosion is set to 0.1 N/m^2, again as per **Table 6-2**. Once the bed shear stress exceeds this value, the bed is eroded and the sediments (from dredging) are re-suspended (it is highlighted again that existing bed thickness is not taken into account, as this is unknown and highly

variable). The wave field was included in the plume model, so the plume model calculates bed shear stress taking into account both the currents and the wave field.

6.2.5 Model Output

A range of outputs have been prepared for the above dredge scenarios, presenting excess SSC due to dredging. The modelled SSC is excess SSC above the ambient (or background) concentration.

6.2.5.1 Percentile Maps

The SSC model results due to dredging have been processed to calculate the spatial percentile exceedance maps over the:

- duration of the dredging (Scenario 1, 2 and 3); and
- duration of dredging + one week (Scenario 1 and 3 - due to their short durations the percentile maps may look different for a time after dredging has ceased, due to the way the dredge plumes advect and disperse).

The following percentile maps are presented:

- 50th percentile, showing the SSC value that is predicted to be exceeded for 50 per cent of the time during the dredging, or 84 hours in a week; and
- 95th percentile, showing the SSC value that is predicted to be exceeded for five per cent of the time during the dredging, or 8.4 hours in a week.

It is noted that the percentile plots do not show an actual dredge plume at any point in time. They are duration-based plots which show statistical summaries of the dredge plume concentrations over the selected analysis period. The percentile plots show the value for which SSC throughout the dredging duration is 'less than' a given percentage of the time. For example:

- the 50th percentile shows the value that is predicted to be exceeded for 50 per cent of the time, or 84 hours in a week; and
- the 95th percentile shows the value that is predicted to be exceeded for five per cent of the time, or 8.4 hours in a week.

The highest percentiles correspond to relatively acute and short-lived increases in SSC.

6.2.5.2 Time-Series

Time-series plots of the dredging SSC provide an understanding of the relative influence of the SSC from dredging on water quality. The following locations were identified within the study area to provide a greater resolution as to the influence of dredged material on water quality:

- Alongshore up to approximately 20km north of the project site;
- At nominated sensitive receptor (seagrass) locations (also refer SLR, 2024);
- On arcs emanating from the various dredge locations; and
- Near local areas of interest (Town Beach, Batavia Coast Marina).

Specifically, time series for each scenario are presented:

- at a number of nominated nearshore output locations (A to E) north of the project site (refer **Figure 6-6**);

- at a number of nominated output locations (L1 to L13) in sensitive receptor areas (refer **Figure 6-7**);
- at a number of output locations in a stepped arrangement emanating from the:
    - B1 dredge area (10 nominated output locations along the 100, 250, 500 and 1000m arcs – refer **Figure 6-8**);
    - B8/New Tug Harbour dredge area (14 nominated output locations along the 100, 250, 500 and 1000m arcs – refer **Figure 6-9**); and
- at a number of nominated output locations along Town Beach (TB1 to TB3) and at/in the vicinity of Batavia Coast Marina (BCM1 to BCM3) (refer **Figure 6-10**);

The time step of SSC time-series presented in this report are as follows:

- Scenario 1: 10 minutes
- Scenario 2: 30 minutes; and
- Scenario 3: 10 minutes.



Figure 6-6: Nearshore model output locations north of the project site



Figure 6-7: Model output locations in sensitive receptor areas



Figure 6-8: Model output locations emanating from the B1 dredge area (10 nominated output locations along the 100, 250, 500 and 1000m arcs)

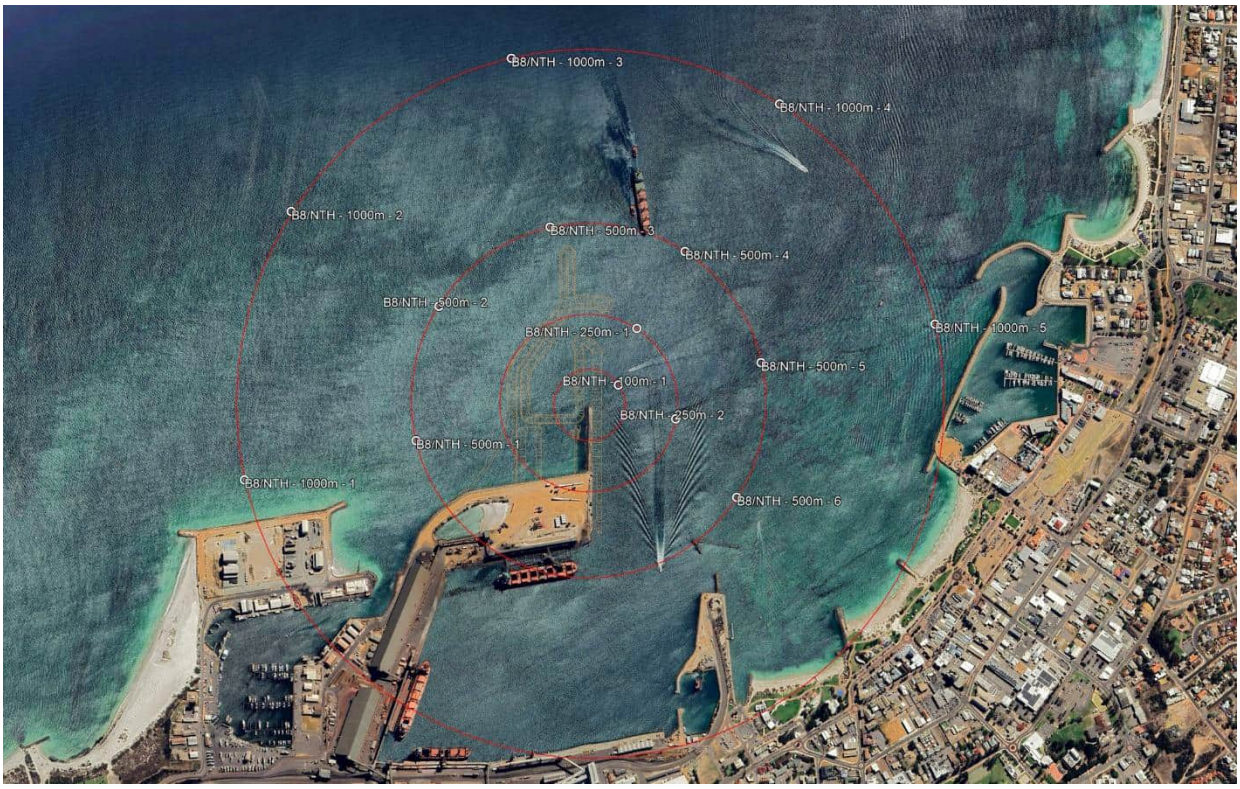


Figure 6-9: Model output locations emanating from the B8/New Tug Harbour dredge area (14 nominated output locations along the 100, 250, 500 and 1000m arcs)



Figure 6-10: Nominated model output locations at Town Beach and near the Batavia Coast Marina

6.2.5.3 Sedimentation Maps

Sedimentation maps of modelled fines (i.e., silts and clays from dredging activity) have been prepared for Scenarios 1, 2 and 3. The maps show sedimentation at the end of dredging. As outlined in **Section 6.2.4**, existing bed thickness is not taken into account (as it is unknown and highly variable) and therefore not shown.

6.2.5.4 Impact Maps

Introduction

For the purpose of this assessment, 'impact' maps for sedimentation and SSC as a result of dredging have been prepared for Scenarios 1, 2 and 3 based on guidelines provided in EPA (2016):

- Zone of influence/moderate impact/high impact for sedimentation; and
- Zone of influence/moderate impact/high impact for SSC.

The EPA guidelines specifically apply to the "*environmental impact assessment of development proposals that are predicted to cause impact or serious damage to, or permanent loss of, benthic communities and habitats*".

Accounting for Uncertainty

Uncertainty associated with impact predictions of sedimentation and suspended sediment concentration is relatively low, given the prescribed (by MWPA) dredge periods, prescribed dredge equipment and available soil information (the latter two going to source terms). As a result, the impact maps presented herein are considered to describe a **'most realistic'** impact scenario, as per the guidance in section 3.4 of EPA (2016).

Criteria

Impact zone thresholds for excess SSC and net sedimentation, utilised in generating the impact maps for each scenario herein, are presented in **Table 6-3** and based on EPA (2016) guidelines. The threshold of 2mg/L is similar to the 10-hr and 24-hr rolling average median ambient TSS (2.2mg/L and 2.4mg/L, respectively – converted from NTU, refer **Section 6.4** for details) at a turbidity data collection site considered representative of the entrance to the Port, where dredging is proposed (LL4 – refer **Section 6.4**). Turbidity at this location are estimated to be representative of 'normal' (typical) background conditions expected within Champion Bay and not significantly impacted by elevated turbidity in case of a breakout of the Chapman River (refer **Section 6.4**).

Table 6-3: Impact zone thresholds for excess SSC and net sedimentation (SLR, 2025)

Impact Zone	Definition (as defined by EPA, 2016)	SSC threshold	Net sedimentation threshold
ZoI*	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.	≥2 mg/L above background conditions for at least one (1) time step during a scenario	≥0.4 cm and <2 cm
ZoMI*	The area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of the dredging activities. This zone abuts, and lies	≥2 mg/L over 18 continuous days	≥2 cm and <3 cm

	immediately outside of, the zone of high impact.		
ZoHI*	The area where impacts on benthic communities or habitats are predicted to be irreversible. The term irreversible means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'. Areas within and immediately adjacent to proposed dredge and disposal sites are typically within zones of high impact.	Loss of perennial seagrasses: ≥2 mg/L for continuous 90 days	≥3 cm

** ZoI = Zone of Influence, ZoMI = Zone of Moderate Impact and ZoHI = Zone of High Impact*

The above output and key observations are presented in **Section 6.5.6**, **Section 6.6.6** and **Section 6.7.6** for Scenarios 1, 2 and 3, respectively.

6.3 Laboratory Settling Velocity Investigations

6.3.1 Introduction

Settling velocity is an input parameter required for the numerical modelling and it varies depending on site-specific parameters of the sediment/rock and water. Rather than adopting values calculated empirically or from published literature, the settling velocity was established from a laboratory investigation of the actual material to be dredged, to provide greater confidence in modelling outcomes.

The findings of the laboratory-based investigations in relation to the settleability of fine sediment in terms of settling velocity is summarised below. A comprehensive analysis report discussing (among other things) methodology, critical particle size analysis, limitations and quality assurance and control is presented in **Appendix A1**.

6.3.2 Sediment and Rock Source and Characteristics

Sediment for the laboratory testing was recovered by SLR in April 2024 and rock used for testing was recovered by BG&E in August 2023.

The selected sediment sample (B1-5) was obtained from the surface of the seabed, at the southern end of Berth 1 (refer **Figure 6-11**). The sample was selected based on the relatively high percentage of fine-grained particles (i.e., silts and clays), in comparison to the other sediment samples recovered. The higher percentage of fines within the sample was considered a conservative approach as these particles are expected to settle more slowly and remain in suspension for a longer period of time compared to coarser material (i.e., sands and gravels).

The rock core (BH-01OS) was obtained from a terrestrial borehole at the north end of The Esplanade (refer **Figure 6-11**). The depth of sample correlates with the dredge depth and similar material is expected to be encountered in the dredge footprint. Dredging activities are expected to crush the rock and generate fines. To produce a sample containing sand size and finer grained particles, the rock was crushed using a ring mill. The sample was then sieved to achieve a sub-sample less than 150µm, so as to remove coarser particles that would settle relatively quickly.



Figure 6-11: Sediment and rock sampling locations recovered by SLR in 2024 and BG&E in 2023, respectively

The particle size distribution (PSD) and moisture content for B1-5 was based on the findings of the laboratory analysis conducted for SLR in April 2024. The PSD is based on a combination of sieve and hydrometer analysis. The PSD for the crushed rock (BH-01OS) was undertaken using the Mastersizer 2000. The particle size was based on a representative dried sample.

A summary of the samples used for testing are provided in **Table 6-4** and the PSD is provided in **Figure 6-12**. Further details on the water source and characteristics utilised in the investigation are outlined in **Appendix A1**.

Table 6-4: Summary of samples tested

ID	Depth	Sediment Unit	Geology Description	Moisture Content (%)	% Particle Size[o]			
					Clay	Silt	Sand	Gravel
B1-5[^]	0 to 0.2 m below bed	Assumed Marine Deposit	Sandy SILT: Fine to medium grained, dark brown	46.8	18	47	34	1
BH-01OS[#]	14.5 to 14.7 m below ground level (-12.6 to -12.8 m RL[*])	Tamala Limestone	CALCARENITE: fine to medium grained, pale grey, trace gravels, fine to medium grained, sub-rounded, various lithology, trace shell fragments.	0	14	40	46	-

[o]*Percentage particle size classification based on AS 1726:2017: Clay = <0.02 mm; Silt = 0.02-0.75mm; Sand = 0.75-2.36mm; Gravel = >2.36mm2*
[^]*PSD determined from NATA Laboratory PSD analysis for SLR. Geological description by RHDHV*
[#]*PSD for the rock determined using Mastersizer 2000 for particles <150 um. Geology description from BG&E Geotechnical Factual Report (2023)*
[*]*RL – Reduced Level datum*

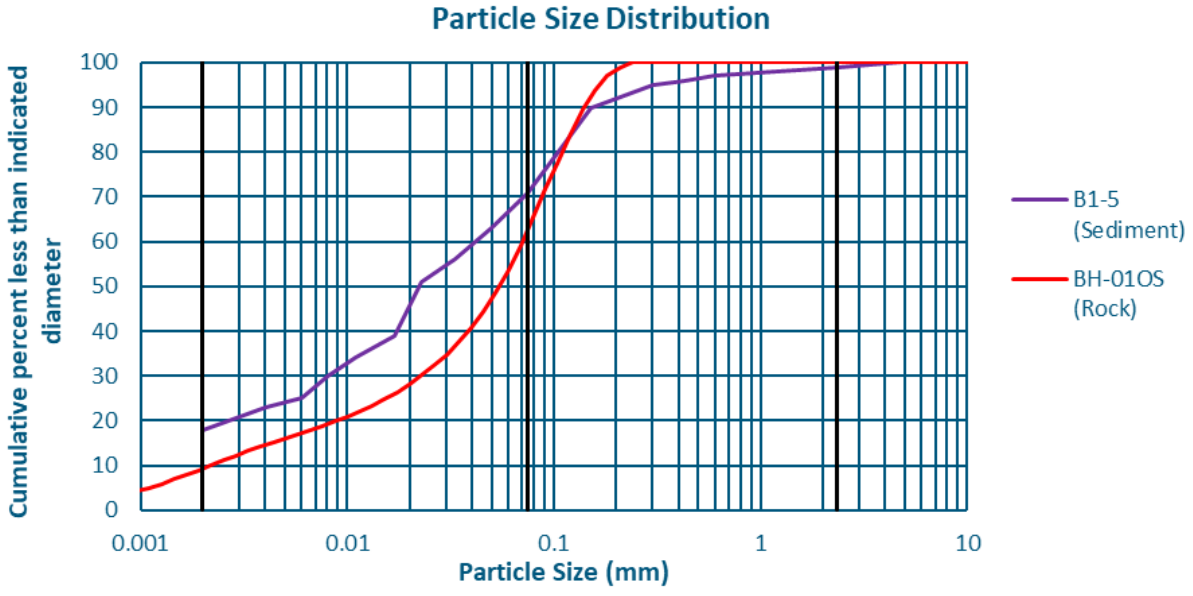


Figure 6-12: Sediment unit particle size distribution

6.3.3 Methodology

The procedure for the critical particle size analysis aimed to establish the PSD of suspended sediment within the water column at various time intervals during dredging and disposal activities, in addition to the

determination of the particle size in suspension used to estimate settling velocity and support modelling efforts.

Critical particle size analysis was undertaken with a Mastersizer 2000. The Mastersizer 2000 establishes the particle size distribution based on the difference in refraction between the dispersant and the suspended sediment sample. This instrument is sensitive to the reflective and refractive properties of particles and concentration of suspended particles (i.e., Total Suspended Solids - TSS). Both the sediment sample (B1-5) and crushed rock sample (BH-01OS) were analysed.

Further details on methodology are provided in **Appendix A1**.

6.3.4 Critical Particle Size Analysis

Results from the critical particle size analysis, indicating the D90 particle size in suspension at various time intervals, are provided in **Figure 6-13**. D90 is the particle diameter where ninety percent of the sample has a smaller particle size.

In all tests, the D90 particle size and the overall PSD was coarser at greater depths within the water column. Further, the D90 particle size in suspension progressively decreased over time. The above is to be expected based on theoretical settlement rates defined by Stokes Law where larger particles settle out of suspension faster than smaller particles.

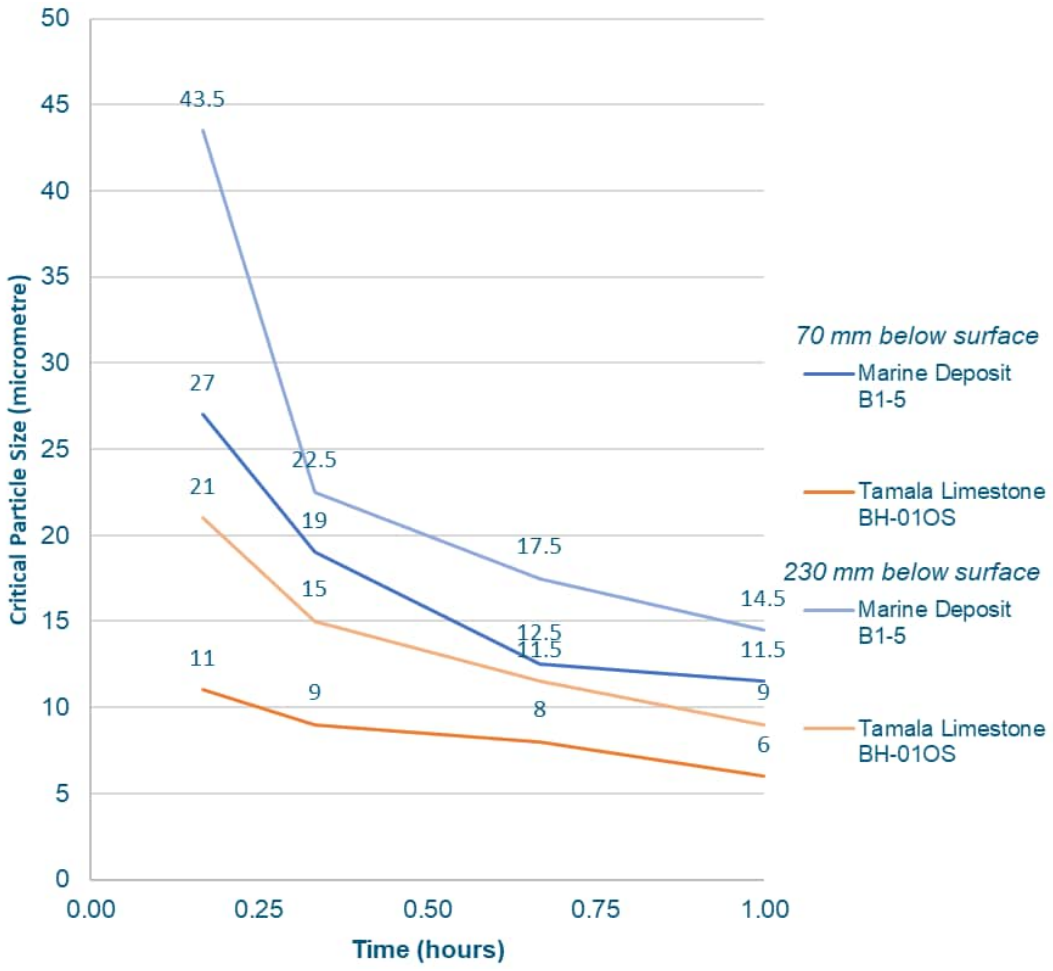


Figure 6-13: Visual summary of results from the critical particle size analysis

6.3.5 Coagulation, Flocculation and Settling Behaviour

Various tests were undertaken to better understand settling behaviour of the sediment and crushed rock.

Seawater is a natural coagulant that neutralises charges in colloidal clays and promotes flocculation. In general, due to coagulation, particle settling velocity of fines is typically higher in seawater compared to freshwater.

However, discrete flocculent settling (Class II – refer **Appendix A1**) was not observed, which is an important consideration for the dredge plume modelling and dredging operations as the settling velocity is slower than similar material that does readily flocculate in seawater. Further, increasing the concentration of suspended sediment/ crushed rock in suspension is not expected to increase settling velocity.

6.3.6 Settling Velocity

Based on the D90 particle size in suspension, at a given depth and after a predefined time interval, the settling velocity can be calculated. The settling velocities calculated from the critical particle size analysis are provided in **Figure 6-14** along with theoretical settling velocities determined by Stokes Law for a seawater temperature of 13 °C. Water temperature was not monitored as part of the critical particle size analysis. However, the temperature would have been similar to that measured as part of determination of the physico-chemical parameters (refer **Appendix A1**), which was 13.3-13.4°C. It should be noted that the water temperature at Geraldton is expected to be higher all year round than this temperature, which would result in an increase in the settling velocity in practice.

Settling velocity results indicates the crushed Tamala Limestone (BH-01OS) presents higher settling velocities than the marine deposit (B1-5). It is evident that the settling velocities determined from the critical particle size analysis results for the marine deposit sediment sample were generally lower than the theoretical settling velocity determined by Stokes Law, whilst the crushed Tamala Limestone settling velocities were similar to Stokes Law, albeit slightly higher with increased particle size. The lack of discrete flocculent settling (Class II) is an important consideration for Geraldton as settling velocity is expected to be lower than Stokes Law, which is shown by the critical particle size analysis.

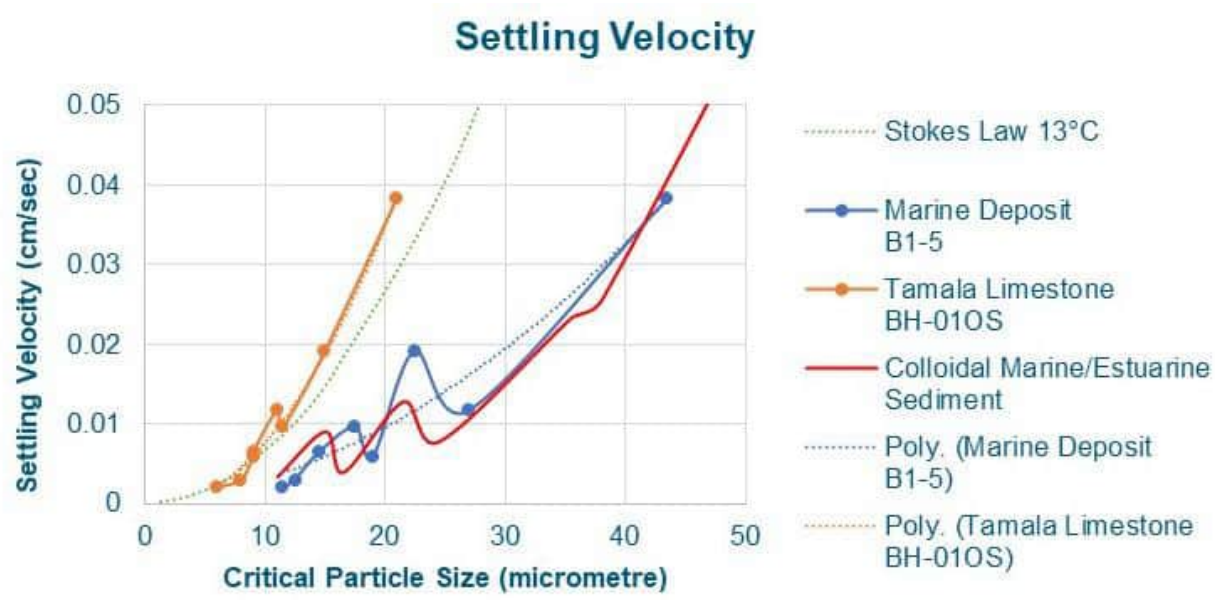


Figure 6-14: Settling velocity calculated from the critical particle size analysis

A discussion on the measured settling velocities compared to Stokes Law is provided in **Appendix A1**. For the purpose of the numerical plume modelling investigations, settling velocities for the marine deposit sample B1-5 were adopted.

6.4 Ambient Suspended Sediment Conditions

6.4.1 Introduction

The ambient suspended sediment concentration for the Geraldton Port region is of particular relevance to this project due to the project's dredging requirements and the potential for influence on sensitive ecological habitats. Limited turbidity (which is typically used as an indicator of SSC) and TSS data is available from various sources and was reviewed and assessed. A comprehensive memo is provided in **Appendix A2**. A summary is provided below.

6.4.2 Review of Measured Turbidity and TSS Data

6.4.2.1 Purpose

The purpose of this assessment is to present a summary of available turbidity and TSS data to inform the development of a baseline TSS concentration for a number of sites within Champion Bay. Note that baseline may also be referred to as ambient or background and represents the naturally occurring turbidity and TSS in the absence of any dredging operations. The baseline TSS would potentially be used to assess the significance of the dredge plume modelling results.

6.4.2.2 Available Data

Available datasets provided to RHDHV are summarised in **Table 6-5**. The datasets include TSS and/or turbidity (measured in NTU), noting that TSS and NTU are typically correlated. Monitoring locations for relevant datasets are shown in **Figure 6-15**.

Table 6-5: Summary of available and relevant datasets for determining baseline turbidity/TSS

Dredging Campaign	Available Relevant Data	Monitoring Locations	Relevant Data Capture Period	Comments
Geraldton Port Maintenance Dredging 2021	Episodic Turbidity Depth Profiles	WQD1, WQ2, WQL3, WQ4	16/08/21 – 2/12/21	• Collected prior to, during and post dredging to provide depth profiles and depth average results.
	Episodic TSS sampling	WQD1, WQ2, WQL3, WQ4	16/08/21 – 2/11/21	• Collected prior to and during dredging for model validation.
	Continuous turbidity monitoring	DL	23/07/21 – 1/12/21	• Collected prior to, during and post dredging. • 1-hr frequency
MWPA MEQMMP and PMaxP baseline data collection 2024	Continuous turbidity	LL1, LL3 and LL4	6/06/24 – 13/11/24	• 15-min frequency



Figure 6-15: Relevant baseline turbidity and TSS monitoring locations

6.4.2.3 Adopted Data

Turbidity data collected within Champion Bay, in the vicinity of the proposed dredging and modelled dredge plume, was used for the analysis herein.

The 2021 continuous turbidity monitoring data was limited to one location (DL) within Geraldton Port (Berth 6) and turbidity depth profiling was limited to two monitoring events to determine baseline conditions (i.e., pre-dredging) within Champion Bay. This dataset was not considered to be of sufficient duration for the purposes of the assessment herein. The turbidity measurements during dredging, while interesting for model calibration, do not provide baseline turbidity.

The 2024 continuous turbidity monitoring dataset was adopted for locations LL1, LL3 and LL4 within Champion Bay (shown on **Figure 6-15**) and considered adequate for the purposes of developing a baseline. The data was collected by O2 Marine. It is noted that monitoring location LL3, located furthest north, was deployed on its side and processed erroneous readings with higher-than-expected turbidity up until redeployment on 07 September 2024. As such, only data from this date onwards at LL3 was analysed.

6.4.2.4 Turbidity Time-Series Results

The turbidity data obtained from LL1, LL3 and LL4 is provided in **Figure 6-16**, **Figure 6-17** and **Figure 6-18**, respectively. The graphs present the 15-minute interval turbidity data, the 10-hour rolling average and the data collection and redeployment dates for each instrument.

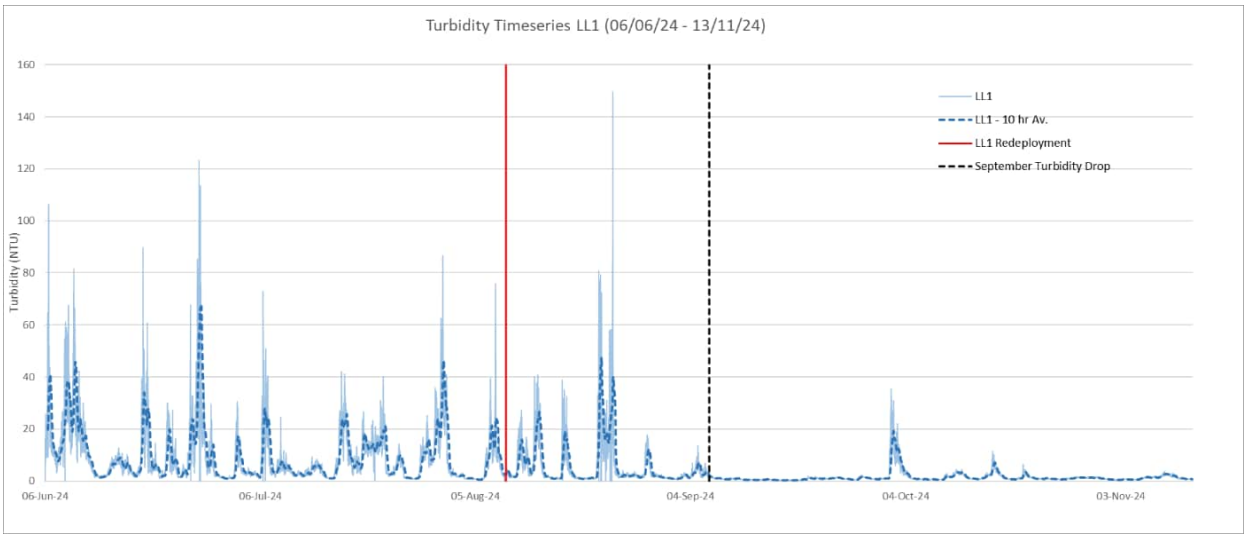


Figure 6-16: LL1 turbidity time-series

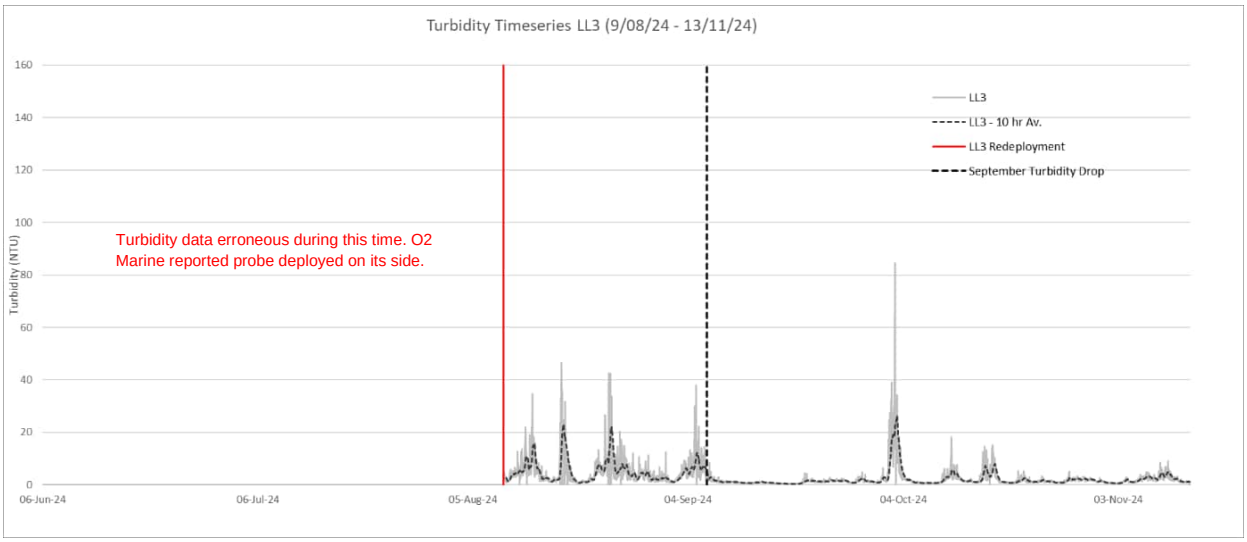


Figure 6-17: LL3 turbidity time-series

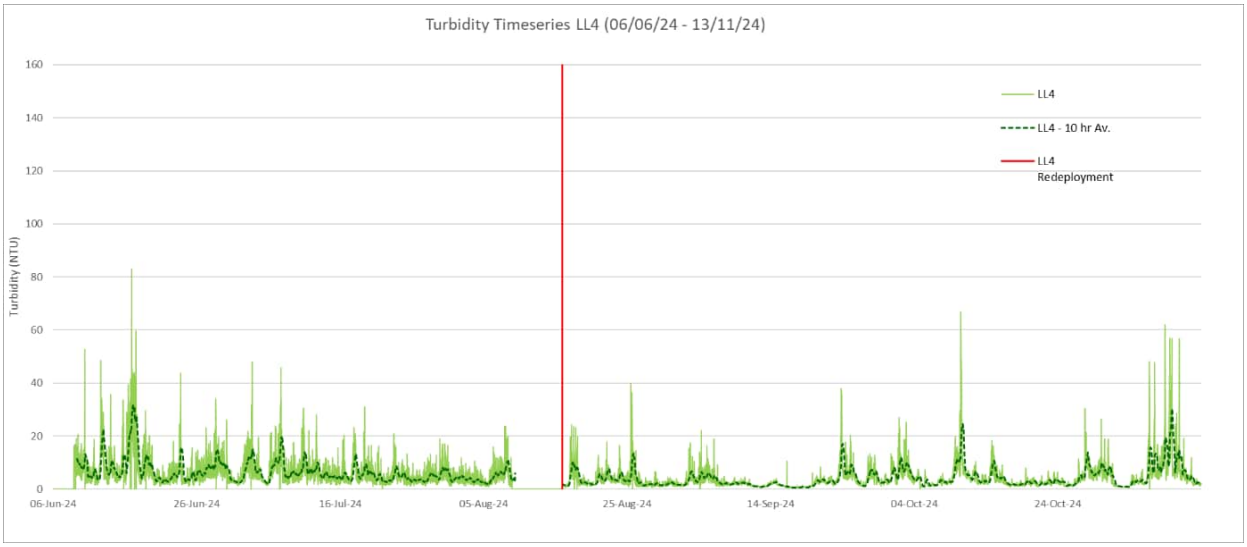


Figure 6-18: LL4 turbidity time series

The turbidity at LL1 and LL3 within Champion Bay presented a noticeable reduction in early September which remained consistent until the end of the data capture period in November. Turbidity spikes were evident during this time, particularly in early October. However, overall turbidity levels within the Bay were noticeably reduced. The higher turbidity levels reported at LL1 and LL3 were likely associated with sediment derived from the Chapman River breakout. O2 Marine anecdotally indicated that the water within the Bay was notably turbid following the breakout of the Chapman River on 10 June 2024 as reported in a local newspaper. Moreover, a review of aerial images retrieved from the Copernicus Browser during the data collection period (refer table 3 in **Appendix A2**) illustrated persistent turbidity plumes throughout parts of the Bay and evidence of the Chapman River entrance remaining open. During this time, it is likely sediment continued to discharge from the Chapman River during rainfall events and was subject to swell induced sediment resuspension, as discussed in **Section 6.4.2.5**.

6.4.2.5 Observed Drivers of Turbidity in Champion Bay

Turbidity results were compared with local wind and wave data obtained from Beacon 1 (refer location in **Figure 5-2**) and rainfall data obtained from the Bureau of Meteorology Geraldton weather station (ID:

008050) to gain some understanding of the primary drivers of turbidity observed throughout the data collection period (06/06/24 – 13/11/24). Time-series plots were created for turbidity and each potential key driver (refer **Appendix A2**). The primary drivers of turbidity are:

- Tidal currents;
- Swell;
- Local wind generated sea; and,
- Rainfall and runoff from the catchment (Chapman River).

In summary, wind, waves and rainfall are all considered to be contributing to turbidity levels observed during the data collection period, particularly at LL1 and LL3. The stronger correlations between these drivers at LL1 and LL3 prior to turbidity reducing throughout the Bay is likely due to the greater exposure of LL1 and LL3 to the prevailing southerly winds, sea and swell, and proximity to observed sediment plumes associated with the Chapman River breakout. It is also noted that the rainfall recorded during the months of June and July in 2024 was 42% and 75% higher than the long-term average for these months, respectively (period 1977-2024).

The observed reduction in overall turbidity following early September does not appear to be associated with changes to wind and wave conditions, as these conditions remained broadly consistent during this time. As discussed in **Section 6.4.2.4**, several lines of evidence including field observations and aerial imagery (refer to table 3 in **Appendix A2**) indicate that the elevated turbidity reported at LL1 and LL3 is associated with sediment sourced from the Chapman River breakout and subsequent discharge events during a wetter than average winter. A reduction in rainfall intensity and frequency evident post September and aerial imagery showing the Chapman River entrance narrowing further supports this conclusion.

Turbidity at LL4 did not present the same response to waves, wind and rainfall due to its position relative to Point Moore which affords partial protection from the prevailing southerly winds and waves, in addition to its observed disconnect from sediment plumes originating from the Chapman River.

6.4.2.6 Considerations for Baseline Turbidity/ TSS Selection

Considering the higher than average rainfall reported during the monitoring period and evidence of Chapman River breakout plumes impacting locations LL1 and LL3 at the beginning of the monitoring period, in combination with the visually correlated effects of the wind and wave climate on turbidity, it is expected that turbidity levels at LL1 and LL3 prior to the reduction in overall turbidity observed in early September would be representative of ‘high’ (non-typical) background conditions expected within Champion Bay. Following the overall reduction in turbidity observed after 07 September 2024, turbidity levels reported at LL1 and LL3 are considered more representative of typical ambient conditions expected in the Bay during periods of low rainfall commonly experienced in Geraldton, particularly outside of the winter months.

Turbidity at LL4 is expected to be more representative of the entrance to the Port, where dredging is proposed, due to its position relative to Point Moore and partial protection from the prevailing southerly winds and waves, in addition to its observed disconnect from sediment plumes originating from the Chapman River. As such, it is considered that adopting a background turbidity/ TSS concentration from the LL4 dataset would provide a more accurate representation of typical background conditions in the proposed dredging areas in proximity to the Port entrance.

A statistical summary of turbidity and TSS results at LL1, LL3 and LL4 for the 10-hour rolling average and daily (24-hr) average results is provided in **Table 6-6** and **Table 6-7**, respectively. Further analyses are available in **Appendix A2**.

Table 6-6: Statistical results for turbidity and TSS at all monitored locations, presenting the 10-hr rolling average

	LL1 Full Dataset		LL1 Pre-September Turbidity Drop		LL1 Post-September Turbidity Drop		LL3 Post-September Turbidity Drop		LL4 Full Dataset	
Data range (2024)	*6 June - 13 November*		*6 June - 6 September*		*7 September - 13 November*		*7 September - 13 November*		*9 June - 13 November*	
Unit / Statistic	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*
Mean	5.5	3.2	8.5	5.2	1.5	0.7	2.0	1.0	5.2	2.9
Median	2.0	0.9	4.5	2.5	0.9	0.4	1.3	0.6	4.0	2.2
SD	8.3	5.1	9.8	6.1	2.0	1.0	2.8	1.4	4.1	2.2
Max.	67.2	58.6	67.2	58.6	19.3	13.6	26.0	19.3	31.5	24.2
Min.	0.3	0.1	0.5	0.2	0.3	0.1	0.3	0.1	0.7	0.3
1st Percentile	0.3	0.1	0.7	0.3	0.3	0.1	0.4	0.1	0.7	0.3
5th Percentile	0.5	0.2	1.0	0.4	0.4	0.1	0.5	0.2	1.2	0.5
10th Percentile	0.7	0.3	1.1	0.5	0.5	0.2	0.7	0.3	1.6	0.7
20th Percentile	0.9	0.4	1.7	0.8	0.6	0.3	0.8	0.3	2.2	1.1
30th Percentile	1.1	0.5	2.3	1.1	0.7	0.3	1.0	0.4	2.8	1.4
40th Percentile	1.3	0.6	3.0	1.5	0.8	0.3	1.1	0.5	3.3	1.7
50th Percentile	2.0	0.9	4.5	2.5	0.9	0.4	1.3	0.6	4.0	2.2
60th Percentile	2.8	1.4	6.5	3.8	1.1	0.5	1.6	0.7	4.9	2.7
70th Percentile	4.7	2.6	9.4	5.9	1.3	0.6	1.9	0.9	6.0	3.5
80th Percentile	8.4	5.1	14.7	9.9	1.5	0.7	2.3	1.2	7.4	4.4
90th Percentile	16.4	11.2	21.7	15.7	2.5	1.2	3.4	1.8	10.0	6.3
95th Percentile	22.8	16.5	27.6	20.7	3.4	1.8	5.0	2.8	12.7	8.4
99th Percentile	39.5	31.4	44.3	36.0	12.7	8.4	18.8	13.2	22.4	16.2

Table 6-7: Statistical results for turbidity and TSS at all monitored locations, presenting the daily (24-hr) average

	LL1 Full Dataset		LL1 Pre-September Turbidity Drop		LL1 Post-September Turbidity Drop		LL3 Post-September Turbidity Drop		LL4 Full Dataset	
Data range (2024)	*6 June - 13 November*		*6 June - 6 September*		*7 September - 13 November*		*7 September - 13 November*		*9 June - 13 November*	
Unit / Statistic	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*
Mean	5.6	3.2	8.6	5.3	1.4	0.7	2.0	1.0	5.2	2.9
Median	2.1	1.0	5.3	3.0	1.0	0.4	1.3	0.6	4.4	2.4
SD	7.4	4.4	8.4	5.1	2.0	0.9	2.5	1.2	3.8	2.0
Max.	37.9	30.0	37.9	30.0	13.6	9.1	17.5	12.2	27.8	20.8
Min.	0.3	0.1	0.7	0.3	0.3	0.1	0.3	0.1	0.7	0.3
1st Percentile	0.4	0.1	0.9	0.4	0.3	0.1	0.4	0.1	0.8	0.3
5th Percentile	0.6	0.2	1.0	0.4	0.5	0.2	0.6	0.2	1.5	0.7
10th Percentile	0.7	0.3	1.3	0.6	0.5	0.2	0.7	0.3	1.8	0.9
20th Percentile	0.9	0.4	2.1	1.0	0.7	0.3	0.9	0.4	2.3	1.1
30th Percentile	1.0	0.5	2.6	1.3	0.7	0.3	1.0	0.4	3.0	1.5
40th Percentile	1.5	0.7	3.1	1.6	0.9	0.4	1.1	0.5	3.4	1.8
50th Percentile	2.1	1.0	5.3	3.0	1.0	0.4	1.3	0.6	4.4	2.4
60th Percentile	2.9	1.5	7.8	4.7	1.0	0.4	1.6	0.7	4.9	2.8
70th Percentile	5.3	3.0	11.9	7.8	1.2	0.6	2.0	0.9	5.8	3.3
80th Percentile	10.9	7.0	14.3	9.6	1.5	0.7	2.2	1.1	7.6	4.6
90th Percentile	14.9	10.0	18.5	12.9	2.4	1.2	3.4	1.8	9.6	6.0
95th Percentile	24.0	17.6	27.5	20.6	2.9	1.5	4.6	2.5	11.4	7.3
99th Percentile	30.8	23.6	32.4	25.0	10.4	6.6	14.0	9.4	16.6	11.4

6.4.3 Justification for Exclusion of Ambient SSC Modelling

An ambient model was set up for this investigation, however reproducing background SSC in a model environment at Geraldton has proven to be very challenging. As a result, it was decided to exclude modelled ambient SSC from this assessment. This was done on the basis that the background SSC in a model, and in reality, is influenced by wave conditions (as outlined in **Section 6.4** and **Appendix A2**, from the measurements at LL1 and LL4 it was determined that the background SSC is highly correlated with wave activity) as well as the availability of bed material (among other factors), which is both unknown and highly variable. The re-suspension of bed material by large waves is responsible for the peaks observed in

the turbidity measurements. However, at LL4 (refer **Figure 6-15**), peak wave events did not result in SSC peaks, likely due to insufficient bed material available for resuspension.

To further explore the possibility of generating an ambient SSC model, a best-estimate initial bed sediment thickness map based on presence of seagrass, shallow reefs, etc., was generated. While the initial ambient model results showed very good correlation between modelled and measured turbidity (SSC) at LL1 (refer **Figure 6-15**), the background SSC produced in all model tests (tests included a re-run of Scenario 2 including ambient conditions), including those yielding good results for LL1, was not realistic.

As a result, modelling of ambient SSC was not pursued further and SSC due to dredging alone was assessed.

6.5 Scenario 1: Berth 1 Maintenance Dredging

6.5.1 Introduction

Maintenance dredging removes naturally accumulated sediment from within a port's harbour or navigation channel to return it to its original design depth, and differs from capital dredging, which involves enlarging or deepening berths or navigation channels.

Maintenance dredging near the proposed new Berth 1 comprises the removal by a Trailer Suction Hopper Dredge (TSHD) of 17,629m^3 of silt built up in a previously dredged area, to facilitate construction of the new Berth 1 revetments (refer **Figure 6-19** and **Figure 6-20**). Hence, no rock breaking will be involved in this dredging exercise.

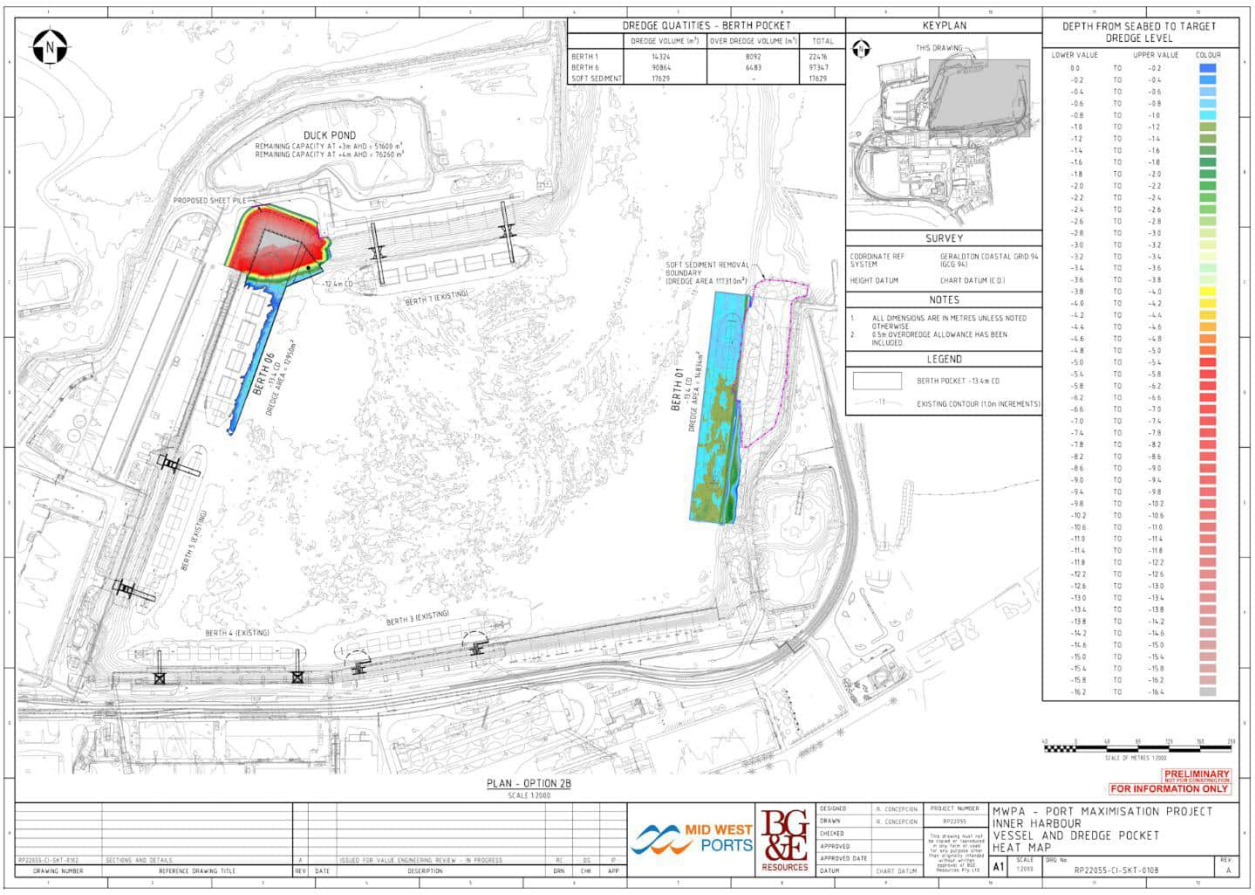


Figure 6-19: Berth 1 maintenance dredge area (magenta dash-dot line)

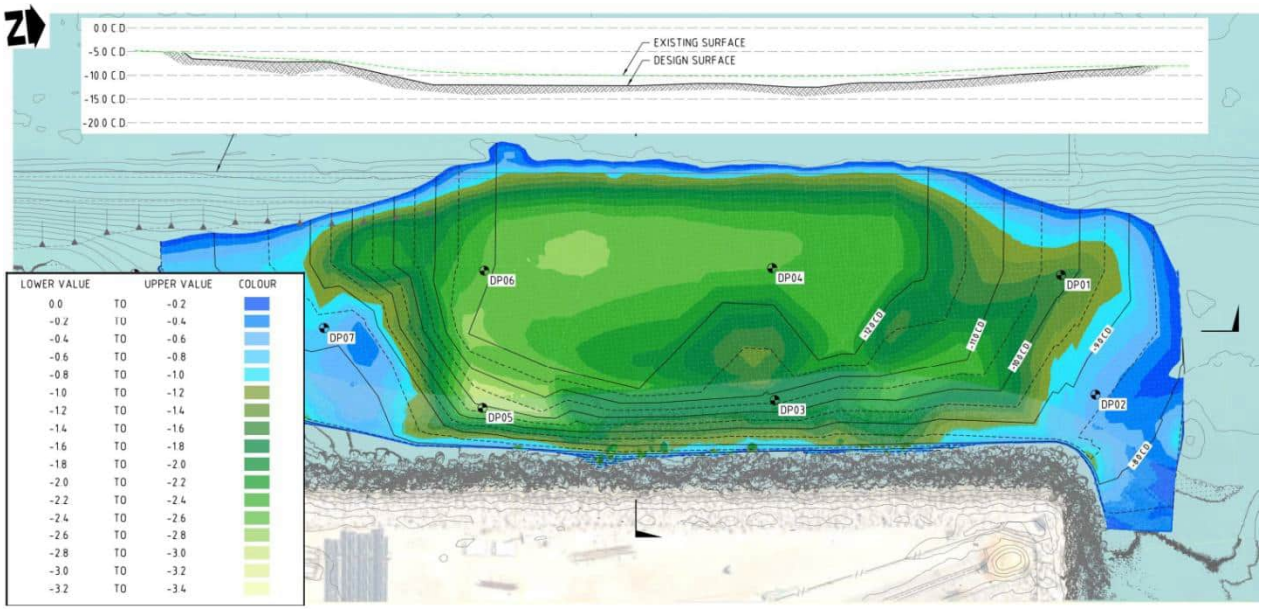


Figure 6-20: Berth 1 maintenance dredge depths

6.5.2 Geotechnical Information

The source terms presented in **Section 6.5.4** are further informed by the available geotechnical information near the future Berth 1. This information comprises particle size distribution (PSD) information from a seabed sampling exercise undertake by MWPA divers in early 2024. Sampling locations are presented in **Figure 6-21**.

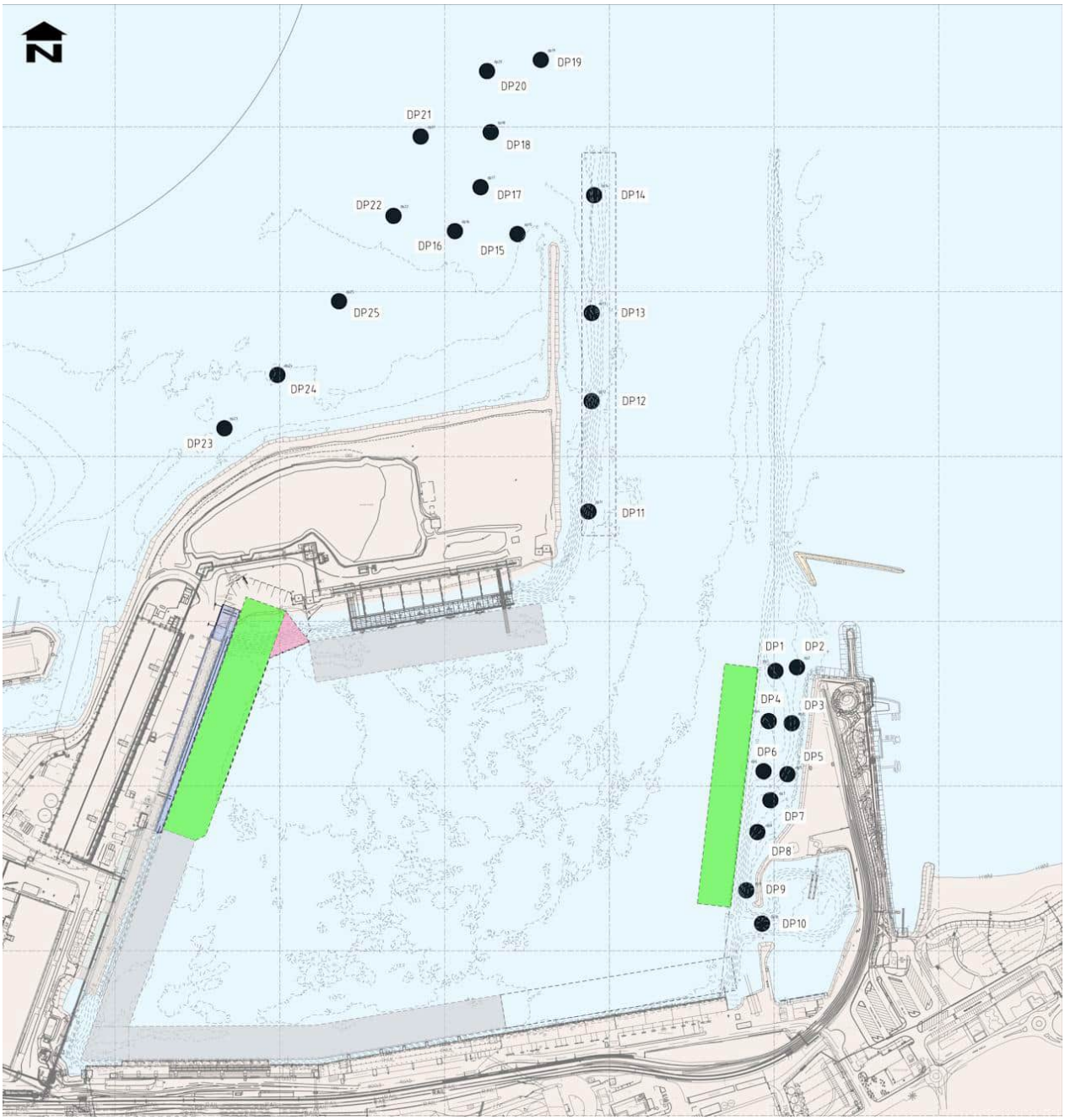


Figure 6-21: Seabed sampling locations

Suitable surface samples, relevant to the proposed maintenance dredge area near future Berth 1, were collected at DP1 and DP6 (refer **Figure 6-21**) and visually described as soft, silty mud. PSD information was obtained through analysis of the samples by ALS Environmental (commissioned by SLR). PSD graphs for samples from locations DP1 and DP6 are presented in **Figure 6-22**.

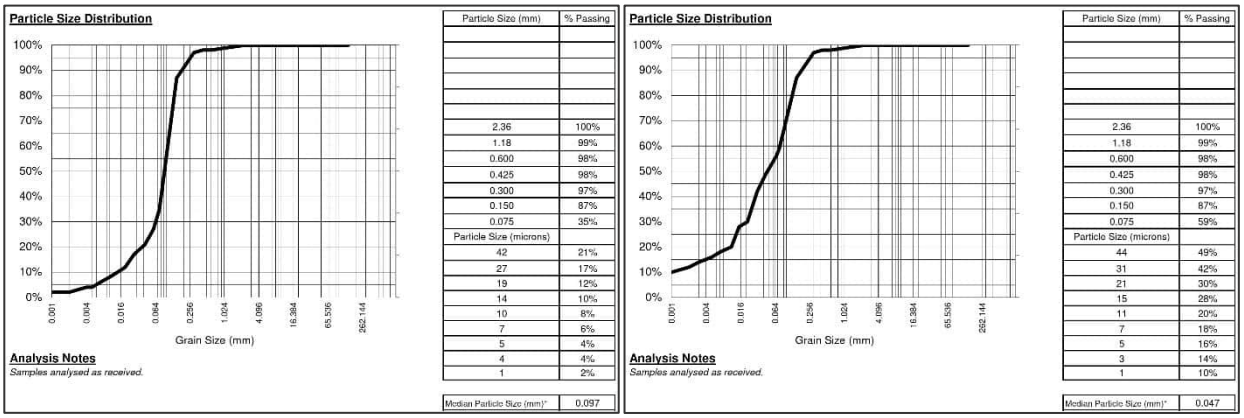


Figure 6-22: Particle size distribution for seabed samples at DP1 (left pane) and DP6 (right)

6.5.3 Dredge Methodology

RHDHV engaged a dredging expert to develop a realistic dredging strategy that would likely be employed to deliver the required dredging works. A strategy was developed from the perspective of a dredging contractor whereby the most efficient means of dredging would be achieved. The methodology was informed by the proposed dredging design, available geotechnical information and availability of suitable plant.

As outlined in **Section 6.5.1**, maintenance dredging of the future Berth 1 will occur utilising a TSHD. Given the size of the maintenance dredging works (volume of material to be dredged) and typically available equipment, the specifications of the Damen TSHD (modular series) 1500 (refer **Figure 6-23**) were used in the development of the dredging strategy and source terms. It is noted that the above reference dredge is slightly larger than the TSHD Modi R (Rohde Nielsen – Denmark) and therefore production rates are slightly higher and flux inputs are slightly conservative.



Figure 6-23: Damen 1500 Trailing Suction Hopper Dredge (TSHD)

Discharge of the material collected by the TSHD will occur via pumping into the nearby reclamation site *New reclaimed land at existing duck pond* (refer **Figure 1-3**). The pump-out discharge location for the small TSHD is assumed to be at the eastern end of this reclamation area, just south of future Berth 8. This may consist of a shore connection and floating hose to an anchored buoy onto which the TSHD moors by a single line over the bow during the discharge period.

Maintenance dredging of Berth 1 is scheduled to take place in January 2026 (this means that the proposed expansion of Geraldton Port, to accommodate the new tug harbour and Berth 8/Berth 9, has not yet occurred) and estimated to be completed in two (2) days and 17 hours based on:

- a dredge volume of 17,629m^3;
- continuous dredging (168hrs/week or 24hrs/day); and
- the production rate of the TSHD.

In addition to the above, it is assumed that during dredging and disposal of dredged material:

- no overflow from the hopper of the TSHD is allowed;
- no jets on drag-heads are allowed;
- no losses through hopper doors, valves or split hull are allowed; and
- deployment of silt curtain around the TSHD dredger is not possible.

Further assumptions in relation to the discharge of dredged material into the nearby reclamation area comprise:

- Minimal release of fines under the TSHD during pump-out through water intakes; and
- No fines are to be contained in the discharge of transport water from the reclamation area (return water) at the outlet point to the receiving environment. (alternatively, the reclamation area will be of adequate capacity to allow settling of all fines and 'polishing' the return water without discharging to the receiving environment until after the dredging works are completed).

In light of the above and for the purpose of the dredge plume modelling exercise, the following sources of fines have been taken into account:

- The draghead of the TSHD;
- Scouring of the seabed due to TSHD propwash; and
- Discharge under the TSHD at the end of the pump-out location (near the reclamation area).

6.5.4 Source Term Estimates

Table 6-8 summarises the estimated fines fluxes by the appointed dredging expert used as inputs for the maintenance dredge plume modelling (refer Hoogerwerf (2024a) provided in **Appendix A3**), assuming 168hrs/week (or 24hrs/day) of dredging. For modelling purposes, the silt fraction (2-75µm) is further divided into four size ranges:

- coarse silt (60-75 µm);
- medium silt (40-60 µm);
- fine silt (20-40 µm), and
- very fine silt (2-20 µm).

Based on the available geotechnical information at the Berth 1 maintenance dredge area (refer **Section 6.5.2**), it was estimated that these silt fractions constitute approximately 40%, 30%, 20%, and 10% of the overall silt fraction, respectively (Hoogerwerf, 2024a, or **Appendix A3**).

Table 6-8: Source term (flux) estimates for Berth 1 maintenance dredging (based on: Table 3 of Hoogerwerf, 2024a)

Point of release	Total loss of fines (<75µm) [kg/s]	Silt (2-75µm) [kg/s]	Clay (<2µm) [kg/s]	Release level	Distribution [%]
Draghead	2.18	1.89	0.29	Seabed to +2m	100%
Propwash/scour	0.94	0.76	0.18	Surface to -3m	15%
				Mid-level	35%
				Seabed to +3m	50%
Discharge under TSHD at end of pump-out	0.10	0.09	0.01	Surface to -3m	10%
				Mid-level	40%
				Seabed to +3m	50%
Total	3.22	2.74	0.48		

6.5.5 Model Setup

The source terms and release levels outlined in **Table 6-8** as estimated by Hoogerwerf (2024a) were translated to MIKE MT module input, taking into account to the following (modelling) constraints:

- The 3D dredge plume model comprises five (5) vertical layers with varying thickness depending on local depth;
- The available types of spilling (release of fines) in the model set-up, i.e. a combination of:
  - Spill in bottom layer;
  - Spill in surface layer;
  - Spill in both bottom and surface later; and
  - Spill over entire water column (uniformly distributed over all model layers).
- Local depth at the maintenance dredge area.

Given the above, the modelled fluxes and points of release are as presented in **Table 6-9**. These rates have been applied continuously over the entire maintenance dredge period (two (2) days and 17 hours). A graph showing fluxes (all fines) for each source (draghead, propwash or discharge) is presented in **Figure 6-24**.

Table 6-9: Modelled fractions, fluxes and release points for Berth 1 maintenance dredging

Cause of Plume	Spilling Type	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay	Silt Flux [kg/s]	Clay Flux [kg/s]
Draghead	Bottom layer	40%	30%	20%	10%	100%	1.890	0.290
Propwash/ scour	Entire column	40%	30%	20%	10%	100%	0.570	0.135
	Bottom layer	40%	30%	20%	10%	100%	0.190	0.045
Discharge under TSHD	Entire column	40%	30%	20%	10%	100%	0.063	0.007
	Bottom layer	40%	30%	20%	10%	100%	0.027	0.003
						Total	2.74	0.48

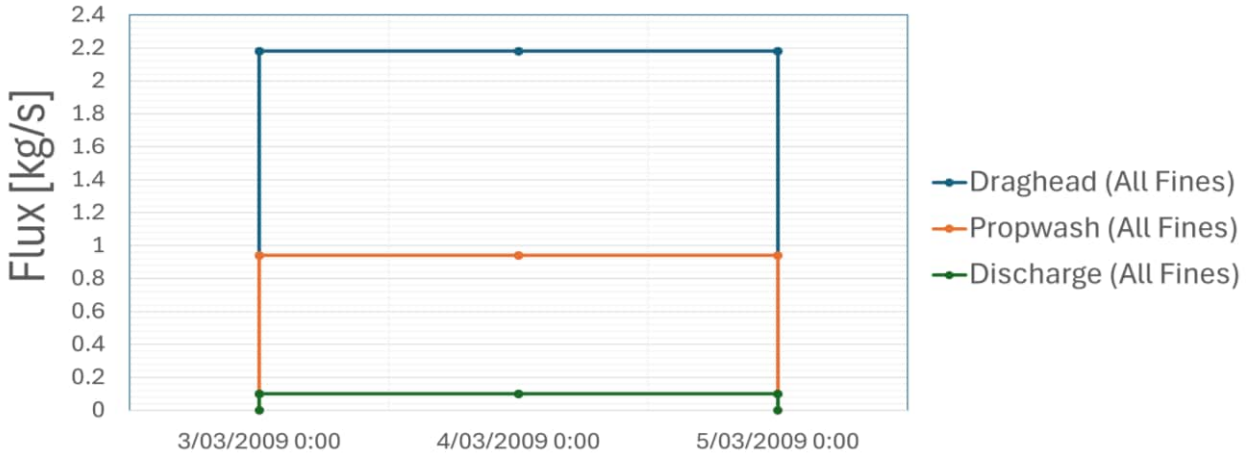


Figure 6-24: Berth 1 maintenance dredging fluxes

6.5.6 Results - Above Background

The following output has been presented for Scenario 1 (Berth 1 maintenance dredging):

Percentile maps

- **Figure 6-25** and **Figure 6-26**: 50%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week; and
- **Figure 6-27** and **Figure 6-28**: 95%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week.

Time-series (10-minute time step)

- **Figure 6-30**: time-series of excess near-bed and near-surface SSC at output locations (A to G) northward along the coast from Geraldton Port;
- **Figure 6-32** to **Figure 6-35**: time-series of excess near-bed SSC at sensitive receptors locations (L1-L13);
- **Figure 6-37** to **Figure 6-42**: time-series of excess near-bed and near-surface SSC at locations on arcs emanating from the Berth 1 maintenance dredge area; and
- **Figure 6-44** and **Figure 6-45**: time-series of excess near-surface SSC at locations along Town Beach and near Batavia Coast Marina.

Sedimentation map

- **Figure 6-46**: sedimentation thickness of fines at the end of dredging.

Impact maps

- **Figure 6-47** to **Figure 6-49**: impact zone maps for sedimentation and SSC.

6.5.6.1 50%ile and 95%ile Excess SSC

Based on the output presented below, the following key observations can be made:

- The 50th percentile and 95th percentile SSC maps over the dredging period are similar in terms of concentration and extent due to the relatively short duration of the dredging works (less than three days). When considering a time period equal to the dredging period plus an additional week after dredging has ceased, the 50th percentile SSC map shows no significant excess SSC, while the 95th percentile SSC map remains similar to the results over the dredging period only;

- Near-surface percentile SSC maps show similar trends to the near-bed results in terms of spatial extent and concentrations, except for the immediate dredge location;
- The 95th percentile plot indicates that the area of SSC above 100 mg/L is concentrated around the dredging location;
- The 95th percentile plot shows that the 95th percentile SSC quickly (within a few 100m) drops below 50 mg/L outside the immediate Geraldton Port area; and
- In the cross-shore direction, the modelled 95th percentile SSC values drop below 5 mg/L in less than one km.

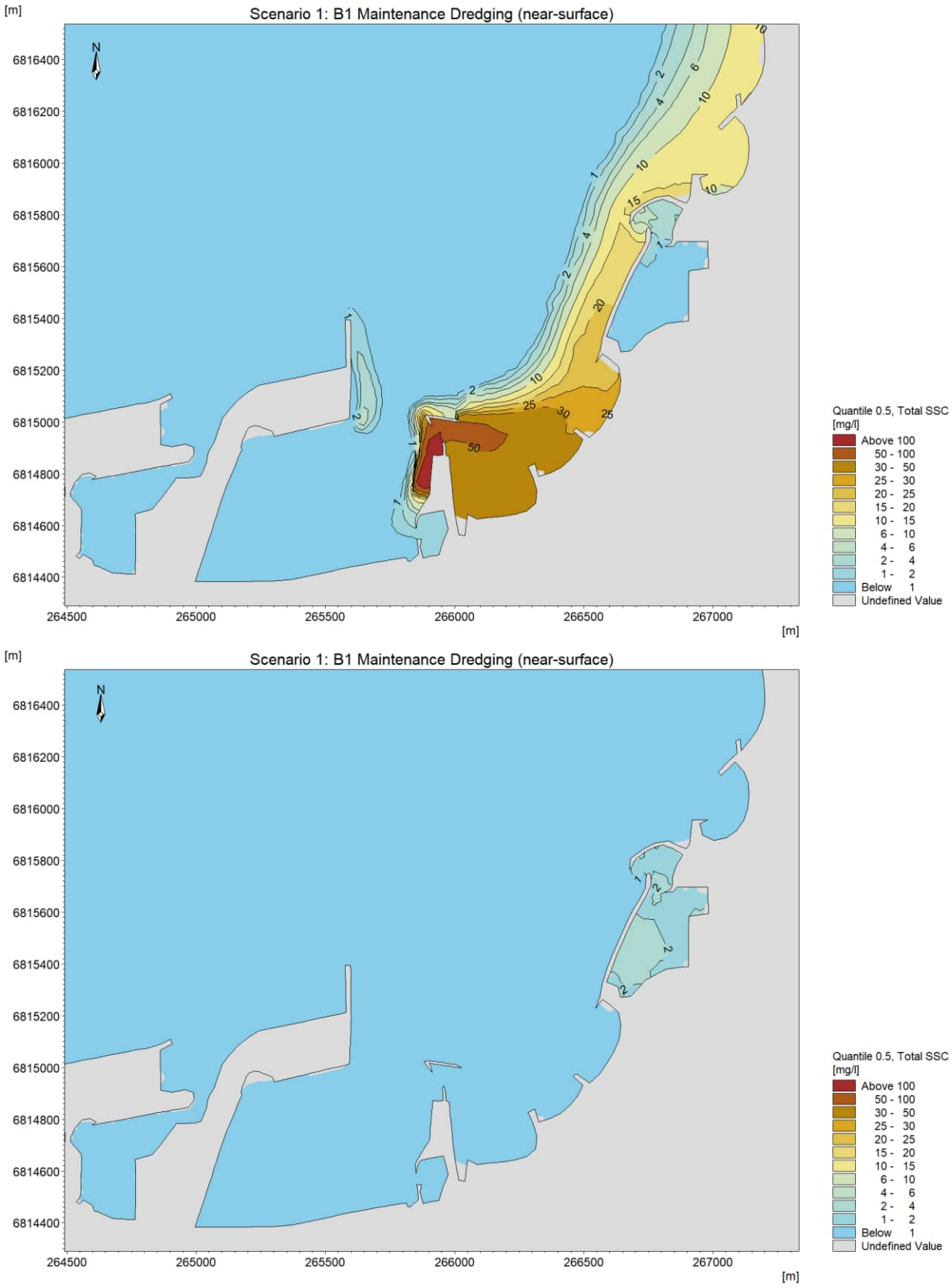


Figure 6-25: Near-surface 50%ile excess SSC over the three-day dredging period (or 36 hours in three days - top pane) and three-day dredging period + one week (or 120 hours in ten days - bottom pane) for Berth 1 maintenance dredging

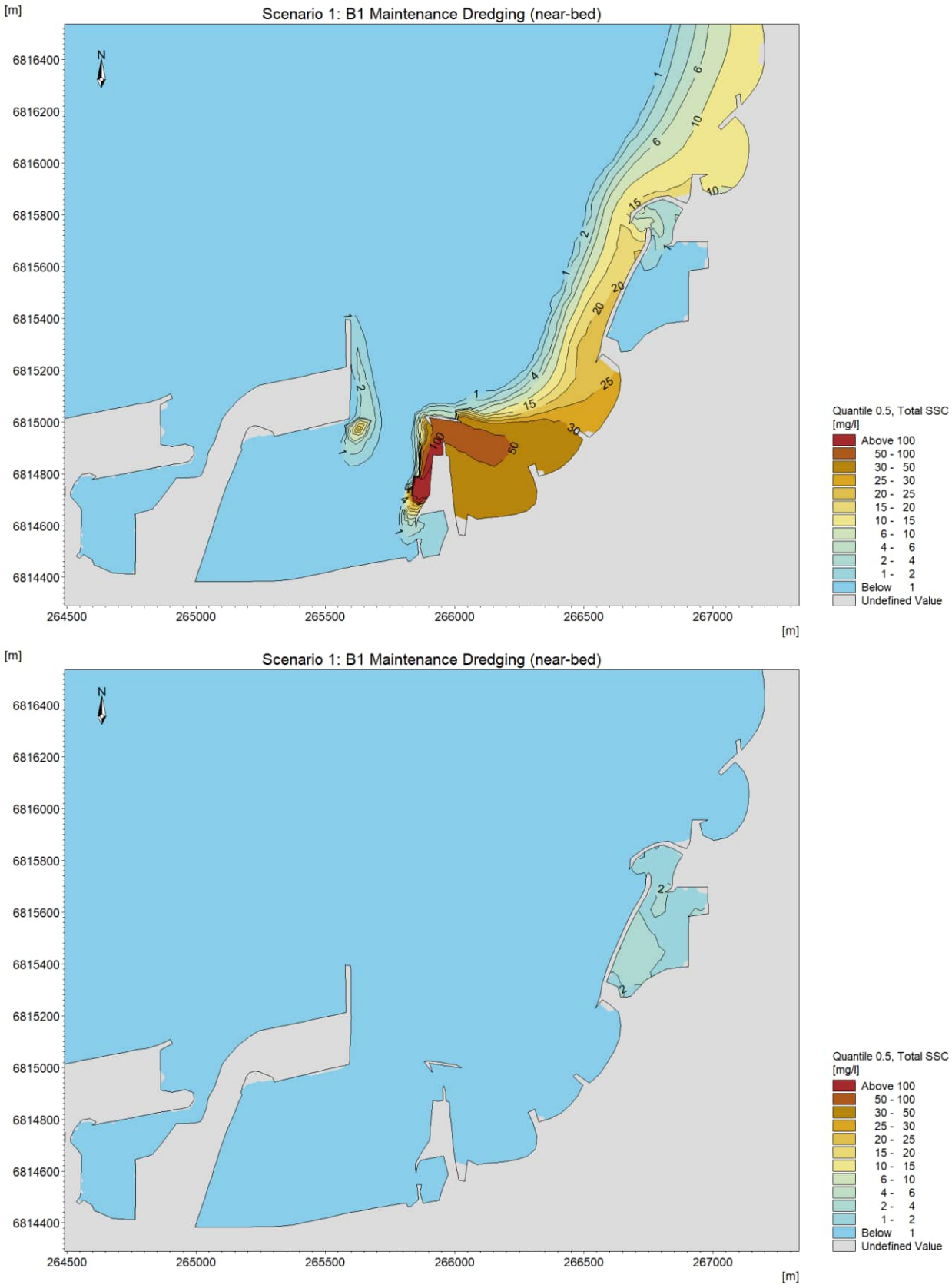


Figure 6-26: Near-bed 50%ile excess SSC over the three-day dredging period (or 36 hours in three days - top pane) and dredging period + one week (or 120 hours in ten days - bottom pane) for Berth 1 maintenance dredging

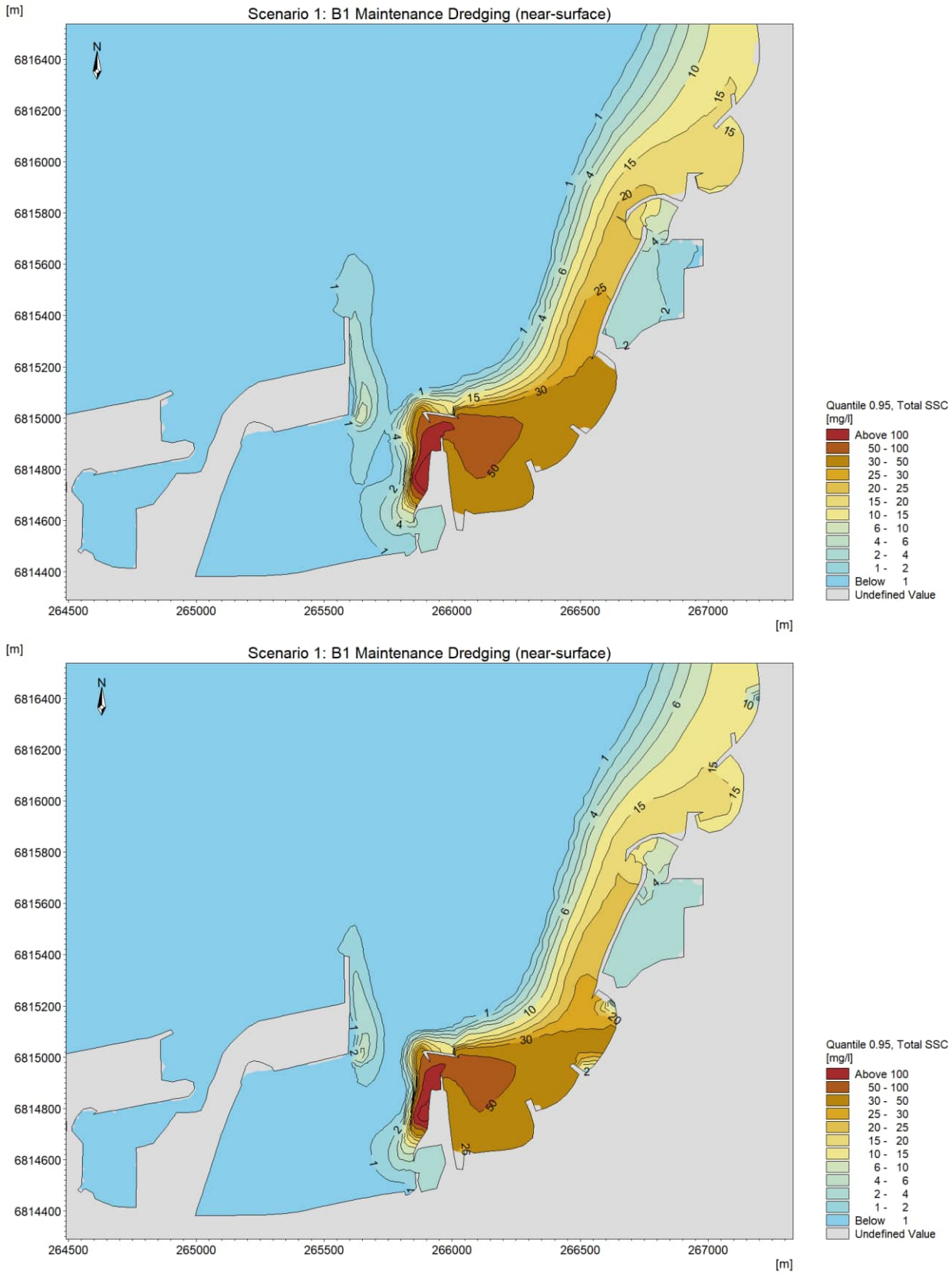


Figure 6-27: Near-surface 95%ile excess SSC over the three-day dredging period (or 3.6 hours in three days - top pane) and dredging period + one week (or 12 hours in ten days - bottom pane) for Berth 1 maintenance dredging

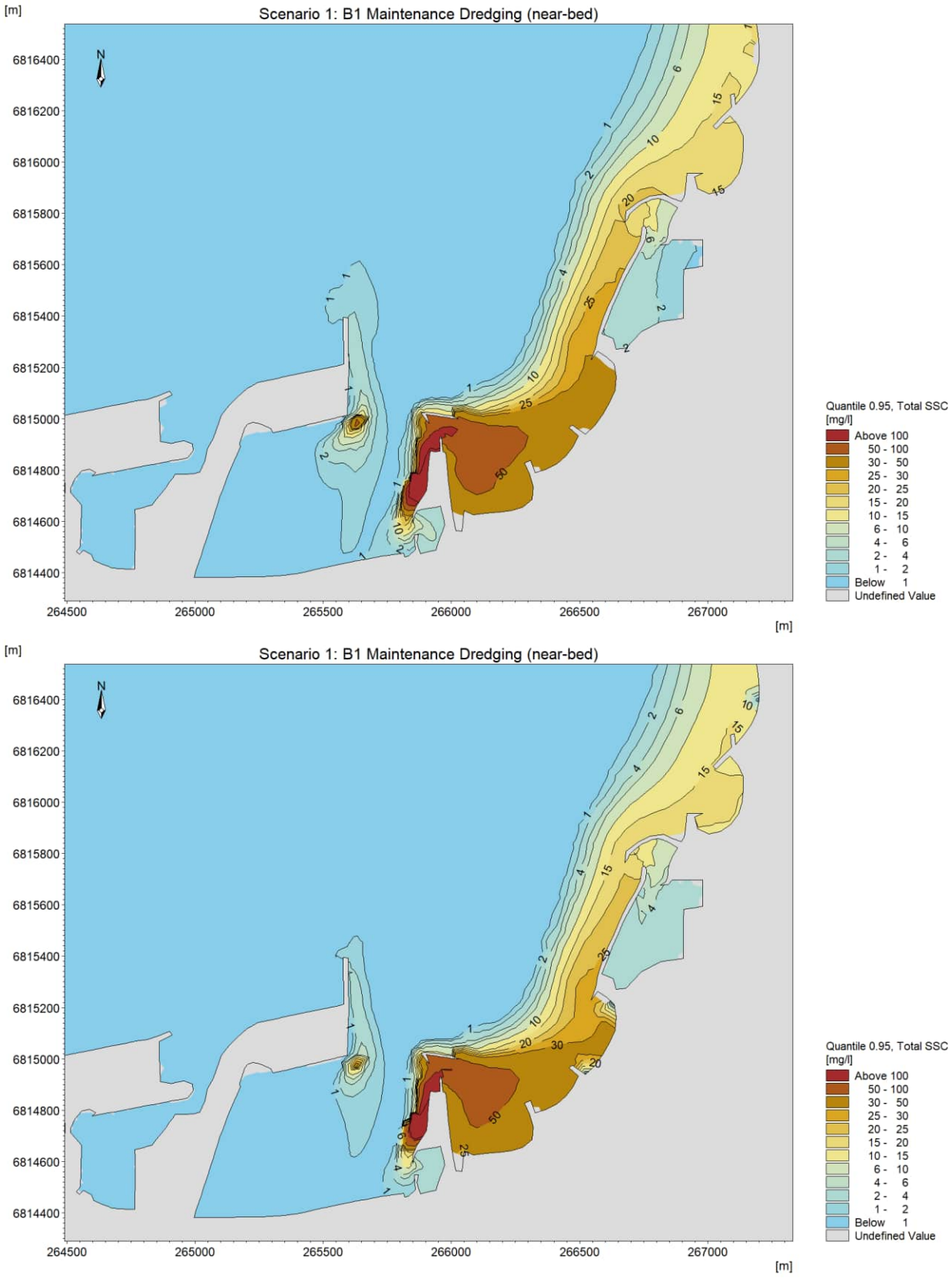


Figure 6-28: Near-bed 95%ile excess SSC over the three-day dredging period (or 3.6 hours in three days - top pane) and dredging period + one week (or 12 hours in ten days - bottom pane) for Berth 1 maintenance dredging

6.5.6.2 Time-Series of Excess SSC

Based on the output presented below, the following key observations can be made:

- Along the shoreline north of Town Beach, the SSC does not exceed 17 mg/L (based on output locations B to G) and reduces to below 10 mg/L approximately ten km from the site;
- Time-series of SSC generally (i.e., at most output locations) show that the SSC decreases to insignificant levels generally within one day after dredging has ceased;
- SSC at the sensitive receptor locations peaks at around 50mg/L at L1 and is insignificant (<1mg/L) at most other sensitive receptor locations; and
- SSC near Town Beach and the Batavia Coast Marina peak at around 50mg/L and 30mg/L, respectively and decreases to insignificant levels (order of a few mg/L) within one day after dredging has ceased.

Northward along the coast (nearshore)



*Figure 6-29: Nearshore model output locations north of the project site (repeated from **Figure 6-6**)*

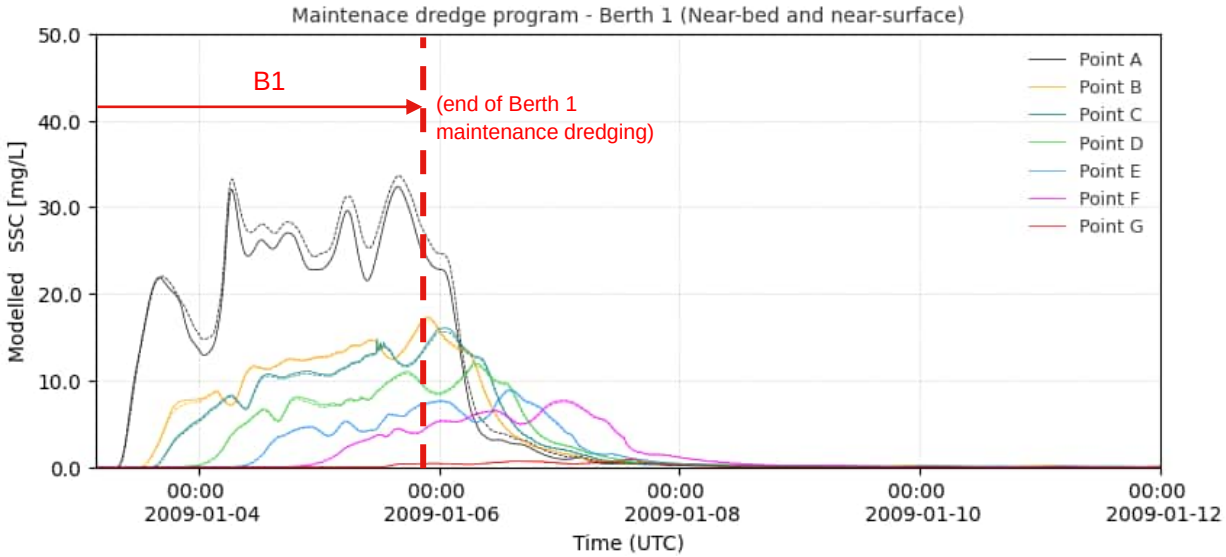


Figure 6-30: Time-series of excess near-bed (solid lines) and near-surface (dashed lines) SSC during maintenance dredging at Berth 1 at output locations (A to G) northward along the coast from Geraldton Port

Sensitive receptors



*Figure 6-31: Model output locations in sensitive receptor areas (repeated from **Figure 6-7**)*

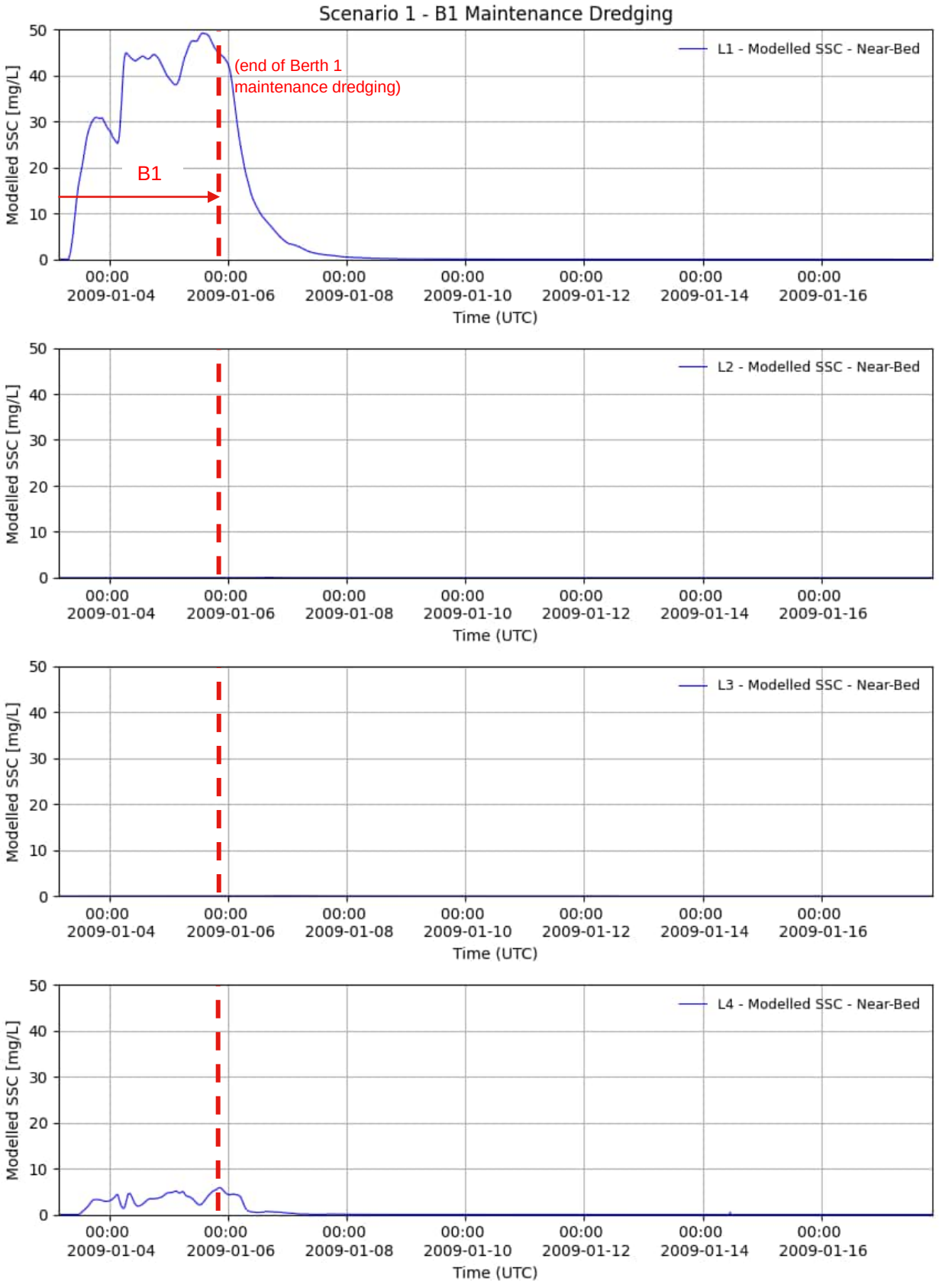


Figure 6-32: Time-series of excess near-bed SSC during maintenance dredging at Berth 1 at sensitive receptors locations (L1-L4)

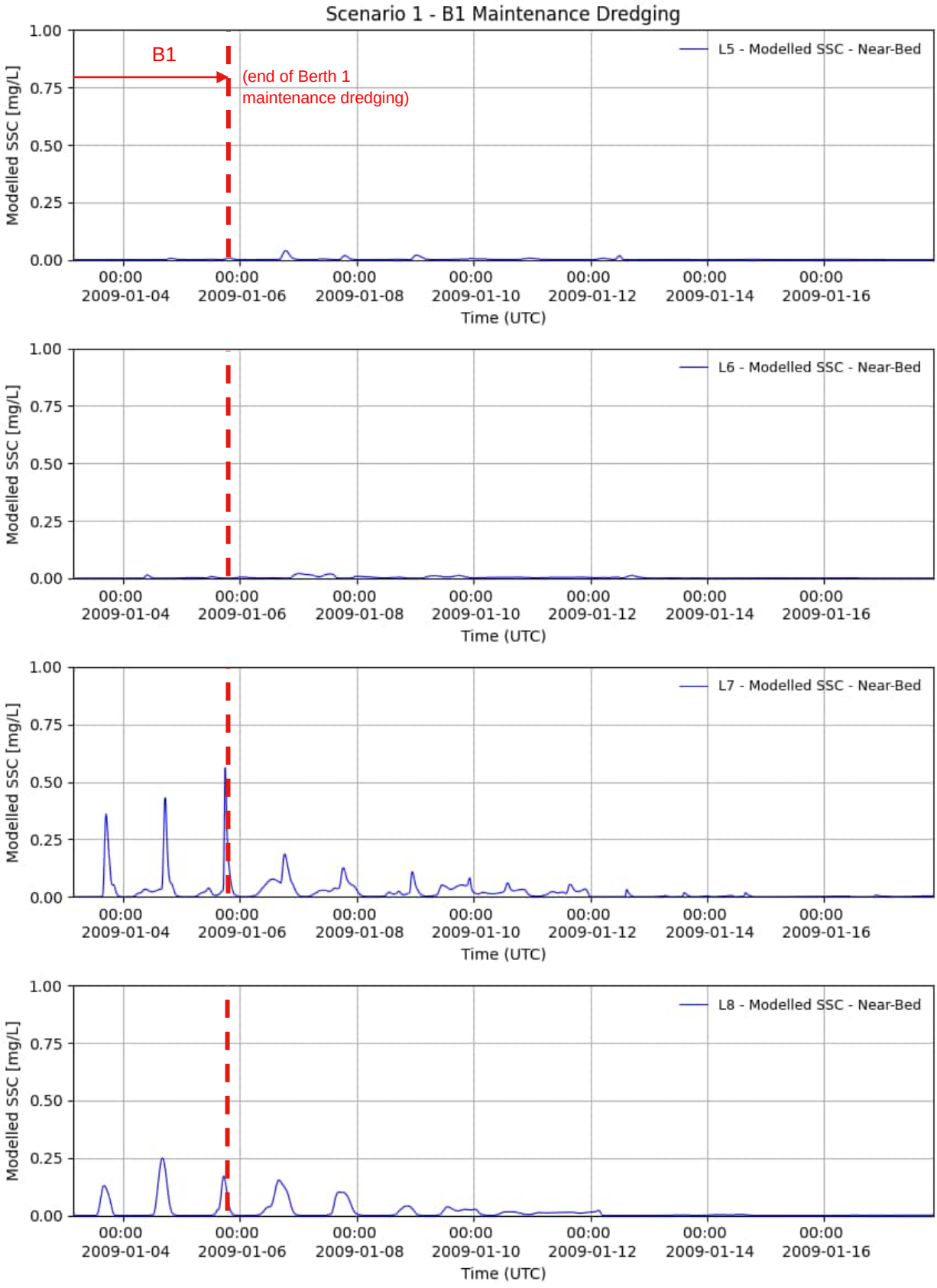


Figure 6-33: Time-series of excess near-bed SSC during maintenance dredging at Berth 1 at sensitive receptors locations (L5-L8)

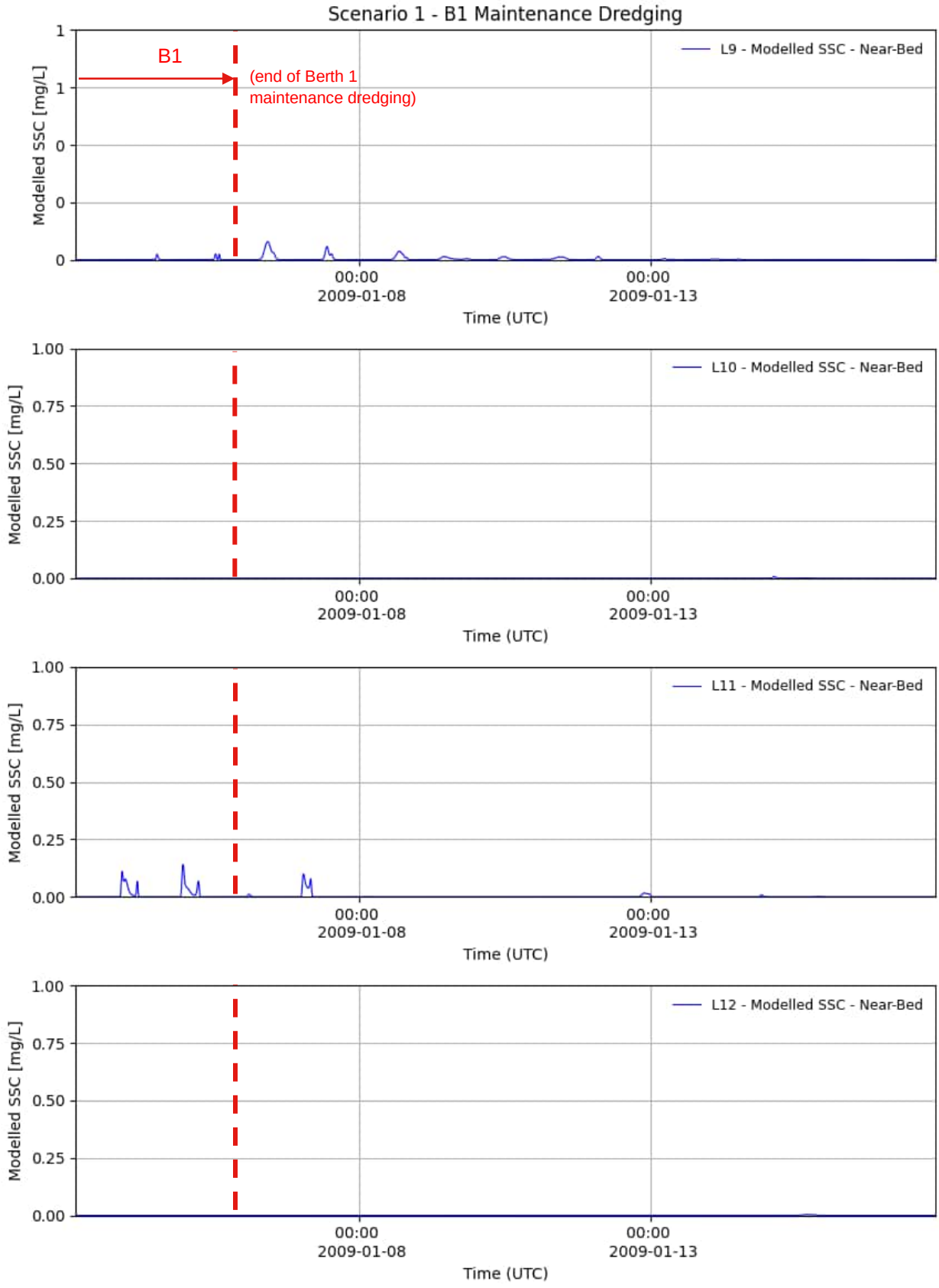


Figure 6-34: Time-series of excess near-bed SSC during maintenance dredging at Berth 1 at sensitive receptors locations (L9-L12)

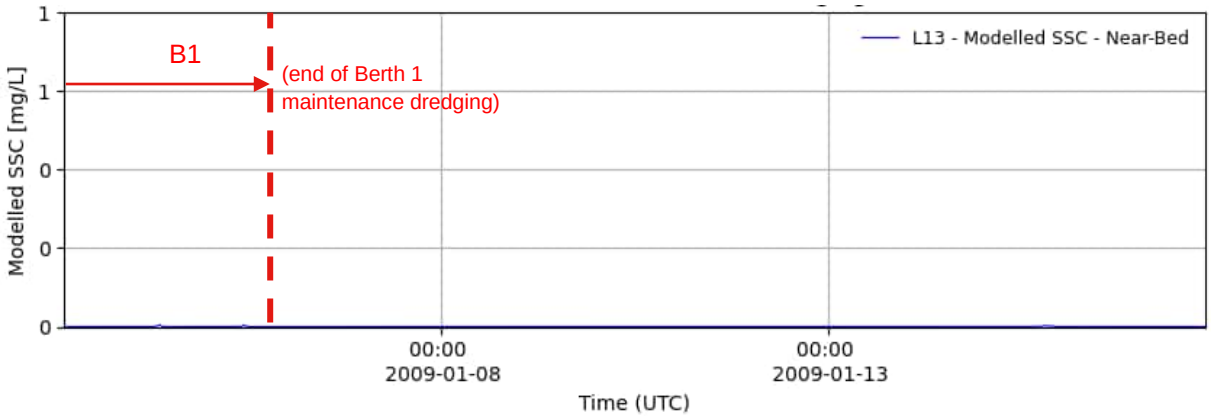


Figure 6-35: Time-series of excess near-bed SSC during maintenance dredging at Berth 1 at sensitive receptors locations (L13)

Arcs emanating from the Berth 1 dredge area



*Figure 6-36: Model output locations emanating from the B1 dredge area (10 nominated output locations along the 100, 250, 500 and 1000m arcs) (repeated from **Figure 6-8**)*

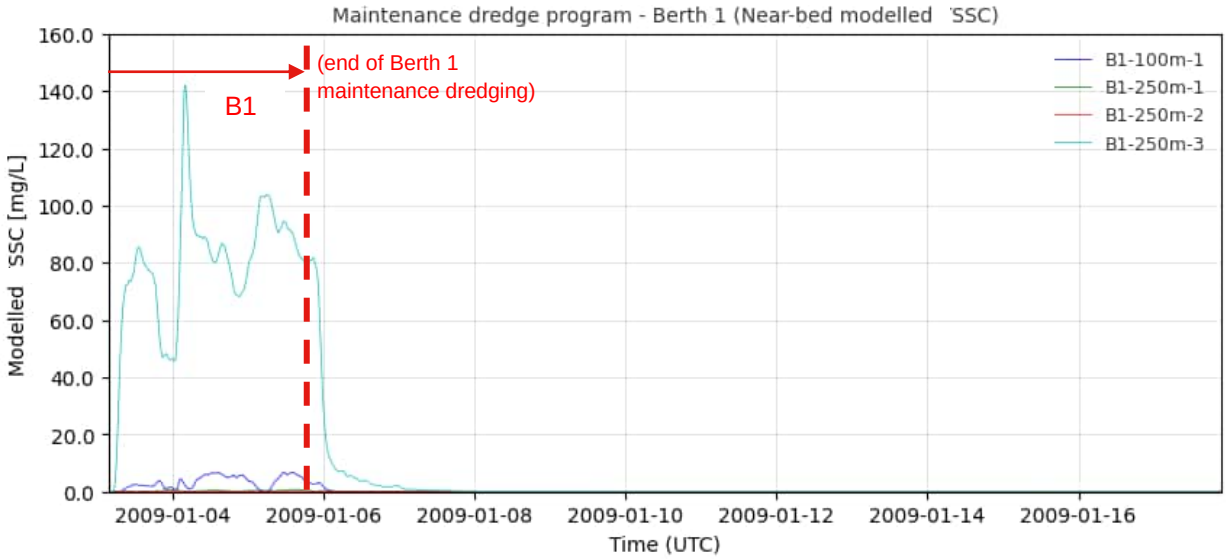


Figure 6-37: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 maintenance dredge area (1)

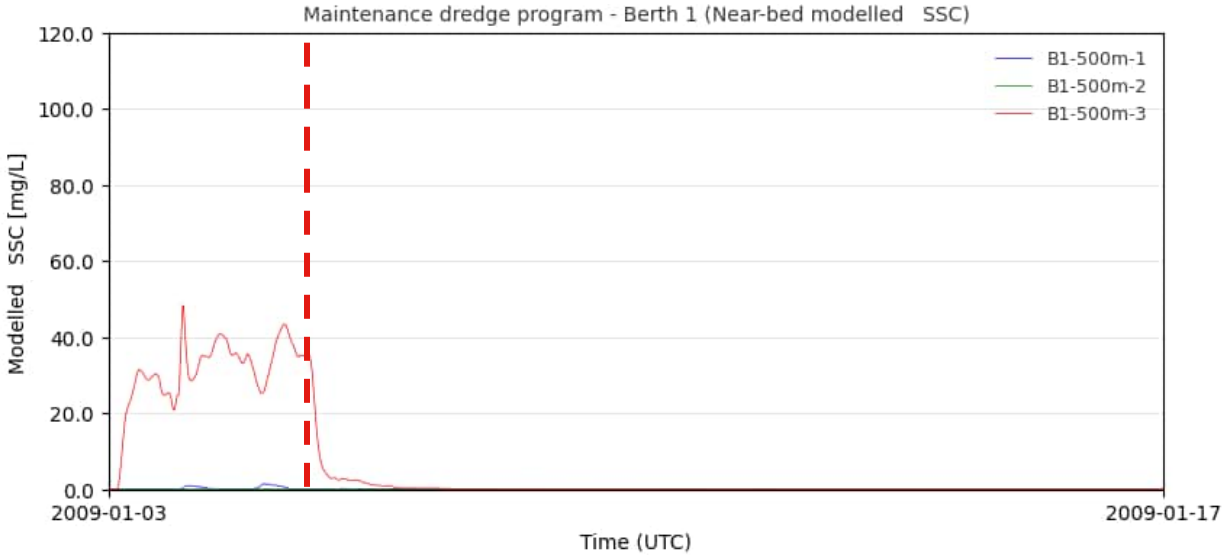


Figure 6-38: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 maintenance dredge area (2)

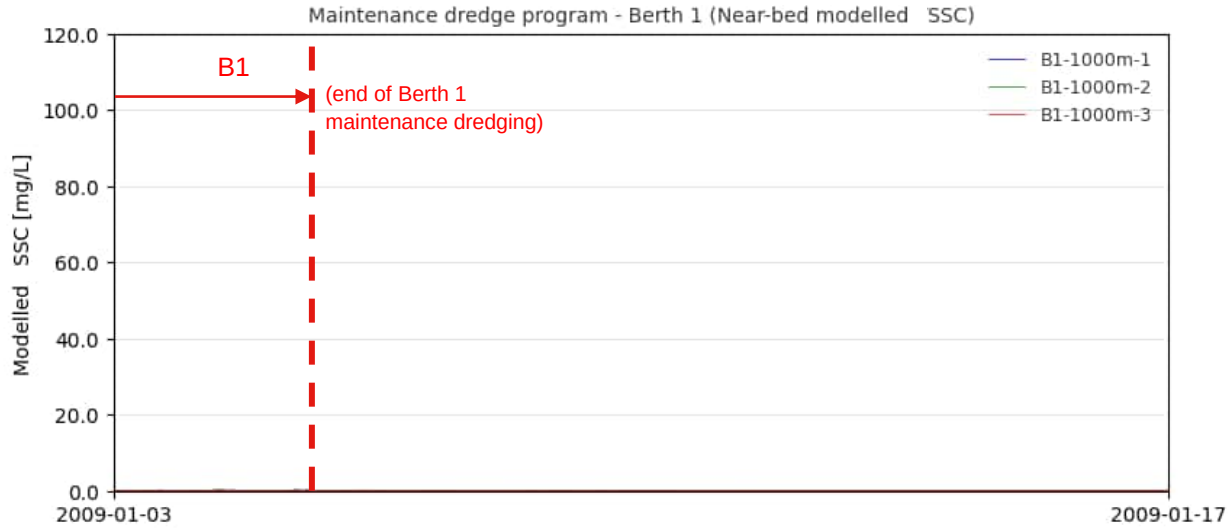


Figure 6-39: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 maintenance dredge area (3)

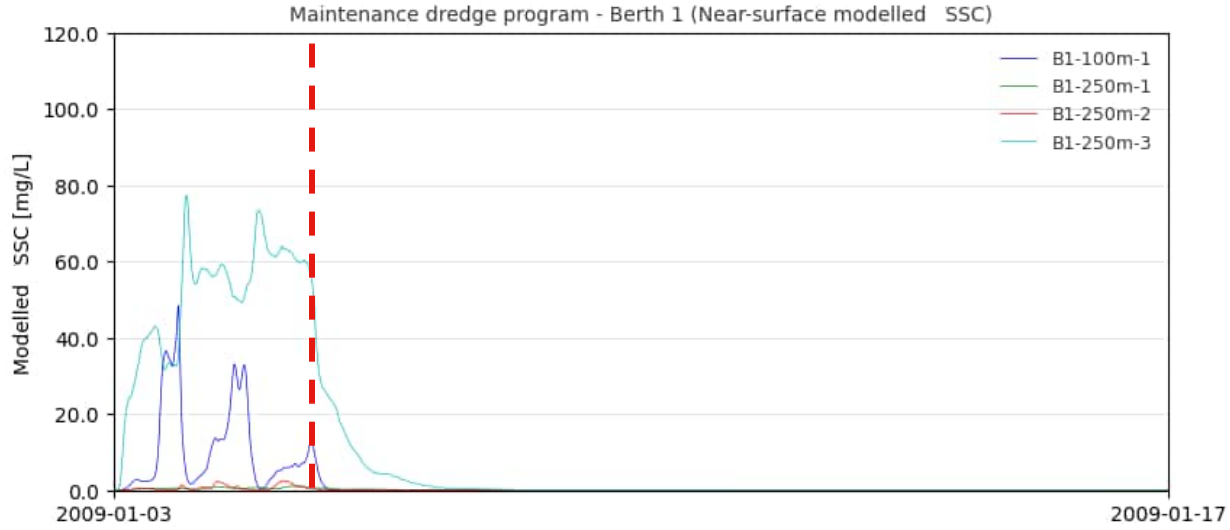


Figure 6-40: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 1 maintenance dredge area (1)

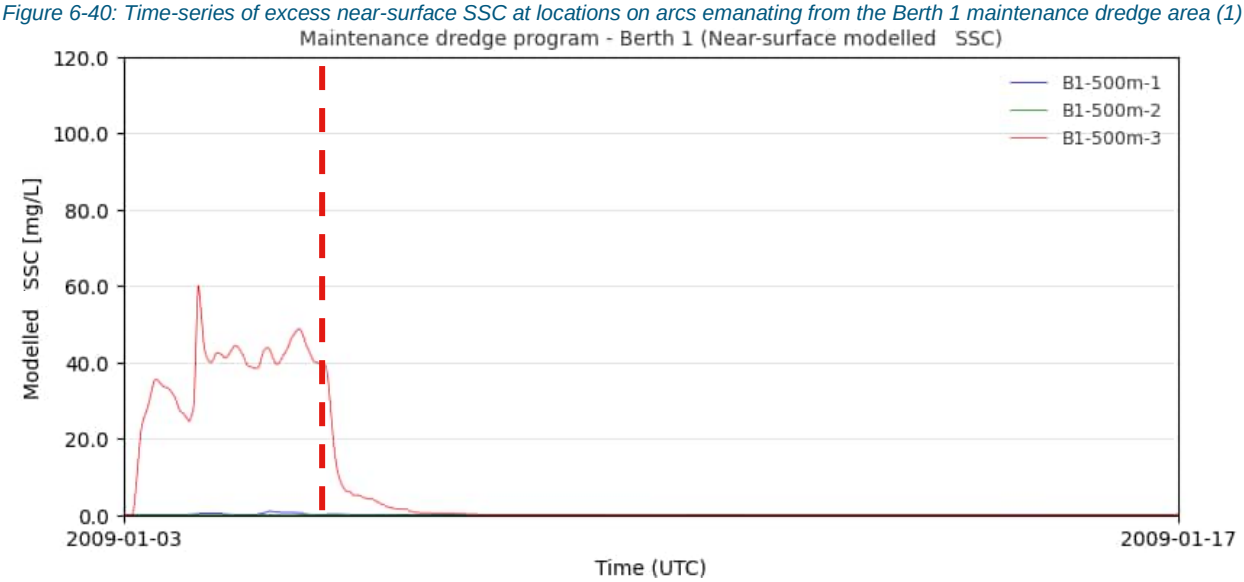


Figure 6-41: Time-series of excess near-surface SSC at locations arcs emanating from the Berth 1 maintenance dredging area (2)

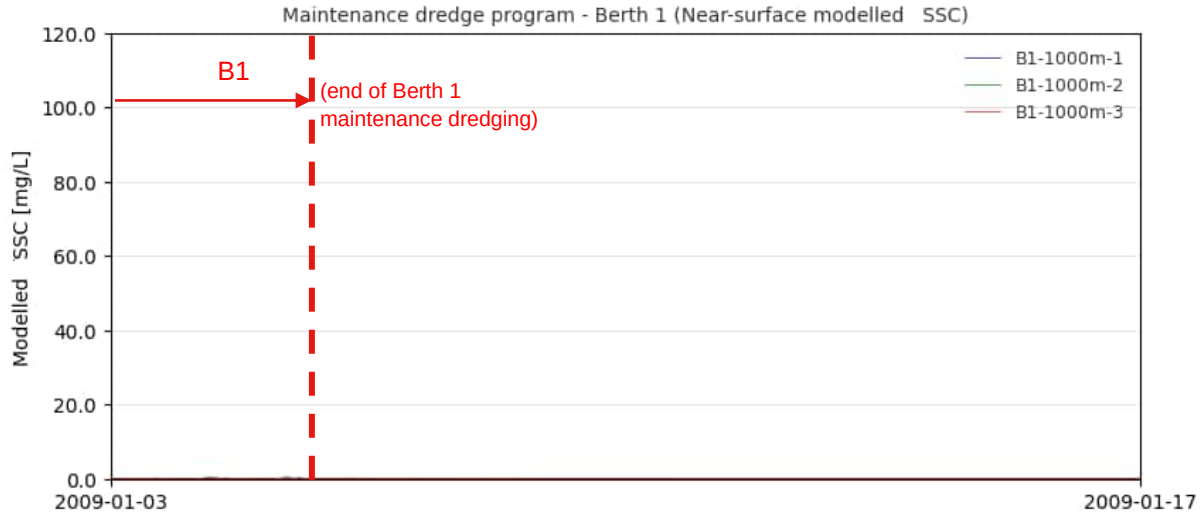


Figure 6-42: Time-series of excess near-surface SSC at locations arcs emanating from the Berth 1 maintenance dredging area (3)

Town Beach/Batavia Coast Marina



*Figure 6-43: Nominated model output locations at Town Beach and near the Batavia Coast Marina (repeated from **Figure 6-10**)*

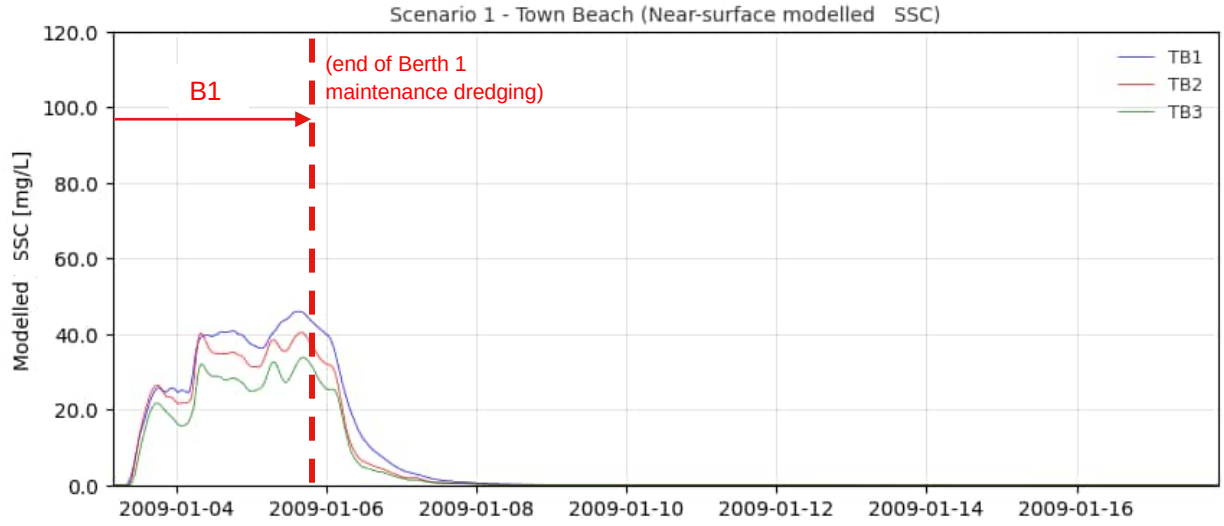


Figure 6-44: Time-series of excess near-surface SSC during Berth 1 maintenance dredging at locations along Town Beach

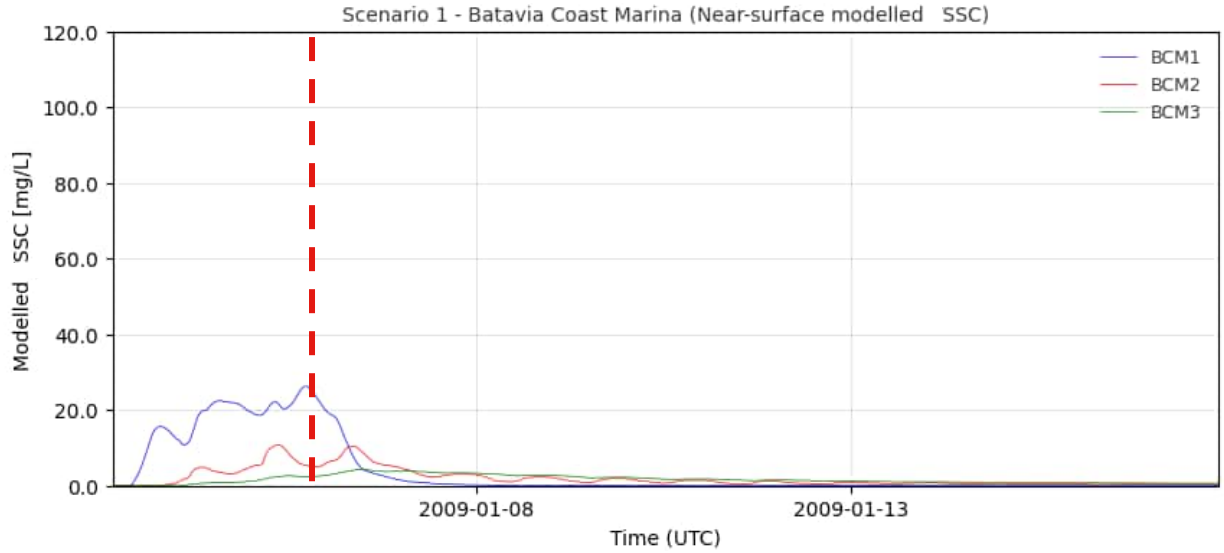


Figure 6-45: Time-series of excess near-surface SSC during Berth 1 maintenance dredging at locations near Batavia Coast Marina

6.5.6.3 Sedimentation

Based on the output presented below, the following key observations can be made:

- In areas in close proximity to the dredging locations, high rates of sedimentation are observed due to the modelled bed shear stress not exceeding the critical bed shear stress for erosion and re-suspension; and
- Sedimentation is largely contained to the immediate dredge area, with the exception of a predicted sedimentation area in front of Town Beach with a thickness between 4 and 20mm.

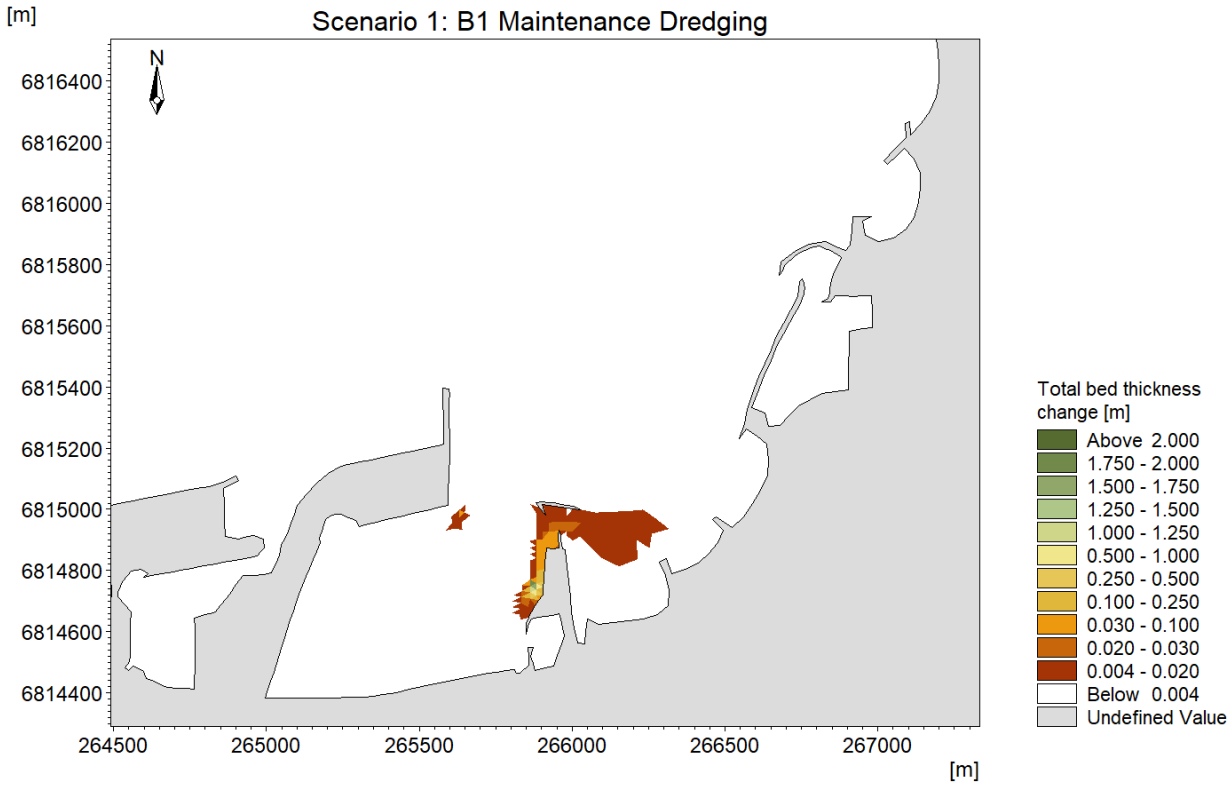


Figure 6-46: Sedimentation thickness of fines at the end of Berth 1 maintenance dredging

6.5.6.4 Impact Zones

Based on the output presented below, the following key observations can be made:

- The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berth 1 maintenance dredge area and is within the project development envelope (also refer **Figure 1-3**); and
- Impact due to SSC is limited to a 'zone of influence' covering Town Beach and the Batavia Coast Marina, and extending approx. 20-25km northward alongshore.

It is noted that the ZoHI includes the direct disturbance (dredge) footprint, in addition to the ZoHI areas presented in **Figure 6-47** to **Figure 6-49**.



Figure 6-47: Impact zones (sedimentation) for the Berth 1 maintenance dredging campaign

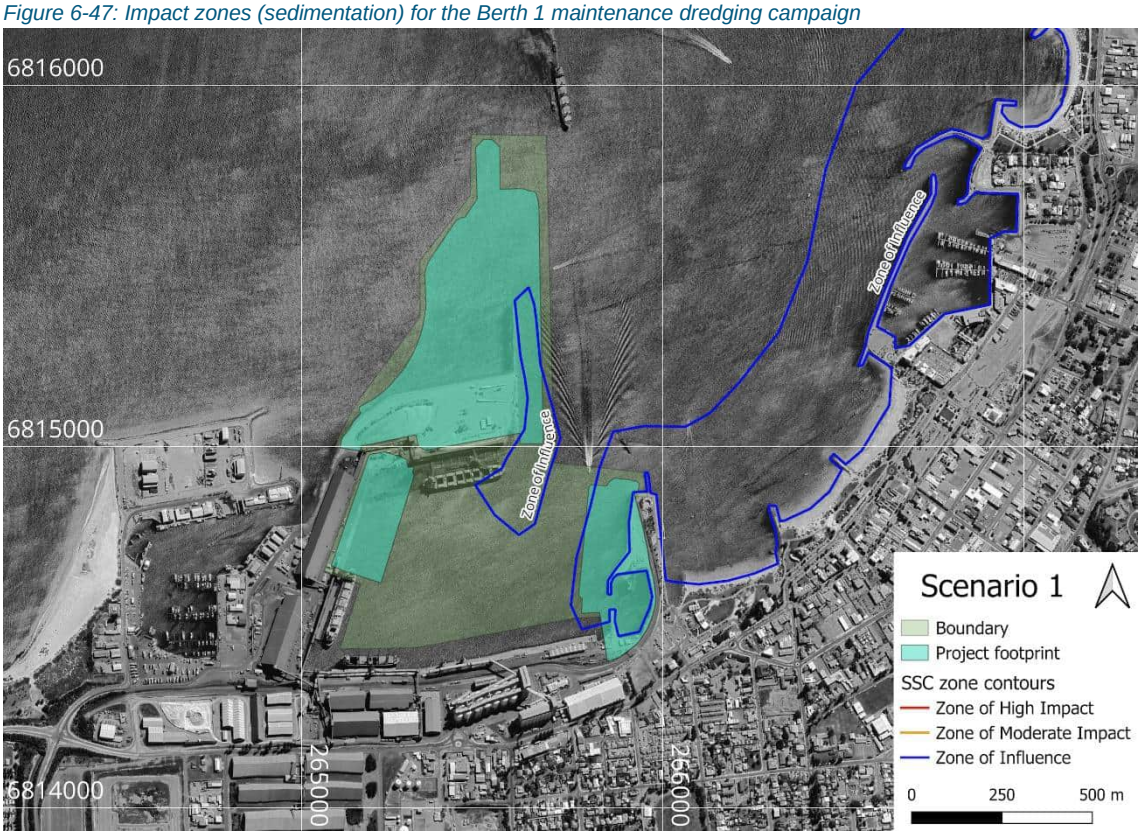


Figure 6-48: Impact zones (SSC) for the Berth 1 maintenance dredging campaign

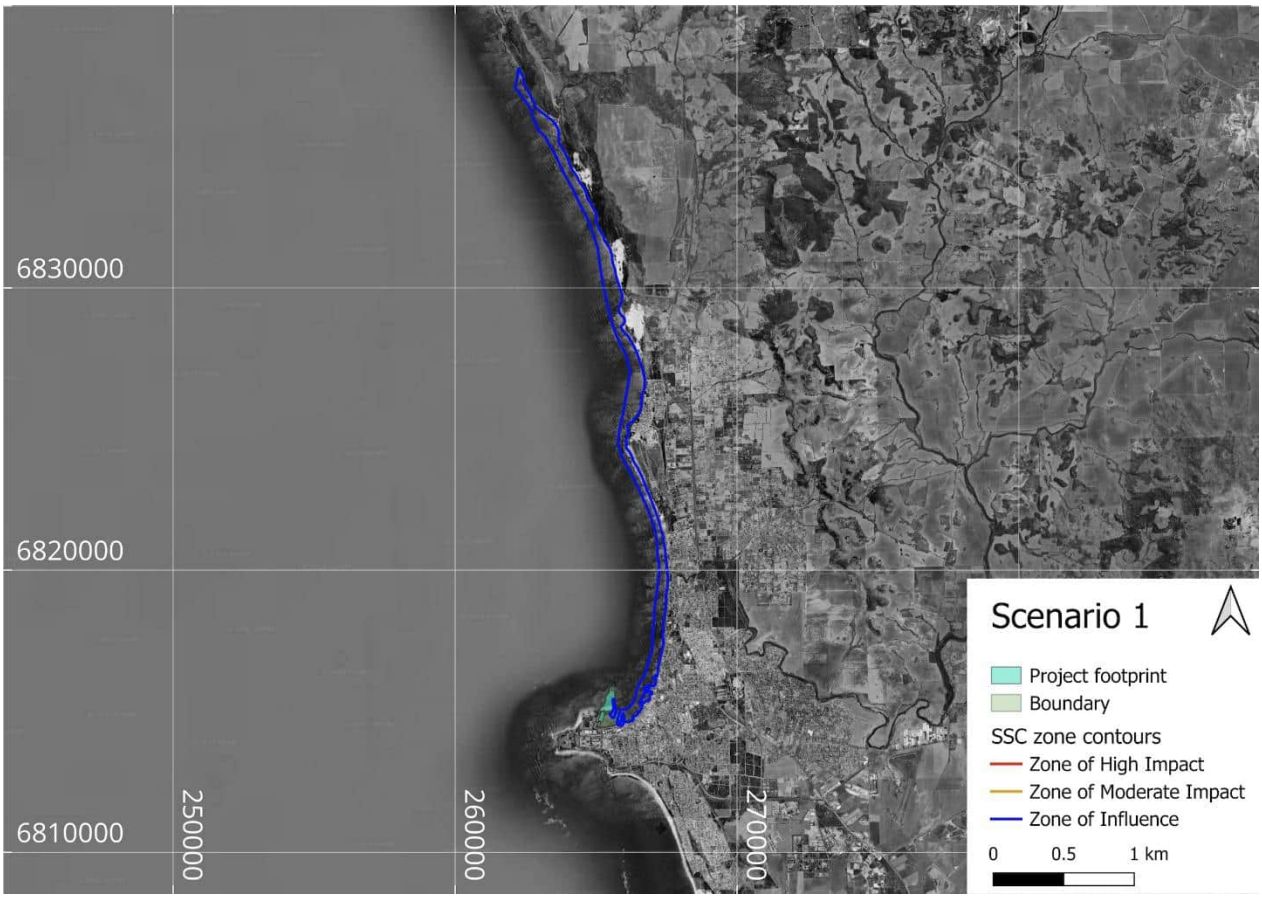


Figure 6-49: Impact zones (SSC) for the Berth 1 maintenance dredging campaign (regional)

6.6 Scenario 2: Berth 1, Berth 6 and Berth 8 Capital Dredging

6.6.1 Introduction

Capital dredging is the removal and relocation of the natural and previously undisturbed seabed to increase water depth.

The proposed capital dredging at Berth 6 and future Berth 1 and Berth 8 comprises the ripping and breaking by hammer of rock and the subsequent removal by a Backhoe Dredge (BHD) of material ranging from very loose sediment to high-strength rock, to facilitate construction or extension of the new berthing facilities and enable mooring of larger vessels (refer **Figure 1-4**). The proposed dredge areas and dredge depths are presented in **Figure 6-50** (Berth 1 and Berth 6) and **Figure 6-51** (Berth 8).

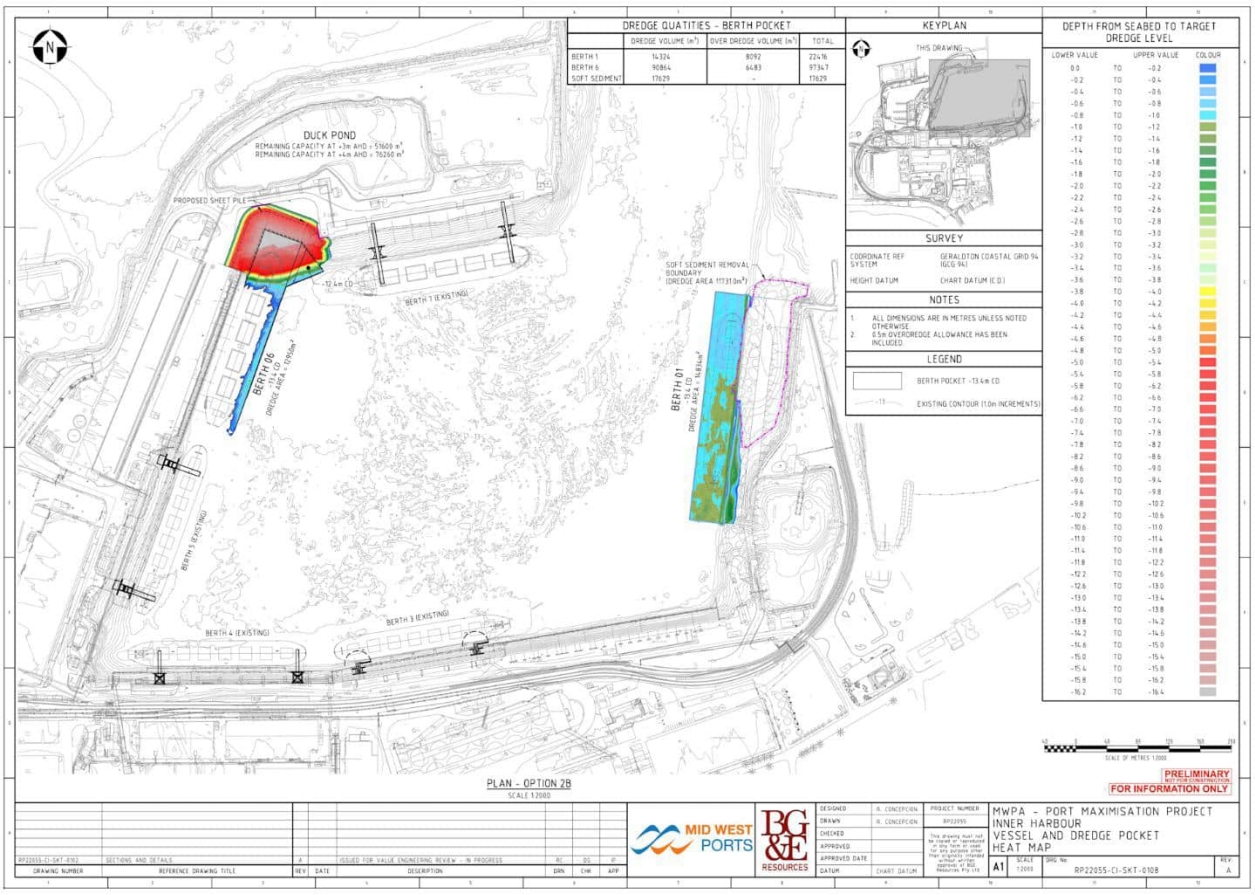


*Figure 6-50: Berth 1 and Berth 6 capital dredge areas (repeated from **Figure 6-19**)*

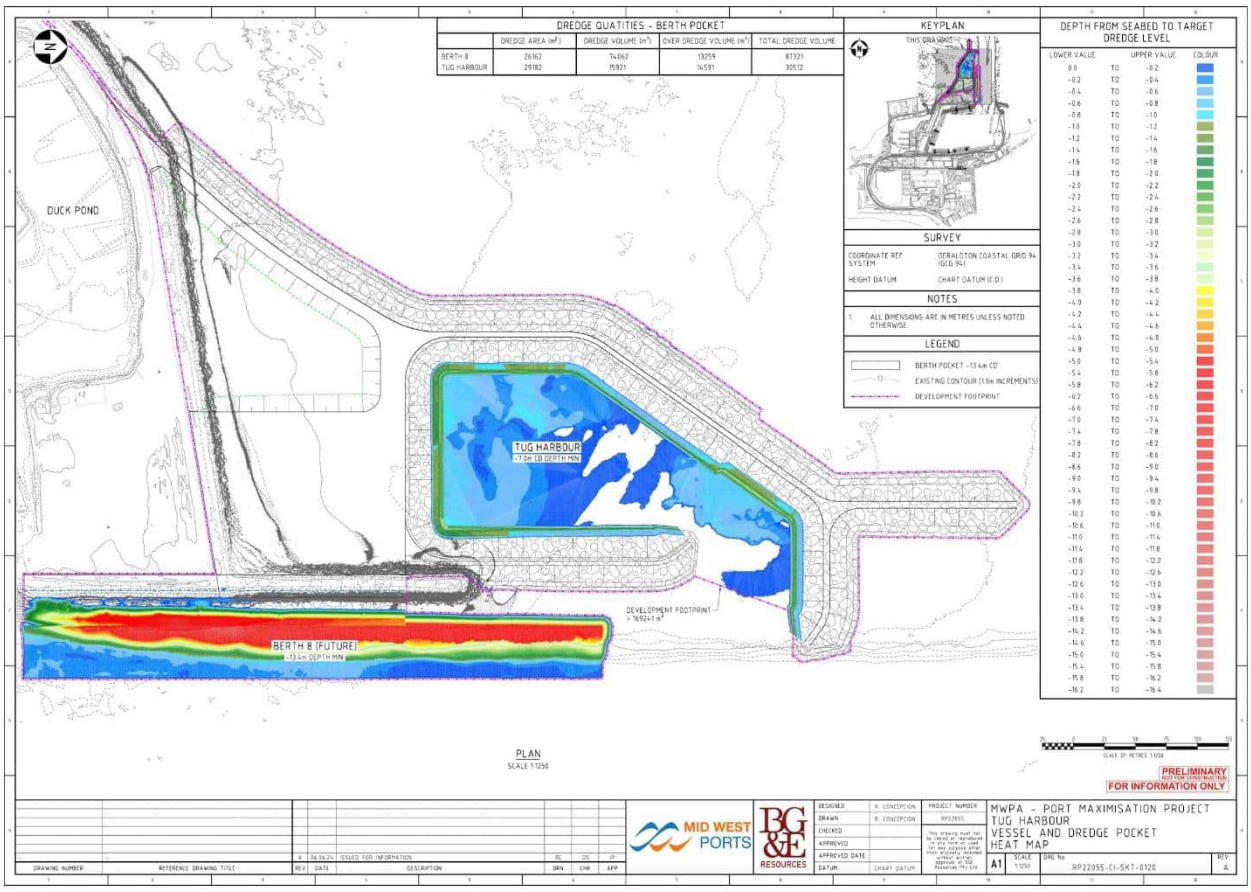


Figure 6-51: Future Berth 8 capital dredge area (the new tug harbour capital dredge area is also shown, however not relevant for this scenario – covered in Scenario 3)

6.6.2 Geotechnical Information

An assessment was made by the appointed dredging expert of the available historical geotechnical reports and borehole information relating to Geraldton Port and the materials present in the areas near Berth 6 and future Berth 1 and Berth 8, with the aim to inform the dredge strategy and source terms. References to these reports, borehole information and assessment results are presented in **Appendix A4** (Hoogerwerf, 2024b).

6.6.3 Dredge Methodology

RHDHV engaged a dredging expert to develop a dredging methodology for the capital dredging works having regard to a number of influencing factors:

- Materials to be dredged (geotechnical conditions);
- Design dredge depths;
- Proposed dredge material disposal areas;
- Issues experienced during the 2002-2003 dredging campaign at Geraldton Port;
- Metocean conditions; and
- Likely environmental constraints.

The geotechnical conditions are a key factor for the assessment of the dredging methodology due to the presence of rock. A number of options for dredging were initially considered and evaluated based on the

consideration of various technical and environmental factors. These options, as well as the different materials to be dredged (and their adopted classes) and the reference equipment for dredging are summarised in Hoogerwerf (2024b).

Based on the geotechnical information (refer **Section 6.6.2**) and other factors outlined above, the proposed equipment and methodology to complete the Berth 1, Berth 6 and Berth 8 dredging activities is as follows:

Berth 1

- Over-water work (BHD supported by hopper barges or flat-top barges). The methodology is as follows:
    - Removal of very loose material (other than rock - OTR) and crushed spill from previous dredging by cutter suction dredge (CSD) operations;
    - Pre-treatment of more competent rock by ripping or hammering as required;
    - Loading into barges with capacity to match BHD production rates;
    - Unloading of barges alongside an existing wharf by long-reach excavators (in number and production rate to match BHD production rates) and trucking to the reclamation area (old tug harbour – refer annotation on the bottom-right of **Figure 1-3**); and
    - Overflow of barges is assumed to be allowed and is accounted for in the estimated losses to the water column.

Berth 6

- Over-land work (north end – use of long-reach excavators); and
    - Removal of armour/rip-rap/fill and silty sand and trucking to reclamation area (old tug harbour – refer above) from approx. +3mCD to -5mCD.
- Over-water work (BHD supported by hopper barges or flat-top barges)
    - BHD dredging below -5mCD, supported by hopper barges or flat-top barges as per Berth 1 above.

Berth 8

- Over-water work (BHD supported by hopper or flat-top barges)
    - Removal of very loose material (other than rock - OTR) and crushed spill from historical dredging by CSD operations;
    - Pre-treatment of more competent rock by ripping or hammering as required;
    - Loading into barges with capacity to match BHD production rates;
    - Unloading of barges alongside an existing wharf by long-reach excavators (LRE - in number and production rate to match BHD production rates) and trucking to the reclamation area (old tug harbour – refer annotation on the bottom-right of **Figure 1-3**); and
    - Overflow of barges is assumed to be allowed and is accounted for in the estimated losses to the water column.

Examples of a very large BHD, long-reach excavator and hopper barge as outlined above are presented in **Figure 6-52** to **Figure 6-54**, respectively.



Figure 6-52: Example very large BHD operating with standard open bucket attachment



Figure 6-53: Example long-reach excavator



Figure 6-54: Example BHD loading adjacent hopper barge with open bucket attachment

6.6.4 Source Term Estimates

Table 6-10 to **Table 6-19** summarise the fines fluxes estimated by the appointed dredging expert used as inputs for the capital dredge plume model (refer Hoogerwerf (2024b) provided in **Appendix A4**), as well as the silt fraction percentages of the overall silt fraction based on the available geotechnical information at the Berth 1, Berth 6 and Berth 8 capital dredge area (refer **Section 6.6.2**). Similar to the maintenance dredging at Berth 1, the silt fraction (2-75µm) is further divided into four size ranges (refer **Section 6.5.4**). The following tables are presented:

- **Berth 1**
  - Source terms due to losses from bucket (over-water dredging) and overflow of the barges are presented in **Table 6-10** and **Table 6-11**, respectively. Silt fraction percentages are presented in **Table 6-12**.
- **Berth 6**
  - Source terms due to losses from bucket (land-based and over-water dredging) and overflow of the barges are presented in **Table 6-13**, **Table 6-14** and **Table 6-15**, respectively. Silt fraction percentages are presented in **Table 6-16**.
- **Berth 8**
  - Source terms due to losses from bucket (over-water dredging) and overflow of the barges are presented in **Table 6-17** and **Table 6-18**, respectively. Silt fraction percentages are presented in **Table 6-19**.

Berth 1

Table 6-10: Berth 1 capital dredging - source terms due to losses from bucket

Material	Equipment	Duration [wks]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR	BHD dredging	0.30	0.57	1.42	Distr. over WC*
Very low strength rock	BHD dredging	1.27	0.13	0.03	Distr. over WC
Low strength rock	BHD dredging	0.30	0.07	0.01	Distr. over WC
Low-medium strength rock	BHD ripping	0.08	0.08	0.02	Seabed
	BHD dredging	0.06	0.18	0.04	Distr. over WC
Medium strength rock	BHD hammer	0.06	0.03	0.01	Seabed
	BHD dredging	0.01	0.16	0.04	Distr. over WC
	Total duration:	2.08			

* *Distributed over entire water column (WC)*

Table 6-11: Berth 1 capital dredging - source terms due to overflow of 1400m^3 split hopper barge (SHB)

Material	Duration [hrs]	Barge Cycle Time [hrs]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR + CSD fines	0.76	6.88	0.70	1.39	Surface
Very low strength rock	3.57	13.76	0.61	0.20	Surface
Low strength rock	13.76	27.52	0.25	0.07	Surface
Low-medium strength rock	3.57	13.76	0.40	0.05	Surface
Medium strength rock	3.57	13.76	0.53	0.06	Surface

Table 6-12: Berth 1 silt fraction percentages

	Coarse silt (60-75micron)	Medium silt (40-60micron)	Fine silt (20-40micron)	Very fine silt (02-20micron)
Very loose – dense OTR	20%	20%	25%	35%
Very low strength rock	50%	25%	15%	10%
Low strength rock	40%	30%	15%	15%
Low-medium strength rock	10%	20%	30%	40%
Medium strength rock	25%	25%	30%	20%

Berth 6

Table 6-13: Berth 6 capital dredging - source terms due to losses from bucket of shore-based long-reach excavator (LRE)

Material	Equipment	Duration [wks]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR + Fill	LRE	5.00	0.31	0.10	Distr. over WC
	Total duration:	5.00			

Table 6-14: Berth 6 capital dredging - source terms due to losses from bucket (over-water BHD)

Material	Equipment	Duration [wks]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR	BHD dredging	0.65	0.57	1.71	Distr. over WC*
Very low strength rock	BHD dredging	3.06	0.13	0.03	Distr. over WC
Low strength rock	BHD dredging	2.27	0.07	0.01	Distr. over WC
Low-medium strength rock	BHD ripping	2.45	0.08	0.02	Seabed
	BHD dredging	1.84	0.18	0.04	Distr. over WC
Medium strength rock	BHD hammer	0.37	0.03	0.01	Seabed
	BHD dredging	0.09	0.16	0.04	Distr. over WC
	Total duration:	10.73			

Table 6-15: Berth 6 capital dredging - source terms due to overflow of 1400m^3 split hopper barge (SHB)

Material	Duration [hrs]	Barge Cycle Time [hrs]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR	0.76	6.88	0.87	1.88	Surface
Very low strength rock	3.57	13.76	0.61	0.20	Surface
Low strength rock	13.76	27.52	0.25	0.70	Surface
Low-medium strength rock	3.57	13.76	0.40	0.05	Surface
Medium strength rock	3.57	13.76	0.53	0.06	Surface

Table 6-16: Berth 6 silt fraction percentages

	Coarse silt (60-75micron)	Medium silt (40-60micron)	Fine silt (20-40micron)	Very fine silt (02-20micron)
Very loose – dense OTR + Fill	35%	25%	25%	15%
Very loose – dense OTR	20%	20%	25%	35%
Very low strength rock	50%	25%	15%	10%
Low strength rock	40%	30%	15%	15%
Low-medium strength rock	10%	20%	30%	40%
Medium strength rock	25%	25%	30%	20%

Berth 8

Table 6-17: Berth 8 capital dredging - source terms due to losses from bucket (over-water BHD)

Material	Equipment	Duration [wks]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR	BHD big dredging	0.60	0.57	1.42	DoWC*
Very low strength rock	BHD small dredging	1.50	0.13	0.03	DoWC
Low strength rock	BHD small dredging	5.11	0.07	0.01	DoWC
Low-medium strength rock	BHD rock dredging	1.13	0.13	0.03	DoWC
Medium strength rock	BHD rip dredging	3.83	0.16	0.04	Seabed
	BHD dredging	0.96	0.28	0.60	DoWC
Medium-high strength rock	BHD hammer	0.90	0.16	0.04	Seabed
	BHD dredging	0.22	0.28	0.06	DoWC
	Total duration:	14.25			

* *DoWC = Distributed over entire water column*

Table 6-18: Berth 8 capital dredging - source terms due to overflow of 1400m^3 split hopper barge (SHB)

Material	Duration [hrs]	Barge Cycle Time [hrs]	Silt Flux [kg/s]	Clay Flux [kg/s]	Release Point
Very loose – dense OTR + CSD fines	0.76	6.88	0.82	1.65	Surface
Very low strength rock	3.57	13.76	0.61	0.20	Surface
Low strength rock	13.76	27.52	0.25	0.07	Surface
Low-medium strength rock	3.57	13.76	0.30	0.04	Surface
Medium strength rock	3.57	13.76	0.53	0.06	Surface
Medium-high strength rock	3.57	13.76	0.58	0.03	Surface

Table 6-19: Berth 8 silt fraction percentages

	Coarse silt (60-75micron)	Medium silt (40-60micron)	Fine silt (20-40micron)	Very fine silt (02-20micron)
Very loose – dense OTR	20%	20%	25%	35%
Very low strength rock	50%	25%	15%	10%
Low strength rock	40%	30%	15%	15%
Low-medium strength rock	10%	20%	30%	40%
Medium strength rock	25%	25%	30%	20%
Medium-high strength rock	20%	20%	30%	30%

6.6.5 Model Setup

The source terms and release levels presented in **Section 6.6.4** as estimated by Hoogerwerf (2024b) were translated to MIKE MT module input, taking into account to the (modelling) constraints outlined in **Section 6.5.5**.

Given that the points of release as indicated by Hoogerwerf (2024b) are either near-surface, near-bed or evenly distributed over the entire water column and are covered by the available types of spilling in the MIKE MT module, no further accounting is necessary and the model fluxes (and silt fraction percentages) are as presented in **Table 6-10** to **Table 6-19** in **Section 6.6.4**. They assume 168hrs/week (or 24hrs/day, 7days/week) of dredging, except for the land-based dredging at Berth 6 (**Table 6-13**), which occurs 12hrs/day and five days per week.

Graphs showing fluxes (all fines) for each source (BHD/LRE and SHB overflow) and material type are presented in **Figure 6-55** to **Figure 6-57**.

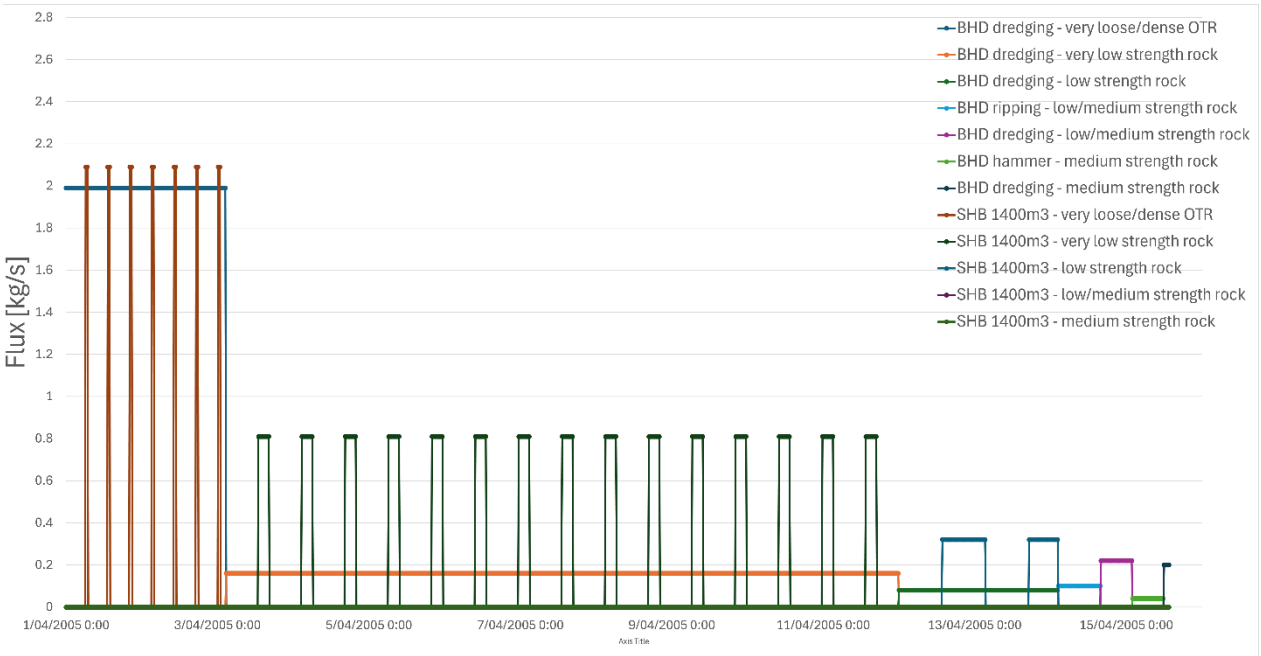


Figure 6-55: Berth 1 capital dredging model fluxes

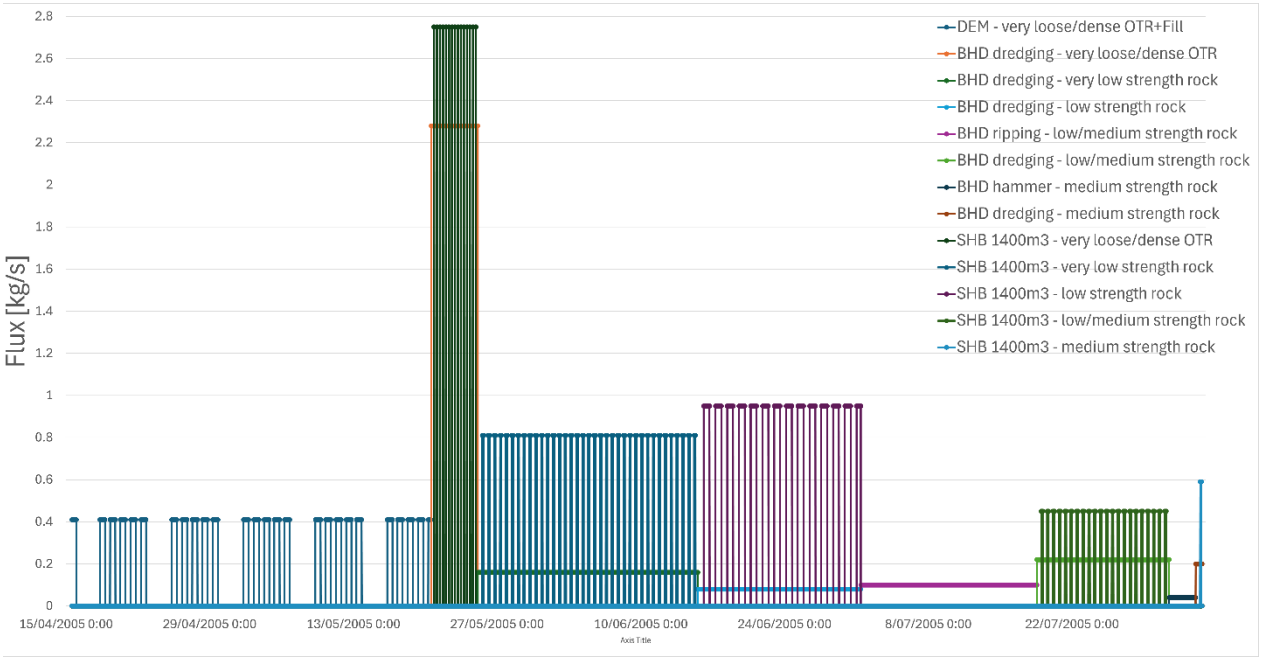


Figure 6-56: Berth 6 capital dredging model fluxes

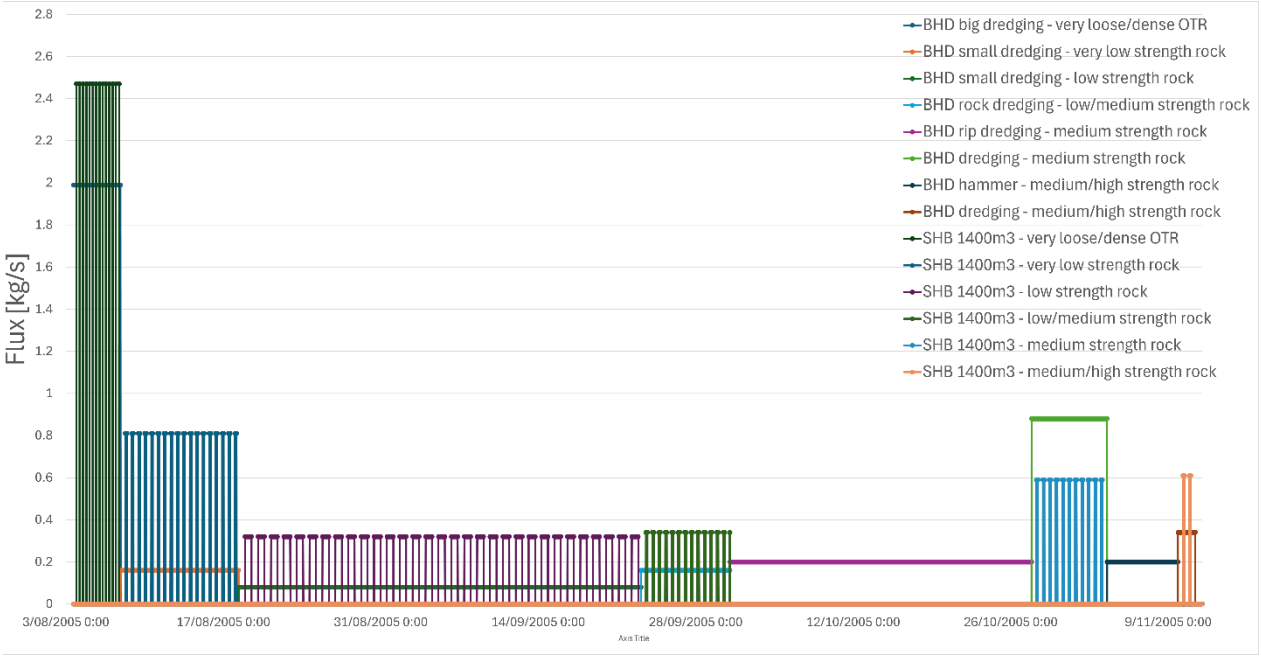


Figure 6-57: Berth 8 capital dredging model fluxes

6.6.6 Results - Above Background

The following output has been presented for Scenario 2 (Berth 1, 6 and 8 capital dredging):

Percentile maps

- **Figure 6-58** and **Figure 6-59**: 50%ile excess near-surface and near-bed SSC map over the dredging period for capital dredging at Berths 1, 6 and 8, and Berths 1 and Berth 6 only; and

- **Figure 6-60** and **Figure 6-61**: 95%ile excess near-surface and near-bed SSC map over the dredging period for capital dredging at Berths 1, 6 and 8, and Berths 1 and Berth 6 only.

Time-series (30-minute time step)

- **Figure 6-63**: time-series of excess near-bed and near-surface SSC at output locations (A to G) northward along the coast from Geraldton Port for capital dredging at Berths 1, 6 and 8, and Berths 1 and Berth 6 only;
- **Figure 6-65** to **Figure 6-68**: time-series of excess near-bed SSC at sensitive receptors locations (L1-L13) for capital dredging at Berths 1, 6 and 8;
- **Figure 6-70** to **Figure 6-75**: time-series of excess near-bed and near-surface SSC at locations on arcs emanating from the Berth 1 capital dredge area for capital dredging at Berths 1, 6 and 8;
- **Figure 6-77** to **Figure 6-82**: time-series of excess near-bed and near-surface SSC at locations on arcs emanating from the Berth 8 capital dredge area for capital dredging at Berths 1, 6 and 8; and
- **Figure 6-84** and **Figure 6-85**: time-series of excess near-surface SSC at locations along Town Beach and near Batavia Coast Marina for capital dredging at Berths 1, 6 and 8.

Sedimentation maps

- **Figure 6-86** and **Figure 6-87** sedimentation thickness of fines at the end of dredging for capital dredging at Berths 1, 6 and 8, and Berths 1 and Berth 6 only, respectively.

Impact maps

- **Figure 6-88** to **Figure 6-93**: impact zone maps for sedimentation and SSC for capital dredging at Berths 1, 6 and 8, and Berths 1 and Berth 6 only.

6.6.6.1 50%ile and 95%ile Excess SSC

Based on the output presented below, the following key observations can be made:

- Percentile maps show that there is no significant difference in SSC extent and concentration outside the immediate Port area between the Berths 1, 6 and 8 scenario and the Berth 1 and Berth 6 only scenario. Subsequent observations are made for the former scenario;
- The 50th percentile and 95th percentile plots are vastly different in terms of concentration and extent due to the considerable duration of the dredging works (over 32 weeks, or 7.4 months);
- Near-surface plots show similar trends to the near-bed results in terms of spatial extent and concentrations, except for the immediate dredge locations (where mixing over the water column has not occurred due to the close proximity to the dredge location);
- The 95th percentile plot indicates that the area of SSC above 100 mg/L is small and concentrated around the immediate dredging locations;
- The 95th percentile plot shows that the 95th percentile SSC quickly decreases outside the immediate Geraldton Port area;
- The 95th percentile plot shows that dredging impacts the areas to the immediate north and to the west of the New Tug Harbour breakwaters, particularly due to dredging at Berth 6 and Berth 8 as the dredge plume generated at these sites travels counterclockwise around the New Tug Harbour breakwaters, with a 95th percentile SSC between 5 and 10 mg/L; and
- In the cross-shore direction, the modelled 95th percentile SSC values decrease to below 5 mg/L in less than one km.

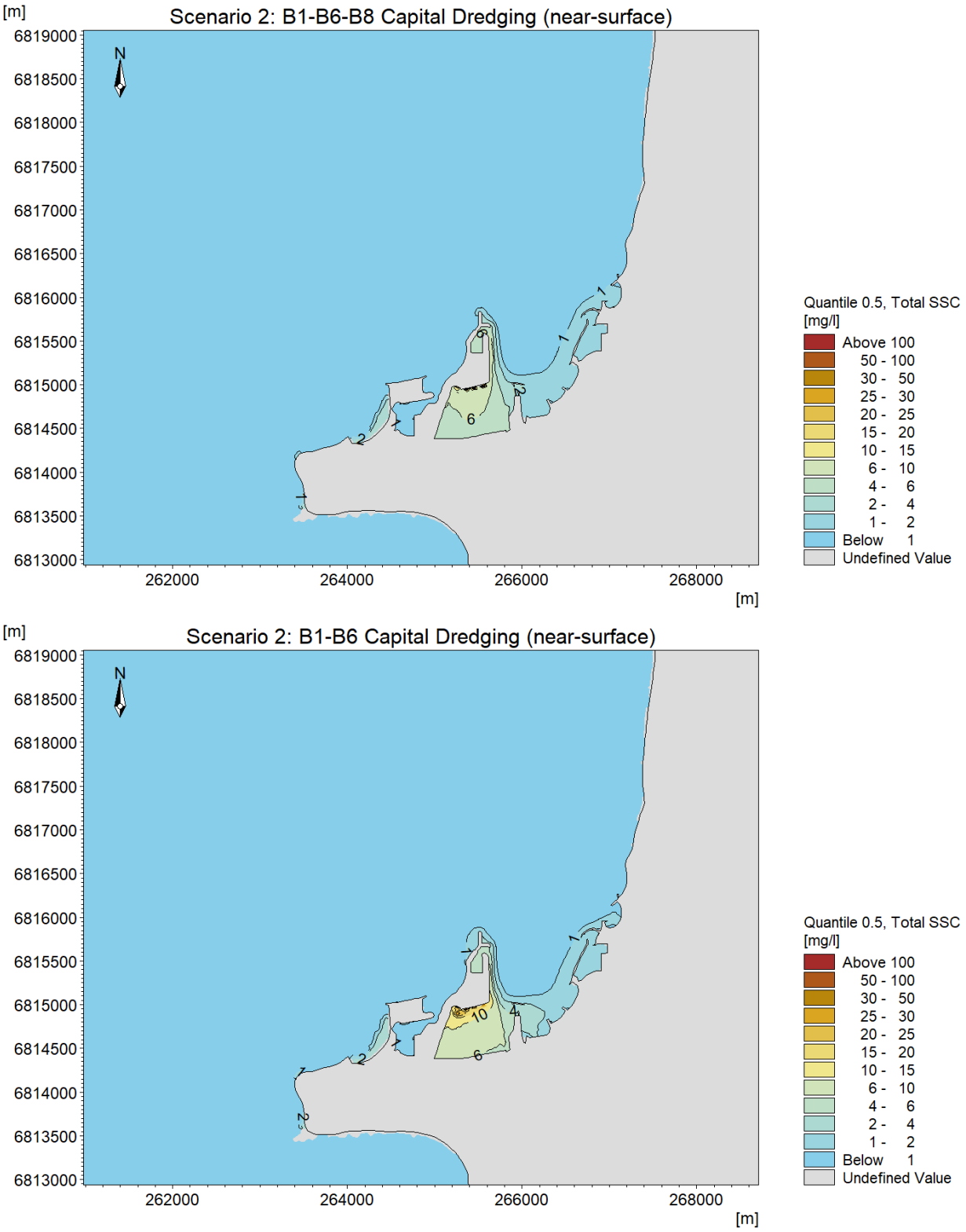


Figure 6-58: Near-surface 50%ile excess SSC (i.e., 84 hours per week) over the dredging period for Berth 1, 6 and 8 capital dredging (top pane) and for Berth 1 and 6 only capital dredging (bottom pane)

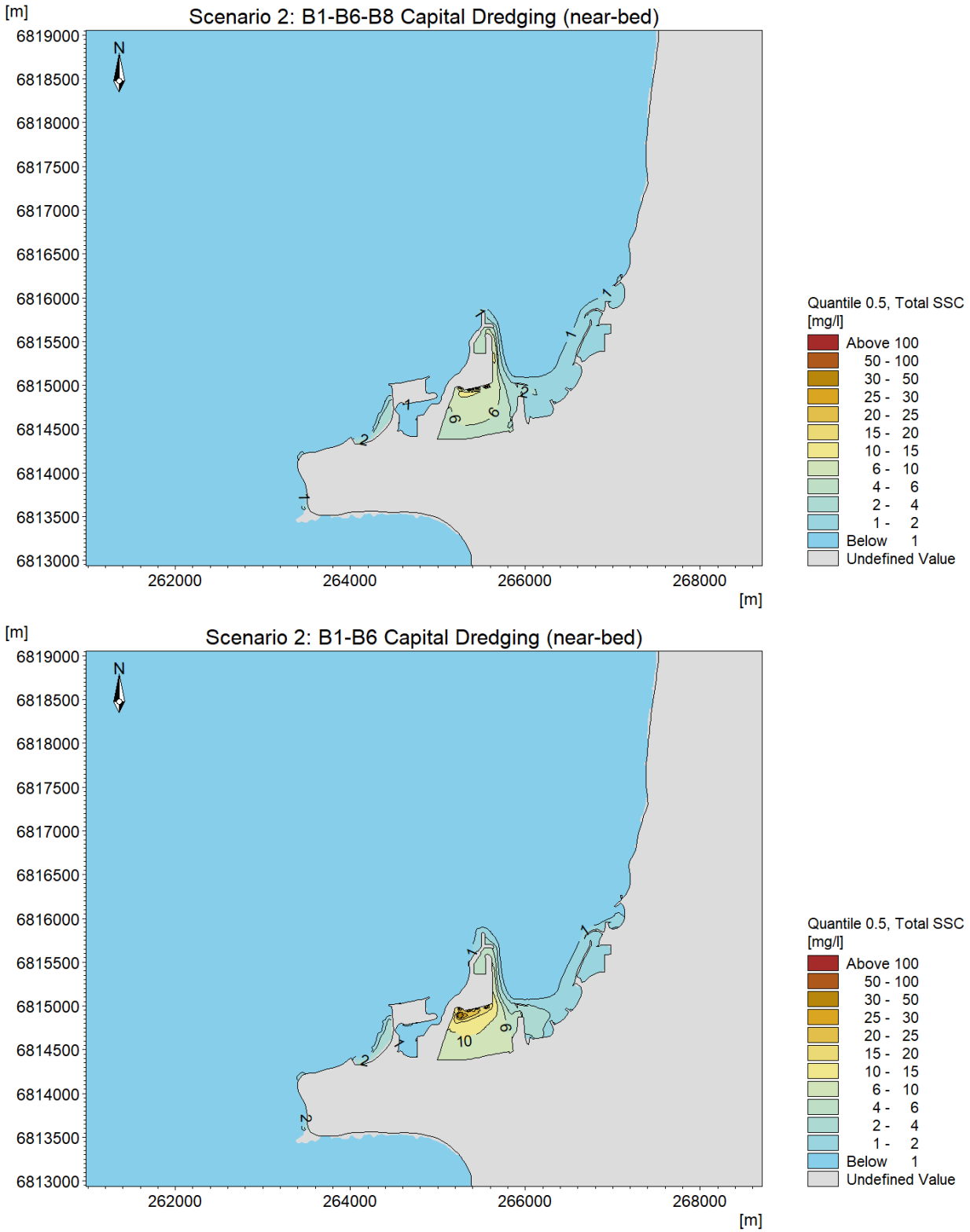


Figure 6-59: Near-bed 50%ile excess SSC (i.e., 84 hours per week) over the dredging period for Berth 1, 6 and 8 capital dredging (top pane) and for Berth 1 and 6 only capital dredging (bottom pane)

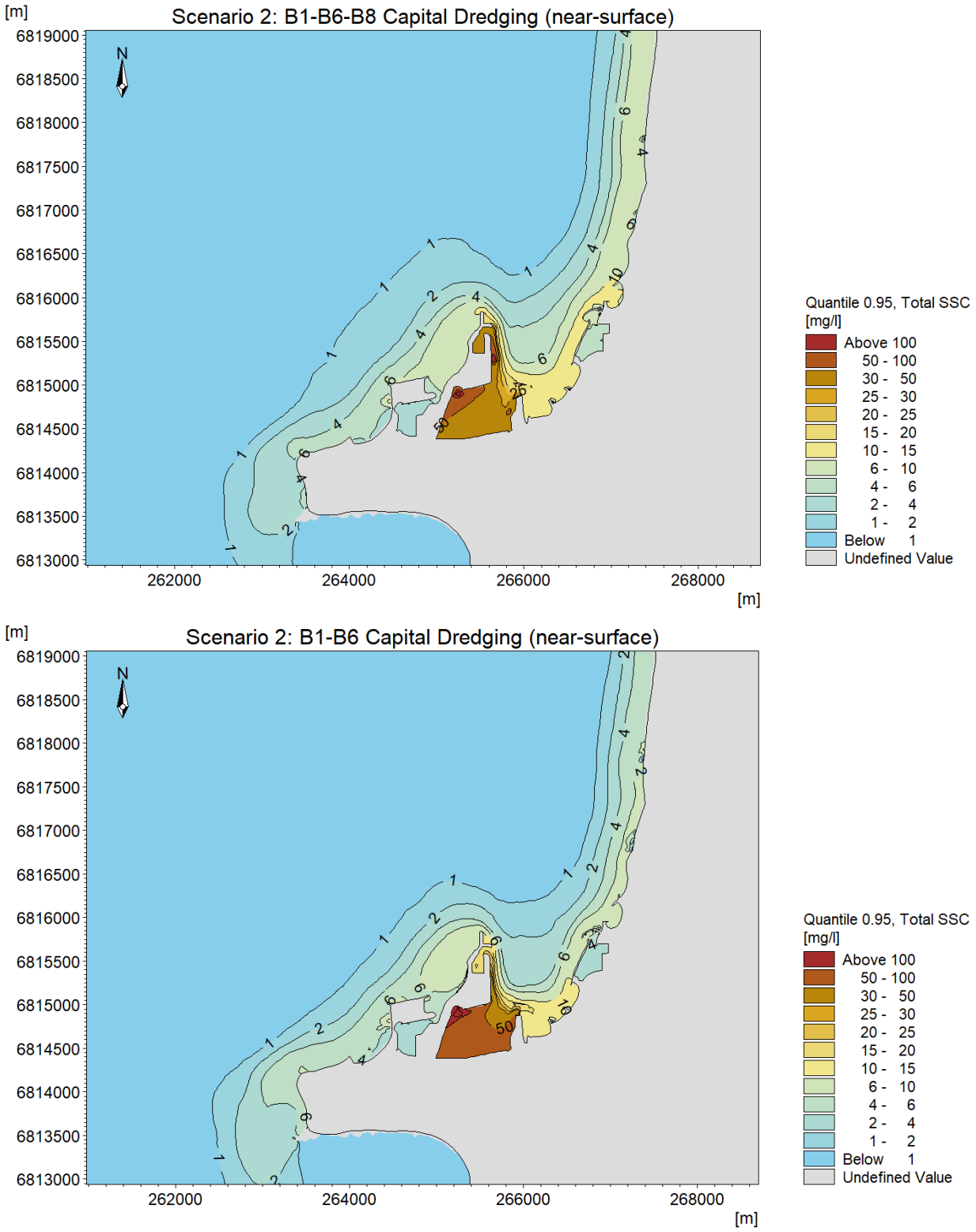


Figure 6-60: Near-surface 95%ile excess SSC (i.e., 8.4 hours per week) over the dredging period for Berth 1, 6 and 8 capital dredging (top pane) and for Berth 1 and 6 only capital dredging (bottom pane)

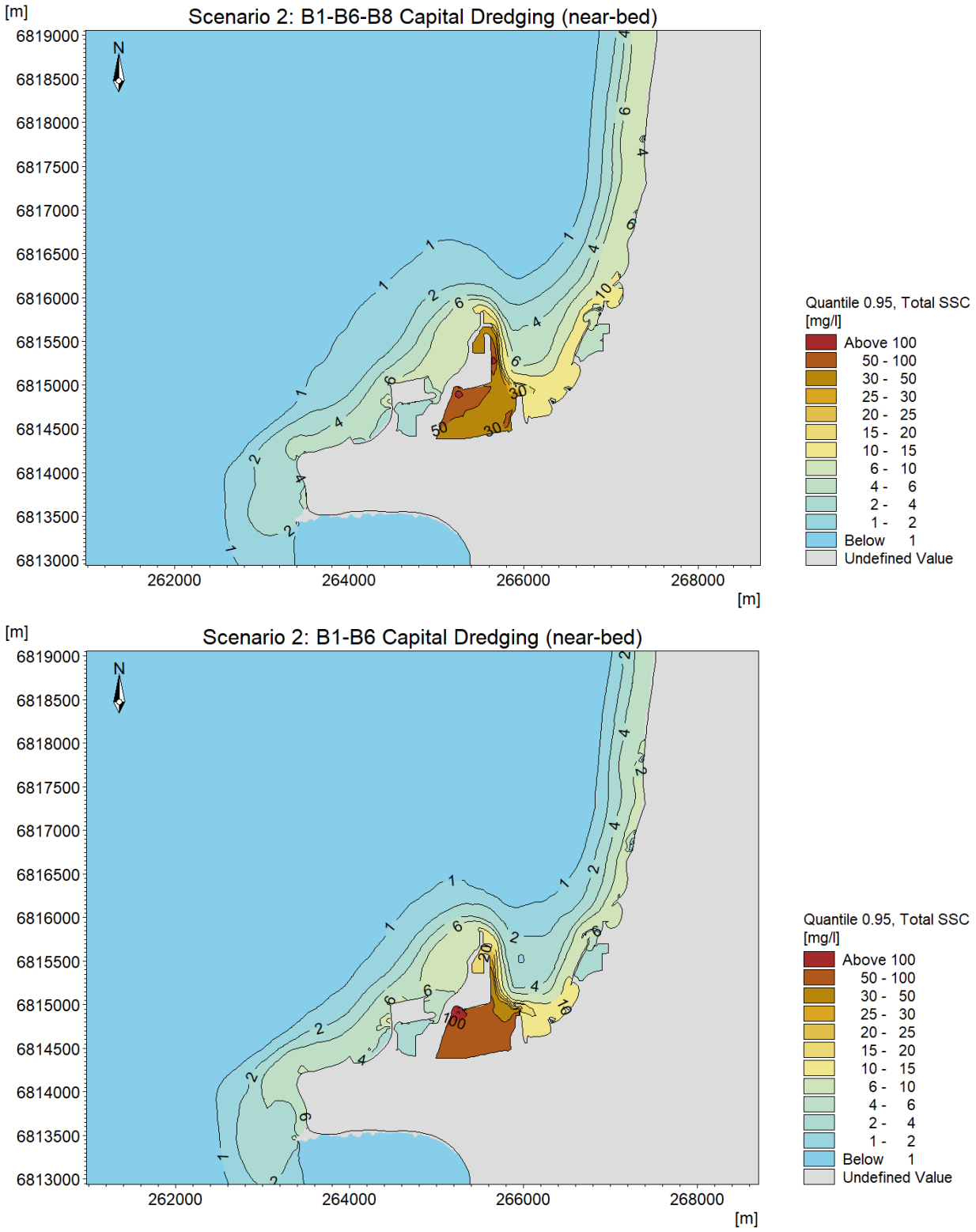


Figure 6-61: Near-bed 95%ile excess SSC (i.e., 8.4 hours per week) over the dredging period for Berth 1, 6 and 8 capital dredging (top pane) and for Berth 1 and 6 only capital dredging (bottom pane)

6.6.6.2 Time-Series of Excess SSC

Based on the output presented below, the following key observations can be made:

- Along the shoreline north of Town Beach and the Batavia Coast Marina, the 95th percentile SSC does not exceed 10 mg/L;
- Along the shoreline north of Town Beach, the SSC does not exceed 20 mg/L (based on output locations B to G). Comparison of the Berths 1, 6 and 8 scenario and the Berths 1 and Berth 6 only scenario shows that the SSC decreases to insignificant levels within a few days after completion of capital dredging at Berth 6. Subsequent observations are made for the former scenario;
- SSC at the sensitive receptor locations relatively briefly (order of a few days) exceeds 50mg/L at L1. Further occasional peaks (also at other sensitive receptor locations) in the order of 10-20mg/L occur;
- Further notable SSC peaks occur around early to mid-August and early November. These spikes coincide with the capital dredging (including associated overflow of barges) of very loose material at Berth 8 at the start, as well as capital dredging of medium strength rock towards the end (refer **Figure 6-57**), respectively, which introduced considerable sediment fluxes;
- Following completion of the dredging works (around 11 October as selected for this modelling exercise), the SSC values at all locations quickly drop below the order of a few mg/L as the dredge plume disperses; and
- SSC near Town Beach and the Batavia Coast Marina peak at around 20mg/L (with the exception of a brief peak of around 60mg/L and 40mg/L, respectively, at the start of capital dredging at Berth 1) and decreases to insignificant levels within one day after dredging has ceased.

Northward along the coast (nearshore)



*Figure 6-62: Nearshore model output locations north of the project site (repeated from **Figure 6-6**)*

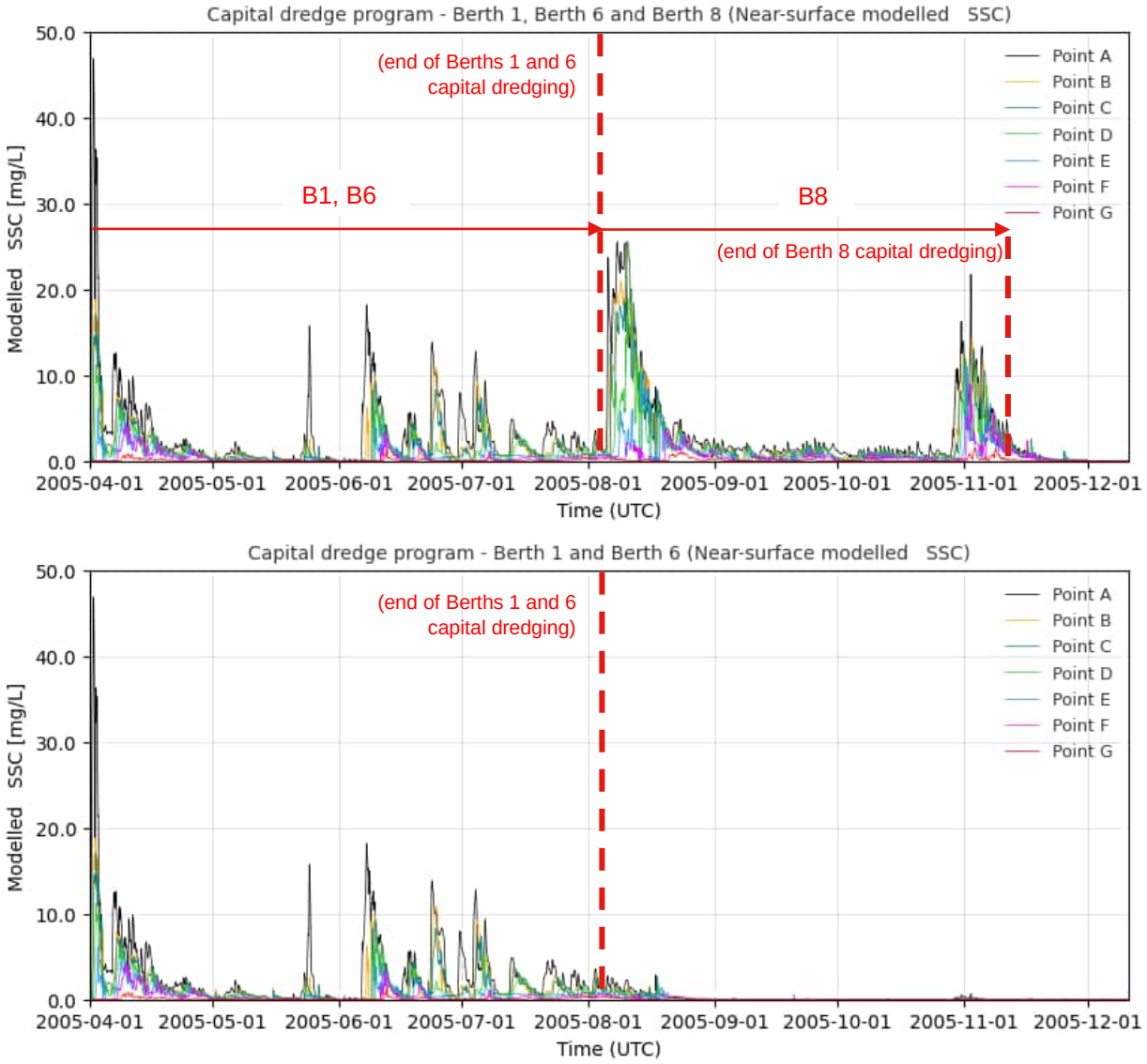


Figure 6-63: Time-series of excess near-surface SSC during capital dredging at Berths 1, 6 and 8 (top pane) and during capital dredging at Berth 1 and 6 only (bottom pane) at output locations northward along the coast from Geraldton Port (red-dashed line = end of dredging stage)

Sensitive Receptors



*Figure 6-64: Model output locations in sensitive receptor areas (repeated from **Figure 6-7**)*

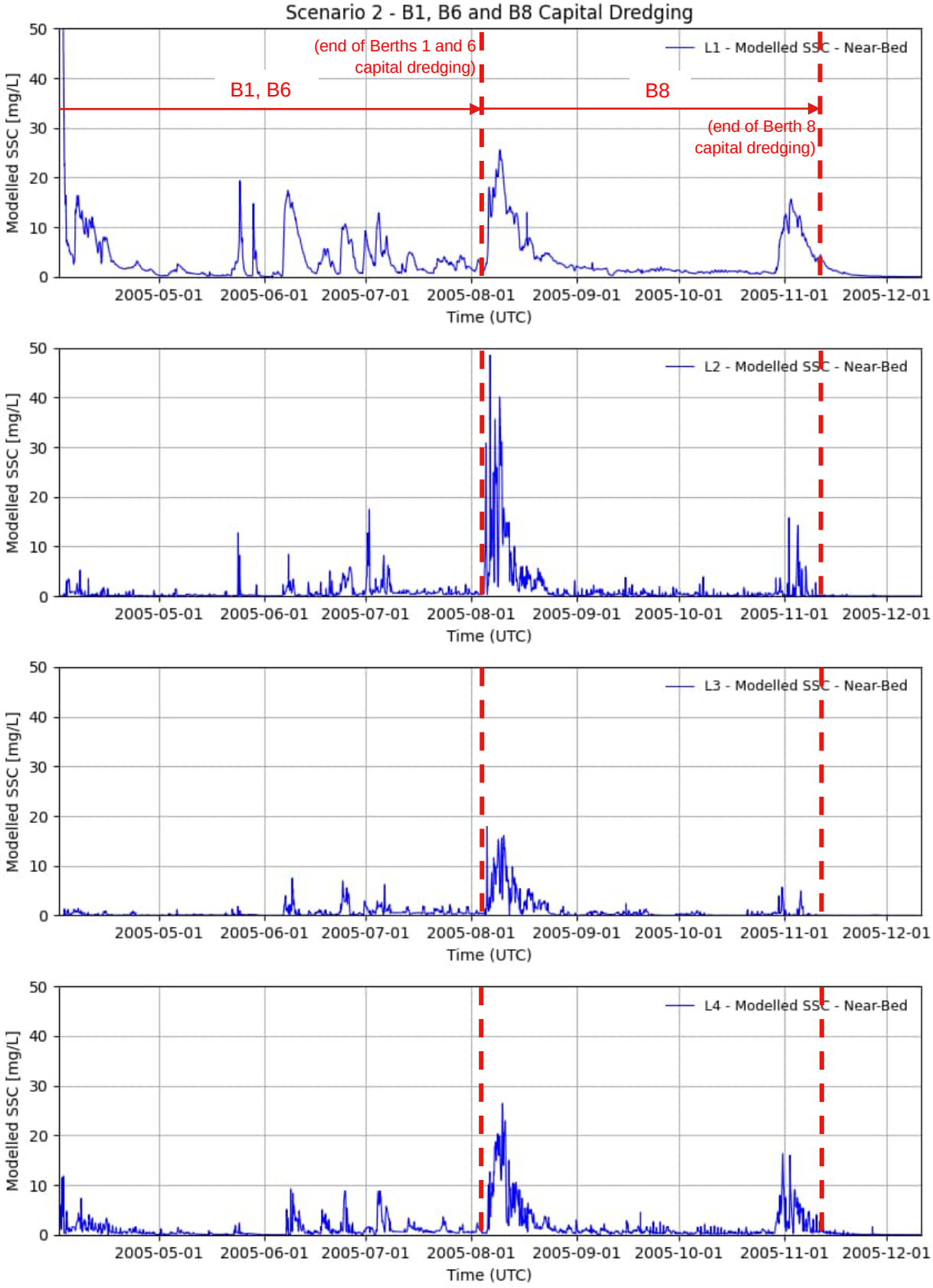


Figure 6-65: Time-series of excess near-bed SSC during capital dredging at Berth 1, 6 and 8 at sensitive receptors locations (L1-L4)

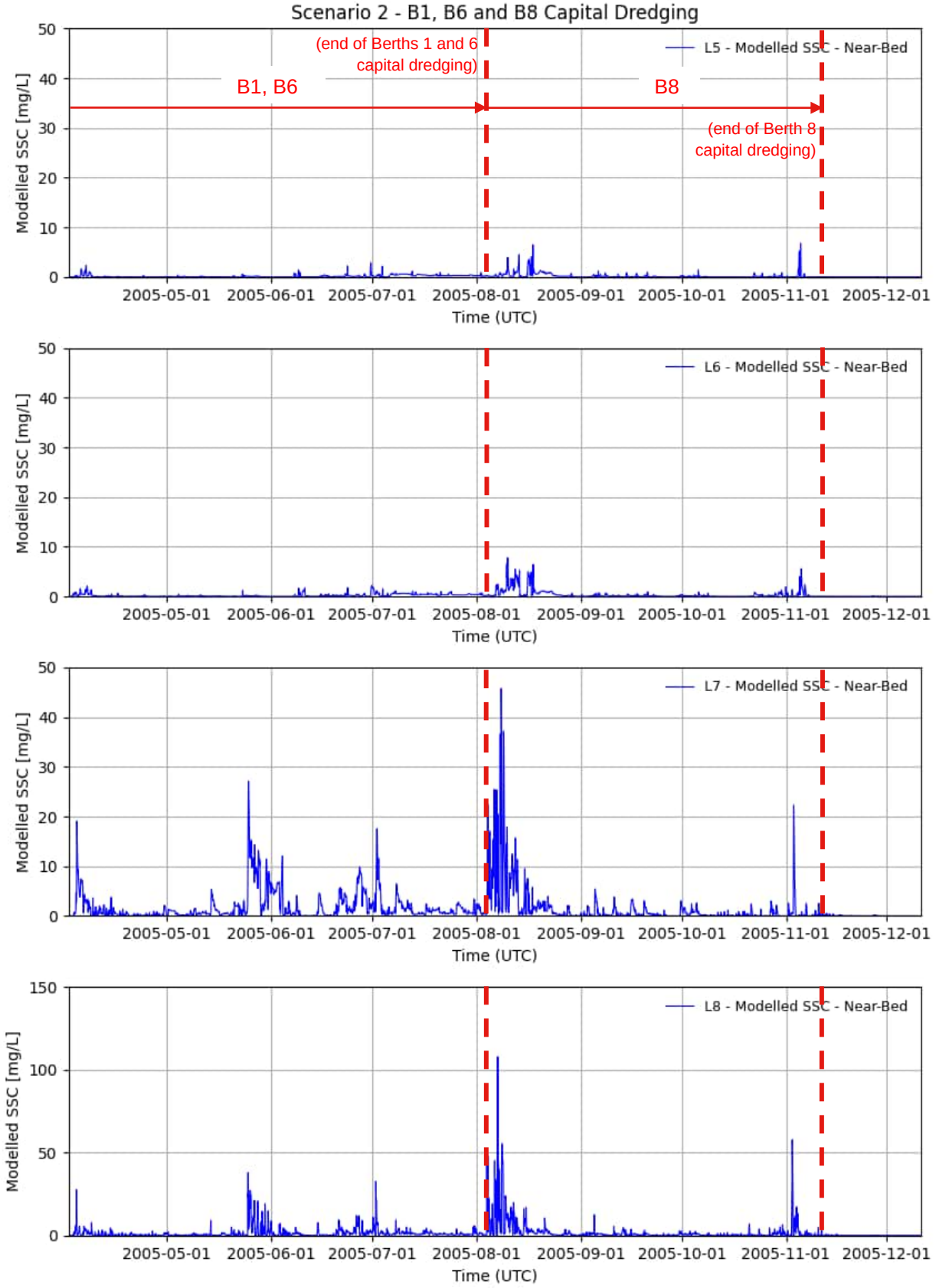


Figure 6-66: Time-series of excess near-bed SSC during capital dredging at Berth 1, 6 and 8 at sensitive receptors locations (L5-L8)

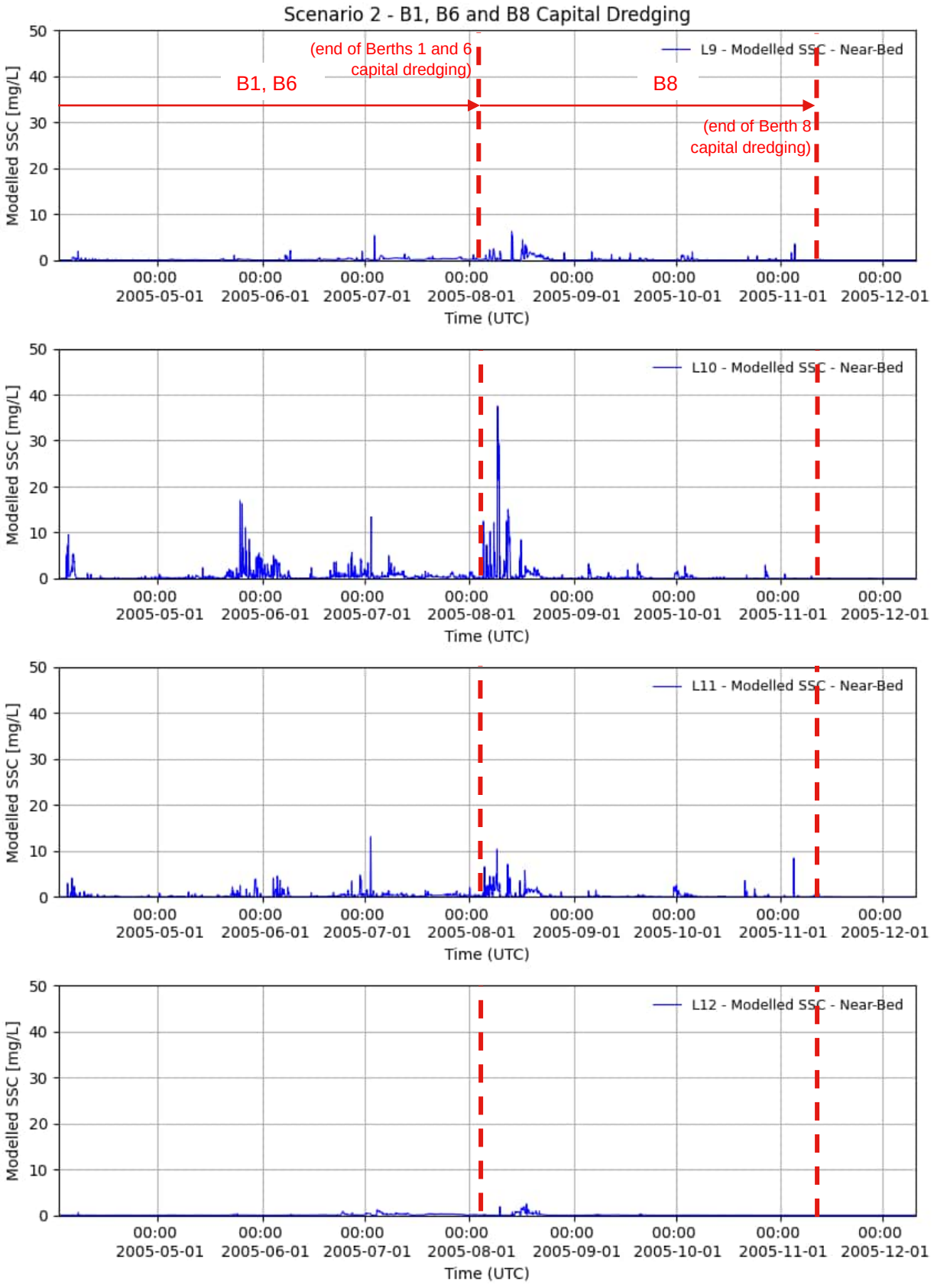


Figure 6-67: Time-series of excess near-bed SSC during capital dredging at Berth 1, 6 and 8 at sensitive receptors locations (L9-L12)

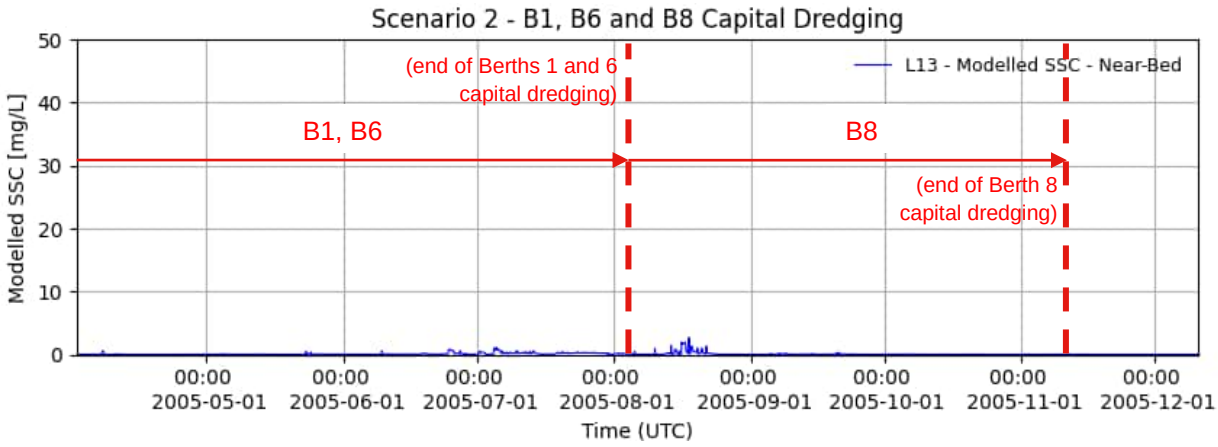


Figure 6-68: Time-series of excess near-bed SSC during capital dredging at Berth 1, 6 and 8 at sensitive receptors locations (L13)

Arcs emanating from the Berth 1 dredge area



*Figure 6-69: Model output locations emanating from the B1 dredge area (10 nominated output locations along the 100, 250, 500 and 1000m arcs) (repeated from **Figure 6-8**)*

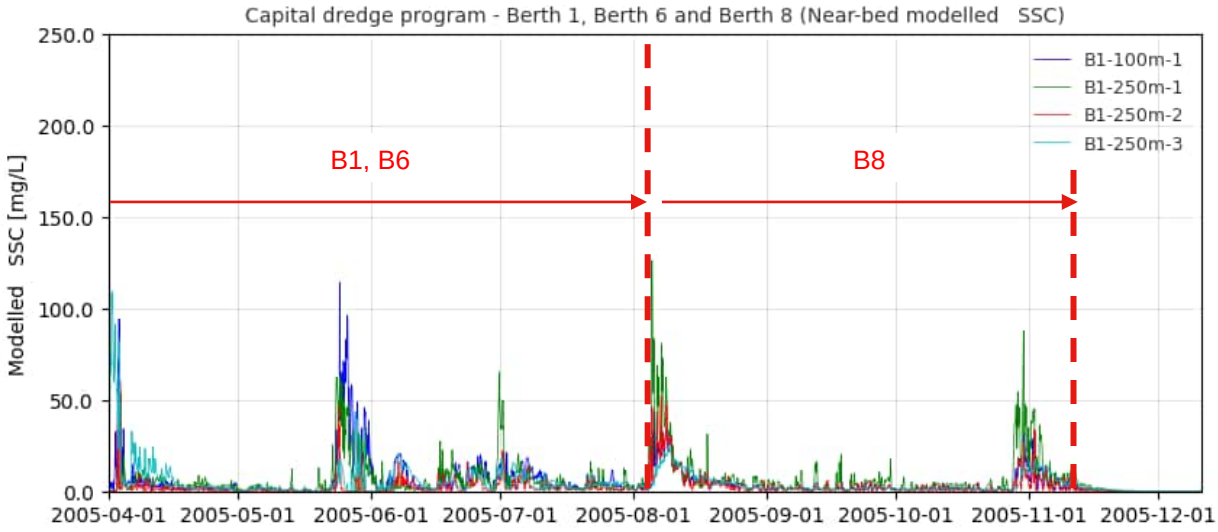


Figure 6-70: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 capital dredge area (1)

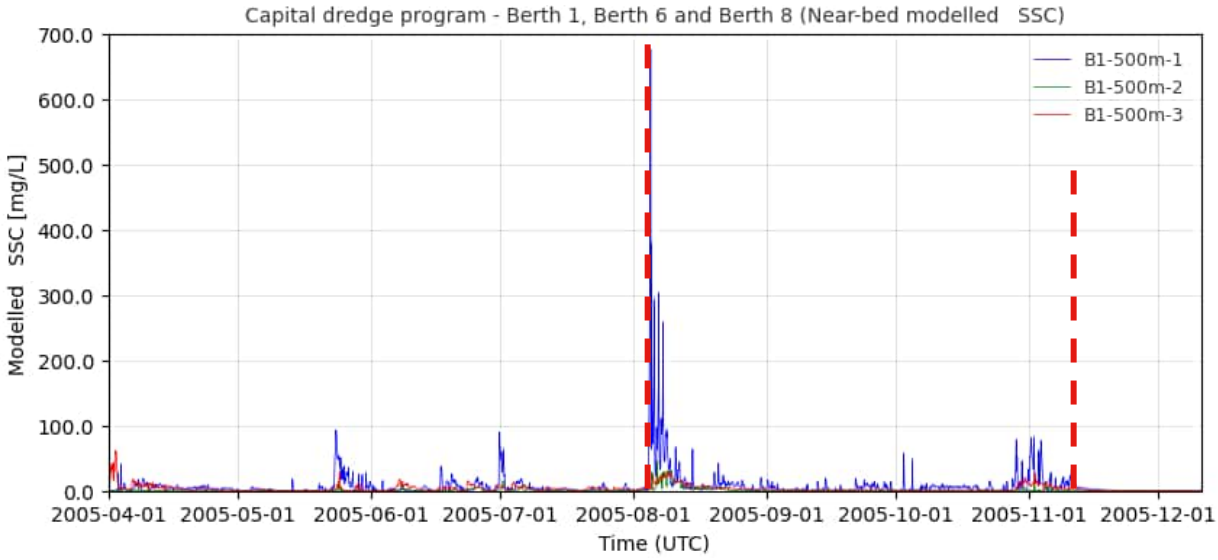


Figure 6-71: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 capital dredge area (2)

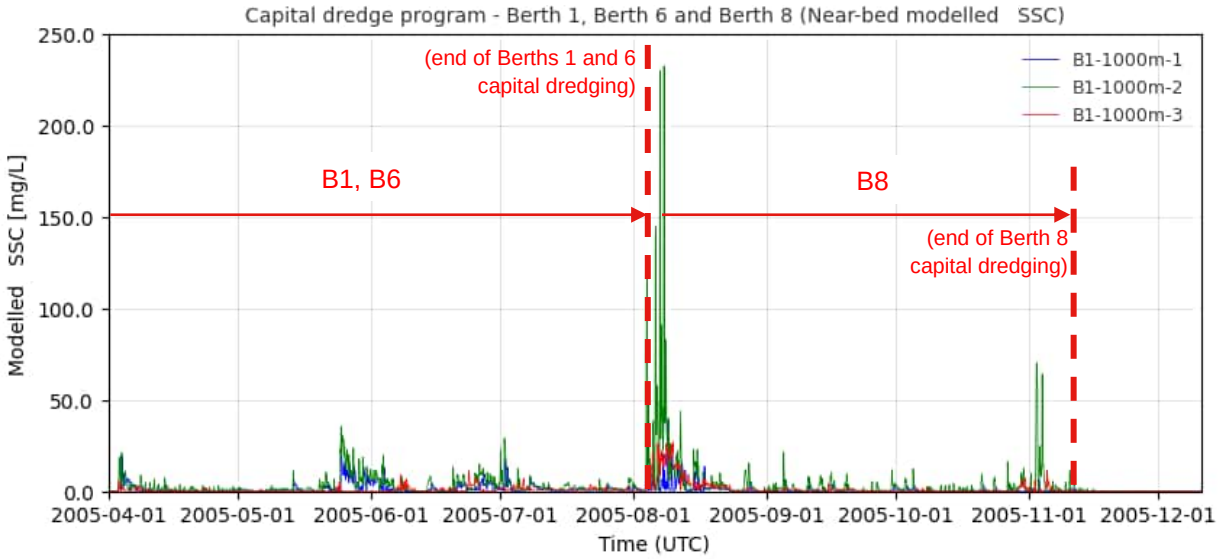


Figure 6-72: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 1 capital dredge area (3)

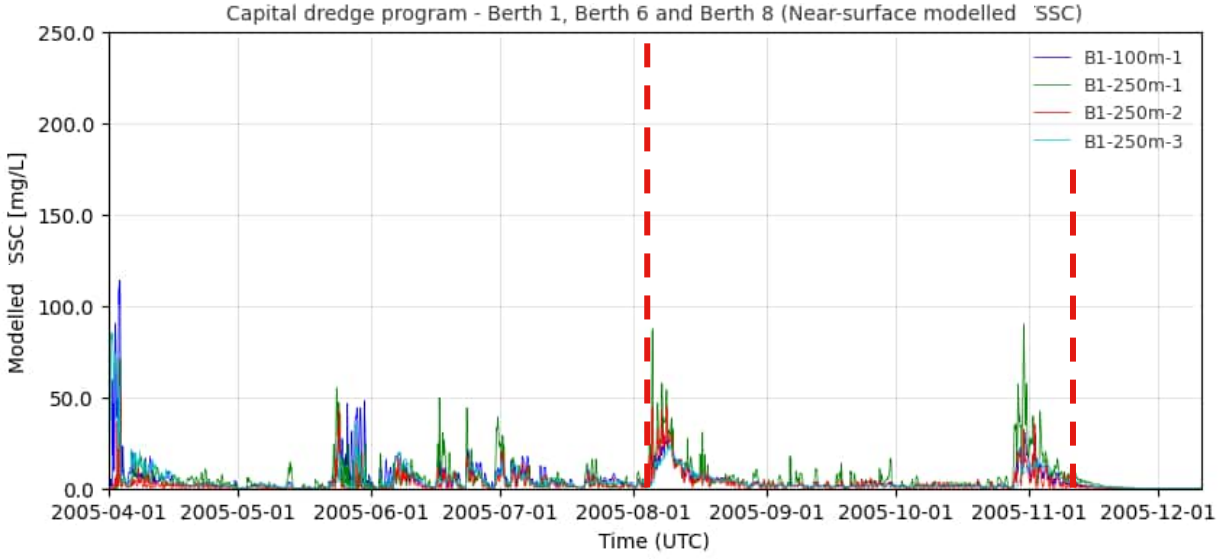


Figure 6-73: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 1 capital dredge area (1)

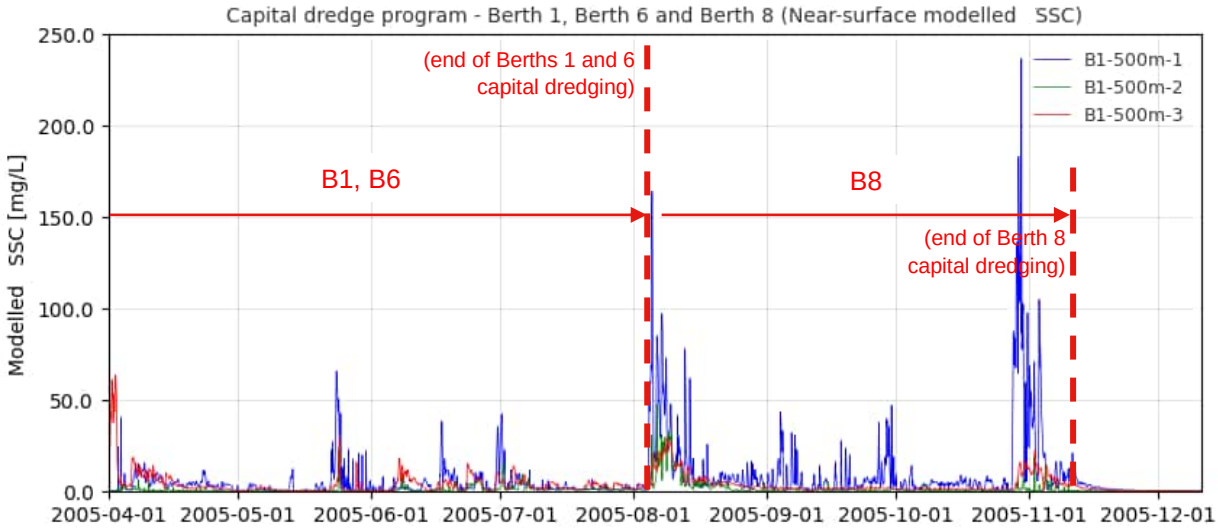


Figure 6-74: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 1 capital dredge area (2)

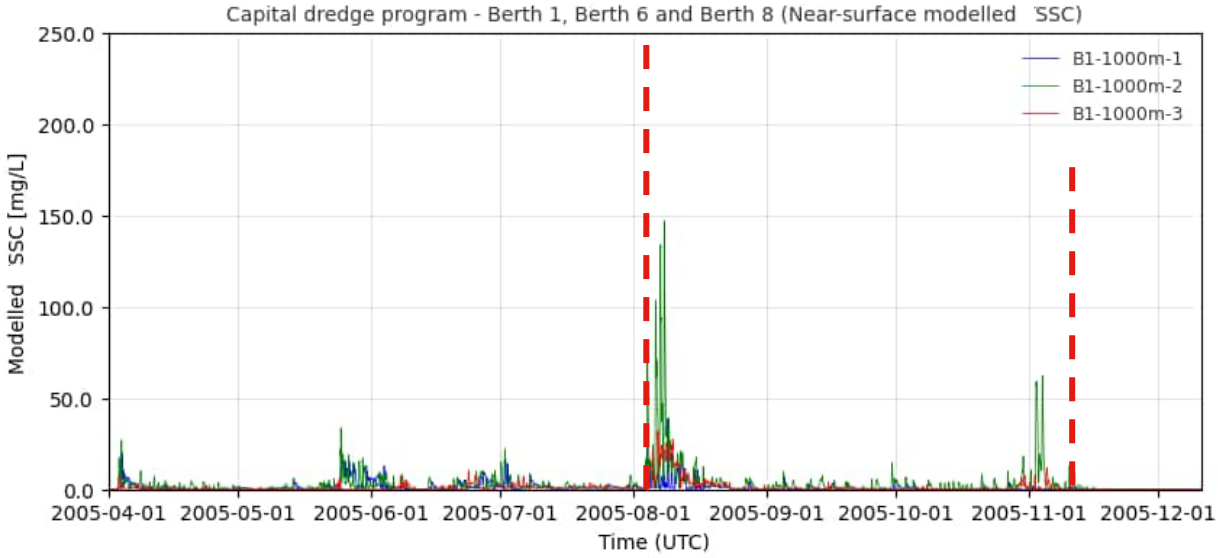


Figure 6-75: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 1 capital dredge area (3)

Arcs emanating from the Berth 8 dredge area



*Figure 6-76: Model output locations emanating from the B8/New Tug Harbour dredge area (14 nominated output locations along the 100, 250, 500 and 1000m arcs) (repeated from **Figure 6-9**)*

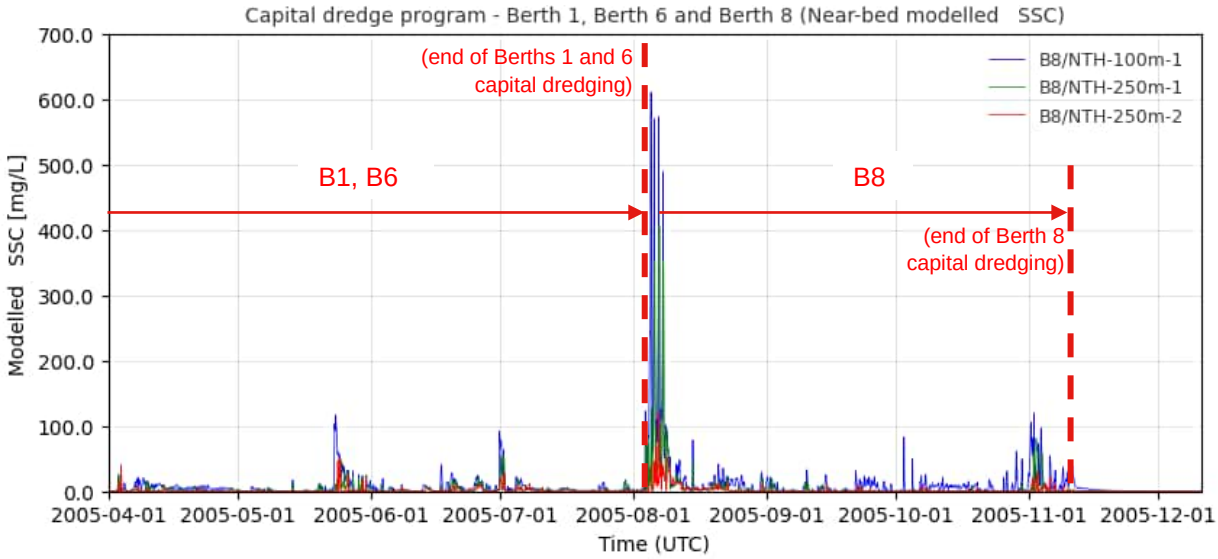


Figure 6-77: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 8 capital dredge area (1)

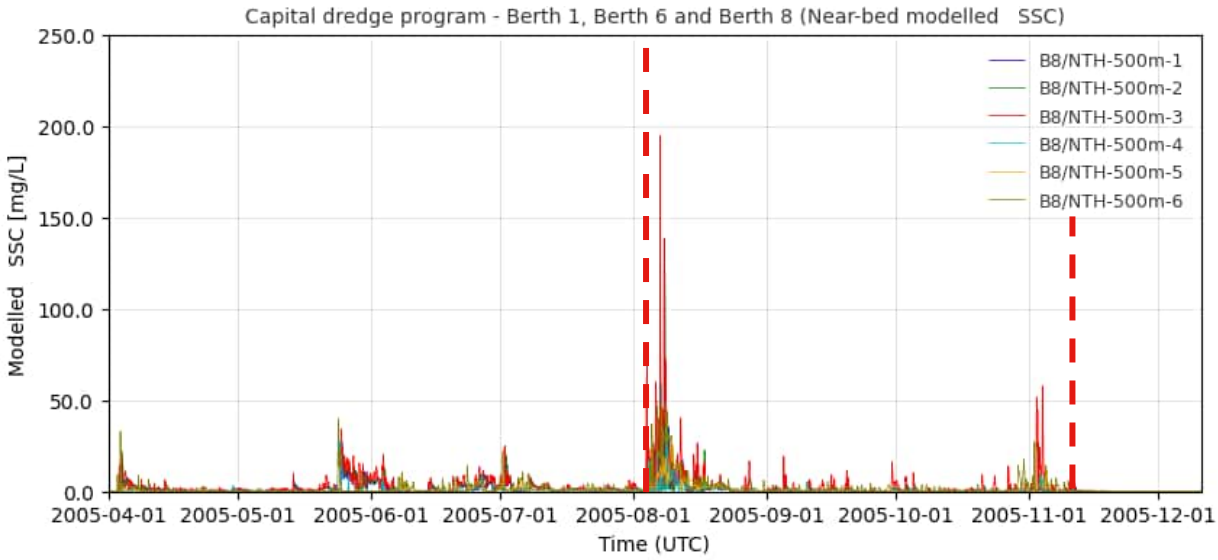


Figure 6-78: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 8 capital dredge area (2)

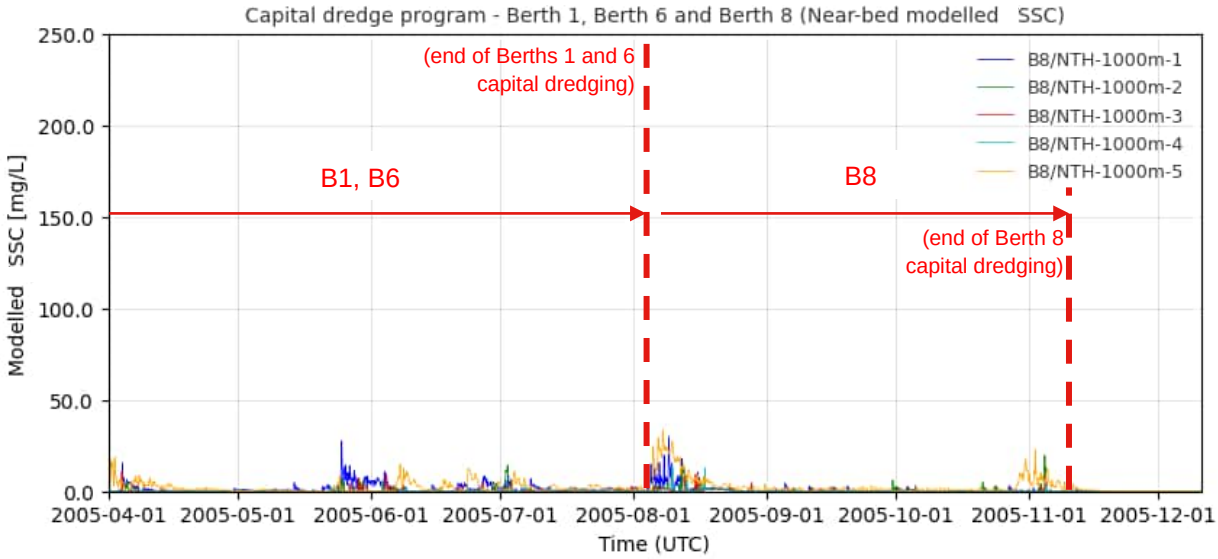


Figure 6-79: Time-series of excess near-bed SSC at locations on arcs emanating from the Berth 8 capital dredge area (3)

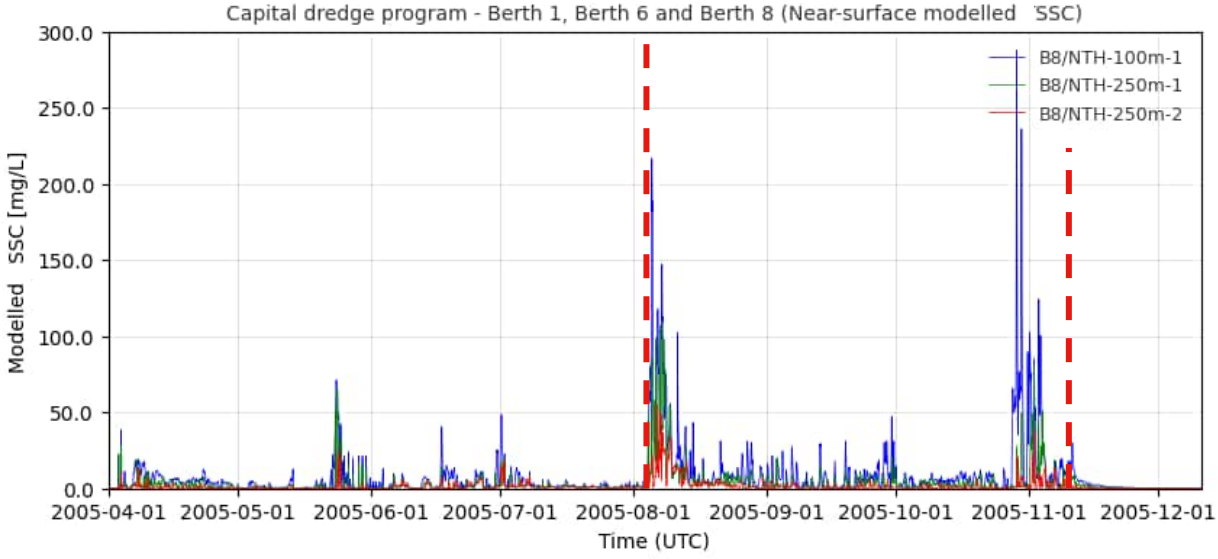


Figure 6-80: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 8 capital dredge area (1)

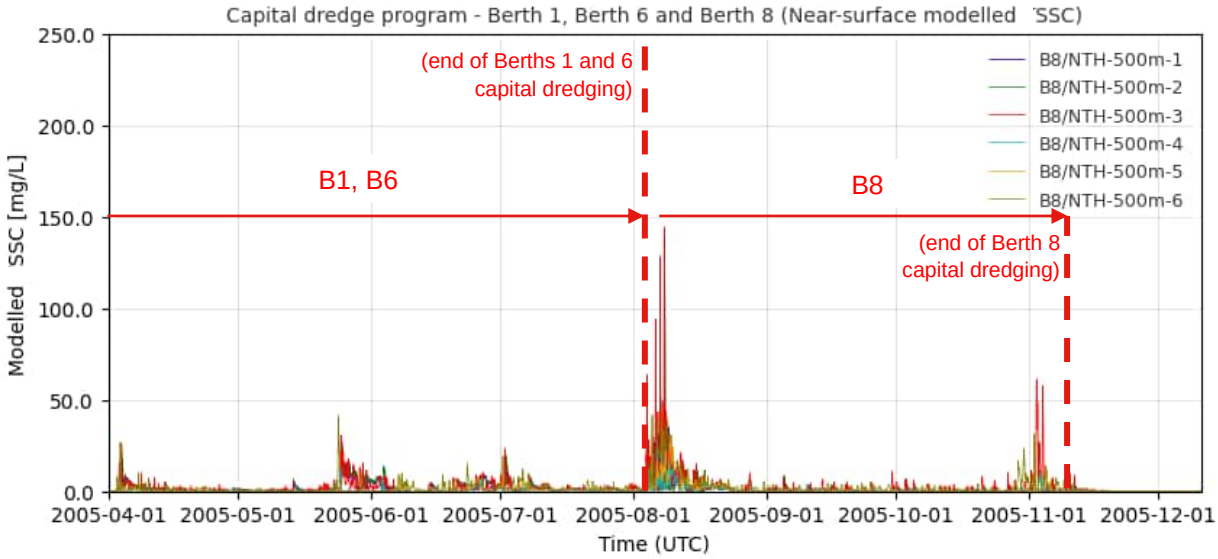


Figure 6-81: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 8 capital dredge area (2)

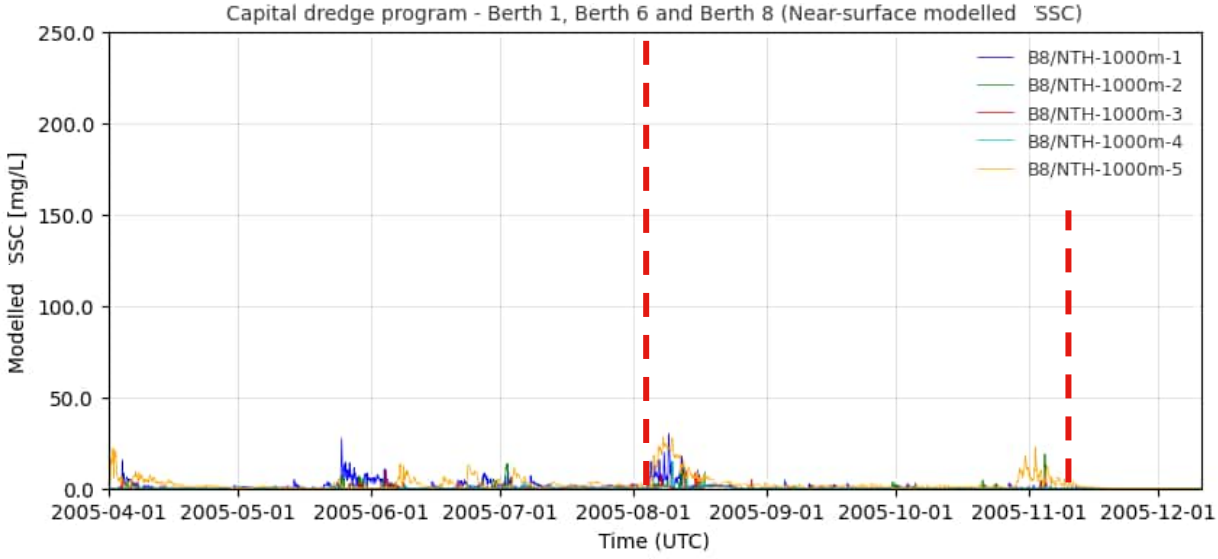


Figure 6-82: Time-series of excess near-surface SSC at locations on arcs emanating from the Berth 8 capital dredge area (3)

Town Beach/Batavia Coast Marina



*Figure 6-83: Nominated model output locations at Town Beach and near the Batavia Coast Marina (repeated from **Figure 6-10**)*

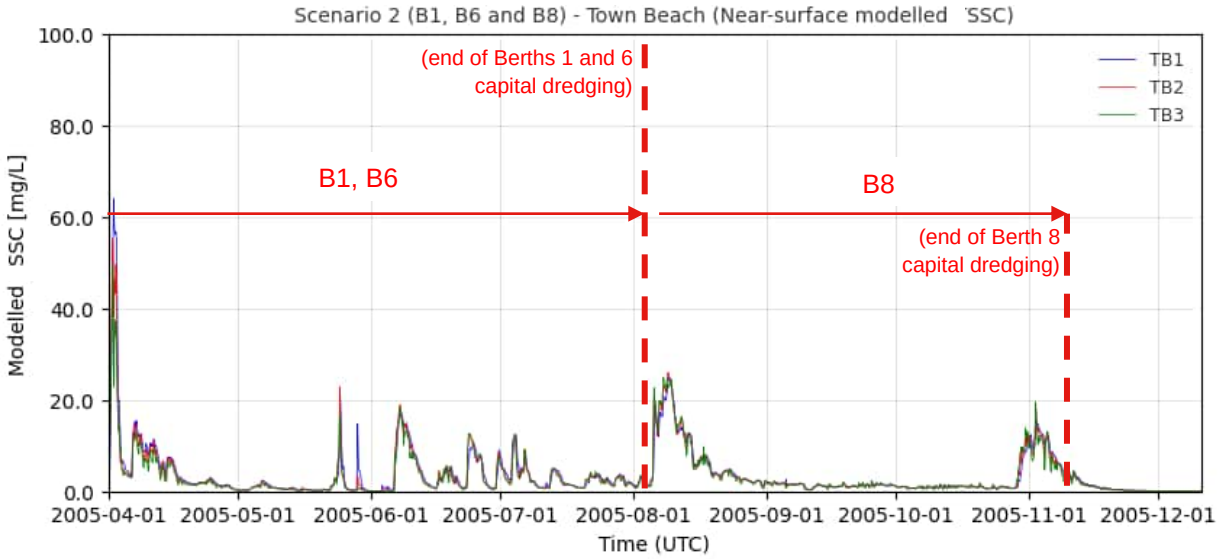


Figure 6-84: Time-series of excess near-surface SSC during Berth 1, 6 and 8 capital dredging at locations along Town Beach

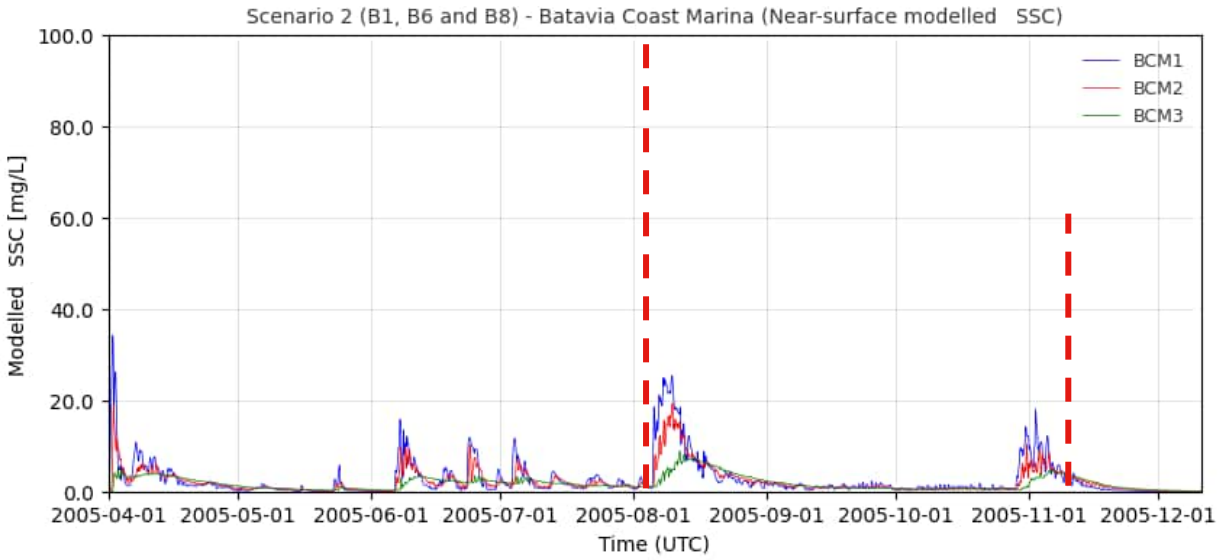


Figure 6-85: Time-series of excess near-surface SSC during Berth 1, 6 and 8 capital dredging at locations near Batavia Coast Marina

6.6.6.3 Sedimentation

Based on the output presented below, the following key observations can be made:

- In areas in close proximity to the dredging locations, high rates of sedimentation are observed due to the modelled bed shear stress not exceeding the critical bed shear stress for erosion and re-suspension; and
- Sedimentation is largely confined to the dredge areas and immediate vicinity.

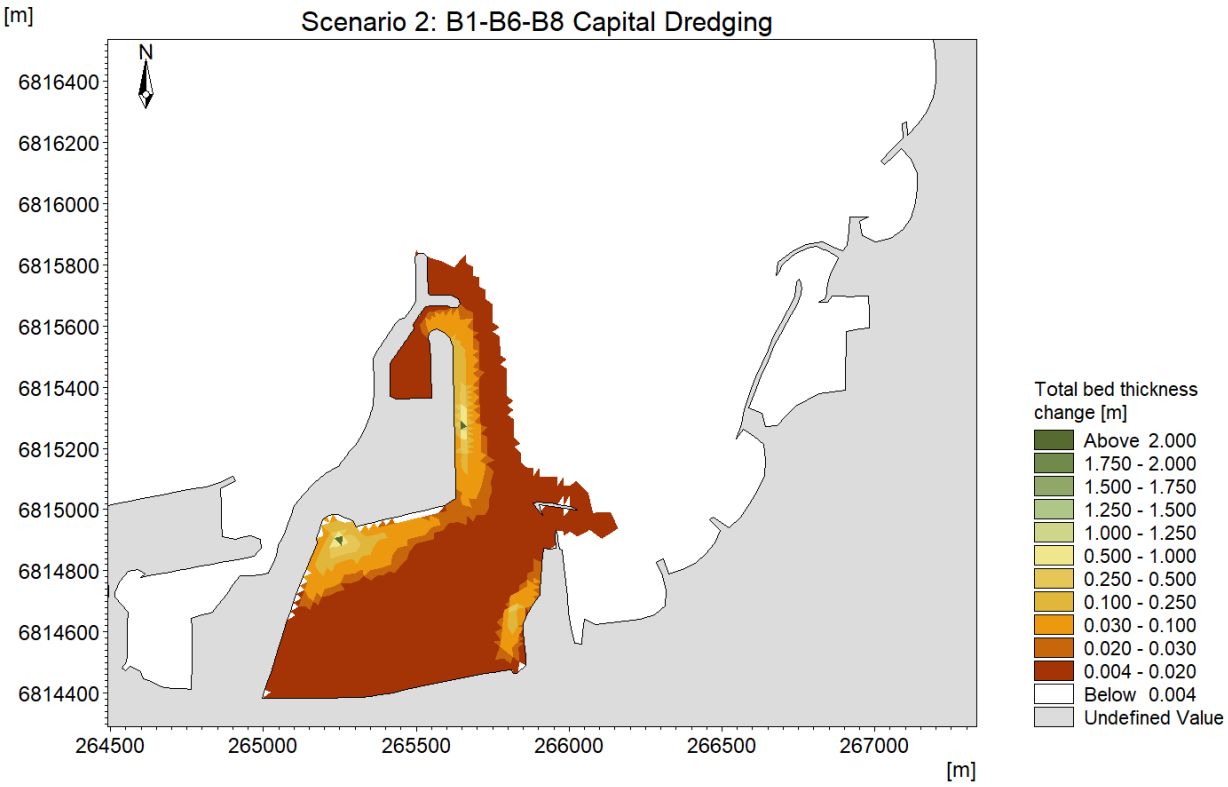


Figure 6-86: Sedimentation thickness of fines at the end of Berth 1, 6 and 8 capital dredging

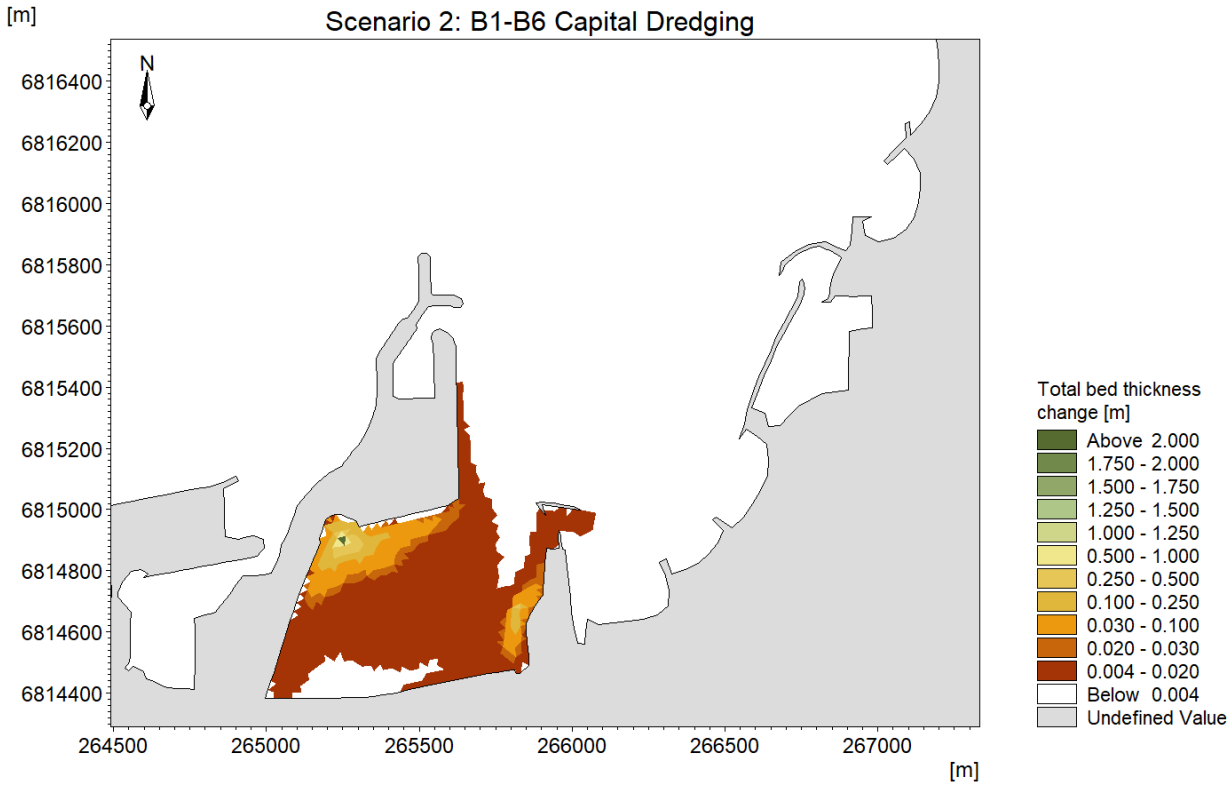


Figure 6-87: Sedimentation thickness of fines at the end of Berth 1 and 6 capital dredging

6.6.6.4 Impact Zones

Based on the output presented below, the following key observations can be made:

- The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berths 1, 6 and 8 capital dredge areas and is within the project development envelope (also refer **Figure 1-3**); and
- The zone of high impact due to SSC is confined within Geraldton Port area. Town Beach and the Batavia Coast Marina are zones of moderate impact. The zone of influence extends approx. 20km northward alongshore.

It is noted that the ZoHI includes the direct disturbance (dredge) footprint, in addition to the ZoHI areas presented in **Figure 6-88** to **Figure 6-93**.

Capital dredging at Berth 1, Berth 6 and Berth 8

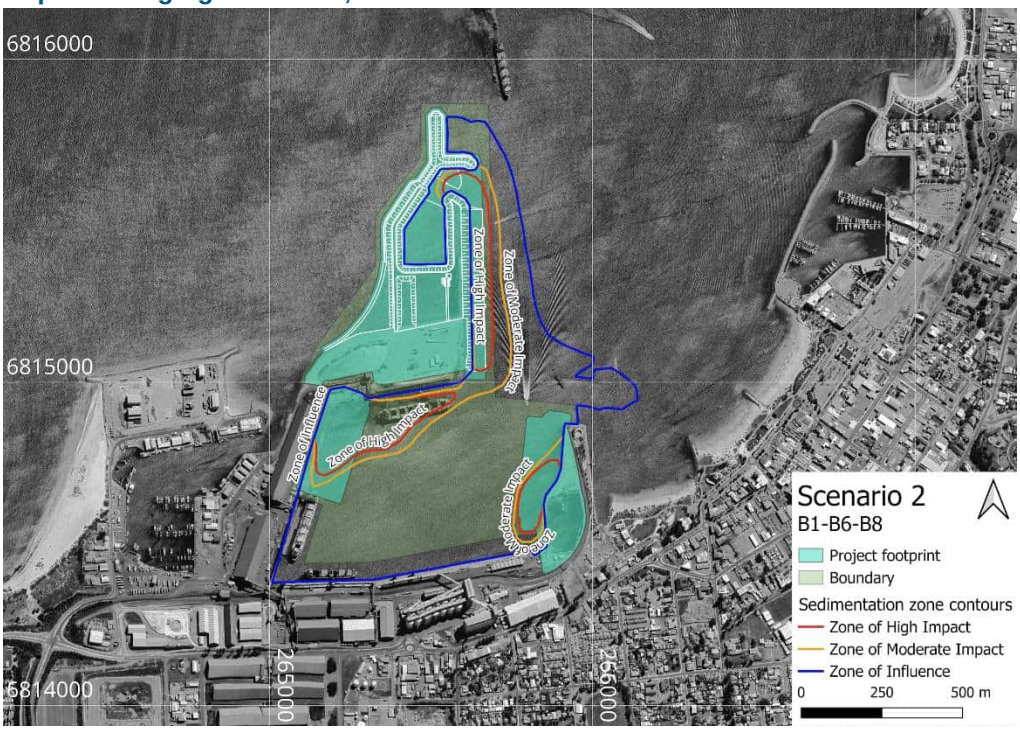


Figure 6-88: Impact zones (sedimentation) for the Berth 1, 6 and 8 capital dredging campaign

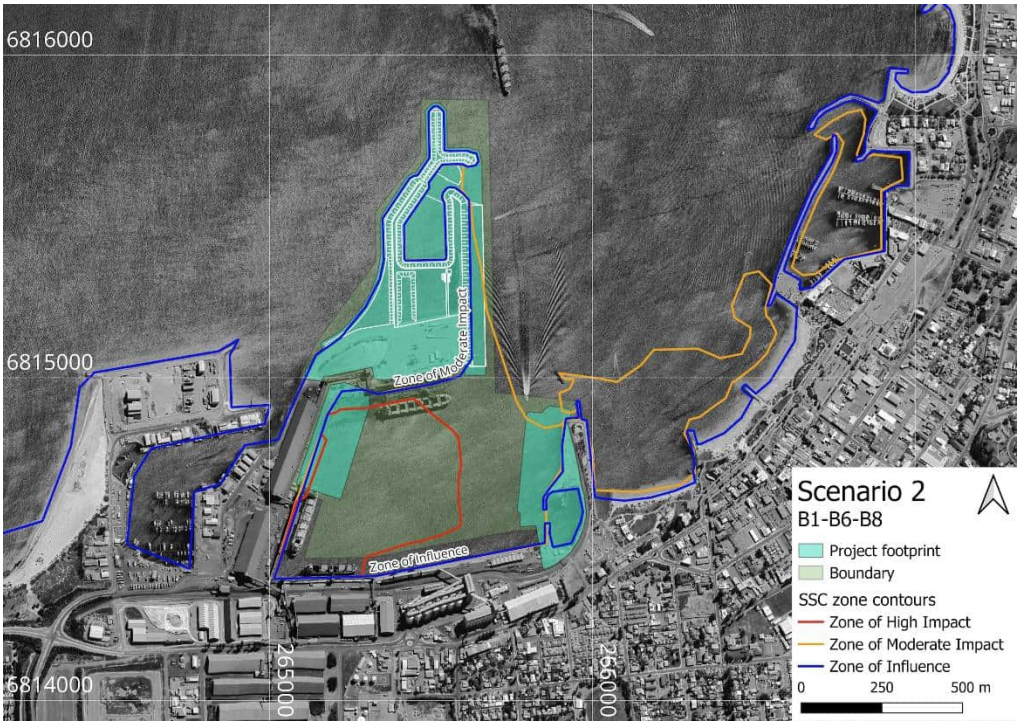


Figure 6-89: Impact zones (SSC) for the Berth 1, 6 and 8 capital dredging campaign

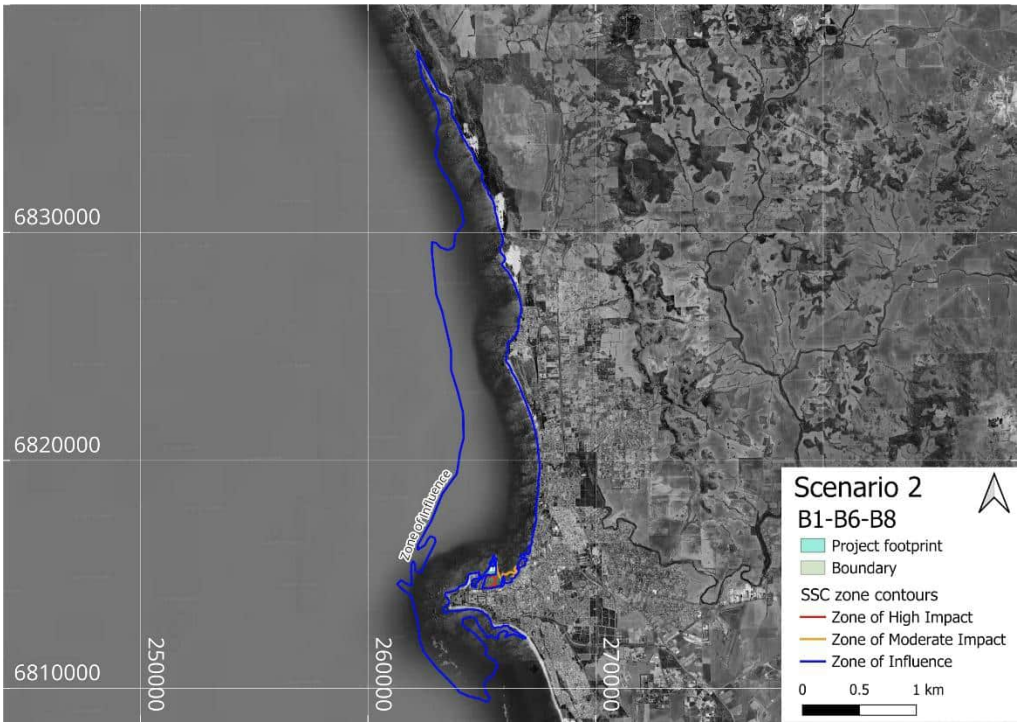


Figure 6-90: Impact zones (SSC) for the Berth 1, 6 and 8 capital dredging campaign (regional)

Capital dredging at Berth 1and Berth 6 only



Figure 6-91: Impact zones (sedimentation) for the Berth 1 and 6 capital dredging campaign

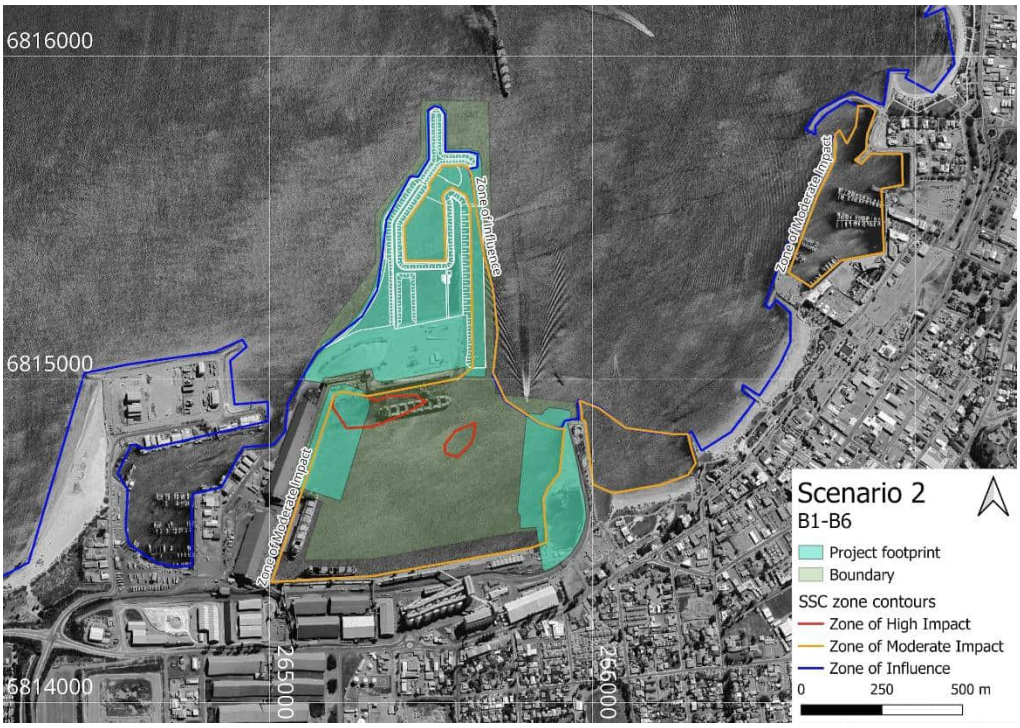


Figure 6-92: Impact zones (SSC) for the Berth 1 and 6 capital dredging campaign

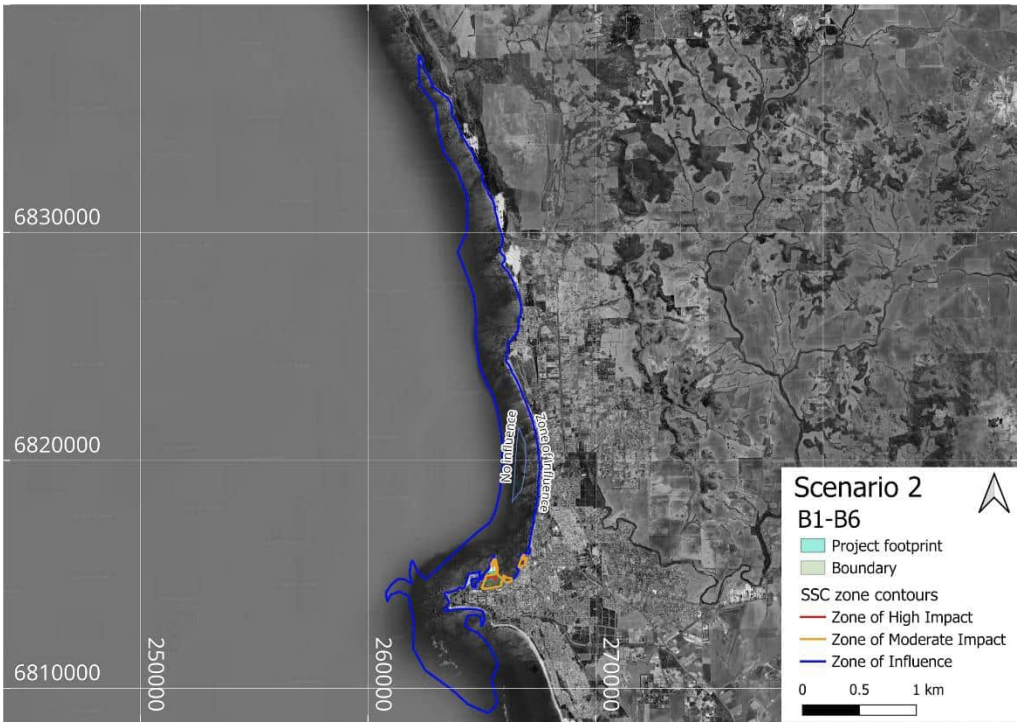


Figure 6-93: Impact zones (SSC) for the Berth 1 and 6 capital dredging campaign (regional)

6.7 Scenario 3: New Tug Harbour Capital Dredging

6.7.1 Introduction

Capital dredging at the proposed new tug harbour (refer **Figure 6-94**) comprises the removal by a TSHD of 19,252m^3 of sand with minor fines-content, as well as soft-stiff gravelly clays and possibly minor volumes of weathered/very low strength calcareous/limestone rock.

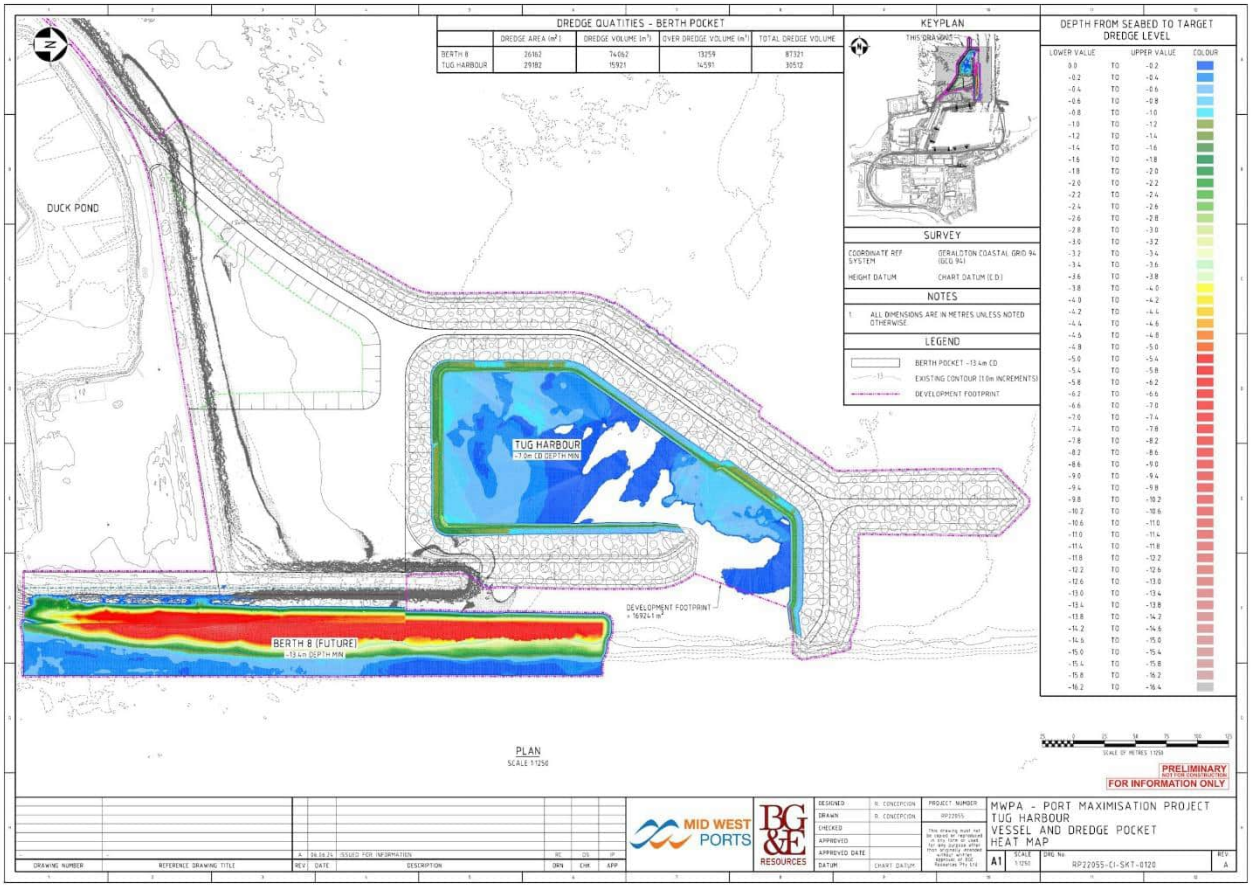
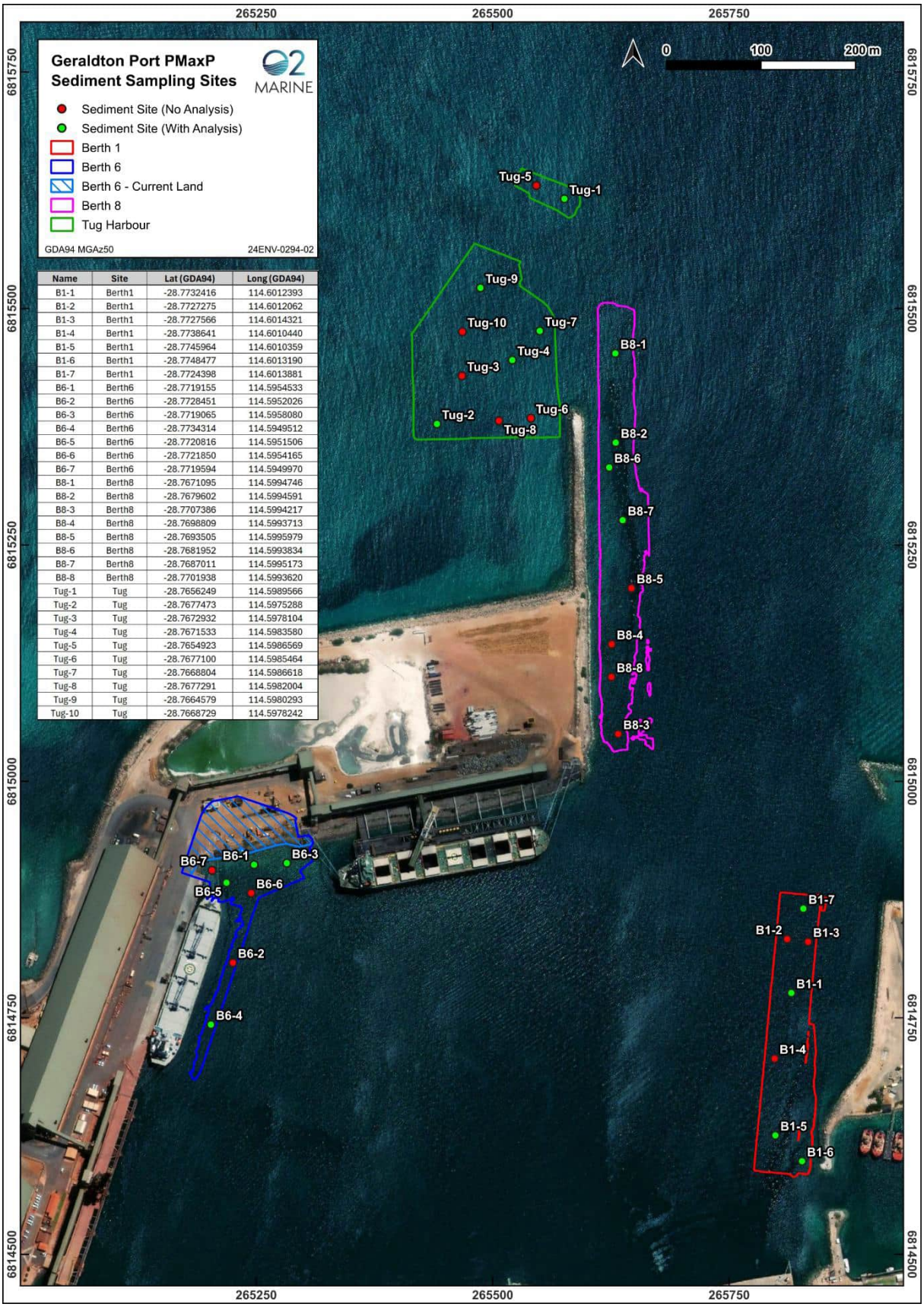


*Figure 6-94: Future new tug harbour capital dredge area (repeated from **Figure 6-51**) (the Berth 8 capital dredge area is also shown, however not relevant for this scenario – covered in Scenario 2)*

6.7.2 Geotechnical Information

The source terms presented in **Section 6.7.4** are further informed by the available geotechnical information at the proposed new tug harbour. This information comprises PSD information from a seabed sampling exercise undertake by MWPA divers in early 2024 (refer **Figure 6-95**), as well as borehole information (Dames and Moore (2000), URS (2002) – also refer **Section 6.6.2** and **Appendix A4**) – refer **Figure 6-96**.



Name	Site	Lat (GDA94)	Long (GDA94)
B1-1	Berth1	-28.7732416	114.6012393
B1-2	Berth1	-28.7727275	114.6012062
B1-3	Berth1	-28.7727566	114.6014321
B1-4	Berth1	-28.7738641	114.6010440
B1-5	Berth1	-28.7745964	114.6010359
B1-6	Berth1	-28.7748477	114.6013190
B1-7	Berth1	-28.7724398	114.6013881
B6-1	Berth6	-28.7719155	114.5954533
B6-2	Berth6	-28.7728451	114.5952026
B6-3	Berth6	-28.7719065	114.5958080
B6-4	Berth6	-28.7734314	114.5949512
B6-5	Berth6	-28.7720816	114.5951506
B6-6	Berth6	-28.7721850	114.5954165
B6-7	Berth6	-28.7719594	114.5949970
B8-1	Berth8	-28.7671095	114.5994746
B8-2	Berth8	-28.7679602	114.5994591
B8-3	Berth8	-28.7707386	114.5994217
B8-4	Berth8	-28.7698809	114.5993713
B8-5	Berth8	-28.7693505	114.5995979
B8-6	Berth8	-28.7681952	114.5993834
B8-7	Berth8	-28.7687011	114.5995173
B8-8	Berth8	-28.7701938	114.5993620
Tug-1	Tug	-28.7656249	114.5989566
Tug-2	Tug	-28.7677473	114.5975288
Tug-3	Tug	-28.7672932	114.5978104
Tug-4	Tug	-28.7671533	114.5983580
Tug-5	Tug	-28.7654923	114.5986569
Tug-6	Tug	-28.7677100	114.5985464
Tug-7	Tug	-28.7668804	114.5986618
Tug-8	Tug	-28.7677291	114.5982004
Tug-9	Tug	-28.7664579	114.5980293
Tug-10	Tug	-28.7668729	114.5978242

Figure 6-95: New tug harbour seabed sampling locations

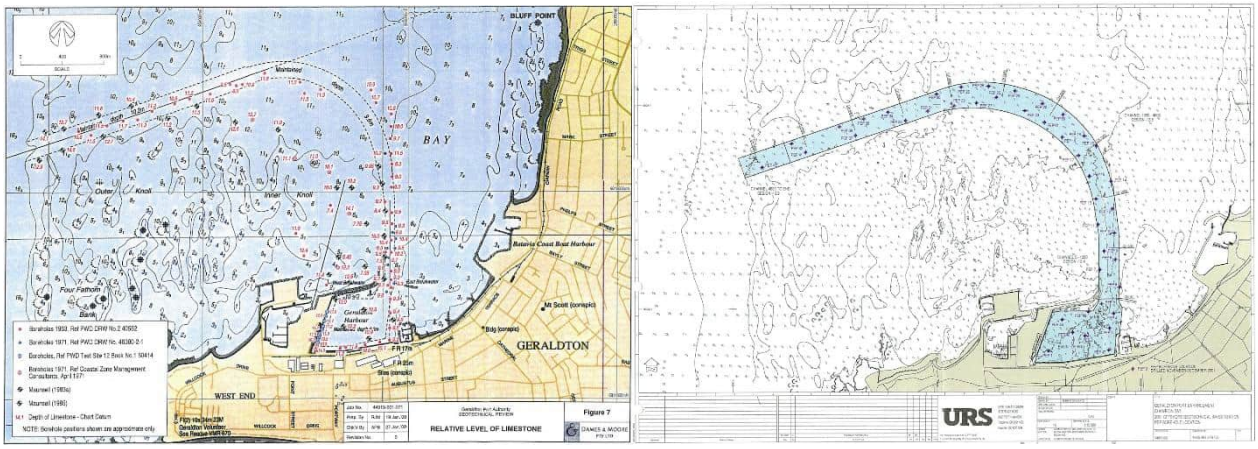


*Figure 6-96: Borehole locations (for further details refer Hoogerwerf (2024c) in **Appendix A5**)*

6.7.3 Dredge Methodology

RHDHV engaged a dredging expert to develop a realistic dredging strategy that would likely be employed to deliver the required dredging works. A strategy was developed based on MWPA's requirement to undertake the dredging works utilising a TSHD. The methodology was informed by the proposed design, available geotechnical information and availability of suitable plant.

As outlined in **Section 6.7.1**, capital dredging of the proposed new tug harbour will occur utilising a TSHD. Given the size of the capital dredging works (volume of material to be dredged) and typically available equipment, the specifications of the Damen TSHD (modular series) 1500 (refer **Figure 6-23**) were used in the development of the dredging strategy and source terms. Based on the material estimated to be present in the seabed, as well as some restrictions around TSHD access (refer the assumptions further below), the dredging process is split up into four (4) consecutive phases with appropriate source terms.

Discharge of the material collected by the TSHD will occur via pumping into the nearby reclamation site *New reclaimed land at existing duck pond* (refer **Figure 6-97**). The pump-out discharge location for the small TSHD is assumed to be at the northern end of this reclamation area. This may consist of a shore connection and floating hose to an anchored buoy onto which the TSHD moors by a single line over the bow during the discharge period. The eastern end of this reclamation area, just south of future Berth 8, could serve as an alternative pump-out discharge location for the small TSHD (refer **Figure 6-97**), however this scenario was not modelled.

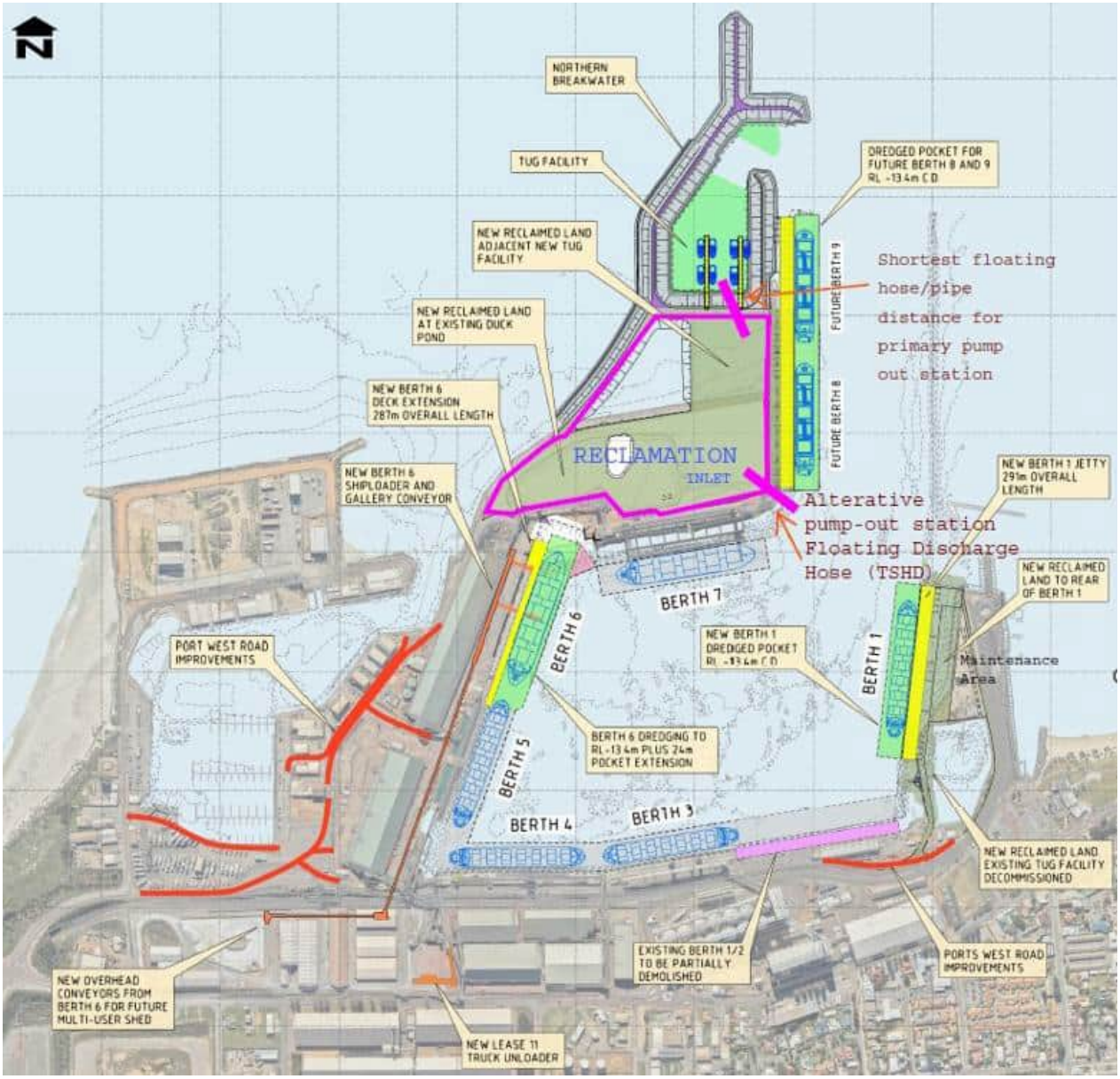


Figure 6-97: Reclamation area and pump-out location for TSHD (in magenta)

Capital dredging of the proposed new tug harbour is scheduled to take place in May 2027 (this means that the proposed expansion of Geraldton Port, to accommodate the new tug harbour and Berth 8/Berth 9, has already occurred and it is therefore assumed the breakwaters are in place) and estimated to be completed in approximately one (1) week based on:

- a dredge volume of 19,252m^3;
- continuous dredging (168hrs/week or 24hrs/day, seven (7) days/week); and
- the production rate of the TSHD.

The individual phases are estimated to be take:

- Phase 1: 0.26 wks;
- Phase 2: 0.20 wks;
- Phase 3: 0.29 wks; and
- Phase 4: 0.22 wks.

There are several major assumptions relating to components of the proposed works:

- Due its configuration (with the new tug harbour breakwaters in place, restricting access to southern section of the new tug harbour, in particular the southeast and southwest corners), the whole of the dredge area is not available to a small TSHD. It is assumed that these areas are finally dredged to line and level by BHD during other capital dredging works;
- The restricted dredge area requires additional manoeuvring of the TSHD causing resuspension and scour;
- No overflow from the hopper of the TSHD is allowed;
- No jets on drag-heads are allowed;
- No losses through hopper doors, valves or split hull are allowed; and
- Deployment of a silt curtain around the TSHD dredger is not possible.

Further assumptions in relation to the discharge of dredged material into the nearby reclamation area comprise:

- Losses of material are released under the TSHD during pump-out through the water intake(s), while located at the pump-out station; and
- No fines are to be contained in the discharge of transport water from the reclamation area (return water) at the outlet point to the receiving environment. (Alternatively, the reclamation area will be of adequate capacity to allow settling of all fines and polishing of the return water without discharging to the receiving environment until after the dredging works are completed).

In light of the above and for the purpose of the dredge plume modelling exercise, the following sources of fines have been taken into account:

- The draghead of the TSHD;
- Scouring of the seabed due to TSHD propwash; and
- Discharge under the TSHD at the pump-out location (near the reclamation area).

It is noted that lower turbidity levels can be achieved by using alternative dredge methodologies:

- CSD within the sheltered area of the breakwaters pumping into the reclamation (efficient and economic); or
- BHD loading barges within the sheltered area of the breakwaters (costly, however efficient in removing all material above design levels within the footprint of the proposed new tug harbour).

6.7.4 Source Term Estimates

Table 6-20 summarises the fines fluxes estimated by the appointed dredging expert used as inputs for the capital dredge plume model (refer Hoogerwerf (2024c) provided in **Appendix A5**), assuming 168hrs/week (or 24hrs/day, 7days/week) of dredging. Similar to the maintenance dredging at Berth 1, the silt fraction (2-75µm) is further divided into four size ranges (refer **Section 6.5.4**).

Based on the available geotechnical information at the new tug harbour capital dredge area (refer **Section 6.7.2**), it was estimated that these silt fractions constitute approximately 20%, 20%, 20%, and 40% of the overall silt fraction in phase one (1),and 10%, 20%, 20%, and 50% of the overall silt fraction in phases two to four (2-4), respectively (Hoogerwerf, 2024c).

Table 6-20: Source term (flux) estimates for the new tug harbour capital dredging (based on: Table 3 of Hoogerwerf, 2024c)

Point of release	Total loss of fines (<75µm) [kg/s]	Silt (2-75µm) [kg/s]	Clay (<2µm) [kg/s]	Release level
Phase 1				
Draghead	0.08	0.05	0.03	Seabed to +2m
Prop wash	0.18	0.09	0.09	Seabed-Surface
Pump-out station	0.04	0.02	0.02	Draft @4m to Seabed
Phase 2				
Draghead	0.29	0.06	0.23	Seabed to +2m
Prop wash	0.77	0.18	0.59	Seabed-Surface
Pump-out station	0.04	0.02	0.02	Draft @4m to Seabed
Phase 3				
Draghead	0.46	0.08	0.38	Seabed to +2m
Prop wash	1.78	0.40	1.38	Seabed-Surface
Pump-out station	0.04	0.02	0.02	Draft @4m to Seabed
Phase 4				
Draghead	0.10	0.02	0.08	Seabed to +2m
Prop wash	1.78	0.40	1.38	Seabed-Surface
Pump-out station	0.04	0.02	0.02	Draft @4m to Seabed

6.7.5 Model Setup

The source terms and release levels outlined in **Table 6-20** as estimated by Hoogerwerf (2024c) were translated to MIKE MT module input, taking into account to the (modelling) constraints outlined in **Section 6.5.5**. Given those constraints, the modelled fluxes and points of release during the four phases are as presented in **Table 6-21** to **Table 6-24**. These rates have been applied continuously over the entire maintenance dredge period (approximately one week). A graph showing fluxes (all fines) for each source (draghead, propwash or discharge) is presented in **Figure 6-98**.

Table 6-21: Modelled fractions, fluxes and release points for new tug harbour capital dredging (phase 1)

Cause of Plume	Spilling Type	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay	Silt Flux [kg/s]	Clay Flux [kg/s]
Draghead	Bottom layer	20%	20%	20%	40%	100%	0.050	0.030
Propwash/ scour	Entire column	20%	20%	20%	40%	100%	0.068	0.068
	Bottom layer	20%	20%	20%	40%	100%	0.023	0.023
Discharge under TSHD	Entire column	20%	20%	20%	40%	100%	0.010	0.010
	Bottom layer	20%	20%	20%	40%	100%	0.010	0.010
						Total	0.160	0.140

Table 6-22: Modelled fractions, fluxes and release points for new tug harbour capital dredging (phase 2)

Cause of Plume	Spilling Type	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay	Silt Flux [kg/s]	Clay Flux [kg/s]
Draghead	Bottom layer	10%	20%	20%	50%	100%	0.060	0.230
Propwash/ scour	Entire column	10%	20%	20%	50%	100%	0.135	0.443
	Bottom layer	10%	20%	20%	50%	100%	0.045	0.148
Discharge under TSHD	Entire column	10%	20%	20%	50%	100%	0.010	0.010
	Bottom layer	10%	20%	20%	50%	100%	0.010	0.010
						Total	0.260	0.840

Table 6-23: Modelled fractions, fluxes and release points for new tug harbour capital dredging (phase 3)

Cause of Plume	Spilling Type	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay	Silt Flux [kg/s]	Clay Flux [kg/s]
Draghead	Bottom layer	10%	20%	20%	50%	100%	0.080	0.380
Propwash/ scour	Entire column	10%	20%	20%	50%	100%	0.300	1.035
	Bottom layer	10%	20%	20%	50%	100%	0.100	0.345
Discharge under TSHD	Entire column	10%	20%	20%	50%	100%	0.010	0.010
	Bottom layer	10%	20%	20%	50%	100%	0.010	0.010
						Total	0.500	1.780

Table 6-24: Modelled fractions, fluxes and release points for new tug harbour capital dredging (phase 4)

Cause of Plume	Spilling Type	Coarse silt	Medium silt	Fine silt	Very fine silt	Clay	Silt Flux [kg/s]	Clay Flux [kg/s]
Draghead	Bottom layer	10%	20%	20%	50%	100%	0.020	0.080
Propwash/ scour	Entire column	10%	20%	20%	50%	100%	0.300	1.035
	Bottom layer	10%	20%	20%	50%	100%	0.100	0.345
Discharge under TSHD	Entire column	10%	20%	20%	50%	100%	0.010	0.010
	Bottom layer	10%	20%	20%	50%	100%	0.010	0.010
						Total	0.440	1.480

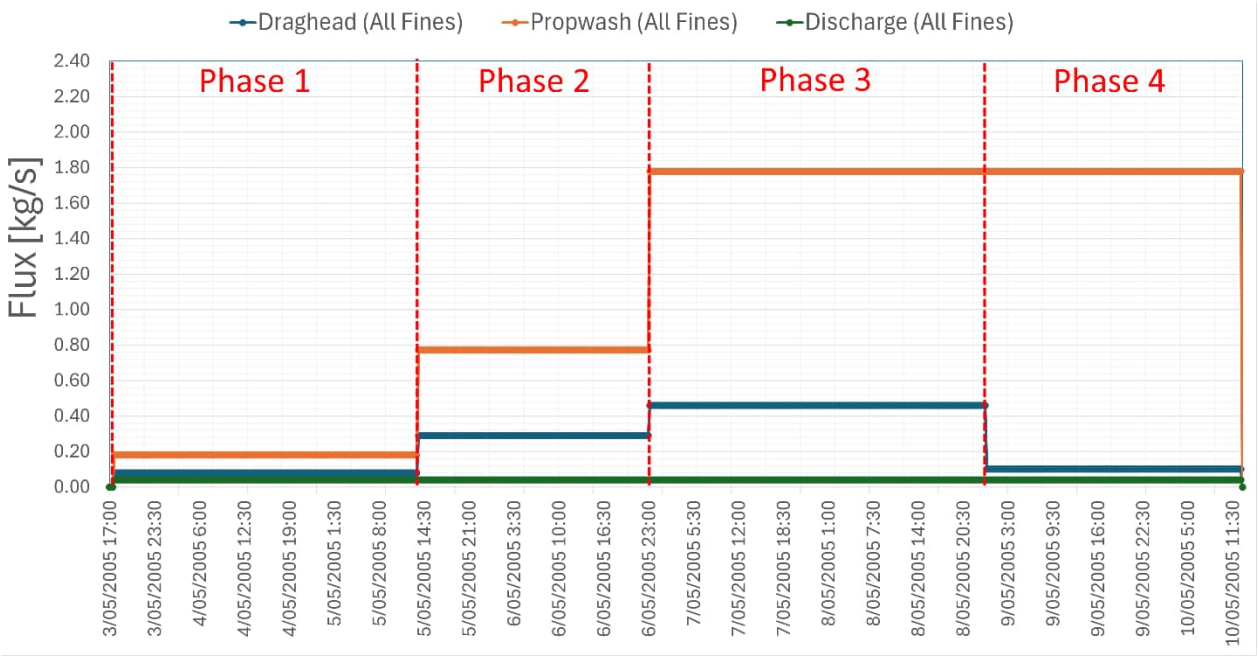


Figure 6-98: New tug harbour capital dredging fluxes

6.7.6 Results – Above Background

The following output has been presented for Scenario 3 (new tug harbour capital dredging):

Percentile maps

- **Figure 6-99** and **Figure 6-100**: 50%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week (dredging in April);
- **Figure 6-101** and **Figure 6-102**: 95%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week (dredging in April);
- **Figure 6-103** and **Figure 6-104**: 50%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week (dredging in May); and
- **Figure 6-105** and **Figure 6-106**: 95%ile excess near-surface and near-bed SSC map over the dredging period and dredging period + one week (dredging in May).

Time-series (10-minute time step)

- **Figure 6-108** and **Figure 6-109**: time-series of excess near-bed and near-surface SSC at output locations (A to G) northward along the coast from Geraldton Port for dredging in April and May, respectively;
- **Figure 6-111** to **Figure 6-114**: time-series of excess near-bed SSC at sensitive receptor locations (L1-L13) (dredging in April);
- **Figure 6-115** to **Figure 6-118**: time-series of excess near-bed SSC at sensitive receptor locations (L1-L13) (dredging in May);
- **Figure 6-120** to **Figure 6-125**: time-series of excess near-bed and near-surface SSC at locations on arcs emanating from the New Tug Harbour capital dredge area (dredging in April);
- **Figure 6-126** to **Figure 6-131**: time-series of excess near-bed and near-surface SSC at locations on arcs emanating from the New Tug Harbour capital dredge area (dredging in May);
- **Figure 6-133** and **Figure 6-134**: time-series of excess near-surface SSC at locations along Town Beach and near Batavia Coast Marina (dredging in April); and
- **Figure 6-135** and **Figure 6-136**: time-series of excess near-surface SSC at locations along Town Beach and near Batavia Coast Marina (dredging in May).

Sedimentation maps

- **Figure 6-137** and **Figure 6-138** sedimentation thickness of fines at the end of dredging for capital dredging at the new tug harbour for dredging in April and May, respectively.

Impact maps

- **Figure 6-139** to **Figure 6-141**: impact zone maps for sedimentation and SSC (dredging in April); and
- **Figure 6-142** to **Figure 6-144**: impact zone maps for sedimentation and SSC (dredging in May).

6.7.6.1 50%ile and 95%ile Excess SSC

Based on the output presented below, the following key observations can be made:

- Over the dredge period (approximately one week), the 50th percentile SSC map shows, apart from the immediate dredge location, minimal impact (order of a few mg/L) around the Port, while the 95th percentile SSC map shows an SSC of up to 50mg/L immediately around the New Tug Harbour, and a minor impact (order of a few mg/L) around Point Moore and alongshore northward of the project site;
- When considering an additional week after dredging has ceased, the 50th percentile SSC map shows an SSC up to 10mg/L around the New Tug Harbour and some distance alongshore to the north of the project site, while the 95th percentile SSC map shows a significant increase with SSC around 25mg/L near Town Beach and Batavia Coast Marina; and
- Generally, near-surface percentile SSC maps show similar trends to the near-bed results in terms of spatial extent and concentrations, except for the immediate dredge location.

Dredging in April

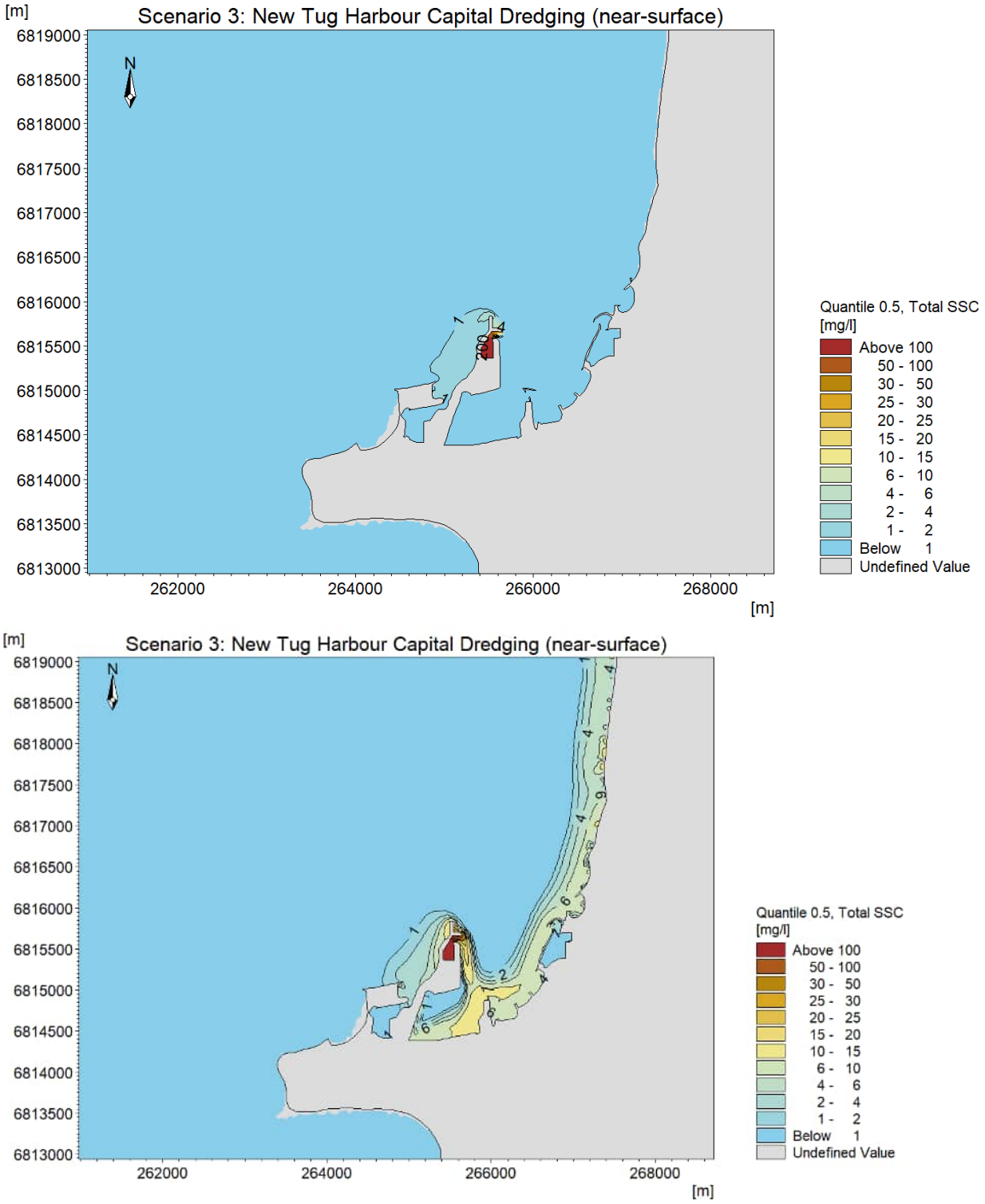


Figure 6-99: Near-surface 50%ile excess SSC over the seven-day dredging period (i.e., 84 hours - top pane) and dredging period + one week (i.e., 168 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (April)

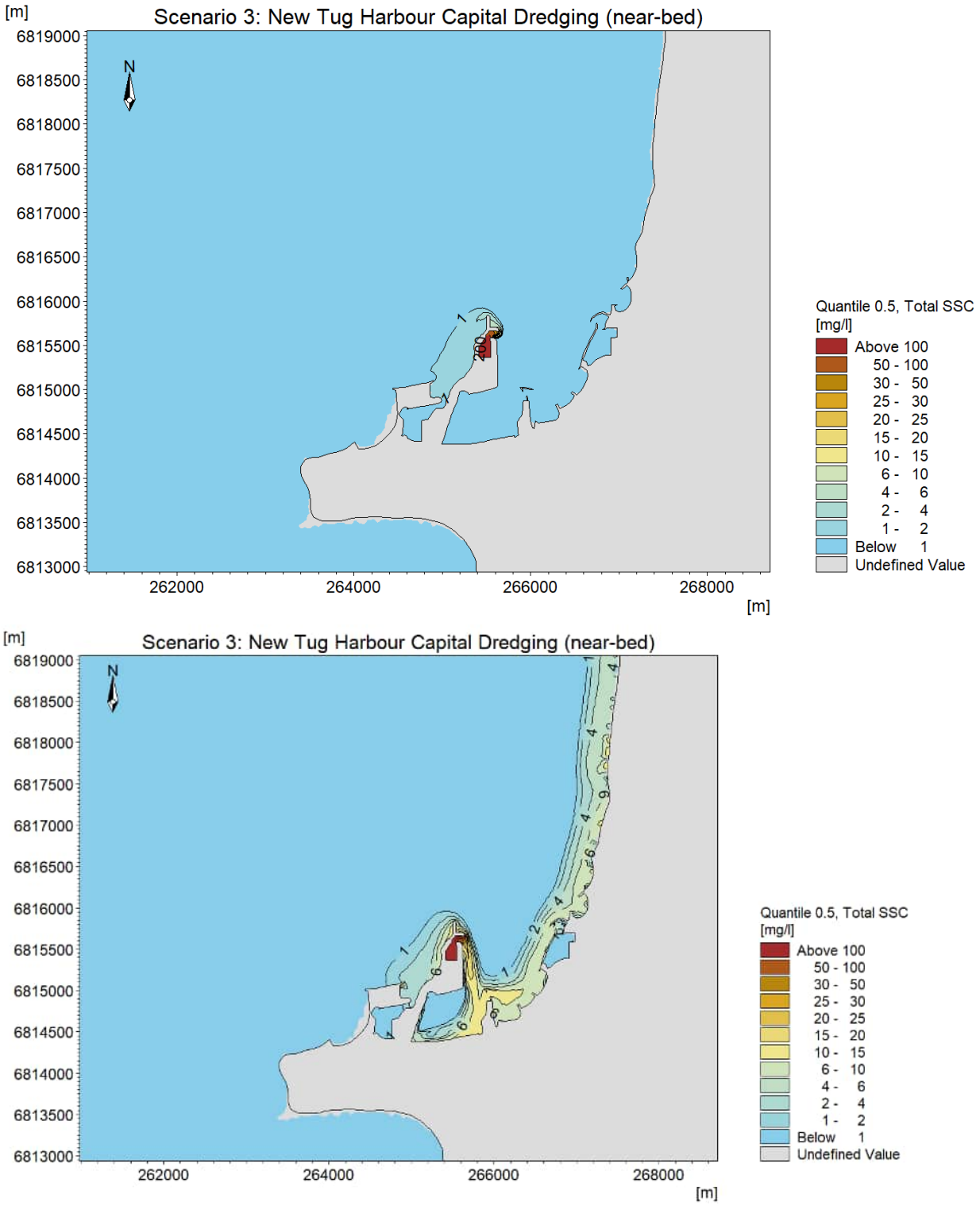


Figure 6-100: Near-bed 50%ile excess SSC over the seven-day dredging period (i.e., 84 hours - top pane) and dredging period + one week (i.e., 168 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (April)

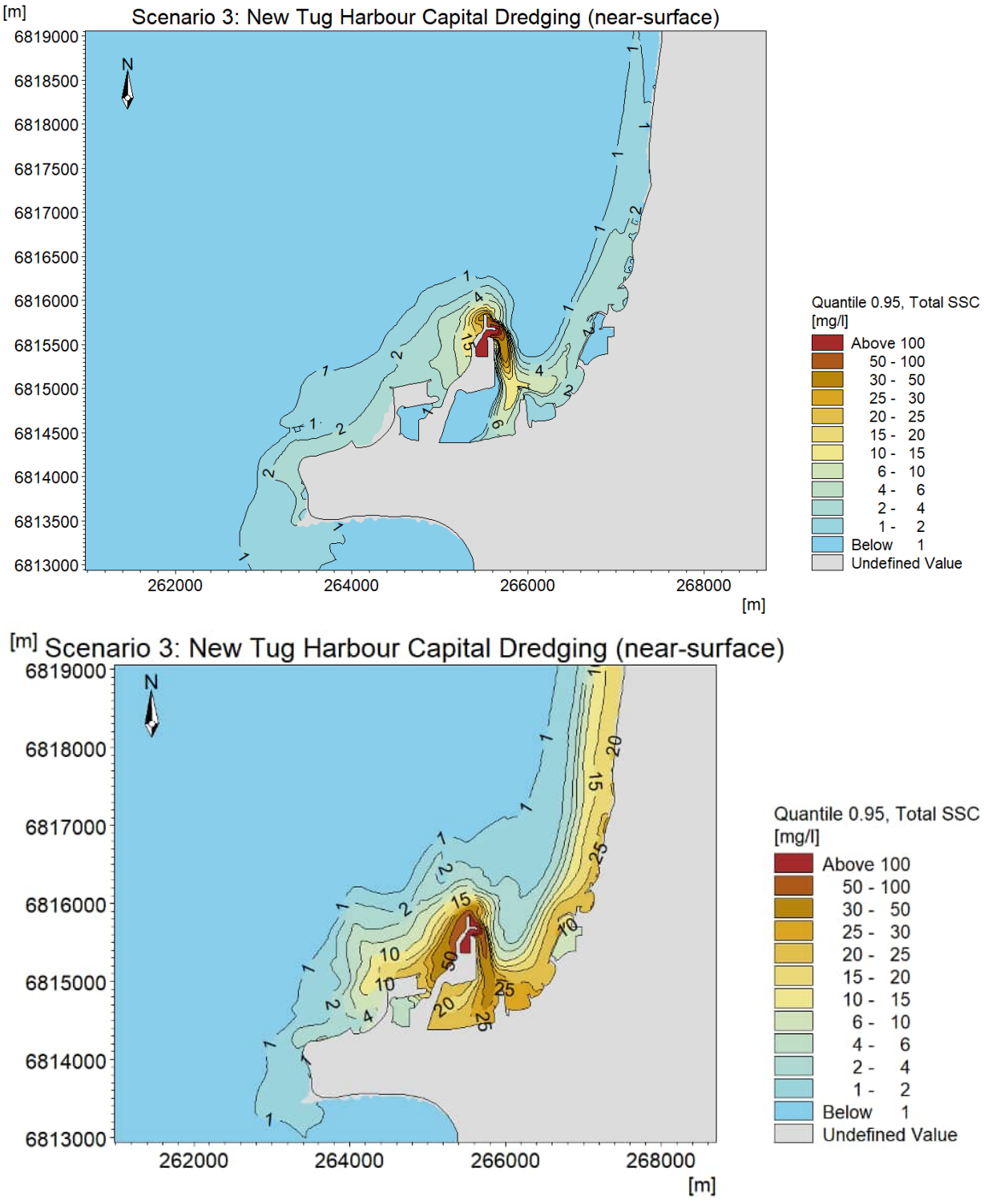


Figure 6-101: Near-surface 95%ile excess SSC over the seven-day dredging period (i.e., 8.4 hours - top pane) and dredging period + one week (i.e., 16.8 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (April)

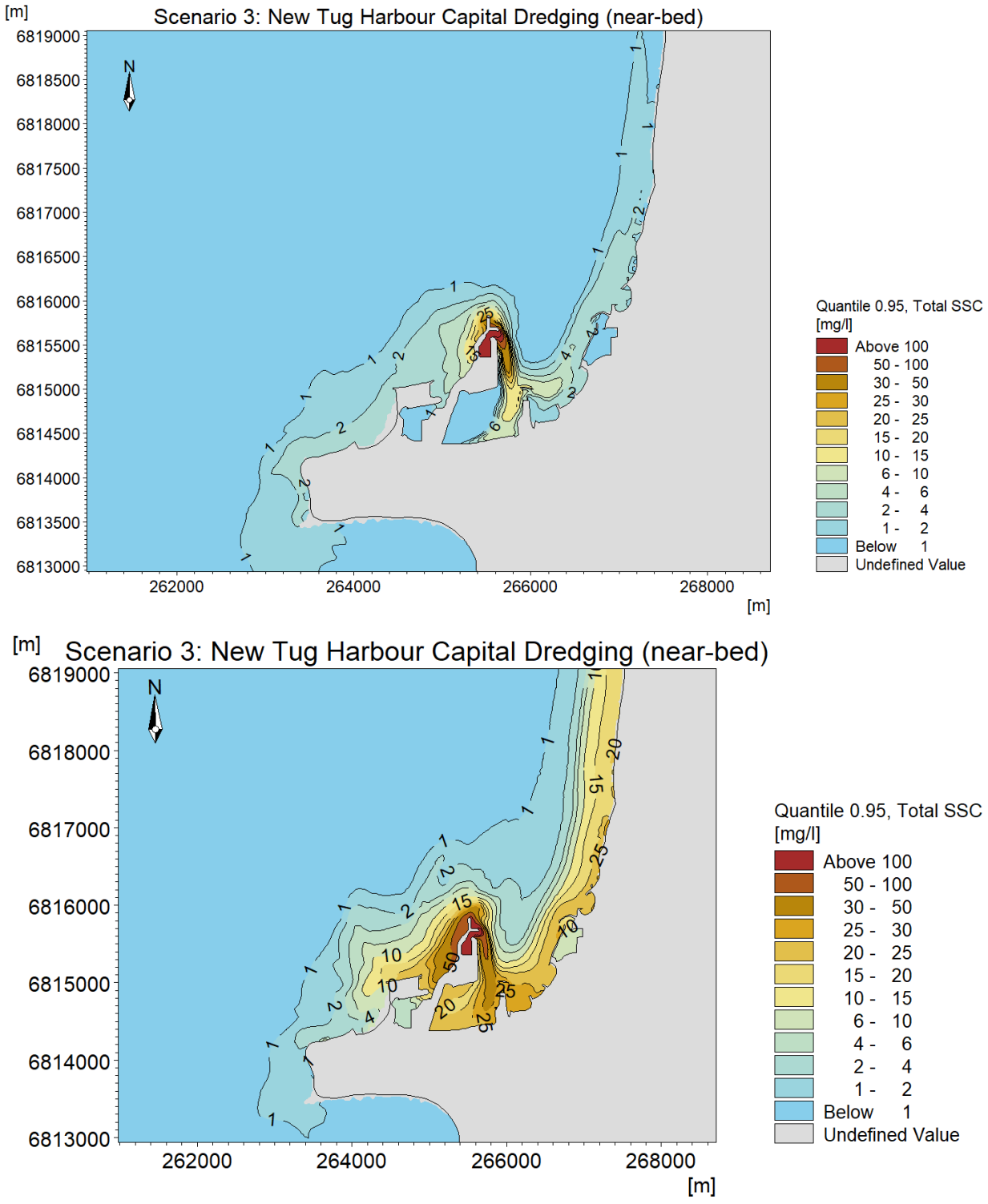


Figure 6-102: Near-bed 95%ile excess SSC over the seven-day dredging period (i.e., 8.4 hours - top pane) and dredging period + one week (i.e., 16.8 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (April)

Dredging in May

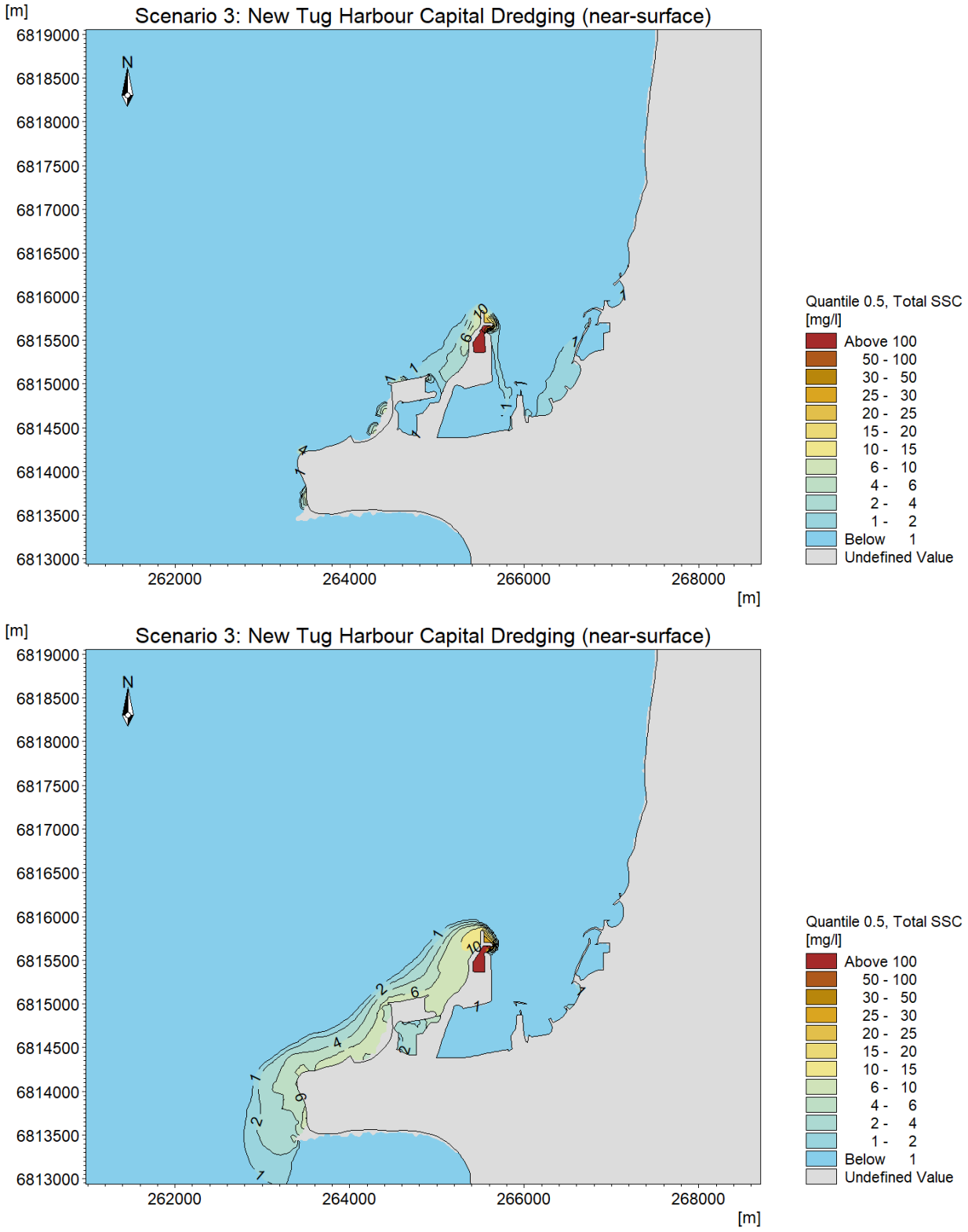


Figure 6-103: Near-surface 50%ile excess SSC over the seven-day dredging period (i.e., 84 hours - top pane) and dredging period + one week (i.e., 168 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (May - period of a-typical meteorological conditions)

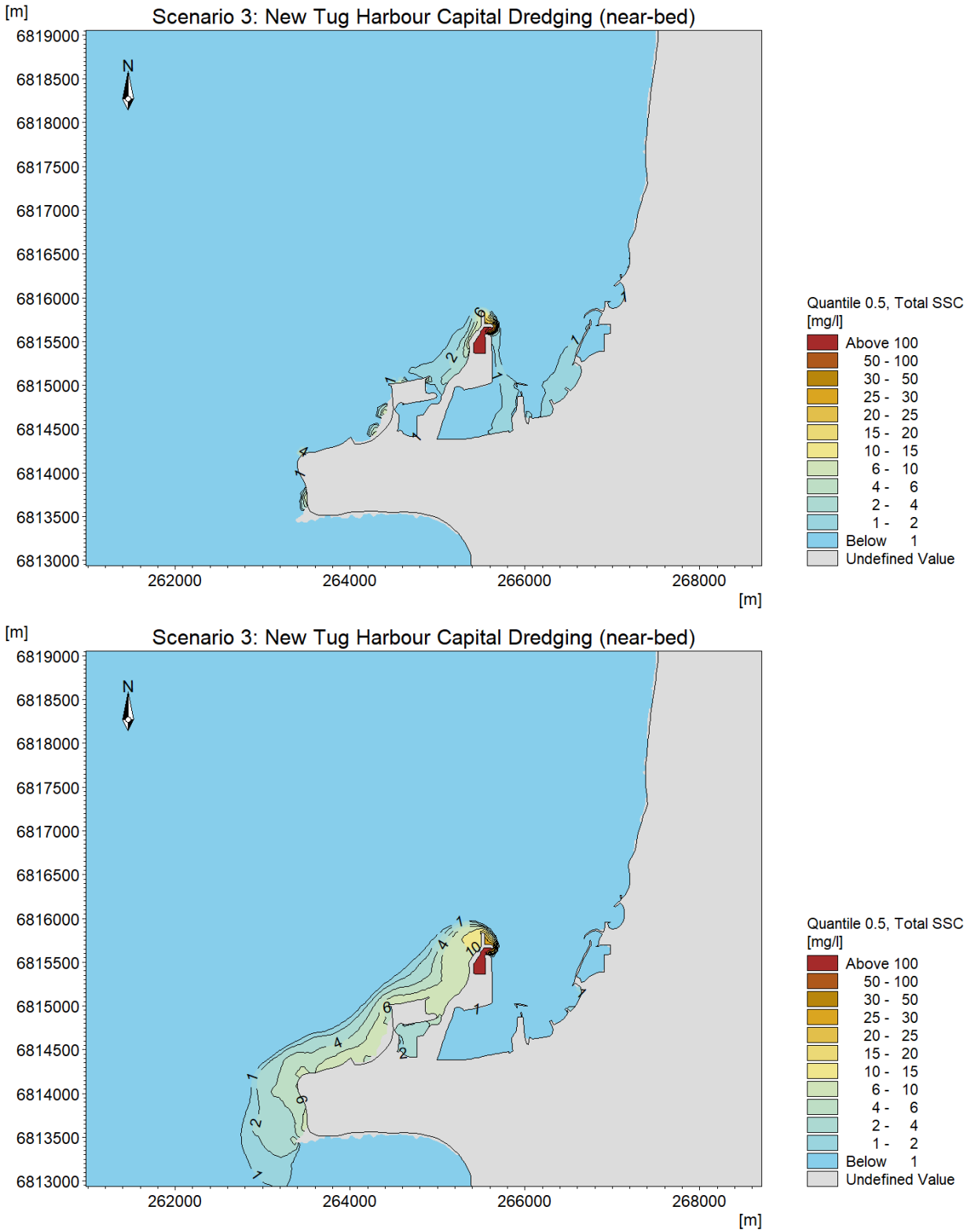


Figure 6-104: Near-bed 50%ile excess SSC over the seven-day dredging period (i.e., 84 hours - top pane) and dredging period + one week (i.e., 168 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (May - period of a-typical meteorological conditions)

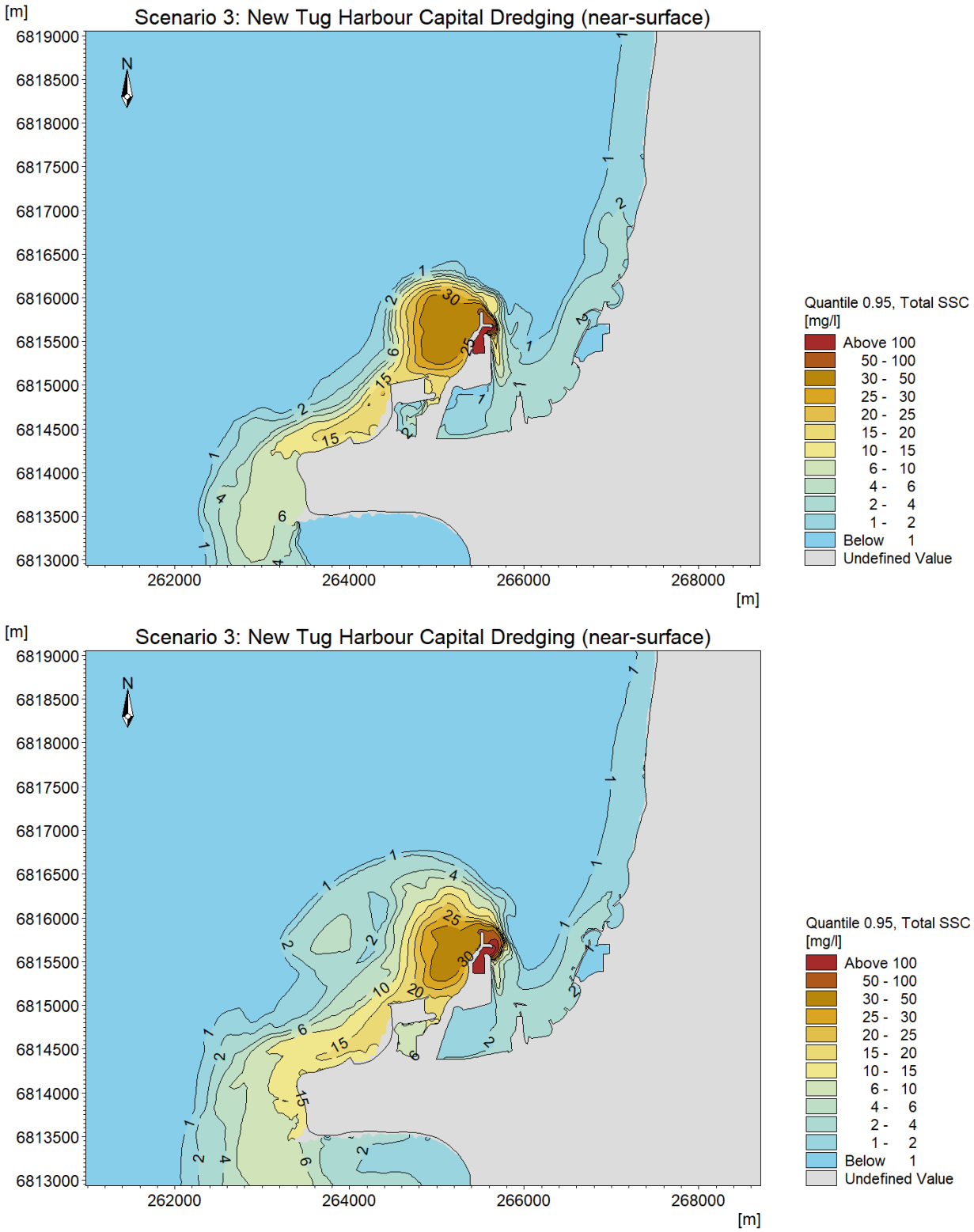


Figure 6-105: Near-surface 95%ile excess SSC over the seven-day dredging period (i.e., 8.4 hours - top pane) and dredging period + one week (i.e., 16.8 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (May - period of a-typical meteorological conditions)

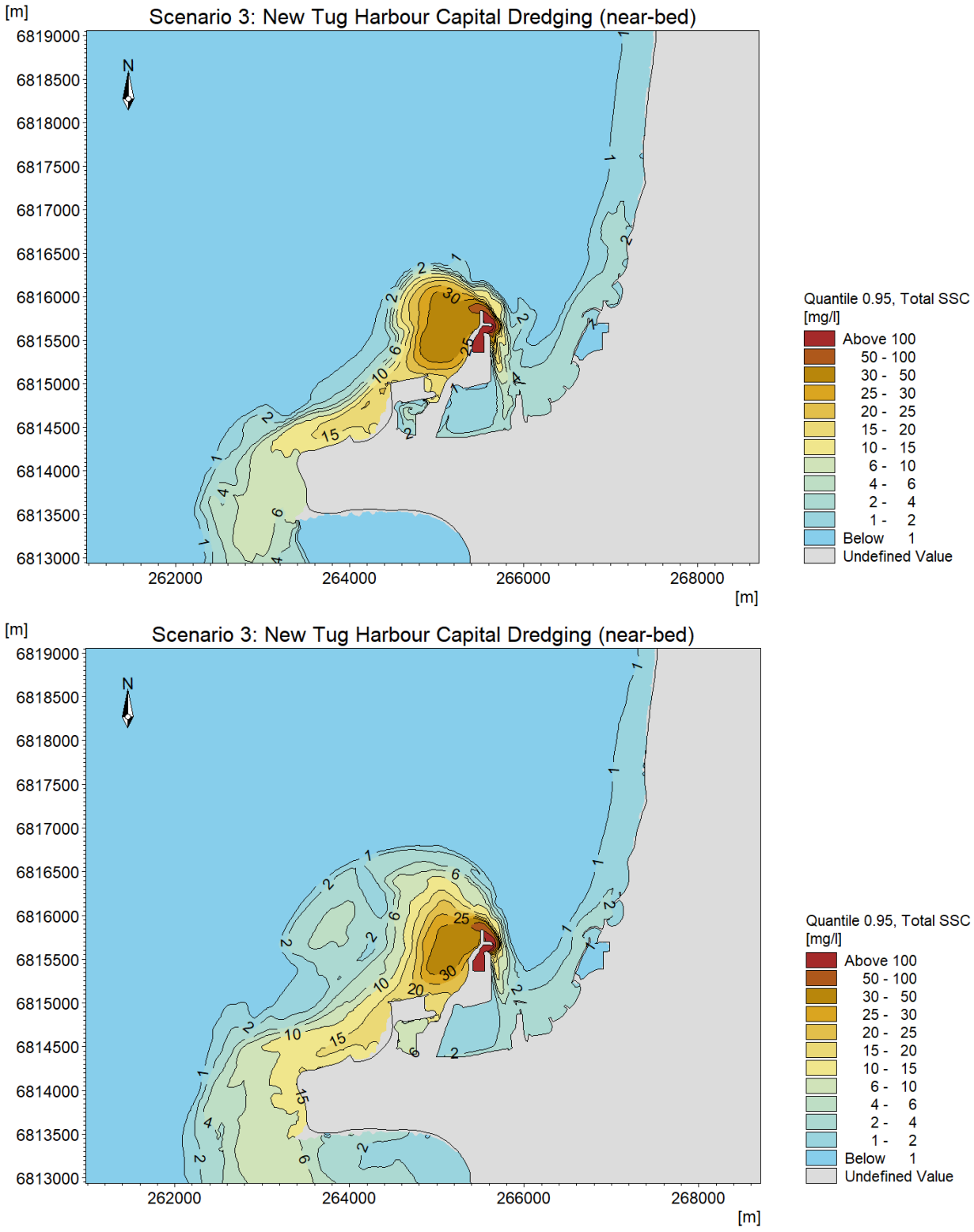


Figure 6-106: Near-bed 95%ile excess SSC over the seven-day dredging period (i.e., 8.4 hours - top pane) and dredging period + one week (i.e., 16.8 hours in 14 days) bottom pane) for the New Tug Harbour capital dredging (May - period of a-typical meteorological conditions)

6.7.6.2 Time-Series of Excess SSC

Based on the output presented below, the following key observations can be made:

- Along the shoreline north of Town Beach, the peak SSC values do not exceed 30 mg/L (based on output locations B to G) and reduce to below 20 mg/L approximately ten km from the site;
- SSC at the sensitive receptor locations peaks at around 150mg/L at L8 (which is immediately north of the New Tug Harbour) and occasionally exhibits brief SSC spikes at other sensitive receptor locations; and
- SSC near Town Beach and the Batavia Coast Marina peaks at around 30mg/L.

Northward along the coast (nearshore)



*Figure 6-107: Nearshore model output locations north of the project site (repeated from **Figure 6-6**)*

Dredging in April

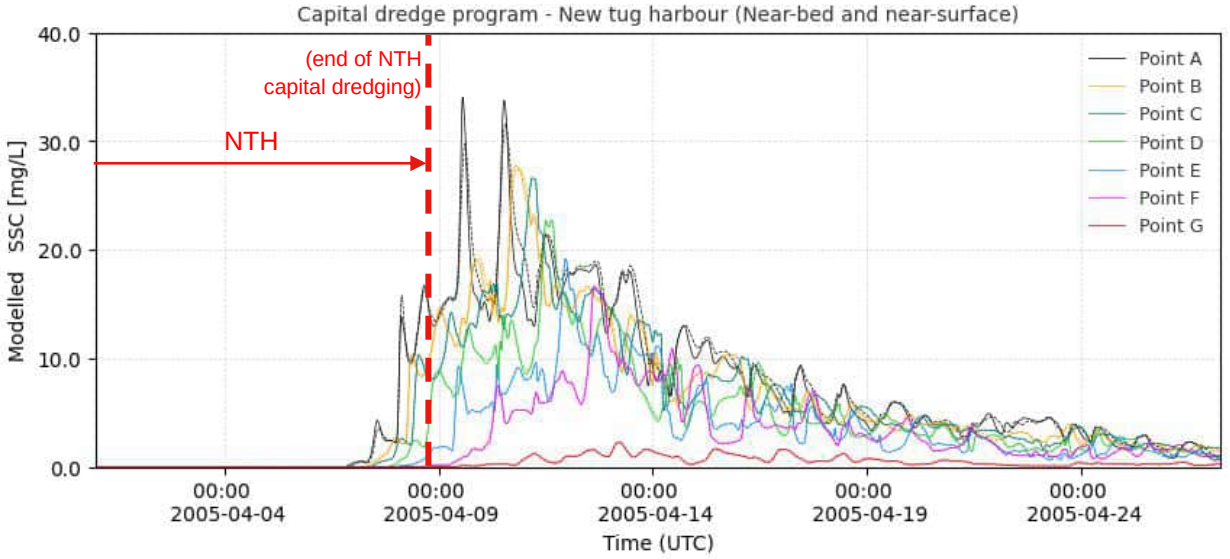


Figure 6-108: Time-series of excess near-bed (solid lines) and near-surface (dashed lines) SSC during capital dredging at the NTH at output locations (A to G) northward along the coast from Geraldton Port (red-dashed line = end of dredging) – April

Dredging in May

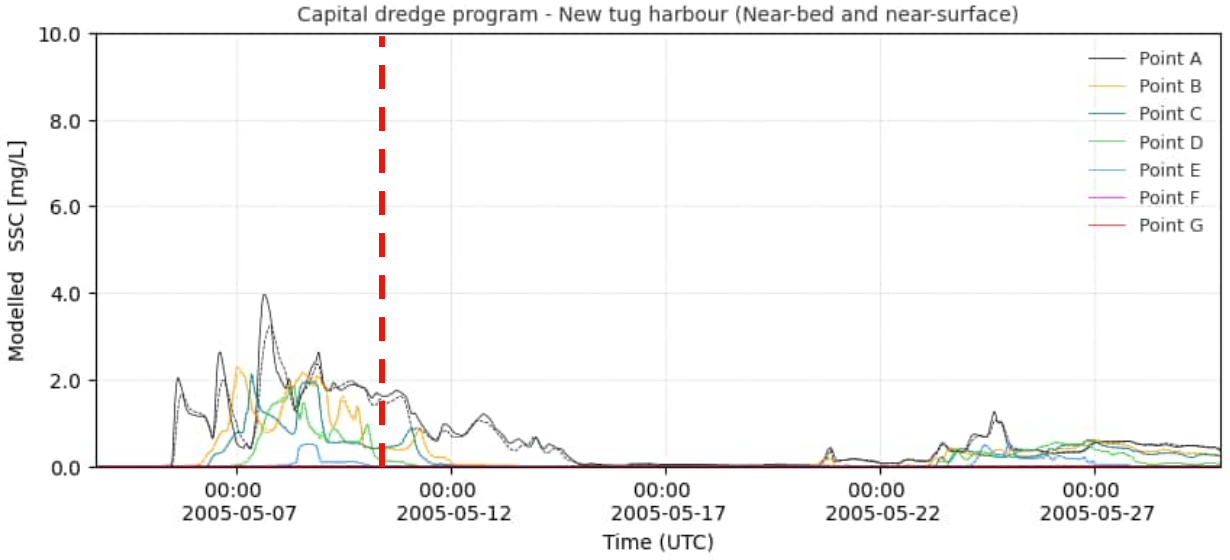


Figure 6-109: Time-series of excess near-bed (solid lines) and near-surface (dashed lines) SSC during capital dredging at the NTH at output locations (A to G) northward along the coast from Geraldton Port (red-dashed line = end of dredging) - May

Sensitive Receptors



*Figure 6-110: Model output locations in sensitive receptor areas (repeated from **Figure 6-7**)*

Dredging in April

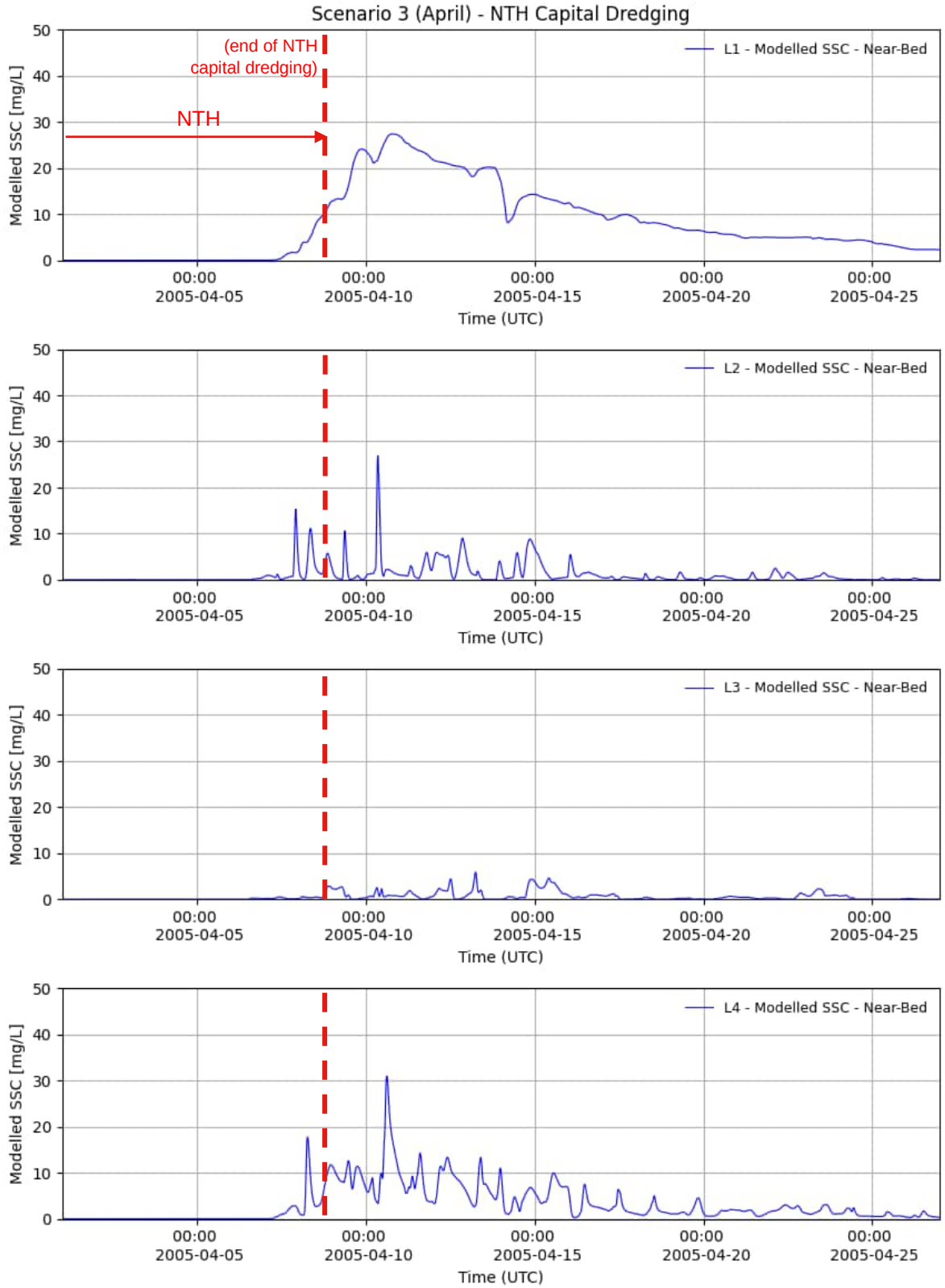


Figure 6-111: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L1-L4) - April

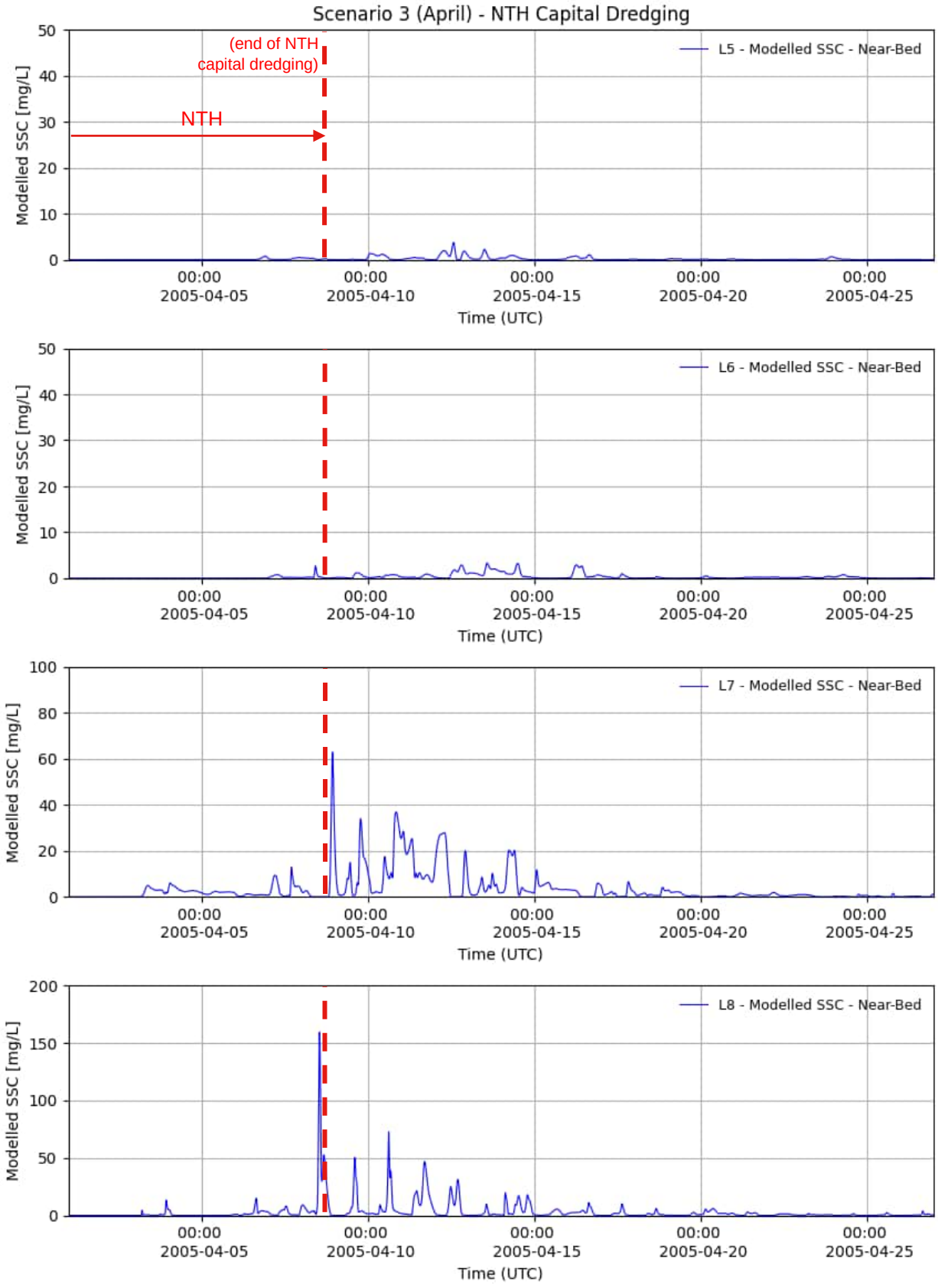


Figure 6-112: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L5-L8) - April

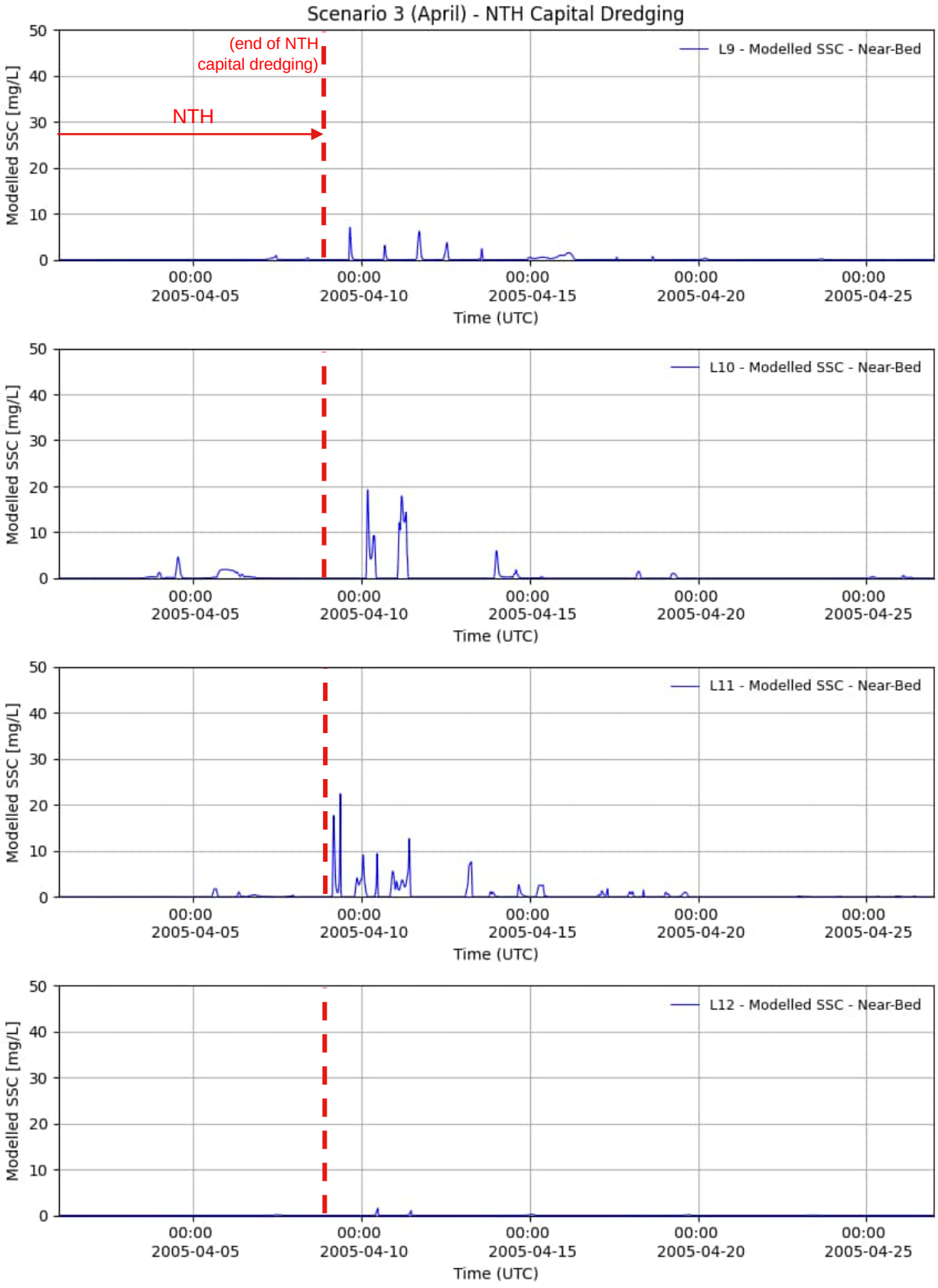


Figure 6-113:Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L9-L12) - April

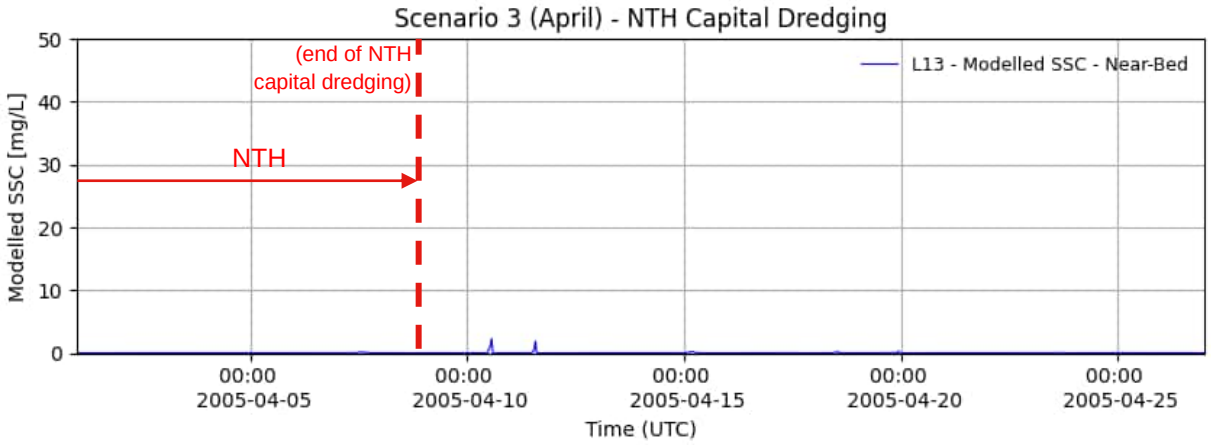


Figure 6-114: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L13) - April

Dredging in May

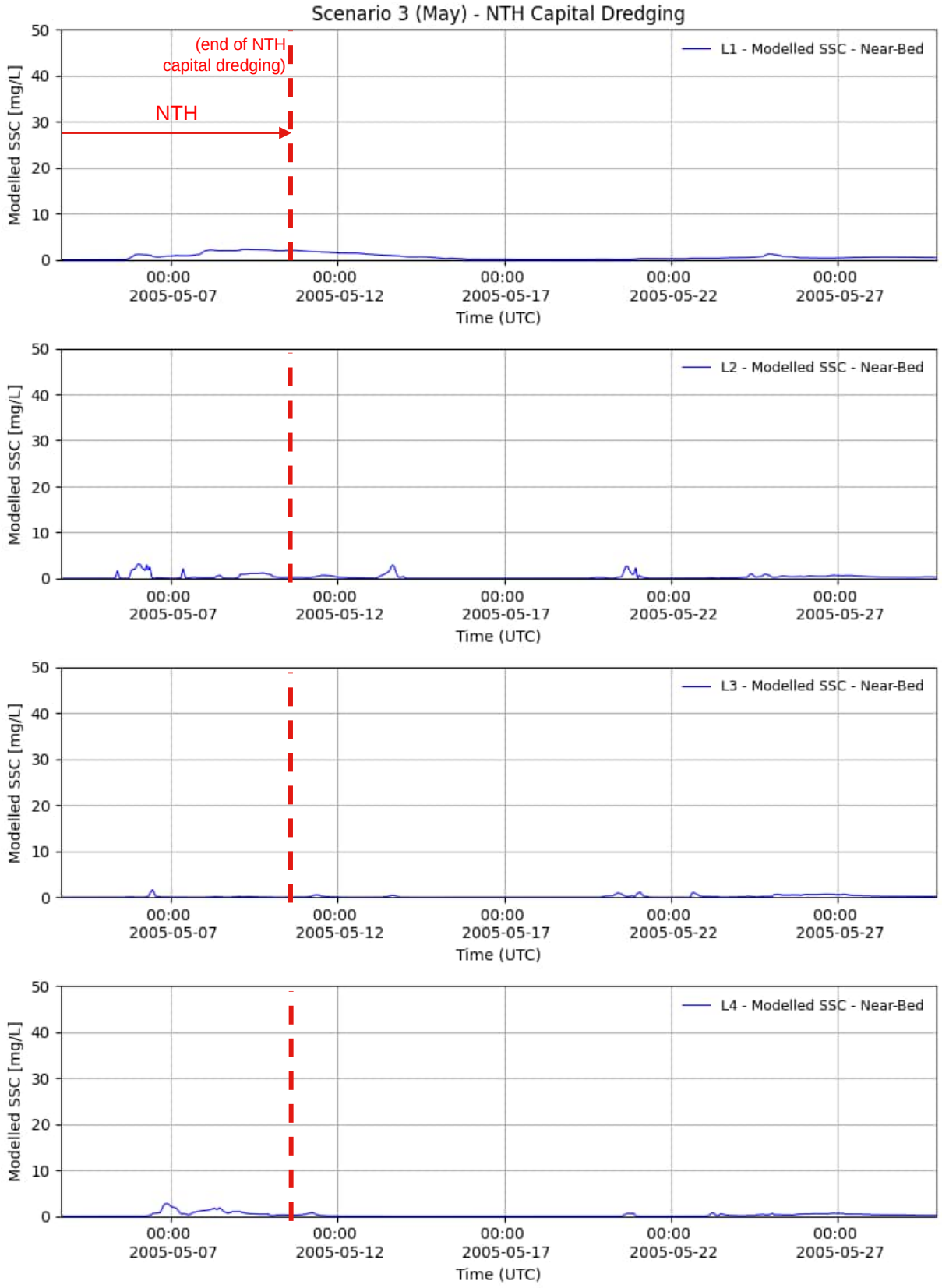


Figure 6-115: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L1-L4) - May

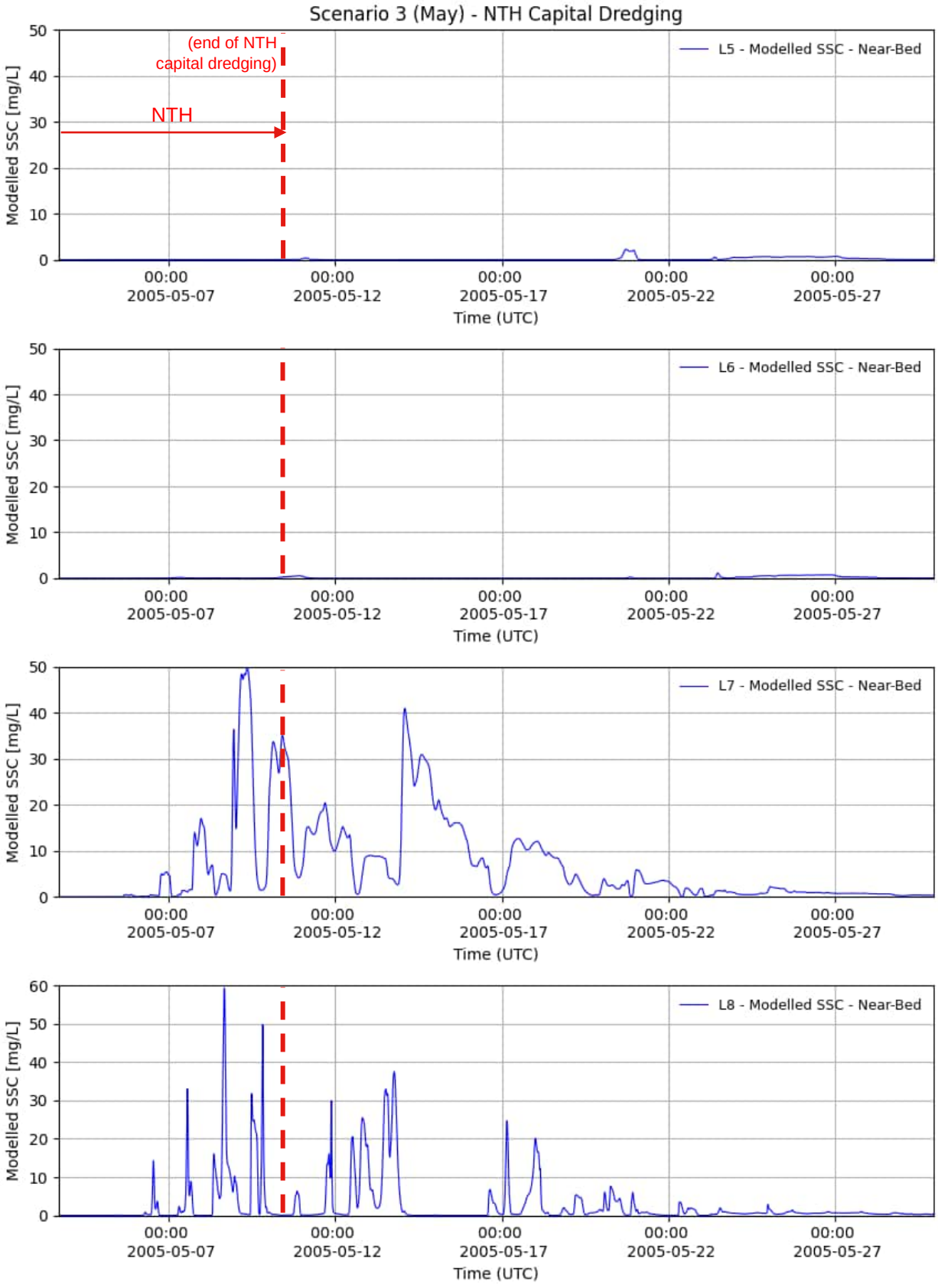


Figure 6-116: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L5-L8) – May

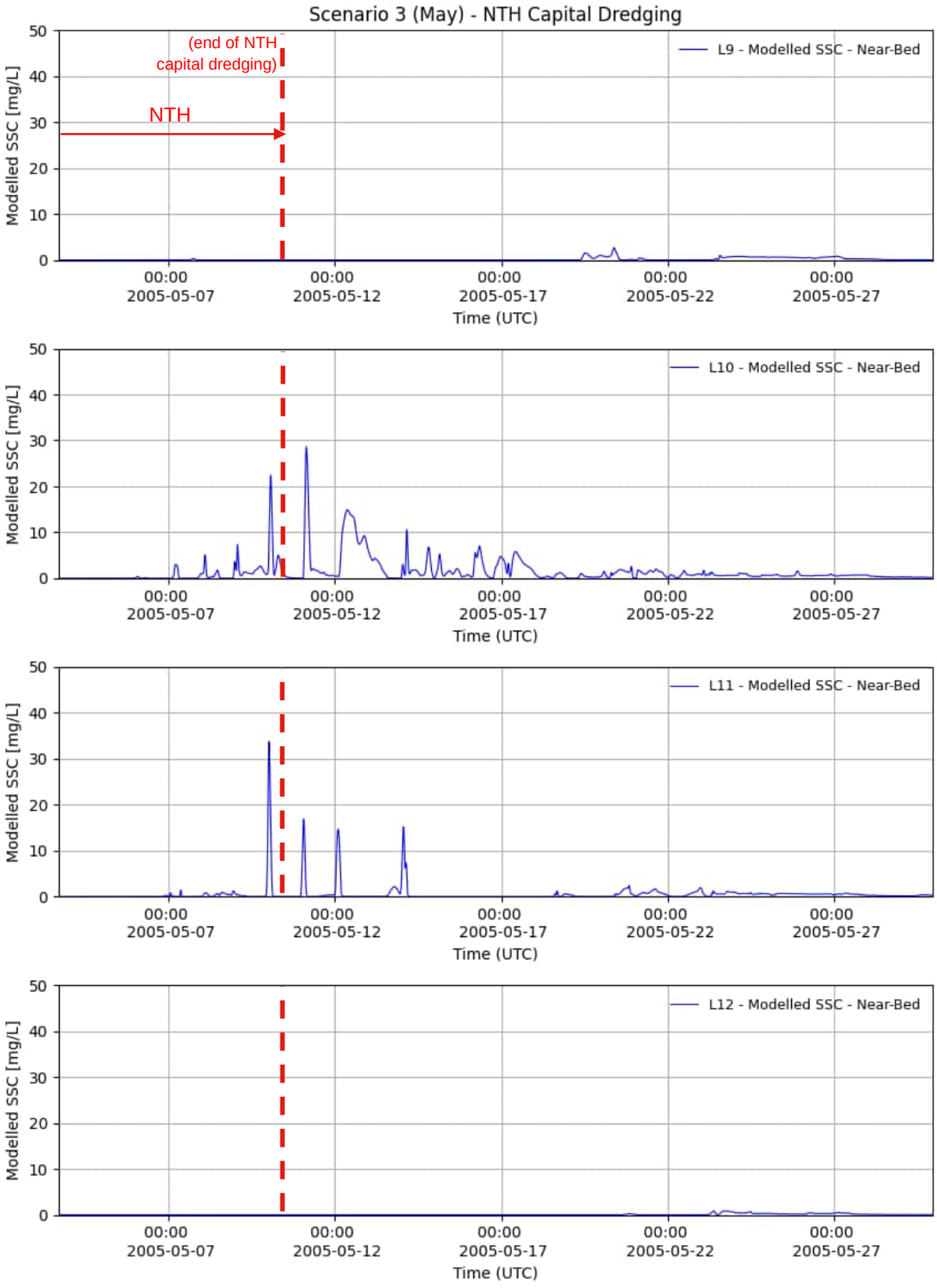


Figure 6-117: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L9-L12) – May

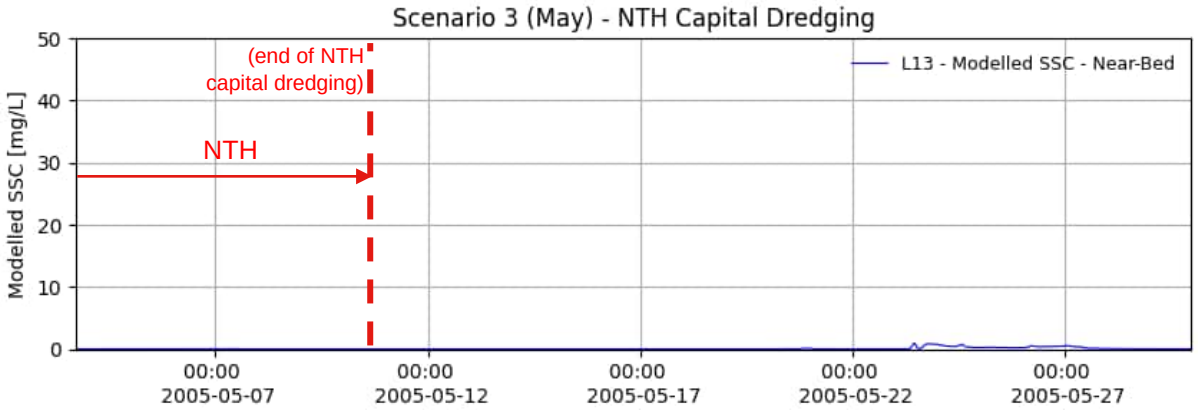


Figure 6-118: Time-series of excess near-bed SSC during capital dredging at the NTH at sensitive receptors locations (L13) – May

Arcs emanating from the NTH dredge area

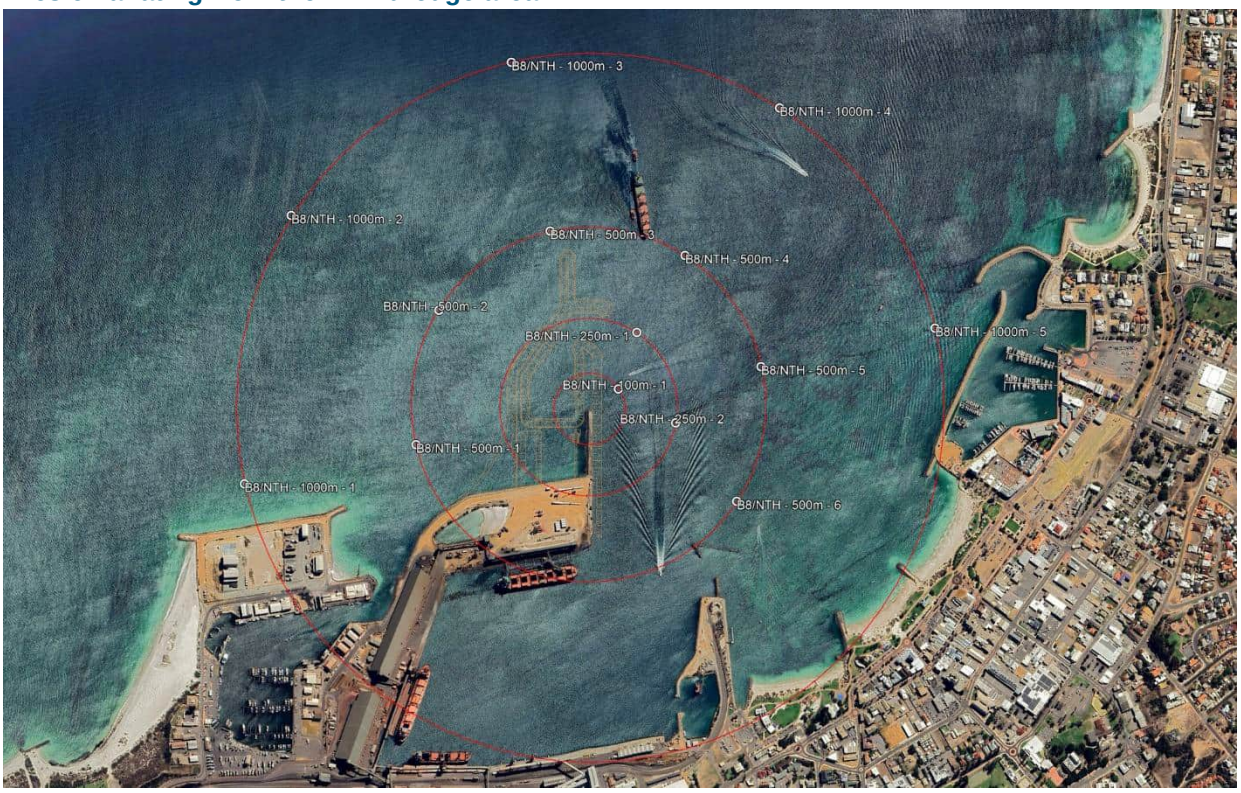


*Figure 6-119: Model output locations emanating from the B8/New Tug Harbour dredge area (14 nominated output locations along the 100, 250, 500 and 1000m arcs) (repeated from **Figure 6-9**)*

Dredging in April

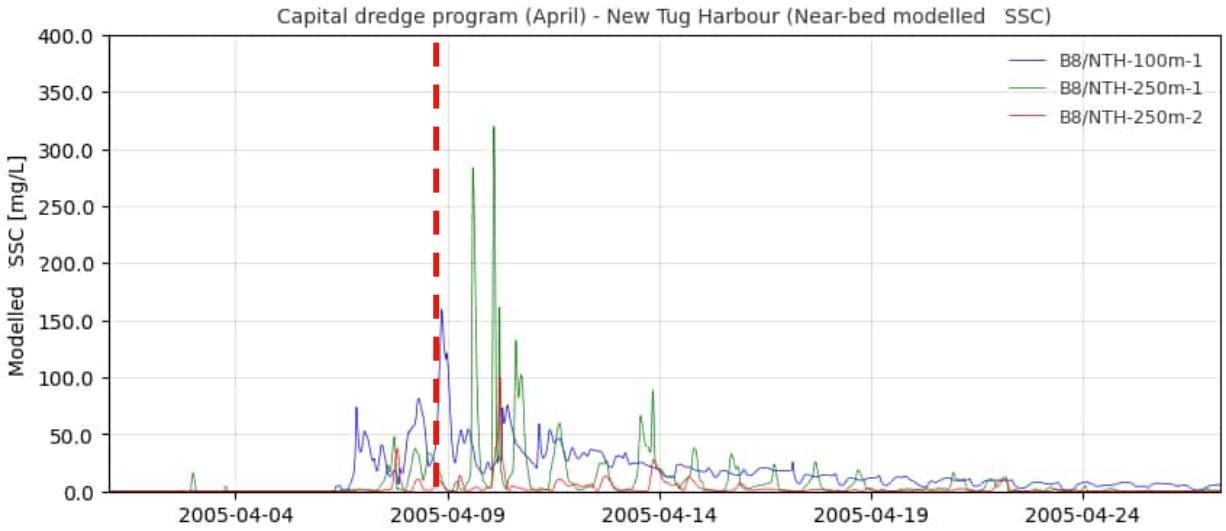


Figure 6-120: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (1) – April

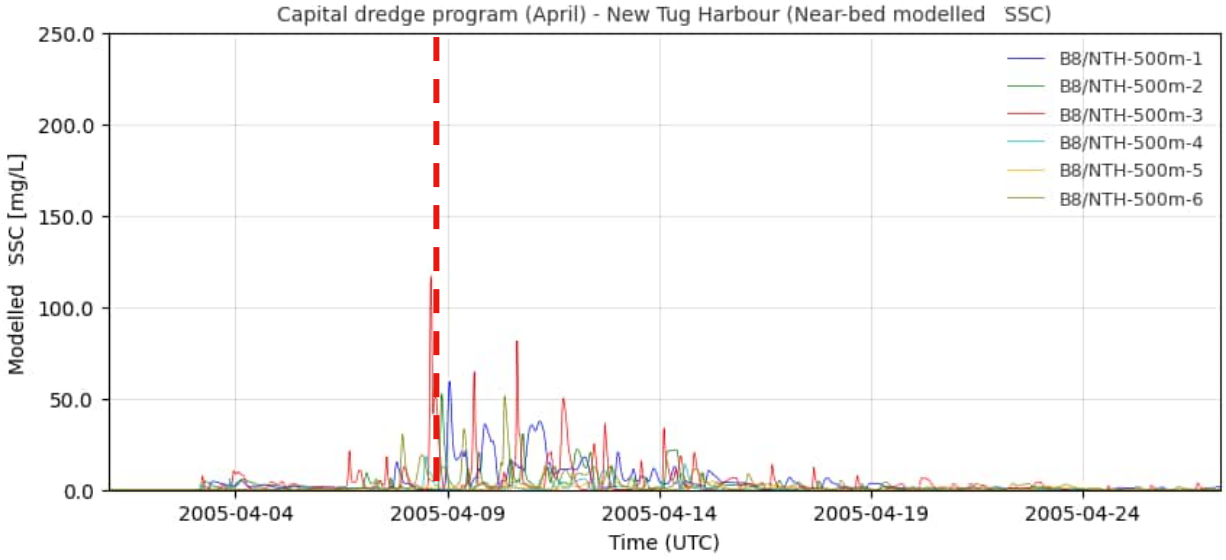


Figure 6-121: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (2) - April

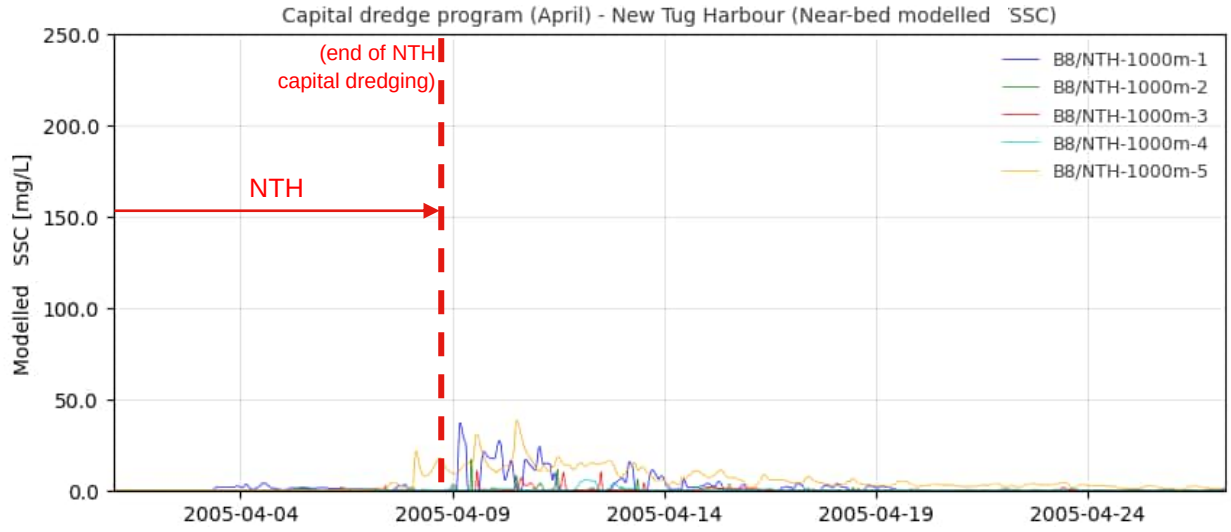


Figure 6-122: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (3) - April

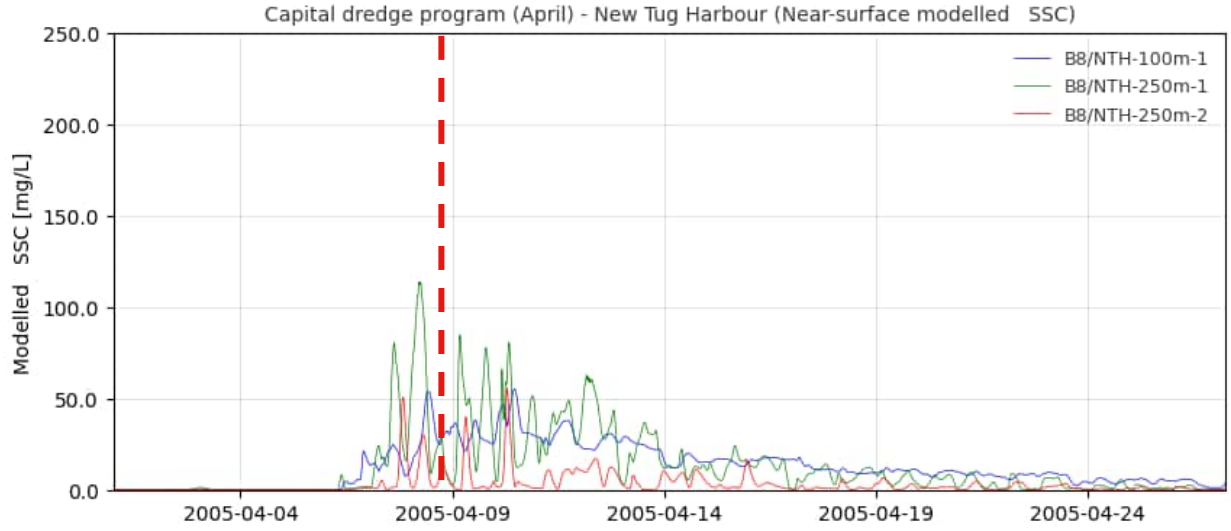


Figure 6-123: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (1) - April

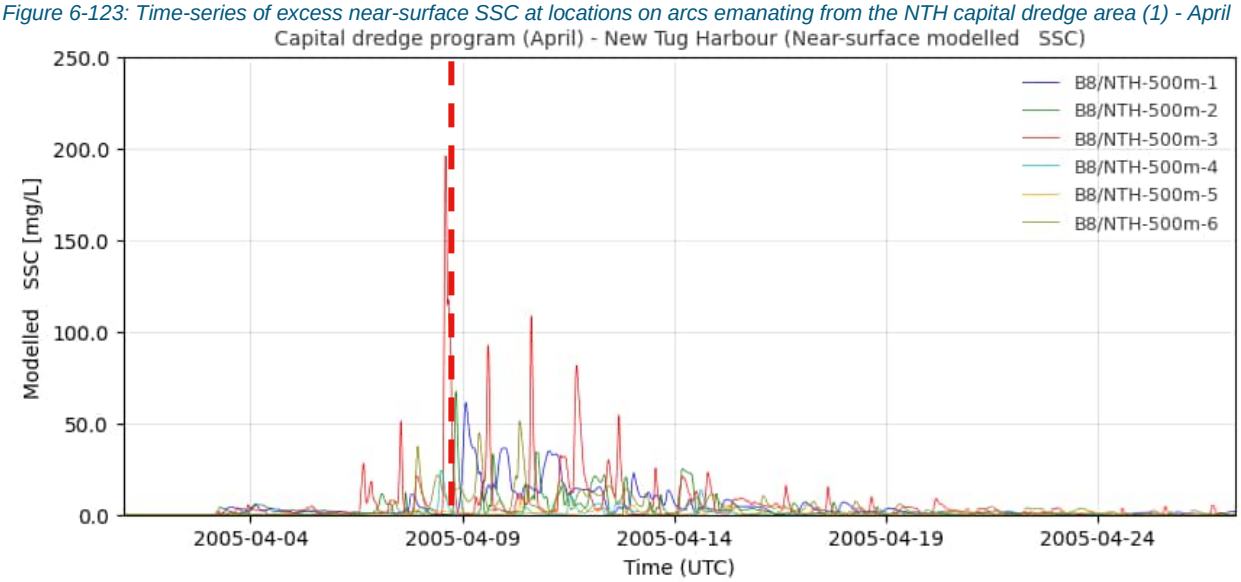


Figure 6-124: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (2) - April

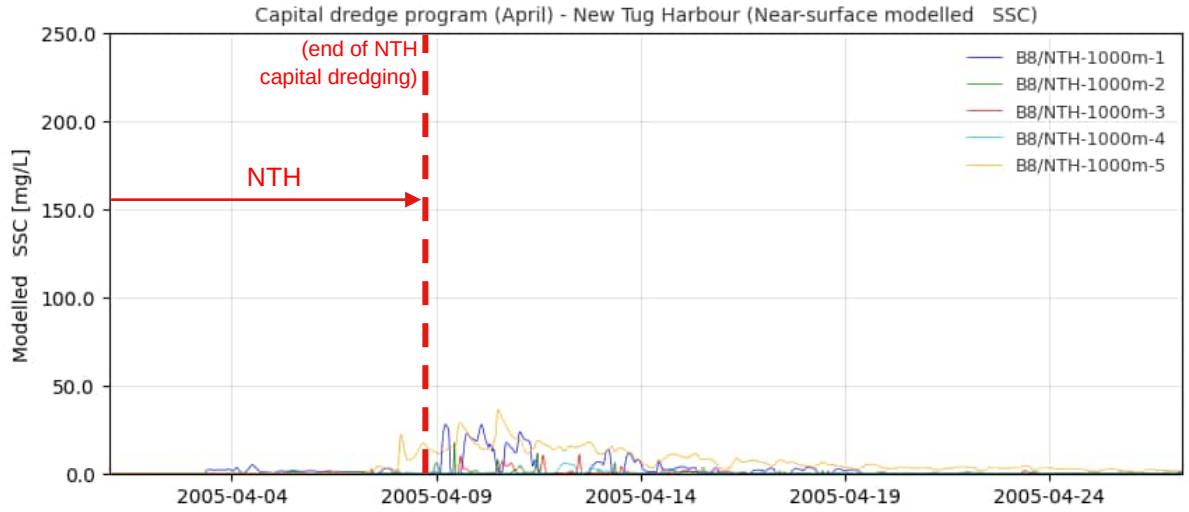


Figure 6-125: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (3) - April

Dredging in May

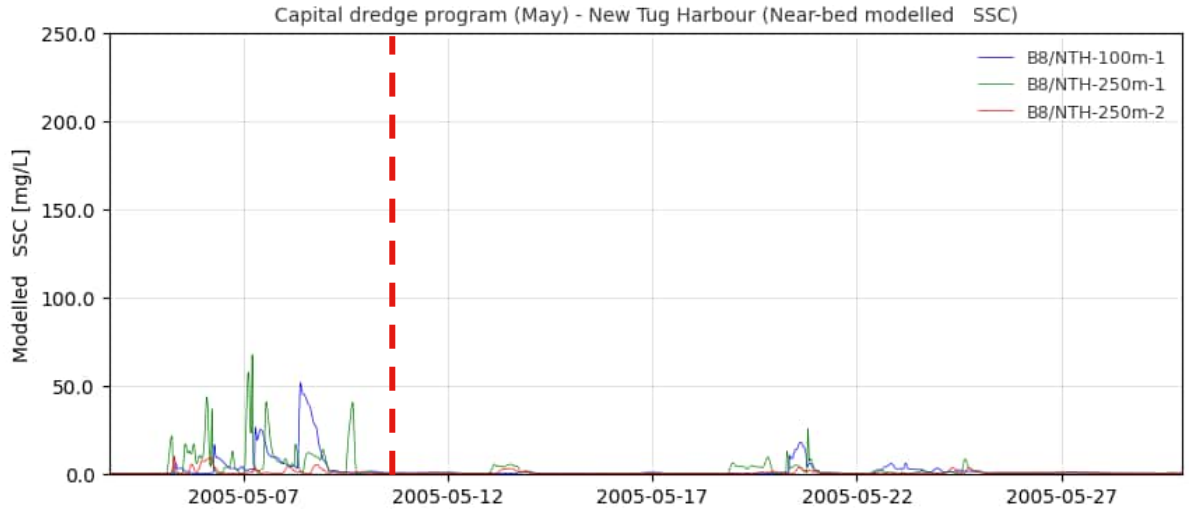


Figure 6-126: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (1) - May

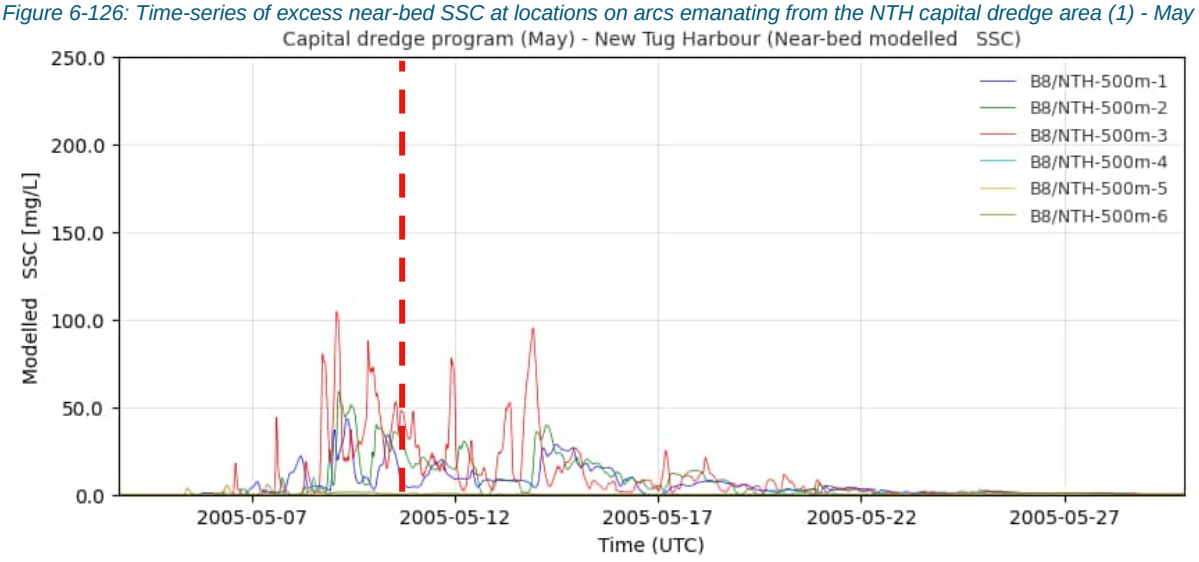


Figure 6-127: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (2) – May

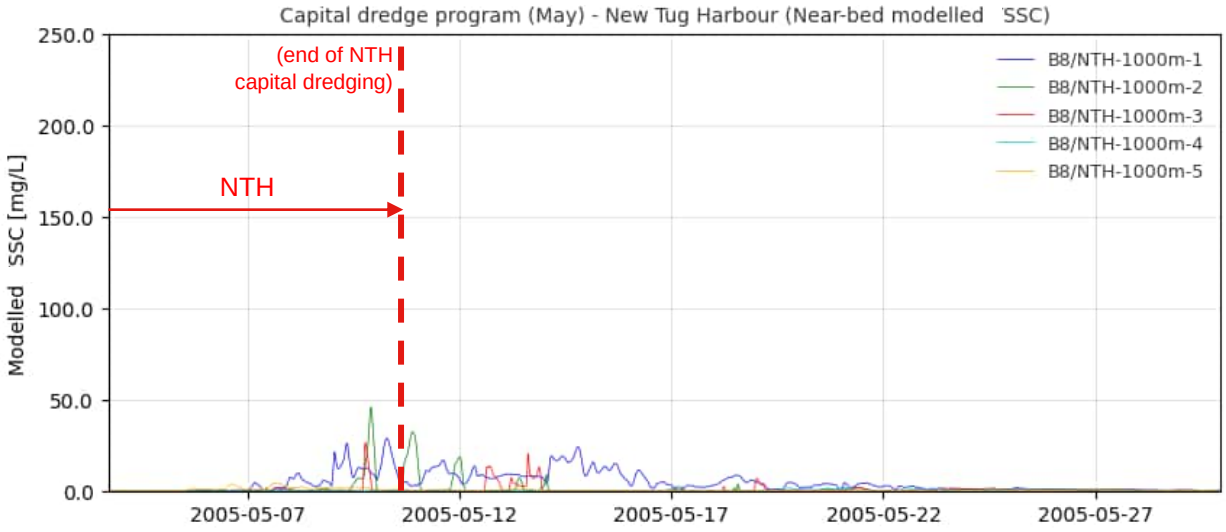


Figure 6-128: Time-series of excess near-bed SSC at locations on arcs emanating from the NTH capital dredge area (3) – May

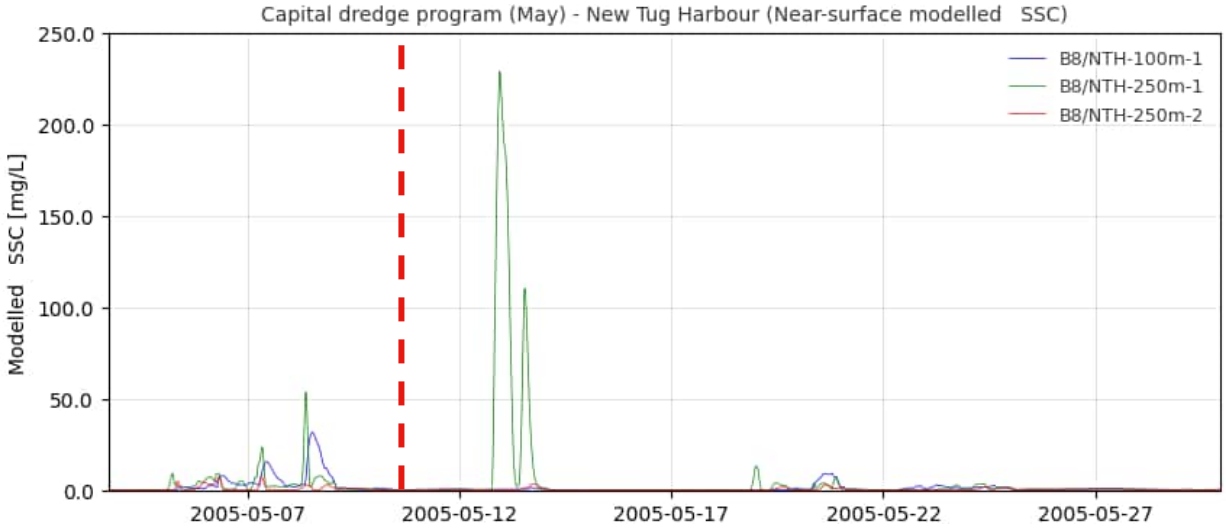


Figure 6-129: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (1) – May

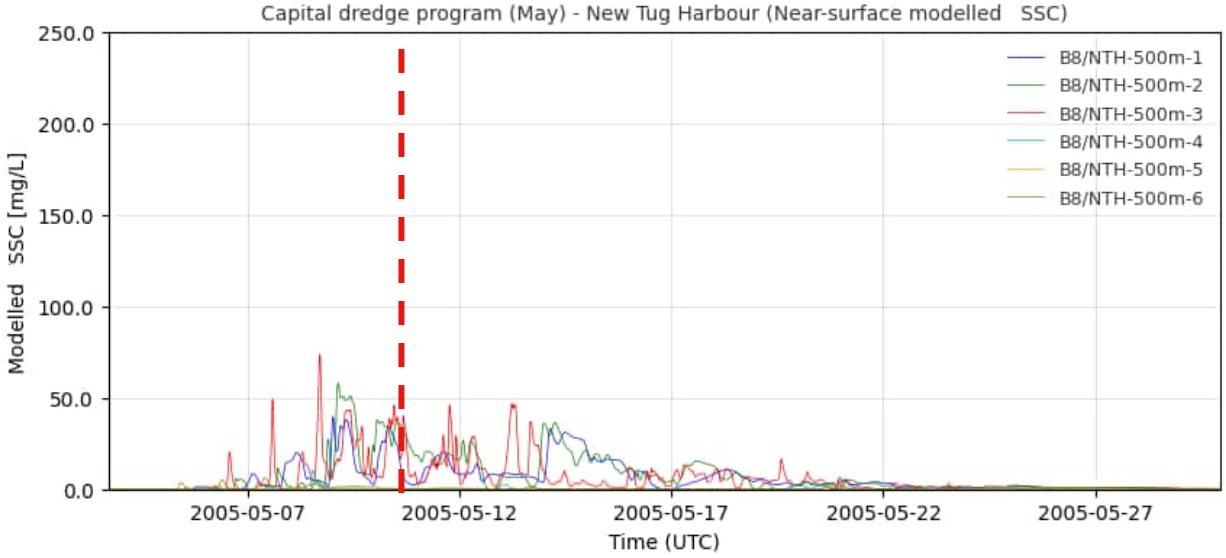


Figure 6-130: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (2) – May

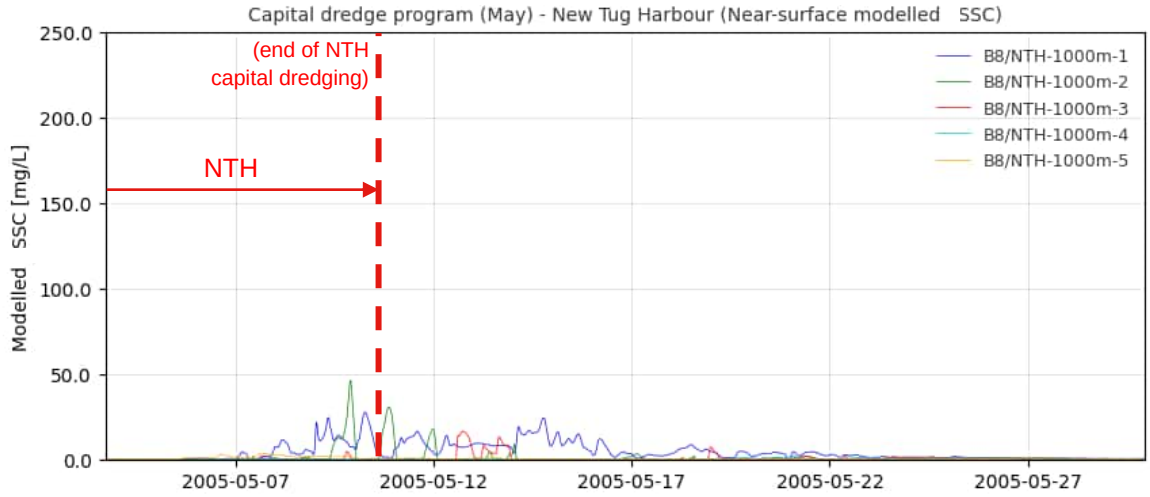


Figure 6-131: Time-series of excess near-surface SSC at locations on arcs emanating from the NTH capital dredge area (3) – May

Town Beach/Batavia Coast Marina



*Figure 6-132: Nominated model output locations at Town Beach and near the Batavia Coast Marina (repeated from **Figure 6-10**)*

Dredging in April

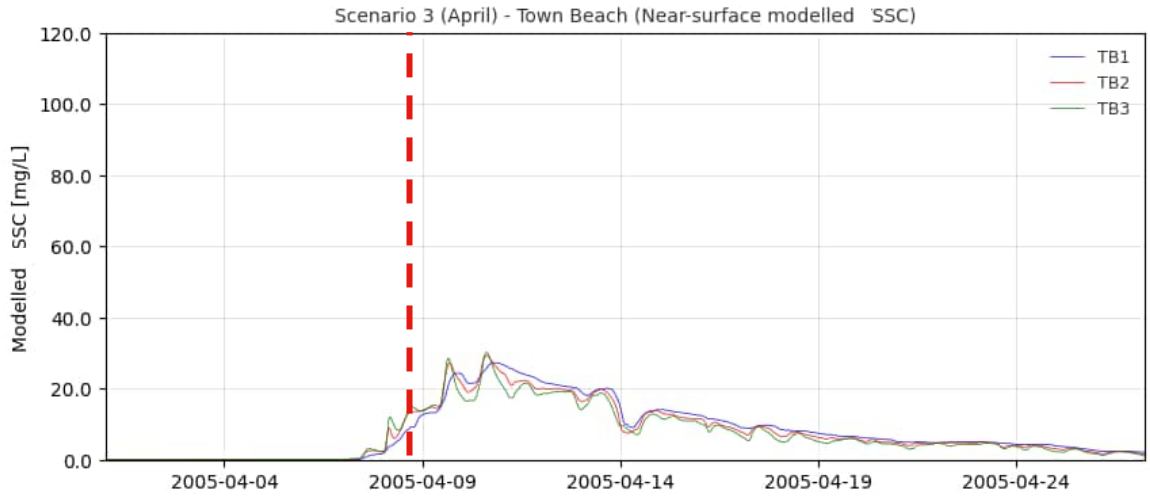


Figure 6-133: Time-series of excess near-surface SSC during NTH capital dredging at locations along Town Beach - April

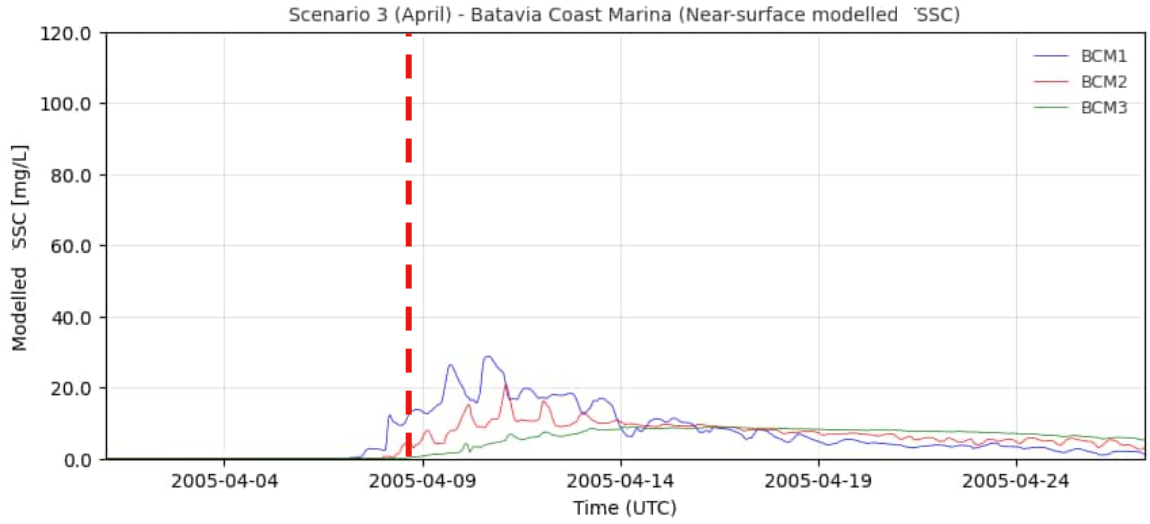


Figure 6-134: Time-series of excess near-surface SSC during NTH capital dredging at locations near Batavia Coast Marina – April

Dredging in May

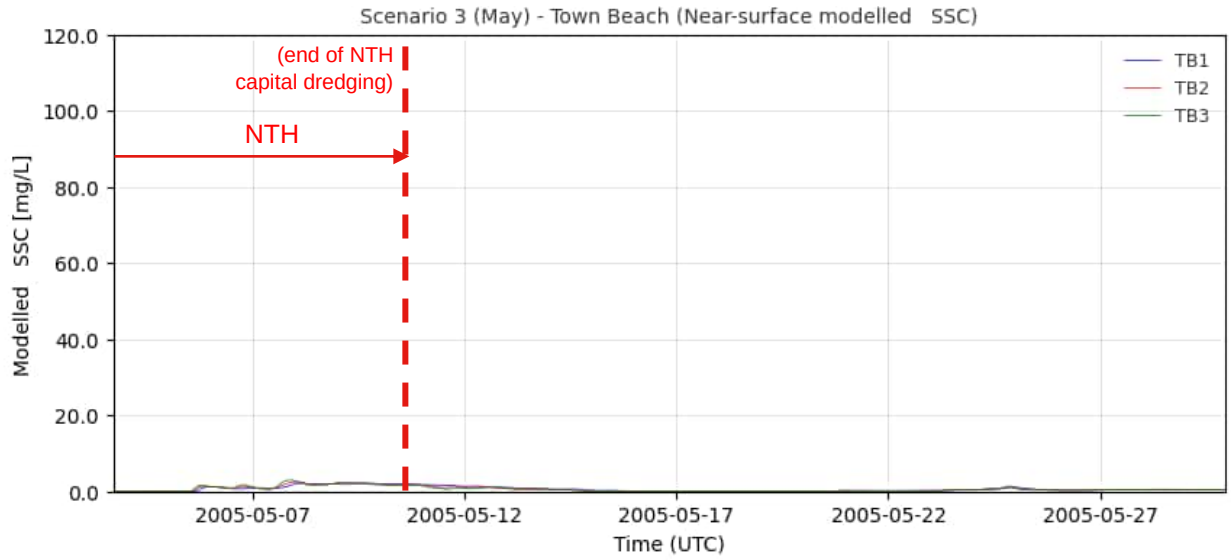


Figure 6-135: Time-series of excess near-surface SSC during NTH capital dredging at locations along Town Beach - May

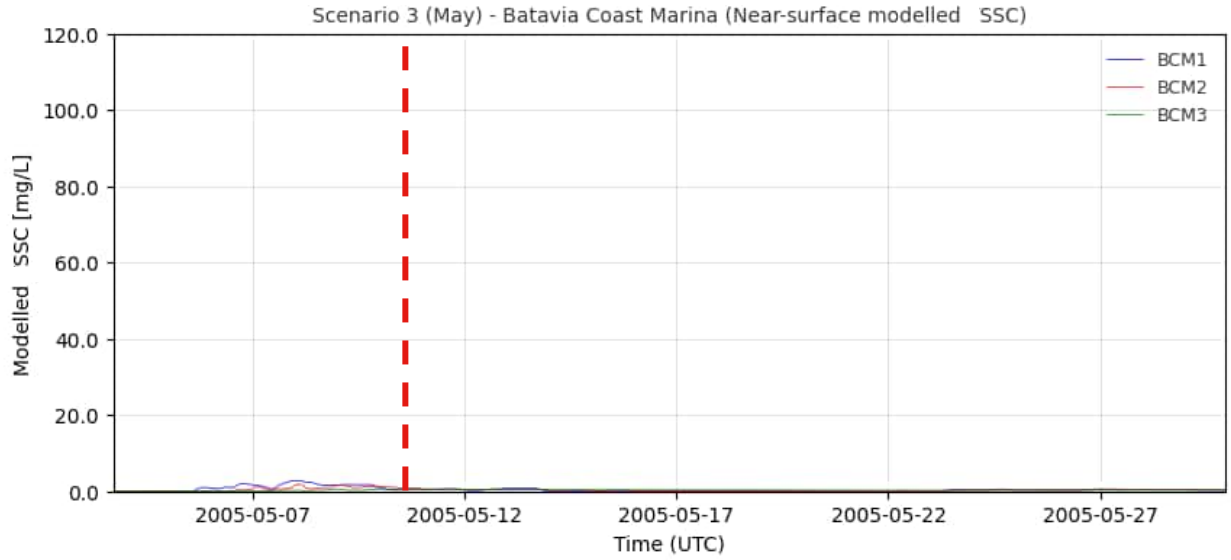


Figure 6-136: Time-series of excess near-surface SSC during NTH capital dredging at locations near Batavia Coast Marina – May

6.7.6.3 Sedimentation

Based on the output presented below, the following key observations can be made:

- Sedimentation is confined to the immediate dredge area and is minimal due to the prevailing hydrodynamic conditions, not allowing the material to settle.

Dredging in April

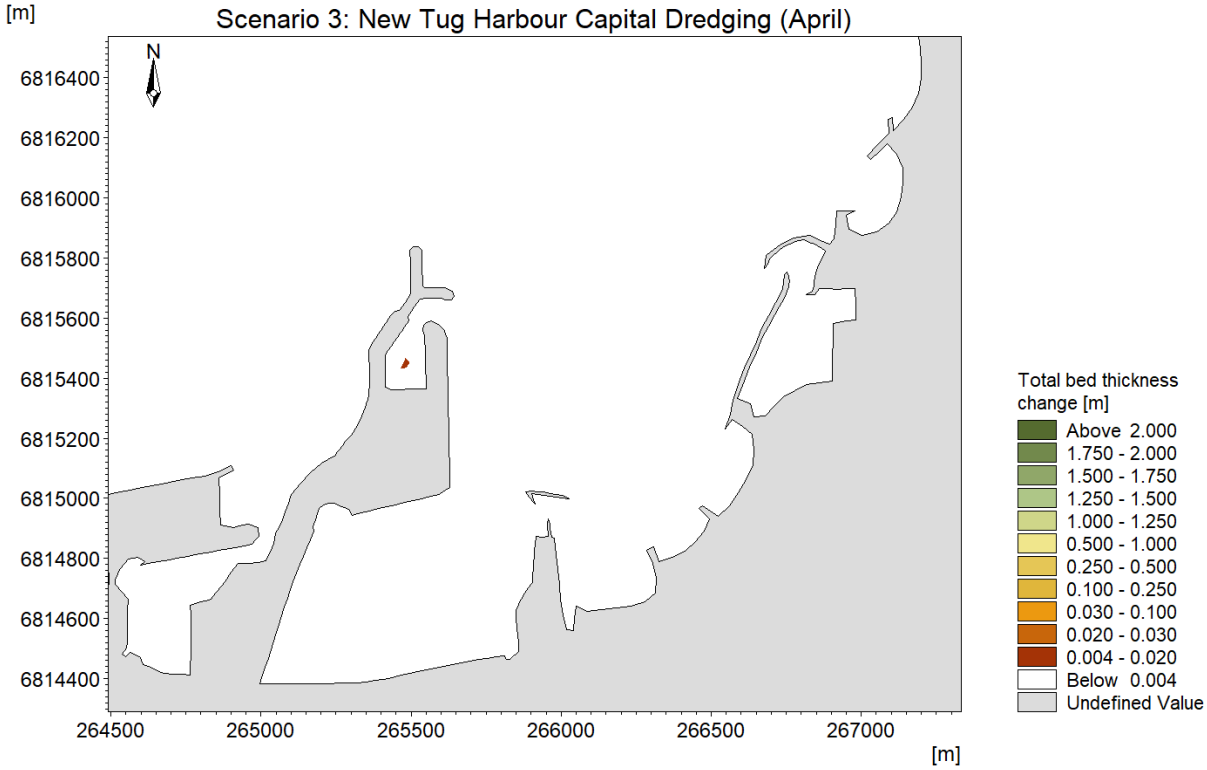


Figure 6-137: Sedimentation thickness of fines at the end of the new tug harbour capital dredging (April)

Dredging in May

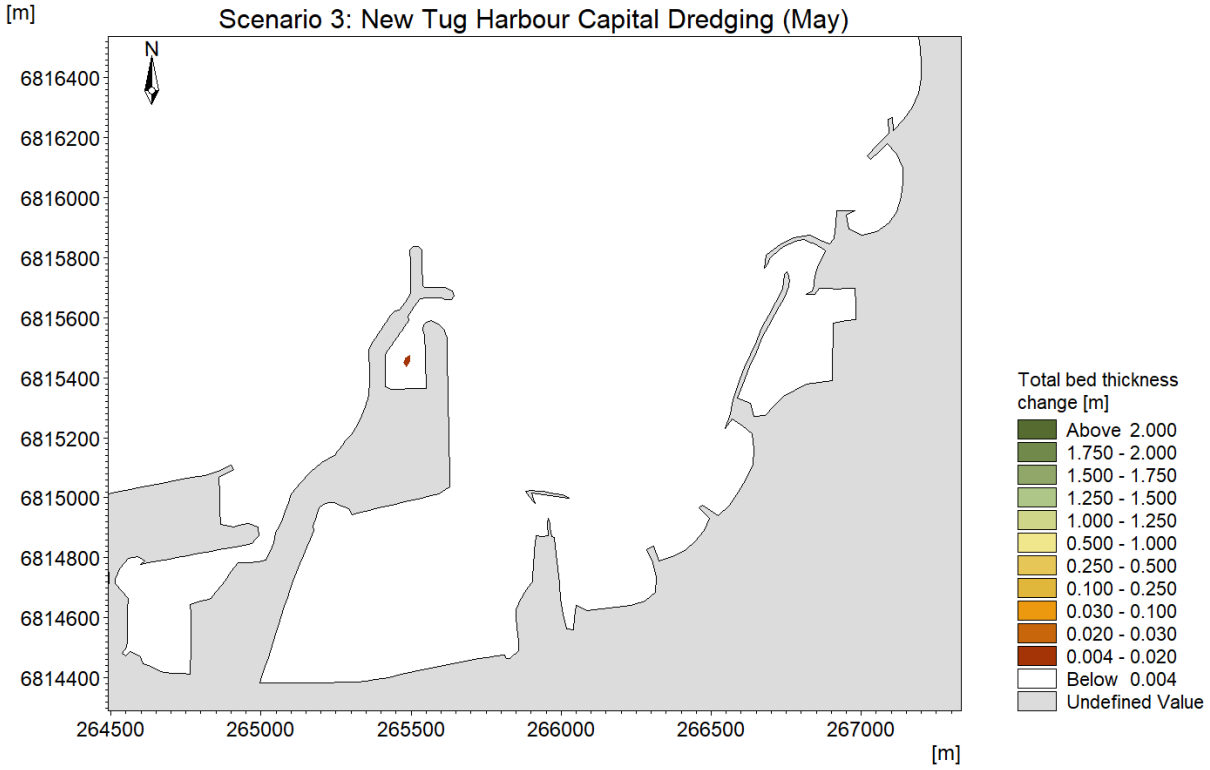


Figure 6-138: Sedimentation thickness of fines at the end of the new tug harbour capital dredging (May - period of a-typical meteorological conditions)

6.7.6.4 Impact Zones

Based on the output presented below, the following key observations can be made:

- Impact due to sedimentation is limited to a small 'zone of influence' inside the New Tug Harbour; and
- The zone of moderate impact covers Town Beach and part of the Batavia Coast Marine. The zone of influence due to SSC extends approx. 20km northward alongshore.

It is noted that the ZoHI includes the direct disturbance (dredge) footprint, in addition to the ZoHI areas presented in **Figure 6-139** to **Figure 6-141**.

Dredging in April



Figure 6-139: Impact zones (sedimentation) for the NTH capital dredging campaign - April

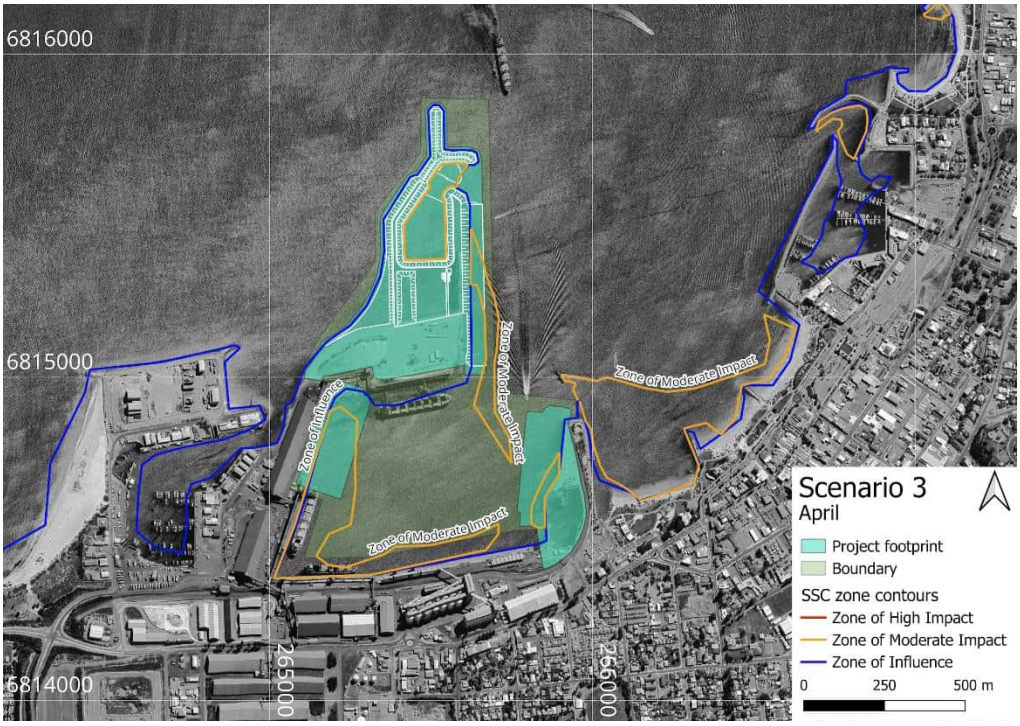


Figure 6-140: Impact zones (SSC) for the NTH capital dredging campaign - April

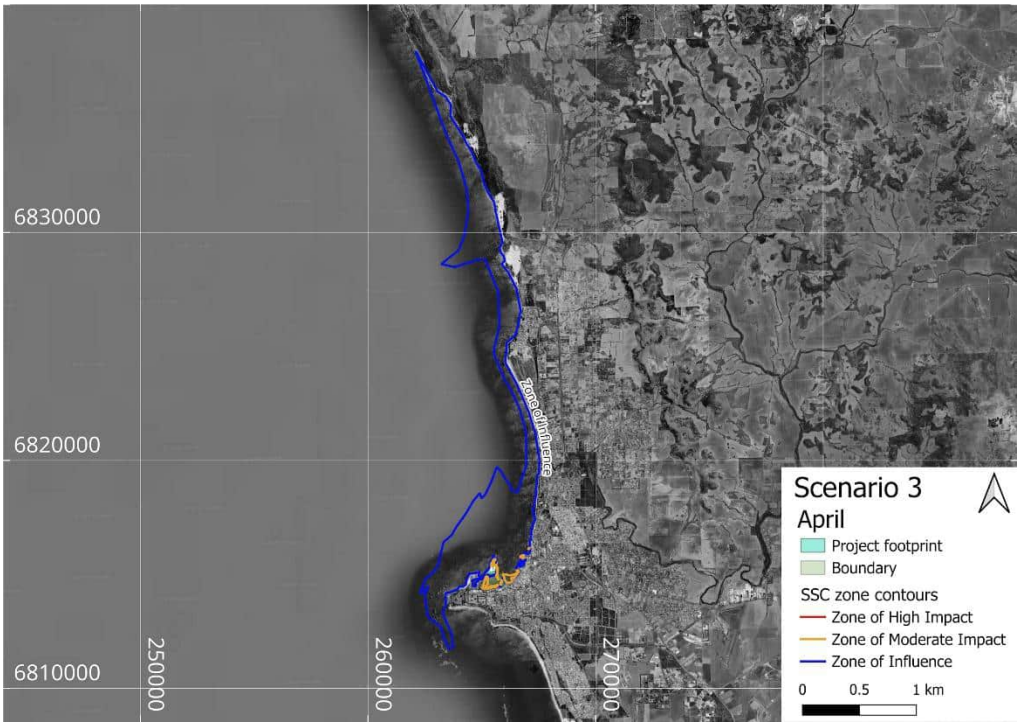


Figure 6-141: Impact zones (SSC) for the NTH capital dredging campaign (regional) - April

Dredging in May



Figure 6-142: Impact zones (sedimentation) for the NTH capital dredging campaign – May (period of a-typical meteorological conditions)

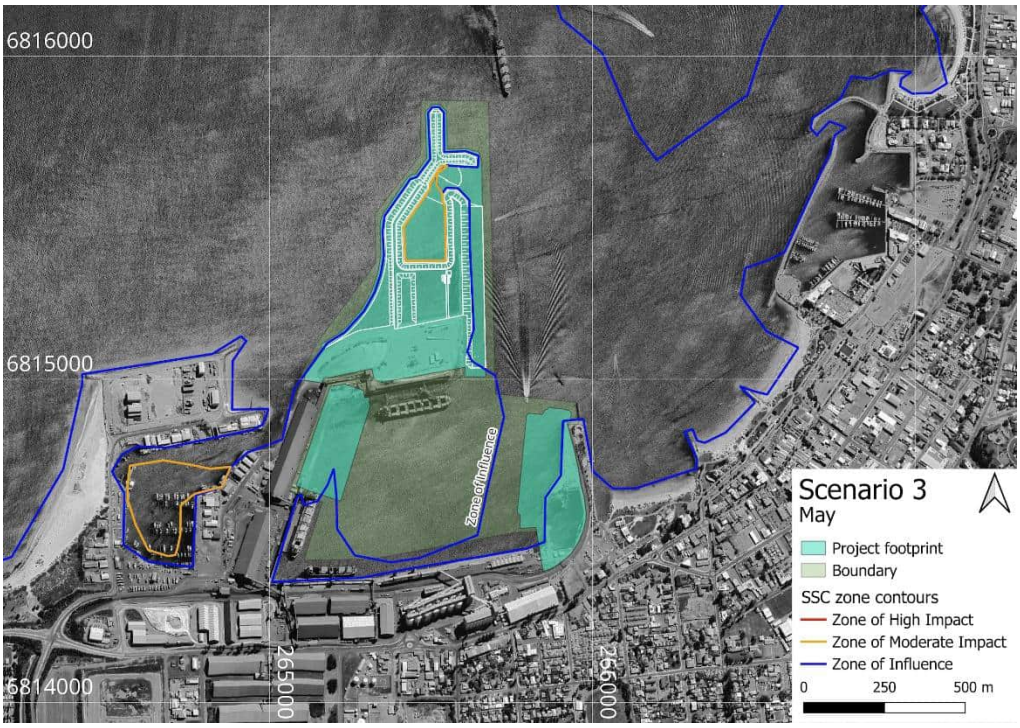


Figure 6-143: Impact zones (SSC) for the NTH capital dredging campaign - May (period of a-typical meteorological conditions)

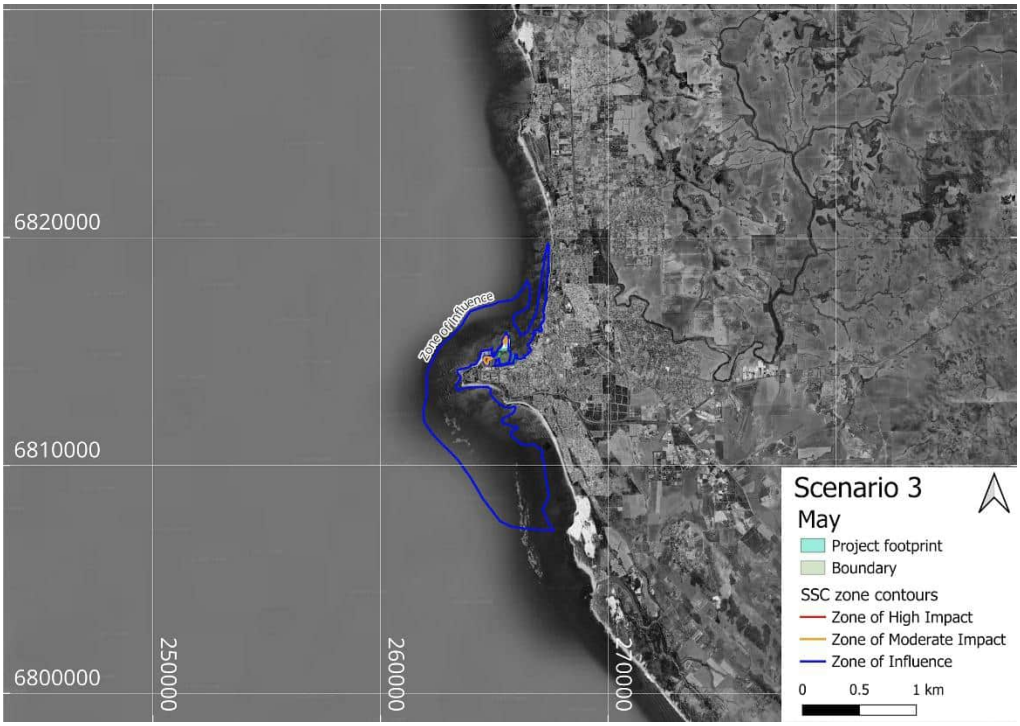


Figure 6-144: Impact zones (SSC) for the NTH capital dredging campaign (regional) - May (period of a-typical meteorological conditions)

6.7.6.5 Dredging in April vs. May

When comparing the above April results with the case simulated in May (with a-typical metocean conditions – refer Section 6.2.3.2), it is apparent from e.g. the percentile and impact maps that in the May

case, the Town Beach and Batavia Coast Marina areas are much less affected as plumes are primarily driven counterclockwise around the new tug harbour and Point Moore. However, impacts are greater in the FBH and to the west and south of Point Moore.

7 Summary and Conclusion

This study involved computer modelling of three maintenance and capital dredging scenarios at Geraldton Port as part of the PMaxP to assess the impact on water quality. The three maintenance and capital dredge scenarios are referred to as Scenario 1 (maintenance dredging at Berth 1), Scenario 2 (capital dredging at Berths 1, 6 and 8) and Scenario 3 (capital dredging at the new tug harbour) and were simulated to investigate the transport and fate of sediment plume plumes (and sedimentation). Central to this was the application of a calibrated and validated wave model, a calibrated and validated 3D hydrodynamic model and a sediment transport model configured to model the fate of sediment plumes created by dredging activities. The model provides insight into the extent and concentration of sediment plumes at Geraldton Port, Champion Bay and beyond.

To further inform the assessment, a dredge expert was engaged to review geotechnical information and suitable dredge equipment and scenarios, to ultimately estimate source terms (fluxes of fines introduced into the water column due to the act of dredging). In addition, laboratory investigations were undertaken to estimate settling velocities of fines, rather than adopting values calculated empirically or from published literature (thereby providing greater confidence in modelling outcomes).

Time-series and map results for the above dredge scenarios have been presented showing excess SSC due to dredging (i.e., SSC above the ambient or background concentration). Modelling of ambient SSC was attempted however not taken further (refer **Section 6.4.3**). A separate assessment of ambient turbidity (which is typically used as an indicator of SSC) was undertaken based on turbidity which is current being collected as part of the MWPA MEQMMP and PMaxP baseline data collection program at four locations in Champions Bay (however, the record length is insufficient to generate reliable long-term statistics).

Critical output was presented in terms of zones of impact and influence for Scenarios 1, 2 and 3, based on modelled sedimentation and SSC. This output showed the following:

- Scenario 1
  - The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berth 1 maintenance dredge area and is within the project development envelope; and
  - Impact due to SSC is limited to a ‘zone of influence’.
- Scenario 2
  - The zone of high impact due to sedimentation is confined within the immediate vicinity of the Berths 1, 6 and 8 capital dredge areas and is within the project development envelope; and
  - The zone of high impact due to SSC is confined within Geraldton Port area. Town Beach and the Batavia Coast Marina are zones of moderate impact.
- Scenario 3
  - Impact due to sedimentation is limited to a small ‘zone of influence’ inside the New Tug Harbour; and
  - Impact due to SSC is limited to a ‘zone of influence’.

It is noted that the ZoHI includes the direct disturbance (dredge) footprint, in addition to the ZoHI areas due to sedimentation and SSC.

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A1 Settlement Characteristics of Sediments and Fine Crushed Rock - Laboratory Investigation

REPORT

Geraldton Port Dredge Strategy

Settlement Characteristics of Sediments and Fine Crushed Rock - Laboratory Investigation Report

Client: SLR Consulting

Reference: PA3387-RHD-XX-ZZ-RP-Z-001

Status: 01/Final

Date: 9 October 2024

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Enhancing Society Together

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Project related

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Executive Summary

The Port of Geraldton (the Port), operated by the Mid West Ports Authority (MWPA), is one of Western Australia's most diverse ports catering for a range of products. MWPA is proposing a Port Maximisation Project (PMaxP), which aims to maximise the utilisation and operability of the port facilities. PMaxP includes dredging and reclamation to provide additional berths. It is understood that dredging would be undertaken using a backhoe dredge (BHD) and material would be placed in reclamation areas located within the Port. To support the proposed works, Royal HaskoningDHV (RHDHV) has undertaken a laboratory-based investigation to assess the settling behaviour of the sediment and fine crushed rock settling behaviour of the sediment entering the water column during dredging. The findings of the investigation would:

- support the dredge plume modelling by deriving site-specific input parameters;
- develop preliminary Total Suspended Solids (TSS)/Turbidity relationships to support compliance monitoring during the dredging works; and,
- provide illustrative TSS samples to help with communication and visualisation of TSS versus turbidity during Regulator and Stakeholder consultation.

A total of one sediment sample and one crushed rock sample were selected for analysis based on their high fines content (combined silt and clay sized fraction) relative to other materials expected to be dredged during the proposed works. The rock was crushed using a ring mill to generate particles with a similar grain size to those expected to be generated by dredging activities. The fines content varied between 65% (marine sediment B1-5) and 54% (crushed rock BH-01OS).

The samples were homogenised prior to testing, to ensure repeatability and reliability of the results. A total of three (3) tests were undertaken as outlined below:

1. preliminary tests - sample mass sensitivity test;
2. column test to derive TSS/Turbidity relationship; and
3. critical particle size analysis.

Seawater used for testing was obtained from Sydney Harbour due to logistical challenges in transporting large quantities of site water from the Port of Geraldton to Sydney. Prior to using Sydney Harbour water, a comparative assessment was conducted to determine if Sydney Harbour seawater could serve as a suitable substitute to seawater from the Port of Geraldton. The analysis included:

- visual inspection and physicochemical parameter measurements of water from both locations; and,
- critical particle size analysis of site sediment (sample B1-5) mixed with seawater obtained from Sydney Harbour and a separate test on site sediment mixed with a minor quantity of seawater obtained from the Port of Geraldton,
- a visual assessment of turbidity.

Results indicated that the physicochemical properties of the seawater and particle size distribution were nearly identical, with marginal differences reported. Additionally, there was negligible visual difference in settling behaviour and turbidity over a one-hour period. Therefore, Sydney Harbour seawater was deemed representative of the Port's water for the purposes of this project.

Sample mass sensitivity testing was conducted on B1-5 to determine the optimal sample mass required for running the critical particle size analysis tests for the maximum duration, without experiencing hindered and zone settling regimes or samples with insufficient turbidity to analyse in the Mastersizer 2000. Results indicated that most of the material settled relatively quickly and a sample containing 2 g of dry fines in 1 L of water (i.e., 2,000 mg/L) was deemed the most suitable for critical particle size analysis testing to achieve the longest possible test period, whilst avoiding any potential zone settling or hindered settling from increased sample mass.

The column test is considered representative of material settling through the water column (i.e., material falling from the bucket of a BHD. The turbidity values equivalent to 50 mg/L suspended solids range from 59 NTU (B1-5) to 55 NTU (BH-01OS). The selected TSS value of 50 mg/L is based on the water quality criterion commonly adopted for major marine construction projects. However, the water quality criterion for the project has not yet been defined and may vary. Overall, TSS-turbidity data collected during the column tests is considered to be reliable for the purpose of establishing a preliminary relationship between TSS and turbidity. However, collection of field TSS-turbidity data during construction is recommended so that the relationships between TSS and turbidity can be continually validated and improved.

Critical particle size analysis aimed to establish the particle size of material that would contribute to turbidity and TSS in the water column following dredging and disposal activities, in addition to the determination of the particle size in suspension used to estimate settling velocity. The adopted particle size for the analysis was D90, which is the particle diameter where ninety percent of the distribution has a smaller particle diameter. The results indicated that after 10 minutes, the D90 particle size in suspension varied from 11 to 27 µm at a depth 70 mm below the water surface, and 21 to 43.5 µm at a depth 230 mm below the water surface, for all samples. After 60 minutes, the D90 particle size in suspension was 6 to 11.5 µm at a depth 70 mm below the water surface, and 9 to 14.5 µm at a depth 230 mm below the water surface. Settling velocity was inferred to be generally slower than Stokes Law for the marine sediment, indicating that this material would likely settle slower than predicted by Stokes Law.

Additional tests were undertaken on the marine sediment sample to assess the impact of varying the sediment concentration on settling velocity. The results indicate that discrete non-flocculent settling (Class I) was occurring rather than discrete flocculent settling (Class II), as increasing the concentration of the sediment did not visually increase settling velocity. Further salinity sensitivity testing supported these findings, showing that the material is either weakly colloidal or only partially colloidal. This indicates that the dredge material does not readily flocculate in seawater, resulting in reduced settling rates in the water column.

Royal HaskoningDHV

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Appendix C – NATA Accredited Laboratory Certificates of Analysis and RHDHV Laboratory Log Records
Appendix D – Quality Assurance / Quality Control (QA/QC) Report

1 Introduction

1.1 Project Background

The Port of Geraldton (the Port), operated by the Mid West Port Authority (MWPA), is one of Western Australia's most diverse ports, catering for bulk carriers (iron ore, sand, minerals, and grain), tankers (fuel), cruise ships, oil rig tenders and other specialist craft. MWPA is proposing a Port Maximisation Project (PMaxP), which aims to maximise the utilisation and flexibility of the port facilities.

PMaxP includes dredging and reclamation to cater for deeper draft vessels and provide additional berths. Dredging of berth pockets at Berths 1, 6, and 8/9 to a depth of -13 m Chart Datum (CD), is proposed, along with dredging of a new tug harbour. Berths 1, 6 and 8/9 are proposed to be reconstructed. Reclamation of the existing tug harbour and around the proposed tug harbour is proposed, using the dredge material. The Port layout and proposed dredge and reclamation areas are presented in **Figure 1-1.**

To support these proposed works, Royal HaskoningDHV (RHDHV) has been engaged to undertake numerical plume dispersion modelling and development of a dredge management strategy.

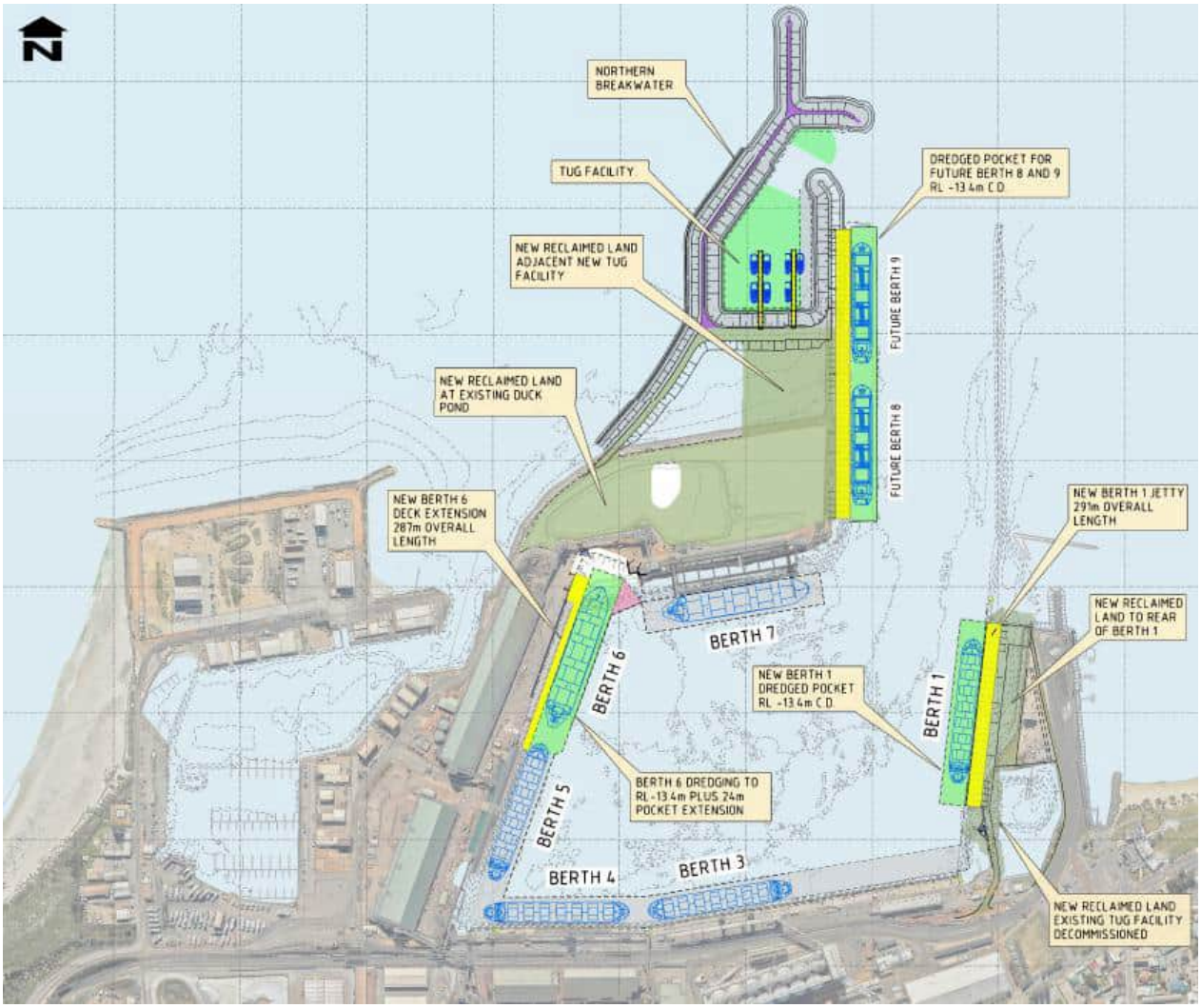


Figure 1-1: Proposed port layout and capital dredging/ reclamation areas.

1.2 Purpose of this Investigation

This laboratory-based investigation develops a better understanding surrounding the settleability and settling behaviour of fine sediment and crushed rock particles at the Port, which would be dredged and likely placed in reclamation areas. The findings of the investigation would:

- support the dredge plume modelling by deriving site-specific input parameters;
- develop preliminary Total Suspended Solids (TSS)/ Nephelometric Turbidity Unit (NTU) relationships to support compliance monitoring. These results will aid in monitoring turbidity during dredging and disposal operations; and,
- provide illustrative TSS samples to help with communication and visualisation of TSS versus turbidity during Regulator and Stakeholder consultation.

1.3 Structure of this Report

The report is structured as follows:

- **Section 1:** The introduction, including project background, report purpose, document structure, scope of works and a summary of the sediment and rock source and characteristics.
- **Section 2:** Methodology for the laboratory tests conducted, including quality assurance and quality control (QA/QC) measures implemented.
- **Section 3:** Analysis of the results, including QA/QC results and suitability of the data for interpretive use.
- **Section 4:** Discussion of the results and limitations in relation to the purpose of the investigation.
- **Section 5**: Conclusions.
- **Section 7:** References.

1.4 Scope of Works

The scope of works conducted as part of this investigation is summarised in **Table 1-1**, including a summary of the relevance of each scope item.

Table 1-1: Scope of works.

Scope Item	Reasoning
Determination of Suitable Sediment/ Rock Profiles for Testing	The delineation of sediment/ rock types including review of the Geotechnical Investigation results (e.g., borehole/ grab sample logs and Particle Size Distribution (PSD) results) enables the identification of different sediment units within the works area. The laboratory investigation focused on sediment/ rock with a higher fines (silt and clay fraction) content, which have the potential for greater environmental impact.
Preparation of the sample material	Preparation of the testing material is an important step in attaining uniform samples (i.e., grainsize, moisture content, presence of shells etc). This is important to ensure reliability and repeatability of the tests. Sample preparation includes crushing of the rock cores to produce a sample comprising sand size and finer grained particles that may be generated during dredging.
Preliminary Mass Sensitivity Tests	The preliminary mass sensitivity test is used to understand the settling/deposition behaviour of the sediment at different mass concentrations. This test is used to set the variables (mass of sediment) for the critical particle size analysis and provides insights into the settling regime of the material.
Column test to derive total suspended solids (TSS)/ turbidity (NTU) relationship	As part of the environmental management of major projects involving disturbance of the seabed and materials entering the water column, water quality criteria relating to impacts on sensitive receptors are commonly specified in terms of TSS. However, in accordance with standard industry

Scope Item	Reasoning
	practice, compliance with these criteria is typically assessed through real time turbidity monitoring, as TSS concentrations are not as easily and quickly measured in the field. A TSS-NTU relationship is used to convert a TSS criterion into NTU (turbidity) values that can be readily measured in the field during the proposed works and thus used for compliance monitoring and triggers for management actions. The relationship between TSS and turbidity is highly site-specific, being dependant on the physical, optical, and geochemical properties of the suspended solids and the geochemical properties of the water. As such, testing is required to establish relationships between these properties for the sediment and rock material that would be encountered during dredging activities.
Critical Particle Size Analysis	Critical particle size analysis provides information on the particle size that would contribute to turbidity and TSS in the water column during dredging and disposal activities. This test would also determine the D90 particle size in suspension that is used to estimate the settling velocity. Settling velocity is an input parameter required for the numerical modelling and it varies depending on site-specific parameters of the sediment/ rock and water. Rather than adopting values calculated empirically or from published literature, the settling velocity would be established from the laboratory investigation of the actual material to be dredged.
Jar Sample Creation	The creation of jar samples is undertaken during the column test and provides a visual indication of water turbidity at a range of TSS concentrations. These jars are helpful in communication and visualisation during Regulator and Stakeholder consultation, especially in relation to defining limiting criteria adopted from guidelines or literature review (in mg/L) versus the visual impact in the field. A summary table with accompanying sample information pertaining to the jar visualisation samples was provided to MWPA under a separate cover.
Quality assurance and quality control (QA/QC)	QA/QC measures including sample preparation, the collection and analysis of sample duplicates and aliquots, and laboratory sampling ensure the results from the settlement tests and critical particle size analysis are accurate, repeatable, and reliable.

1.5 Material Source and Characteristics

1.5.1 Sediment and Rock

Sediment for the laboratory testing was recovered by SLR in April 2024 and rock used for testing was recovered by BG&E in August 2023.

The selected sediment sample (B1-5) was obtained from the surface of the seabed, at the east end of Berth 1. The sample was selected based on the relatively high percentage of fine grained particles (i.e., silts and clays), in comparison to the other sediment samples recovered. The higher percentage of fines within the sample was considered a conservative approach as these particles are expected to settle slower and remain in suspension for a longer period of time compared to coarser material (i.e., sands and gravels).

The rock core was obtained from a terrestrial borehole at the north end of The Esplanade. The depth of sample correlates with the dredge depth and similar material is expected to be encountered in the dredge footprint. Dredging activities are expected to crush the rock and generate fines. To produce a sample containing sand size and finer grained particles, the rock was crushed using a ring mill. The sample was then sieved to 150µm, to remove particles that would settle relatively quickly.

The PSD and moisture content for B1-5 was based on the findings of the laboratory analysis conducted for SLR in April 2024. The PSD is based on a combination of sieve and hydrometer analysis. The PSD for the crushed rock (BH-01OS) was undertaken using the Mastersizer 2000. The particle size was based on a representative dried sampled.

A summary of the samples used for testing are provided in **Table 1-2** and the PSD is provided in **Figure 1-2.** The locations where these samples were recovered from are shown in **Figure 1-3**.

Table 1-2: Summary of samples tested.

ID	Depth	Sediment Unit	Geology Description	Moisture Content (%)	% Particle Size[2]			
					Clay	Silt	Sand	Gravel
B1-5 [3]	0 to 0.2 m below bed	Assumed Marine Deposit	Sandy SILT: Fine to medium grained, dark brown	46.8	18	47	34	1
BH-01OS [4]	14.5 to 14.7 m below ground level (-12.6 to -12.8 m RL[1])	Tamala Limestone	CALCARENITE: fine to medium grained, pale grey, trace gravels, fine to medium grained, sub-rounded, various lithology, trace shell fragments.	0	14	40	46	-

[1]RL – Reduced Level datum
[2]Percentage particle size classification based on AS 1726:2017: Clay = <0.02 mm; Silt = 0.02-0.75mm; Sand = 0.75-2.36mm; Gravel = >2.36mm[2]
[3]PSD determined from NATA Laboratory PSD analysis for SLR. Geological description by RHDHV.
[4]PSD for the rock determine using Mastersizer 2000 for particles <150 um. Geology description from BG&E Geotechnical Factual Report (2023)

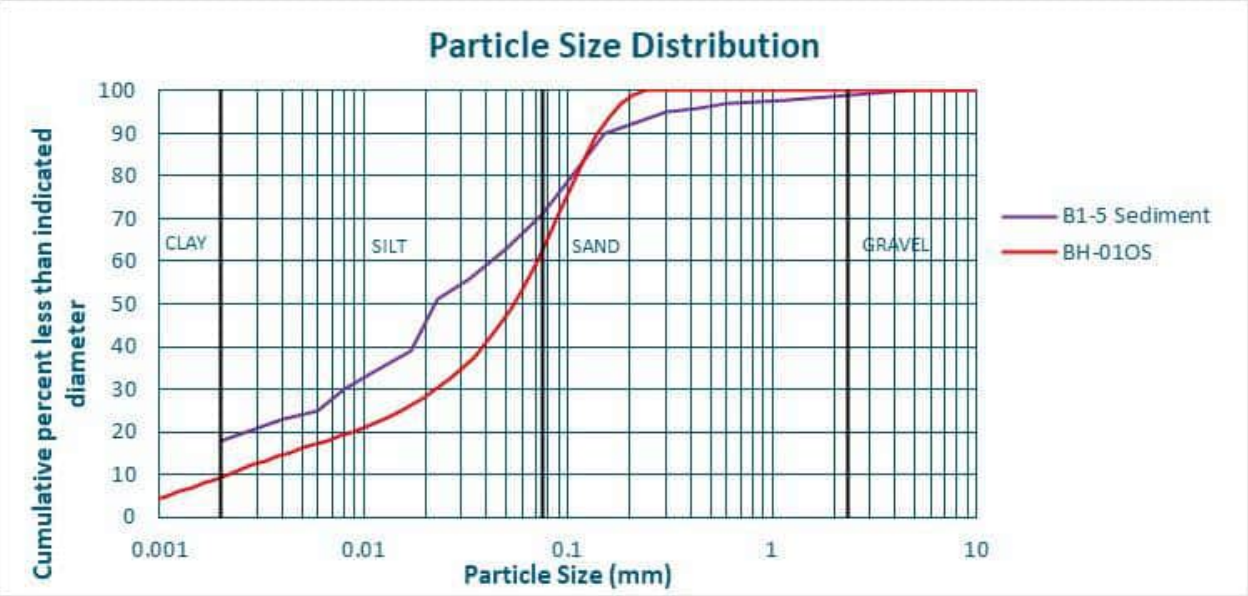


Figure 1-2: Sediment unit particle size distribution.

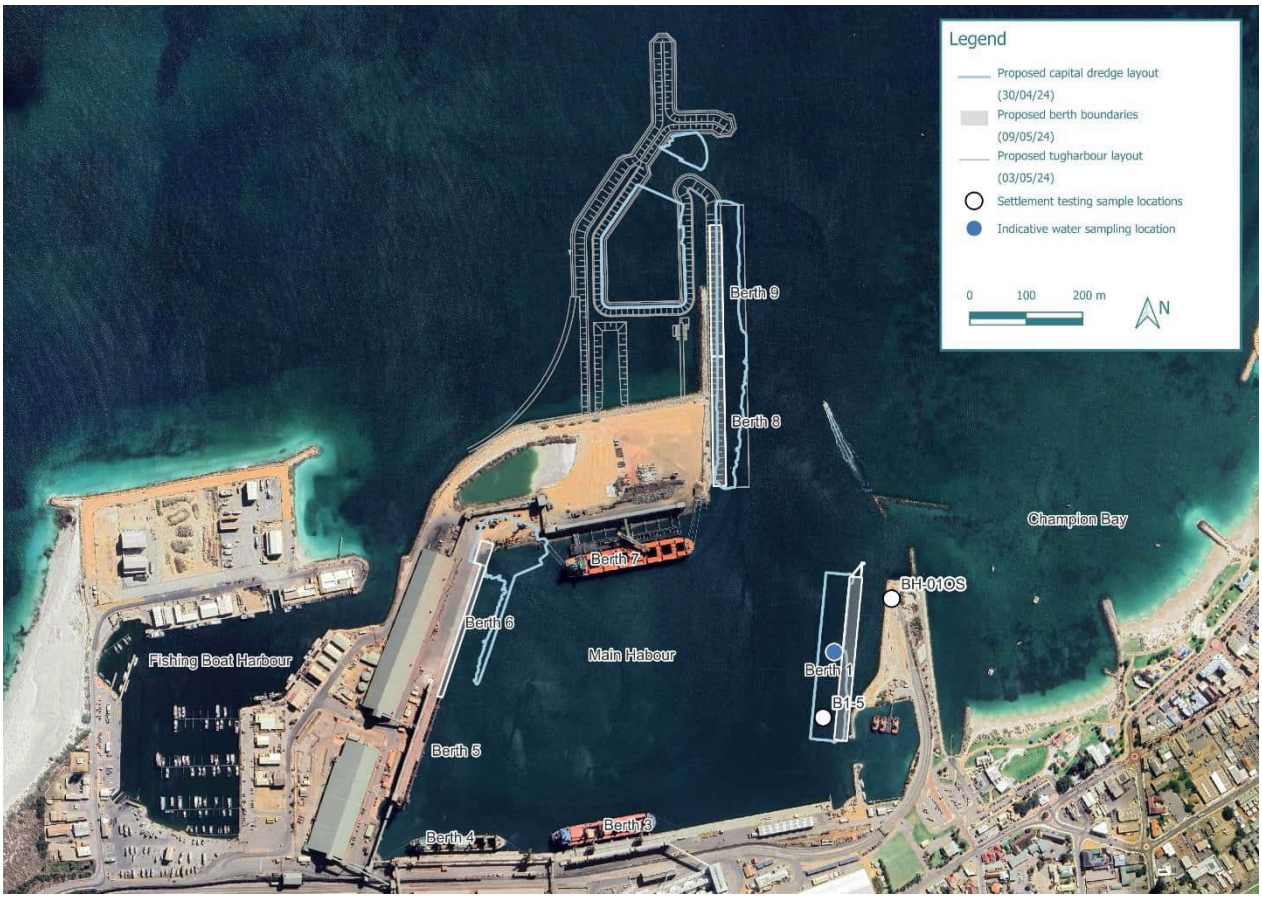


Figure 1-3: Sediment and rock sampling locations recovered by SLR (2024) and BG&E (2023), respectively. Noting water sample location used for comparative testing with Sydney Harbour water (refer below for detail) was collected from within Berth 1.

1.5.2 Water Source and Characteristics

Ambient water properties such as pH, temperature, ionic strength, and concentration of dissolved salts can influence settling behaviour of sediment. As such, conducting testing using site seawater or representative seawater is preferable.

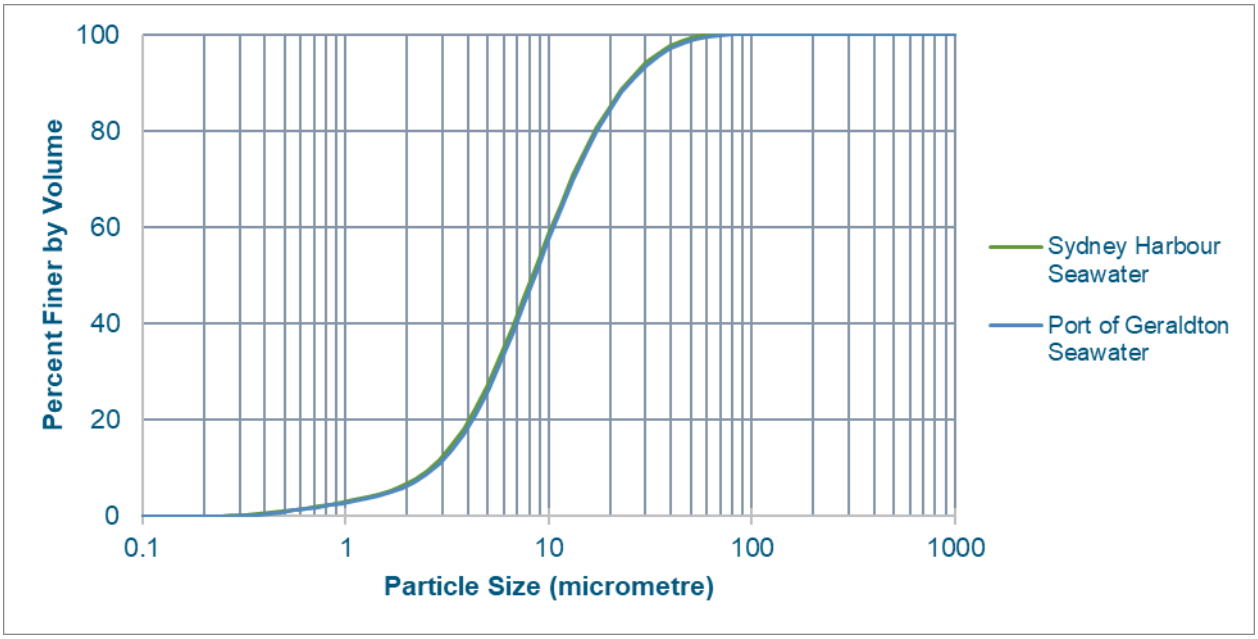
Due to logistical constraints in transporting large quantities of site water from the Port to Sydney, it was hypothesized that Sydney Harbour seawater would exhibit similar properties and yield suitable results. To validate this assumption, a comparative assessment of water collected from the Port (Berth 1) and water collected from Sydney Harbour (Balmoral Beach) was conducted. The comparative assessment included a visual inspection, measurement of physicochemical parameters using a YSI ProDSS multiparameter meter and critical particle size analysis of site sediment (B1-5) mixed individually with seawater from the Port and Sydney Harbour .

A summary of the physico-chemical parameters of the water from Sydney Harbour and the Port are provided in **Table 1-3**. Based on the similarity of physicochemical parameters measured, particle size distribution result discussed below and visual settling observations, the water from Sydney Harbour was deemed to be suitable for the laboratory analysis and does not impact settling velocities. The slightly lower specific conductivity and electrical conductivity is due to reduced salinity, which is likely linked to the rainfall event, 4 days prior to sampling of water in Sydney Harbour.

The critical particle size analysis was undertaken using the standard procedure outlined in **Section 2.4**. The 1L columns were filled with water from the Port and Sydney Harbour and 2.3g of site sediment (B1-5). The duration of the tests was 15 minutes. **Graph 1-1** presents the PSD graph for the two tests. Photographs illustrating the settling process, over a 1 hour period, are also presented in **Figure 1-4**, noting a 200mL sample was collected for critical particle size analysis at the 15 minute mark. The PSDs of the turbid sample using the Port and Sydney Harbour water are near identical for B1-5 and the maximum difference in the measured percent finer by volume for each discrete particle size reported was less than 1.4%. Further, there is negligible visual difference in settling behaviour and turbidity over 1-hour.

Table 1-3: Summary of collection details and comparative assessment between seawater recovered from Sydney Harbour and the Port.

Sample details	Unit	Sydney Harbour Seawater	Port of Geraldton Seawater
Sample location	-	Balmoral Beach Jetty	Berth 1
Sample date	-	18-06-24	20-05-24
Sample time	-	2:00 PM	1:10 PM
Tide	-	Flooding mid tide 1.1 m	Ebbing approaching low tide 0.7 m
Rainfall in the 48 hrs preceding (BoM)	mm	0.6mm. 74mm recorded 4 days prior to sampling.	0.0
Rainfall station	-	Sydney Botanic Gardens (066006)	Geraldton Town (008050)
Physico-chemical parameters			
Temperature at time of testing	Deg C	13.4	13.3
Dissolved Oxygen	%RTB	99	100
Specific Conductivity	µs/cm	51331	54861
Electrical Conductivity	µs/cm	39995	42609
pH	pH units	7.88	7.91
Redox Potential	mV	171.9	175.38
Turbidity	NTU	1.32	1.34



Graph 1-1: Comparison of PSD results for site sediment (B1-5) separately mixed with seawater from the Port and Sydney Harbour in 1L cylinders and left to settle for 15 minutes. Sample extracted 70mm below the water surface.

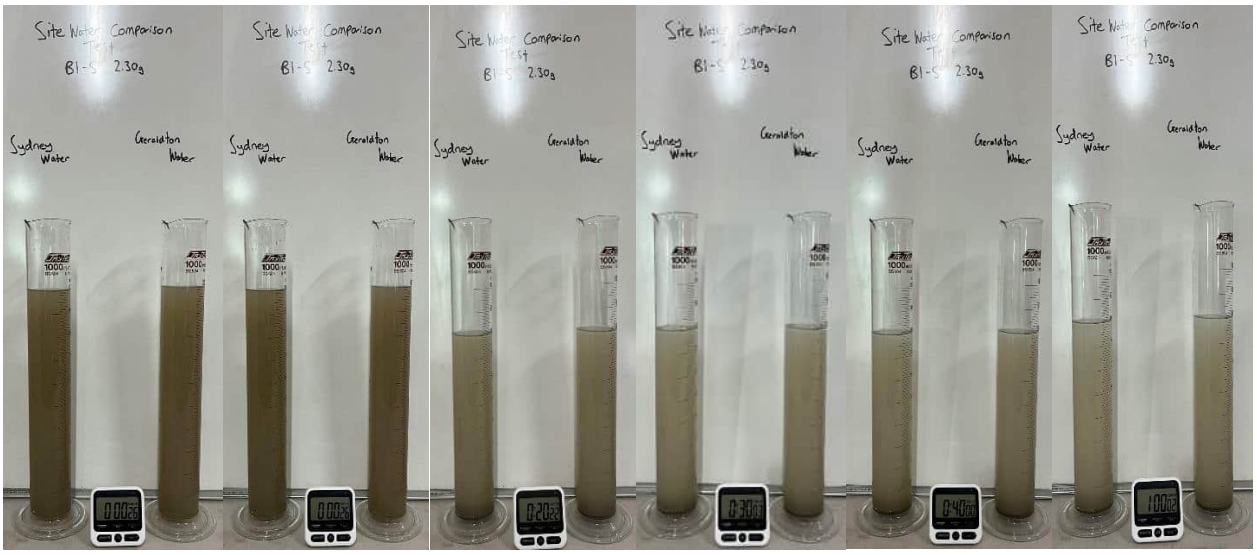


Figure 1-4: Visual comparison of Sydney Harbour seawater vs the Port seawater, noting a 200 ml sample was collected for critical particle size analysis at the 15 minute mark

2 Methodology

2.1 Sample Preparation

The sample preparation methodology for the detailed settlement tests was designed to ensure the generation of repeatable and reliable results. The preparation method between B1-5 and BH-01OS varied due to the nature of each sample:

- Sediment recovered from B1-5 was thoroughly homogenised in a stainless-steel bowl by hand using nitrile gloves and mixing spoons. Any gravel and shells were removed from the sample as testing was primarily focused on fine grained particles (i.e., silts and clays).
- The rock core sample from BH-01OS was broken down into fine-grained crushed rock for laboratory testing using a hammer, jaw crusher and a ring mill. Cores were placed in heavy duty plastic bags and broken into cobble-sized fragments using a hammer. The sample was then further pulverised using a mechanic jaw crusher followed by a ring mill where it was passed through a 150µm sieve to remove any coarse grain gravels and shells. The sample was thoroughly mixed to create a uniform sample.

Following sediment homogenisation and rock crushing as described above, the next steps for sample preparation varied based on the nature and objective of each test (i.e., TSS/NTU relationship and critical particle size analysis). Further sample preparation methods for each test are detailed in **Section 2.3** and **Section 2.4.**

2.2 Preliminary Sample Mass Sensitivity Test

Sample mass sensitivity testing was conducted on B1-5 to determine the optimal sample mass required for running the critical particle size analysis tests for the maximum duration, without experiencing hindered and zone settling regimes or samples with insufficient turbidity to analyse in the Mastersizer 2000.

The test involved filling five 1L cylinders with sediment slurry of different raw sample mass (2g, 5g, 10g, 30g, 100g) and representative seawater obtained from Sydney Harbour. Each cylinder was fully agitated by capping the top and shaking the cylinders until a uniform slurry is visible inside the cylinders. A photograph captured immediately following agitation of the cylinders is shown in **Figure 2-1**.

The test was run for 120 minutes and observations were made on the settling behaviours of each cylinder. A 200mL sample was also collected after approximately 55 minutes to determine which sample mass presented the slowest settling regime and to confirm whether sufficient obscuration[1] was achieved in the Mastersizer 2000. The sampling involved gently lowering a glass pipette into the cylinder, approximately 70mm below the water surface (i.e., 800mL line on the 1L cylinder), and extracting 200mL of the turbid sample.

[1] *Obscuration is a measure of the concentration of particles within the system.*

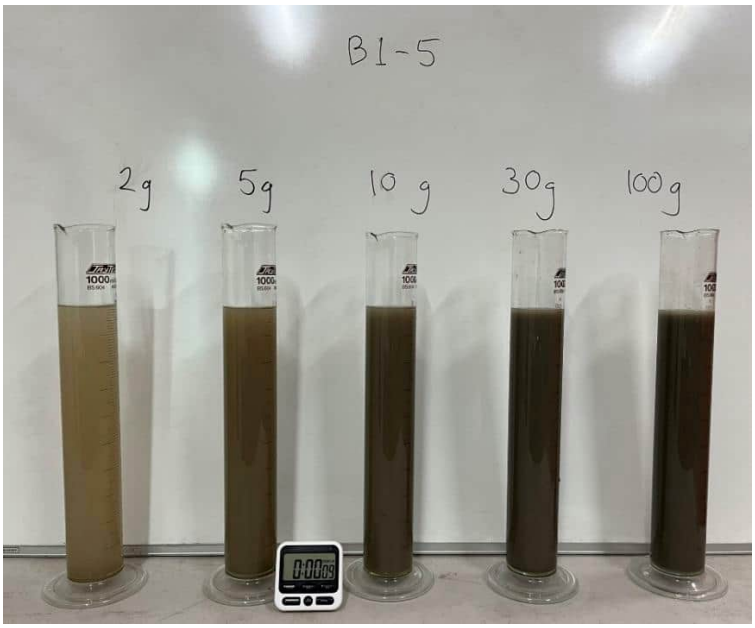


Figure 2-1: Photograph immediately following agitation.

2.3 TSS-Turbidity Relationship Column Test

The tests to establish TSS-turbidity relationships were based on recommendations outlined in the US Army Corps of Engineers guidelines “Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring” (Thackston and Palermo, 2000). This guideline recommends specific procedures to develop TSS-turbidity relationships for three distinct areas related to field monitoring:

1. monitoring suspended solids during less intensive methods of dredging (e.g., BHD) and open-water dredged-material placement. The ‘Column Test’ procedure is recommended for this type of monitoring;
2. monitoring suspended solids in the effluent discharge from sedimentation ponds. The ‘Column Test’ procedure is recommended for this type of monitoring; and,
3. monitoring re-suspension of solids in the immediate vicinity of sediment disturbance (e.g. adjacent to dredge cutter heads). The ‘Dilution Test’ procedure is recommended for this type of monitoring.

Given the investigation is assessing less intensive methods of dredging (e.g., BHD) and varying placement methods including reclamation in settling basins or within a bunded area, the Column Test procedure is considered to be most appropriate (i.e., Item 1 and 2 above).

Column tests were carried out in large settling columns with a diameter of 200mm and an overall height of 2000mm to minimise the ‘wall effects’ of the column sides on settling behaviour. The Column Test methodology was based on the method outlined in Thackston and Palermo (2000).

1. Filling the column with 40L of clean representative seawater from the Sydney Harbour.
2. Subsampling the sediment from the homogenised primary sample B1-5 and mixing approximately 200g into a slurry with seawater using hands with nitrile gloves, mixing spoons and an electric paddle stirrer to remove any large visible clumps of material. Similarly, 200g of the crushed down and sieved rock sample BH-01OS was mixed with seawater using mixing spoons and an electric paddle stirrer to remove any large visible clumps of material.
3. Place the sediment slurry and rock slurry into separate 200L columns. The weight of each sediment unit placed into the column varied depending on the amount needed to reach a desired upper surface turbidity level of approximately 250 NTU in the column following agitation.

4. Agitate the slurry/ water mixtures until uniform mixing throughout the column/s and a surface turbidity of around 250 NTU was achieved.
5. Measure surface turbidity inside the column/s with a YSI ProDSS meter by submerging 3cm below the water surface. The depth of 3cm was selected as this corresponded to a marking on the turbidity probe, which ensured consistency in the depth of measurement.
6. Collect a 750mL sample from 3cm below the water surface by submerging a plastic beaker into the column/s.
7. Decant approximately 80mL of the sample from each column into a 100mL container housed within a black box and measure turbidity. The purpose of this step was to replicate the measurement environment used for calibration the probe to ensure accurate readings are achieved.
8. Decant a sub-sample into a plastic laboratory supplied sample container for TSS and turbidity analysis, and another sub-sample into a 500mL clear plastic jar for future visualisation. Excess water following the subsampling was not introduced back into the column to avoid re-agitation of the mixture. Extracted samples were sent to a NATA-accredited laboratory for TSS and NTU analysis.
9. Repeat Steps 5 to 8 at periodic time intervals for determination of turbidity and TSS. Frequent measurements were required initially when rapid change was occurring, with increasing time interval between measurements as the test progresses. Samples were collected until the turbidity decreased to low levels. The subsampling beaker and calibration container was rinsed with Sydney tap water between each sampling interval.
10. Collect a photograph of the column at each measurement time and recording any observations within the column during the test (e.g., height of stratification layer(s)).

Figure 2-2 provides a photographic summary of several key components of the testing methodology and settling columns in use for each sediment sample immediately following agitation of the sediment/ water mixture.



Figure 2-2: Photographic summary of the core components of the Column Test methodology Settling columns used for TSS-NTU column test immediately after agitation (Left: B1-5 sediment. Right: BH-01OS crushed rock).

2.4 Critical Particle Size Analysis

The procedure for the critical particle size analysis aimed to establish the PSD of suspended sediment within the water column at various time intervals during dredging and disposal activities, in addition to the determination of the particle size in suspension used to estimate settling velocity and support modelling efforts.

Critical particle size analysis was undertaken with a Mastersizer 2000. The Mastersizer 2000 establishes the particle size distribution based on the difference in refraction between the dispersant and the suspended sediment sample. This instrument is sensitive to the reflective and refractive properties of particles and concentration of suspended particles (i.e., TSS). Both the sediment sample (B1-5) and crushed rock sample (BH-01OS) were analysed.

As detailed in **Section 2.2** and **Section 3.1**, the mass of sample used for critical particle size analysis was based on the sample mass sensitivity test. The raw sample mass was selected at 2g of dry fines, which equated to a higher actual mass when accounting for the moisture content reported in B1-5 (sediment) and the PSD of both B1-5 and BH-01OS (noting that some particles were larger than fines). A summary of the sample mass used for each critical particle size analysis test is provided in **Table 2-1**.

Table 2-1: Sample mass calculated for each sample.

Sample ID	% Fines	Moisture Content (%)	Sample Mass for critical particle size analysis (g)
B1-5	65	46.8	4.52
BH-01OS	59	0	3.38

The methodology for critical particle size analysis conducted on each sample was as follows, established internally based on experience:

1. Prepare four subsamples of the B1-5 sediment unit from the homogenised primary sample and four subsamples of the BH-01OS rock unit from the oven dried and sieved (150 µm) primary sample. Samples were weighed with scientific scales to ensure accuracy within 2 decimal places. The raw mass of each subsample was based on the calculated masses provided shown in **Table 2-1**.
2. Create a slurry using the representative seawater. Mix the slurry using hands with nitrile gloves, mixing spoons and an electric paddle stirrer to remove any large visible clumps of material.
3. Fill four 1L glass measuring cylinders with the sediment slurry and four with the rock slurry. Then ass add seawater until the 1L measurement line is reached. The four separate cylinders for each unit are required to obtain information regarding critical particle size in suspension at time intervals of 10 minutes, 20 minutes, 30 minutes and 60 minutes. The selected intervals were based on results of the preliminary mass sensitivity tests whereby there was an insufficient amount of suspended of material to accurately run critical particle size analysis after 60 minutes.
4. Agitate the sediment/ water mixture and crushed rock/ water mixture inside the columns by capping the top and inverting the cylinders until a uniform slurry is visible inside the columns. It's noted that the tests for B1-5 and BH-01OS were completed at different times to reduce the amount of subsampling required at each subsampling time interval.
5. Start a timer following agitation of the cylinders.
6. Extract a sample of approximately 200mL of turbid water via a pipette and place the sample into a clean glass beaker. Samples were extracted from approximately 70mm below the water surface and 230mm below the water surface at the required time intervals of 10 minutes, 20 minutes, 30 minutes and 60 minutes.
7. Analysing the particle size distribution of suspended sediment with the Mastersizer 2000. The method for analysis with the Mastersizer 2000 was as follows:
    a. Clean the Mastersizer 2000 prior to each test with Sydney tap water.
    b. Pour a dispersant into the mixing basin of the Mastersizer 2000 and recording the background refraction of the dispersant. The dispersant was representative seawater obtained from the same source as that used to fill the 1L columns in Step 3.
    c. Ensure the suspended sediment sample in the beaker is fully agitated by mixing with an electric paddle stirrer.
    d. Add the suspended sediment/ crushed rock slurry subsample to the mixing basin of the Mastersizer 2000 (with the dispersant). Subsamples were added until an obscuration[2] of 5 to 10% was achieved.

To ensure repeatability and reliability of results from the Mastersizer 2000, a known sediment standard of 150 to 180µm was analysed at the start of each day of analysis.

The General-Purpose model based on the Mie Theory (Malvern Instruments, 2007) was adopted for particle size analysis with the Mastersizer 2000. The particle properties adopted for the sediment were:

[2]*Obscuration is a measure of the concentration of particles within the system.*

- Refractive index – 1.52 (default).
- Absorption – 2.

The refractive index for representative seawater (Sydney Harbour seawater) and the Port seawater (refer **Section 1.5.2**) was adopted as the default value of 1.33.

2.5 Quality Assurance/ Quality Control (QA/QC)

The various detailed tests undertaken as part of this works package were devised and refined in order to develop a laboratory investigation that was considered:

- Valid - to ensure the results satisfactorily address the aims of the experiment; and
- Reliable - to ensure the tests are repeatable.

To ensure the results from the column tests and critical particle size analysis were valid and reliable, several QA/QC tests were conducted. These included:

Column Test:

- analyse one intra-laboratory aliquot (split) sample from one test at a random measurement interval to assess the variability of the sample matrix.
- analyse one inter-laboratory aliquot (split) sample from one test taken at a random measurement interval and analysed for TSS and NTU at a second NATA accredited laboratory to assess the comparability of results between NATA accredited laboratories.
- undertake NTU analysis at a NATA accredited laboratory on all subsamples collected during the column test to validate the accuracy of YSI ProDSS turbidity probe.
- assessment of ALS laboratory QA/QC results to evaluate the validity of their TSS and NTU results, including:
    - holding time compliance;
    - laboratory duplicates;
    - laboratory controls; and,
    - method blanks.

Calibration of the YSI ProDSS probe was undertaken by the supplier (Air-Met Scientific) prior to the investigation and by RHDHV prior to running the column tests. The Air-Met Scientific calibration certificate and RHDHV calibration log is provided in **Appendix C**.

Critical Particle Size Analysis:

- validate the Mastersizer 2000 by determining the particle size distribution of a known standard.
- analyse one aliquot (split) turbid water sample extracted from the B1-5 test at a single time interval to assess the repeatability of the critical particle size analysis and calculation of particle fall velocity.
- duplicate the critical particle size analysis test on separate columns for both tests (B1-5 and BH-01OS) at a single time interval to assess the reliability of the sample preparation and testing methods.

Further detail on the QA/QC methodology and results is provided in **Appendix C**. A summary of the QA/QC results is provided in **Section 3.3**.

It is noted that the critical particle size analysis was undertaken using laser techniques, which can produce different results compared to conventional mechanical sieving and hydrometer methods.

3 Analysis of Results

The laboratory investigations commenced on 19 June 2024. The final test concluded on 3 July 2024. Results from the investigations are provided in **Section 3.1** to **Section 3.3**.

3.1 Preliminary Sample Mass Sensitivity Test

The 2g, 5g and 10g samples showed gradual clarification over the approximate 120 minute test period. Gradual clarification of the upper layer was also evident in the 30g and 100g samples. However, in the 30g and 100g samples, clarification occurred above a stratified layer of higher turbidity. Out of the 5 columns, the 30g sample had visibly higher turbidity near the surface compared to the other columns after approximately 120 minutes.

The 30g sample formed a relatively thin and deep stratification layer soon after the test began, whilst the 100g sample formed a more defined stratification layer, indicating stratification became more pronounced with increasing sample mass and TSS. The 100g sample settled as a zone, with a slightly turbid upper layer similar in clarity to the 5g and 10g sample at the completion of the test.

The 2g, 5g and 10g tests were sampled from 70mm below the surface after approximately 55 minutes and analysed in the Mastersizer 2000 to ascertain whether adequate obscuration[3] was achieved. This was undertaken to determine whether the concentration of particles in suspension was sufficient for completing a valid test. The 2g, 5g and 10g samples all reported an obscuration within the set range of 5-10% after 55 minutes.

Based on the preliminary test, the 2g sample of fines was deemed the most suitable for critical particle size analysis testing to achieve the longest possible test period, whilst avoiding any potential hindered or zone settling effects from increased sample mass.

Photographs taken at regular time intervals following agitation of material are shown in **Figure 3-1.**

Further discussion of these observations, including individual particle settlement and hindered/zone settlement is provided in **Section 4.5.3**.

[3] *Obscuration is a measure of the concentration of particles within the system.*

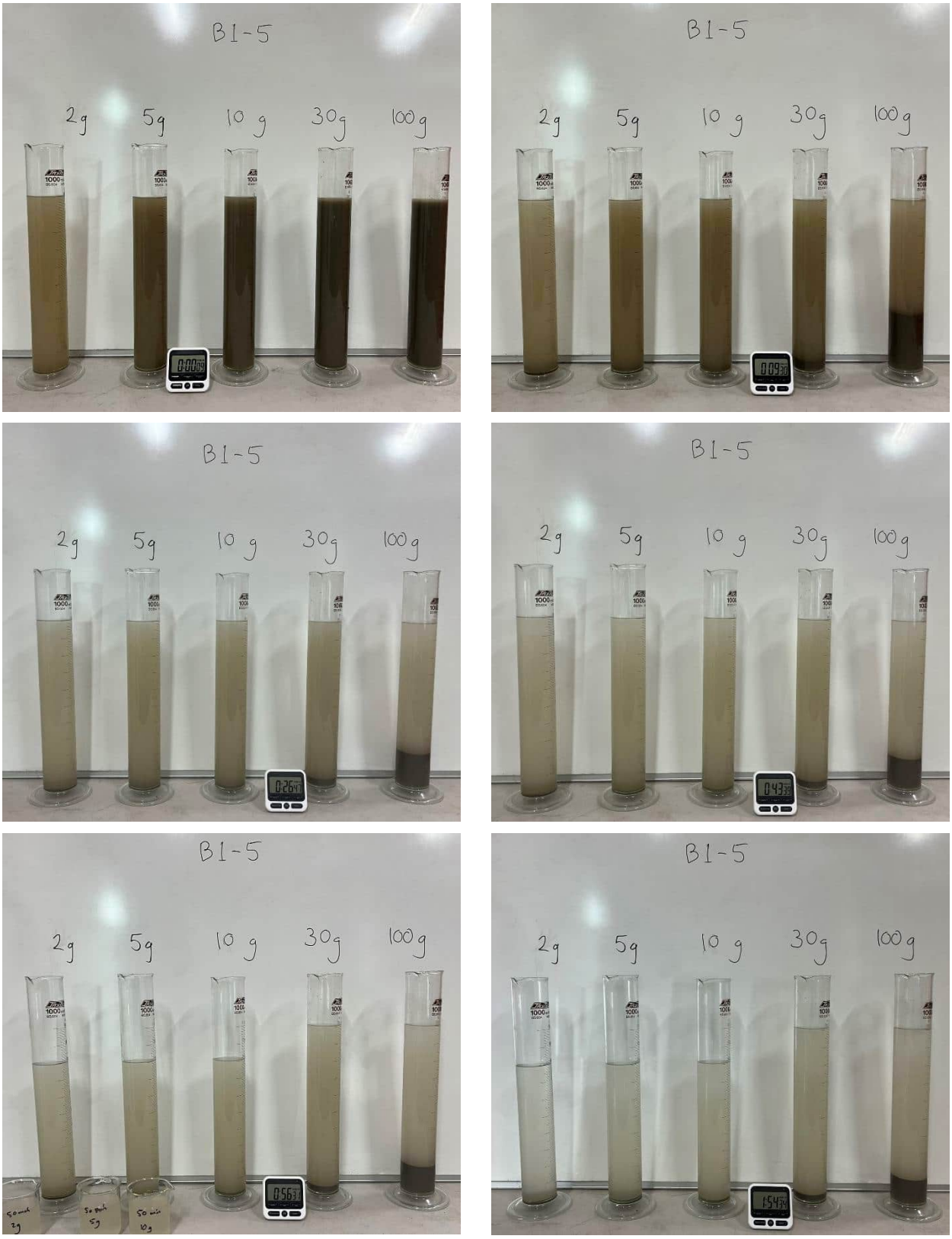


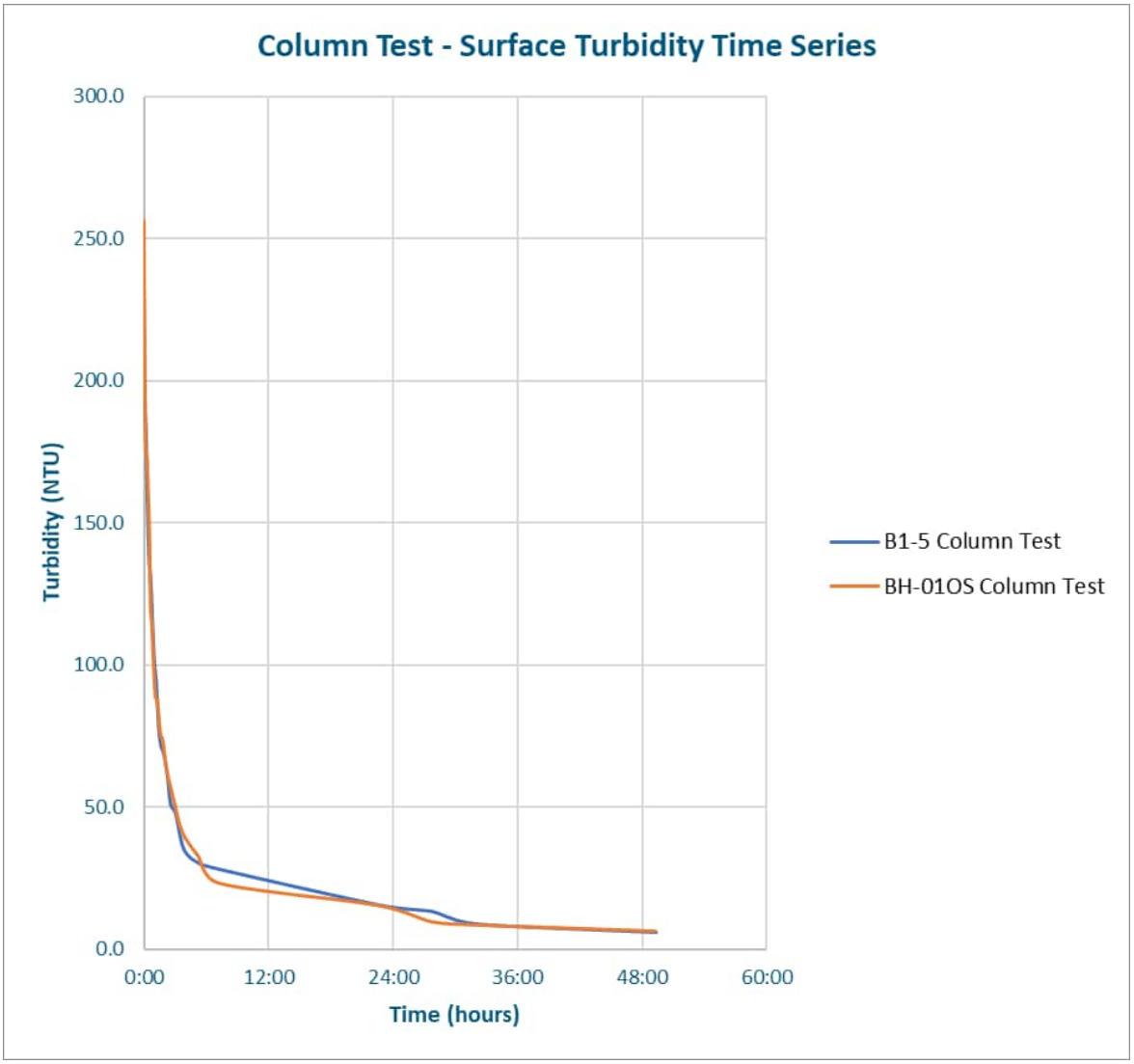
Figure 3-1: Photographs at discrete time intervals during the preliminary mass sensitivity test. Mass of sediment in the columns from left to right was 2g, 5g, 10g, 30g and 100g. Note: 200mL of sediment extracted from 70mm below the water surface after 55 minutes.

3.2 Detailed Tests

Detailed column and critical particle size analysis test results are presented in **Appendix A (B1-5) and Appendix B (BH-01OS)**. A summary of the column and critical particle size analysis test results is provided in **Section 3.2.1** and **Section 3.2.2**, respectively.

3.2.1 Column Test to Derive TSS-Turbidity Relationship

A summary of the surface turbidity results measured during the column tests is provided in **Graph 3-1**. Immediately following agitation and mixing of the columns, surface turbidity varied between approximately 200 and 250 NTU. Surface turbidity decreased rapidly over the initial 4 hours to approximately 35 to 40 NTU for both samples. After 4 hours, the reduction in surface turbidity was relatively linear, reducing to approximately 6 NTU after 49 hours when the test was concluded.



Graph 3-1: Surface turbidity measured during the column tests.

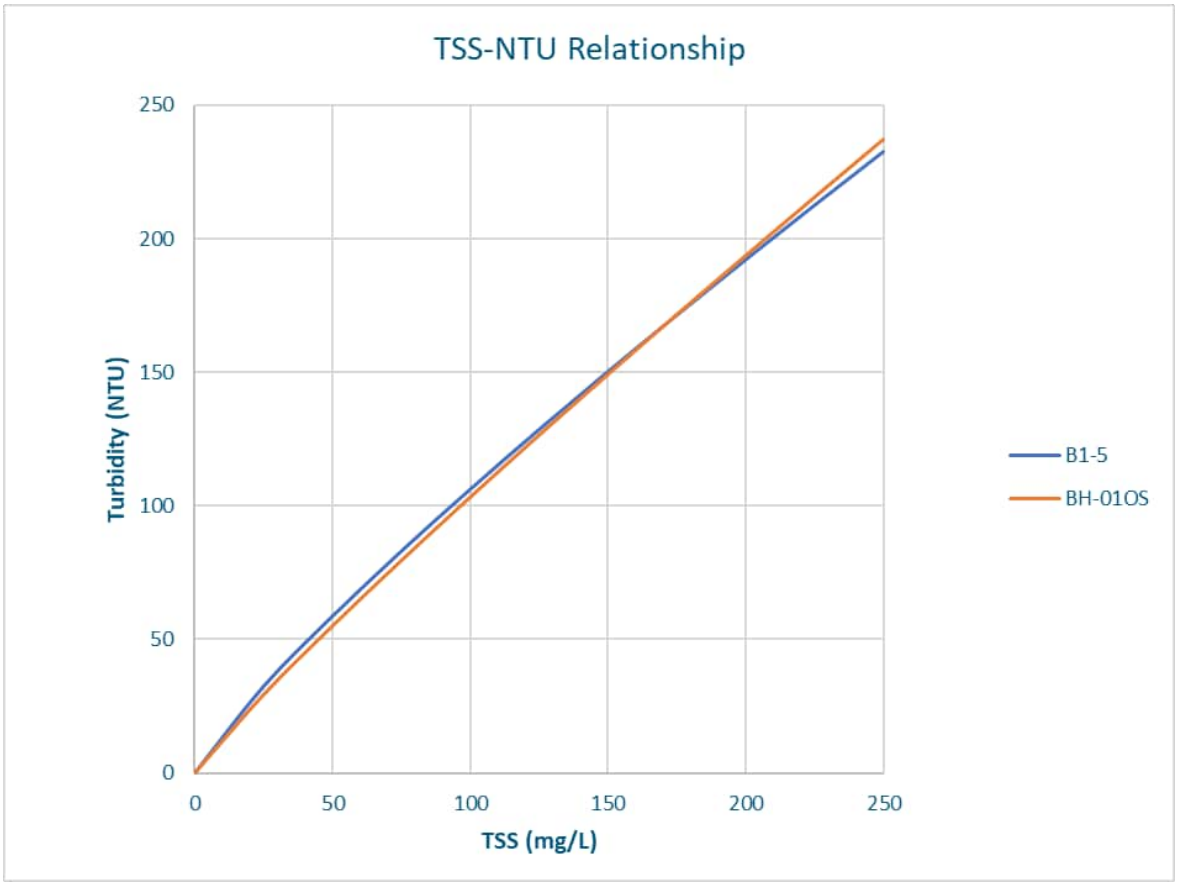
Sub-samples were taken from the settling columns at varying time intervals throughout each column test for turbidity and TSS analysis. It should be noted that the surface turbidity results during the column tests shown in **Graph 3-1** were likely influenced by the ongoing sub-sampling activity and, in addition, the progressive removal of surface water and suspended sediment for laboratory analysis would have

artificially modified the settlement profile inside the column by reducing the depth of the upper clarifying layer.

A summary of the TSS-turbidity relationships determined for each sediment sample is provided in **Table 3-1**, including the turbidity values equivalent to a TSS concentration of 50 mg/L for each relationship. The selected TSS value of 50 mg/L is based on the water quality criterion commonly adopted for major marine construction projects. However, the water quality criterion for the project has not yet been defined and may vary. The trendlines corresponding to the line of best fit through the datasets are provided in **Graph 3-2**. The high R^2 values indicate a good fit between each dataset and the respective trendlines.

Table 3-1: Summary of TSS-turbidity relationships for the sediment and crushed rock samples.

Test ID	Material Origin	Number of values	Trendline of Best Fit through Dataset – Power Function	R^2 value	Turbidity (NTU) equivalent to 50 mg/L TSS
B1-5	Marine Deposit	22 (including 1 values with TSS < 5mg/L)	$y = 2.0684x^{0.8552}$	0.98	59
BH-01OS	Tamala Limestone	22 (including 1 values with TSS < 5mg/L)	$y = 1.5843x^{0.9072}$	0.96	55



Graph 3-2: Trendline of best fit through datasets from the column test - Power Function.

More than 20 samples were collected for each test, as recommended by Thackston and Palermo (2000). The power function was determined to provide a suitable trendline for the datasets. High R^2 values were associated with the power function relationships (0.96 to 0.98), which indicates a good fit between each dataset and the respective trendlines. Turbidity is correlated to TSS and the trendline would provide a reasonable prediction of turbidity for a given TSS concentration or vice versa. Linear functions

were also determined for the dataset and presented similar R^2 values. However, the power trendline provided a better visual fit of the data points compared to the linear trendline for both B1-5 and BH-01OS, as graphed in **Appendix A** and **Appendix B**, respectively.

The turbidity values, equivalent to 50 mg/L suspended solids were similar for both the sediment (B1-5) and crushed rock (BH-01OS), equating to 59 NTU and 55 NTU respectively.

Overall, TSS-turbidity data collected during the column tests is considered to be reliable for the purpose of establishing a preliminary relationship between TSS and NTU. However, collection of field TSS-NTU data during dredging is recommended so that the relationships between turbidity and suspended solids can be continually validated and improved.

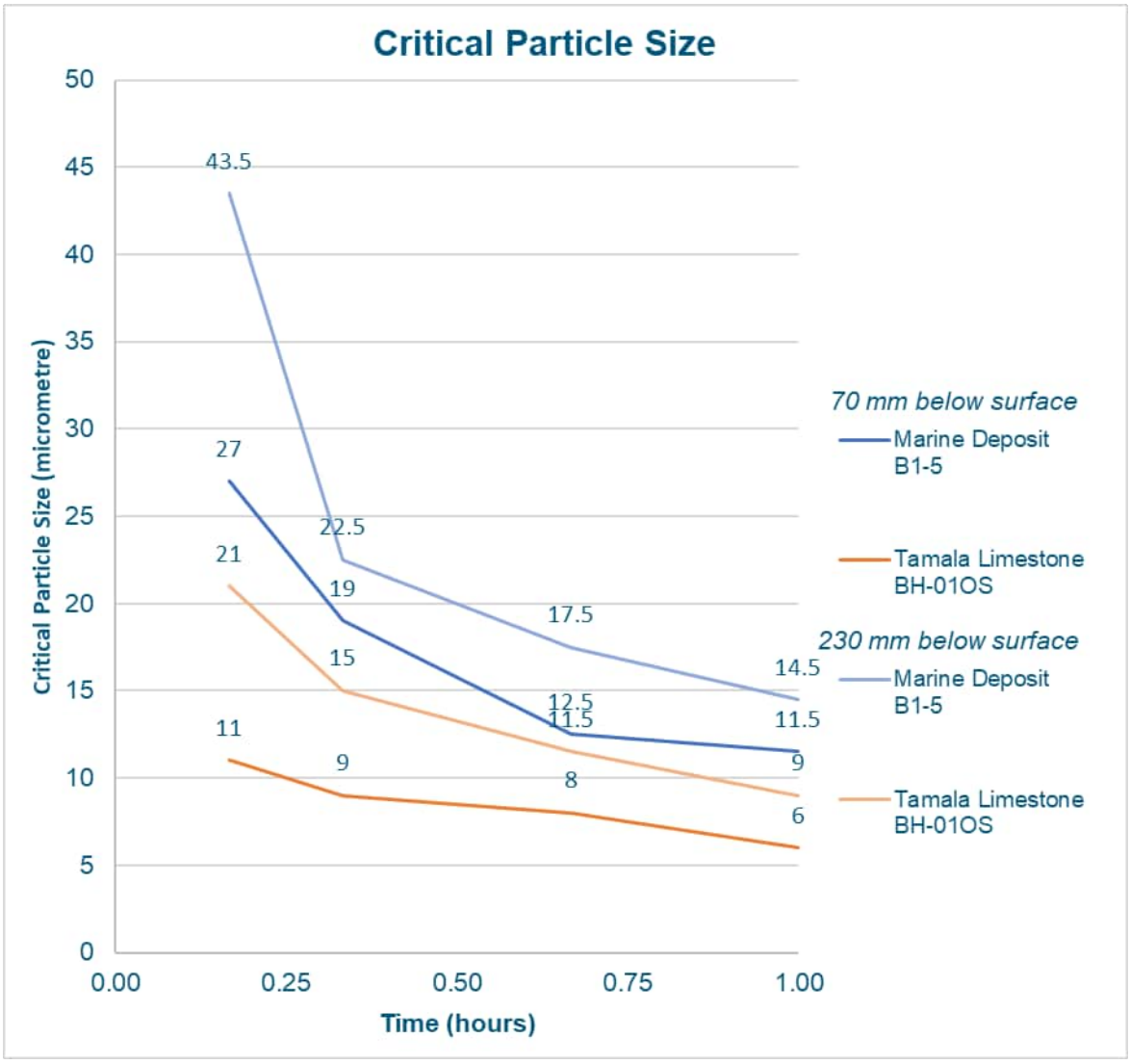
3.2.2 Critical Particle Size Analysis

Results from the critical particle size analysis, indicating the D90 particle size in suspension at various time intervals, are provided in **Table 3-2** and shown in **Graph 3-3**. D90 is the particle diameter where ninety percent of the distribution has a smaller particle size.

In all tests, the D90 particle size and the overall PSD was coarser at greater depths within the water column. Further, the D90 particle size in suspension progressively decreased over time. This is to be expected based on theoretical settlement rates defined by Stokes Law where larger particles settle out of suspension faster than smaller particles.

Table 3-2: Tabulated summary of results from the critical particle size analysis (rounded to 0.5 µm).

Test Number	Depth below water surface	Time (minutes)			
		10	20	30	30
		D90 Particle Size in Suspension (µm)			
B1-5	70 mm below water surface	27.0	19.0	12.5	11.5
	230 mm below water surface	43.5	22.5	17.5	14.5
BH-01OS	70 mm below water surface	11.0	9.0	8.0	6.0
	230 mm below water surface	21.0	15.0	11.5	9.0



Graph 3-3: Visual summary of results from the critical particle size analysis.

Based on the D90 particle size in suspension, at a given depth and after a predefined time interval, the settling velocity can be calculated. The settling velocities calculated from the critical particle size analysis are provided in **Graph 3-4** along with theoretical settling velocities determined by Stokes Law for a seawater temperature of 13 °C. Water temperature was not monitored as part of the critical particle size analysis. However, the temperature would have been similar to the physico-chemical parameters reported in **Table 1-3**, which was 13.3-13.4°C. It should be noted that the water temperature at Geraldton is expected to be higher all year round, which would result in an increase in the settling velocity.

Settling velocity results indicates the crushed Tamala Limestone (BH-01OS) presents higher settling velocities than the marine deposit (B1-5). It is evident that the settling velocities determined from the critical particle size analysis results for the marine deposit sediment sample was generally slower than the theoretical settling velocity determined by Stokes Law, whilst the crushed Tamala Limestone settling velocities were similar to Stokes Law, albeit slightly higher with increased particle size.

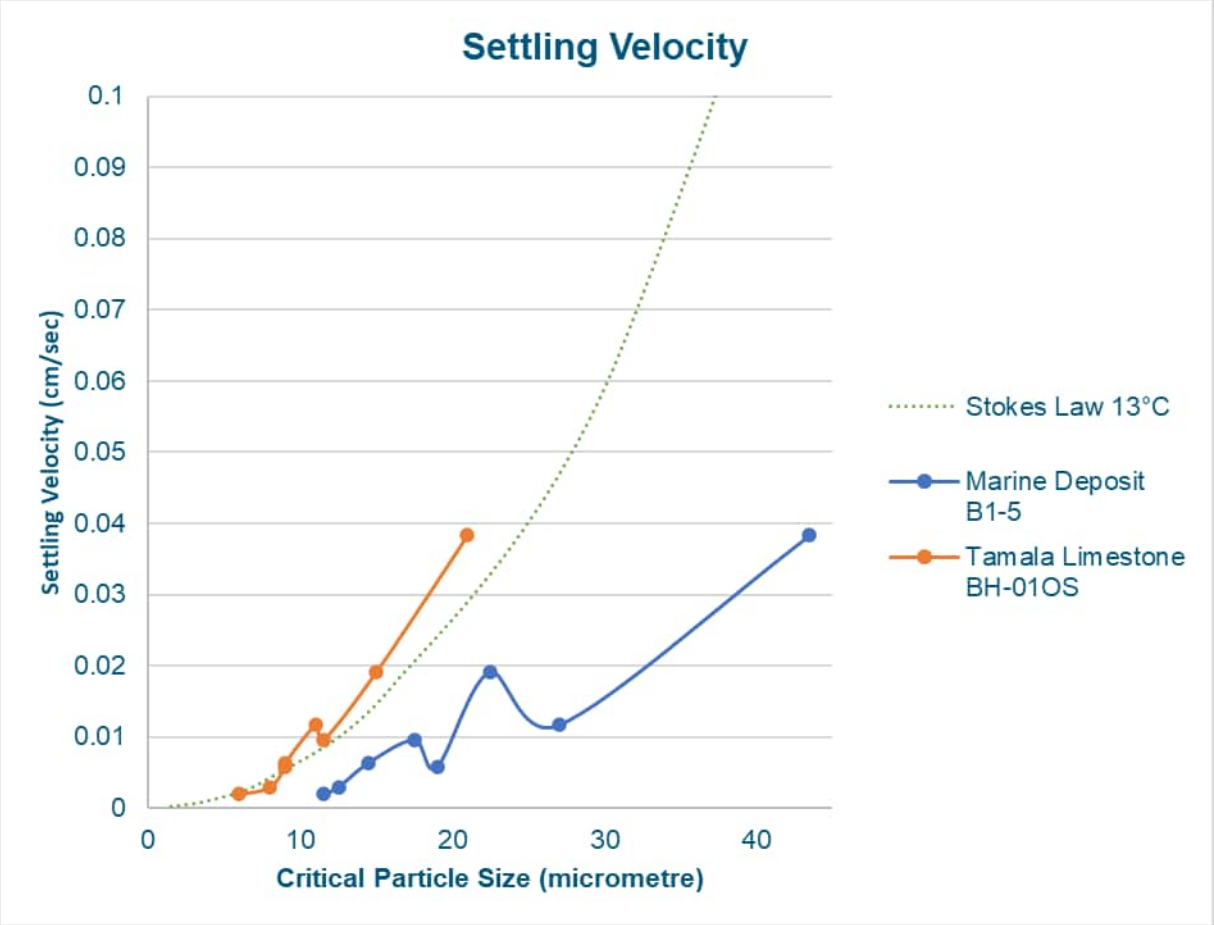
There is some uncertainty around:

1. selection of refractive index and absorption. The same refractive index and absorption were used for all samples as discussed in **Section 4.3.1**. BH-01OS was a light grey colour whereas B1-5

was a darker colour. Further, BH-01OS was a crushed rock sample, which may have comprised angular particles, compared to the marine sediment in B1-5. The light colour or surface texture of the sediment in BH-01OS may have altered the refractive index and absorption properties of the particles.

2. nature and behaviour of flocs. A detailed discussion is provided in **Section 4.5**. Based on the discussion, it is thought that the subsampling and analysis using Mastersizer 2000 resulted in floc breakage and the PSD reflects individual particles rather than flocs.

A discussion regarding Stokes Law and settling velocities is provided in **Section 4.6**.



Graph 3-4: Settling velocity calculated from the critical particle size analysis.

3.3 QA/QC Results Summary

A summary of the QA/QC results for the laboratory tests is provided in **Section 3.3.1** and **Section 3.3.2** below. Further detail on the QA/QC methodology and results is provided in **Appendix D**.

Overall, the results indicate that the equipment and methodology used in settlement tests and critical particle size analysis produces repeatable and reliable results that are suitable for interpretive use.

3.3.1 Column Test

QA/QC procedures for the column test comprised collecting sample duplicates to validate sampling methods, aliquots for measuring sample variability, and testing turbidity in all samples at ALS

Environmental to check the reliability of the turbidity probe used by RHDHV. An assessment of ALS Environmental' s QA/QC results was also conducted to check the reliability and validity of their results.

Aliquots
One RPD exceedance was reported for turbidity (NTU) in the B1-5 column test, which may have been a result of laboratory error (e.g. insufficient agitation of sample bottles prior to analysis) or heterogeneity of the sample matrix. However, all internal ALS aliquots were within reported data quality limits and intra-laboratory results were within acceptable limits for TSS. Based on the findings of these aliquot results presented above, the sample results are deemed reliable.

Turbidity Comparison
The RHDHV turbidity results gradually decreased during the test, with each sample extracted from the column generally yielding a lower turbidity. In contrast, the ALS turbidity results yielded variability, which did not align with the visual observations in the settling column. The variable ALS results may have been a result of laboratory error (e.g. insufficient agitation of sample bottles prior to analysis) or cementing of the particles over time within the sampling bottle. As such, turbidity in the TSS/NTU analysis was adopted based on the RHDHV measurements in the lab, to eliminate potential errors.

The YSI ProDSS probe was successfully calibrated prior to the column testing and measurements were taken in a controlled environment (i.e., the calibration rig) immediately after subsampling. Therefore, the variability between RHDHV and ALS turbidity results is not expected to impact the validity of the results.

ALS Laboratory QA/QC
No laboratory QA/QC issues were reported by ALS Environmental.

3.3.2 Critical Particle Size Analysis

Critical particle size analysis QA/QC comprised Mastersizer 2000 validation by measuring the PSD of a known standard, test duplication to check the reliability of the sample preparation and testing method, and aliquot testing to check the repeatability of the analysis.

Validation of Mastersizer 2000
PSD analysis of the laboratory standard conducted on each day of testing indicates that the Mastersizer 2000 produced consistent and near-identical measurements of the laboratory standard over various days. These results suggest that the Mastersizer 2000 produced reliable and repeatable measurements of sediment and crushed rock samples when used under normal operating conditions.

Duplicates
A duplicate test was undertaken for BH-01OS at the 40 minute time interval. The results indicate minimal difference between the PSD results for the primary and duplicate tests. The maximum difference in the measured cumulative percent finer by volume for each discrete particle size reported was less than 3%. The results were within acceptable limits and validate that the sample preparation and testing methodology used to conduct critical particle size analyses was repeatable and reliable.

Aliquot
Aliquot tests were undertaken for B1-5 (Marine Deposit) after 20 minutes and BH-01OS (Tamala Limestone) after 10 minutes at the lower sampling depth (230 mm below the water surface). The results indicate there is minimal difference between the PSD results for the primary and aliquot tests. The maximum difference in the measured percent finer by volume for each discrete particle size reported was less than 3.1%. The results were within acceptable limits and validate that the subsampling methodology used to conduct critical particle size analyses was repeatable and reliable.

4 Discussion and Limitations

A discussion of the results and limitations is provided herein. Limitations in the laboratory investigation arise due to assumptions adopted for the investigation and due to scale effects. The limitations of the laboratory investigation include:

- Representivity of Particle Size Distribution;
- Scale Effects;
- Measurement of Particle Diameter;
- Hydrodynamic Stability of Sediments.
- Coagulation, Flocculation and Settling Behaviour; and,
- Settling Velocity and Stokes Law.

The limitations are discussed in **Section 4.1** to **Section 4.6**.

4.1 Representivity of Particle Size Distribution

The particle size distribution which would be produced during dredging of the rock (by BHD) is not certain. The distribution of the particle sizes will not be known until dredging operations commence. However, it is expected that a proportion of fines would be produced. Accordingly, the rock sample was crushed to ensure rock fines could be tested in the laboratory.

The laboratory investigation did not consider crushed rock particle sizes coarser than 150µm (determined with a sieve) as they would settle out of suspension relatively quickly, with the settling velocity suitably predicted by Stokes Law. The sieved crushed rock sample used for the laboratory investigation is well graded and has a good representation of particle sizes from approximately 1µm (determined with the Mastersizer 2000) to 150µm (determined with a sieve screen), with approximately 50% of the particles coarser than 55µm.

The maximum particle size of the sieved crushed rock in the laboratory investigation (150 µm) is significantly smaller than the expected maximum particle size which would be produced during the dredging operations. This is not expected to influence the overall findings of the investigation, given that coarse crushed rock (i.e. greater than 75µm) would be expected to readily settle relatively quickly, in accordance with Stokes Law, following placement. Such material is unlikely to contribute to surface turbidity or elevated concentrations of TSS.

The PSD of the material to be dredged is based on a single sample of marine origin collected from the vibrocoring investigation (SLR, 2024) and single core segment of rock recovered from the geotechnical investigation (BG&E, 2023). This material was selected based on the high fines content (combined silt and clay sized fraction) relative to other materials expected to be dredged during the proposed works. However, it is noted that other material in the dredge footprint may behave slightly differently to the results and observations reported herein.

4.2 Scale Effects

As with all laboratory testing and small-scale physical modelling, it is necessary to consider scale effects. Scale effects are errors that can be introduced when the model input parameters and results are scaled up to prototype values when there is not complete similarity between the model and prototype. The laboratory testing herein adopted a scaled water column only. The fluid type and properties (seawater) and physical properties of the sediment and crushed rock were not scaled.

The water columns used for the laboratory testing are inert and as large as practical. The interaction between suspended solids and the wall of the column, referred to as the 'wall effect', can lead to inaccuracies in laboratory testing. Large diameter columns, used for determining the TSS/NTU relationship described herein, minimise the potential for wall effects. However, these effects are not completely eliminated. As a result of the 'wall effect', lower settlement rates may be encountered in the field, in comparison to the settlement rates observed during the laboratory investigations.

4.3 Measurement of Particle Diameter

Particle size analysis was undertaken using the Mastersizer 2000, which is a laser diffraction particle analyser. It is noted that the Mastersizer 2000 reports volume of material in each size 'bin' (discrete size range) whereas conventional sieve analysis (Australian Standard 1289.3.6.1-2009) and hydrometer particle size methods (Australian Standard 1289.3.6.3-2003) report 'mass of material' in each 'bin'.

Conventional sieve methods and laser particle sizing may report different gradings for the same material depending on the shape of the particles. Elongated particles, such as those shown in **Figure 4-1**, may pass through a sieve screen lengthwise and would be reported as a lesser particle size. However, depending on the orientation of the particles in the viewing window of the Mastersizer 2000, a larger particle size corresponding to the length of the particle could be estimated.



Figure 4-1: Elongated particles may be reported as a different size, depending on the method of particle sizing.

Conventional hydrometer methods and laser particle sizing may report different gradings for the same material depending on a range of factors, including shape and charge of particles and salinity of the dispersant. Conventional hydrometer methods measure the 'hydrodynamic diameter' based on the fall velocity and Stokes Law. As discussed in **Section 4.6**, there are a number of assumptions underpinning Stokes Law that do not necessarily apply to fines (<75µm). In addition, the settlement rate of fine particles is dependent on the salinity of the dispersant which can have two opposing influences; saline water results in higher water density and reduced settling velocity but can also cause coagulation of ionic colloids and increased settling velocities.

Laser particle size analysis measures the 'optical diameter' based on diffraction of a laser beam. Laser particle size analysis is independent of the charge of particles or salinity of the dispersant. However, it is dependent on the optical properties of the particle, and it is somewhat dependant on the shape of particles, as discussed above.

Future testing, and comparison of test results, should consider the method of analysing the particle size distribution.

4.3.1 Mastersizer Parameters

The General-Purpose model based on the Mie Theory (Malvern Instruments, 2007) was adopted for particle size analysis with the Mastersizer 2000. In order to use this Mie Theory correctly, the complex refractive index for the material being measured is required. This complex refractive index comprises a real and imaginary part. The real part of the refractive index is required to predict the diffraction from the particle surface and can be determined from refractometer measurements, microscope observations or can be estimated using empirical methods. The imaginary refractive index accounts for the attenuation of light as it passes through the particle and is commonly referred to as the absorption of the material (Malvern, 2024). A schematic of the particle refractive index and absorption is shown in **Figure 4-2**.

The particle properties adopted for the sediment and crushed rock were:

- Refractive index (RI) – 1.52 (default).
- Absorption – 2.

The RI for water (seawater) was adopted as the default value of 1.33.

The RI of the particle and the water were selected as the default values. The primary parameter of interest is the absorption index. The absorption index accounts for the molecular structure and physical properties of a particle. A rough surface structure, complex internal structure and dark coloured particles will result in higher absorption.

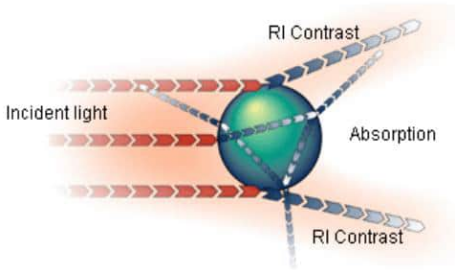


Figure 4-2: Schematic of Mie theory showing absorption and RI of the particle.

An assessment of the sensitivity of absorption on the reported particle size was undertaken to assess sensitivity of the parameter on similar estuarine/marine sediment from an alternate location. The analysis was undertaken for a critical particle size analysis at 5 minutes and 70mm below the water surface, with the absorption index varying from 0.1 to 2. The reported D90 varied by less than 10% (<3µm) with a lower absorption index resulting in a smaller D90.

For consistency and comparison of results, the same material properties were adopted for all samples. For the purpose of the critical particle size analysis, a larger D90 is preferred as it indicates a conservatively slower settling velocity, which would result in less settling (greater TSS) in the numerical plume dispersion modelling.

4.4 Hydrodynamic Stability of Sediment and Crushed Rock

The laboratory investigation included an assessment of the D90 particle size that remains in suspension after a given period and simulated various placement methodologies. Therefore, the laboratory investigation assists in defining particle sizes that could theoretically be placed in a waterbody and settle

in a manageable period and provides some insight on viable dredging and placement methodologies (hydraulic vs. mechanical methods).

The laboratory investigation was not designed to assess whether smaller particles, once settled, remain in place or whether they are remobilised by currents from natural events and/or propellor wash from ships. Hydrodynamic and sediment (and crushed rock) transport modelling, or a laboratory investigation in a flume, would be required to assess the risk of mobilisation or remobilisation of the settled sediment and crushed rock.

4.5 Coagulation, Flocculation and Settling Behaviour

A discussion on the coagulation, flocculation and settling behaviour of sediment/ crushed rock is provided herein. Various additional tests were undertaken to better understand settling behaviour of the sediment and crushed rock.

Seawater is a natural coagulant that neutralises charges in colloidal clays and promotes flocculation. In general, due to coagulation, particle settling velocity of fines is typically higher in seawater compared to freshwater.

However, as discussed herein, discrete flocculent settling (Class II) was not observed, which is an important consideration for the dredge plume modelling and dredging operations as the settling velocity is slower than similar material that does readily flocculate in seawater. Further, increasing the concentration of suspended sediment/ crushed rock in suspension is not expected to increase settling velocity.

4.5.1 Coagulation and Flocculation

Sands and gravels are generally classified as granular or non-cohesive sediment. The particles settle relatively quickly, generally in accordance with Stokes Law, and generally do not contribute to persistent and long-term turbidity. Conversely, fines (in particular clay) particles may remain in suspension for an extended period of time, and they are the focus of the laboratory investigation herein.

Clay particles are *generally* negatively charged due to broken mineral bonds on the face (IECA, 2016, Edelvang, 2024). Clay minerals are referred to as cohesive sediment and the electrochemical properties (negative charge) leads to the colloidal nature of the particles in water. The median diameter of colloidal clay minerals is typically in the range of 1-2µm, and the spread is about 0.1 to 10µm (Mehta et al, 2024). Colloids remain suspended in water for extended periods of time because:

- colloids have a very large surface area relative to their mass. The greater the surface area relative to the particle mass increases the effect of the charge;
- the mass of the particles is small enough that Brownian motion is sufficient to ‘stir’ the clay particles in suspension; and,
- the colloids cannot agglomerate into larger particles and settle because they repel one another in the same way that similar poles of two magnets repel each other (IECA, 2016).

A coagulant is utilized to neutralize or destabilize the charge on clay and other colloidal particles. Coagulation increases the potential for flocculation, which is the process of contact and adhesion whereby dispersed particles form larger-sized clusters as shown in **Figure 4-3** (IECA, 2016). The larger clusters of particles settle faster than the individual particles.

Seawater (predominantly sodium chloride salt, NaCl) is a weak ionic solution, which coagulates (neutralises) clay and other colloidal particles. Seawater comprises an assembly of positively charged cations ($Na+$) and negatively charged anions (Cl^-). The negative colloidal (clay) particles attract an

equivalent amount of cationic (positive) charge to form a double layer. The cations accumulate in the liquid near the particle surface where they are referred to as counter-ions. In still water, Brownian motion leads to the suspended particles randomly approaching one another until their counter-ions interfere and the particles repel each other. The repulsive potential decreases exponentially with the distance between the particles as shown in **Figure 4-4** (Suopajarvi, 2015). Colloidal particles also possess forces of attraction due to van der Waals' forces. The magnitude of the force varies inversely with distance between particles, increasing rapidly with decreasing distance. If the collision of particles occurs with adequate energy to overcome double layer repulsive forces, then the attractive van der Waals' force drags the particles into contact, where they adhere to form flocs (Suopajarvi, 2015, Bharti, 2019).

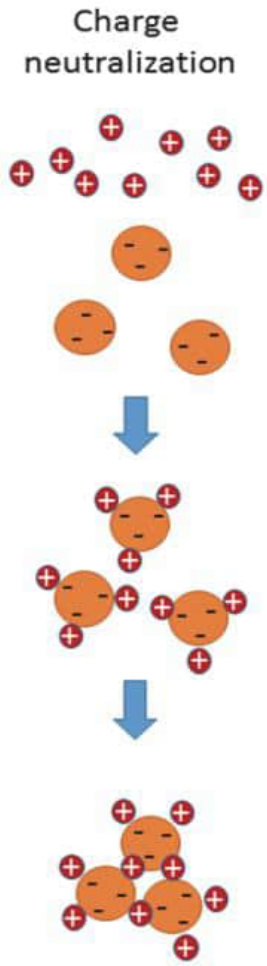


Figure 4-3: Mechanism of coagulation and flocculation (IECA, 2016).

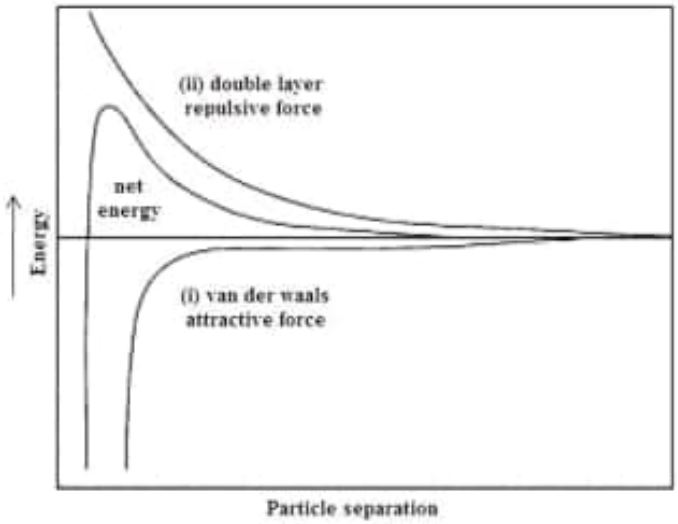


Figure 4-4: Schematic diagram showing the energy variation with particle distance (Suopajarvi, 2015).

Floc breakup occurs when a stress is induced that exceeds the strength of the attractive van der Waals' forces. Turbulent shear (due to mixing of the water) and collision between particles (including flocs) settling at different velocities are the main forces responsible for the formation and breakup of flocs. Both turbulent shear and collisions are sufficient to form and breakup flocs, depending on the strength of the forces involves (Winterwerp and van Kesteren, 2004).

The size, structure and density of flocs are determined by the forces experienced by the particles. Water chemistry variables including pH, temperature, ionic strength, and concentration of dissolved salts also influence flocculation (IECA, 2016, Suopajarvi, 2015). Leaching of the sodium chloride ions or dilution of seawater and the reduction in ionic strength may alter the characteristics of flocs.

4.5.2 Settling Behaviour – Concentration and Flocculation

The settling behaviour of a sediment in suspension is governed by its concentration and flocculation tendency and can be classified into four regimes (refer **Figure 4-5**), which are:

- Class I - discrete non-flocculent settling;
- Class II - discrete flocculent settling;
- Class III - zone settling or hindered settling; and,
- Class IV - compressive settling.

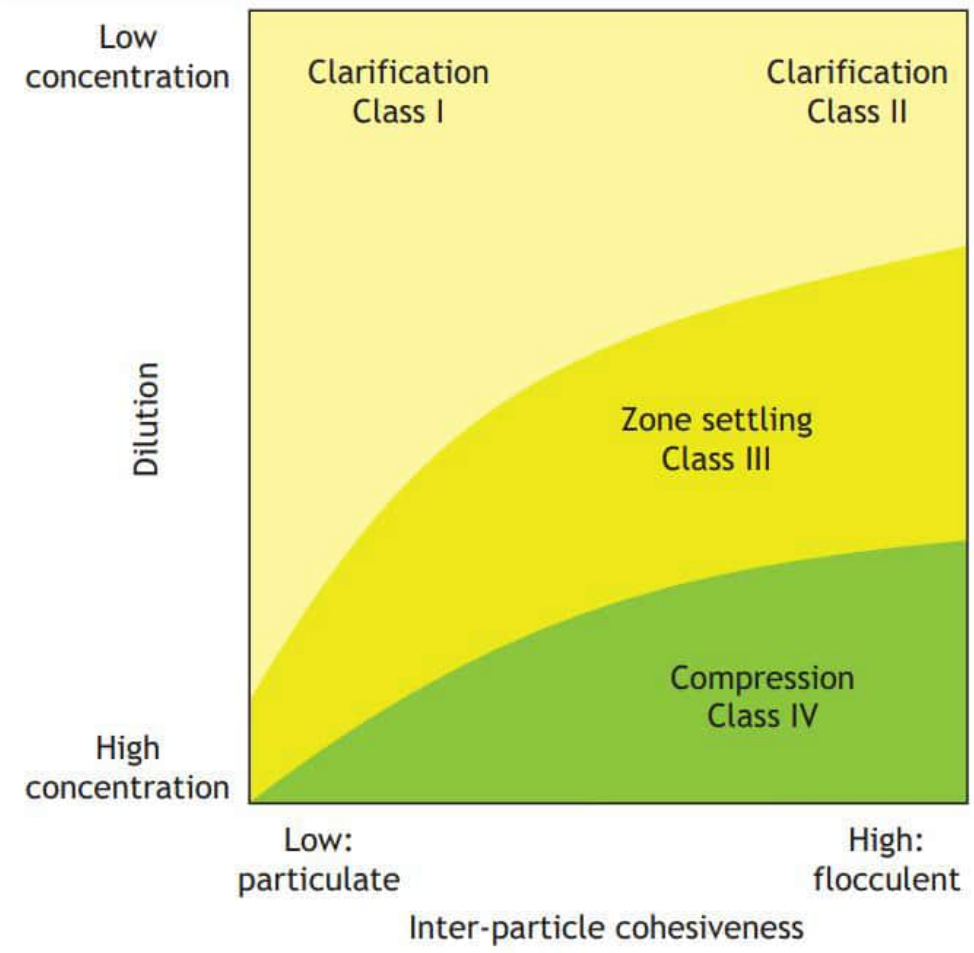


Figure 4-5: Settling regimes (Ekama et al., 1997).

The various classes are described by Torfs et al, 2016 and described below:

- Classes I and II – at low concentrations, the particles are completely dispersed, there is no physical contact between the particles and the concentration is typically too diluted for particles to influence each other's settling behaviour. Each particle settles at its own characteristic terminal velocity, which depends on individual particle properties such as shape, size, porosity and density. If these dilute particles show no tendency to flocculate, this regime is called discrete non-flocculent settling (Class I). However, certain suspensions have a natural tendency to flocculate even at low concentrations (Ekama et al., 1997). The formation of larger flocs increases the settling velocity. This regime is called discrete flocculent settling (Class II). During discrete flocculent settling, the formed flocs will still settle at their own characteristic terminal velocity. Hence, both discrete non-flocculent and discrete flocculent settling undergo basically the same settling dynamics. The difference lies in the fact that, for discrete flocculent settling, an additional flocculation process is occurring simultaneously with the settling process, which alters the particles' individual properties and consequently their terminal settling velocity. Seawater is a natural coagulant that neutralizes colloidal clay particles and promotes flocculation. Therefore, colloidal clays in seawater represents discrete flocculent settling (Class II) whereas colloidal clays in freshwater represents non-flocculent settling (Class I). Increasing the concentration of the suspension in seawater increases the potential of floc formation and consequently settling velocity (i.e. discrete flocculent settling (Class II)), up to the threshold concentration for hindered settling (Φ_h), as shown in **Figure 4-6** (Dronkers, 2024).

- Class III – the transition from discrete settling to hindered settling (Class III) occurs if the solid concentration exceeds a threshold concentration for hindered settling (Φ_h), where the particles no longer settle independently of one another. Φ_h depends on the flocculation state. In wastewater treatment, the transition for secondary sludge occurs at concentrations of 600 - 700mg/L whereas for granular sludge the threshold concentration can go up to 1,600-5,500mg/L (depending on the granulation state) (Mancell-Egala et al., 2016). Above Φ_h, the particles are so close together that the velocity field of the fluid displaced by the adjacent particles overlap and the rate at which the particles settle depends on the rate at which interstitial water can escape upward. Each particle is hindered by the other particles and the inter-particle forces are sufficiently strong to drag each particle along at the same velocity, irrespective of size and density. In other words, the particles settle collectively as a zone, and therefore this regime is also called zone settling. In this regime, a distinct interface between the clear(er) supernatant and the subsiding particles is formed. The rate of hindered settling decreases as the concentration of solids increases (and flow permeability decreases), as shown in **Figure 4-6** (Dronkers, 2024).

- Class IV – when the solids concentration further increases above a critical concentration (approximately 5-10g/L), the settling behaviour changes to compressive settling (Class IV). The exact transition concentration depends once more on the flocculation state of the particles (De Clercq et al., 2008). At these elevated concentrations, the solids come into physical contact with one another and are subjected to compaction due to the weight of overlying particles. The settling velocity will be much lower than in the hindered settling regime.

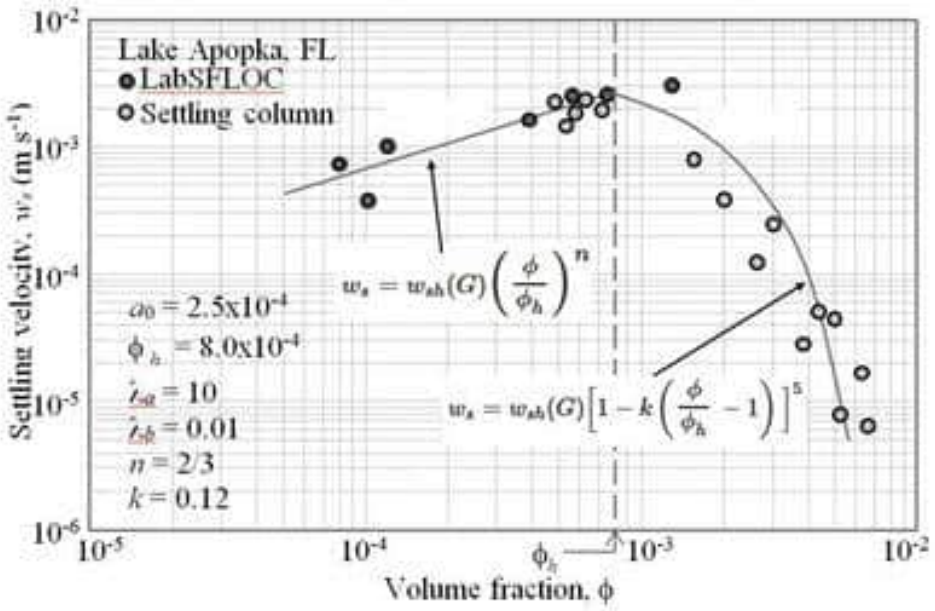


Figure 4-6: Settling velocity as a function of volume fraction; data from Lake Apopka (Dronkers, 2024).

Batch settling tests are commonly used to measure the settling velocity for hindered/zone settling and compression settling. The tests involve complete mixing of material in a column and measurement of the interface between the supernatant-suspension interface over time. **Figure 4-7** represents the distribution of settling regions over the depth of the column at different times during a batch settling experiment, where:

- Region A represents the supernatant;
- Region B represents hindered/zone settling;
- Region C represents transition settling. The transition layer is a layer of constant thickness and is formed by particles coming from the decreasing hindered settling layer and particles coming from the increasing compression layer. Although during this phase the same characteristics exist as in the zone settling regime, the settling velocity decreases because the concentration gradient increases with depth (Torfs et al, 2016); and,
- Region D represents compression phase. During the compression phase the particles undergo compaction, thus creating an increasing concentration gradient as well as a decreasing settling velocity (Torfs et al, 2016).

The position of the supernatant-suspension interface is indicated with a red arrow. Hence, the phases that are recorded in a batch settling curve occur as the suspension-supernatant interface passes through these different settling regions. If the column is not stirred, then the velocity at which the interface moves downward is called the hindered settling velocity (Torfs et al, 2016), which can be graphed (refer **Figure 4-8)**.

Figure 4-8 represents a typical batch settling curve, where:

- lag phase occurs from the beginning of the test up to point (a). In this phase, the suspension recovers from disturbances due to turbulence caused by the filling of the batch column;
- hindered/zone settling phase starts at point (a) and ends at point (b);
- transition phase starts at point (b) and ends at point (c); and,
- compression phase starts at point (c). The time at which the compression phase starts, called the compression point, is difficult to identify.

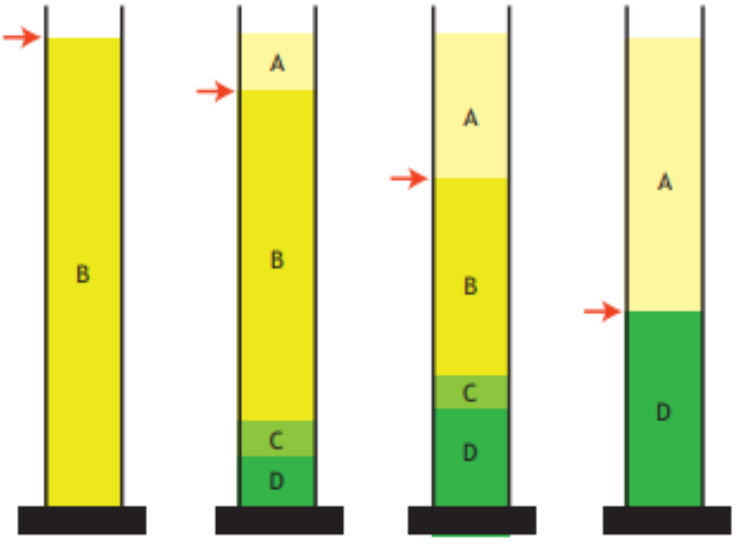


Figure 4-7: Chronological process of a batch settling test (Ekama et al., 1997).

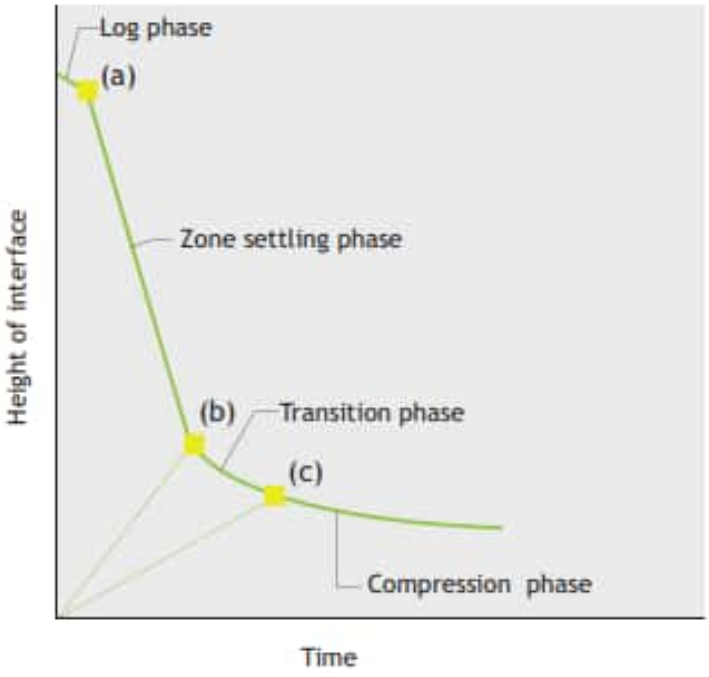


Figure 4-8: Evolution of the supernatant-suspension height over time, indicating the four phases (Rushton et al., 2000).

4.5.3 Sediment Concentration

Given uncertainties at the time of scoping the investigations around a number of construction matters including dredging method, dredging and placement rates, placement locations, placement methodology, and location of turbidity control measures, the laboratory investigation did not attempt to scale or replicate potential TSS in the field.

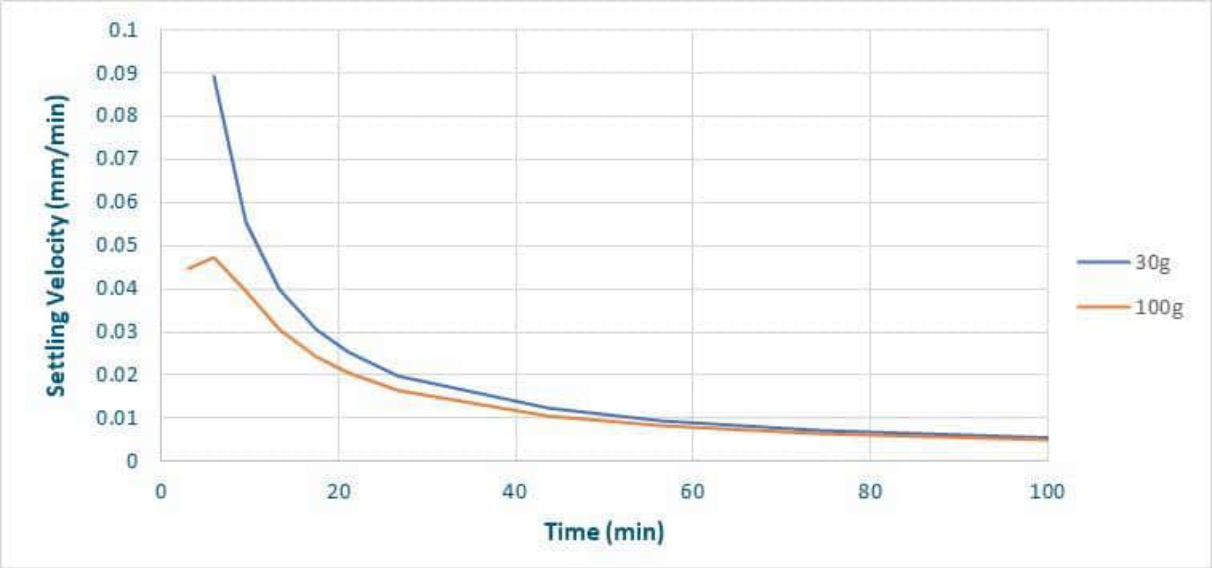
The laboratory investigation did not consider the effect of the concentration of TSS on settlement rates or the distribution of particle sizes in suspension in detail. However, the sample mass sensitivity test was undertaken on a single sediment sample (B1-5) on the 19th of June 2024 to assess the impact of varying sediment concentration on settling velocity. A total of five (5) 1L columns were completely agitated with varying sediment volumes of 2g, 5g, 10g, 30g and 100g. The TSS in each column, immediately following agitation, is outlined in **Table 4-1**. It is noted that the sediment was homogenized but not dried. As such, the samples contained moisture. It is also possible that the coarse particles settled too fast to subsample (i.e., within seconds) and the TSS does not directly relate to the sample mass.

Photographs taken at approximately 0 minutes, 10 minutes, 25 minutes, 45 minutes, 55 minutes and 1 hour and 55 minutes following agitation of material are shown in **Figure 3-1.**

Table 4-1: Total suspended sediment for each test, immediately following agitation of the column.

Mass (g)	Total Suspended Sediment (mg/L)
2	661
5	1,600
10	2,830
30	7,870
100	21,500

The sample mass of 2g to 10g exhibited discrete non-flocculent settling (Class I). The 30g and 100g samples exhibited zone settling or hindered settling (Class III) and discrete non-flocculent settling (Class I) as shown in **Figure 3-1**. In the hindered settling regime (Class III), each particle is hindered by the other particles and particles settle at the same velocity, irrespective of size and density. A distinct interface between the supernatant and the subsiding particles formed. However, the supernatant remained turbid. The distance from the interface to the water surface was measured at various time intervals to determine the zone settling velocity. This test is often referred to as a 'batch test' and the results (batch curve) are shown in **Graph 4-1**. Increasing the concentration of sediment decreases the settling velocity as expected, due to the rate at which interstitial water can escape upward.



Graph 4-1: Settling velocity determined from batch test measuring the supernatant-suspension interface in the hindered/zone settling regime.

Based on the results presented above, increasing the concentration of material in suspension did not enhance coagulation of particles and floc formation (i.e. discrete flocculent settling (Class II)). Rather, the material presented either weakly or partially colloidal properties, attributed to a lack of charge in the clay particles or the ionic concentration of seawater being insufficient to neutralise the sediment, resulting in the inability to form flocs.

4.5.4 Water Salinity

The laboratory investigation did not consider the effect of the salinity of the seawater in detail. However, an additional salinity sensitivity test was undertaken on both the marine sediment (B1-5) and the crushed rock (BH-01OS) on 1st October 2024 with Sydney Harbour seawater to assess the impact of varying salinity on settling velocity. This test comprised six (6) 1L columns containing 2g of material completely agitated with varying ratios of seawater and freshwater.

A photograph of the columns 5 minutes, 30 minutes, 60 minutes and 120 minutes following agitation are provided in **Figure 4-9** and **Figure 4-10** for the marine sediment (B1-5) and the crushed rock (BH-01OS) respectively.

For the marine sediment (B1-5), turbidity was visually lowest for a seawater/freshwater ratio of 50/50 to 20/80. The freshwater sample exhibited the slowest settling velocity, with the highest visual turbidity. This is expected at freshwater does not lead to the coagulation of colloidal clay particles. For the crushed rock (BH-01OS), turbidity was visually lowest for a seawater/freshwater ratio of 100/0 to 50/50. The freshwater

sample exhibited the slowest settling velocity, with the highest visual turbidity. However, the changes are difficult to ascertain due to the colour of the sediment.

Based on the findings summarised above, it is inferred that the optimal ratio of seawater/freshwater for the particular sediment type and mass is approximately 50/50. Saltwater is a natural coagulant and sufficient salt ions are required to neutralize the colloidal clay particles. However, increasing the salt concentration increases the density of water. All else being equal, a higher water density would result in lower settling velocity. Therefore, the seawater/freshwater ratio of 50/50 appears to represent a 'saturation point' whereby the salt ions are sufficient to coagulate the colloidal clay particles, without further increasing water density. This finding suggests that the dilution of seawater with freshwater is not expected to adversely impact settleability, which is relevant for assessing settleability in reclamation ponds where salinity may vary due to rainfall or evaporation. Furthermore, the limited difference in turbidity observed in the columns with seawater over the testing period indicates that the material is either weakly or partially colloidal and does not readily flocculate in seawater, regardless of freshwater input.

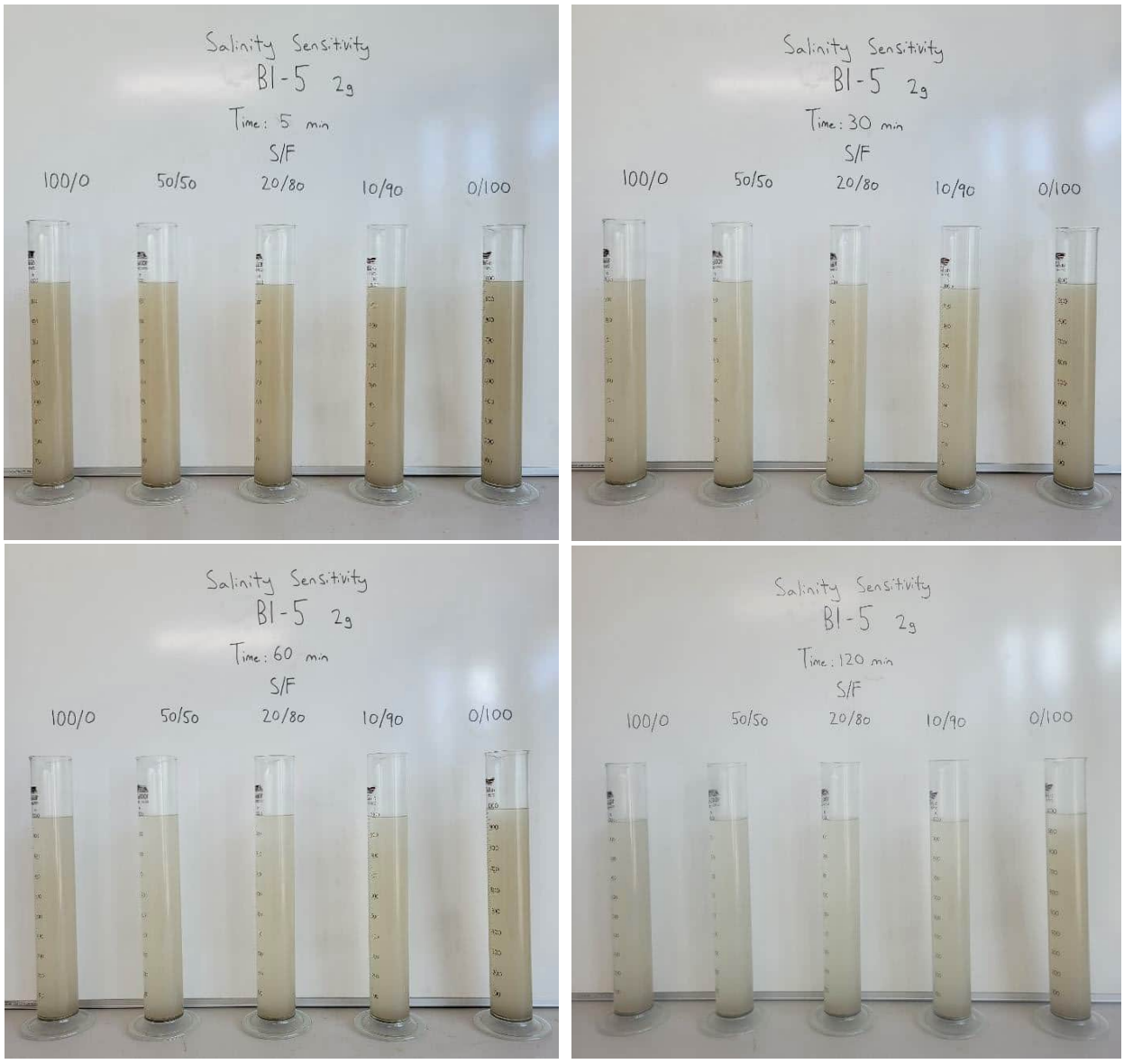


Figure 4-9: 1L columns with 2 grams of marine sediment (B1-5) and varying proportions of seawater/freshwater. Volume of seawater in the columns from left to right was 1,000mL, 500mL, 200mL, 100mL and 0mL. Time intervals clockwise from top right, 5 minutes, 30 minutes, 60 minutes and 120 minutes.

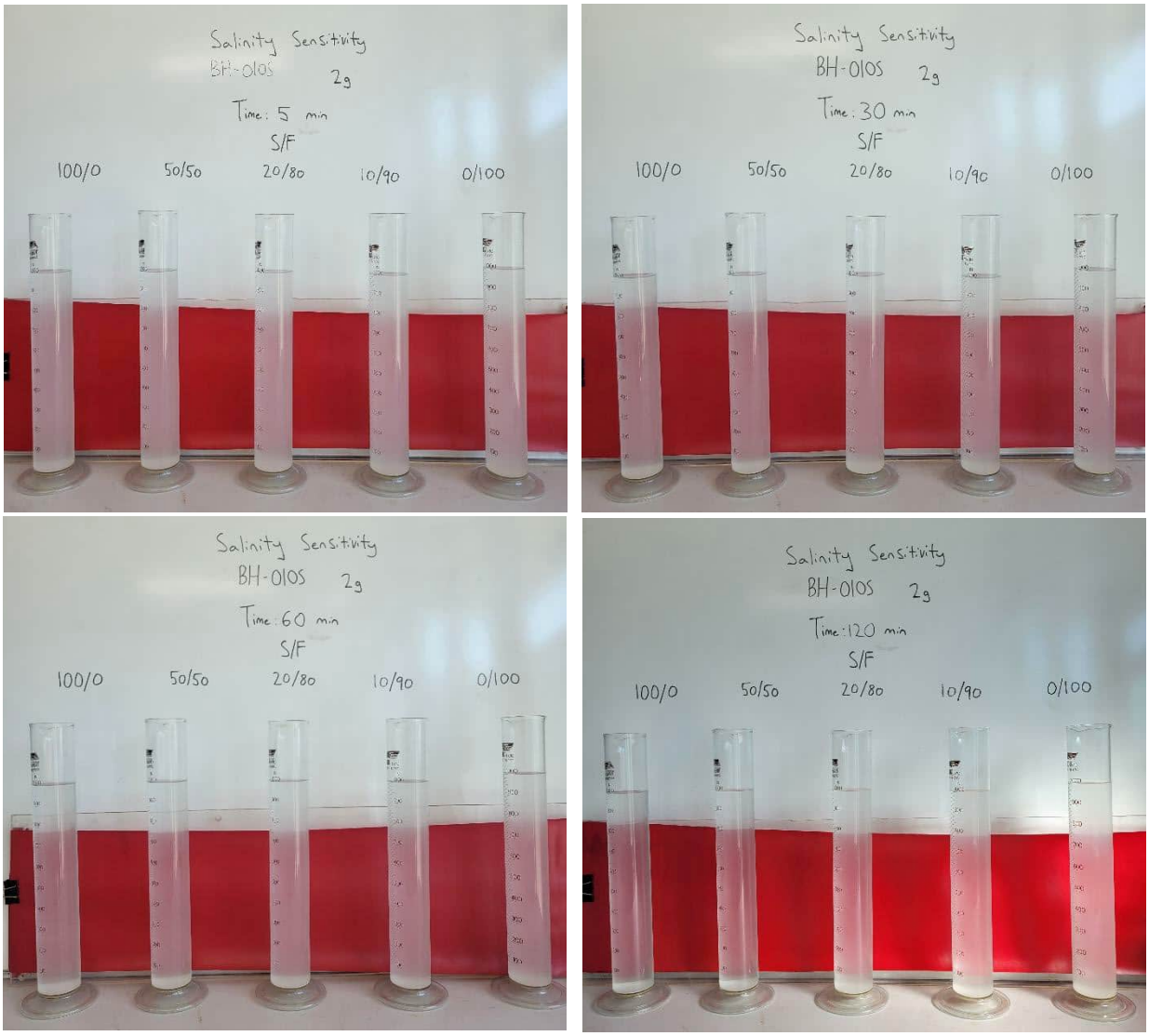


Figure 4-10: 1L columns with 2 grams of crushed rock (BH-01OS) and varying proportions of seawater/freshwater. Volume of seawater in the columns from left to right was 1,000mL, 500mL, 200mL, 100mL and 0mL. Time intervals clockwise from top right, 5 minutes, 30 minutes, 60 minutes and 120 minutes.

4.5.5 Behaviour of Marine/Alluvial Colloidal Sediments

The findings of mass and salinity sensitivity testing conducted on two sediment samples exhibiting colloidal properties from a project on the east coast of Australia have been discussed below to facilitate a comparison with the weakly or partially colloidal and non-flocculating nature of Geraldton material observed.

4.5.5.1 Sample Mass Sensitivity Test

A sample mass sensitivity test was undertaken on the marine/estuarine colloidal sediment sample as photographed in **Figure 4-11**. The sample mass of 2g to 10g exhibited discrete non-flocculent settling (Class I) and discrete flocculent settling (Class II). Increasing the mass of sediment from 2g to 10g resulted in visually less turbidity over time. It was inferred that increasing the concentration of sediment in suspension increased the potential for collision between particles resulting in agglomeration of smaller particles and corresponding increased settlement rates. Conversely, the marine sediment from Geraldton

did not exhibit discrete flocculent settling (Class II). As shown in **Figure 4-12**, increasing the sample mass of 2g to 10g did not substantially alter the clarification of the columns, which suggest flocs were not forming.

The colloidal marine/estuarine 30g and 100g samples both exhibited zone settling or hindered settling (Class III). The supernatant was relatively clear, indicating that surface concentration as commencement of the test was sufficient to initiate hindered settling. However, in the tests for Geraldton, the supernatant remained turbid.

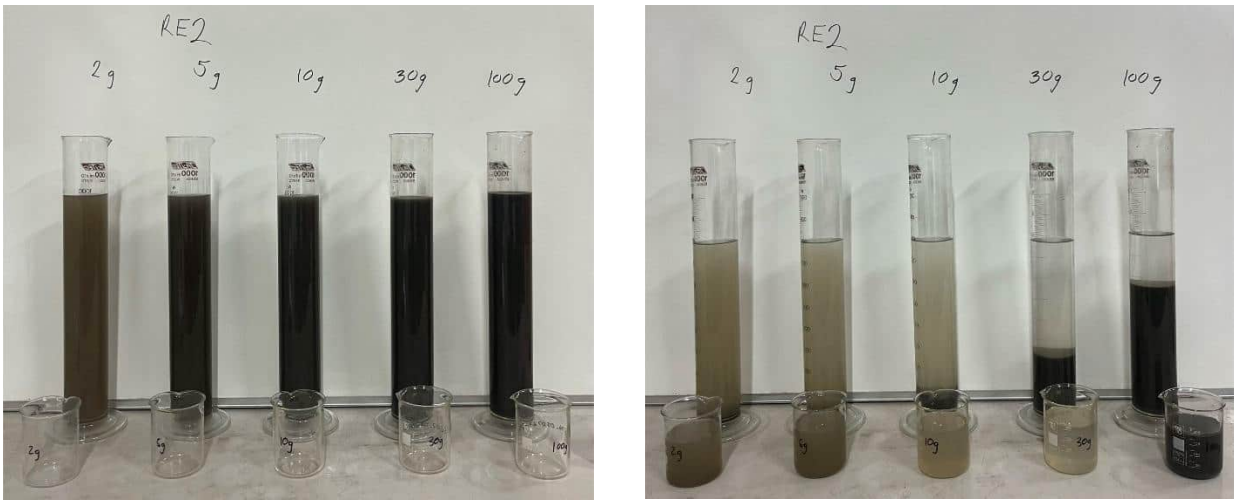


Figure 4-11: Photographs of the marine/estuarine colloidal sediment from the east coast of Australia immediately following agitations and after 50 minutes.

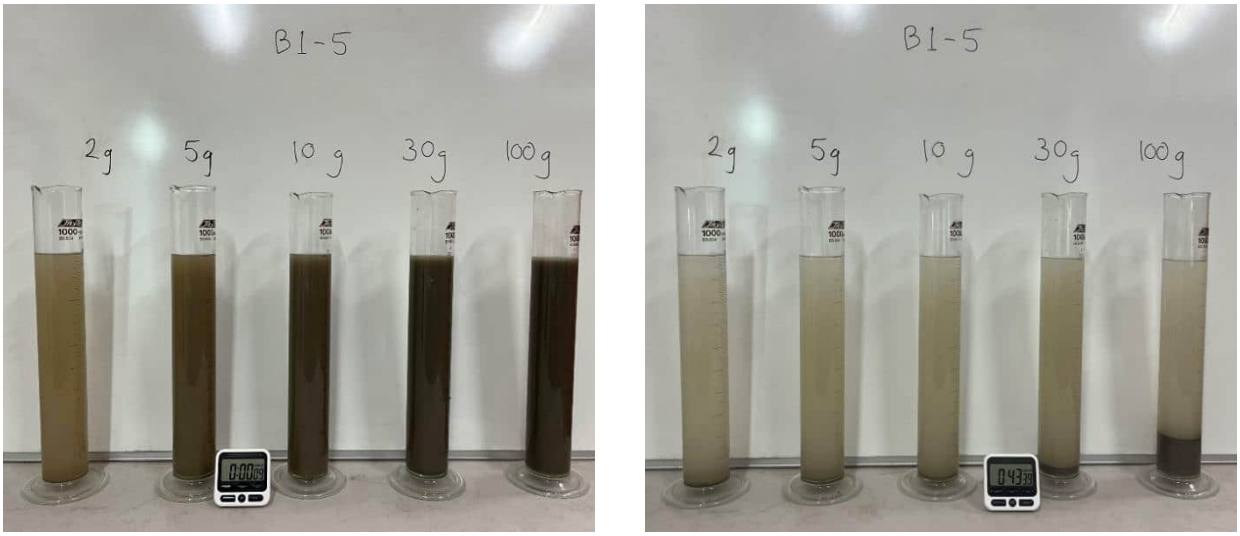


Figure 4-12: Photographs of the marine sediment from Geraldton (B1-5) immediately following agitations and after 45 minutes.

4.5.5.2 Water Salinity Sensitivity Test

The salinity sensitivity test was also undertaken for a residual sandy clay, collected from the east coast of Australia. The mass of sediment used in the test was 3.18g and a photograph of the column 50 minutes following agitation is provided in **Figure 4-13**. The clay dominant material exhibited strong colloidal properties with persistent residual turbidity observed in the freshwater sample that was significantly more turbid than the saltwater samples. This distinct difference was not observed in the marine sediment (B1-5)

and the crushed rock (BH-01OS) from Geraldton (refer to **Figure 4-9** and **Figure 4-10**), attributed to the weakly or partially colloidal properties of the material.

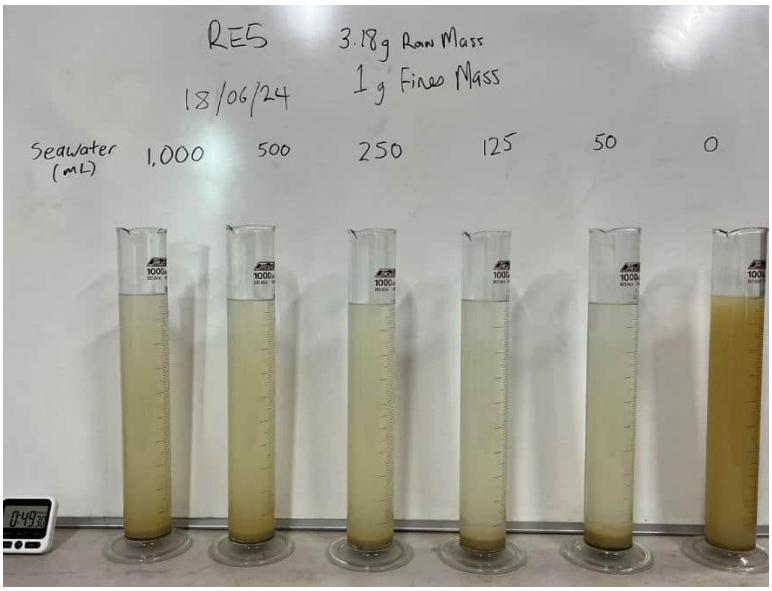


Figure 4-13: 1L columns with 3.18 g of residual sandy clay (not from Geraldton) of and varying proportions of seawater/freshwater. Photograph taken approximately 50 minutes after agitation.

4.5.5.3 Surface Turbidity and Critical Particle Size Analysis

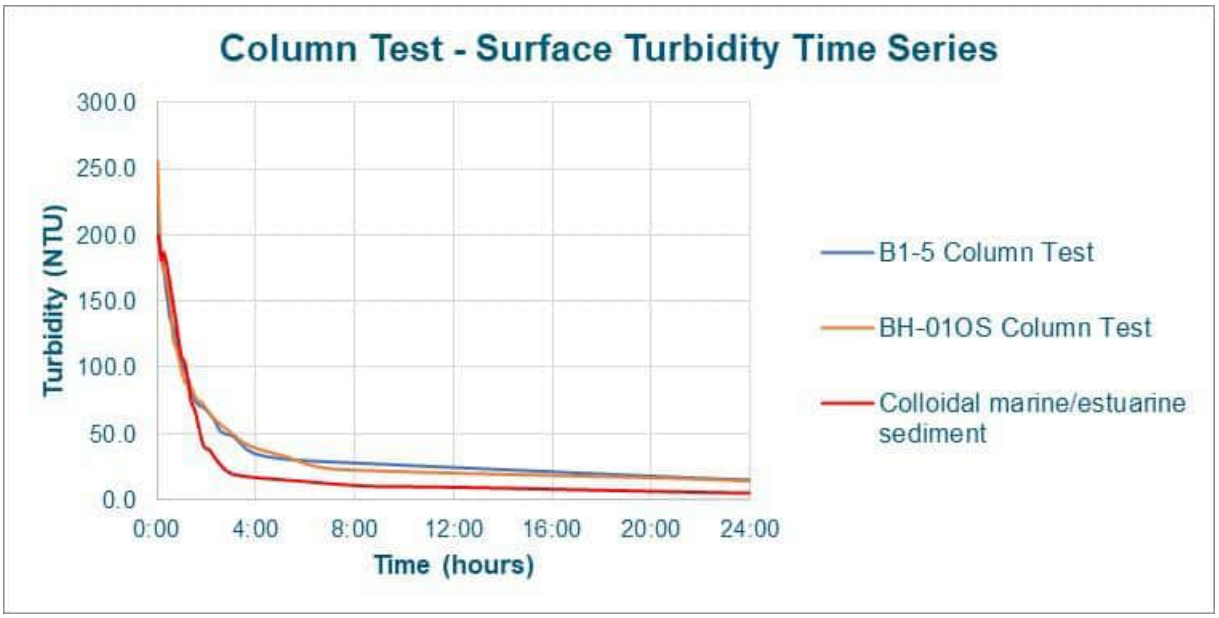
A comparison between the column test surface turbidity results and the critical particle size analysis settling velocity results for the colloidal marine/estuarine sediment, and the marine sediment and crushed rock from Geraldton, is provided in **Graph 4-2** and **Graph 4-3** respectively. The sediment concentration in the colloidal marine/estuarine sediment critical particle size analysis was set at 1.5g of fines to target discrete non-flocculent settling (Class I) velocity, which was expected to be slower than discrete flocculent settling (Class II) whereas the 2g of fines was used for the from sediment/crushed rock from Geraldton.

The results indicate that the settling velocity of the colloidal marine/estuarine sediment is similar to the Geraldton marine sediment (B1-5) and slower than the Geraldton crushed rock (BH-01OS) sample.

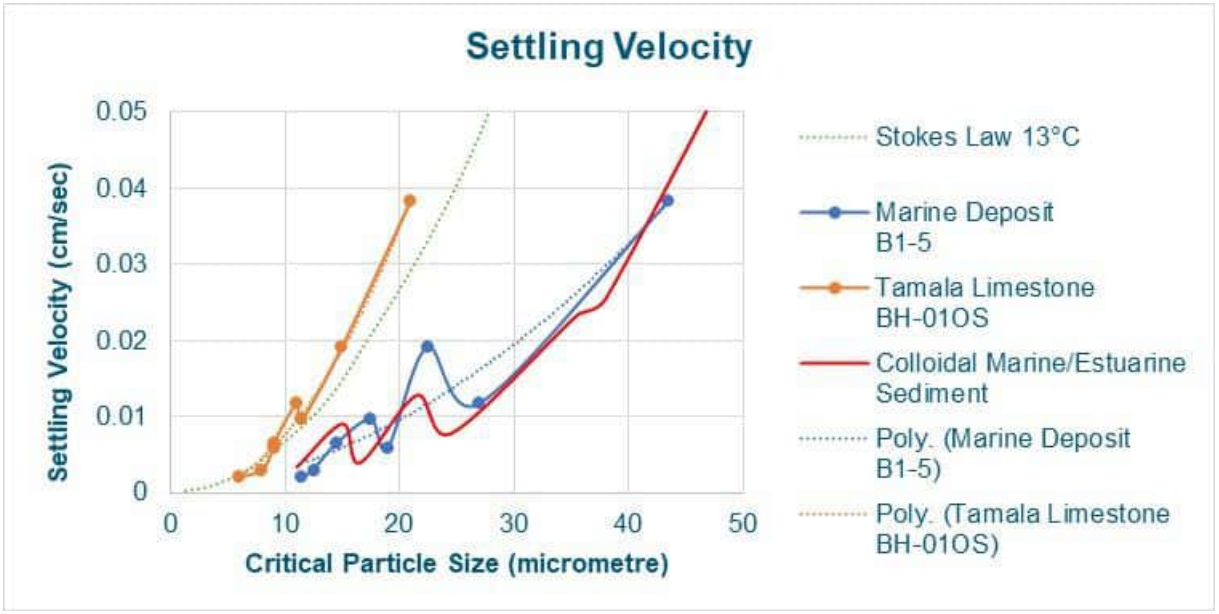
The surface turbidity of the colloidal marine/estuarine sediment in the column test decreased relatively quickly compared to the Geraldton marine sediment (B1-5) and crushed rock (BH-01OS). It is inferred that the surface turbidity of the colloidal marine/estuarine sediment decreased relatively quickly due to a higher initial concentration of sediment in the column test leading to coagulation and discrete flocculent settling (Class II) of the sediment. Discrete flocculent settling (Class II) was shown to increase the settling velocity and decrease turbidity.

The crushed rock sample had a faster settling velocity than the colloidal marine/estuarine sediment. However, the surface turbidity in the column test for the crushed rock sample remained elevated for a longer period of time. This result is counterintuitive which may be due to the percentage of clay sized particles (<2µm), which remain in suspension and contribute to persistent turbidity.

The lack of discrete flocculent settling (Class II) is an important consideration for Geraldton as settling velocity is expected to be slower than Stokes Law, which is shown by the critical particle size analysis.



Graph 4-2: Comparison between column test surface turbidity results for colloidal marine/estuarine sediment sample and Geraldton sediment and crushed rock.



Graph 4-3: Comparison between settling velocity for colloidal marine/estuarine sediment sample and Geraldton sediment and crushed rock.

4.6 Settling Velocity and Stokes Law

Results for the critical particle size analysis in **Section 3.2.2** suggests that the settling velocity of the marine sediment measured in the laboratory is slower than theoretical settling velocities determined by Stokes Law.

Stokes Law only applies with the following assumptions:

1. there is no other particle nearby that would affect flow pattern;
2. the motion of the particle is constant;

3. the particle is spherical and rigid;
4. the water velocity right at the particle surface is zero; and,
5. the fluid is incompressible.

Stokes Law is based on individual particle settling and is does not consider discrete flocculent settling (Class II) or hindered/zone settling (Class III).

Several of the assumptions underpinning Stokes Law do not hold true for the settlement of particles in the laboratory investigation, nor would they hold true for settlement of particles in the field. Particles are unlikely to be spherical, rather there would be a range of particle shapes including elongated and flat particles, which would not settle in the same way as a spherical particle. In addition, the assumption that no other particles nearby would affect flow pattern is unlikely to be true and collision between particles is likely to occur.

Stokes Law is the basis for the conventional hydrometer analysis for determining the distribution of fines based on the 'hydrodynamic particle diameter' as discussed in **Section 4.6**. Hydrometer analysis was not used in the laboratory investigation herein, other than the PSD results provided with the geotechnical investigation. Rather determining the 'optical diameter' of fines with the Mastersizer 2000 was the preferred method for analysing the distribution of particles. As mentioned previously, future testing, and comparison of test results, should consider the method of analysing the particle size distribution.

Given that not all assumptions behind Stokes Law hold true for settlement of particles in the laboratory investigation, the settlement velocity of the marine sediment calculated from the critical particle size analysis herein is considered to be reasonable. Given the low settlement velocity, minor disturbances in the water column from wave action and currents are likely to disrupt the settlement process resulting in the advection of suspended particles.

The settling velocity of the crushed rock appear to be high, which is counterintuitive given site observations from previous dredging campaigns. The higher settling velocity may be due to discrete flocculent settling (Class II). However, this assumes that the crushed rock is a colloid, which is coagulated by the seawater.

6 Conclusions

This laboratory investigation was undertaken to assess the settling behaviour of the sediment and rock proposed to be dredged and placed in a reclamation area as part of the Port of Geraldton PMaxP. The investigation supports dredge plume modelling efforts, environmental compliance monitoring for TSS and provides visual aids (i.e., representative TSS samples) for stakeholder consultation. The key findings of the investigation and resultant implications for the project are summarised as follows:

- A total of one sediment sample and one crushed rock sample were analysed as part of the investigation. The fines content varied between 65% (marine sediment B1-5) and 54% (crushed rock BH-01OS) and were selected for analysis based on their high fines content relative to other materials expected to be dredged during the proposed works.

- The column test is considered representative of material settling through the water column (i.e., material falling from the bucket of a BHD). The turbidity values, equivalent to 50mg/L suspended solids which is based on the water quality criterion commonly adopted for major marine construction projects, range from 59 NTU (B1-5) to 55 NTU (BH-01OS). However, it is noted that the water quality criterion for the project has not yet been defined and may vary. Overall, TSS-turbidity data collected during the column tests is considered to be reliable for the purpose of establishing a preliminary relationship between TSS and turbidity. However, collection of field TSS-turbidity data during construction is recommended so that the relationships between turbidity and suspended solids can be continually validated and improved.

- The critical particle size analysis focused on discrete non-flocculent settling (Class I) rather than hindered or zone settling (Class III). The mass of fines for the critical particle size analysis was selected to be 2g of dry fines in 1L of water (i.e., 2,000mg/L). The results indicated that after 10 minutes, the D90 particle size in suspension varied from 11 to 27µm, 70 mm below the water surface, and 21 to 43.5 µm, 230 mm below the water surface for all samples. After 60 minutes, the D90 particle size in suspension was 6 to 11.5 µm, 70 mm below the water surface, and 9 to 14.5 µm, 230 mm below the water surface. Settling velocity was inferred to be generally slower than Stokes Law for the marine sediment, indicating that this material would likely settle slower than predicted by Stokes Law.

- The QA/QC analysis indicates that the results are reliable and repeatable for the parameters analysed. Further, the additional tests on sediment concentration and salinity yield similar results to the primary tests, which further indicates repeatability of the test results.

- Sample mass sensitivity tests in 1 L columns with seawater indicated that increasing the concentration of dredge material did not visually increase settling velocity and discrete flocculent settling (Class II) was not observed. Low concentrations of sediment exhibited discrete non-flocculent settling (Class I) and higher concentrations exhibited zone settling or hindered settling (Class III). Further salinity sensitivity testing supported these findings, showing that the material is either weakly colloidal or only partially colloidal. This indicates that the dredge material does not readily flocculate in seawater, resulting in reduced settling rates in the water column.

7 References

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Appendix A – B1-5 (Marine Deposit)

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Graph 4: PSD at varying time intervals 230 mm below the water surface. Note the PSD for the sediment was provided by ALS Environmental (for SLR Consulting) by hydrometer and the results represent percent passing by mass. 5

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1 Introduction

The sample B1-5 was collected by O2 Marine as part of an SLR-led sediment investigation on the 20th April 2024. An overview of the sample is provided in **Table 1**. The origin of the sample has been inferred by RHDHV.

Table 1: Overview of sediment sample.

Sample ID	Depth (m below bed)	% Fines	Moisture Content	Origin
B1-5	0-0.2	71	46.8	Marine Deposit

2 Results

2.1 TSS-NTU Column Test

The column test, used to obtain the TSS-Turbidity relation for B1-5, was commenced on the 1th July 2024 and was concluded on the 3rd July 2024.

The column test is considered representative of material settling through the water column (e.g. sediment introduced throughout the vertical water column as encountered during backhoe dredger operations).

The Certificate of Analysis provided by ALS Environmental for the TSS and turbidity analyses undertaken for samples collected during testing and laboratory log records completed during the TSS-turbidity test are provided in **Appendix C**.

Photographs taken during the column test are provided in **Figure 1.** These photographs were taken:

- Seawater from Sydney Harbour without the addition of sediment.
- Column test immediately following agitation (0 hrs);
- Column test 2 hours after commencement; and,
- Column test 49 hours after commencement.

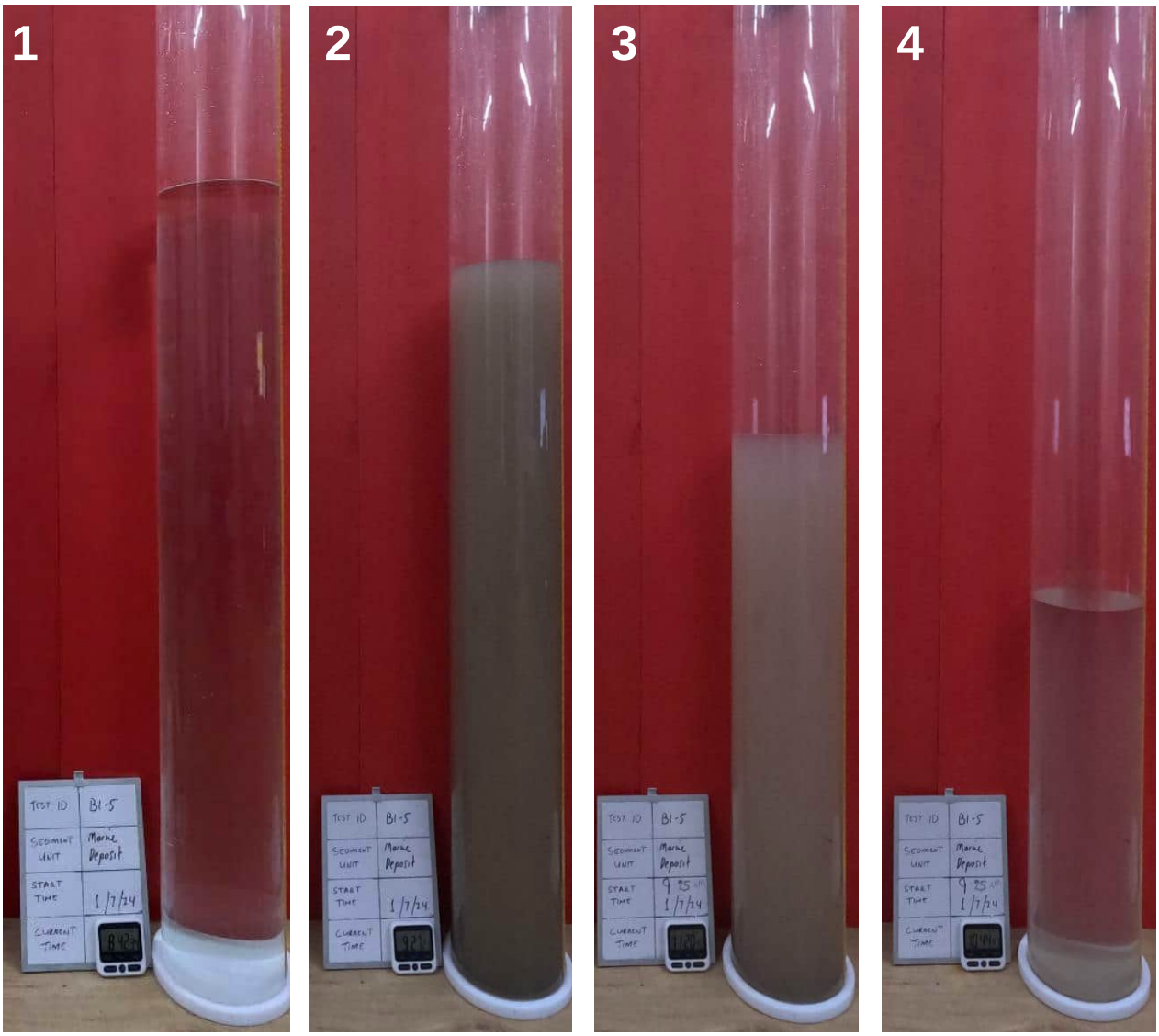
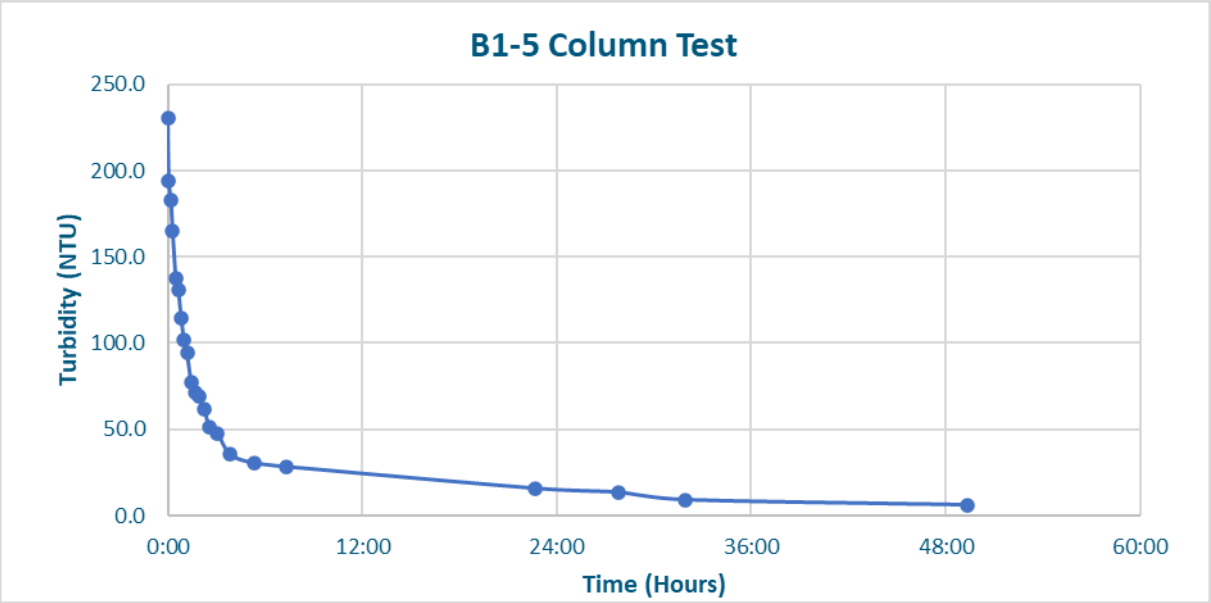


Figure 1: Column test –

1. *Seawater from Sydney Harbour without addition of sediment.*
2. *Column test immediately following agitation (0 hours).*
3. *Column test 2 hours after commencement.*
4. *Column test 49 hours after commencement.*

Surface Turbidity vs Time Results

The variation in surface turbidity is plotted in **Graph 1**. The graph shows that surface turbidity decreased relatively rapidly from 230 NTU to 60 NTU during the first two hours of testing. After 5.5 hours, surface turbidity reduced to 30 NTU. From 5.5 hours to 49 hours, the reduction in surface turbidity was relatively linear and after 49 hours, surface turbidity was approximately 6 NTU. A very faint turbid cloud was reported at this time.



Graph 1: Surface turbidity measured during the column test.

TSS – Turbidity Results

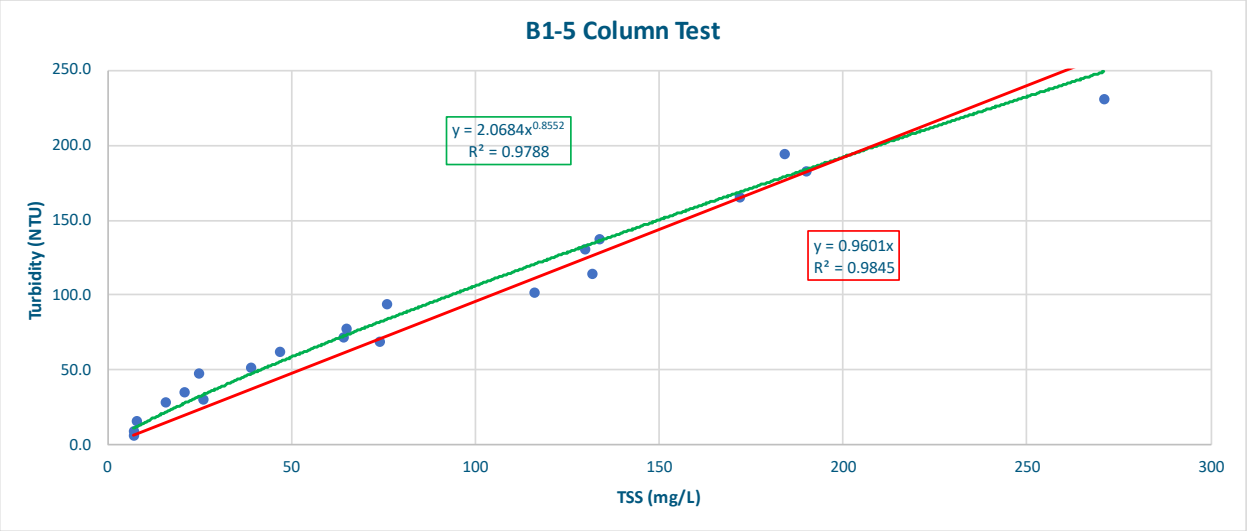
A total of 22 samples were collected during testing for laboratory TSS and turbidity analysis. TSS values for the collected samples ranged between <5 mg/L[1] and 271 mg/L.

A plot of TSS versus turbidity for all data collected during testing is provided in **Graph 2**. Turbidity values used in this dataset are the measurements taken during testing (from a controlled sampling container prior to subsampling for laboratory analysis) rather than the laboratory results[2]. This dataset is plotted with trendlines corresponding to both linear and power functions. The power function provides a similar fit of the data compared to the linear function, characterised by R^2 values of 0.979[3] and 0.985, respectively. Considering the similarity between the R^2 values, the power function has been adopted for use in this assessment based on the visual fit between the data and the power trendline. The high R^2 value indicates a strong correlation between TSS and turbidity for the dataset and is considered to be valid for the data collected during testing.

[1] The Limit of Reporting (LOR) value for TSS analysis is 5 mg/L, refer **Appendix C**. Results for samples with TSS concentrations below the LOR value are reported as <5 mg/L.

[2] Turbidity results reported by the laboratory were compared with turbidity results obtained during testing using the YSI ProDSS sensor. No significant differences between the turbidity datasets were evident (i.e. selection of the turbidity dataset does not significantly influence the TSS-turbidity relationship).

[3] The R^2 value, also known as the coefficient of determination, is a measure of how close the plotted data are to the fitted regression line (i.e. the line of best fit). An R^2 value of 1 indicates that the regression line perfectly fits the data.



Graph 2: Column test TSS-turbidity relationship.

TSS – Turbidity Relationship

A summary of the TSS-turbidity relationships determined is provided in **Table 2**, including the turbidity values equivalent to a TSS concentration of 50 mg/L for each of the linear and power function trendlines. The selected TSS value of 50 mg/L is somewhat arbitrary and the water quality limit for the project may vary.

Table 2: Summary of TSS-turbidity relationships from the column test

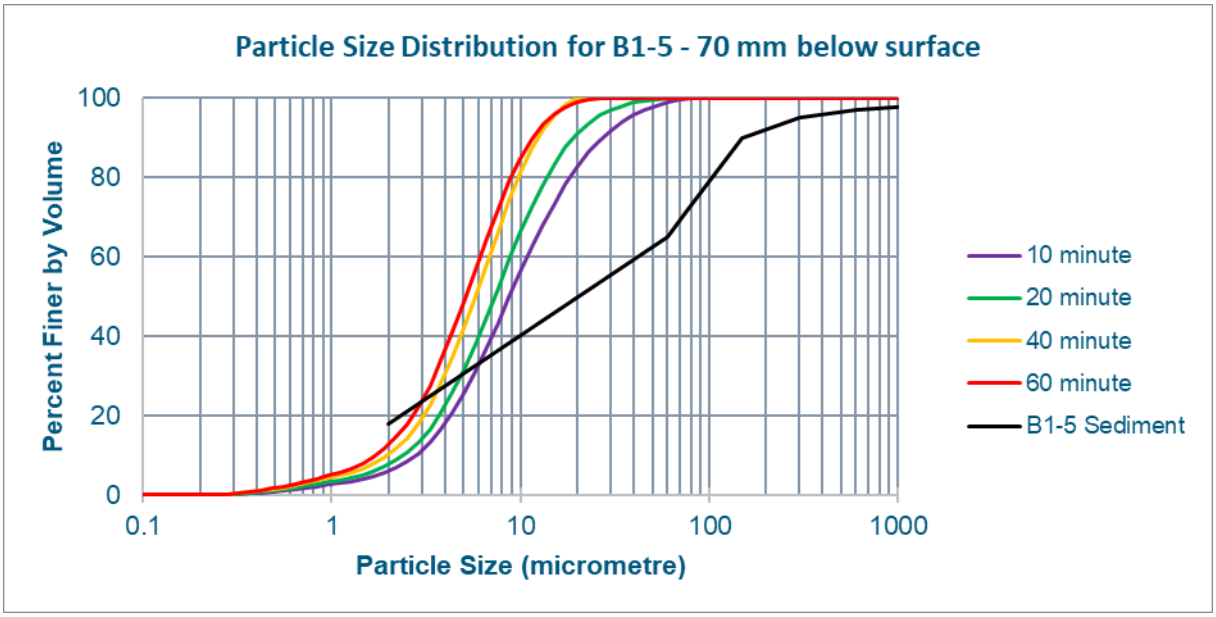
Trendline	Number of values	R^2 value	Relationship	Turbidity (NTU) equivalent to 50 mg/L TSS
Linear	22 (including 1 value with TSS < 5mg/L)	0.98	y = 0.9601x	48
Power		0.98	$y = 2.0684x^{0.8552}$	59

As noted above, the power function trendline provides a similar fit to the linear function. Based on the adopted power trendline, the turbidity value equivalent to 50 mg/L suspended solids is 59 NTU for this dataset.

2.2 Critical Particle Size

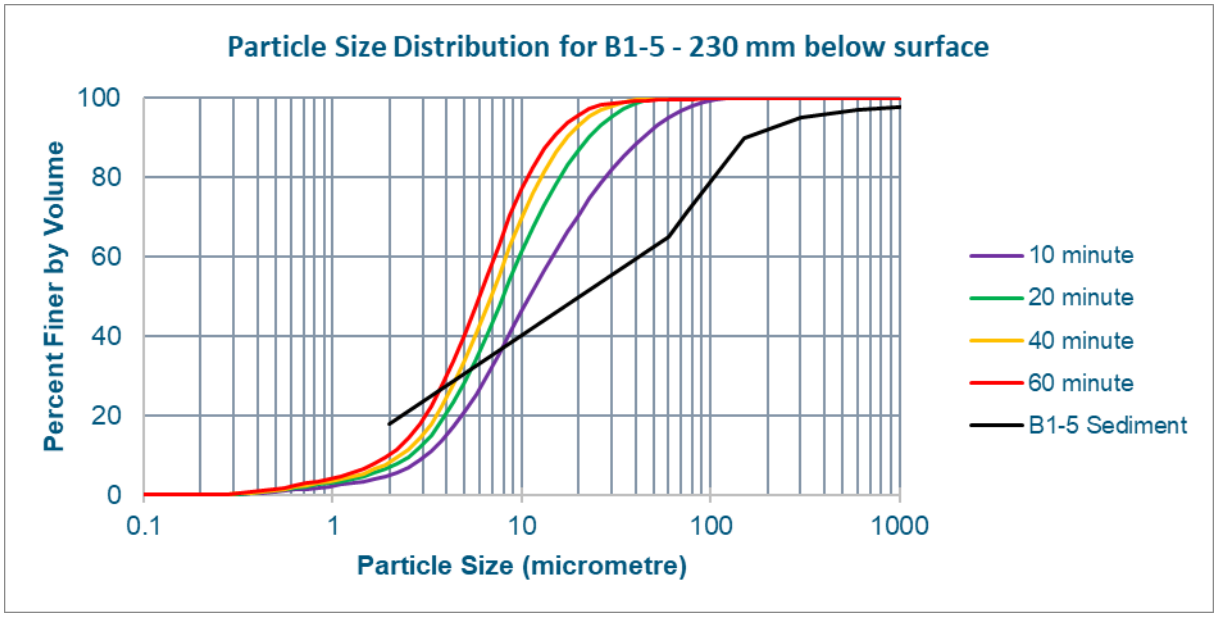
The tests to determine the critical particle size in suspension commenced on 19th June 2024. Particle size analysis using the Mastersizer 2000 was completed on the same day.

Graph 3 plots the particle size distribution (PSD) of B1-5 and the particle size that remains in suspension after each time interval (10 minutes, 20 minutes, 40 minutes and 60 minutes) at 70 mm below the water surface.



Graph 3: PSD at varying time intervals, 70 mm below the water surface. Note the PSD for the sediment was provided by ALS Environmental (for SLR Consulting) by hydrometer and the results represent percent passing by mass.

Graph 4 plots the particle size distribution of B1-5 and the particle size that remains in suspension after each time interval (10 minutes, 20 minutes, 40 minutes and 60 minutes) at 230 mm below the water surface.



Graph 4: PSD at varying time intervals 230 mm below the water surface. Note the PSD for the sediment was provided by ALS Environmental (for SLR Consulting) by hydrometer and the results represent percent passing by mass.

The D90 particle size in suspension at various time intervals is outlined in **Table 3.** D90 means that 90% of the total particles are smaller than this size. The D90 particle size in suspension decreases over time and increased with depth.

Table 3: D90 particle size in suspension at varying time intervals, 70 and 230 mm below the water surface, rounded to the nearest 0.5.

Time	Maximum particle size in suspension (µm)	
	70 below the water surface	230 mm below the water surface
10 minutes	27.0	43.5
20 minutes	19.0	22.5
40 minutes	12.5	17.5
60 minutes	11.5	14.5

Appendix B – BH-01OS (Rock Core)

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1 Introduction

The sample BH-01OS was collected by BG&E Resources on the 30th August 2023. Several sections of rock core from recovered from within the dredging profile at BH-01OS (14-16 m below ground level [bgl]) were provided to RHDHV.

Two sections were selected for crushing (using a hammer, jaw crusher and ring mill), dry sieving to 150µm and preliminary PSD analysis using the Mastersizer 2000 to determine the core split with a higher percentage fines. These samples were conservatively selected based on a higher proportion of consolidated fine grained material visually observed in each section and less presence of courser grained sands, gravels and shell fragments. Higher fines content (i.e., silts and clays) is considered the conservative approach as this material is expected to remain in suspension for longer during dredging works.

An overview of the two core samples is provided in **Table 1**, with the specific section selected for laboratory testing (14.5-14.7 m bgl) highlighted in bold text. Images of these sections pre- and post-crushing are provided in **Figure 1**. **Graph 1** plots the particle size distribution (PSD) of both rock samples, illustrating a higher volume of fines observed within the 14.5-14.7 m bgl sample. It is noted that the sample selected for testing presented a darker grey colour which was attributed to moisture within the core. This sample was oven dried to remove any moisture to facilitate the dry sieving process prior to particle size analysis.

Table 1: Overview of the two rock core samples further assessed for laboratory testing. Noting the sample selected is highlighted in bold text.

Sample ID	Depth (m bgl)	% Fines[1]	Moisture Content (%)[2]	Origin
BH-01OS	**14.5-14.7**	**59**	**0**	**Tamala Limestone**
BH-01OS	15.2-14.5	53	0	Tamala Limestone

[1] % fines was determined using the Mastersizer 2000 calculated by crushing the rock in a ring mill the rock, oven drying, sieving to 150 um, then performing laser diffraction PSD analysis with the Mastersizer 2000.
[2]Samples oven dried prior to PSD analysis to remove moisture.

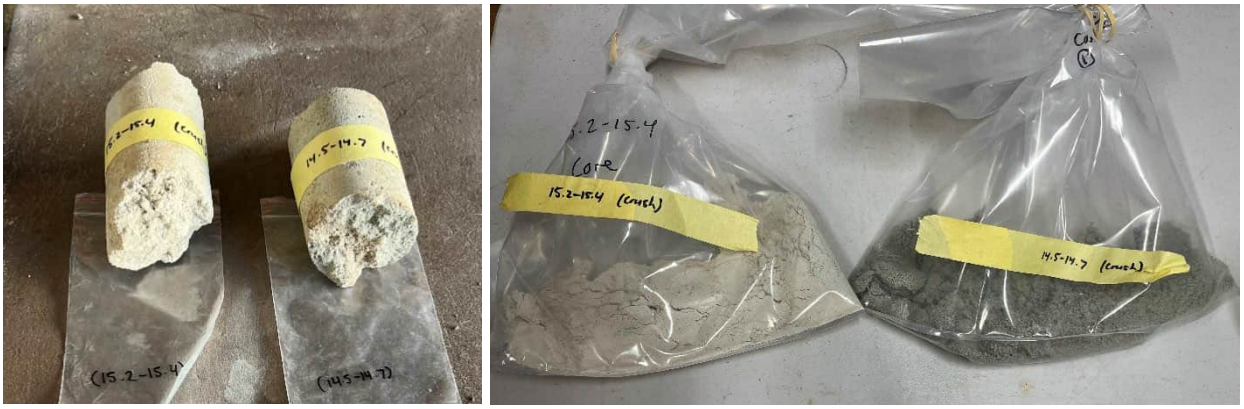
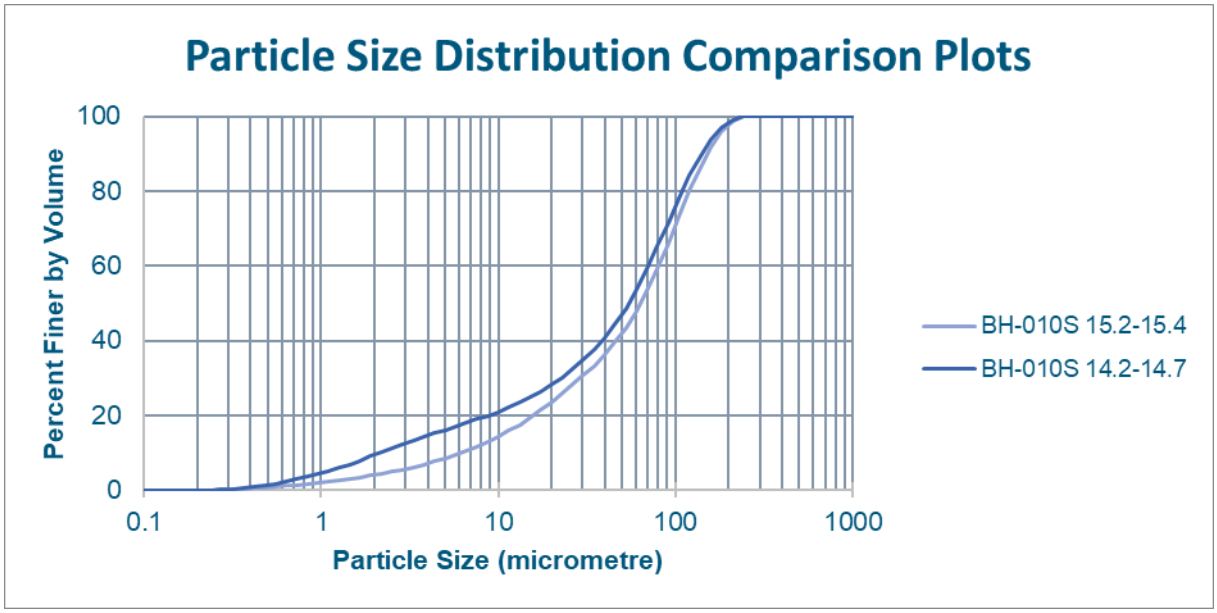


Figure 1: Photographs of selected rock core samples recovered from the dredge profile pre- and post- crushing.



Graph 1: PSD of two select rock core samples to determine the higher percentage fines content within the samples. Noting the results represent percent passing by mass.

2 Results

2.1 TSS-NTU Column Test

The column test, used to obtain the TSS-Turbidity relation for BH-01S, was commenced on the 1st July 2024 and was concluded on the 3rd July 2024.

The column test is considered representative of material settling through the water column (e.g. sediment introduced throughout the vertical water column as encountered during backhoe dredger operations).

The Certificate of Analysis provided by ALS Environmental for the TSS and turbidity analyses undertaken for samples collected during testing and laboratory log records completed during the TSS-turbidity test are provided in **Appendix C**.

Photographs taken during the column test are provided in **Figure 2**. These photographs were taken:

- Seawater from Sydney Harbour without addition of crushed rock.
- Column test immediately following agitation (0 hrs);
- Column test 2 hours after commencement; and,
- Column test 49 hours after commencement.

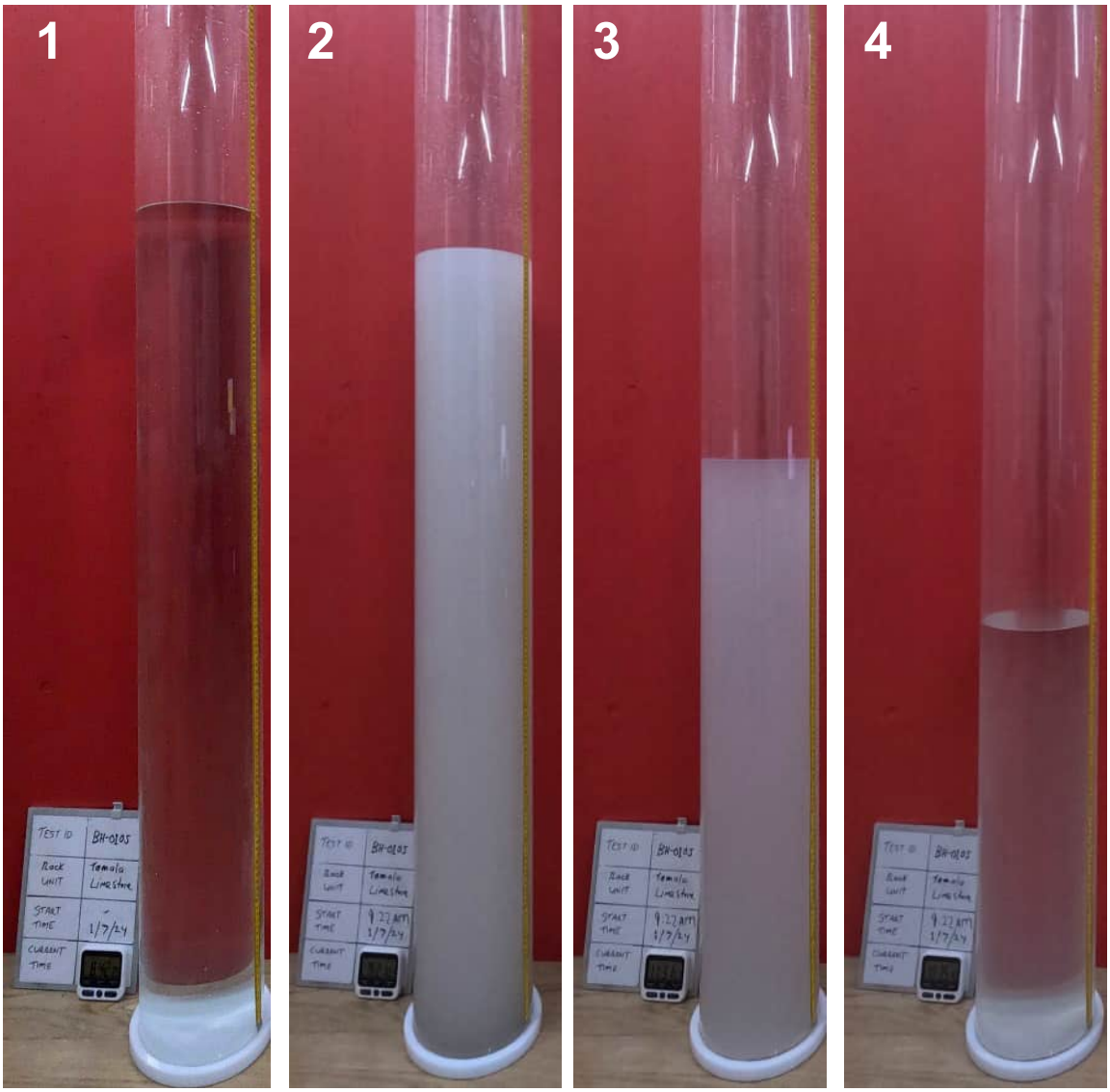
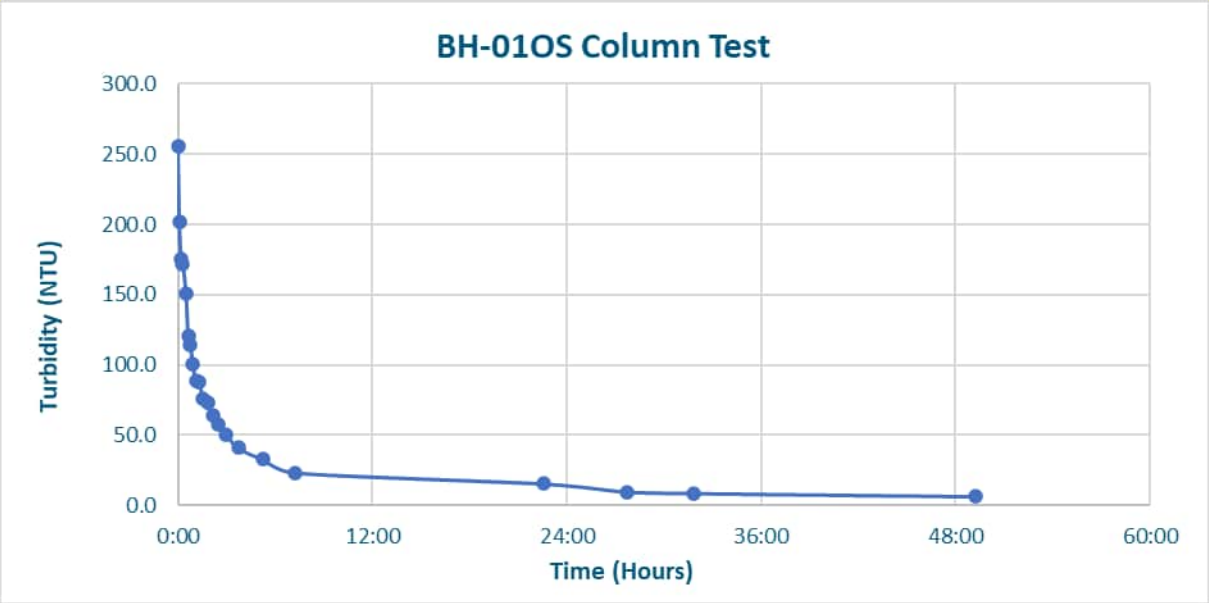


Figure 2: Column test – BH-01OS

1. *Seawater from Sydney Harbour without addition of crushed rock.*
2. *Column test immediately following agitation (0 hours).*
3. *Column test 2 hours after commencement.*
4. *Column test 49 hours after commencement.*

Surface Turbidity vs Time Results

The variation in surface turbidity is plotted in **Graph 2**. The graph shows that surface turbidity decreased relatively rapidly from 255 NTU to 60 NTU during the first two hours of testing. After 5 hours, surface turbidity reduced to 30 NTU. From 5 hours to 49 hours, the reduction in surface turbidity was relatively linear and after 49 hours, surface turbidity was approximately 6 NTU. A very faint turbid cloud was reported throughout the column at this time.



Graph 2: Surface turbidity measured during the column test.

TSS – Turbidity Results

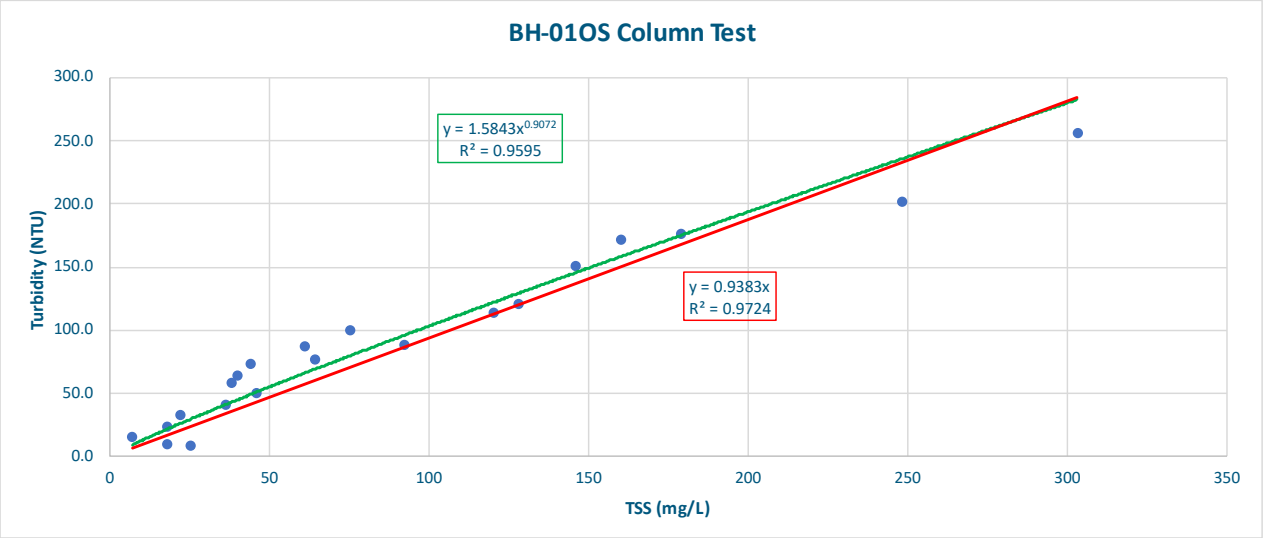
A total of 22 samples were collected during testing for laboratory TSS and turbidity analysis. TSS values for the collected samples ranged between <5 mg/L[1] and around 300 mg/L.

A plot of TSS versus turbidity for all data collected during testing is provided in **Graph 3**. Turbidity values used in this dataset are the measurements taken during testing (from the sampling beaker prior to subsampling) rather than the laboratory results[2]. This dataset is plotted with trendlines corresponding to both linear and power functions. The power function provides a similar fit of the data compared to the linear function, characterised by R^2 values of 0.960[3] and 0.972, respectively. Considering the similarity between the R^2 values, the power function has been adopted for use in this assessment based on the visual fit between the data and the power trendline. The high R^2 value indicates a strong correlation between TSS and turbidity for the dataset and is considered to be valid for the data collected during testing.

[1] The Limit of Reporting (LOR) value for TSS analysis is 5 mg/L, refer **Appendix C.** Results for samples with TSS concentrations below the LOR value are reported as <5 mg/L.

[2] Turbidity results reported by the laboratory were compared with turbidity results obtained during testing using the YSI ProDSS sensor. No significant differences between the turbidity datasets were evident (i.e. selection of the turbidity dataset does not significantly influence the TSS-turbidity relationship).

[3] The R^2 value, also known as the coefficient of determination, is a measure of how close the plotted data are to the fitted regression line (i.e. the line of best fit). An R^2 value of 1 indicates that the regression line perfectly fits the data.



Graph 3: Column test TSS-turbidity relationship

TSS – Turbidity Relationship

A summary of the TSS-turbidity relationships determined is provided in **Table 2**, including the turbidity values equivalent to a TSS concentration of 50 mg/L for each of the linear and power function trendlines. The selected TSS value of 50 mg/L is somewhat arbitrary and the water quality limit for the project may vary.

Table 2: Summary of TSS-turbidity relationships from the column test

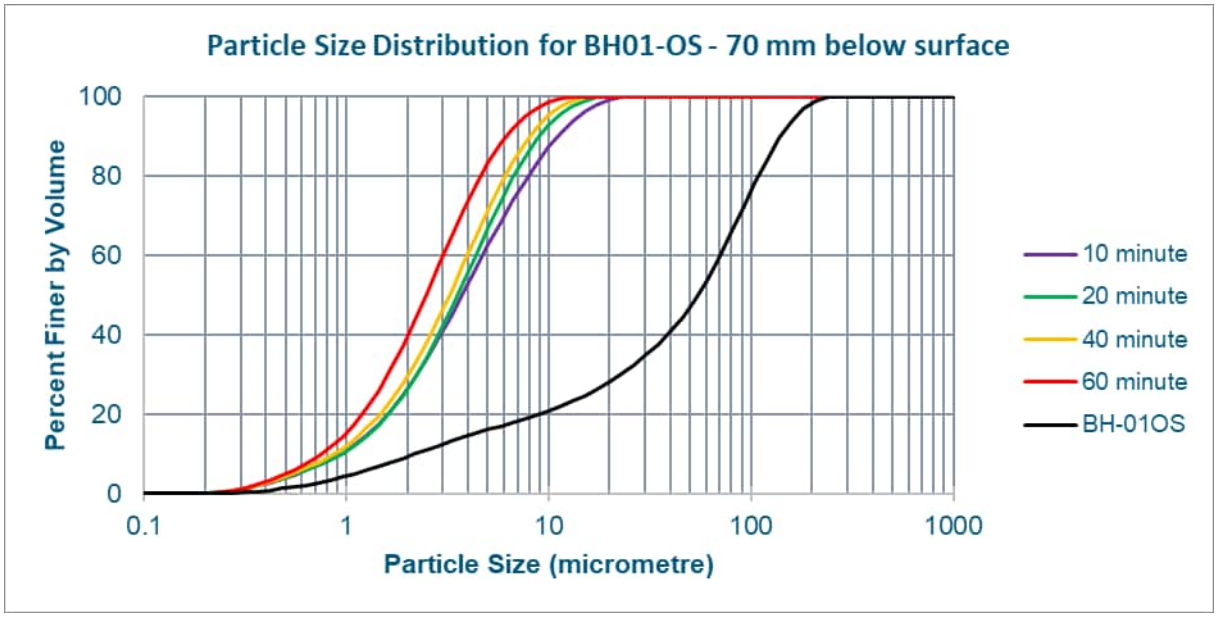
Trendline	Number of values	R^2 value	Relationship	Turbidity (NTU) equivalent to 50 mg/L TSS
Linear	22 (including 1 value with TSS < 5mg/L)	0.97	y = 0.9383x	47
Power		0.96	$y = 1.5843x^{0.9072}$	55

As noted above, the power function trendline provides a similar fit to the linear function. The turbidity value equivalent to 50 mg/L suspended solids is 55 NTU for this dataset.

2.2 Critical Particle Size

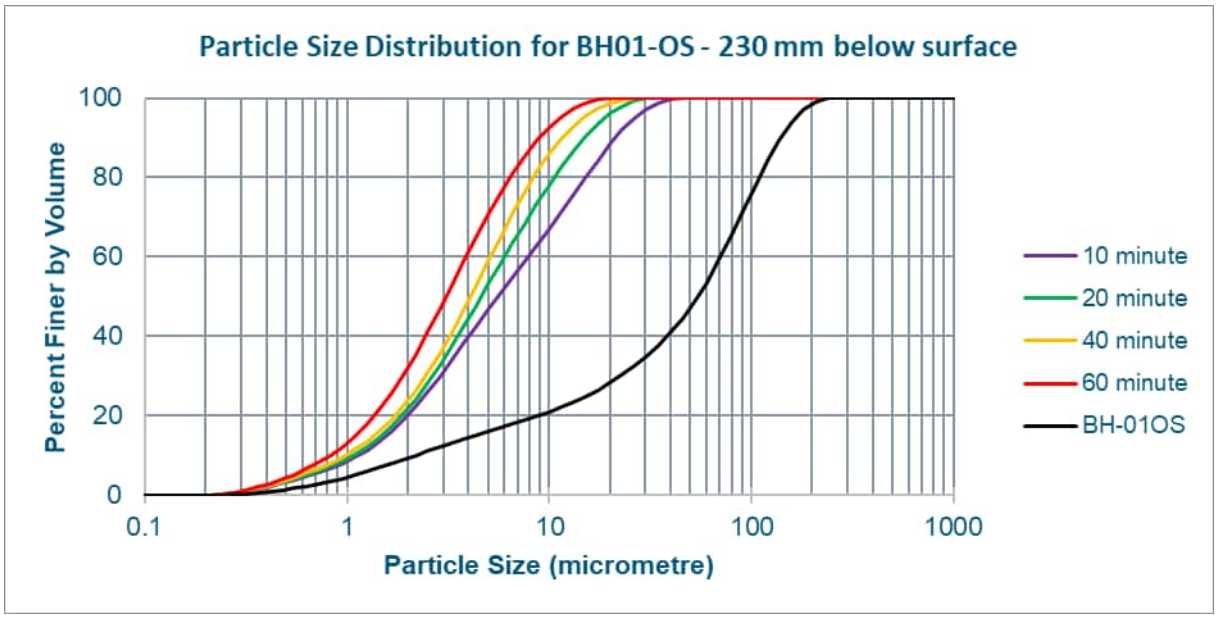
The tests to determine the critical particle size in suspension commenced on 28th June 2024. Particle size analysis using the Mastersizer 2000 was completed on the same day.

Graph 4 plots the PSD of BH-01OS and the particle size that remains in suspension after each time interval (10 minutes, 20 minutes, 40 minutes and 60 minutes) at 70 mm below the water surface.



Graph 4: PSD at varying time intervals, 70 mm below the water surface.

Graph 5 plots the PSD of BH-01OS and the particle size that remains in suspension after each time interval (10 minutes, 20 minutes, 40 minutes and 60 minutes) at 230 mm below the water surface.



Graph 5: PSD at varying time intervals 230 mm below the water surface.

The D90 particle size in suspension at various time intervals is outlined in **Table 3.** D90 means that 90% of the total particles are smaller than this size. The D90 particle size in suspension decreases over time and increased with depth.

Table 3: D90 particle size in suspension at varying time intervals, 70 and 230 mm below the water surface, rounded to the nearest 0.5.

Time	Maximum particle size in suspension (µm)	
	70 below the water surface	230 mm below the water surface
10 minutes	11	21
20 minutes	9	15
40 minutes	8	11.5
60 minutes	6	9

CERTIFICATE OF ANALYSIS

Work Order	: **ES2421688**	Page	: 1 of 11
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 02-Jul-2024 13:50
Order number	: PA3387	Date Analysis Commenced	: 03-Jul-2024
C-O-C number	: ----	Issue Date	: 09-Jul-2024 13:10
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 44		
No. of samples analysed	: 43		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	B1-5_01	B1-5_02	B1-5_03	B1-5_04	B1-5_05
			Sampling date / time	01-Jul-2024 09:25	01-Jul-2024 09:29	01-Jul-2024 09:37	01-Jul-2024 09:43	01-Jul-2024 09:55
Compound	CAS Number	LOR	Unit	ES2421688-001	ES2421688-002	ES2421688-003	ES2421688-004	ES2421688-005
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**271**	**184**	**190**	**172**	**134**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**263**	**216**	**208**	**102**	**157**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	B1-5_06	B1-5_07	B1-5_08	B1-5_09	B1-5_10
			Sampling date / time	01-Jul-2024 10:04	01-Jul-2024 10:15	01-Jul-2024 10:25	01-Jul-2024 10:36	01-Jul-2024 10:52
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-006**	**ES2421688-007**	**ES2421688-008**	**ES2421688-009**	**ES2421688-010**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**130**	**132**	**116**	**76**	**65**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**121**	**134**	**73.0**	**95.4**	**75.2**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	B1-5_11	B1-5_12	B1-5_13	B1-5_14	B1-5_15
			Sampling date / time	01-Jul-2024 11:05	01-Jul-2024 11:20	01-Jul-2024 11:40	01-Jul-2024 11:59	01-Jul-2024 12:29
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-011**	**ES2421688-012**	**ES2421688-013**	**ES2421688-014**	**ES2421688-015**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**64**	**74**	**47**	**39**	**25**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**74.8**	**72.1**	**61.7**	**34.5**	**45.1**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	B1-5_16	B1-5_17	B1-5_18	B1-5_19	B1-5_20
			Sampling date / time	01-Jul-2024 13:16	01-Jul-2024 14:46	01-Jul-2024 16:46	02-Jul-2024 08:03	02-Jul-2024 13:12
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-016**	**ES2421688-017**	**ES2421688-018**	**ES2421688-019**	**ES2421688-020**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**21**	**26**	**16**	**8**	<5
EA045: Turbidity								
Turbidity	----	0.1	NTU	**27.7**	**23.8**	**24.0**	**10.0**	**7.4**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	AL01	SEAWATER-GP	SEAWATER-SH	BH-01OS_01	BH-01OS_02
			Sampling date / time	01-Jul-2024 00:00	02-Jul-2024 13:00	02-Jul-2024 13:02	01-Jul-2024 09:22	01-Jul-2024 09:27
Compound	CAS Number	LOR	Unit	ES2421688-021	ES2421688-022	ES2421688-023	ES2421688-024	ES2421688-025
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**224**	**----**	**----**	**303**	**248**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**253**	**0.4**	**0.8**	**167**	**271**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	BH-01OS_03	BH-01OS_04	BH-01OS_05	BH-01OS_06	BH-01OS_07
			Sampling date / time	01-Jul-2024 09:34	01-Jul-2024 09:40	01-Jul-2024 09:52	01-Jul-2024 10:00	01-Jul-2024 10:08
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-026**	**ES2421688-027**	**ES2421688-028**	**ES2421688-029**	**ES2421688-030**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**179**	**160**	**146**	**128**	**120**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**243**	**236**	**167**	**134**	**164**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	BH-01OS_08	BH-01OS_09	BH-01OS_10	BH-01OS_11	BH-01OS_12
			Sampling date / time	01-Jul-2024 10:18	01-Jul-2024 10:28	01-Jul-2024 10:40	01-Jul-2024 10:56	01-Jul-2024 11:11
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-031**	**ES2421688-032**	**ES2421688-033**	**ES2421688-034**	**ES2421688-035**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**75**	**92**	**61**	**64**	**44**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**22.8**	**44.8**	**120**	**108**	**100**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Sample ID	BH-01OS_13	BH-01OS_14	BH-01OS_15	BH-01OS_16	BH-01OS_17
			Sampling date / time	01-Jul-2024 11:31	01-Jul-2024 11:51	01-Jul-2024 12:21	01-Jul-2024 13:05	01-Jul-2024 14:35
Compound	CAS Number	LOR	Unit	ES2421688-036	ES2421688-037	ES2421688-038	ES2421688-039	ES2421688-040
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**40**	**38**	**46**	**36**	**22**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**41.8**	**58.8**	**60.8**	**51.3**	**21.2**

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	BH-01OS_18	BH-01OS_19	BH-01OS_20	----	----
			Sampling date / time	01-Jul-2024 16:35	02-Jul-2024 07:57	02-Jul-2024 13:07	----	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421688-041**	**ES2421688-042**	**ES2421688-043**	--------	--------
				Result	Result	Result	----	----
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**18**	**7**	**18**	**----**	**----**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**10.4**	**6.6**	**4.7**	**----**	**----**

QUALITY CONTROL REPORT

Work Order	: **ES2421688**	Page	: 1 of 3
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 02-Jul-2024
Order number	: PA3387	Date Analysis Commenced	: 03-Jul-2024
C-O-C number	: ----	Issue Date	: 09-Jul-2024
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 44		
No. of samples analysed	: 43		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EA025: Total Suspended Solids dried at 104 ± 2°C (QC Lot: 5904576)									
ES2421688-001	B1-5_01	EA025H: Suspended Solids (SS)	----	5	mg/L	271	234	14.8	0% - 20%
ES2421688-011	B1-5_11	EA025H: Suspended Solids (SS)	----	5	mg/L	64	58	8.6	0% - 50%
ES2421688-021	AL01	EA025H: Suspended Solids (SS)	----	5	mg/L	224	224	0.0	0% - 20%
ES2421688-033	BH-01OS_10	EA025H: Suspended Solids (SS)	----	5	mg/L	61	68	10.5	0% - 50%
EA025: Total Suspended Solids dried at 104 ± 2°C (QC Lot: 5904577)									
ES2421688-043	BH-01OS_20	EA025H: Suspended Solids (SS)	----	5	mg/L	18	12	39.3	No Limit
EA045: Turbidity (QC Lot: 5899991)									
ES2421335-004	Anonymous	EA045: Turbidity	----	0.1	NTU	60.5	60.6	0.2	0% - 20%
ES2421688-008	B1-5_08	EA045: Turbidity	----	0.1	NTU	73.0	72.6	0.5	0% - 20%
EA045: Turbidity (QC Lot: 5899992)									
ES2421688-019	B1-5_19	EA045: Turbidity	----	0.1	NTU	10.0	10.4	3.9	0% - 20%
ES2421688-028	BH-01OS_05	EA045: Turbidity	----	0.1	NTU	167	166	0.6	0% - 20%
EA045: Turbidity (QC Lot: 5899993)									
ES2421688-039	BH-01OS_16	EA045: Turbidity	----	0.1	NTU	51.3	50.7	1.2	0% - 20%
ES2421869-005	Anonymous	EA045: Turbidity	----	0.1	NTU	0.3	0.3	0.0	No Limit

Method Blank (MB) and Laboratory Control Sample (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA025: Total Suspended Solids dried at 104 ± 2°C (QCLot: 5904576)								
EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	102	83.0	129
				<5	1000 mg/L	97.0	82.0	110
				<5	928 mg/L	95.2	83.0	118
EA025: Total Suspended Solids dried at 104 ± 2°C (QCLot: 5904577)								
EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	95.7	83.0	129
				<5	1000 mg/L	97.5	82.0	110
				<5	928 mg/L	96.9	83.0	118
EA045: Turbidity (QCLot: 5899991)								
EA045: Turbidity	----	0.1	NTU	<0.1	40 NTU	95.5	91.0	105
EA045: Turbidity (QCLot: 5899992)								
EA045: Turbidity	----	0.1	NTU	<0.1	40 NTU	97.5	91.0	105
EA045: Turbidity (QCLot: 5899993)								
EA045: Turbidity	----	0.1	NTU	<0.1	40 NTU	96.5	91.0	105

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2421688**	Page	: 1 of 5
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 02-Jul-2024
Site	: ----	Issue Date	: 09-Jul-2024
Sampler	: HAYDEN NICHOLS	No. of samples received	: 44
Order number	: PA3387	No. of samples analysed	: 43

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, where applicable to the methodology, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA025: Total Suspended Solids dried at 104 ± 2°C							
Clear Plastic Bottle - Natural (EA025H)							
B1-5_01, B1-5_02, B1-5_03, B1-5_04, B1-5_05, B1-5_06, B1-5_07, B1-5_08, B1-5_09, B1-5_10, B1-5_11, B1-5_12, B1-5_13, B1-5_14, B1-5_15, B1-5_16, B1-5_17, B1-5_18, AL01, BH-01OS_01, BH-01OS_02, BH-01OS_03, BH-01OS_04, BH-01OS_05, BH-01OS_06, BH-01OS_07, BH-01OS_08, BH-01OS_09, BH-01OS_10, BH-01OS_11, BH-01OS_12, BH-01OS_13, BH-01OS_14, BH-01OS_15, BH-01OS_16, BH-01OS_17, BH-01OS_18	**01-Jul-2024**	**----**	----	----	**05-Jul-2024**	08-Jul-2024	✓
Clear Plastic Bottle - Natural (EA025H)							
B1-5_19, B1-5_20, BH-01OS_19, BH-01OS_20	**02-Jul-2024**	**----**	----	----	**05-Jul-2024**	09-Jul-2024	✓

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA045: Turbidity							
Clear Plastic Bottle - Natural (EA045)							
B1-5_01, B1-5_02, B1-5_03, B1-5_04, B1-5_05, B1-5_06, B1-5_07, B1-5_08, B1-5_09, B1-5_10, B1-5_11, B1-5_12, B1-5_13, B1-5_14, B1-5_15, B1-5_16, B1-5_17, B1-5_18, AL01, BH-01OS_01, BH-01OS_02, BH-01OS_03, BH-01OS_04, BH-01OS_05, BH-01OS_06, BH-01OS_07, BH-01OS_08, BH-01OS_09, BH-01OS_10, BH-01OS_11, BH-01OS_12, BH-01OS_13, BH-01OS_14, BH-01OS_15, BH-01OS_16, BH-01OS_17, BH-01OS_18	**01-Jul-2024**	**----**	----	----	**03-Jul-2024**	03-Jul-2024	✓
Clear Plastic Bottle - Natural (EA045)							
B1-5_19, B1-5_20, SEAWATER-GP, SEAWATER-SH, BH-01OS_19, BH-01OS_20	**02-Jul-2024**	**----**	----	----	**03-Jul-2024**	04-Jul-2024	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Suspended Solids (High Level)	EA025H	5	45	**11.11**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	6	50	**12.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Suspended Solids (High Level)	EA025H	8	45	**17.78**	**12.50**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	3	50	**6.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Suspended Solids (High Level)	EA025H	3	45	**6.67**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	3	50	**6.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Suspended Solids (High Level)	EA025H	WATER	In house: Referenced to APHA 2540D. A gravimetric procedure employed to determine the amount of `non-filterable` residue in a aqueous sample. The prescribed GFC (1.2um) filter is rinsed with deionised water, oven dried and weighed prior to analysis. A well-mixed sample is filtered through a glass fibre filter (1.2um). The residue on the filter paper is dried at 104+/-2C . This method is compliant with NEPM Schedule B(3)
Turbidity	EA045	WATER	In house: Referenced to APHA 2130 B. This method is compliant with NEPM Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES2421688**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: hayden.nichols@rhdhv.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: PA3387-Geraldton	Page	: 1 of 3
Order number	: PA3387	Quote number	: EB2017HASAUS0001 (EN/222)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: HAYDEN NICHOLS		

Dates

Date Samples Received	: 02-Jul-2024 13:50	Issue Date	: 03-Jul-2024
Client Requested Due Date	: 09-Jul-2024	Scheduled Reporting Date	: **09-Jul-2024**

Delivery Details

Mode of Delivery	: Client Drop Off	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 4.8, 0.4, 3.7'C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 43 / 43
		No. of samples NOT collected	1

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The laboratory will process these samples unless instructions are received from you indicating you do not wish to proceed. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Sample AL02 was not received due to the following reason: sample not received
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Sampling date / time*	*Sample ID*	WATER - EA025H Suspended Solids - Standard Level	WATER - EA045 Turbidity
ES2421688-001	01-Jul-2024 09:25	B1-5_01	✓	✓
ES2421688-002	01-Jul-2024 09:29	B1-5_02	✓	✓
ES2421688-003	01-Jul-2024 09:37	B1-5_03	✓	✓
ES2421688-004	01-Jul-2024 09:43	B1-5_04	✓	✓
ES2421688-005	01-Jul-2024 09:55	B1-5_05	✓	✓
ES2421688-006	01-Jul-2024 10:04	B1-5_06	✓	✓
ES2421688-007	01-Jul-2024 10:15	B1-5_07	✓	✓
ES2421688-008	01-Jul-2024 10:25	B1-5_08	✓	✓
ES2421688-009	01-Jul-2024 10:36	B1-5_09	✓	✓
ES2421688-010	01-Jul-2024 10:52	B1-5_10	✓	✓
ES2421688-011	01-Jul-2024 11:05	B1-5_11	✓	✓
ES2421688-012	01-Jul-2024 11:20	B1-5_12	✓	✓
ES2421688-013	01-Jul-2024 11:40	B1-5_13	✓	✓
ES2421688-014	01-Jul-2024 11:59	B1-5_14	✓	✓
ES2421688-015	01-Jul-2024 12:29	B1-5_15	✓	✓
ES2421688-016	01-Jul-2024 13:16	B1-5_16	✓	✓
ES2421688-017	01-Jul-2024 14:46	B1-5_17	✓	✓
ES2421688-018	01-Jul-2024 16:46	B1-5_18	✓	✓
ES2421688-019	02-Jul-2024 08:03	B1-5_19	✓	✓
ES2421688-020	02-Jul-2024 13:12	B1-5_20	✓	✓
ES2421688-021	01-Jul-2024 00:00	AL01	✓	✓
ES2421688-022	02-Jul-2024 13:00	SEAWATER-GP		✓
ES2421688-023	02-Jul-2024 13:02	SEAWATER-SH		✓
ES2421688-024	01-Jul-2024 09:22	BH-01OS_01	✓	✓
ES2421688-025	01-Jul-2024 09:27	BH-01OS_02	✓	✓
ES2421688-026	01-Jul-2024 09:34	BH-01OS_03	✓	✓
ES2421688-027	01-Jul-2024 09:40	BH-01OS_04	✓	✓
ES2421688-028	01-Jul-2024 09:52	BH-01OS_05	✓	✓
ES2421688-029	01-Jul-2024 10:00	BH-01OS_06	✓	✓
ES2421688-030	01-Jul-2024 10:08	BH-01OS_07	✓	✓
ES2421688-031	01-Jul-2024 10:18	BH-01OS_08	✓	✓
ES2421688-032	01-Jul-2024 10:28	BH-01OS_09	✓	✓
ES2421688-033	01-Jul-2024 10:40	BH-01OS_10	✓	✓
ES2421688-034	01-Jul-2024 10:56	BH-01OS_11	✓	✓
ES2421688-035	01-Jul-2024 11:11	BH-01OS_12	✓	✓

			WATER - EA025H Suspended Solids - Standard Level	WATER - EA045 Turbidity
ES2421688-036	01-Jul-2024 11:31	BH-01OS_13	✓	✓
ES2421688-037	01-Jul-2024 11:51	BH-01OS_14	✓	✓
ES2421688-038	01-Jul-2024 12:21	BH-01OS_15	✓	✓
ES2421688-039	01-Jul-2024 13:05	BH-01OS_16	✓	✓
ES2421688-040	01-Jul-2024 14:35	BH-01OS_17	✓	✓
ES2421688-041	01-Jul-2024 16:35	BH-01OS_18	✓	✓
ES2421688-042	02-Jul-2024 07:57	BH-01OS_19	✓	✓
ES2421688-043	02-Jul-2024 13:07	BH-01OS_20	✓	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	ap.hk.finance@au.rhdhv.com

Esdat Deliverables

- EDI Format - ESDAT (ESDAT)	Email	ESdat_AU+rhdhv@ESdatLabSync.net

HAYDEN NICHOLS

- *AU Certificate of Analysis - NATA (COA)	Email	hayden.nichols@rhdhv.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	hayden.nichols@rhdhv.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	hayden.nichols@rhdhv.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	hayden.nichols@rhdhv.com
- Chain of Custody (CoC) (COC)	Email	hayden.nichols@rhdhv.com
- EDI Format - ENMRG (ENMRG)	Email	hayden.nichols@rhdhv.com
- EDI Format - ESDAT (ESDAT)	Email	hayden.nichols@rhdhv.com

HT

CHAIN OF

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS :	☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)
OFFICE: Level 15, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g., Ultra Trace Organics)	☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact? Yes / No / N/A
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: EB2017HASAUS0001	COC SEQUENCE NUMBER (Circle)	Free ice / frozen ice bricks present upon receipt? Yes / No / N/A
ORDER NUMBER: PA3387		COC 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: 4.8, 0.4, 3.7
PROJECT MANAGER: Hayden Nichols	CONTACT PH: 0423 956 796	OF: 1 2 3 4 5 6 7	Other comment:
SAMPLER: Hayden Nichols	SAMPLER MOBILE: 0423 956 796	RELINQUISHED BY: HN	RECEIVED BY: Dom
COC emailed to ALS? (YES) / NO)	EDD FORMAT (or default): ESDAT		DATE/TIME: 2/7 1:50pm
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com		DATE/TIME: 02/07/2024 @ 1:45 PM	RELINQUISHED BY:
Email Invoice to (will default to PM if no other addresses are listed): APJHK.FINANCE@au.rhdhv.com			DATE/TIME:
			RECEIVED BY:
			DATE/TIME: 2/7/24 1843

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA025H TSS	EA045 Turbidity																	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	BH-S_01	1/07/2024 9:05	WAT	1 x 250 ml green bottle	1		X	X																	
2	BH-S_02	1/07/2024 9:20	WAT	1 x 250 ml green bottle	1		X	X																	
3	BH-S_03	1/07/2024 9:37	WAT	1 x 250 ml green bottle	1		X	X																	
4	BH-S_04	1/07/2024 9:42	WAT	1 x 250 ml green bottle	1		X	X																	
5	BH-S_05	1/07/2024 9:55	WAT	1 x 250 ml green bottle	1		X	X																	
6	BH-S_06	1/07/2024 10:04	WAT	1 x 250 ml green bottle	1		X	X																	
7	BH-S_07	1/07/2024 10:19	WAT	1 x 250 ml green bottle	1		X	X																	
8	BH-S_08	1/07/2024 10:25	WAT	1 x 250 ml green bottle	1		X	X																	
9	BH-S_09	1/07/2024 10:39	WAT	1 x 250 ml green bottle	1		X	X																	
10	BH-S_10	1/07/2024 10:50	WAT	1 x 250 ml green bottle	1		X	X																	
11	BH-S_11	1/07/2024 11:25	WAT	1 x 250 ml green bottle	1		X	X																	
12	BH-S_12	1/07/2024 11:30	WAT	1 x 250 ml green bottle	1		X	X																	
13	BH-S_13	1/07/2024 11:40	WAT	1 x 250 ml green bottle	1		X	X																	
14	BH-S_14	1/07/2024 11:58	WAT	1 x 250 ml green bottle	1		X	X																	
15	BH-S_15	1/07/2024 12:05	WAT	1 x 250 ml green bottle	1		X	X																	
					15																				

Environmental Division
Sydney
Work Order Reference
ES2421688

Telephone : +61-2-8784 8555

Water Container Codes: P = Unpreserved Plastic; N = Nitric Preserved Plastic; ORC = Nitric Preserved ORC; SH = Sodium Hydroxide/Cd Preserved; S = Sulfuric Hydroxide Preserved Plastic; AG = Amber Glass Unpreserved; AP = Airfreight Unpreserved Plastic;
V = VOA Vial HCl Preserved; VS = 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.

CHAIN OF

ALS

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)	
OFFICE: Level 15, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact?	Yes No N/A
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: EB2017HASAUS0001	Free ice / frozen ice bricks present upon receipt?	Yes No N/A
ORDER NUMBER: PA3387	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt	°C
PROJECT MANAGER: Hayden Nichols CONTACT PH: 0423 556 796	SOF: 1 2 3 4 5 6 7	Other comment:	
SAMPLER: Hayden Nichols SAMPLER MOBILE: 0423 556 796	RELINQUISHED BY: HN	RECEIVED BY:	RELINQUISHED BY: RECEIVED BY:
COC emailed to ALS? (YES) / NO) EDD FORMAT (or default): ESDAT			DATE/TIME: 2/7/24 1847
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com	DATE/TIME: 02/07/2024 @ 1:45 PM	DATE/TIME:	DATE/TIME:
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA025H TSS	EA045 Turbidity																	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
16	B1-S_16	1/07/2024	13:15	WAT	1 x 500 ml green bottle	1		X	X																	
17	B1-S_17	1/07/2024	14:40	WAT	1 x 250 ml green bottle	1		X	X																	
18	B1-S_18	1/07/2024	15:45	WAT	1 x 250 ml green bottle	1		X	X																	
19	B1-S_19	2/07/2024	9:05	WAT	1 x 250 ml green bottle	1		X	X																	
20	B1-S_20	2/07/2024	15:15	WAT	1 x 250 ml green bottle	1		X	X																	
21	ALS1			WAT	1 x 500 ml green bottle	1		X	X																	
22	SEAWATER-CP	2/07/2024	1:00:00 PM	WAT	1 x 500 ml green bottle	1			X																	
23	SEAWATER-SH	2/07/2024	1:02:00 PM	WAT	1 x 500 ml green bottle	1			X																	
						8																				

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; VS = VOA Vial Sodium Bisulphate Preserved; VA = 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 Sulfate Soils; B = Unpreserved Bag.

CHAIN OF

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)	
OFFICE: Level 15, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g., Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact?	Yes No N/A
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: ES2017HASAU50001	Free ice / frozen ice bricks present upon receipt?	Yes No N/A
ORDER NUMBER: PA3387	COC SEQUENCE NUMBER (Circle) COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt:	°C
PROJECT MANAGER: Hayden Nichols CONTACT PH: 0423 956 796	COC: 1 2 3 4 5 6 7	Other comments:	
SAMPLER: Hayden Nichols SAMPLER MOBILE: 0423 956 796	RELINQUISHED BY: HN	RECEIVED BY:	RELINQUISHED BY:
COC emailed to ALS? (YES) NO) EDD FORMAT (or default): ESDAT			RECEIVED BY:
Email Reports to (will default to PM if no other addresses are listed): ESdal_AU+rhdhv@ESdalLabSync.net; hayden.nichols@rhdhv.com	DATE/TIME: 02/07/2024 @ 1:48 PM	DATE/TIME:	DATE/TIME: 2/7/24 1843
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: **Please HOLD all remaining sample material following analysis; Please** AGITATE THOROUGHLY **prior to analysis**

ALS USE	SAMPLE DETAILS MATRIX: SOLID (S) WATER (W)			CONTAINER INFORMATION			ANALYSIS REQUIRED including SUITES (NB. Suite Codes must be listed to ensure correct analysis) 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 CONTAINERS	HOLD	EA025H TSS	EA045 Turbidity		Comments on likely contaminant levels, dilutions or samples requiring specific QC analysis etc.
24	BH-01CB_01	1/07/2024 9:00	WAT	1 x 250 ml green bottle	1		X	X		
25	BH-01CB_02	1/07/2024 9:27	WAT	1 x 250 ml green bottle	1		X	X		
26	BH-01CB_03	1/07/2024 9:54	WAT	1 x 250 ml green bottle	1		X	X		
27	BH-01CB_04	1/07/2024 10:46	WAT	1 x 250 ml green bottle	1		X	X		
28	BH-01CB_05	1/07/2024 9:52	WAT	1 x 250 ml green bottle	1		X	X		
29	BH-01CB_06	1/07/2024 10:05	WAT	1 x 250 ml green bottle	1		X	X		
30	BH-01CB_07	1/07/2024 10:05	WAT	1 x 250 ml green bottle	1		X	X		
31	BH-01CB_08	1/07/2024 10:15	WAT	1 x 250 ml green bottle	1		X	X		
32	BH-01CB_09	1/07/2024 10:25	WAT	1 x 250 ml green bottle	1		X	X		
33	BH-01CB_10	1/07/2024 10:40	WAT	1 x 250 ml green bottle	1		X	X		
34	BH-01CB_11	1/07/2024 10:55	WAT	1 x 250 ml green bottle	1		X	X		
35	BH-01CB_12	1/07/2024 11:11	WAT	1 x 250 ml green bottle	1		X	X		
36	BH-01CB_13	1/07/2024 11:21	WAT	1 x 250 ml green bottle	1		X	X		
37	BH-01CB_14	1/07/2024 11:51	WAT	1 x 250 ml green bottle	1		X	X		
38	BH-01CB_15	1/07/2024 12:21	WAT	1 x 250 ml green bottle	1		X	X		
					13					

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 Bottle; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag.

CHAIN OF

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS :	☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)
OFFICE: Level 16, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g. Ultra Trace Organics)	☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact? Yes No N/A
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: EB2017HASAU50001	COC SEQUENCE NUMBER (Circle)	Free Ice / Frozen Ice Bricks present upon receipt? Yes No N/A
ORDER NUMBER: PA3387		COC: 1 2 3 4 5 6 7	Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Hayden Nichols	CONTACT PH: 0423 956 756	CF: 1 2 3 4 5 6 7	Other comment:
SAMPLER: Hayden Nichols	SAMPLER MOBILE: 0423 956 756	RELINQUISHED BY: HN	RECEIVED BY:
COC emailed to ALS? (YES / NO)	EDD FORMAT (or default): ESDAT	DATE/TIME: 02/07/2024 @ 1:45 PM	DATE/TIME:
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com		RELINQUISHED BY:	RECEIVED BY:
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com		DATE/TIME:	DATE/TIME: 2/7/24 1843

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA025H TSS	EA045 Turbidity																Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
39	BH-0105_55	1/07/2024 13:05	WAT	1 x 250 ml green bottle	1		X	X																
40	BH-0105_57	1/07/2024 14:05	WAT	1 x 250 ml green bottle	1		X	X																
41	BH-0105_59	1/07/2024 15:35	WAT	1 x 500 ml green bottle	1		X	X																
42	BH-0106_53	29/7/2024 7:57	WAT	1 x 500 ml green bottle	1		X	X																
43	BH-0106_29	29/7/2024 10:07	WAT	1 x 500 ml green bottle	1		X	X																
44	ALS2		WAT	1 x 500 ml green bottle	1		X	X																
					8																			

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 Bottle; ST = Sterile Bottle; ASS = Plastic Bag for Acid Sulphate Soils; B = Unpreserved Bag

CERTIFICATE OF ANALYSIS

Work Order	: **ES2421862**	Page	: 1 of 2
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387- Geraldton	Date Samples Received	: 03-Jul-2024 11:50
Order number	: PA3387	Date Analysis Commenced	: 03-Jul-2024
C-O-C number	: ----	Issue Date	: 10-Jul-2024 12:06
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	**B1-5_21**	**B1-5_22**	**BH-01OS_21**	**BH-01OS_22**	**----**
			Sampling date / time	02-Jul-2024 17:22	03-Jul-2024 10:44	02-Jul-2024 17:13	03-Jul-2024 10:35	----
Compound	*CAS Number*	*LOR*	*Unit*	**ES2421862-001**	**ES2421862-002**	**ES2421862-003**	**ES2421862-004**	**--------**
				Result	Result	Result	Result	----
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**7**	**7**	**25**	<5	**----**
EA045: Turbidity								
Turbidity	----	0.1	NTU	**6.6**	**3.3**	**6.2**	**3.8**	**----**

QUALITY CONTROL REPORT

Work Order	: **ES2421862**	Page	: 1 of 3
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387- Geraldton	Date Samples Received	: 03-Jul-2024
Order number	: PA3387	Date Analysis Commenced	: 03-Jul-2024
C-O-C number	: ----	Issue Date	: 10-Jul-2024
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 4		
No. of samples analysed	: 4		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EA025: Total Suspended Solids dried at 104 ± 2°C (QC Lot: 5908786)									
ES2421669-002	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	44	45	3.4	No Limit
ES2421777-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	53	53	0.0	0% - 50%
ES2421835-008	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	58	66	11.7	0% - 50%
ES2421867-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	47	47	0.0	No Limit
EA045: Turbidity (QC Lot: 5900646)									
EN2406089-001	Anonymous	EA045: Turbidity	----	0.1	NTU	0.3	0.3	0.0	No Limit
EA045: Turbidity (QC Lot: 5905717)									
EN2406158-003	Anonymous	EA045: Turbidity	----	0.1	NTU	11.4	11.2	1.8	0% - 20%
ES2421887-005	Anonymous	EA045: Turbidity	----	0.1	NTU	1.8	1.8	0.0	0% - 50%

Method Blank (MB) and Laboratory Control Sample (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA025: Total Suspended Solids dried at 104 ± 2°C (QCLot: 5908786)								
EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	99.3	83.0	129
				<5	1000 mg/L	99.4	82.0	110
				<5	928 mg/L	97.9	83.0	118
EA045: Turbidity (QCLot: 5900646)								
EA045: Turbidity	----	0.1	NTU	<0.1	40 NTU	93.8	91.0	105
EA045: Turbidity (QCLot: 5905717)								
EA045: Turbidity	----	0.1	NTU	<0.1	40 NTU	96.2	91.0	105

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2421862**	Page	: 1 of 4
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Telephone	: +61-2-8784 8555
Project	: PA3387- Geraldton	Date Samples Received	: 03-Jul-2024
Site	: ----	Issue Date	: 10-Jul-2024
Sampler	: HAYDEN NICHOLS	No. of samples received	: 4
Order number	: PA3387	No. of samples analysed	: 4

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, where applicable to the methodology, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)		Sample Date	Extraction / Preparation			Analysis		
			Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA025: Total Suspended Solids dried at 104 ± 2°C								
Clear Plastic Bottle - Natural (EA025H)								
B1-5_21,	BH-01OS_21	**02-Jul-2024**	**----**	----	----	**08-Jul-2024**	09-Jul-2024	✓
Clear Plastic Bottle - Natural (EA025H)								
B1-5_22,	BH-01OS_22	**03-Jul-2024**	**----**	----	----	**08-Jul-2024**	10-Jul-2024	✓
EA045: Turbidity								
Clear Plastic Bottle - Natural (EA045)								
B1-5_21,	BH-01OS_21	**02-Jul-2024**	**----**	----	----	**03-Jul-2024**	04-Jul-2024	✓
Clear Plastic Bottle - Natural (EA045)								
B1-5_22,	BH-01OS_22	**03-Jul-2024**	**----**	----	----	**05-Jul-2024**	05-Jul-2024	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Suspended Solids (High Level)	EA025H	4	39	**10.26**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	3	29	**10.34**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Suspended Solids (High Level)	EA025H	5	39	**12.82**	**12.50**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	2	29	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Suspended Solids (High Level)	EA025H	2	39	**5.13**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard
Turbidity	EA045	2	29	**6.90**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Suspended Solids (High Level)	EA025H	WATER	In house: Referenced to APHA 2540D. A gravimetric procedure employed to determine the amount of `non-filterable` residue in a aqueous sample. The prescribed GFC (1.2um) filter is rinsed with deionised water, oven dried and weighed prior to analysis. A well-mixed sample is filtered through a glass fibre filter (1.2um). The residue on the filter paper is dried at 104+/-2C . This method is compliant with NEPM Schedule B(3)
Turbidity	EA045	WATER	In house: Referenced to APHA 2130 B. This method is compliant with NEPM Schedule B(3)

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES2421862**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: hayden.nichols@rhdhv.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: PA3387- Geraldton	Page	: 1 of 2
Order number	: PA3387	Quote number	: EB2017HASAUS0001 (EN/222)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: HAYDEN NICHOLS		

Dates

Date Samples Received	: 03-Jul-2024 11:50	Issue Date	: 03-Jul-2024
Client Requested Due Date	: 10-Jul-2024	Scheduled Reporting Date	: **10-Jul-2024**

Delivery Details

Mode of Delivery	: Client Drop Off	Security Seal	: Not Available
No. of coolers/boxes	: 1	Temperature	: 1.2, 5.9, 5.2°C - Ice present
Receipt Detail	:	No. of samples received / analysed	: 4 / 4

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Sample AL02 forwarded to Eurofins for analysis.**
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The laboratory will process these samples unless instructions are received from you indicating you do not wish to proceed. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	*Sampling date / time*	*Sample ID*	WATER - EA025H Suspended Solids - Standard Level	WATER - EA045 Turbidity
ES2421862-001	02-Jul-2024 17:22	B1-5_21	✓	✓
ES2421862-002	03-Jul-2024 10:44	B1-5_22	✓	✓
ES2421862-003	02-Jul-2024 17:13	BH-01OS_21	✓	✓
ES2421862-004	03-Jul-2024 10:35	BH-01OS_22	✓	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	ap.hk.finance@au.rhdhv.com

Esdat Deliverables

- EDI Format - ESDAT (ESDAT)	Email	ESdat_AU+rhdhv@ESdatLabSync.net

HAYDEN NICHOLS

- *AU Certificate of Analysis - NATA (COA)	Email	hayden.nichols@rhdhv.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	hayden.nichols@rhdhv.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	hayden.nichols@rhdhv.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	hayden.nichols@rhdhv.com
- A4 - AU Tax Invoice (INV)	Email	hayden.nichols@rhdhv.com
- Chain of Custody (CoC) (COC)	Email	hayden.nichols@rhdhv.com
- EDI Format - ENMRG (ENMRG)	Email	hayden.nichols@rhdhv.com
- EDI Format - ESDAT (ESDAT)	Email	hayden.nichols@rhdhv.com

HT

CHAIN OF

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)	
OFFICE: Level 16, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g., Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact?	No / N/A
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: EB2017HARAMS0001	COC SEQUENCE NUMBER (Circle): 1 2 3 4 5 6 7	Free Ice / frozen ice bricks present upon receipt? Yes / No / N/A
ORDER NUMBER: PA3387			Random Sample Temperature on Receipt: °C
PROJECT MANAGER: Hayden Nichols	CONTACT PH: 0423 956 786		Other comment: 1.2, 5.9, 8.2
SAMPLER: Hayden Nichols	SAMPLER MOBILE: 0423 956 786	RELINQUISHED BY: IIN	RECEIVED BY:
COC emailed to ALS? (YES) / NO)	EDD FORMAT (or default): ESDAT	DATE/TIME: 05/07/2024 @ 11:30 AM	DATE/TIME: 3/7 11:50am
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com			
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA029H TSS	EA045 Turbidity	
1	BH-S_21	3/07/2024 17:22	WAT	1 x 500 ml green bottle	1		X	X	
2	BH-S_22	3/07/2024 16:41	WAT	1 x 500 ml green bottle	1		X	X	
3	BH-WQM_21	3/07/2024 17:43	WAT	1 x 500 ml green bottle	1		X	X	
4	BH-WQM_22	3/07/2024 16:06	WAT	1 x 500 ml green bottle	1		X	X	
—	ALS2	1/07/2024	WAT	1 x 500 ml green bottle	1		X	X	Please forward to Eurofins for the same testing
					5				

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.

Subcon / Forwarded Lab / Split WO: Eurofins
Lab / Analysis: TSS + Turbidity
Organised By / Date:
Relinquished By / Date:
Courier / Courier:
WO No: ES2421862
Attached By PO / Internal Sheet:

Environmental Division
Sydney
Work Order Reference
ES2421862

Telephone +61-2-8784 8555

SAMPLE RECEIPT NOTIFICATION (SRN)

Work Order	: **ES2420146**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
E-mail	: hayden.nichols@rhdhv.com	E-mail	: ALSEnviro.Sydney@ALSGlobal.com
Telephone	: ----	Telephone	: +61-2-8784 8555
Facsimile	: ----	Facsimile	: +61-2-8784 8500
Project	: PA3575-PoH	Page	: 1 of 2
Order number	: PA3575	Quote number	: EB2017HASAUS0001 (EN/222)
C-O-C number	: ----	QC Level	: NEPM 2013 B3 & ALS QC Standard
Site	: ----		
Sampler	: HAYDEN NICHOLS		

Dates

Date Samples Received	: 19-Jun-2024 17:15	Issue Date	: 20-Jun-2024
Client Requested Due Date	: 27-Jun-2024	Scheduled Reporting Date	: **27-Jun-2024**

Delivery Details

Mode of Delivery	: Client Drop Off	Security Seal	: Not Available
No. of coolers/boxes	: ----	Temperature	: 14.0, 14.5, 14.8'C
Receipt Detail	:	No. of samples received / analysed	: 5 / 5

General Comments

- This report contains the following information:
  - Sample Container(s)/Preservation Non-Compliances
  - Summary of Sample(s) and Requested Analysis
  - Proactive Holding Time Report
  - Requested Deliverables
- **Please refer to the Proactive Holding Time Report table below which summarises breaches of recommended holding times that have occurred prior to samples/instructions being received at the laboratory. The laboratory will process these samples unless instructions are received from you indicating you do not wish to proceed. The absence of this summary table indicates that all samples have been received within the recommended holding times for the analysis requested.**
- Please direct any queries you have regarding this work order to the above ALS laboratory contact.
- Analytical work for this work order will be conducted at ALS Sydney.
- Sample Disposal - Aqueous (3 weeks), Solid (2 months ± 1 week) from receipt of samples.
- Please be aware that APHA/NEPM recommends water and soil samples be chilled to less than or equal to 6°C for chemical analysis, and less than or equal to 10°C but unfrozen for Microbiological analysis. Where samples are received above this temperature, it should be taken into consideration when interpreting results. Refer to ALS EnviroMail 85 for ALS recommendations of the best practice for chilling samples after sampling and for maintaining a cool temperature during transit.

Sample Container(s)/Preservation Non-Compliances

All comparisons are made against pretreatment/preservation AS, APHA, USEPA standards.

- **No sample container / preservation non-compliance exists.**

Summary of Sample(s) and Requested Analysis

Some items described below may be part of a laboratory process necessary for the execution of client requested tasks. Packages may contain additional analyses, such as the determination of moisture content and preparation tasks, that are included in the package.
If no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component

Matrix: **WATER**

Laboratory sample ID	Sampling date / time	Sample ID	WATER - EA025H Suspended Solids - Standard Level
ES2420146-001	19-Jun-2024 15:30	BC1-5_SMS_2g	✓
ES2420146-002	19-Jun-2024 15:30	BC1-5_SMS_5g	✓
ES2420146-003	19-Jun-2024 15:30	BC1-5_SMS_10g	✓
ES2420146-004	19-Jun-2024 15:30	BC1-5_SMS_30g	✓
ES2420146-005	19-Jun-2024 15:30	BC1-5_SMS_100g	✓

Proactive Holding Time Report

Sample(s) have been received within the recommended holding times for the requested analysis.

Requested Deliverables

ALL INVOICES

- A4 - AU Tax Invoice (INV)	Email	ap.hk.finance@au.rhdhv.com

Esdat Deliverables

- EDI Format - ESDAT (ESDAT)	Email	ESdat_AU+rhdhv@ESdatLabSync.net

HAYDEN NICHOLS

- *AU Certificate of Analysis - NATA (COA)	Email	hayden.nichols@rhdhv.com
- *AU Interpretive QC Report - DEFAULT (Anon QCI Rep) (QCI)	Email	hayden.nichols@rhdhv.com
- *AU QC Report - DEFAULT (Anon QC Rep) - NATA (QC)	Email	hayden.nichols@rhdhv.com
- A4 - AU Sample Receipt Notification - Environmental HT (SRN)	Email	hayden.nichols@rhdhv.com
- Chain of Custody (CoC) (COC)	Email	hayden.nichols@rhdhv.com
- EDI Format - ENMRG (ENMRG)	Email	hayden.nichols@rhdhv.com
- EDI Format - ESDAT (ESDAT)	Email	hayden.nichols@rhdhv.com

CERTIFICATE OF ANALYSIS

Work Order	: **ES2420146**	Page	: 1 of 2
Amendment	: **1**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 19-Jun-2024 17:15
Order number	: PA3575	Date Analysis Commenced	: 25-Jun-2024
C-O-C number	: ----	Issue Date	: 27-Jun-2024 11:00
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 5		
No. of samples analysed	: 5		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contract for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- Amendment (27/06/2024): This report has been amended to alter the project reference code. All analysis results are as per the previous report.

Analytical Results

Sub-Matrix: **WATER** (Matrix: **WATER**)			Sample ID	BC1-5_SMS_2g	BC1-5_SMS_5g	BC1-5_SMS_10g	BC1-5_SMS_30g	BC1-5_SMS_100g
			Sampling date / time	19-Jun-2024 15:30	19-Jun-2024 15:30	19-Jun-2024 15:30	19-Jun-2024 15:30	19-Jun-2024 15:30
Compound	*CAS Number*	*LOR*	*Unit*	**ES2420146-001**	**ES2420146-002**	**ES2420146-003**	**ES2420146-004**	**ES2420146-005**
				Result	Result	Result	Result	Result
EA025: Total Suspended Solids dried at 104 ± 2°C								
Suspended Solids (SS)	----	5	mg/L	**661**	**1600**	**2830**	**7870**	**21500**

QUALITY CONTROL REPORT

Work Order	: **ES2420146**	Page	: 1 of 3
Amendment	: **1**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Contact	: Customer Services ES
Address	: LEVEL 15 99 MOUNTH ST NORTH SYDNEY 2060	Address	: 277-289 Woodpark Road Smithfield NSW Australia 2164
Telephone	: ----	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 19-Jun-2024
Order number	: PA3575	Date Analysis Commenced	: 25-Jun-2024
C-O-C number	: ----	Issue Date	: 27-Jun-2024
Sampler	: HAYDEN NICHOLS		
Site	: ----		
Quote number	: EN/222		
No. of samples received	: 5		
No. of samples analysed	: 5		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted, unless the sampling was conducted by ALS. This document shall not be reproduced, except in full.

This Quality Control Report contains the following information:

- Laboratory Duplicate (DUP) Report; Relative Percentage Difference (RPD) and Acceptance Limits
- Method Blank (MB) and Laboratory Control Spike (LCS) Report; Recovery and Acceptance Limits
- Matrix Spike (MS) Report; Recovery and Acceptance Limits

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Ankit Joshi	Senior Chemist - Inorganics	Sydney Inorganics, Smithfield, NSW

General Comments

The analytical procedures used by ALS have been developed from established internationally recognised procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are fully validated and are often at the client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis. Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

Key : Anonymous = Refers to samples which are not specifically part of this work order but formed part of the QC process lot
CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
RPD = Relative Percentage Difference
# = Indicates failed QC

Laboratory Duplicate (DUP) Report

The quality control term Laboratory Duplicate refers to a randomly selected intralaboratory split. Laboratory duplicates provide information regarding method precision and sample heterogeneity. The permitted ranges for the Relative Percent Deviation (RPD) of Laboratory Duplicates are specified in ALS Method QWI-EN/38 and are dependent on the magnitude of results in comparison to the level of reporting: Result < 10 times LOR: No Limit; Result between 10 and 20 times LOR: 0% - 50%; Result > 20 times LOR: 0% - 20%.

Sub-Matrix: **WATER**

				Laboratory Duplicate (DUP) Report					
Laboratory sample ID	*Sample ID*	*Method: Compound*	*CAS Number*	*LOR*	*Unit*	*Original Result*	*Duplicate Result*	*RPD (%)*	*Acceptable RPD (%)*
EA025: Total Suspended Solids dried at 104 ± 2°C (QC Lot: 5882262)									
EN2405593-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	12600	12500	0.6	0% - 20%
ES2420221-002	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	8	6	28.6	No Limit
ES2420314-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	39	43	10.3	No Limit
ES2420521-001	Anonymous	EA025H: Suspended Solids (SS)	----	5	mg/L	<5	6	0.0	No Limit

Method Blank (MB) and Laboratory Control Sample (LCS) Report

The quality control term Method / Laboratory Blank refers to an analyte free matrix to which all reagents are added in the same volumes or proportions as used in standard sample preparation. The purpose of this QC parameter is to monitor potential laboratory contamination. The quality control term Laboratory Control Sample (LCS) refers to a certified reference material, or a known interference free matrix spiked with target analytes. The purpose of this QC parameter is to monitor method precision and accuracy independent of sample matrix. Dynamic Recovery Limits are based on statistical evaluation of processed LCS.

Sub-Matrix: **WATER**

				Method Blank (MB) Report	Laboratory Control Spike (LCS) Report			
					Spike	Spike Recovery (%)	Acceptable Limits (%)	
Method: Compound	CAS Number	LOR	Unit	Result	Concentration	LCS	Low	High
EA025: Total Suspended Solids dried at 104 ± 2°C (QCLot: 5882262)								
EA025H: Suspended Solids (SS)	----	5	mg/L	<5	150 mg/L	98.7	83.0	129
				<5	1000 mg/L	100	82.0	110
				<5	928 mg/L	102	83.0	118

Matrix Spike (MS) Report

The quality control term Matrix Spike (MS) refers to an intralaboratory split sample spiked with a representative set of target analytes. The purpose of this QC parameter is to monitor potential matrix effects on analyte recoveries. Static Recovery Limits as per laboratory Data Quality Objectives (DQOs). Ideal recovery ranges stated may be waived in the event of sample matrix interference.

- **No Matrix Spike (MS) or Matrix Spike Duplicate (MSD) Results are required to be reported.**

QA/QC Compliance Assessment to assist with Quality Review

Work Order	: **ES2420146**	Page	: 1 of 4
Amendment	: **1**		
Client	: **HASKONING AUSTRALIA- ROYAL HASKONING**	Laboratory	: Environmental Division Sydney
Contact	: HAYDEN NICHOLS	Telephone	: +61-2-8784 8555
Project	: PA3387-Geraldton	Date Samples Received	: 19-Jun-2024
Site	: ----	Issue Date	: 27-Jun-2024
Sampler	: HAYDEN NICHOLS	No. of samples received	: 5
Order number	: PA3575	No. of samples analysed	: 5

This report is automatically generated by the ALS LIMS through interpretation of the ALS Quality Control Report and several Quality Assurance parameters measured by ALS. This automated reporting highlights any non-conformances, facilitates faster and more accurate data validation and is designed to assist internal expert and external Auditor review. Many components of this report contribute to the overall DQO assessment and reporting for guideline compliance.

Brief method summaries and references are also provided to assist in traceability.

Summary of Outliers

Outliers : Quality Control Samples

This report highlights outliers flagged in the Quality Control (QC) Report.

- **NO Method Blank value outliers occur.**
- **NO Duplicate outliers occur.**
- **NO Laboratory Control outliers occur.**
- **NO Matrix Spike outliers occur.**
- **For all regular sample matrices, where applicable to the methodology, NO surrogate recovery outliers occur.**

Outliers : Analysis Holding Time Compliance

- **NO Analysis Holding Time Outliers exist.**

Outliers : Frequency of Quality Control Samples

- **NO Quality Control Sample Frequency Outliers exist.**

Analysis Holding Time Compliance

If samples are identified below as having been analysed or extracted outside of recommended holding times, this should be taken into consideration when interpreting results.

This report summarizes extraction / preparation and analysis times and compares each with ALS recommended holding times (referencing USEPA SW 846, APHA, AS and NEPM) based on the sample container provided. Dates reported represent first date of extraction or analysis and preclude subsequent dilutions and reruns. A listing of breaches (if any) is provided herein.

Holding time for leachate methods (e.g. TCLP) vary according to the analytes reported. Assessment compares the leach date with the shortest analyte holding time for the equivalent soil method. These are: organics 14 days, mercury 28 days & other metals 180 days. A recorded breach does not guarantee a breach for all non-volatile parameters.

Holding times for ***VOC in soils*** vary according to analytes of interest. Vinyl Chloride and Styrene holding time is 7 days; others 14 days. A recorded breach does not guarantee a breach for all VOC analytes and should be verified in case the reported breach is a false positive or Vinyl Chloride and Styrene are not key analytes of interest/concern.

Matrix: **WATER**

Evaluation: × = Holding time breach ; ✓ = Within holding time.

Method / Container / Client Sample ID(s)	Sample Date	Extraction / Preparation			Analysis		
		Date extracted	Due for extraction	Evaluation	Date analysed	Due for analysis	Evaluation
EA025: Total Suspended Solids dried at 104 ± 2°C							
Clear Plastic Bottle - Natural (EA025H)							
BC1-5_SMS_2g, BC1-5_SMS_5g, BC1-5_SMS_10g, BC1-5_SMS_30g, BC1-5_SMS_100g	**19-Jun-2024**	**----**	----	----	**25-Jun-2024**	26-Jun-2024	✓

Quality Control Parameter Frequency Compliance

The following report summarises the frequency of laboratory QC samples analysed within the analytical lot(s) in which the submitted sample(s) was(were) processed. Actual rate should be greater than or equal to the expected rate. A listing of breaches is provided in the Summary of Outliers.

Matrix: **WATER**

Evaluation: × = Quality Control frequency not within specification ; ✓ = Quality Control frequency within specification.

Quality Control Sample Type		Count		Rate (%)			Quality Control Specification
Analytical Methods	*Method*	*QC*	*Regular*	***Actual***	***Expected***	*Evaluation*	
Laboratory Duplicates (DUP)							
Suspended Solids (High Level)	EA025H	4	40	**10.00**	**10.00**	✓	NEPM 2013 B3 & ALS QC Standard
Laboratory Control Samples (LCS)							
Suspended Solids (High Level)	EA025H	5	40	**12.50**	**12.50**	✓	NEPM 2013 B3 & ALS QC Standard
Method Blanks (MB)							
Suspended Solids (High Level)	EA025H	2	40	**5.00**	**5.00**	✓	NEPM 2013 B3 & ALS QC Standard

Brief Method Summaries

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the US EPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request. The following report provides brief descriptions of the analytical procedures employed for results reported in the Certificate of Analysis. Sources from which ALS methods have been developed are provided within the Method Descriptions.

Analytical Methods	Method	Matrix	Method Descriptions
Suspended Solids (High Level)	EA025H	WATER	In house: Referenced to APHA 2540D. A gravimetric procedure employed to determine the amount of `non-filterable` residue in a aqueous sample. The prescribed GFC (1.2um) filter is rinsed with deionised water, oven dried and weighed prior to analysis. A well-mixed sample is filtered through a glass fibre filter (1.2um). The residue on the filter paper is dried at 104+/-2C . This method is compliant with NEPM Schedule B(3)

HT

CHAIN OF

ALS Environmental
BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: samples.brisbane@alsglobal.com
MELBOURNE 2-4 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com
PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: samples.perth@alsglobal.com
TOWNSVILLE 14-15 Desma Court Bohle QLD 4818 Ph: 07 4796 0600 E: samples.townsville@alsglobal.com
GLADSTONE 1/3 Kitchener Drive Paradise QLD 4680 Ph: 07 4972 9700 E: samples.gladstone@alsglobal.com
MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay@alsglobal.com
NEWCASTLE 5/585 Maitland Rd Mayfield West NSW 2304 Ph: 02 4014 2500 E: samples.newcastle@alsglobal.com
SYDNEY 277-289 Woodpark Road Smithfield NSW 2164 Ph: 02 8784 8555 E: samples.sydney@alsglobal.com
ORANGE 1/10 Kite Close Orange NSW 2800 Ph: 02 6364 9000 E: samples.orange@alsglobal.com
WAGGA WAGGA 4/13 Dansie Place North Wagga NSW 2650 Ph: 02 6933 2000 E: samples.wagga@alsglobal.com

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)	
OFFICE: Level 15, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact?	No N/A
PROJECT: PA3575 - Poll	ALS QUOTE NO: EB2017HASAUS0001	Free ice / Frozen ice bricks present upon receipt?	No N/A
ORDER NUMBER: PA3575	COC SEQUENCE NUMBER (Circle) COC 1 2 3 4 5 6 7 OF 1 2 3 4 5 6 7	Random Sample Temperature on Receipt:	14.0, 14.5, 14.8 °C
PROJECT MANAGER: Hayden Nichols CONTACT PH: 0423 956 796		Other comment:	
SAMPLER: Hayden Nichols SAMPLER MOBILE: 0423 956 796	RELINQUISHED BY: HN	RECEIVED BY: Dnm	RELINQUISHED BY:
COC emailed to ALS? (YES) NO	EDD FORMAT (or default): ESDAT	DATE/TIME: 19/6 5:15pm	DATE/TIME:
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com	DATE/TIME: 19/06/2024 @ 6:00 PM		RECEIVED BY:
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com			DATE/TIME: 19/6/24 1927

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA025H 188																		Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
1	BG1-S_SMS_0g	19/06/2024	3:00:00 PM	WAT	1 x 500 ml green bottle	1		X																		
2	BG1-S_SMS_5g	19/06/2024	3:30:00 PM	WAT	1 x 500 ml green bottle	1		X																		
3	BG1-S_SMS_10g	19/06/2024	3:00:00 PM	WAT	1 x 500 ml green bottle	1		X																		
4	BG1-S_SMS_30g	19/06/2024	3:30:00 PM	WAT	1 x 500 ml green bottle	1		X																		
5	BG1-S_SMS_100g	19/06/2024	3:00:00 PM	WAT	1 x 500 ml green bottle	1		X																		
						5																				

Environmental Division Sydney
Work Order Reference
ES2420146
Telephone - 61-2-8784 8555

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; VS = 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

HT

CHAIN OF

ALS

ALS BRISBANE 32 Shand Street Stafford QLD 4053 Ph: 07 3243 7222 E: enquiries@alsglobal.com

ALS MELBOURNE 24 Westall Road Springvale VIC 3171 Ph: 03 8549 9600 E: samples.melbourne@alsglobal.com

ALS NEWCASTLE 5 Rose Road Mayfield West NSW 2304 Ph: 02 4968 9433 E: newcastle@alsglobal.com

ALS TOWNSVILLE 14-15 Desma Court Garbutt QLD 4814 Ph: 07 4796 0600 E: townsville@alsglobal.com

ALS PERTH 10 Hod Way Malaga WA 6090 Ph: 08 9209 7655 E: perth.enquiry@alsglobal.com

ALS MACKAY 78 Harbour Road Mackay QLD 4740 Ph: 07 4944 0177 E: mackay.geo@alsglobal.com

CLIENT: Royal HaskoningDHV Australia	TURNAROUND REQUIREMENTS : ☐ Standard TAT (List due date):	FOR LABORATORY USE ONLY (Circle)	
OFFICE: Level 15, 99 Mount Street, North Sydney	(Standard TAT may be longer for some tests e.g. Ultra Trace Organics) ☐ Non Standard or urgent TAT (List due date):	Custody Seal Intact?	Yes / No / (N/A)
PROJECT: PA3387 - Geraldton	ALS QUOTE NO: EB2017HASAUS0001	Free ice / frozen ice bricks present upon receipt?	(Yes) / No / N/A
ORDER NUMBER: PA3387	COC SEQUENCE NUMBER (Circle): COC 1 2 3 4 5 6 7; SOF 1 2 3 4 5 6 7	Random Sample Temperature on Receipt:	1.2, 5.9, 5.2 °C
PROJECT MANAGER: Hayden Nichols CONTACT PH: 0423 958 796		Other comment:	
SAMPLER: Hayden Nichols SAMPLER MOBILE: 0423 958 796	RELINQUISHED BY: HN	RECEIVED BY: Dan	RECEIVED BY:
COC emailed to ALS? (YES) NO) EDD FORMAT (or default): ESDAT	DATE/TIME: 03/07/2024 @ 11:30 AM	DATE/TIME: 3/7 11:50am	DATE/TIME: 3/7/24 1512
Email Reports to (will default to PM if no other addresses are listed): ESdat_AU+rhdhv@ESdatLabSync.net; hayden.nichols@rhdhv.com	RELINQUISHED BY:	DATE/TIME:	
Email Invoice to (will default to PM if no other addresses are listed): AP.HK.FINANCE@au.rhdhv.com			

COMMENTS/SPECIAL HANDLING/STORAGE OR DISPOSAL: Please HOLD all remaining sample material following analysis; Please AGITATE THOROUGHLY prior to analysis

ALS USE	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 CONTAINERS	HOLD	EA026H TSS	EA045 Turbidity	
1	B1-6_21	2/07/2024	17:22	WAT	1 x 500 ml green bottle	1		X	X	Comments on likely contaminant levels, dilutions, or samples requiring specific QC analysis etc.
2	B1-6_22	3/07/2024	10:44	WAT	1 x 500 ml green bottle	1		X	X	
3	B44105_21	2/07/2024	17:13	WAT	1 x 500 ml green bottle	1		X	X	
4	B44105_22	3/07/2024	10:35	WAT	1 x 500 ml green bottle	1		X	X	
-	AL02	1/07/2024		WAT	1 x 500 ml green bottle	1		X	X	Please forward to Eurofins for the same testing
						5				

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

Environmental Division
Sydney
Work Order Reference
ES2421862

Telephone : +61-2-8784 8555

1115336

Away 5/7 11:30am 6.1°C

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www.eurofins.com.au EnviroSales@eurofins.com

Eurofins Environment Testing Australia Pty Ltd

ABN: 50 005 085 521

Melbourne	Geelong	Sydney	Canberra	Brisbane	Newcastle
6 Monterey Road	19/8 Lewalan Street	179 Magowar Road	Unit 1,2 Dacre Street	1/21 Smallwood Place	1/2 Frost Drive
Dandenong South	Grovedale	Girraween	Mitchell	Murarrie	Mayfield West
VIC 3175	VIC 3216	NSW 2145	ACT 2911	QLD 4172	NSW 2304
+61 3 8564 5000	+61 3 8564 5000	+61 2 9900 8400	+61 2 6113 8091	T: +61 7 3902 4600	+61 2 4968 8448
NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261
Site# 1254	Site# 25403	Site# 18217	Site# 25466	Site# 20794 & 2780	Site# 25079

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Penrose,	Mount Wellington,	Rolleston,	Gate Pa,
Auckland 1061	Auckland 1061	Christchurch 7675	Tauranga 3112
+64 9 526 4551	+64 9 525 0568	+64 3 343 5201	+64 9 525 0568
IANZ# 1327	IANZ# 1308	IANZ# 1290	IANZ# 1402

Sample Receipt Advice

Company name: Haskoning Australia Pty Ltd (RHDHV)
Contact name: Hayden Nichols
Project name: GERALDTON
Project ID: PA3387
Turnaround time: 5 Day
Date/Time received Jul 6, 2024 11:30 AM
Eurofins reference 1115336

Sample Information

✓ A detailed list of analytes logged into our LIMS, is included in the attached summary table.

✓ All samples have been received as described on the above COC.

✓ COC has been completed correctly.

✓ Attempt to chill was evident.

✓ Appropriately preserved sample containers have been used.

✓ All samples were received in good condition.

✓ Samples have been provided with adequate time to commence analysis in accordance with the relevant holding times.

✓ Appropriate sample containers have been used.

✓ Sample containers for volatile analysis received with zero headspace.

X Split sample sent to requested external lab.

X Some samples have been subcontracted.

N/A Custody Seals intact (if used).

Notes

Contact

If you have any questions with respect to these samples, please contact your Analytical Services Manager:

Ursula Long on phone : or by email: UrsulaLong@eurofins.com

Results will be delivered electronically via email to Hayden Nichols - hayden.nichols@rhdhv.com.

Note: A copy of these results will also be delivered to the general Haskoning Australia Pty Ltd (RHDHV) email address.

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web: www.eurofins.com.au
email: EnviroSales@eurofins.com

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ABN: 50 005 085 521

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NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261	NATA# 1261
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+64 9 526 4551	+64 9 525 0568	+64 3 343 5201	+64 9 525 0568
IANZ# 1327	IANZ# 1308	IANZ# 1290	IANZ# 1402

Company Name: Haskoning Australia Pty Ltd (RHDHV)
Address: Level 15, 99 Mount St
North Sydney
NSW 2060

Project Name: GERALDTON
Project ID: PA3387

Order No.:
Report #: 1115336
Phone: (02) 8854 5000
Fax: (02) 9929 0960

Received: Jul 6, 2024 11:30 AM
Due: Jul 15, 2024
Priority: 5 Day
Contact Name: Hayden Nichols

Eurofins Analytical Services Manager : Ursula Long

Sample Detail						Total Suspended Solids Dried at 103 °C to 105 °C	Turbidity
Sydney Laboratory - NATA # 1261 Site # 18217						X	X
External Laboratory							
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**		
1	AL02	Jul 01, 2024		Water	S24-Jl0017115	X	X
Test Counts						1	1

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Certificate of Analysis

Haskoning Australia Pty Ltd (RHDHV)
Level 15, 99 Mount St
North Sydney
NSW 2060

NATA Accredited
Accreditation Number 1261
Site Number 18217

Accredited for compliance with ISO/IEC 17025 – Testing
NATA is a signatory to the ILAC Mutual Recognition Arrangement for the mutual recognition of the equivalence of testing, medical testing, calibration, inspection, proficiency testing scheme providers and reference materials producers reports and certificates.

Attention: **Hayden Nichols**

Report **1115336-W**
Project name GERALDTON
Project ID PA3387
Received Date Jul 06, 2024

Client Sample ID			**AL02**
Sample Matrix			**Water**
Eurofins Sample No.			**S24-Jl0017115**
Date Sampled			**Jul 01, 2024**
Test/Reference	LOR	Unit	
Total Suspended Solids Dried at 103 °C to 105 °C	5	mg/L	130
Turbidity	1	NTU	98

Sample History

Where samples are submitted/analysed over several days, the last date of extraction is reported.

If the date and time of sampling are not provided, the Laboratory will not be responsible for compromised results should testing be performed outside the recommended holding time.

Description	Testing Site	Extracted	Holding Time
Total Suspended Solids Dried at 103 °C to 105 °C	Sydney	Jul 12, 2024	7 Days
- Method: LTM-INO-4070 Analysis of Suspended Solids in Water by Gravimetry			
Turbidity	Sydney	Jul 12, 2024	2 Days
- Method: LTM-INO-4140 Turbidity by Nephelometric Method			

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web: www.eurofins.com.au
email: EnviroSales@eurofins.com

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NSW 2060

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Contact Name: Hayden Nichols

Eurofins Analytical Services Manager : Ursula Long

Sample Detail						Total Suspended Solids Dried at 103 °C to 105 °C	Turbidity
Sydney Laboratory - NATA # 1261 Site # 18217						X	X
External Laboratory							
No	**Sample ID**	**Sample Date**	**Sampling Time**	**Matrix**	**LAB ID**		
1	AL02	Jul 01, 2024		Water	S24-Jl0017115	X	X
Test Counts						1	1

Internal Quality Control Review and Glossary

General

1. Laboratory QC results for Method Blanks, Duplicates, Matrix Spikes, and Laboratory Control Samples follow guidelines delineated in the National Environment Protection (Assessment of Site Contamination) Measure 1999, as amended May 2013. They are included in this QC report where applicable. Additional QC data may be available on request.
2. Unless otherwise stated, all soil/sediment/solid results are reported on a dry weight basis.
3. Unless otherwise stated, all biota/food results are reported on a wet weight basis on the edible portion.
4. For CEC results where the sample's origin is unknown or environmentally contaminated, the results should be used advisedly.
5. Actual LORs are matrix dependent. Quoted LORs may be raised where sample extracts are diluted due to interferences.
6. Results are uncorrected for matrix spikes or surrogate recoveries except for PFAS compounds where annotated.
7. SVOC analysis on waters is performed on homogenised, unfiltered samples unless noted otherwise.
8. Samples were analysed on an 'as received' basis.
9. Information identified in this report with **blue** colour indicates data provided by customers that may have an impact on the results.
10. This report replaces any interim results previously issued.

Holding Times

Please refer to the 'Sample Preservation and Container Guide' for holding times (QS3001).

For samples received on the last day of holding time, notification of testing requirements should have been received at least 6 hours before sample receipt deadlines as stated on the SRA.

If the Laboratory did not receive the information in the required timeframe, and despite any other integrity issues, suitably qualified results may still be reported.

Holding times apply from the sampling date; therefore, compliance with these may be outside the laboratory's control.

For VOCs containing vinyl chloride, styrene and 2-chloroethyl vinyl ether, the holding time is seven days; however, for all other VOCs, such as BTEX or C6-10 TRH, the holding time is 14 days.

Units

mg/kg: milligrams per kilogram	**mg/L:** milligrams per litre	**ppm:** parts per million
µg/L: micrograms per litre	**ppb:** parts per billion	**%:** Percentage
org/100 mL: Organisms per 100 millilitres	**NTU:** Nephelometric Turbidity Units	**MPN/100 mL:** Most Probable Number of organisms per 100 millilitres
CFU: Colony Forming Unit	**Colour:** Pt-Co Units (CU)	

Terms

APHA	American Public Health Association
CEC	Cation Exchange Capacity
COC	Chain of Custody
CP	Client Parent - QC was performed on samples pertaining to this report
CRM	Certified Reference Material (ISO17034) - reported as percent recovery.
Dry	Where moisture has been determined on a solid sample, the result is expressed on a dry weight basis.
Duplicate	A second piece of analysis from the same sample and reported in the same units as the result to show comparison.
LOR	Limit of Reporting.
LCS	Laboratory Control Sample - reported as percent recovery.
Method Blank	In the case of solid samples, these are performed on laboratory-certified clean sands and in the case of water samples, these are performed on de-ionised water.
NCP	Non-Client Parent - QC performed on samples not pertaining to this report, QC represents the sequence or batch that client samples were analysed within.
RPD	Relative Percent Difference between two Duplicate pieces of analysis.
SPIKE	Addition of the analyte to the sample and reported as percentage recovery.
SRA	Sample Receipt Advice
Surr - Surrogate	The addition of a similar compound to the analyte target is reported as percentage recovery. See below for acceptance criteria.
TBTO	Tributyltin oxide (*bis*-tributyltin oxide) - individual tributyltin compounds cannot be identified separately in the environment; however, free tributyltin was measured, and its values were converted stoichiometrically into tributyltin oxide for comparison with regulatory limits.
TCLP	Toxicity Characteristic Leaching Procedure
TEQ	Toxic Equivalency Quotient or Total Equivalence
QSM	US Department of Defense Quality Systems Manual Version 6.0
US EPA	United States Environmental Protection Agency
WA DWER	Sum of PFBA, PFPeA, PFHxA, PFHpA, PFOA, PFBS, PFHxS, PFOS, 6:2 FTSA, 8:2 FTSA

QC - Acceptance Criteria

The acceptance criteria should only be used as a guide and may be different when site-specific Sampling Analysis and Quality Plan (SAQP) have been implemented.

RPD Duplicates: Global RPD Duplicates Acceptance Criteria is ≤30%; however, the following acceptance guidelines are equally applicable:

Results <10 times the LOR:	No Limit
Results between 10-20 times the LOR:	RPD must lie between 0-50%
Results >20 times the LOR:	RPD must lie between 0-30%

NOTE: pH duplicates are reported as a range, not as RPD

Surrogate Recoveries: Recoveries must lie between 20-130% for Speciated Phenols & 50-150% for PFAS. SVOCs recoveries 20 – 150%, VOC recoveries 50 – 150%

PFAS field samples containing surrogate recoveries above the QC limit designated in QSM 6.0, where no positive PFAS results have been reported or reviewed, and no data was affected.

QC Data General Comments

1. Where a result is reported as less than (<), higher than the nominated LOR, this is due to either matrix interference, extract dilution required due to interferences or contaminant levels within the sample, high moisture content or insufficient sample provided.
2. Duplicate data shown within this report that states the word "BATCH" is a Batch Duplicate from outside of your sample batch but within the laboratory sample batch at a 1:10 ratio. The Parent and Duplicate data shown are not data from your samples.
3. pH and Free Chlorine analysed in the laboratory - Analysis on this test must begin within 30 minutes of sampling. Therefore, laboratory analysis is unlikely to be completed within holding time.Analysis will begin as soon as possible after sample receipt.
4. Recovery Data (Spikes & Surrogates) - where chromatographic interference does not allow the determination of recovery, the term "INT" appears against that analyte.
5. For Matrix Spikes and LCS results, a dash "-" in the report means that the specific analyte was not added to the QC sample.
6. Duplicate RPDs are calculated from raw analytical data; thus, it is possible to have two sets of data.

Quality Control Results

Test	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Method Blank							
Total Suspended Solids Dried at 103 °C to 105 °C	mg/L	< 5			5	Pass	
Turbidity	NTU	< 1			1	Pass	
LCS - % Recovery							
Total Suspended Solids Dried at 103 °C to 105 °C	%	93			70-130	Pass	
Turbidity	%	110			70-130	Pass	

Test	Lab Sample ID	QA Source	Units	Result 1			Acceptance Limits	Pass Limits	Qualifying Code
Duplicate									
				Result 1	Result 2	RPD			
Total Suspended Solids Dried at 103 °C to 105 °C	S24-Jl0031685	NCP	mg/L	15	15	1.3	30%	Pass	
Turbidity	S24-Jl0028251	NCP	NTU	8.6	7.9	7.5	30%	Pass	

Comments

Sample Integrity

Custody Seals Intact (if used)	N/A
Attempt to Chill was evident	Yes
Sample correctly preserved	Yes
Appropriate sample containers have been used	Yes
Sample containers for volatile analysis received with minimal headspace	Yes
Samples received within HoldingTime	Yes
Some samples have been subcontracted	No

Authorised by:

Ursula Long	Analytical Services Manager
Ryan Phillips	Senior Analyst-Inorganic



Glenn Jackson
Managing Director

Final Report – this report replaces any previously issued Report

- Indicates Not Requested

* Indicates NATA accreditation does not cover the performance of this service

Measurement uncertainty of test data is available on request or please click here.

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Multi Parameter Water Meter

Instrument **YSI Pro DSS**
Serial No. **21K101474**

Air-Met Scientific Pty Ltd
1300 137 067

Item	Test	Pass	Comments
Battery	Charge Condition	✓	
	Fuses	✓	
	Capacity	✓	
	Recharge OK?	✓	
Switch/keypad	Operation	✓	
Display	Intensity	✓	
	Operation (segments)	✓	
Grill Filter	Condition	✓	
	Seal	✓	
PCB	Condition	✓	
Connectors	Condition	✓	
Sensor	1. pH/ORP	✓	
	2. Turbidity	✓	
	3. Conductivity	✓	
	4. D.O	✓	
	5. Temp	✓	
	6. Depth	✓	
Alarms	Beeper		
	Settings		
Software	Version		
Data logger	Operation		
Download	Operation		
Other tests:			

Certificate of Calibration

This is to certify that the above instrument has been calibrated to the following specifications:

Sensor	Serial no	Standard Solutions	Certified	Solution Bottle Number	Instrument Reading
1. pH 7.00		pH7		419529	6.87
2. pH 4.00		pH4		414104	3.96
3.ORP (mV)		240.88		A420151/B420152	240.1
4. SPC (uS/cm)		2760		424499	2763
5. D.O		0.0%		407802	0.0%
6. Temp (^{o}C)		19.8		MultiTherm	19.6
7. Turbidity (NTU)		100 NTU		426952	99.77

Calibrated by: **Eliza Anwar**

Calibration date: **31/05/2024**

Next calibration due: **30/06/2024**

Turbidity Probe Calibration

Date	Solution	Turbidity before	Turbidity After	Pass/ Fail	Turbidity bef	Turbidity After	Pass/ Fail
25-06-24	0	-2.22	0.12	Pass	-	-	-
	200	206.1	201.02	Pass	-	-	-

Comparison: Geraldton Site Water and Sydney Harbour Water used for testing

Physio-chemical parameter	Unit	Sydney	Geraldton	Comments
Sample location	-	Balmoral Beach Jetty	Geraldton Port Berth 1	
Sample date	-	18-06-24	20-05-24	
Sample time	-	2:00 PM	1:10 PM	
Tide (Willy Weather)	-	Flooding mid tide 1.1 m	Ebbing approaching low tide 0.7 m	
Rainfall in week preceding (Bo	mm	74 mm recorded on 15-06-24	1.4 mm recorded on 15-05-24	
Rainfall station		Sydney Botanic Gardens (066006)	Geraldton Town (008050)	
Temp	Deg C	13.4	13.3	
DO	%RTB	99	100	
SPC	us/cm	51331	54861	
C	us/cm	39995	42609	
pH	pH units	7.88	7.91	
ORP	mV	171.9	175.38	
Turbidity	NTU	1.32	1.34	Request lab NTU
Turbidity ALS	NTU	0.8	0.4	
Colour		Marginally darker than Geraldton water	Marginally clearer than Sydney water	

TSS-Turbidity Column Test Log Records

Sample ID	B1-5 Column Test	
Start Date	01-07-24	
Start Time	9:25 AM	
End Date	03-07-24	
End Time	10:44 AM	
Approximate Sample Mass	80 g	Note: Approximated from slurry with 200 g of raw sediment to achieve an upper turbidity level of approximately 200 to 300 NTU
Seawater Turbidity	1.32	

Test Interval	Date	Time	Date Time	Time Elapsed	Time between measurements	Turbidity (NTU)	Lab Turbidity (NTU)	TSS (mg/L)	Temperature (deg C)	TSS Sample ID	QA Sample	Duplicate sample turbidity (NTU)	QA sample TSS (mg/L)	Observations
1	01-07-24	9:25	01-07-24 9:25	0:00	0:00	230.4	263	271	12.3	B1-5_01				
2	01-07-24	9:29	01-07-24 9:29	0:04	0:04	194.2	216	184	12.3	B1-5_02				Gradual stratification
3	01-07-24	9:37	01-07-24 9:37	0:12	0:08	182.6	208	190	12.3	B1-5_03				
4	01-07-24	9:43	01-07-24 9:43	0:18	0:06	165.2	102	172	12.3	B1-5_04				
5	01-07-24	9:55	01-07-24 9:55	0:30	0:12	137.2	157	134	12.3	B1-5_05	AL02	98	130	
6	01-07-24	10:04	01-07-24 10:04	0:39	0:09	130.5	121	130	12.3	B1-5_06				
7	01-07-24	10:15	01-07-24 10:15	0:50	0:11	114.4	134	132	12.3	B1-5_07				
8	01-07-24	10:25	01-07-24 10:25	1:00	0:10	101.6	73	116	12.3	B1-5_08				
9	01-07-24	10:36	01-07-24 10:36	1:11	0:11	94.1	95.4	76	12.3	B1-5_09				
10	01-07-24	10:52	01-07-24 10:52	1:27	0:16	77.1	75.2	65	12.3	B1-5_10				Gradual stratification continues
11	01-07-24	11:05	01-07-24 11:05	1:40	0:13	71.5	74.8	64	12.3	B1-5_11				
12	01-07-24	11:20	01-07-24 11:20	1:55	0:15	68.9	72.1	74	12.3	B1-5_12				Supernatant layer forming in top 2cm causing lower turbidity readings in column
13	01-07-24	11:40	01-07-24 11:40	2:15	0:20	61.7	61.7	47	12.3	B1-5_13				
14	01-07-24	11:59	01-07-24 11:59	2:34	0:19	51.3	34.5	39	12.4	B1-5_14				
15	01-07-24	12:29	01-07-24 12:29	3:04	0:30	47.7	45.1	25	12.5	B1-5_15				Gradual stratification continues
16	01-07-24	13:16	01-07-24 13:16	3:51	0:47	35.3	27.7	21	12.6	B1-5_16				
17	01-07-24	14:46	01-07-24 14:46	5:21	1:30	30.3	23.8	26	12.9	B1-5_17				
19	02-07-24	8:03	02-07-24 8:03	22:38	15:17	15.7	10	8	12.6	B1-5_19				
20	02-07-24	13:12	02-07-24 13:12	27:47	5:09	13.4	7.4	<5	12.8	B1-5_20				Faint turbid cloud present throughout entire column
21	02-07-24	17:22	02-07-24 17:22	31:57	4:10	9.0	6.3	7	13.1	B1-5_21				Very faint turbid cloud present throughout entire column
22	03-07-24	10:44	03-07-24 10:44	49:19	17:22	6.0	3.3	7	12.6	B1-5_22				Extremely faint turbid cloud present throughout entire column

Sample ID	BH-01OS Column Test	
Start Date	01-07-24	
Start Time	9:22 AM	
End Date	03-07-24	
End Time	10:35 AM	
Approximate Sample Mass	120g	Note: Approximated from slurry with 150 g of raw sediment
Seawater Turbidity	1.32	

Test Interval	Date	Time	Date Time	Time Elapsed	Time between measurements	Turbidity Cal Rig (NTU)	Lab Turbidity (NTU)	TSS (mg/L)	Temperature cal rig (deg C)	TSS Sample ID	QA Sample	Duplicate sample turbidity (NTU)	QA sample TSS (mg/L)	Column observations
1	01-07-24	9:22	01-07-24 9:22	0:00	0:00	256.0	167.0	303	12.3	BH-01OS_01				
2	01-07-24	9:27	01-07-24 9:27	0:05	0:05	201.9	271.0	248	12.3	BH-01OS_02	AL01	253	224	Gradual stratification
3	01-07-24	9:34	01-07-24 9:34	0:12	0:07	175.6	243.0	179	12.3	BH-01OS_03				
4	01-07-24	9:40	01-07-24 9:40	0:18	0:06	171.9	236.0	160	12.3	BH-01OS_04				
5	01-07-24	9:52	01-07-24 9:52	0:30	0:12	150.3	167.0	146	12.3	BH-01OS_05				
6	01-07-24	10:00	01-07-24 10:00	0:38	0:08	120.8	134.0	128	12.3	BH-01OS_06				
7	01-07-24	10:08	01-07-24 10:08	0:46	0:08	114.1	164.0	120	12.3	BH-01OS_07				
8	01-07-24	10:18	01-07-24 10:18	0:56	0:10	100.2	22.8	75	12.3	BH-01OS_08				
9	01-07-24	10:28	01-07-24 10:28	1:06	0:10	88.7	44.8	92	12.3	BH-01OS_09				
10	01-07-24	10:40	01-07-24 10:40	1:18	0:12	87.3	120.0	61	12.3	BH-01OS_10				Gradual stratification continues
11	01-07-24	10:56	01-07-24 10:56	1:34	0:16	76.1	108.0	64	12.3	BH-01OS_11				
12	01-07-24	11:11	01-07-24 11:11	1:49	0:15	73.2	100.0	44	12.3	BH-01OS_12				
13	01-07-24	11:31	01-07-24 11:31	2:09	0:20	63.9	41.8	40	12.3	BH-01OS_13				Supernatant layer forming in top 2cm causing lower turbidity readings in column
15	01-07-24	12:21	01-07-24 12:21	2:59	0:30	50.6	60.8	46	12.5	BH-01OS_15				
16	01-07-24	13:05	01-07-24 13:05	3:43	0:44	40.9	51.3	36	12.6	BH-01OS_16				Gradual stratification continues
17	01-07-24	14:35	01-07-24 14:35	5:13	1:30	32.6	21.2	22	12.8	BH-01OS_17				
18	01-07-24	16:35	01-07-24 16:35	7:13	2:00	23.1	10.4	18	13.1	BH-01OS_18				
19	02-07-24	7:57	02-07-24 7:57	22:35	15:22	15.2	6.6	7	12.6	BH-01OS_19				
20	02-07-24	13:07	02-07-24 13:07	27:45	5:10	9.5	4.7	18	12.8	BH-01OS_20				Faint turbid cloud present throughout entire column
21	02-07-24	17:13	02-07-24 17:13	31:51	4:06	8.4	6.2	25	13.2	BH-01OS_21				Very faint turbid cloud present throughout entire column
22	03-07-24	10:35	03-07-24 10:35	49:13	17:22	6.2	3.8	<5	12.7	BH-01OS_22				Extremely faint turbid cloud present throughout entire column

Settling Visualisation Test

Sample ID	B1-5 (Slurry)
Sample mass (raw)	40 g
Start Date	01-07-24
Start Time	9:01 AM
End Date	01-07-24
End Time	9:10 AM
Seawater Turbidity	1.32 NTU
Media captured	Video

Test Interval	Date	Time	Date Time	Time Elapsed	Time between measurements	Turbidity (NTU)	Temperature (deg C)	Observations
1	07-01-24	9:01	07-01-24 9:01	0:00	0:00	575.0	12.4	
2	07-01-24	9:02	07-01-24 9:02	0:01	1:00	320.2	12.5	
3	07-01-24	9:03	07-01-24 9:03	0:02	2:00	257.9	12.5	
4	07-01-24	9:04	07-01-24 9:04	0:03	3:00	259.4	12.5	
5	07-01-24	9:05	07-01-24 9:05	0:04	4:00	246.0	12.5	
6	07-01-24	9:06	07-01-24 9:06	0:05	5:00	236.0	12.5	
7	07-01-24	9:07	07-01-24 9:07	0:06	6:00	224.2	12.5	
8	07-01-24	9:08	07-01-24 9:08	0:07	7:00	223.0	12.5	
9	07-01-24	9:09	07-01-24 9:09	0:08	8:00	210.7	12.5	
10	07-01-24	9:10	07-01-24 9:10	0:09	9:00	201.5	12.5	

Sample ID	BH-01OS (Slurry)
Sample mass (raw)	40 g
Start Date	01-07-24
Start Time	8:42 AM
End Date	01-07-24
End Time	8:51 AM
Seawater Turbidity	1.32 NTU
Media captured	Video

Test Interval	Date	Time	Date Time	Time Elapsed	Time between measurements	Turbidity (NTU)	Temperature (deg C)	Observations
1	07-01-24	8:42	07-01-24 8:42	0:00	0:00	116.78	12.5	Material clumped in breaker and took a few minutes to extract with the squirt bottle, potentially limiting the upper extent of turbidity readings measured.
2	07-01-24	8:43	07-01-24 8:43	0:01	0:01	96.7	12.6	
3	07-01-24	8:44	07-01-24 8:44	0:02	0:01	81.25	12.6	
4	07-01-24	8:45	07-01-24 8:45	0:03	0:01	78.05	12.6	
5	07-01-24	8:46	07-01-24 8:46	0:04	0:01	70.02	12.6	
6	07-01-24	8:47	07-01-24 8:47	0:05	0:01	71.57	12.6	
7	07-01-24	8:48	07-01-24 8:48	0:06	0:01	71.19	12.6	
8	07-01-24	8:49	07-01-24 8:49	0:07	0:01	70.57	12.6	
9	07-01-24	8:50	07-01-24 8:50	0:08	0:01	70.57	12.6	
10	07-01-24	8:51	07-01-24 8:51	0:09	0:01	68.91	12.6	

Appendix D
Quality Assurance / Quality Control (QA/QC) Tests

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1 Introduction

Royal HaskoningDHV (RHDHV) has been engaged to undertake laboratory testing to facilitating a better understand of the settling characteristics of sediment found within the Port of Geraldton. The laboratory investigation for the sediment and crushed rock comprised the following detailed tests:

- column tests to establish TSS-turbidity relationships, and;
- critical particle size analysis to determine the maximum particle size in suspension that is used to estimate the settling velocity.

The test methods were devised and refined in order to develop a laboratory investigation that was considered:

- valid - to ensure the results satisfactorily address the aims of the experiment; and
- reliable - to ensure the tests are repeatable.

To ensure the results from the settling column tests and critical particle size analysis are valid and reliable, several quality assurance and quality control (QA/QC) tests were conducted by RHDHV and the NATA accredited testing laboratories (ALS Environmental and Eurofins). The procedure and results from the QA/QC tests are presented in **Section 2**.

2 QA/QC Findings

2.1 Column and Dilution Tests

2.1.1 Procedures

The following column test QA/QC procedures were undertaken:

- analysing one intra-laboratory aliquot (split) sample from one test (B1-5) at a random measurement interval to assess the variability of the sample matrix. The intra-laboratory aliquot sample procedure involved splitting the primary turbid water sample recovered from the column into two subsamples and having both analysed for TSS and Turbidity.
- analysing one inter-laboratory aliquot (split) sample from one test (BH-01OS) at a random measurement interval to assess the comparability of results between NATA accredited laboratories. The inter-laboratory procedure also involved splitting the primary turbid water sample recovered from the column into two subsamples and having them both analysed for TSS and Turbidity at the primary laboratory (ALS Environmental) and the secondary laboratory (Eurofins).
- undertaking turbidity analysis on all subsamples collected for TSS during the column test to validate the accuracy of YSI ProDSS turbidity probe. This included measuring turbidity in the column, immediately following subsampling in the calibration container used for calibrating the turbidity probe and at ALS Environmental. Calibration of the YSI ProDSS probe was also undertaken by the supplier (Air-Met Scientific) prior to the investigation and by RHDHV prior to running the column tests. The Air-Met Scientific calibration certificate and RHDHV calibration log is provided in **Appendix C**.

- assessment of ALS laboratory QA/QC results to evaluate the validity of their TSS and Turbidity results, including:
    - holding time compliance;
    - laboratory duplicates;
    - laboratory controls; and,
    - method blanks.

Complete results including laboratory reports provided by ALS and RHDHV laboratory log records are provided in **Appendix C**.

Sub-samples were taken from the settling columns at varying time intervals throughout each column test for turbidity and TSS analysis. It should be noted that the surface turbidity and TSS results during the column tests were likely influenced by the ongoing sub-sampling activity inside the settlement columns, creating some unavoidable variability between column turbidity results and subsampled turbidity results. For example, the progressive removal of surface water and suspended sediment for laboratory analysis would have artificially modified the settlement profile inside the column by reducing the depth of the upper clarifying layer.

2.1.2 Results

Aliquots

A summary of aliquot sample results is provided in **Table 1**.

Table 1: Duplicate sample results for the column test

Column Test Details		TSS (ALS)	Turbidity (ALS)	Turbidity (RHDHV)
		mg/L	NTU	NTU
	LOR	**5**	**0.1**	**0.1**
Field ID	**Date**			
BH-01OS_02	01 Jul 2024	248	271	201
AL01 (interlaboratory - ALS)	01 Jul 2024	224	253	-
	RPD	10	7	-
B1-5_05	01 Jul 2024	134	157	137
AL02 (intra-laboratory - (Eurofins)	01 Jul 2024	130	98	-
	RPD	3	46	-

Table notes:

LOR – Limit of Reporting

RPD – Relative percentage difference

Data quality acceptance criteria in accordance with NATA accredited ALS Environmental :

- <10x LOR – No Criteria;
- 10-20x LOR – <50%; and,
- >20x LOR – <20%.

A multiplier of 0.5 x LOR adopted for samples reported to be <LOR.

Data quality exceedance highlighted grey.

Interlaboratory – Aliquot analysed at the primary laboratory (ALS Environmental)

Interlaboratory – Aliquot sample analysed at a secondary NATA accredited laboratory (Eurofins)

RHDHV turbidity provided for comparison purposes.

One RPD exceedance was reported for turbidity (NTU) in the B1-5 column test, which may have been a result of laboratory error (e.g. insufficient agitation of sample bottles prior to analysis) or heterogeneity of the sample matrix. However, all internal ALS aliquots were within reported data quality limits and intra-laboratory results were within acceptable limits for TSS. Based on the findings of these aliquot results presented above, the sample results are deemed reliable.

Further, turbidity in the TSS/NTU analysis was adopted based on the RHDHV measurements in the lab, to eliminate potential errors.

Turbidity Comparison

A statistical comparison of turbidity results measured by RHDHV with a YSI ProDSS probe during testing and ALS turbidity results is provided in **Table 2**. RPDs were calculated for each sample taken to generate this statistical summary.

Table 2: Statistical summary of turbidity comparison RPD results

Statistic	Column Test
Number of Sample	44
Average RPD	31%
Standard Deviation of RPD	25%
95% UCL of RPD	39%

Table notes:
RPD – Relative percentage difference
Arithmetic average shown

The RHDHV turbidity results gradually decreased during the test, with each sample extracted from the column generally yielding a lower turbidity. In contrast, the ALS turbidity results yielded variability, which did not align with the visual observations in the settling column. The variable ALS results may have been a result of laboratory error (e.g. insufficient agitation of sample bottles prior to analysis) or cementing of the particles over time within the sampling bottle. As such, turbidity in the TSS/NTU analysis was adopted based on the RHDHV measurements in the lab, to eliminate potential errors.

The YSI ProDSS probe was successfully calibrated prior to the column testing and measurements were taken in a controlled environment (i.e., the calibration rig) immediately after subsampling. Therefore, the variability between RHDHV and ALS turbidity results is not expected to impact the validity of the results.

Complete turbidity results are provided in **Appendix C**.

ALS Laboratory QA/QC

A summary of the ALS laboratory QA/QC results I provided in **Table 3**. No QA/QC issues were reported. Detailed ALS laboratory QA/QC reports are provided in **Appendix C**.

Table 3: Statistical summary of turbidity comparison RPD results

Statistic	Outliers/ Discrepancies	Assessment
Holding time compliance	No holding time discrepancies	PASS
Laboratory duplicates	No outliers	PASS
Laboratory Controls	No outliers	PASS

Statistic	Outliers/ Discrepancies	Assessment
Method Blanks	No outliers	PASS

2.2 QA/QC of Critical Particle Size Analysis

2.2.1 Procedures

Particle size analysis was undertaken with a Mastersizer 2000. The Mastersizer 2000 uses a laser to determine the size of particles suspended in a dispersant (fluid). The following critical particle size analysis QA/QC procedures were undertaken:

- analysing a known standard each day of testing to assess the accuracy of the Mastersizer 2000. The method for analysis of the laboratory standard with the Mastersizer 2000 was as follows:
    - add a dispersant to the mixing basin of the Mastersizer 2000 and recording the background refraction. Degassed Sydney tap water was used as the dispersant. Sydney tap water was degassed by pouring the water into a water container and leaving it to settle for at least 24 hours.
    - gradually adding the dry granular laboratory standard (~2 g) to the mixing basin of the Mastersizer 2000 (with the dispersant) until the adopted obscuration of 5 to 10% was achieved.
    - a test was also undertaken with representative seawater to ensure repeatability of results, irrespective of the dispersant.

  The Mastersizer 2000 establishes the particle size distribution of the standard based on the difference in refraction between the dispersant and the suspended sediment sample. The default refractive index for clean water of 1.33 was adopted. Moreover, the refractive index and absorption properties of the standard were adopted based on the project values of 1.52 and 2, respectively. Furthermore, the stirrer and pump of the Mastersizer 2000 were set to 300 rpm and 1100 rpm, respectively. These settlings were used as they ensure particles up to approximately 1 mm to 2 mm in diameter remain in suspension.
- duplicating the critical particle size analysis test on one test unit (BH-01OS) for a single time interval to assess the reliability of the sample preparation and testing methods. This method involved preparing a secondary (duplicate) 1L cylinder to run alongside the primary test and sample with a second pipette at the same time.
- Analysing an aliquot (split) turbid water sample extracted from a single time interval for both testing units to assess the repeatability of the critical particle size analysis. This method involved splitting 200mL sample extracted from the 1L cylinder and splitting it into two separate subsamples for analysis in the Mastersizer 2000.

2.2.2 Results

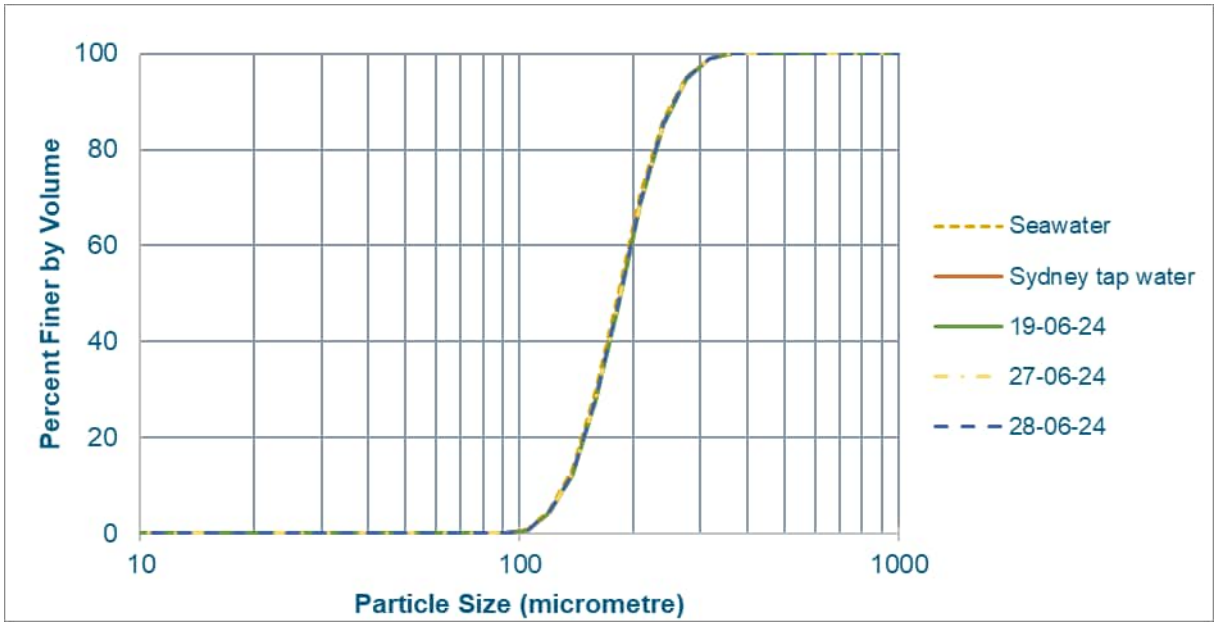
Validation of Mastersizer 2000

Results from discrete measurements of the laboratory standard are provided in **Graph 1**. The measurements are from different days throughout the laboratory investigation.

The first two measurements of the laboratory standard were undertaken with different dispersants. The first measurement was undertaken using degassed Sydney tap water (“Sydney tap water”) as the dispersant and the second measurement was undertaken using a representative seawater sample

("Seawater") as the dispersant. As expected, **Graph 1** indicates that there was no discernible difference between these two measurements. As such, degassed Sydney tap water was used throughout the remainder of the testing program for analysis of the laboratory standard, to reduce the amount of seawater required.

Additional tests of the laboratory standard conducted on each day of testing shown in **Graph 1** indicates that the Mastersizer 2000 produced consistent and near-identical measurements of the laboratory standard over various days. These results suggest that the Mastersizer 2000 produced reliable measurements of sediment samples when used under normal operating conditions.



Graph 1: Multiple tests of the laboratory standard using Mastersizer 2000 on the days of testing

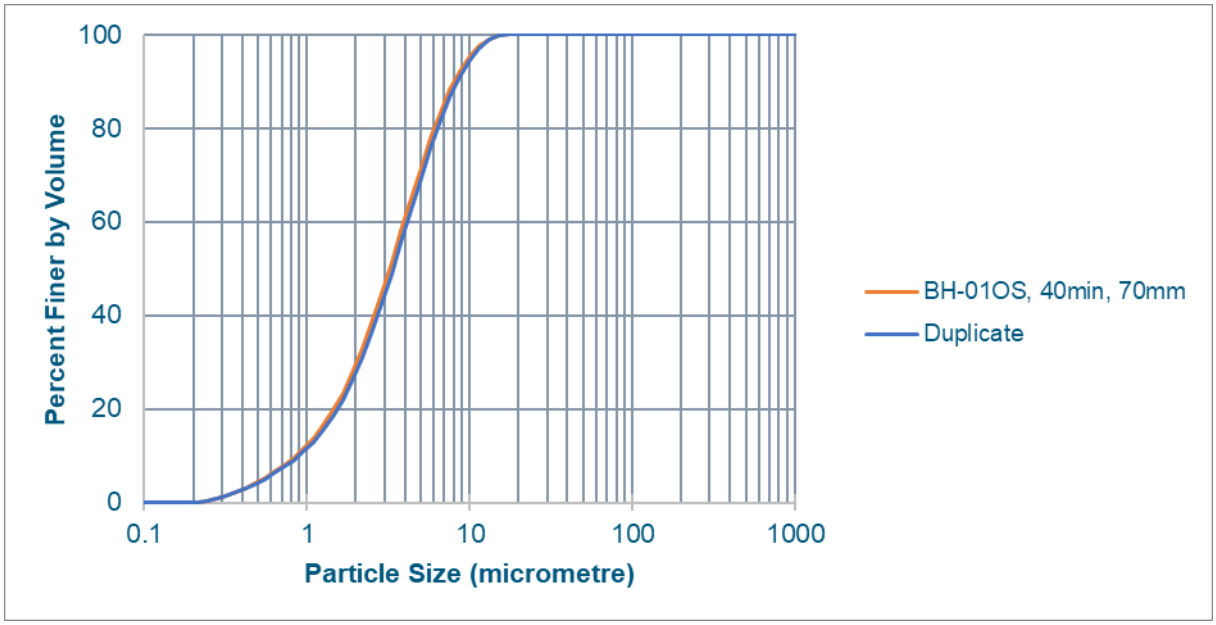
Duplicate

A comparison of the particle size distribution results from the primary and duplicate test was undertaken for BH-01OS (Tamala Limestone) at the 40 minute time interval. Results are provided in **Graph 2** and **Graph 3** for the upper sampling depth (70mm below the water surface) and lower sampling depth (230mm below the water surface) respectively;

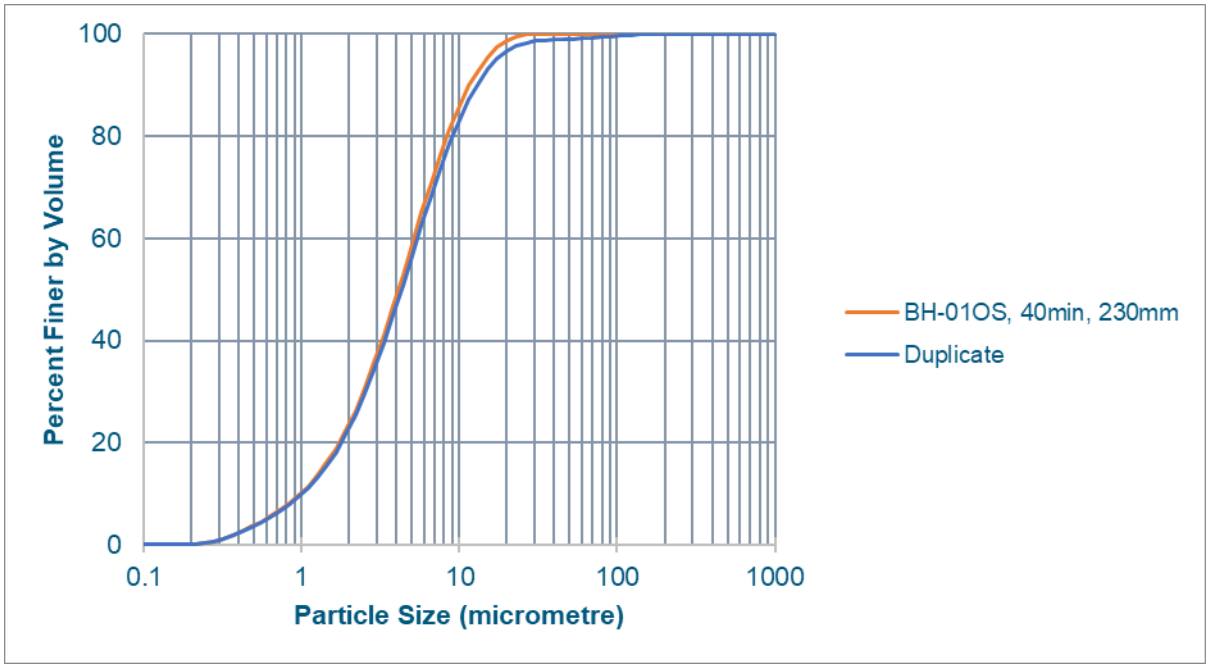
The graphs show 'percent finer by volume' based on the volume in each size 'bin' reported by the Mastersizer 2000.

All graphs indicate minimal difference between the particle size distribution results for the primary and duplicate tests. The maximum difference in the measured cumulative percent finer by volume for each discrete particle size reported was less than 3% for both sampling depths.

Overall, the results were within acceptable limits and validate that the sample preparation and testing methodology used to conduct critical particle size analyses was reliable.



Graph 2: Primary and duplicate test results for BH-01OS at the 40 minute time interval, 70mm below water surface.



Graph 3: Primary and duplicate test results for BH-01OS at the 40 minute time interval, 230mm below water surface.

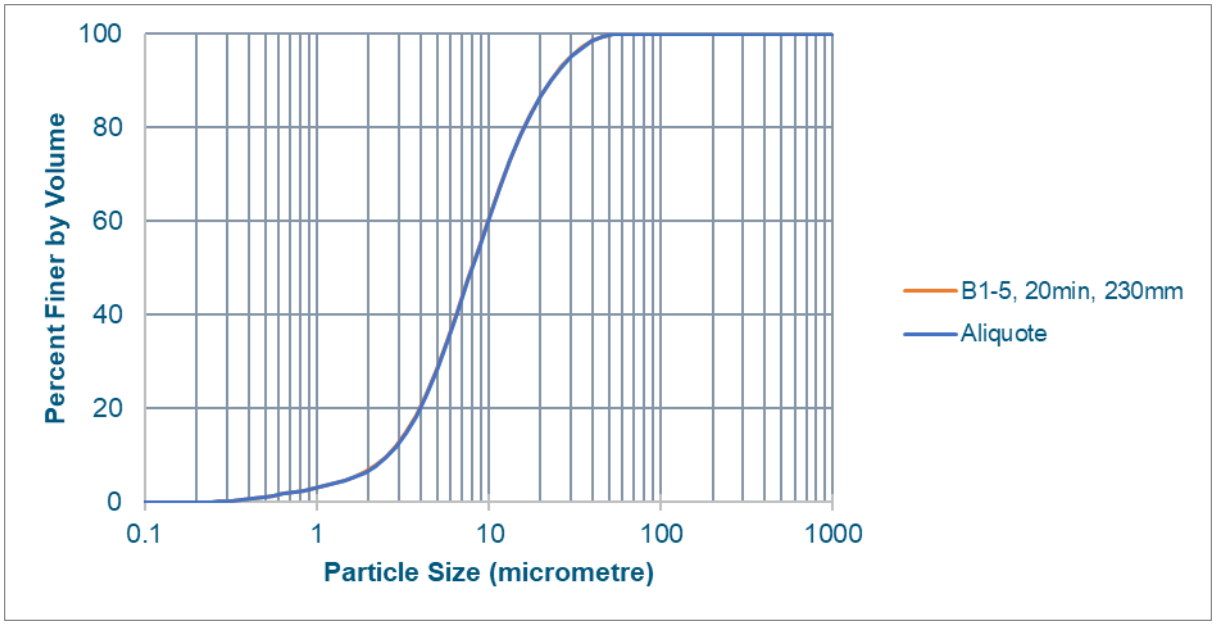
Aliquots

A comparison of the particle size distribution results from the primary and aliquot test for sample B1-5 (Marine Deposit) after 20 minutes and BH-01OS (Tamala Limestone) after 10 minutes at the lower sampling depth (230 mm below the waters surface) is presented in **Graph 4** and **Graph 5**, respectively. These aliquot samples were split from the primary samples.

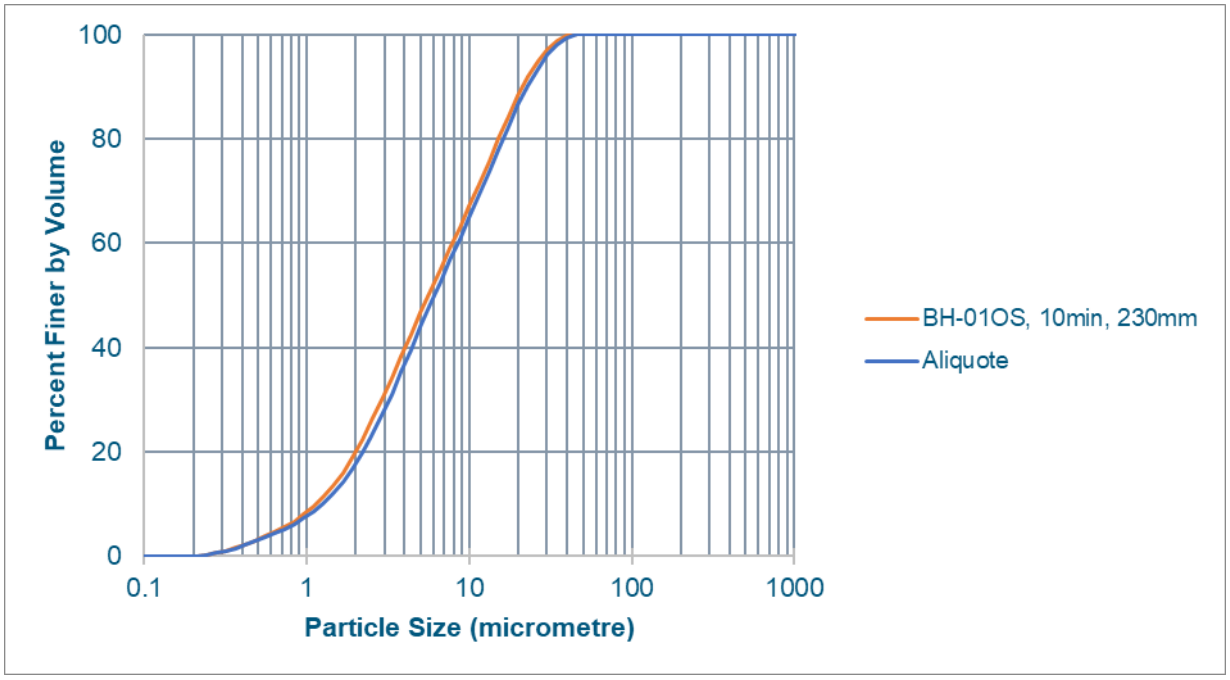
The graphs show 'percent finer by volume' based on the volume in each size 'bin' reported by the Mastersizer 2000.

The graphs indicate minimal difference between the particle size distribution results for the primary and aliquot test at both sampling time intervals. The maximum difference in the measured percent finer by volume for each discrete particle size reported was approximately 3%.

Overall, these results were within acceptable limits and validate that the subsampling methodology used to conduct critical particle size analyses was reliable.



Graph 4: Primary and aliquot test results for B1-5 at the 20 minute time interval, 230 mm below water surface.



Graph 5: Primary and duplicate test results for BH-01OS at the 10 minute time interval, 230 mm below water surface.

3 Conclusion

This appendix documents the various QA/QC tests that were conducted to validate the experimental laboratory methodology.

The findings indicate that the equipment and methodology used in settlement column tests and critical particle size analysis produces repeatable and reliable results that are suitable for interpretive use.

A2 Port of Geraldton PMaxP Baseline Turbidity/TSS Data Review

Note / Memo

Haskoning Australia PTY Ltd.
Water & Maritime

To: Alysia Woodward
SLR Consulting Australia Pty Ltd
Level 1, 500 Hay Street, Subiaco, WA, Australia 6008

From: Arjen Overduin
Date: 31 January 2025
Copy:
Our reference: PA3387-RHD-ME-0001-Baseline-Turbidity-TSS-Memo
Classification: Project related
Checked by Rick Plain & Greg Britton

Subject: **Port of Geraldton PMaxP Baseline Turbidity/ TSS Data Review – Version 3**

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1 Port of Geraldton PMaxP Baseline Turbidity/ TSS Data Review

1.1 Purpose

The Port Maximisation Project (PMaxP) includes dredging and reclamation. Numerical modelling has been undertaken to predict the magnitude of the dredge plume, which could potentially impact sensitive ecological receptors within Champion Bay.

The purpose of this assessment is to present a summary of available turbidity and Total Suspended Solid (TSS) to inform the development of a baseline Total Suspended Solid (TSS) concentration for a number of sites within Champion Bay. Note that baseline may also be referred to as ambient or background and represents the naturally occurring turbidity and TSS in the absence of any dredging operations. The baseline TSS would potentially be used to assess the significance of the dredge plume modelling results.

1.2 Available Data

Available datasets provided to Royal HaskoningDHV (RHDHV) are summarised in **Table 1**. The datasets include TSS and/or turbidity (measured in NTU), noting that TSS and NTU are typically correlated. Monitoring locations for relevant datasets are shown in **Figure 1**.

Table 1: Summary of available and relevant datasets for determining baseline turbidity/ TSS.

Dredging Campaign	Available Relevant Data	Monitoring Locations	Relevant Data Capture Period	Comments
Geraldton Port Maintenance Dredging 2021	Episodic Turbidity Depth Profiles	WQD1, WQ2, WQL3, WQ4	16/08/21 – 2/12/21	• Collected prior to, during and post dredging to provide depth profiles and depth average results.
	Episodic TSS sampling	WQD1, WQ2, WQL3, WQ4	16/08/21 – 2/11/21	• Collected prior to and during dredging for model validation.
	Continuous turbidity monitoring	DL	23/07/21 – 1/12/21	• Collected prior to, during and post dredging. • 1 hr frequency
Proposed PMaxP Pre-dredging data collection 2024	Continuous turbidity	LL1, LL3 and LL4	6/06/24 – 13/11/24	• 15 min frequency

It is important to note that TSS is used for modelling because it is preferred for regulatory purposes and it provides a precise indicator of the quantity of suspended material, rather than turbidity, which is a measure of the optical clarity of water and can be influenced by various factors like dissolved organic material and particle size and shape. However, turbidity is often collected over TSS in the field due to ease and speed of measurement with portable sensors and the ability to cost-effectively provide continuous data at high frequencies. A site-specific correlation between turbidity and TSS is typically determined, which allows for the measurement of turbidity data to infer TSS.

Review of the available TSS data from the 2021 dredging campaign suggests there is insufficient data to generate a field-based site-specific correlation between turbidity and TSS. Monitoring for turbidity and corresponding TSS sampling was limited to five events prior to and during the dredging campaign whereby the majority of TSS samples reported concentrations (in mg/ L) below laboratory detection limits, which is insufficient for the purposes of developing a field-based turbidity/TSS relationship (refer to **Table 2**).

The RHDHV 2024 laboratory-based turbidity/TSS relationship findings for surface sediment collected from within the port have been adopted for this work.

Table 2: Summary of 2021 turbidity results and corresponding TSS samples

Dredge phase	Date	WQD1		WQ2		WQL3		WQ4	
		Turbidity	TSS	Turbidity	TSS	Turbidity	TSS	Turbidity	TSS
Pre- dredge	16-08-21	0.6	9	1	<5	0.7	<5	0.1	<5
	09-09-21	0.2	5	0.1	<5	0.6	<5	0.5	<5
Dredge	15-09-21	2.3	<1	2.2	<1	0.3	1	0.5	<1
	21-09-21	1.2	<1	1	-	1.3	-	0.2	1
	29-09-21	1.4	-	0.6	-	0.2	-	0.1	-
	02-11-21	14	<5	0.6	<5	0.3	<5	0.5	9
	12-11-21	0.2	-	0.2	-	0.3	-	3.3	-
Post- dredge	22-11-21	1.1	-	0	-	0.2	-	0.1	-
	02-12-21	1.5	-	1	-	2.3	-	0.5	-

1.3 Dataset(s) Adopted

Data collected within Champion Bay, in the vicinity of the proposed dredging and modelled dredge plume, was used for the analysis herein.

The 2021 continuous turbidity monitoring data was limited to one location (DL) within Geraldton Harbour (Berth 6) and turbidity depth profiling was limited to two monitoring events to determine baseline conditions (i.e., pre-dredging) within Chapman Bay. This dataset was not considered to be a sufficient duration for the purposes of the assessment herein. The turbidity measurements during dredging, while interesting for model calibration, do not provide baseline turbidity.

The 2024 continuous turbidity monitoring dataset was adopted for locations LL1, LL3 and LL4 within Champion Bay (shown on **Figure 1**) and considered adequate for the purposes of developing a baseline. The data was collected by O2 Marine. It is noted that monitoring location LL3, located furthest north, was deployed on its side and processed erroneous readings with higher-than-expected turbidity up until redeployment on 07 September 2024. As such, only data from this date onwards at LL3 was analysed.

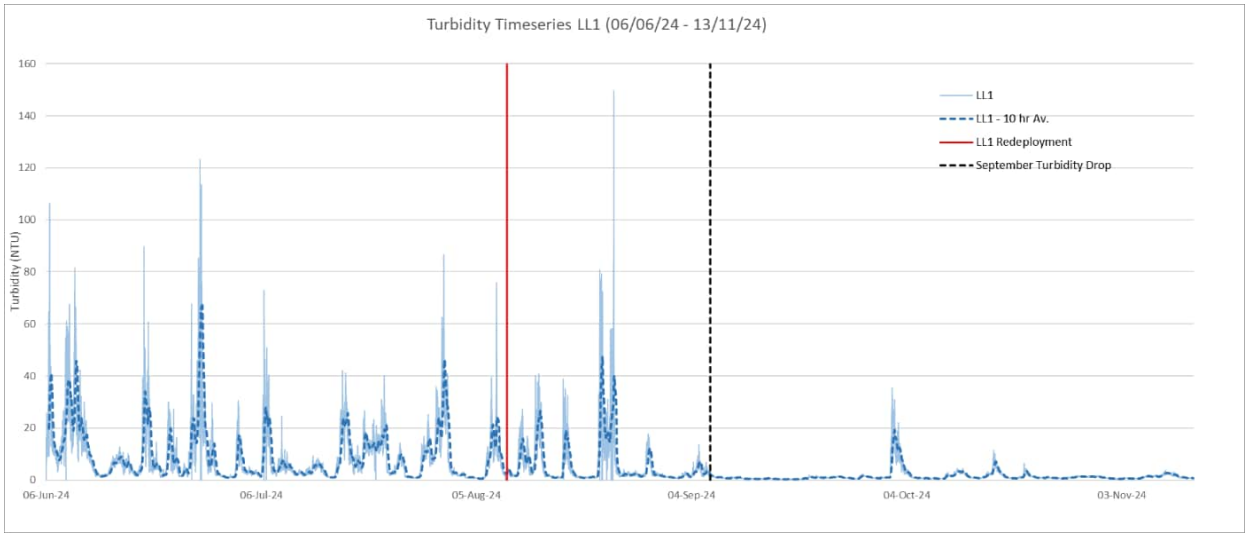


Figure 1: Relevant historical baseline turbidity and TSS monitoring locations

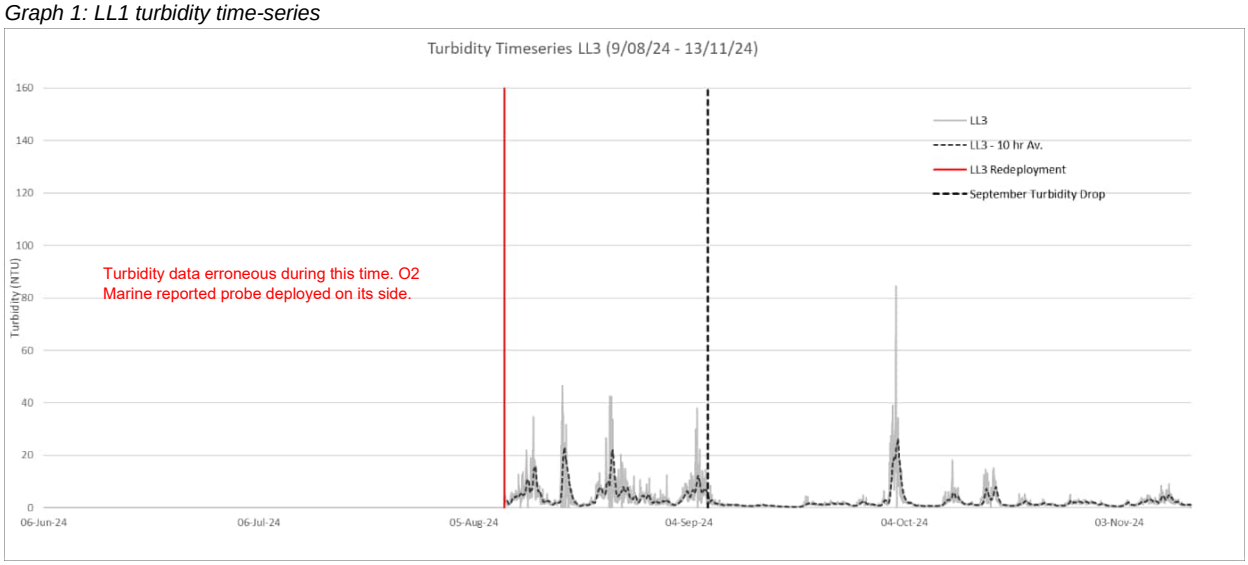
1.4 Turbidity Time Series Results and Aerial Imagery Review

The turbidity data obtained from LL1, LL3 and LL4 is provided in **Graph 1**, **Graph 2** and **Graph 3**, respectively. The graphs present the 15-minute interval turbidity data, 10-hour rolling average and data collection and redeployment dates for each instrument.

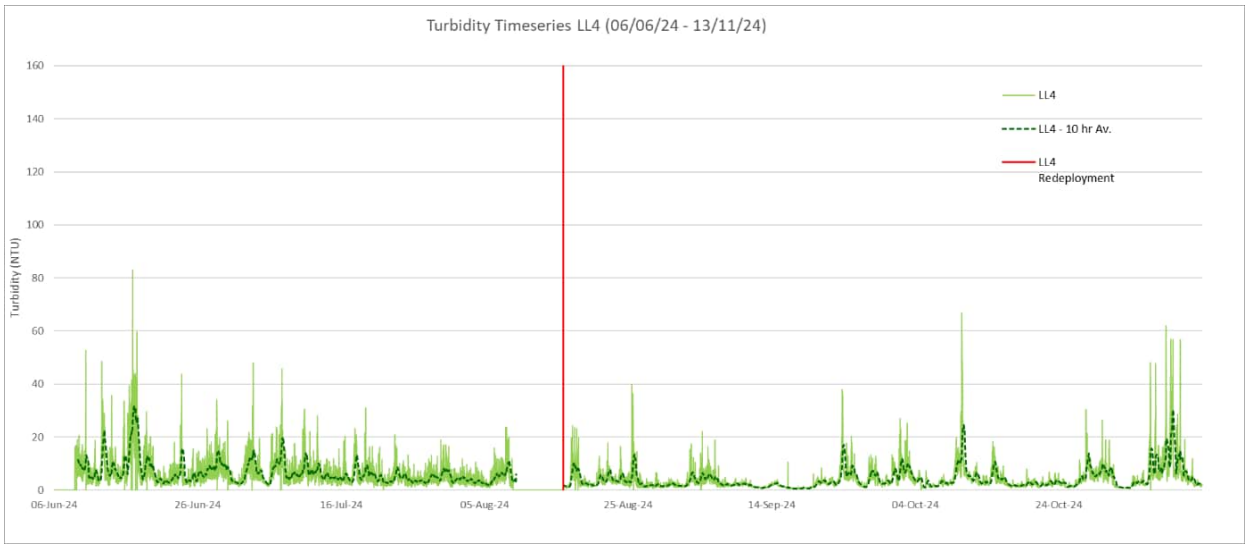
The turbidity at LL1 and LL3 within Champion Bay presented a noticeable drop in turbidity in early September which remained consistent until the end of the data capture period in November. Turbidity spikes were evident during this time, particularly in early October. However, overall turbidity levels within the Bay presented a noticeable reduction. The higher turbidity levels reported at LL1 and LL3 were likely associated with sediment sourced from the Chapman River breakout. O2 Marine anecdotally indicated that the water within the Bay was notably turbid following the breakout of the Chapman River on 10 June 2024 as reported in a local newspaper. Moreover, a review of aerial images retrieved from the Copernicus Browser during the data collection period (refer to **Table 3**) illustrated persistent turbidity pluming throughout parts of the Bay and evidence of the Chapman River entrance remaining open. During this time, it is likely sediment continued to discharge from the Chapman River during rainfall events and was subject to swell induced sediment resuspension, as discussed in **Section 1.5**.



Graph 1: LL1 turbidity time-series

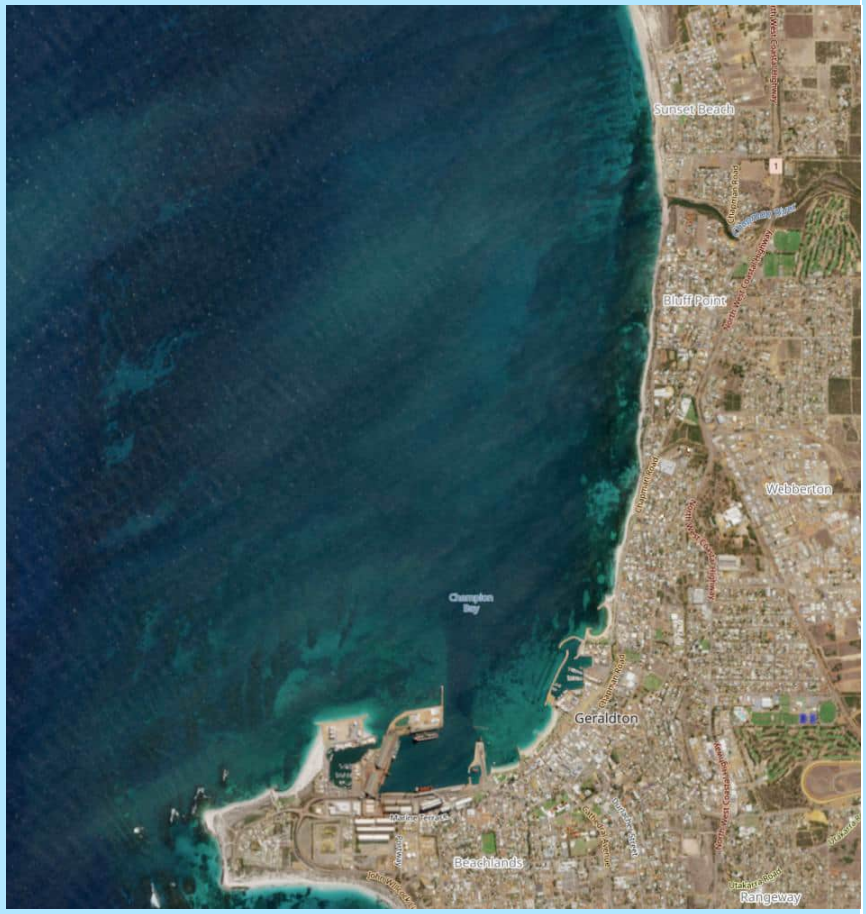
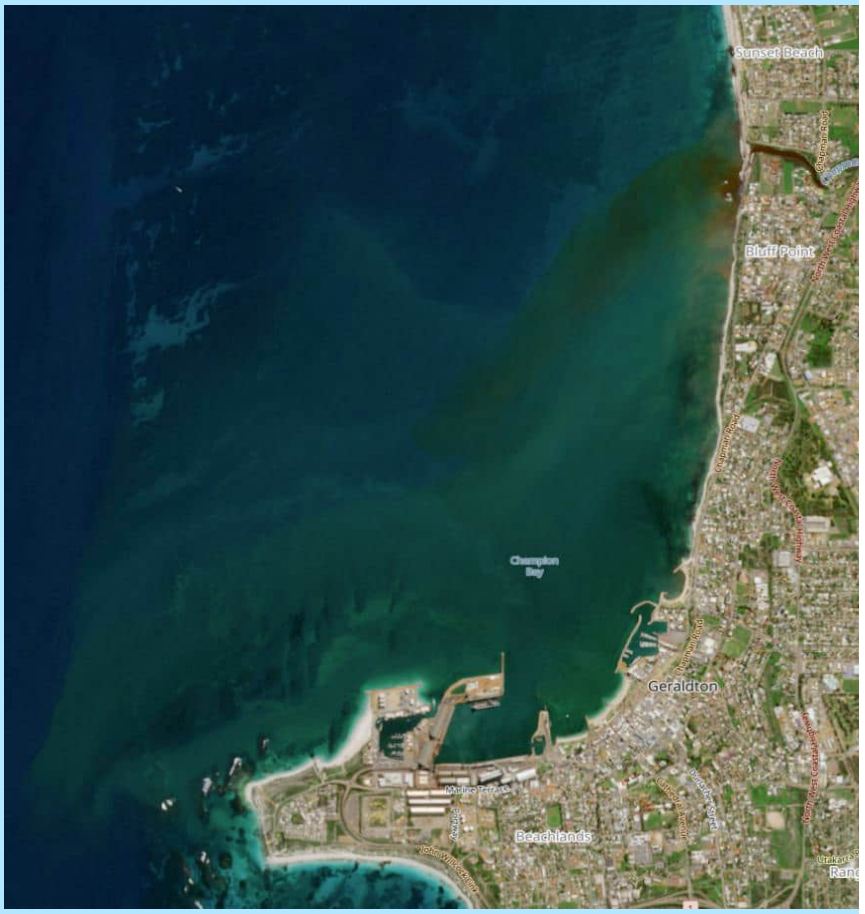


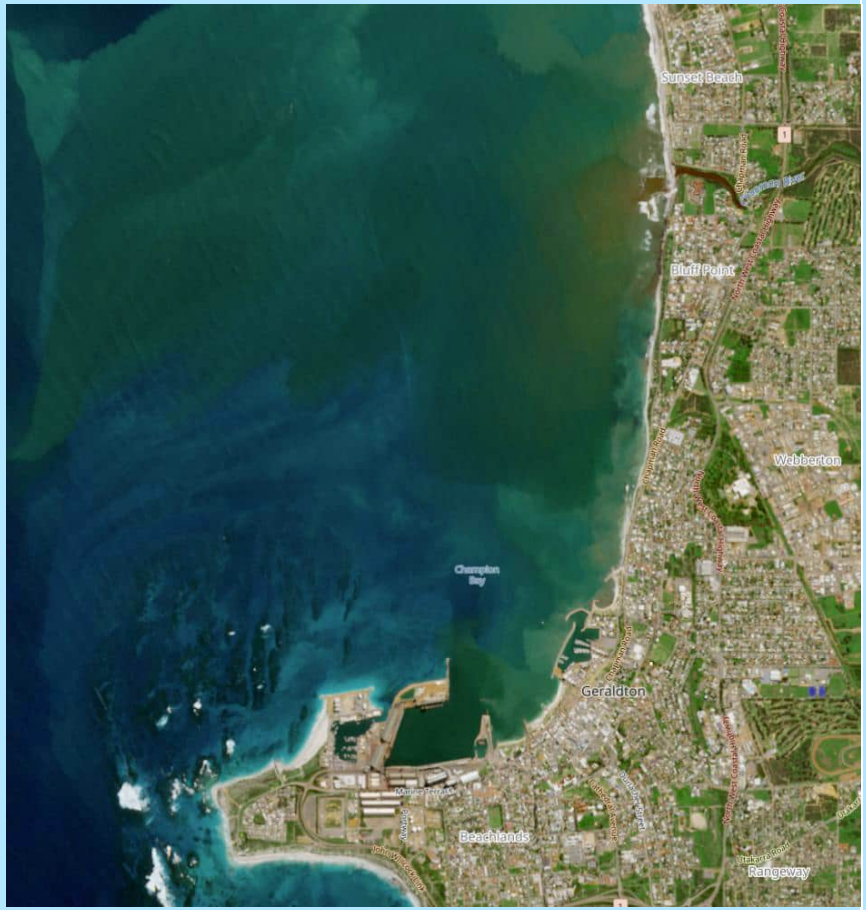
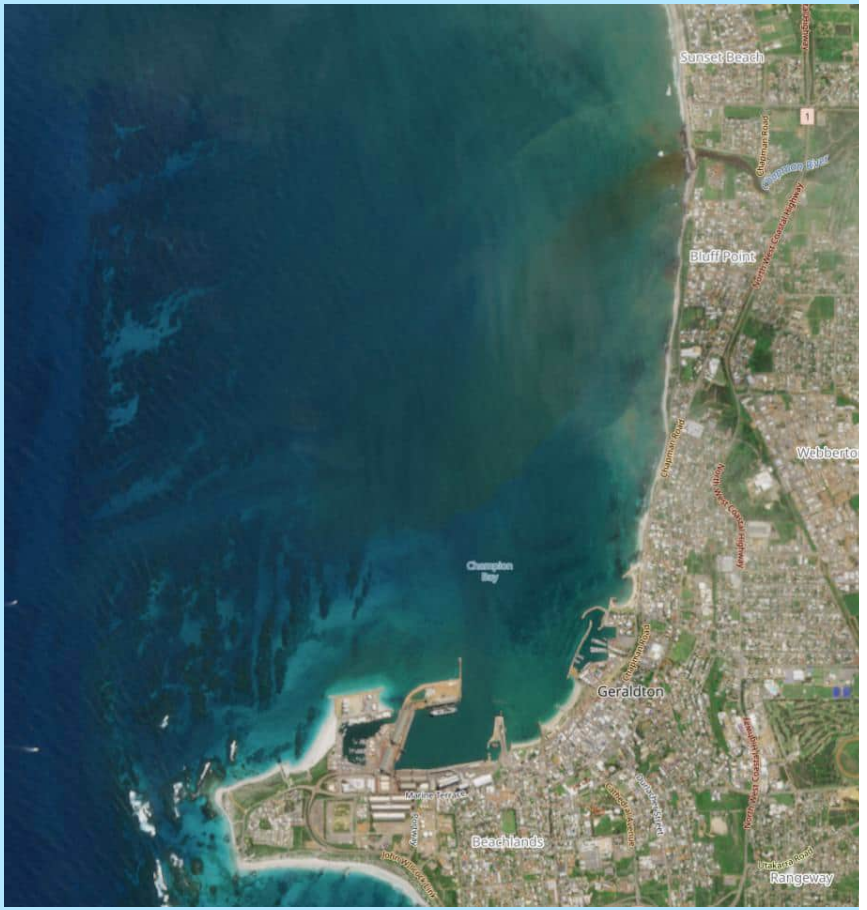
Graph 2: LL3 turbidity time-series

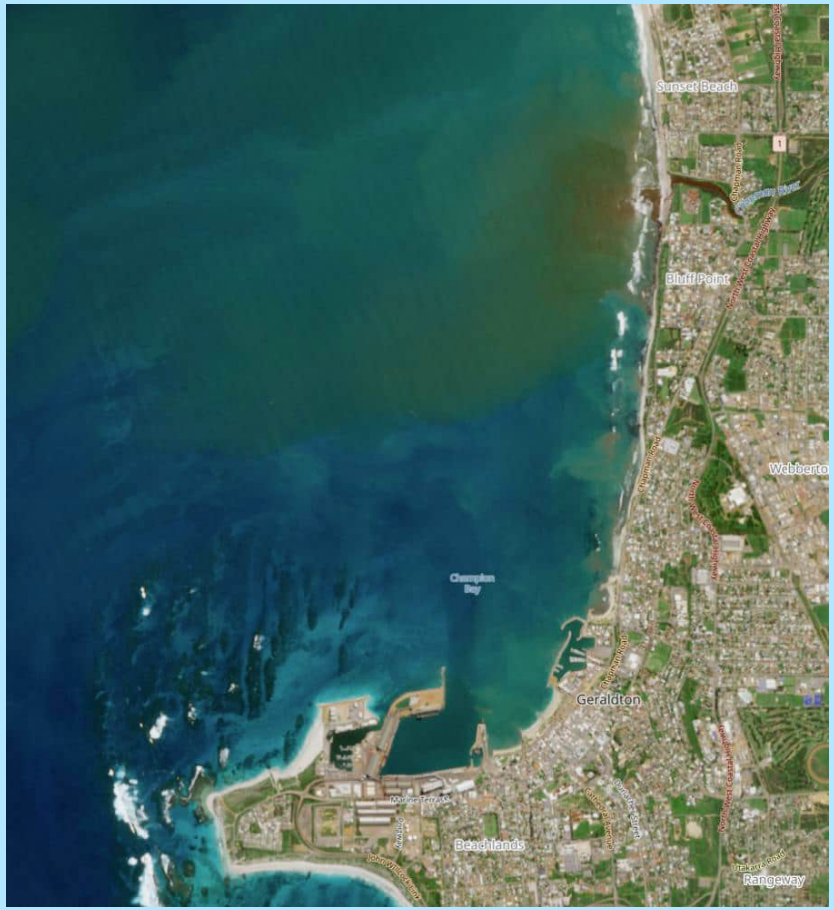
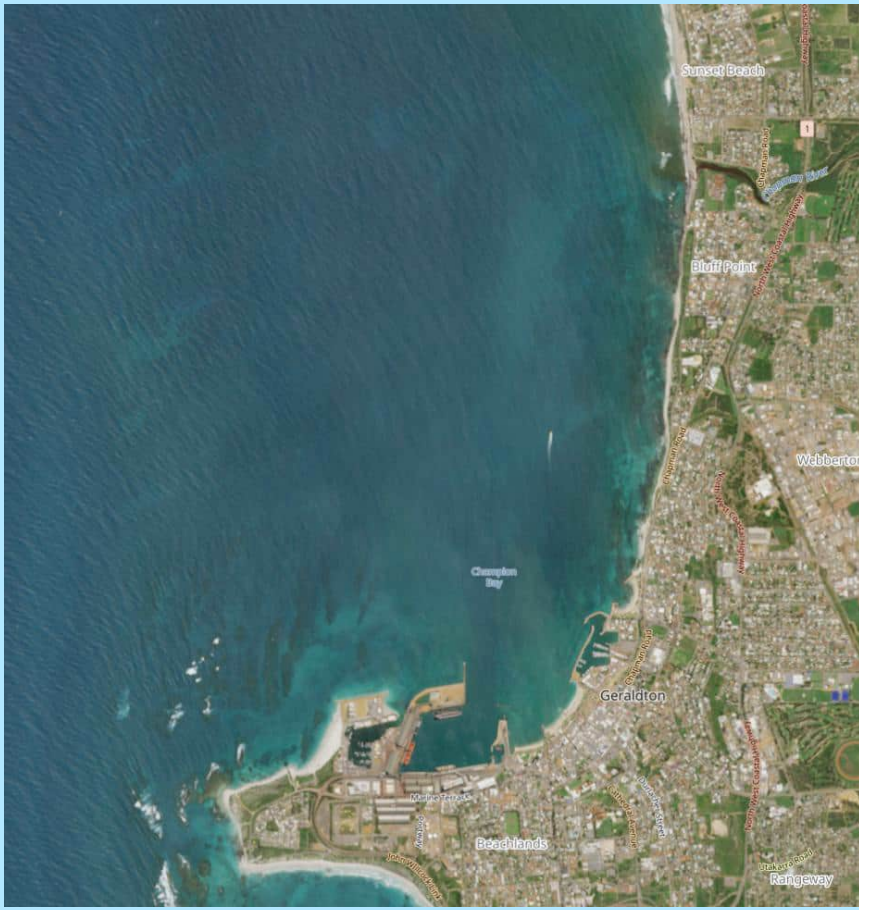


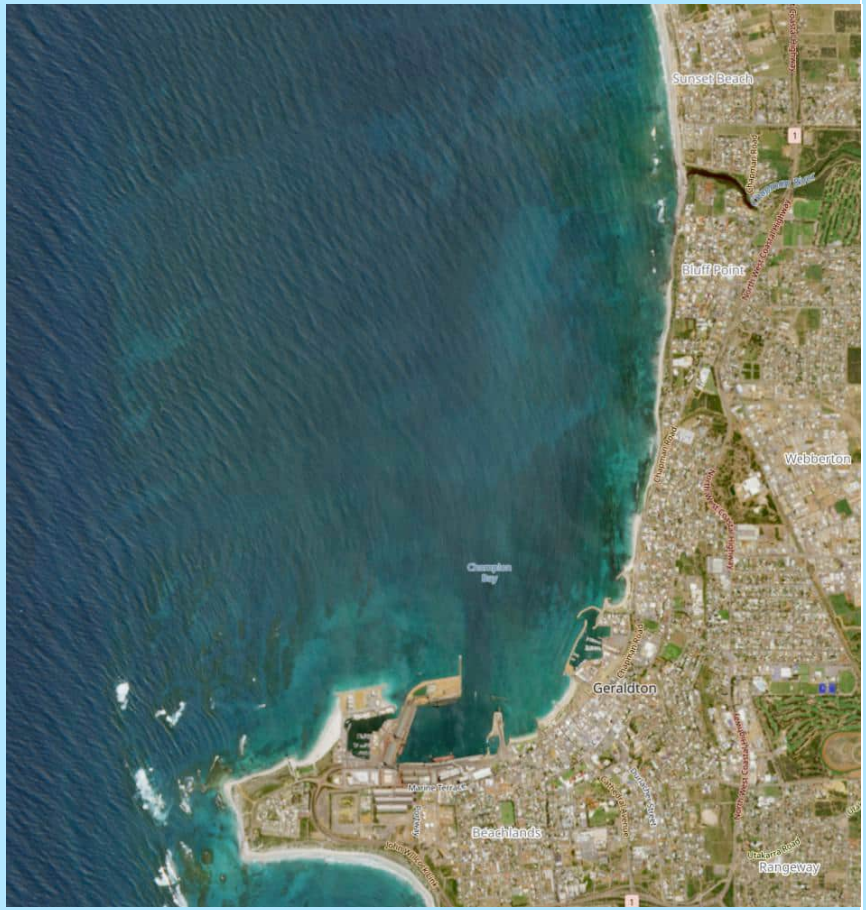
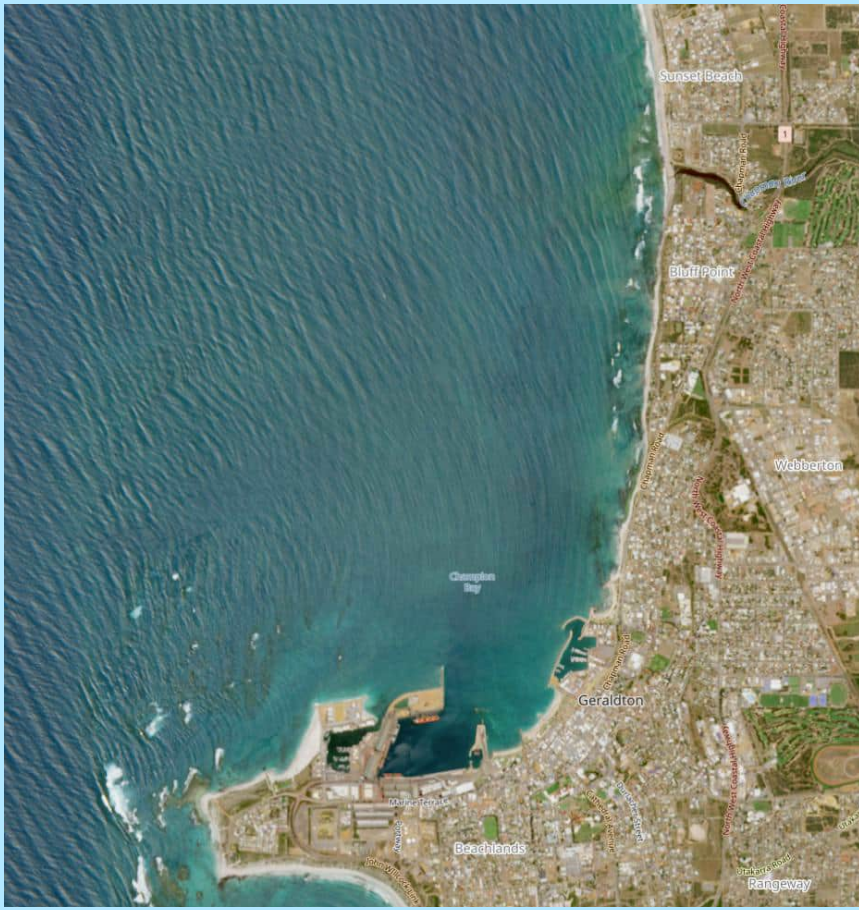
Graph 3: LL4 turbidity time series

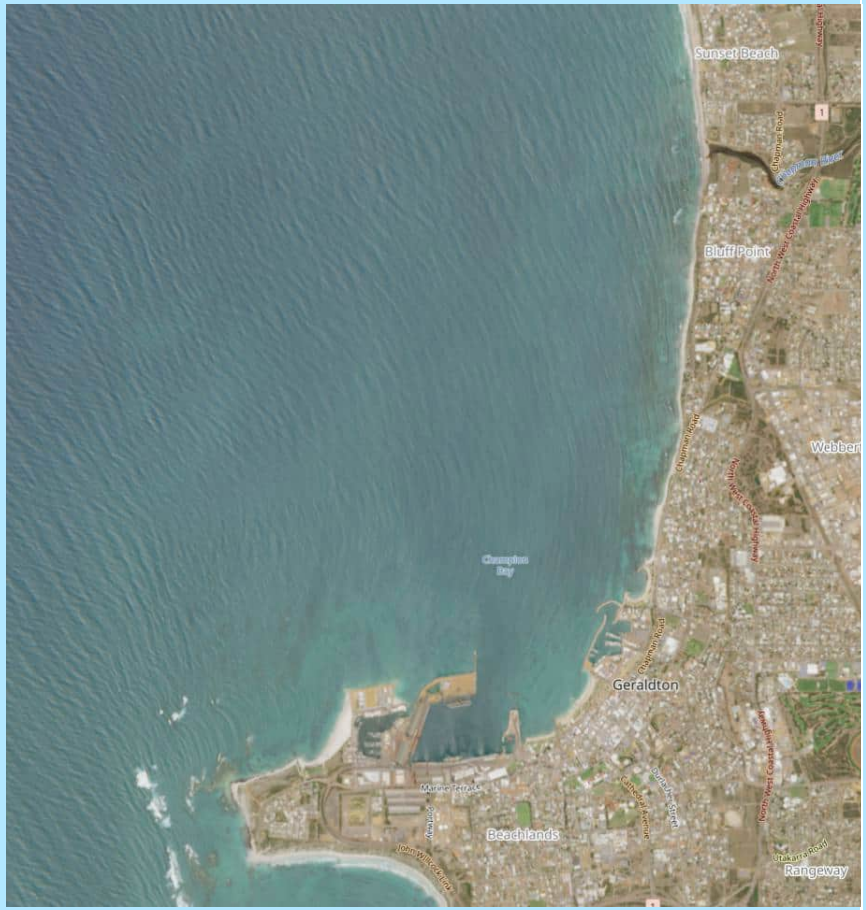
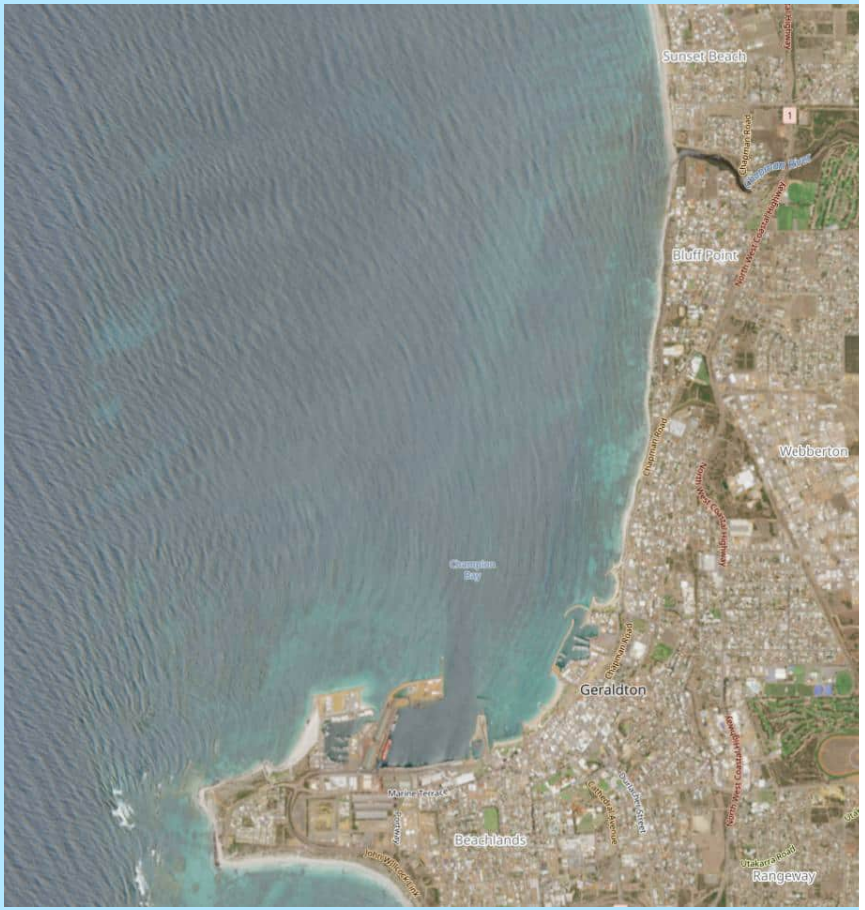
Table 3: Aerial satellite imagery sourced from the Copernicus Browser

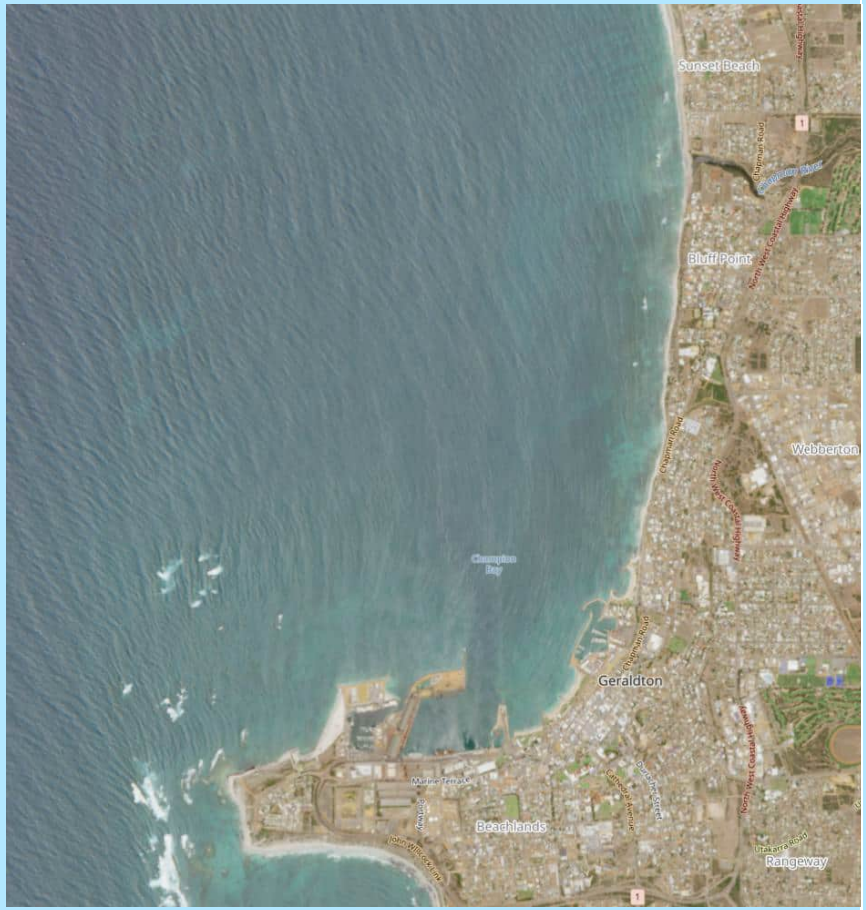
Aerial Satellite Imagery	
18 May 2024	2 July 2024
	

Aerial Satellite Imagery	
22 July 2024	16 August 2024
	

Aerial Satellite Imagery	
26 August 2024	10 September 2024
	

Aerial Satellite Imagery	
20 September 2024	10 October 2022
	

Aerial Satellite Imagery	
30 October 2022	11 November 2024
	

Aerial Satellite Imagery	
9 December 2024	
	

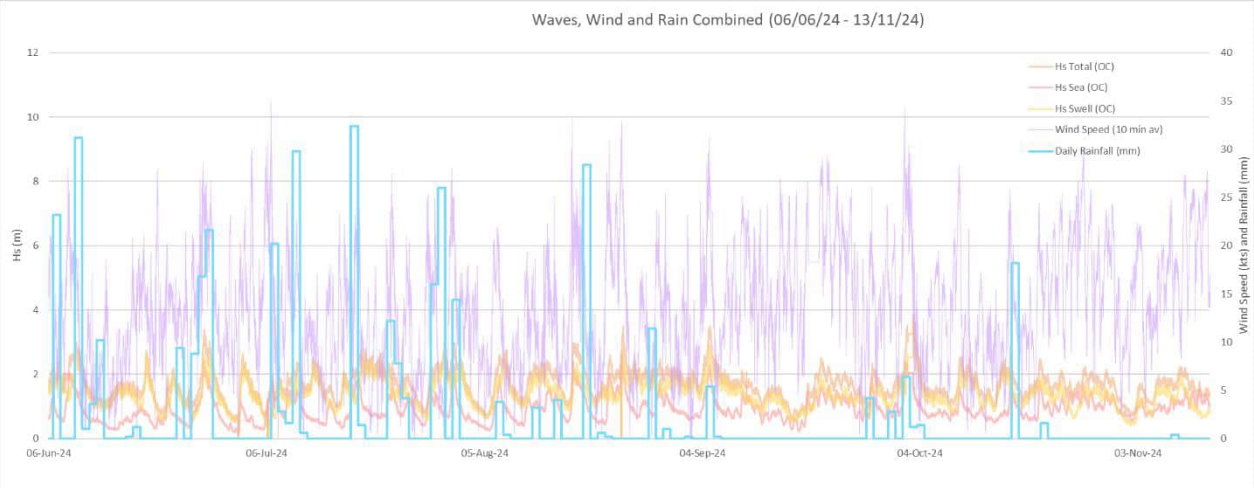
1.5 Observed drivers of turbidity in Champion Bay

Turbidity results were compared with local wind and wave data obtained from Beacon 1 (refer location in **Figure 1)** and rainfall data obtained from the Bureau of Meteorology Geraldton weather station (ID: 008050) to gain some understanding of the primary drivers of turbidity observed throughout the data collection period (06/06/24 – 13/11/24). Time-series plots were created for turbidity and each potential key driver as detailed below. The primary drivers of turbidity are:

- Tidal currents;
- Swell;
- Local wind generated sea; and,
- Rainfall and runoff from the catchment (Chapman River).

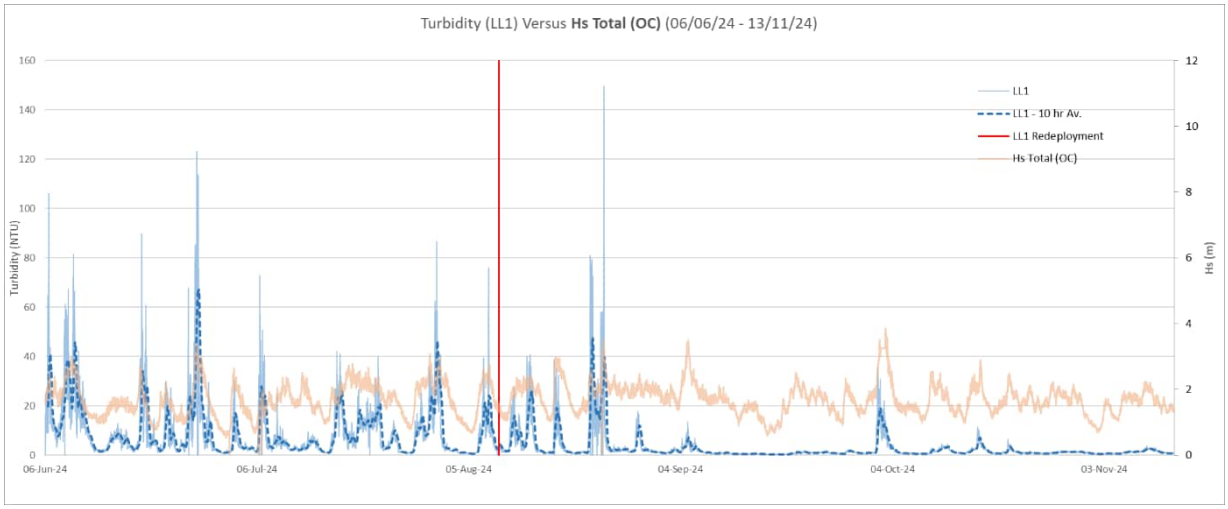
Tidal currents would be expected to result in regular and reoccurring turbidity, correlating to high and low tides and possibly spring/neap cycles. A signature of frequent and reoccurring turbidity, of a similar frequency to the tides, was not observed in the turbidity data. Tidal currents were not considered further as a primary driver. Tidal currents would be a mechanism for transport of material in suspension caused by other primary drivers.

Comparison of combined sea and swell wave data (H_s Total), sea only (H_s Sea), local wind and rainfall is provided in **Graph 4**. Combined sea and swell wave data and H_s Sea is somewhat correlated. As expected, local wind and H_s Sea is correlated as the local wind generates sea. Rainfall is also somewhat correlated to these parameters, which indicates that rainfall coincides with stormy (windy) conditions. As the various drivers are all correlated, determining the primary driver of turbidity is expected to be difficult.

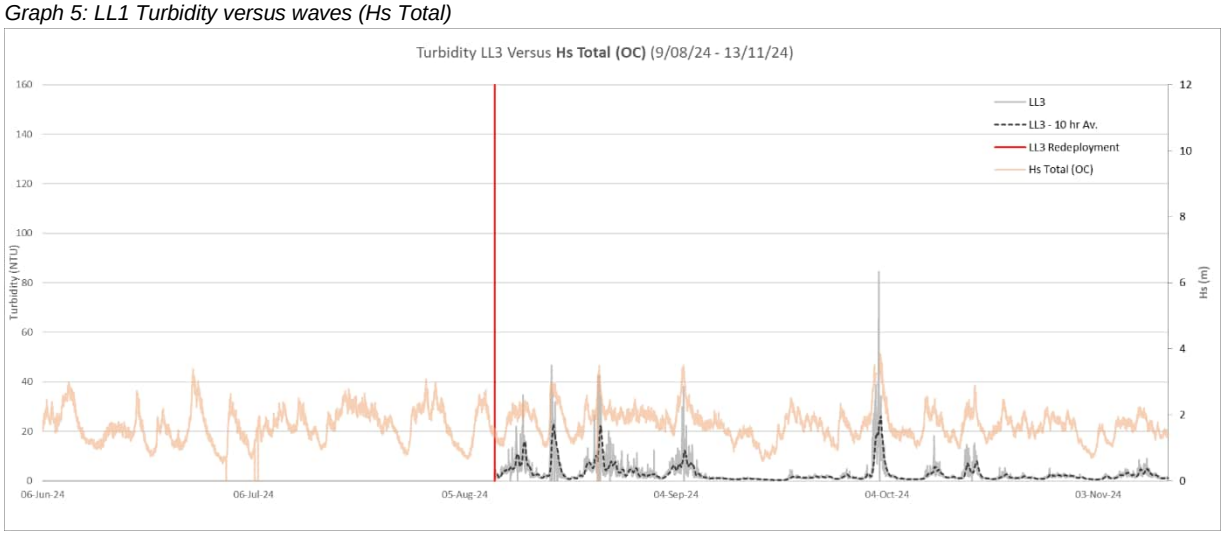


Graph 4: Potential turbidity drivers

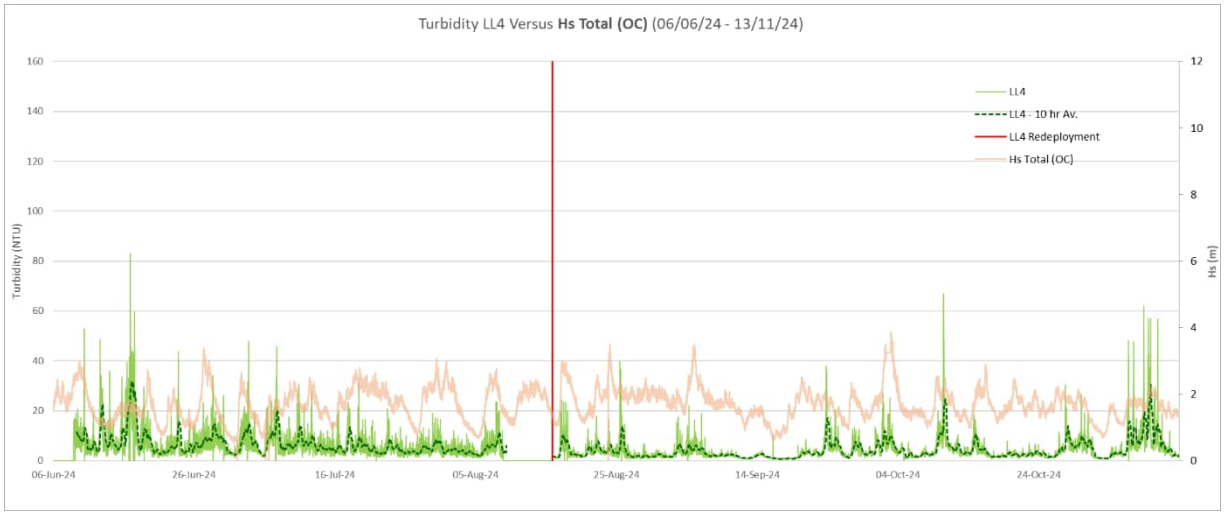
Comparison of turbidity and combined sea and swell wave data (H_s Total) is provided in **Graph 5** (LL1), **Graph 6** (LL3), and **Graph 7** (LL4). The data suggests that LL1 and LL3, located north of Geraldton Harbour, present a stronger correlation between waves and turbidity, particular prior to September when higher turbidity levels were recorded. The correlation at LL4, located at the entrance to Fishing Boat Harbour, is not as pronounced. This is likely because LL1 and LL3 are more exposed to the prevailing south-westerly wind, sea and swell whereas LL4 is semi-protected by Point Moore and nearshore reef outcrops. Turbidity at LL4 is likely dependent on the direction of the sea and swell with north-westerly waves expected to result in higher turbidity, with turbidity also generated from vessel wash within the harbour.



Graph 5: LL1 Turbidity versus waves (Hs Total)

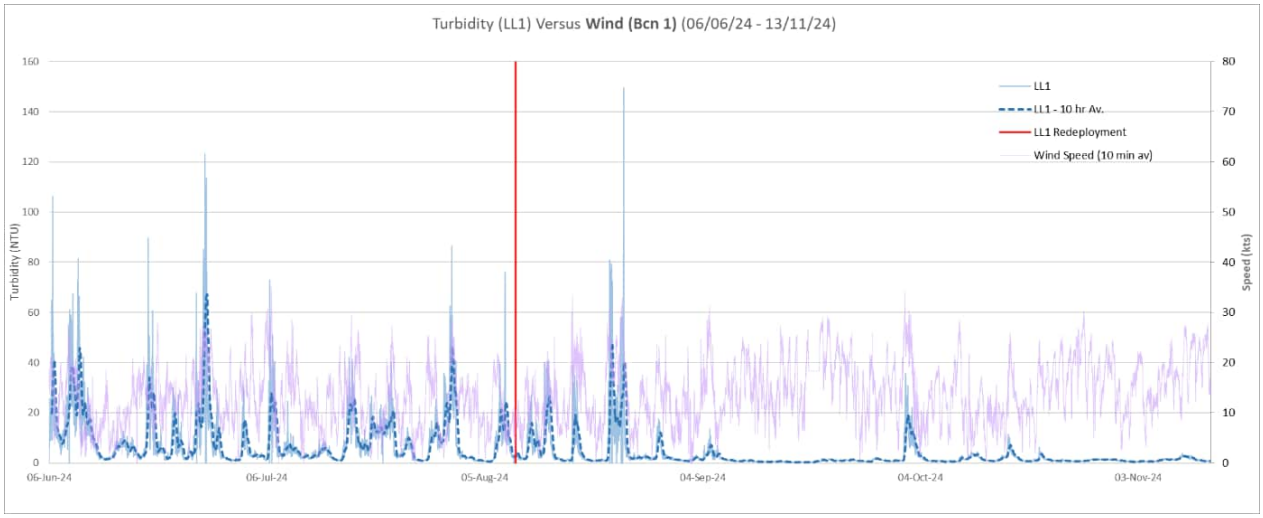


Graph 6: LL3 Turbidity versus waves (Hs Total)

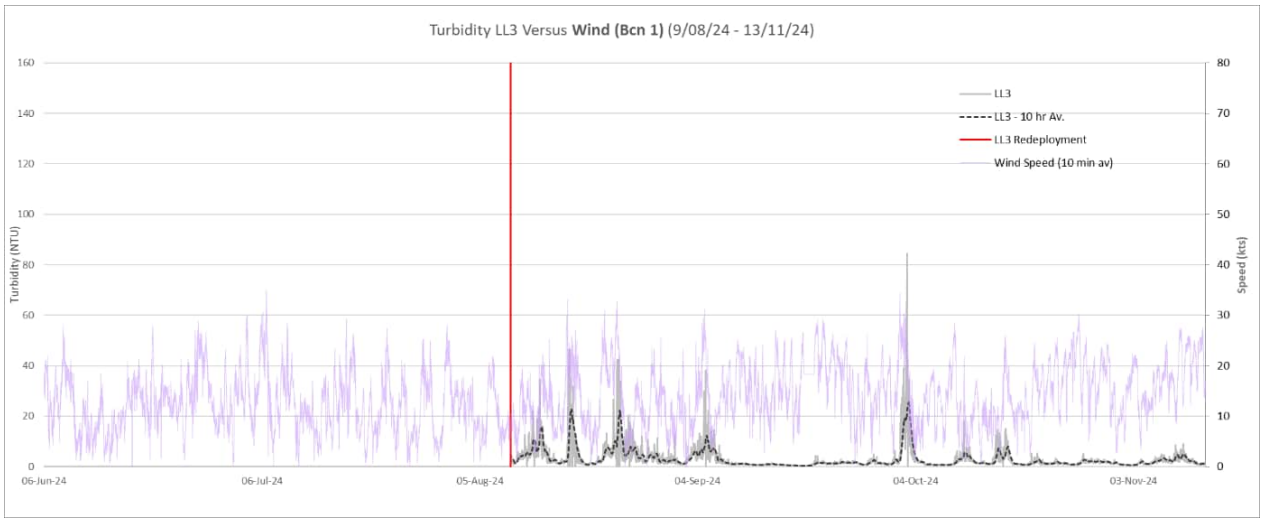


Graph 7: LL4 Turbidity versus waves (Hs Total)

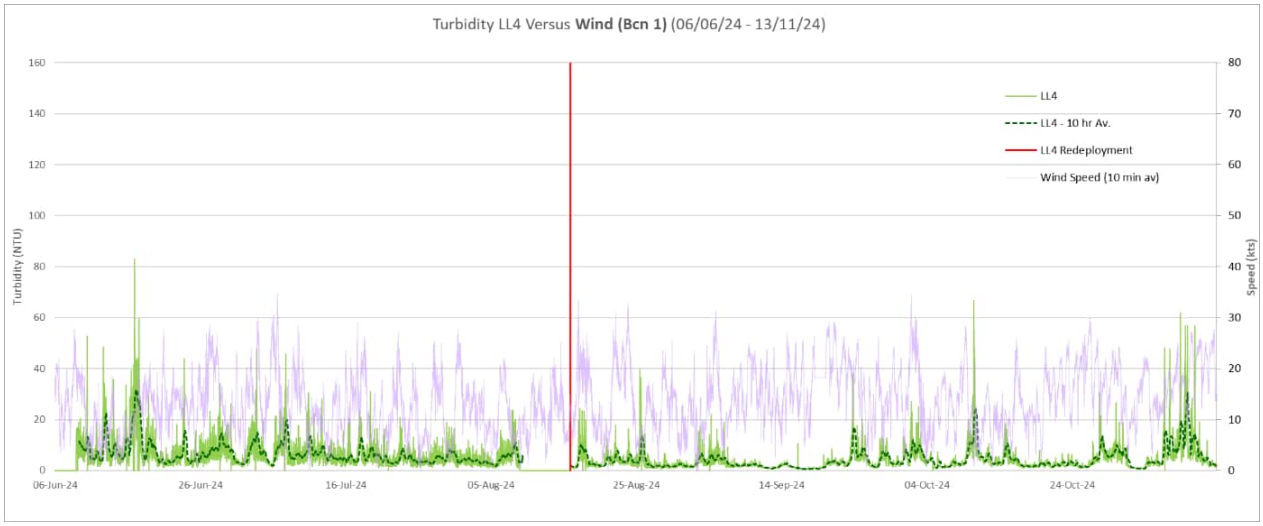
Plotted wind speed data also presents a distinct relationship with turbidity, as shown in **Graph 8** (LL1), **Graph 9** (LL3), and **Graph 10** (LL4). The correlation between wind speed and turbidity is particularly evident at LL1 and LL3. This observation is expected as local wind generates sea and wind and sea are correlated (refer **Graph 4**).



Graph 8: LL1 Turbidity versus wind

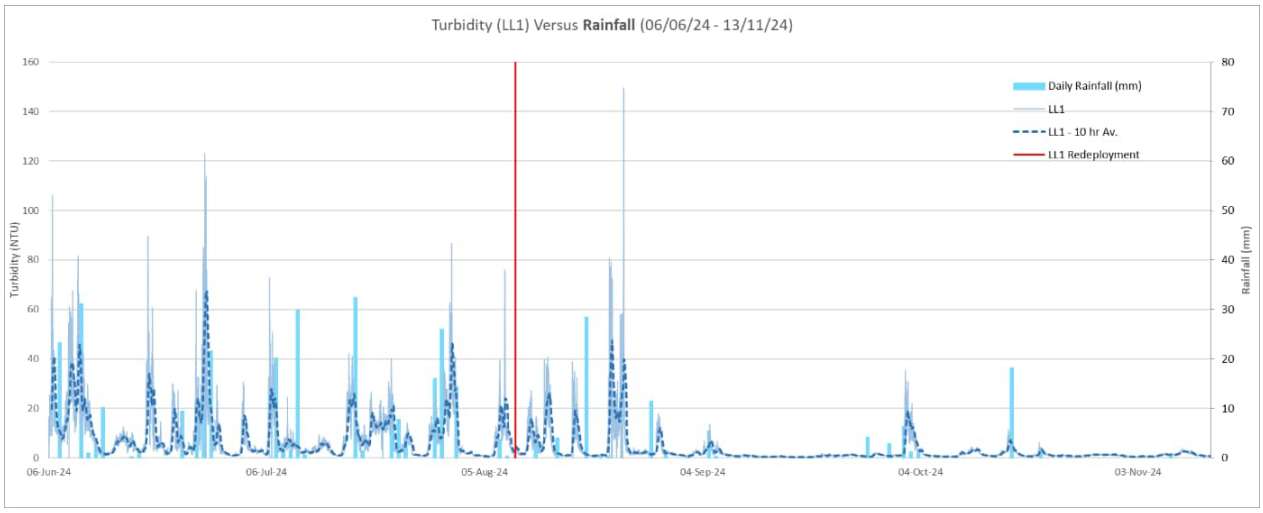


Graph 9: LL3 Turbidity versus wind

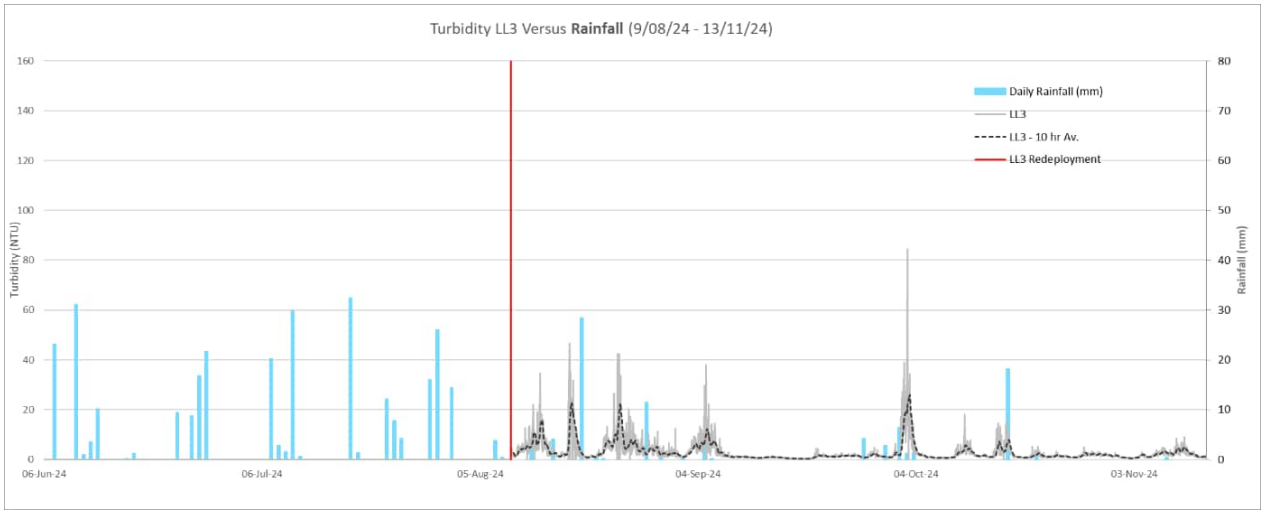


Graph 10: LL4 Turbidity versus wind

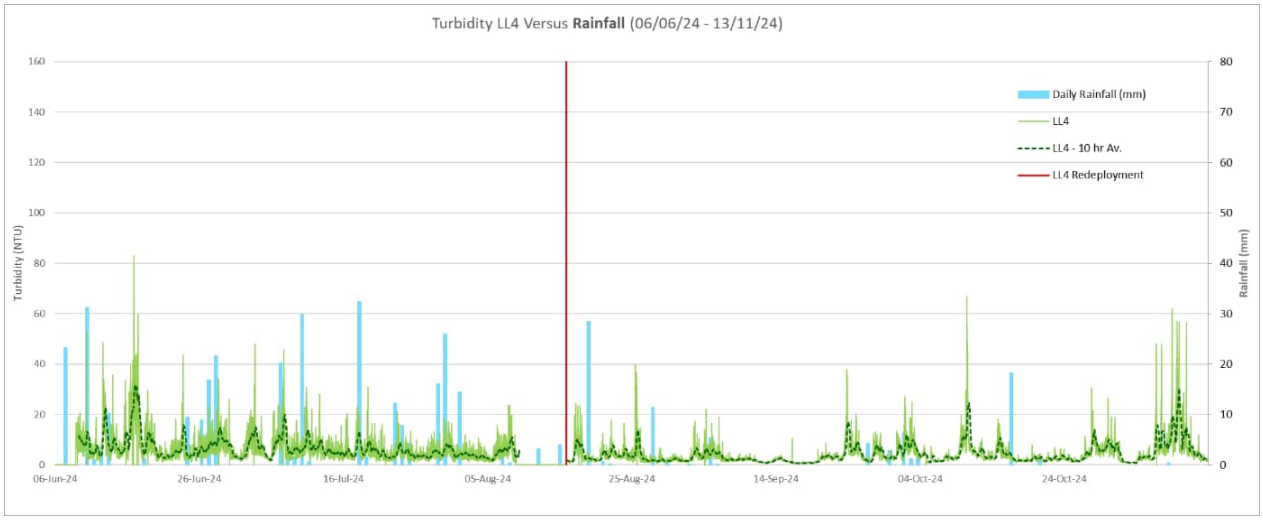
Rainfall data plotted against turbidity in **Graph 11** (LL1), **Graph 12** (LL3), and **Graph 13** (LL4) shows that rainfall is correlated to turbidity levels, particularly during some of the larger isolated rainfall events spanning multiple days. It is expected turbidity would lag behind the rainfall as rainfall on the catchment would lead to runoff and turbidity, when the Chapman River entrance is open. Turbidity at LL1 and LL3 (following redeployment) would appear to be responding more to rainfall events than LL4 which is supported by O2 Marine's field observations and aerial imagery (refer to **Table 3**) showing sediment plumes originating from the Chapman River reaching LL1 and LL3 but not LL4.



Graph 11: LL1 Turbidity versus rainfall



Graph 12: LL3 Turbidity versus rainfall



Graph 13: LL4 Turbidity versus rainfall

Overall, wind, waves and rainfall are all considered to be contributing to turbidity levels observed during the data collection period, particularly at LL1 and LL3. The stronger correlations between these drivers at LL1 and LL3 prior to turbidity reducing throughout the Bay is likely due to the greater exposure to the prevailing southerly winds, sea and swell, and its proximity to observed sediment plumes associated with the Chapman River breakout. It is also noted that the rainfall recorded during the months of June and July in 2024 was 42% and 75% higher than the long-term average, respectively (1977-2024).

The observed reduction in overall turbidity following early September does not appear to be associated with changes to wind and wave conditions, as these conditions remained broadly consistent during this time. As discussed in **Section 1.4**, several lines of evidence including field observations and aerial imagery (refer to **Table 3**) indicate that the elevated turbidity reported at LL1 and LL3 is associated with sediment sourced from the Chapman River breakout and subsequent discharge events during a wetter than average winter. A reduction in rainfall intensity and frequency evident post September and aerial imagery showing the Chapman River entrance narrowing further supports this conclusion.

Turbidity at LL4 did not present the same response to waves, wind and rainfall due to its position relative to Point Moore and partial protection from the prevailing southerly winds and waves, in addition to its observed disconnect from sediment plumes originating from the Chapman River.

1.6 Event Based Analysis

Event based analysis using Matlab was undertaken on the ambient turbidity data to determine the frequency and duration of events that exceeded a specific threshold. The analysis was undertaken on both the 15-minute interval data and the 10-hour rolling average. An arbitrary value of 20 NTU was adopted to provide an indicative understanding of the frequency and intensity of elevated turbidity events. However, this could be adjusted based on the sensitivity of ecological receptors (e.g., seagrass) to turbidity/TSS within the Bay.

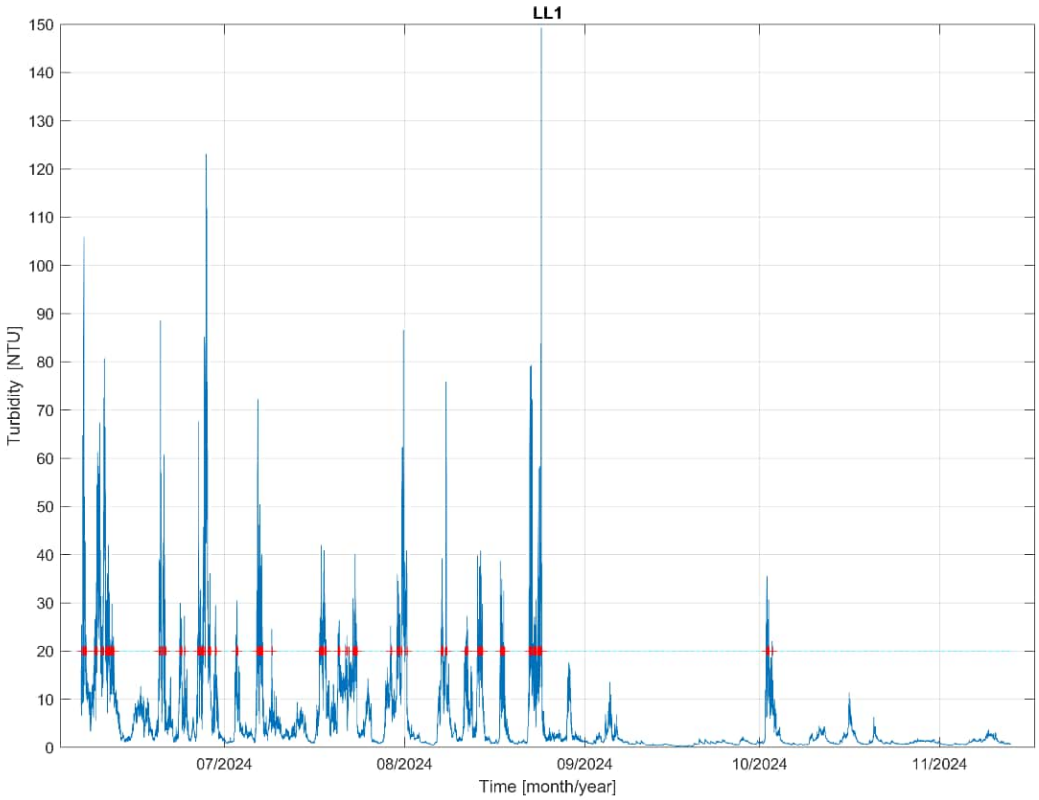
Time-series plots developed for LL1 , LL3 and LL4 showing the events exceeding 20 NTU for both the 15-minute interval data and 10-hour averaged data are illustrated in **Graph 14** to **Graph 25** below. Histograms showing the number of 20 NTU event exceedances and the duration of each of those events are also shown in this set of graphs.

Analysis of the 15-minute turbidity data indicates significantly more turbidity events exceeding the adopted 20 NTU threshold in comparison to the 10-hour average dataset. The majority of these events were short in duration ranging between 0 to 1 hours. Longer-duration events, typically greater than three to four hours, were captured in the 10-hour averaged data. It is understood that longer-duration events are more relevant to understanding potential impacts to sensitive receptors such as seagrass.

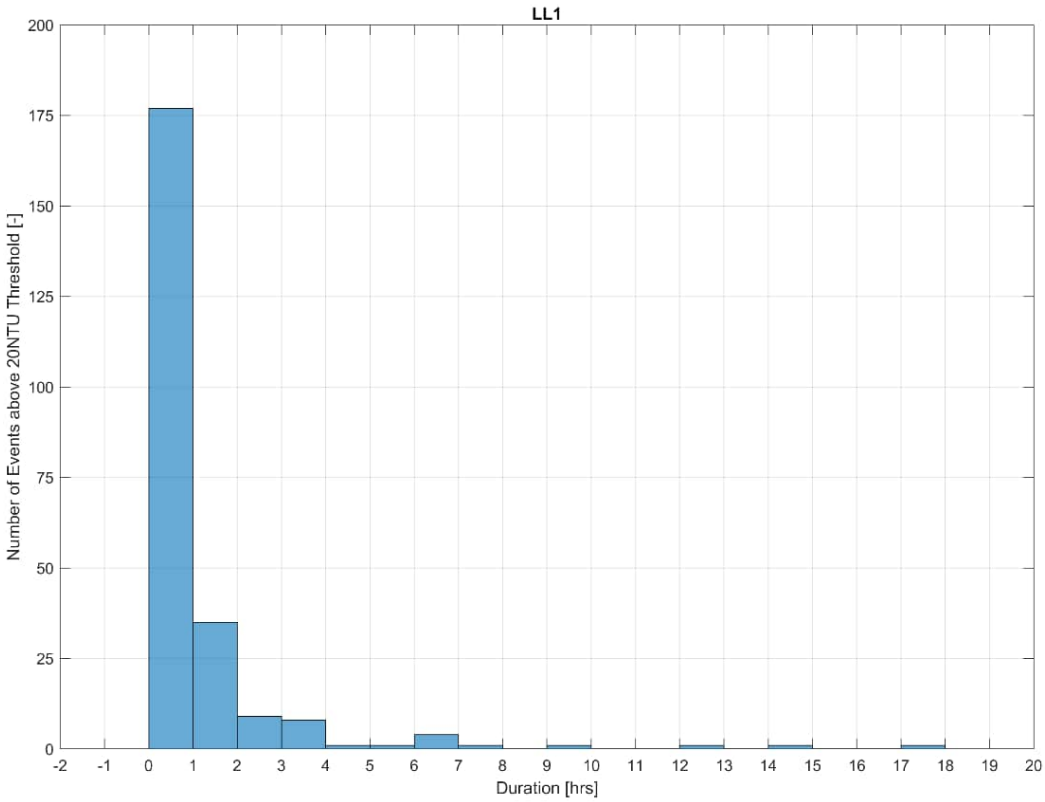
The majority of exceedance events at LL1 and LL3 were before September when overall turbidity levels were higher. Turbidity exceedance events at LL4 were relatively consistent through the data collection period and did not present the same reduction in events after early September as seen in the LL1 and LL3 data.

The duration of events exceeding 20 NTU at LL1 in the 10-hour averaged data ranged from 3 hrs to 28 hrs. This was similar for the 10-hour averaged data from LL4. Events from LL3 ranged from 1 hr to 11 hrs. However, this dataset did not contain the first two months of data from June to August, where turbidity was generally higher, due to issues with the instrument deployment and erroneous data.

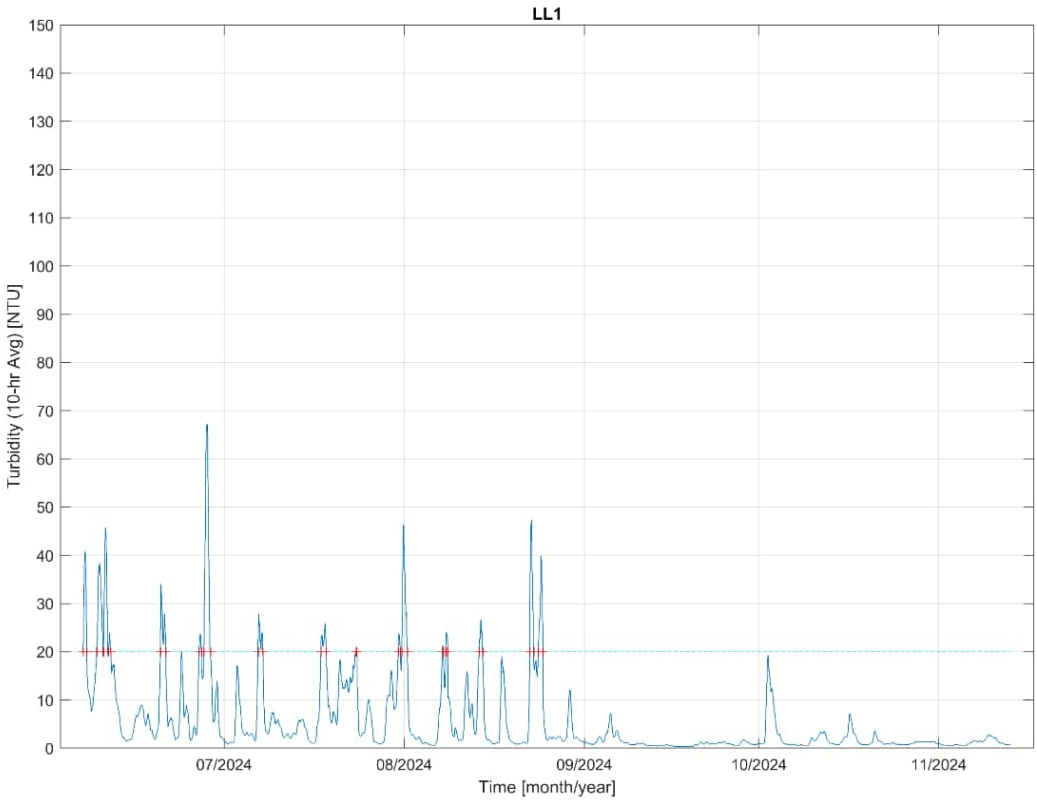
Overall, the event-based analysis indicates that locations LL1 and LL3 presented the highest frequency and longer-duration events prior to early September when sediment from the Chapman River was discharging into Champion Bay in proximity to these locations and being consistently resuspended by wind and waves. Post early September, the frequency and duration of exceedance events declined considerably. LL4 presented a lower frequency of exceedance events, particularly for the 10-hour averaged data. However, the consistency of these events suggests turbidity generated from the Fishing Boat Harbour, such as vessel wash, has a more consistent impact on turbidity at the entrance where LL4 is positioned.



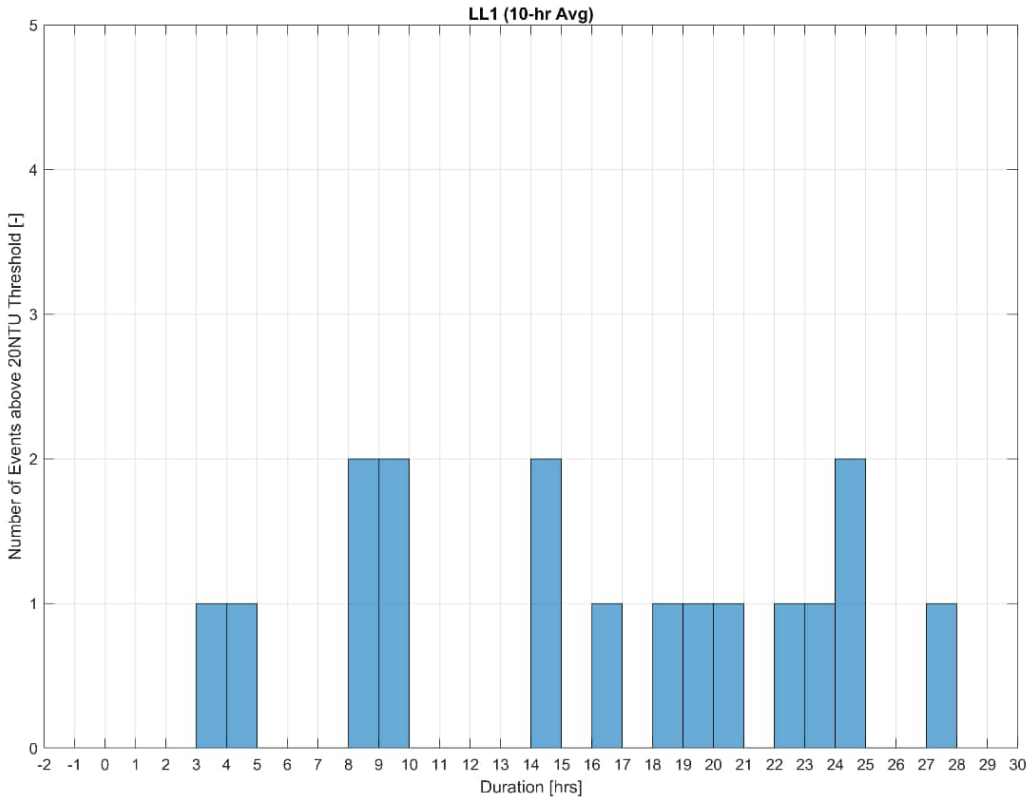
Graph 14: LL1 turbidity timeseries with 20 NTU exceedance events marked (15-minute data)



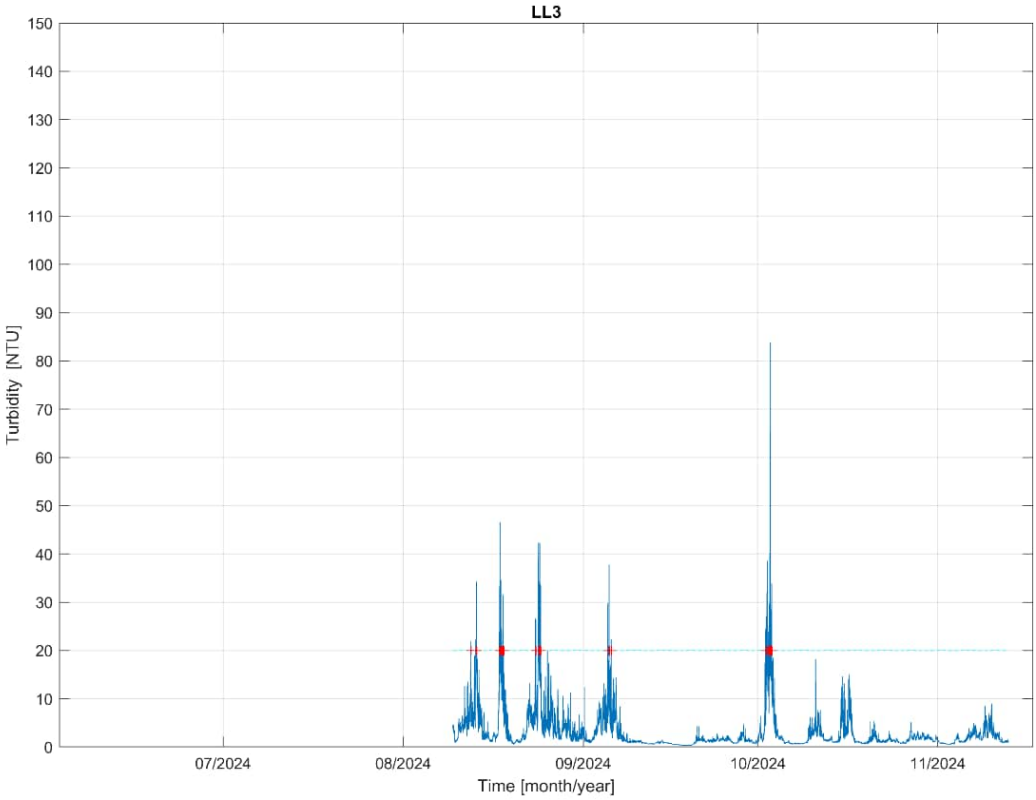
Graph 15: Histogram showing number of 20 NTU exceedance events and the duration of events at LL1 (15-minute data)



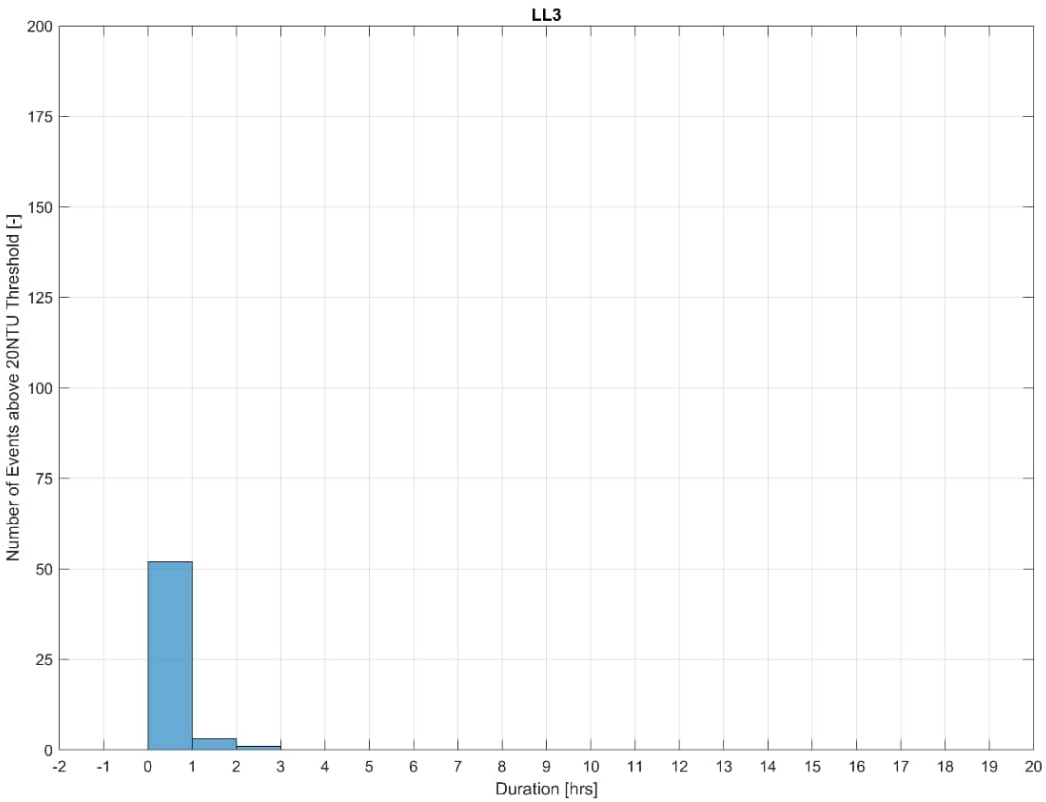
Graph 16: LL1 turbidity timeseries with 20 NTU exceedance events marked (10-hour averaged data)



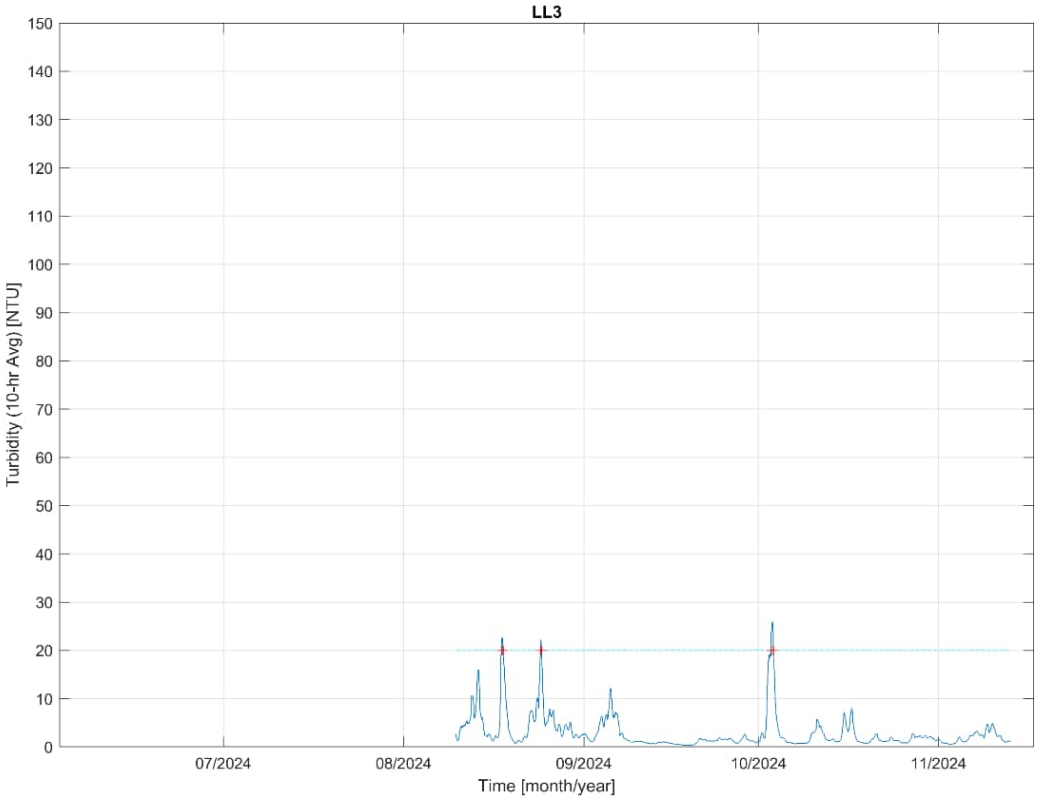
Graph 17: Histogram showing number of 20 NTU exceedance events and the duration of events at LL1 (10-hour averaged data)



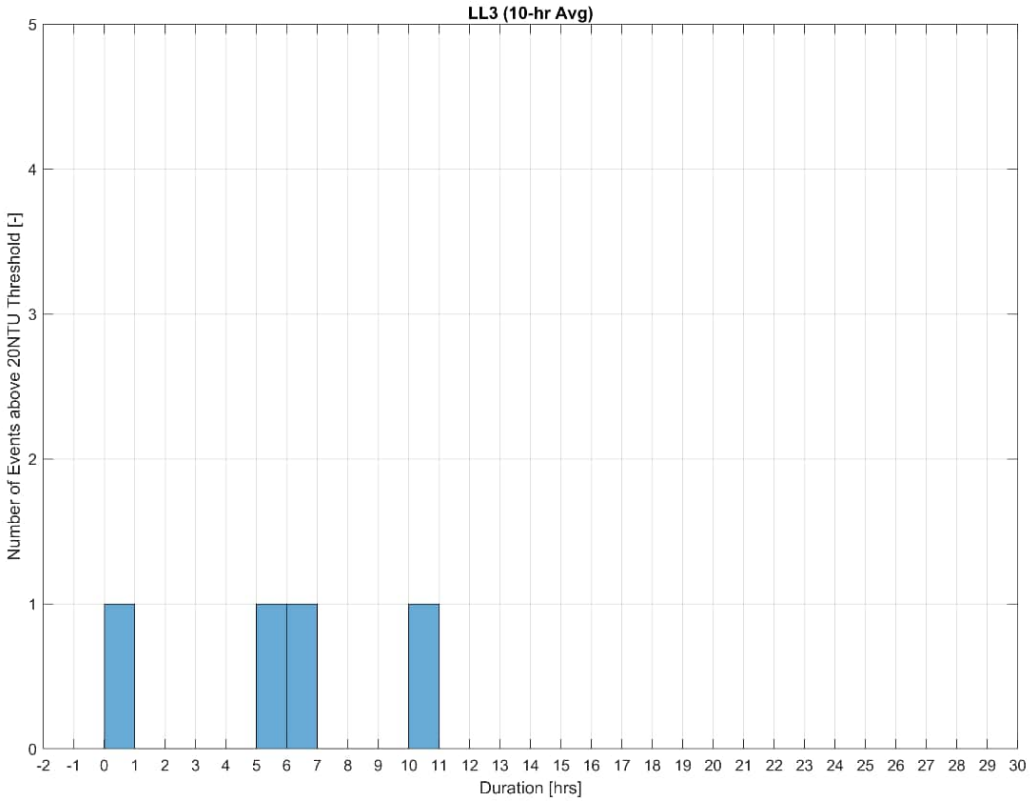
Graph 18: LL3 turbidity timeseries with 20 NTU exceedance events marked (15-minute data)



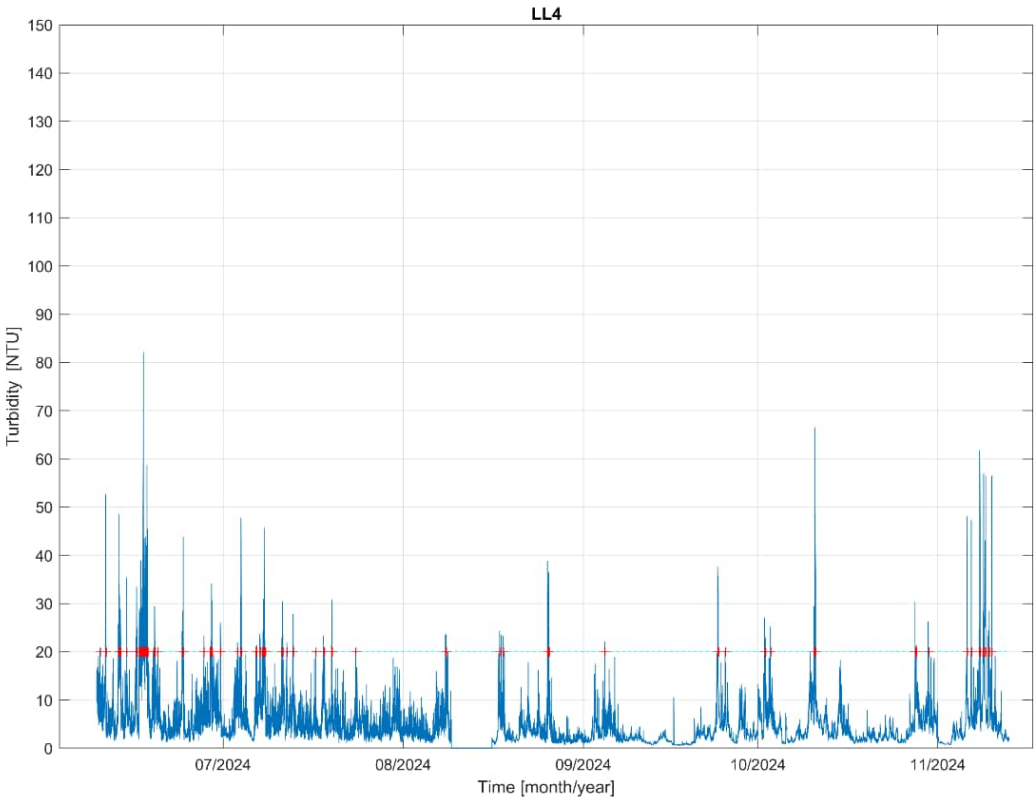
Graph 19: Histogram showing number of 20 NTU exceedance events and the duration of events at LL3 (15-minute data)



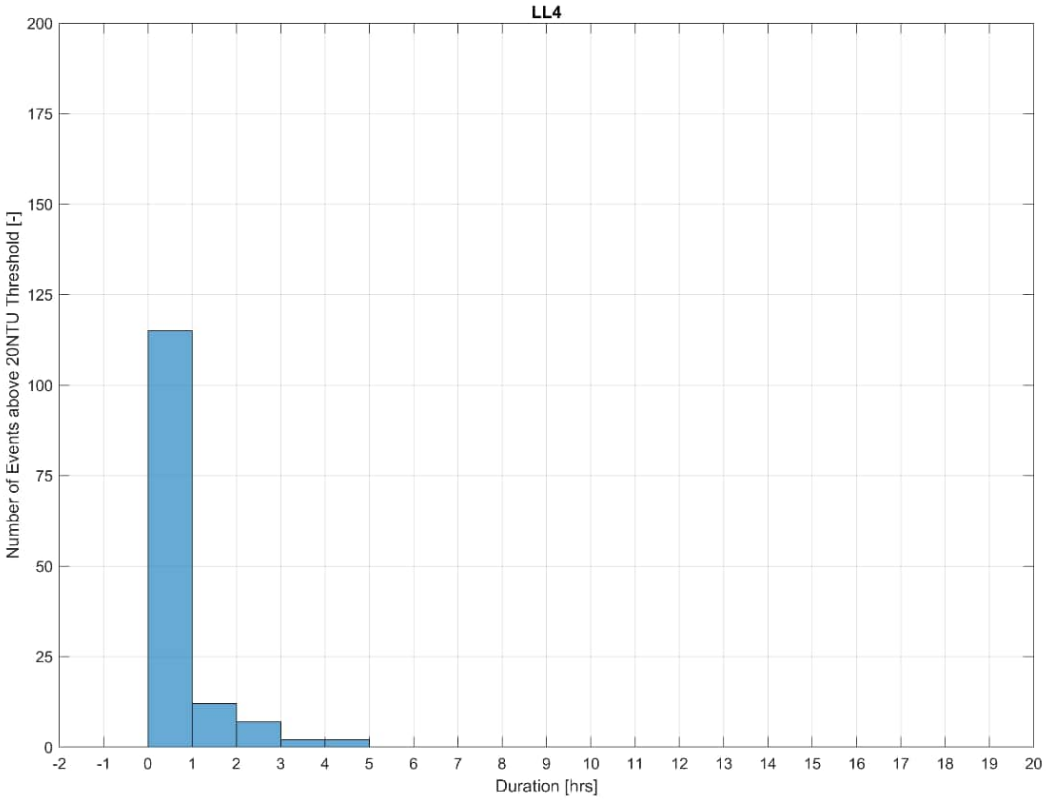
Graph 20: LL3 turbidity timeseries with 20 NTU exceedance events marked (10-hour averaged data)



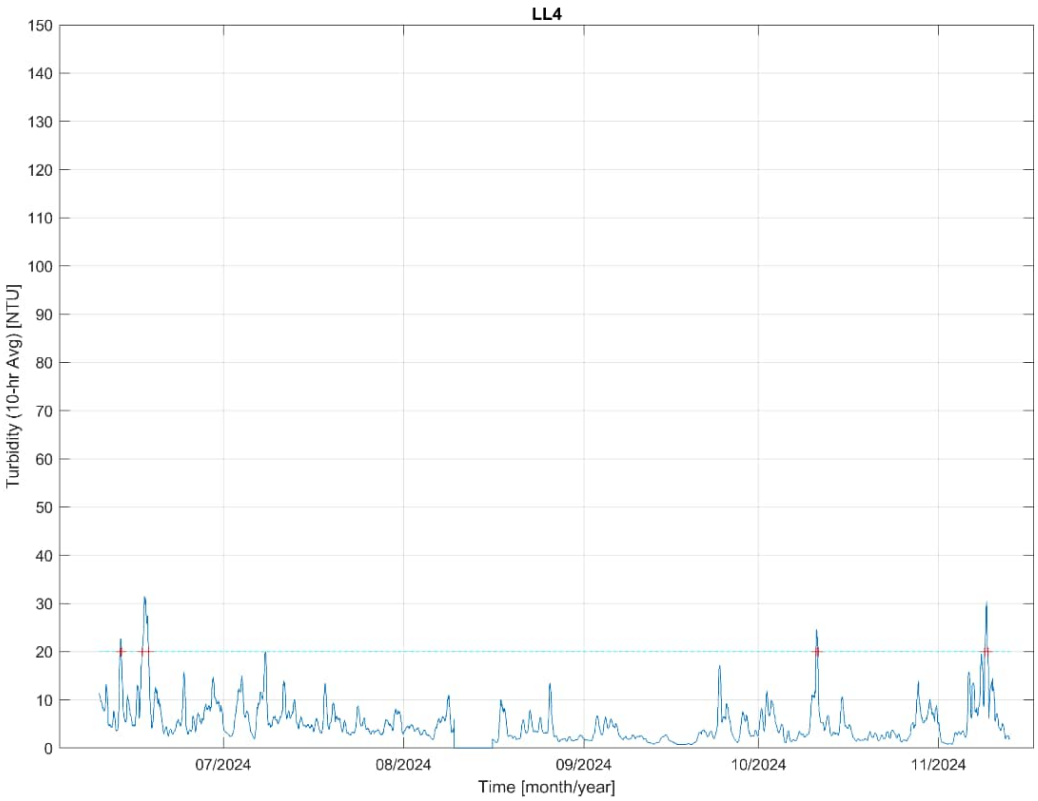
Graph 21: Histogram showing number of 20 NTU exceedance events and the duration of events at LL3 (10-hour averaged data)



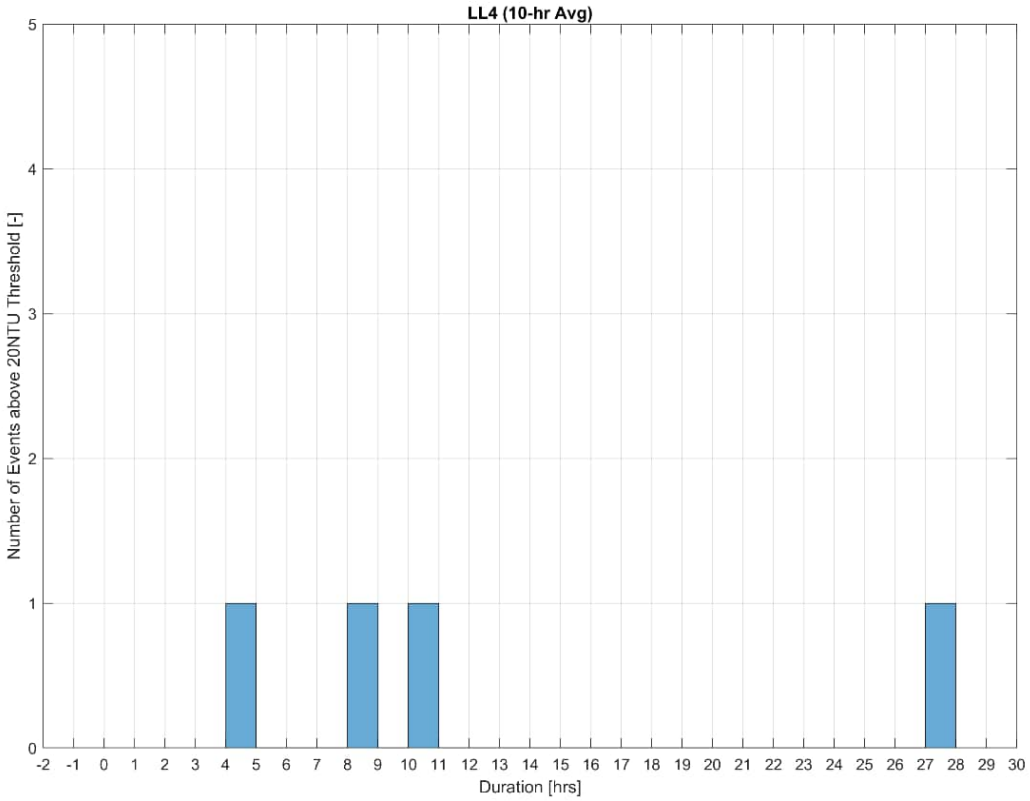
Graph 22: LL4 turbidity timeseries with 20 NTU exceedance events marked (15-minute data)



Graph 23: Histogram showing number of 20 NTU exceedance events and the duration of events at LL4 (15-minute data)



Graph 24: LL4 turbidity timeseries with 20 NTU exceedance events marked (10-hour averaged data)



Graph 25: Histogram showing number of 20 NTU exceedance events and the duration of events at LL3 (10-hour averaged data)

1.7 Considerations for Selecting Baseline Turbidity/ TSS Selection

Considering the higher than average rainfall reported during the monitoring period and evidence of Chapman River breakout plumes impacting locations LL1 and LL3 at the beginning of the monitoring period, in combination with the visually correlated effects of the wind and wave climate on turbidity, it is expected that turbidity levels at LL1 and LL3 prior to the reduction in overall turbidity observed in early September would be representative of 'high' (non-typical) background conditions expected within Champion Bay. Following the overall reduction in turbidity observed after 07 September 2024, turbidity levels reported at LL1 and LL3 are considered more representative of typical ambient conditions expected in the Bay during periods of low rainfall commonly experienced in Geraldton, particularly outside of the winter months.

Turbidity at LL4 is expected to be more representative of the entrance to the Port, where dredging is proposed, due to its position relative to Point Moore and partial protection from the prevailing southerly winds and waves, in addition to its observed disconnect from sediment plumes originating from the Chapman River. As such, adopting a background turbidity/ TSS concentration from the LL4 dataset would provide a more accurate representation of typical background conditions in the proposed dredging areas in proximity to the Port entrance.

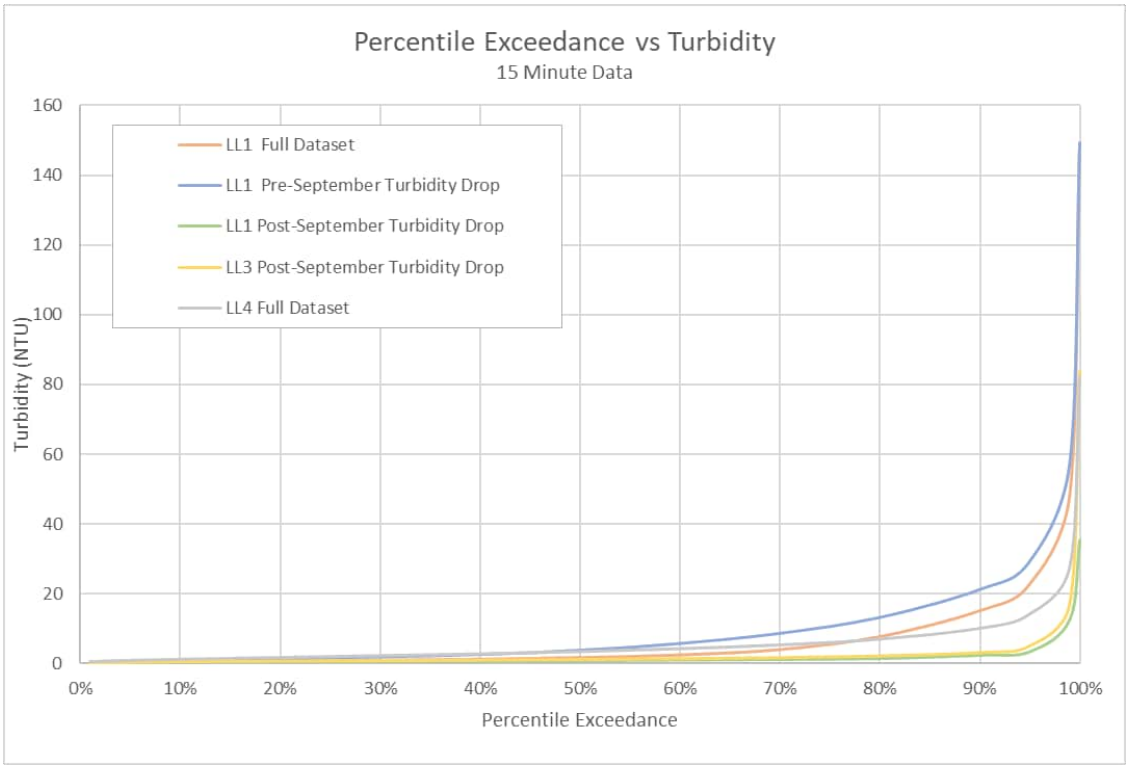
A statistical summary of turbidity and TSS results for the 15 minute interval, 10 hour rolling average and daily (24 hr) average results is provided in **Table 4, Table 5** and **Table 6**, respectively**.** Additionally, as requestion by SLR, Percentile exceedance versus turbidity and TSS graphs have been generated for each of these statistical tables to illustrate the distribution of turbidity levels over the data collection period and how often (as a percentage) certain turbidity and TSS levels are exceeded (refer to **Graph 26** to **Graph 31**). Further, box and whisker plots have been prepared for the daily (24 hr) average data to visualise the statistical distribution of the daily average results (refer to **Graph 32 to Graph 35**).

The monitoring program measured turbidity, whilst TSS is based on the NTU/TSS relationship for marine sediment developed in the Laboratory.

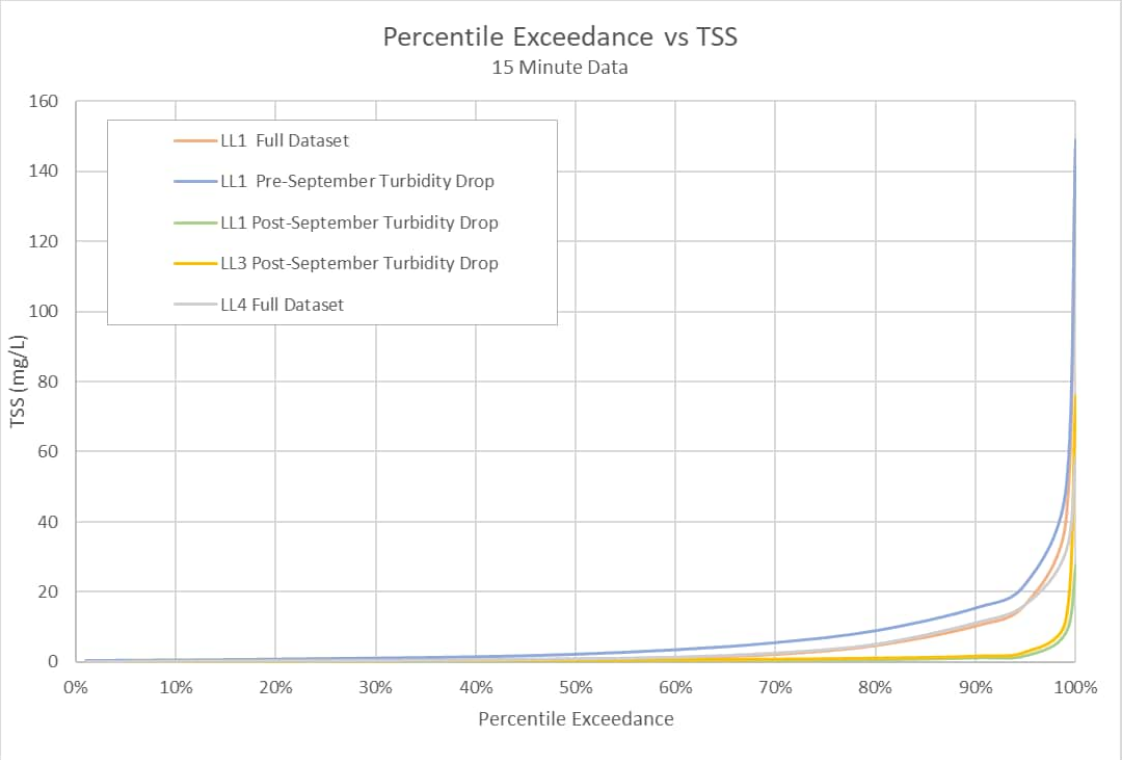
*Table 4: Statistical results for turbidity and TSS all monitored locations, presenting the **15 minute** data*

	LL1 Full Dataset		LL1 Pre-September Turbidity Drop		LL1 Post-September Turbidity Drop		LL3 Post-September Turbidity Drop		LL4 Full Dataset	
Data range (2024)	*6 June - 13 November*		*6 June - 6 September*		*7 September - 13 November*		*7 September - 13 November*		*9 June - 13 November*	
Unit / Statistic	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*
Mean	5.5	3.1	8.5	5.2	1.4	0.7	2.0	1.0	5.2	3.2
Median	1.8	0.8	3.9	2.1	0.9	0.4	1.3	0.6	3.6	0.9
SD	9.4	5.9	11.4	7.3	2.2	1.1	3.2	1.7	5.3	5.1
Max.	149.3	149.0	149.3	149.0	35.5	27.8	83.8	75.9	82.1	58.6
Min.	0.2	0.1	0.4	0.2	0.2	0.1	0.3	0.1	0.5	0.1
1st Percentile	0.3	0.1	0.7	0.3	0.3	0.1	0.3	0.1	0.7	0.1
5th Percentile	0.5	0.2	0.9	0.4	0.4	0.1	0.5	0.2	1.1	0.2
10th Percentile	0.6	0.3	1.1	0.5	0.5	0.2	0.7	0.3	1.4	0.3
20th Percentile	0.8	0.3	1.5	0.7	0.6	0.2	0.8	0.3	1.9	0.4
30th Percentile	1.1	0.5	2.1	1.0	0.7	0.3	0.9	0.4	2.4	0.5
40th Percentile	1.3	0.6	2.8	1.4	0.8	0.3	1.1	0.5	2.9	0.6
50th Percentile	1.8	0.8	3.9	2.1	0.9	0.4	1.3	0.6	3.6	0.9
60th Percentile	2.6	1.3	5.9	3.4	1.1	0.5	1.5	0.7	4.4	1.4
70th Percentile	4.1	2.2	8.8	5.5	1.3	0.6	1.8	0.9	5.5	2.6
80th Percentile	7.8	4.7	13.4	8.9	1.5	0.7	2.3	1.1	7.1	5.1
90th Percentile	15.2	10.3	21.4	15.3	2.4	1.2	3.3	1.7	10.2	11.2
95th Percentile	22.9	16.7	29.5	22.4	3.5	1.8	5.2	2.9	14.3	16.5
99th Percentile	48.7	40.2	57.8	49.1	12.7	8.4	17.3	12.0	27.9	31.4

*TSS concentrations have been determined using the laboratory-based turbidity/ TSS relationship developed for a surface sediment sample obtained within the Port of Geraldton



*Graph 26: Percentile exceedance versus turbidity for the **15 minute** data*

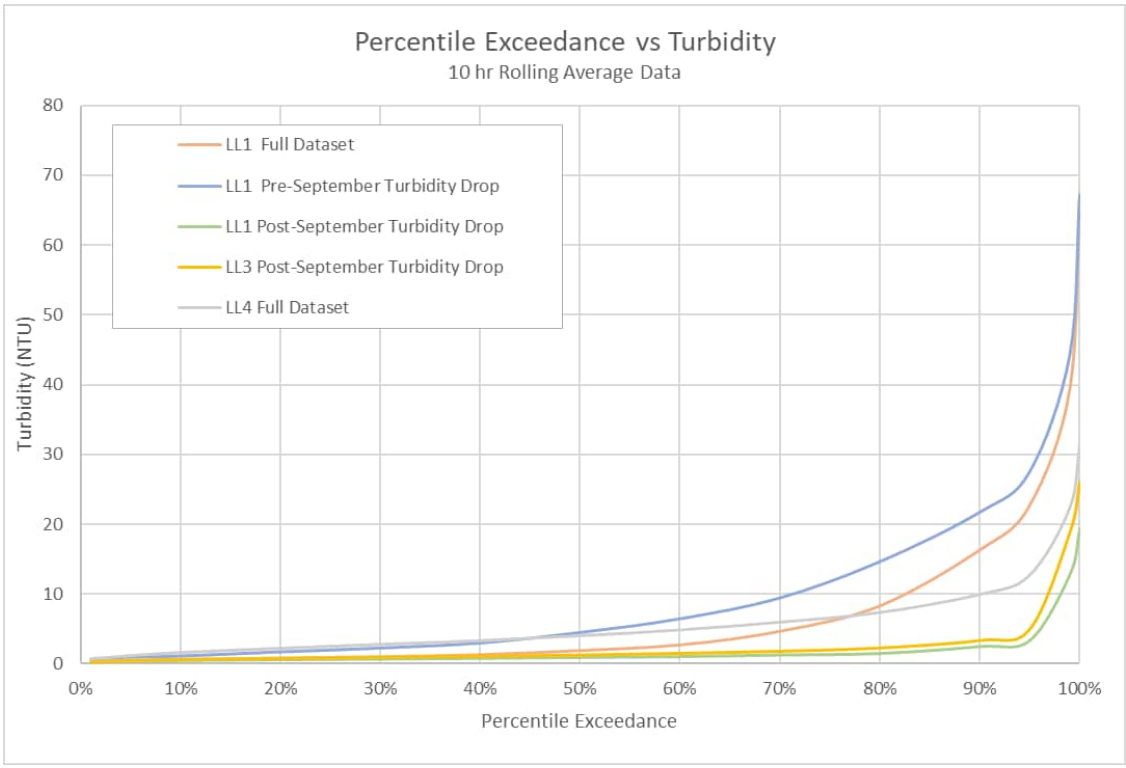


*Graph 27: Percentile exceedance versus TSS for the **15 minute** data*

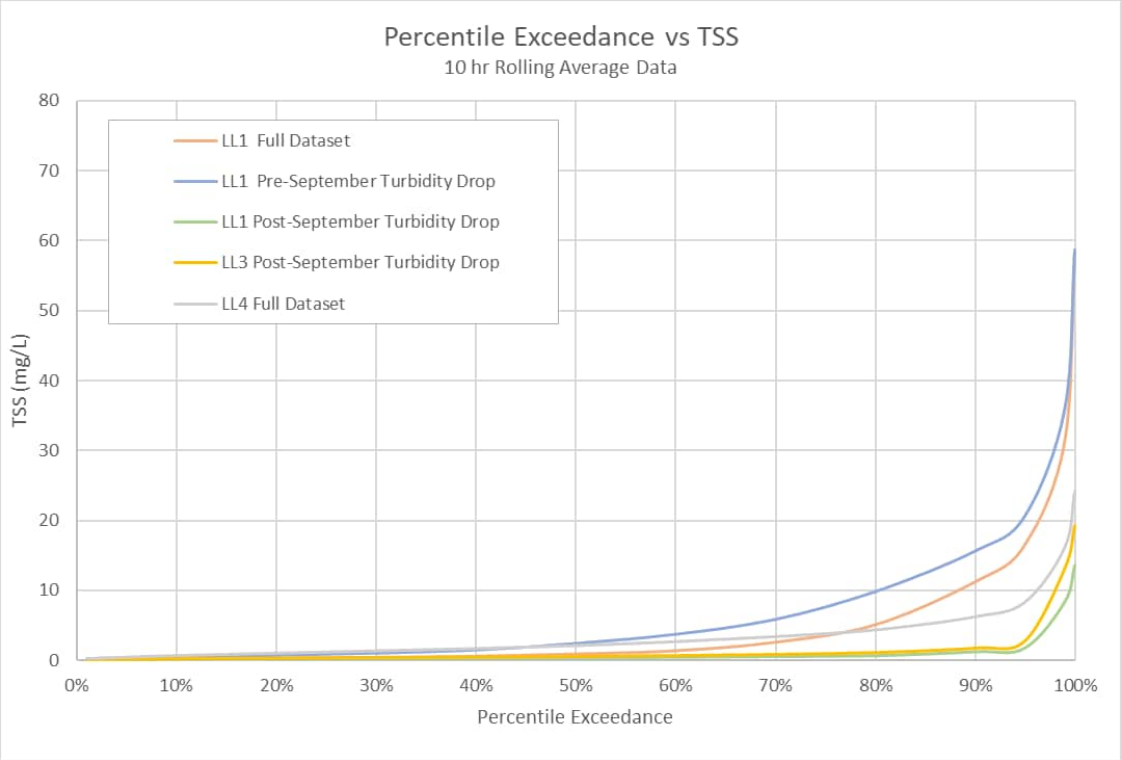
*Table 5: Statistical results for turbidity and TSS all monitored locations, presenting the **10 hr rolling average** data*

	LL1 Full Dataset		LL1 Pre-September Turbidity Drop		LL1 Post-September Turbidity Drop		LL3 Post-September Turbidity Drop		LL4 Full Dataset	
Data range (2024)	*6 June - 13 November*		*6 June - 6 September*		*7 September - 13 November*		*7 September - 13 November*		*9 June - 13 November*	
Unit / Statistic	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*
Mean	5.5	3.2	8.5	5.2	1.5	0.7	2.0	1.0	5.2	2.9
Median	2.0	0.9	4.5	2.5	0.9	0.4	1.3	0.6	4.0	2.2
SD	8.3	5.1	9.8	6.1	2.0	1.0	2.8	1.4	4.1	2.2
Max.	67.2	58.6	67.2	58.6	19.3	13.6	26.0	19.3	31.5	24.2
Min.	0.3	0.1	0.5	0.2	0.3	0.1	0.3	0.1	0.7	0.3
1st Percentile	0.3	0.1	0.7	0.3	0.3	0.1	0.4	0.1	0.7	0.3
5th Percentile	0.5	0.2	1.0	0.4	0.4	0.1	0.5	0.2	1.2	0.5
10th Percentile	0.7	0.3	1.1	0.5	0.5	0.2	0.7	0.3	1.6	0.7
20th Percentile	0.9	0.4	1.7	0.8	0.6	0.3	0.8	0.3	2.2	1.1
30th Percentile	1.1	0.5	2.3	1.1	0.7	0.3	1.0	0.4	2.8	1.4
40th Percentile	1.3	0.6	3.0	1.5	0.8	0.3	1.1	0.5	3.3	1.7
50th Percentile	2.0	0.9	4.5	2.5	0.9	0.4	1.3	0.6	4.0	2.2
60th Percentile	2.8	1.4	6.5	3.8	1.1	0.5	1.6	0.7	4.9	2.7
70th Percentile	4.7	2.6	9.4	5.9	1.3	0.6	1.9	0.9	6.0	3.5
80th Percentile	8.4	5.1	14.7	9.9	1.5	0.7	2.3	1.2	7.4	4.4
90th Percentile	16.4	11.2	21.7	15.7	2.5	1.2	3.4	1.8	10.0	6.3
95th Percentile	22.8	16.5	27.6	20.7	3.4	1.8	5.0	2.8	12.7	8.4
99th Percentile	39.5	31.4	44.3	36.0	12.7	8.4	18.8	13.2	22.4	16.2

*TSS concentrations have been determined using the laboratory-based turbidity/ TSS relationship developed for a surface sediment sample obtained within the Port of Geraldton



*Graph 28: Percentile exceedance versus turbidity for the **10 hr rolling average** data*

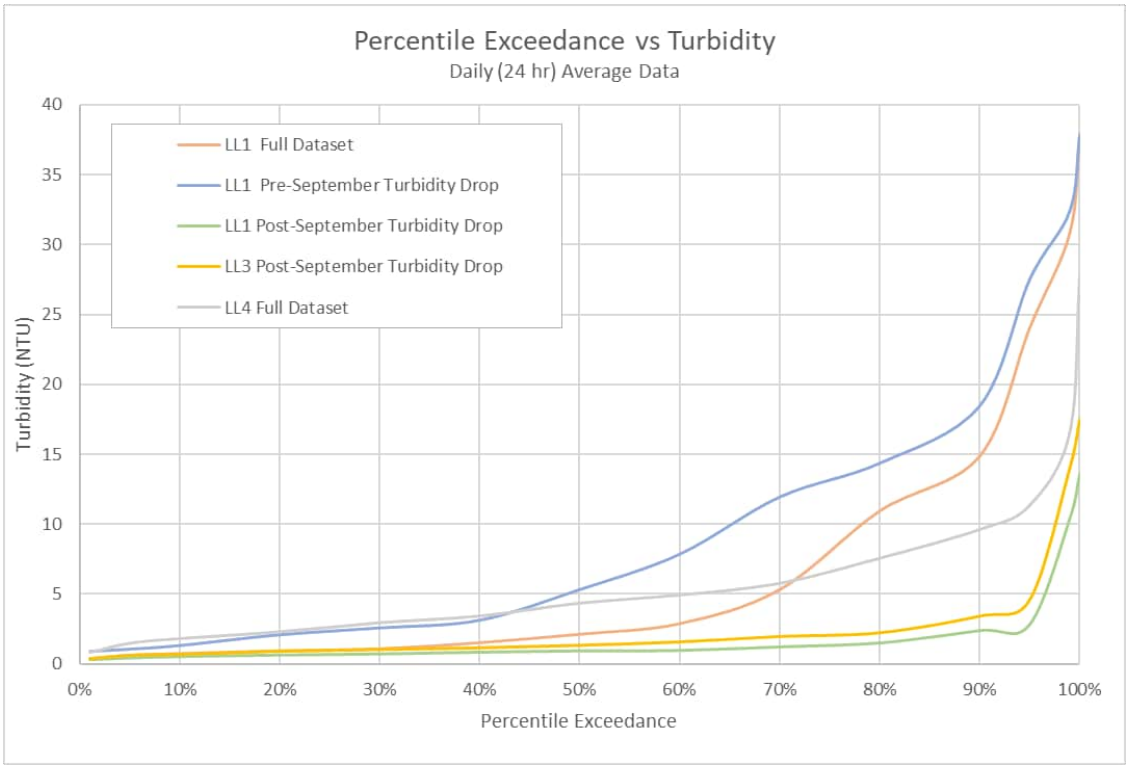


*Graph 29: Percentile exceedance versus TSS for the **10 hr rolling average** data*

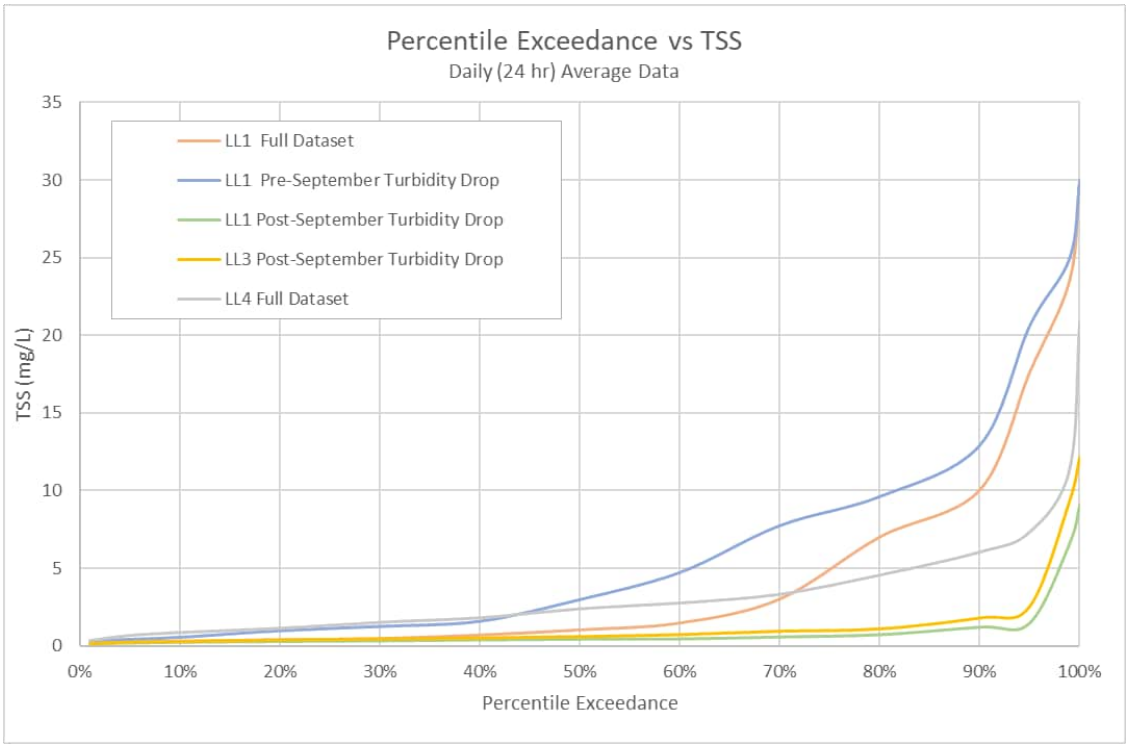
Table 6: Statistical results for turbidity and TSS all monitored locations, presenting the daily (24 hr) average data

	LL1 Full Dataset		LL1 Pre-September Turbidity Drop		LL1 Post-September Turbidity Drop		LL3 Post-September Turbidity Drop		LL4 Full Dataset	
Data range (2024)	*6 June - 13 November*		*6 June - 6 September*		*7 September - 13 November*		*7 September - 13 November*		*9 June - 13 November*	
Unit / Statistic	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*	*Turb (NTU)*	*TSS (mg/L)*
Mean	5.6	3.2	8.6	5.3	1.4	0.7	2.0	1.0	5.2	2.9
Median	2.1	1.0	5.3	3.0	1.0	0.4	1.3	0.6	4.4	2.4
SD	7.4	4.4	8.4	5.1	2.0	0.9	2.5	1.2	3.8	2.0
Max.	37.9	30.0	37.9	30.0	13.6	9.1	17.5	12.2	27.8	20.8
Min.	0.3	0.1	0.7	0.3	0.3	0.1	0.3	0.1	0.7	0.3
1st Percentile	0.4	0.1	0.9	0.4	0.3	0.1	0.4	0.1	0.8	0.3
5th Percentile	0.6	0.2	1.0	0.4	0.5	0.2	0.6	0.2	1.5	0.7
10th Percentile	0.7	0.3	1.3	0.6	0.5	0.2	0.7	0.3	1.8	0.9
20th Percentile	0.9	0.4	2.1	1.0	0.7	0.3	0.9	0.4	2.3	1.1
30th Percentile	1.0	0.5	2.6	1.3	0.7	0.3	1.0	0.4	3.0	1.5
40th Percentile	1.5	0.7	3.1	1.6	0.9	0.4	1.1	0.5	3.4	1.8
50th Percentile	2.1	1.0	5.3	3.0	1.0	0.4	1.3	0.6	4.4	2.4
60th Percentile	2.9	1.5	7.8	4.7	1.0	0.4	1.6	0.7	4.9	2.8
70th Percentile	5.3	3.0	11.9	7.8	1.2	0.6	2.0	0.9	5.8	3.3
80th Percentile	10.9	7.0	14.3	9.6	1.5	0.7	2.2	1.1	7.6	4.6
90th Percentile	14.9	10.0	18.5	12.9	2.4	1.2	3.4	1.8	9.6	6.0
95th Percentile	24.0	17.6	27.5	20.6	2.9	1.5	4.6	2.5	11.4	7.3
99th Percentile	30.8	23.6	32.4	25.0	10.4	6.6	14.0	9.4	16.6	11.4

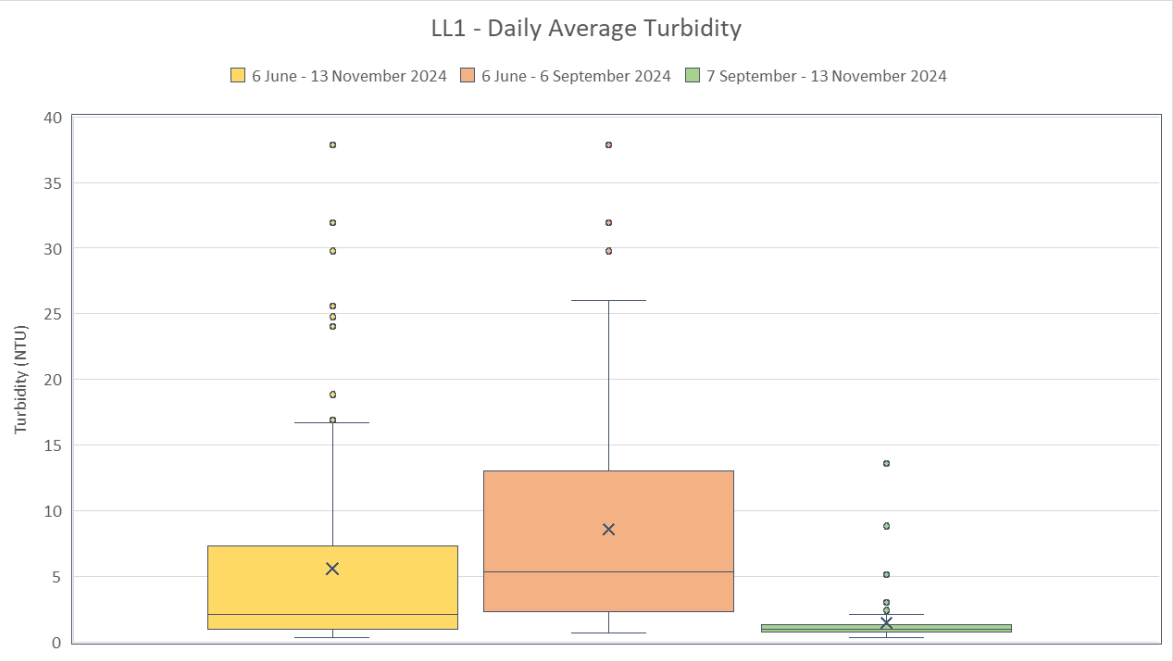
*TSS concentrations have been determined using the laboratory-based turbidity/ TSS relationship developed for a surface sediment sample obtained within the Port of Geraldton



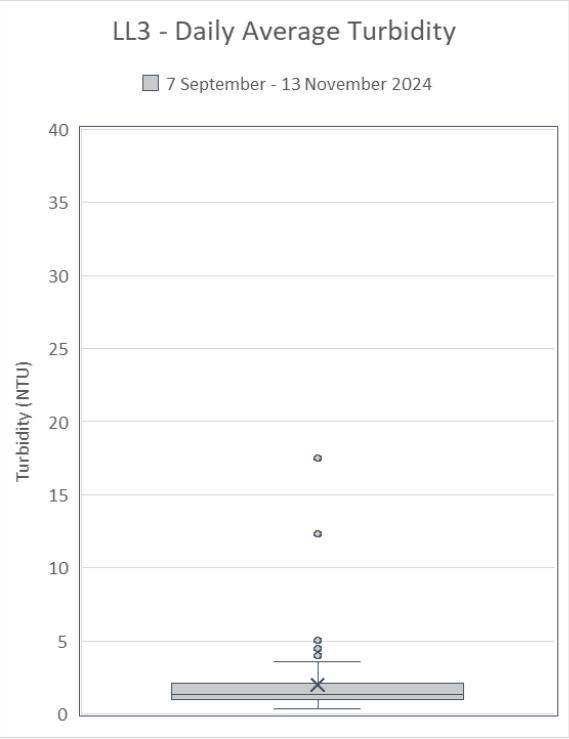
*Graph 30: Percentile exceedance versus turbidity for the **daily (24 hr) average** data*

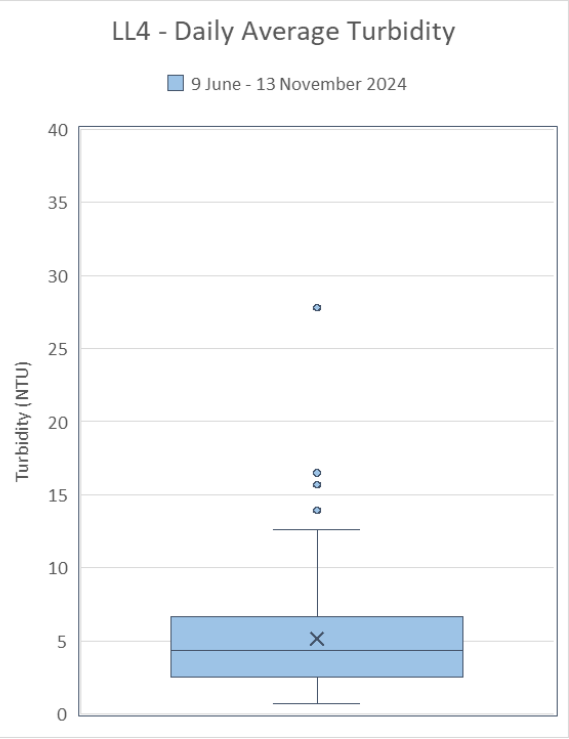


*Graph 31: Percentile exceedance versus TSS for the **daily (24 hr) average** data*

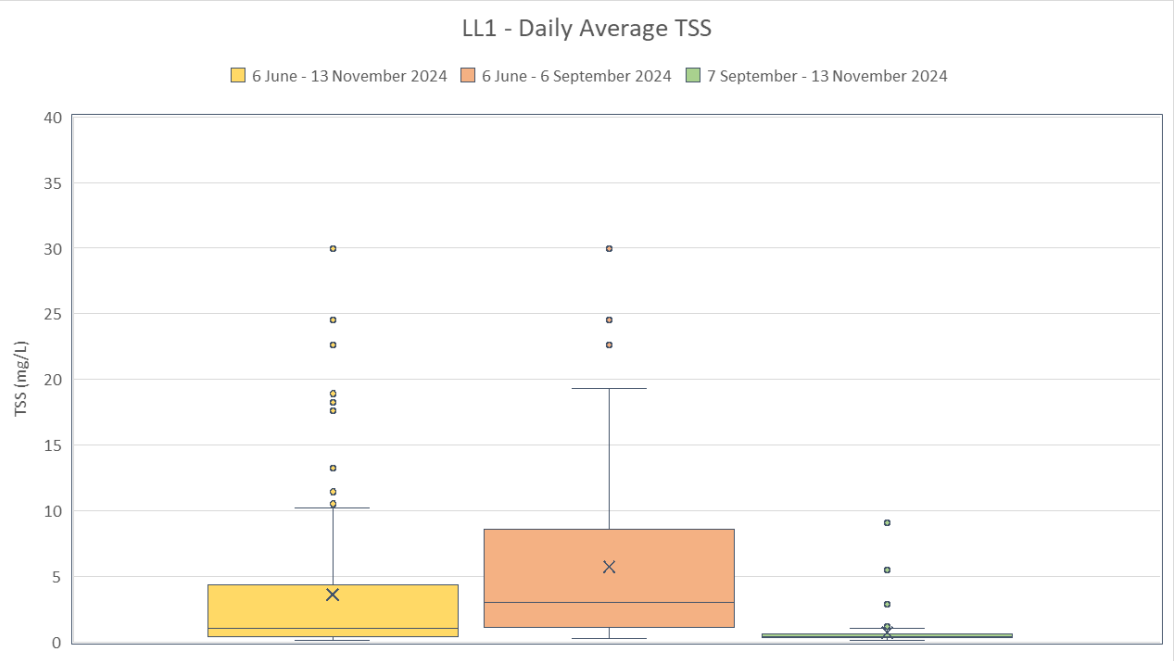


Graph 32: Statistical distribution of daily (24 hr) average turbidity data from LL1

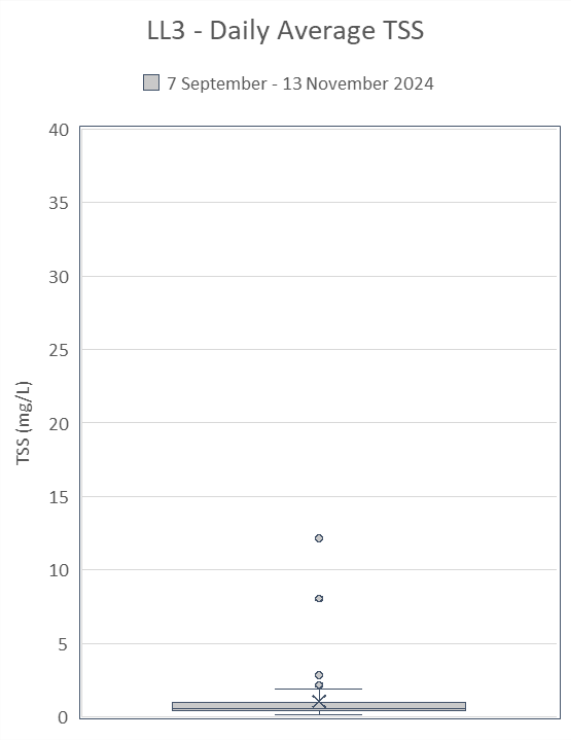


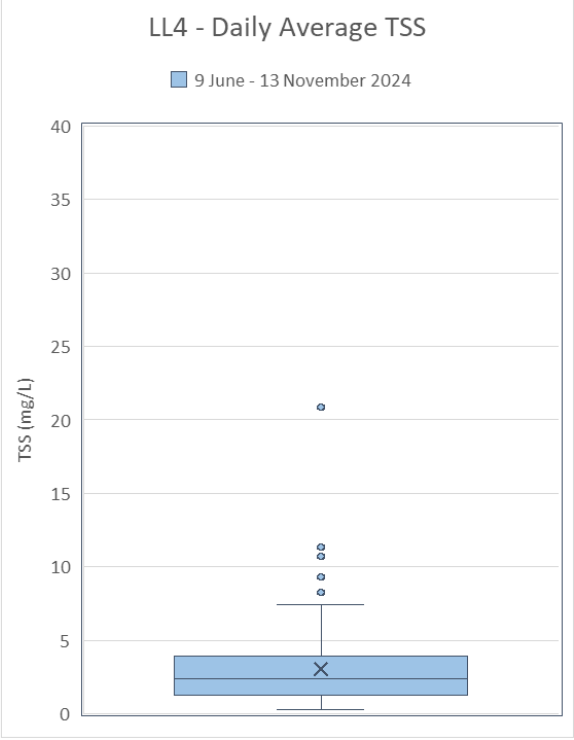


Graph 33: Statistical distribution of daily (24 hr) average turbidity data from LL3 and LL4



Graph 34: Statistical distribution of daily (24 hr) average TSS data from LL1





Graph 35: Statistical distribution of daily (24 hr) average TSS data from LL3 and LL4

A3 Maintenance Dredging Source Term Development - Berth 1

GERALDTON – MID WEST PORT AUTHORITY

PORT MAXIMISATION PROGRAM (PMP) – INNER HARBOUR

NEW BERTH 1 (N/S) – Maintenance Dredging

SUMMARY OF ROM ESTIMATES FOR INPUT SOURCE TERMS RELATING TO MODELLING OF PLUMES FROM DREDGING IN GLADSTONE HARBOUR

OVERVIEW:

An assessment has been made of relevant geotechnical reports relating to maintenance dredging by small trailer suction hopper dredge (smTSHD) in future berth 1 (N/S) of the inner-harbour area, as part of the PMaxP (MWP) project, to inform and calculate a) the production estimate, b) drag-head loss, c) pump-out loss and d) prop-wash resuspension loss to the water column for silts and clays during the Works.

ASSUMPTIONS:

There are several major assumptions relating to components of the proposed Works:

1) TSHD work to remove siltation in an area, which was previously dredged.

- No overflow will be allowed
- No jets on drag-heads will be allowed
- No losses through hopper doors, valves or split hull will be allowed
- Deployment of silt curtain around the TSHD dredger is not possible

2) TSHD discharge will be by pumping into a nearby reclamation site

- Minimum materials to be released under the TSHD during pump-out through water intakes.
- No fines are to be contained in the discharge of transport water from the reclamation at the outlet point to the receiving environment.
  (Alternatively, the reclamation will be of adequate capacity to settle all fines and polish the returned waters without discharging until after the Works).

DRAFT

3) Reference TSHD working 24hrs/7days.
   - DAMEN TSHD (modular series) 1500
     - LoA 70.00m
     - LbPP 66.90m
     - Beam 13.20m
     - Depth (Moulded) 5.40m
     - Draught (Dredging) 4.70m
     - Max dredging depth 20m
     - Propulsion (Twin Prop) 2x 700kW
     - Bow thruster 1x 280kW
     - Hopper Capacity (water) 1500-1800m (resp. sand-mud)
     - Speed (Loaded) 9 knots
     - Speed (Empty) 10 knots
     - Suction Pipe (single) 500mm
     - Adjustable overflow (incl green valve)
     - Pump ashore capability
     - Bottom door discharge
     - Available hours = 168hrs/wk
     - Dredging effective hours= 142.8hrs/wk

Estimated losses of fines to the nearby receiving environment are calculated and provided for plume modelling purposes based on this standard design reference TSHD.

Please note: The above reference dredge is slightly larger than TSHD Modi R (Rohde Nielsen – Denmark) and therefor production and flux inputs are somewhat conservative.

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MAINTENANCE DREDGE AREA



Figure 1 – Location of dredge area and volumes

RECLAMATION PLACEMENT AREA FOR DREDGED MAINTENANCE MATERIAL

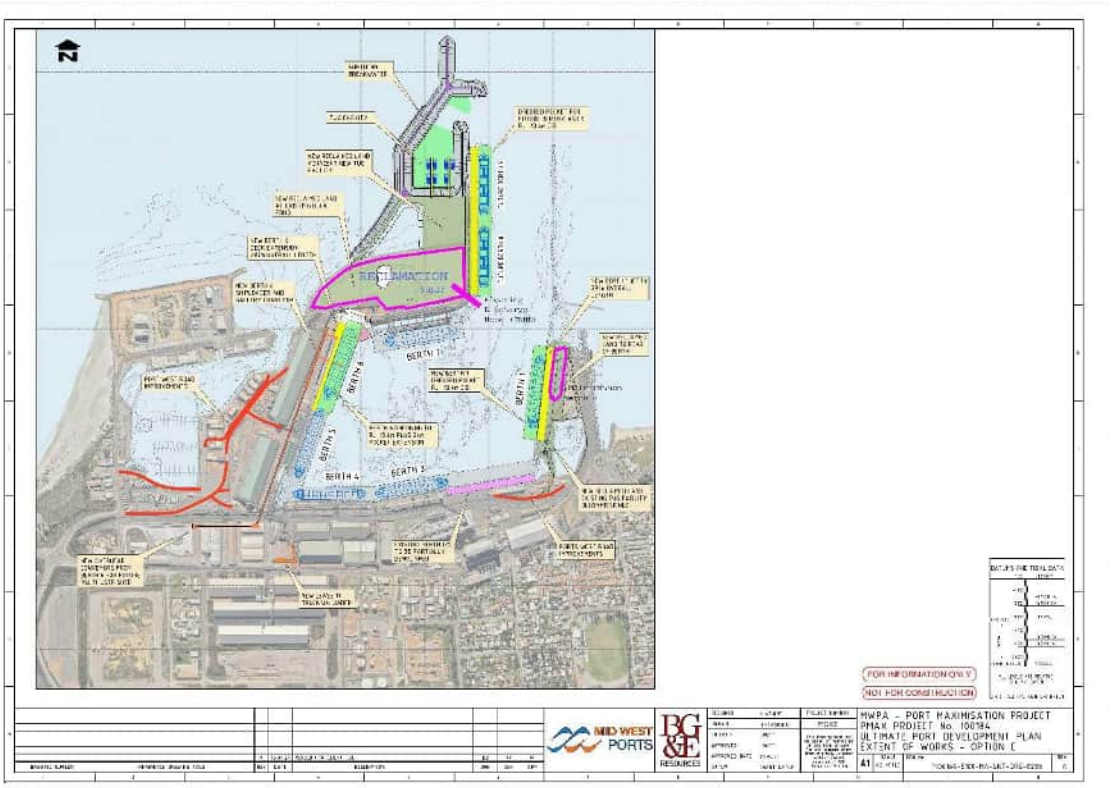


Table 2 Reclamation Area, pump-out location and dredge area for TSHD (in Pink)

As can be noted: The pump-out discharge location for the small TSHD is assumed to be at the eastern end of the reclamation area. This may consist of a shore connection and floating hose to an anchored buoy onto which the smTSHD moors by a single line over the bow during the discharge period.
Position control of the vessel can be further achieved by a small tug and/or by the combined use of bow-thruster and twin-propulsion.
Naturally, the above must not create any restrictions to the commercial shipping within the port.
Release point of mixture – Onshore harbour end of floating line (PINK) within reclamation.
Release point of clean tailwaters to be on the western side of the reclamation by gravity drainage through an adjustable weir box structure.

SUMMARY TABLES FOR ESTIMATED LOSSES OF FINES TO THE WATER COLUMN

***Berth 1 (N/S) – CONTINUOUS** - THSD maintenance dredging – Losses from drag-head, TSHD discharge and resuspension from prop-wash in a relatively shallow areas*

PART1 - GEOTECHNICAL INFORMATION (Ex MWP)

Table 1 – SOIL MODEL – Maintenance dredging

Berth 1 Flat and Slope	Sample	Coarse >75mu	Fines <75mu	Silt 2-75mu	Clay <2mu	Location
	DP1	65%	35%	33%	2%	N-end
	DP6	41%	59%	49%	10%	S-end
	Average	Assume representative		41%	6%	Combined

Note: A sub-distribution of the PSD for SILTS can be found in Table 3 below.

PART 2 – SUMMARY PRODUCTION and DURATION INFORMATION

Production based on DAMEN 1500 - small trailer hopper suction dredge

Table 2 – SUMMARY of THSD PRODUCTION level for dredging and pump-out methodology and DURATION

THSD	Hopper Capacity		Overflow	Jets	Water to reclamation	Solids	Situ Volume and Duration
DAMEN 1500	m3	Available	Nil	Nil	m3/wk	Situ m3/wk	17,629m3 in situ
	1800	95%			270,000	45,900	0.384 wks

Note: The very short duration of the work will not allow any settlement of fines in the reclamation. Whilst pumping to reclamation by a TSHD, approx. 20% of the mixture is bulked solids and 80% is transport water. Short term average bulking factors may be Bf= 1.6 to 1.7 Consequently: The capacity of the reclamation needs to be adequate to receive all the transport waters with bulked fines. Decanting to occur when settlement and polishing has been achieved to acceptable/allowable levels over time (weeks).

PART 3 - SUMMARY TABLE for SOURCE INPUT for MODELLING

Table 3 – FLUX Inputs for selected maintenance dredging methodology

Calculated continuously over 168hrs/wk or a continuous part thereof.

POINT of RELEASE and FLUX	Total Loss of Fines kg/sec	Silt Fines only kg/sec	Clay Fines only kg/sec	Release Level	Distribution
	<75mu	2-75mu	<2mu	from/to	%
Draghead	2.18	1.89	0.29	Seabed to +2m	100%
Sub-distribution for silts **PSD 60-75mu** **PSD 40-60mu** **PSD 20-40mu** **PSD 2-20mu**		40% 30% 20% 10%			
Propwash/Scour	0.94	0.76	0.18	Surface to -3m Mid level Seabed to +3m	15% 35% 50%
Overflow	-	Not allowed			
Discharge under TSHD at end of pump-out	0.1	0.09	0.01	Surface to -3m Mid level Seabed to +3m	10% 40% 50%
Discharge Outlet Reclamation	-	No discharge of turbid waters planned with adequate reclamation and ponding capacity.			
Totals	**3.22**	**2.74**	**0.48**	**kg/sec over 168Hrs/wk**	

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A4 Capital Dredging Source Term Development - Berth 1, Berth 6 and Berth 8

Note / Memo

Haskoning Australia PTY Ltd.
Water & Maritime

To:	Alysia Woodward, SLR Consulting
From:	Greg Britton
Date:	16 February 2024
Copy:	Lachlan Barnes, SLR Consulting Arjen Overduin Frans Hoogerwerf
Our reference:	PA3387-RHD-XX-XX-PP-X-0001-Mid West Ports PMaxP - Dredge Review
Classification:	Project related
Checked by	

Subject: **Mid West Ports Port Maximisation Project (PMaxP) - Dredge Management Strategy and Input Source Terms for Modelling of Plumes from Dredging – Berths 1 & 6 and Old Tug Harbour, and Berth 8 and New Tug Harbour**

Dear Alysia

Further to our recent discussions, I have set out below our recommendations on the above matters for the Mid West Ports PMaxP.

The Memo is structured in the following way:

- Section 1 lists the information supplied for review;
- Section 2 summarises the main issues experienced with the dredging carried out in 2002-2003 and which have raised concerns in regard to the potential environmental impacts of dredging for the PMaxP;
- Section 3 outlines the understanding of the proposed dredging and disposal of dredge material associated with PMaxP for Berths 1 & 6, and Berth 8 and New Tug Harbour;
- Section 4 sets out the recommended dredge management strategy for PMaxP to minimize environmental risk, based on a review of the existing available information and the previous issues; and
- Section 5 sets out recommendations for input source terms for modelling of plumes from dredging for Berths 1 & 6, and Berth 8 and New Tug Harbour.

The Memo is written assuming the reader has a good knowledge of the Port of Geraldton.

1. INFORMATION SUPPLIED FOR REVIEW

The following geotechnical and dredging related information was supplied for review, listed in chronological order, from earliest to latest. It is noted that since initial preparation of this Memo some additional geotechnical information has become available near Berth 1. This information will be reviewed in detail prior to modelling activities, but is not expected to change the recommendations in this Memo.

Date	Name	Contents	Applicability
March 1983	Maunsell- Nedeco PWD of WA Harbours & Rivers Branch – Feasibility Study	Outer Approach Channel Feasibility	Outer Channel
Dec. 1983	Maunsell-Nedeco PWD of WA HRB - Final Report	Evaluation of Drilling programme	Outer Channel
June 1985	PWD WA Harbours & Rivers Dredging Conditions	Review previous studies, staging, materials, availability of equipment	Whole of Port
Sept. 1985	Association of Australian Port and Marine Authorities – Technical Feasibility Study of Dredging	Feasibility Report for deepening of Gladstone Harbour – Assessments of materials	Whole of Port
1993	Soil & Rock Engineering	Geotech	Berths 6-7
Aug. 1993	Soil & Rock Engineering Geotechnical Investigation	Wharf Extension	Berth 5
1999	Douglas Partners	Locations for SI	Berths 6-7-8
May 1999	Douglas Partners – Borehole Plan	Locations of boreholes through wharf deck	Berths Old 1 and 2
June 1999	Douglas Partners Factual Report Marine Geotechnical Investigation	Boreholes and testing of Sediment and Rock	Berths 1 and 2
Jan. 2000	Dames and Moore – Borehole Location Plan	Locations	Harbour and Channel
Feb. 2000	Dames and Moore – Geotechnical Data Review	Available Geotechnical Data Review	Whole of Port
April 2001	Fugro - Report on Seismic Surveys	Seismic Results for Channel and Harbour	Whole of Port
Nov. 2001	URS- Site Visit Report to Esperance	Observations of rock dredging CSD Wombat	N/A
Dec. 2001	Fugro – Seismic Survey Chart	Tracks seismic reflection and seismic refraction	Whole of Port
Feb. 2002	URS – 2001 -Offshore Geotechnical Investigation PEP Volumes 1+2 App D	Borehole Data and UCS Tests. Lab tests and certificates	Berths 1-8

March 2002	URS – Seabed Sediment Survey – GPA PEP	Sampling of sediments and testing	Harbour and Channel
April 2002	Fugro – Report on seismic surveys	Seismic Details	Whole of Port
April 2002	GPA- PEP Contract Section 6-1 Annex	Contract Details	Whole of Port
2002	URS – PEP Borehole plan	Locations	Whole of Port
August 2003	Dept of Civil and Environmental Engineering – Uni of Melbourne and Coffey	Report on Rock testing for Coffey Geosciences. Geraldton dredging Project	Locations unknown
March 2005	GPA – PEP Dredging Works Report	Final Contract Report	Whole of Port
Oct. 2006	Maunsell PGA Port Berths 5&6 Upgrade – Geotechnical report	Boreholes, Rock Testing, Pile loads	Berths 5 and 6
Oct. 2009	AECOM- Karara Iron	Land Based Geotechnical Report	Berth 7
Oct. 2009	AECOM-Karara Iron Ore Project	Geotech and tests	Berth 6
2010	JFA and Fugro Performance versus Seismic velocity in Limestone Material	Review of seismic, boreholes and actual dredging performance	Whole of Port
2010	AECOM Summary Sheet	Basic Geotechnical Data	Whole of Port
July 2012	GHD – Northern Reclaim development	Report on Geotechnical Investigation	Behind Berth 7
Feb. 2014	AECOM – Search for Geotechnical Information	References to Geotechnical reports	Berths 6-7
Dec. 2015	Coffey – Detailed Site Investigation	Limited Boreholes	Wharf deck Berths 4-6
August 2019	Golder – Port Mooring Optimisation	Geotechnical Feasibility Assessment	Berths 1-6
Jan. 2023	BG&E -MWPA Geraldton Port PmaxP Geotechnical Investigation Factual Report	CPTs and Boreholes drilled through wharf deck	Berths 2-4
July 2023	GHD – Northern Reclaim - Development	Geotechnical Investigation	Behind Berth 7

2. MAIN ISSUES EXPERIENCED WITH DREDGING IN 2002-2003

The 2002-2003 Port Enhancement Project, Contract No GPA-02-02, involved the dredging of rock (calcarenite), with some sand, silt, and clay, from the Harbour basin and main shipping channel.

The Harbour basin was deepened from -9.3m Chart Datum (CD) to -12.1m CD, with berth pockets deepened to -13.1m CD. The main shipping channel was deepened from -9.0m CD to -12.5m CD at the Harbour basin end, and down to a maximum clearance depth of -14.2m CD at the seaward end. The width of the shoreward half of the main shipping channel was also increased from 90m to 200m. The total volume of material removed was approximately 5 million m^3.

The dredging and disposal methodology generally involved a large cutter suction dredger (CSD) cutting the seabed material and pumping it directly into split hopper barges, which transported the material to three disposal sites seaward of the end of the main shipping channel, with disposal by bottom dumping.

The split hopper barges were also able to operate as trailing suction hopper dredgers (TSHDs) and carried out some dredging of soft materials, and clean-up work in areas pre-cut by the CSD. It is understood that during pumping of CSD material to the split hopper barges and during the operation of the split hopper barges as TSHDs, overflow was permitted to take place from the hopper. It is not clear where in the water column the overflow occurred, whether at the water surface or below the keel.

Limited dredging of rock in the main shipping channel was also carried out by a large backhoe dredger (BHD). The main reasons for introduction of the large BHD were to mitigate delays in completion of the dredging project, which would otherwise have impacted adversely on a seagrass growing period, and to minimise the extent and duration of the production of 'rock flour' being created by the CSD which was causing turbidity and a reduction in light intensity penetrating to the underlying seagrass (refer below).

The large BHD had achieved satisfactory production rates in a trial, however production rates were poorer in the actual dredging areas, attributed to the considerably higher strength of the calcarenite in these areas, the difficulty in breaking out the calcarenite, adverse seastate, and breakdowns of the BHD.

Dredging by the CSD and pumping to the split hopper barges with overflow, created substantial turbidity which had not been anticipated. Investigations indicated a number of reasons for this excessive turbidity:

- the production of fines (silt and clay sized particles) was significantly higher than the original assumptions; and
- the size distribution of particles within the fines fraction was skewed towards the very fine fraction more so than had been assumed.

The outcome of the above was that the production rate of fine material less than 10 microns in size was higher by a factor of 1.8 and the production rate of fine material in the range 10 to 40 microns was higher by a factor of 2.5.

It was also noted by the dredging contractor that 50% of the total fines were liberated at the cutter head of the CSD and not transported through the pipeline to the barges.

The loss of fines at the cutter head and in the overflow from the barges were the source of the high turbidity. The subsequent disturbance of settled fines by waves was also a significant issue in the exposed main shipping channel.

3. PROPOSED DREDGING FOR PMAXP

The dredging areas proposed for PMaxP can be considered in two main groups, reflecting the chronology of our technical assessment, namely:

- Berths 1 & 6; and
- Berth 8 and New Tug Harbour.

3.1 Berths 1 & 6

BG&E Resources Drawing No. RP2205-C1-SKT-0108 Rev A titled MWPA – Port Maximisation Project Inner Harbour Vessel and Dredge Pocket – Option 2B Heat Map shows proposed dredging areas, dredging depths, and volumes. A copy of this Drawing is included at Attachment A. Note that this Drawing indicates dredging within the Old Tug Harbour, however it is understood that this dredging will not be carried out and that the Old Tug Harbour will be utilised for transfer of dredge material and will be reclaimed.

The dredging volumes for Berths 1 & 6 included on the above Drawing are summarised in Table 3-1. The overdredge volume is based on an overdredging allowance of 0.5m.

The dredge material is proposed to be disposed of within the Berth 1 reclamation area (Old Tug Harbour area).

Table 3-1: Dredging volumes for Berths 1 & 6 and Old Tug Harbour

Location	Dredge Volume to Design Level (m^3)	Overdredge Volume (m^3)	Total (m^3)
Berth 1	13,573	7,480	21,053
Berth 6	85,465	8,765	94,230

3.2 Berth 8 and New Tug Harbour

The proposed dredging for Berth 8 and New Tug Harbour is shown on BG&E Resources Drawing No. RP22055-C1-SKT-0120 Rev A titled MWPA – Port Maximisation Project Tug Harbour Vessel and Dredge Pocket Heat Map. A copy of this Drawing is included at Attachment B.

The dredging volumes included on the above Drawing are summarised in Table 3-2. No overdredging volumes were included on the Drawing.

The dredge material comprising rock is proposed to be disposed of within the Berth 1 reclamation area (Old Tug Harbour area), and dredge material from within the New Tug Berth comprising sand is proposed to be disposed of within the New Tug Harbour reclamation area.

Table 3-2: Dredging volumes for Berth 8 and New Tug Harbour

Location	Dredge Volume to Design Level (m^3)	Overdredge Volume (m^3)	Total (m^3)
Berth 8	60,544	-	60,544
New Tug Harbour	13,315	-	13,315

4. RECOMMENDED DREDGING METHODOLOGY FOR PMAXP

4.1. General

An assessment of the dredging methodology for PMaxP has been undertaken having regard to a number of influencing factors, including:

- materials to be dredged (geotechnical conditions);
- design dredge depth;
- proposed dredge material disposal areas;
- issues experienced during the dredging in 2002-2003;
- metocean conditions; and
- likely environmental constraints.

The geotechnical conditions are a key issue for assessment of dredging methodology due to the existence of rock.

The proposed dredging is confined to within the existing Harbour basin (Berths 1 & 6) and within a future Harbour protected area (Berth 8 and New Tug Harbour), and hence is well sheltered to wave action. This is a benefit in terms of the risk of disturbance of suspended and settled sediments by waves.

In addition, tidal range is relatively small at Geraldton (HAT approximately 1.2m CD) hence tidal velocities are low, which provides some advantage for the deployment of environmental controls such as deep silt curtains.

A number of options for dredging were initially considered and evaluated based on consideration of technical, environmental, and cost factors. The options and evaluation are summarised in Table 4-1. Refer to the Notes below the table for abbreviations. Subsequently, the possible use of a small CSD within the New Tug Harbour for dredging of sand was also identified.

The different materials to be dredged, the adopted classes for the materials, and the reference equipment for dredging, are summarised in Table 4-2. Refer to the Notes below the table for abbreviations.

Table 4-1 Dredging options and evaluation

Option	Sub-Options	Environmental Considerations	Cost Considerations	Recommendation
Option 1: Large BHD loading barges with rehandling of dredge material onshore using dry earthmoving equipment	Large bucket	Low turbidity	Lowest cost option	Recommended for OTR
	Small bucket	Low turbidity	Lowest cost option	Recommended for vl str ROCK
	Rock bucket	Low turbidity	Lowest cost option	Recommended for l str ROCK
	Ripper attachment	Low turbidity	Lowest cost option	Recommended for l-m str ROCK
	Hydraulic hammer	Minor turbidity	Costly, but less than alternatives	Recommended for m str ROCK
	Silt curtains around BHD	Improved control of turbidity	Additional costs and delays	Recommended only if required
Option 2: Pretreatment by CSD crushing rock with subsequent rehandling by BHD into barges, followed by rehandling onshore using dry earthmoving equipment	CSD without silt curtain	Excessive turbidity	High cost with mobilisation and demobilisation of CSD in addition to BHD, and standby delays	Not recommended
	CSD surrounded by silt curtain	Intense turbidity within silt curtain with risk of release when moved for shipping	As above	Not recommended, silt curtain would also increase delays from shipping
Option 3: Pretreatment by drilling and blasting for medium to high strength rock only, followed by rehandling onshore using dry earthmoving equipment	Drill and blast standard pattern	Not likely to be acceptable	High cost	Not recommended
	Reduced drill and blast pattern with separate electric delay detonation for each hole	Not likely to be acceptable, even with low vibration levels and low noise levels	Very high cost	Not recommended

Notes:
1. OTR = Other Than Rock; vl = very low; l = low; l-m = low to medium; m = medium; str = strength

Table 4-2 Dredge material, adopted classes, and reference equipment

Material and Adopted Class	Indicator Properties for Dredgeability		Reference Equipment
	Density/Strength	RQD	
OTR and fill – very loose to dense	N < 35	N/A	Dry earth moving (DEM), BHD with rehandling to onshore reclamation, and possible small CSD pumping to reclamation (within New Tug Harbour)
ROCK – very low strength	UCS < 5 MPa	<75%	BHD (with medium size bucket) spread, direct dredging, and rehandling to onshore reclamation
ROCK – low strength	UCS = 5-15 MPa	<50%	BHD (with small rock bucket) spread, direct dredging, and rehandling to onshore reclamation
ROCK – low to medium strength	UCS = 15-25 MPa	<30%	BHD pretreatment by ripping, dredging, and rehandling to onshore reclamation
ROCK – medium strength	UCS > 25MPa	>20%	BHD pretreatment by hammering, dredging, and rehandling to onshore reclamation

Notes:

1. N = value from the Standard Penetration Test (SPT). It provides an indication of the density of the ground. An N value of <35 indicates the material is very loose to dense.
2. UCS = Unconfined Compressive Strength. MPa = Megapascal.
3. RQD = Rock Quality Designation. It is a measure of the quality of rock taken from a borehole, namely the percentage of 'good' rock.

4.2 Berths 1 & 6

While all supplied information has been reviewed, a specific assessment has been made of the geotechnical reports relating to materials at Berths 1 & 6. These reports and the individual boreholes were as follows:

- Berth 1:
  - URS (2001), BHs PEP3, 4, and 47,
  - Dames and Moore (2000), BH N19.

- Berth 6:
  - AECOM – Karara Iron (2009), BHs GBH01 - GBH05 and GBH08,
  - Soil & Rock Engineering (1993), BHs 6-9 and 11,
  - URS (2001), BH PEP46.

At Berth 1, the available geotechnical information indicates that it is unlikely high strength rock would be found above the design level for the berth pocket (-13.4m CD).

At Berth 6, the available geotechnical information indicates that the deepening, widening, and extension of the berth would likely encounter a layer of medium to high strength rock.

The removal of material at Berths 1 & 6 can be considered in two main components; Component 1 involving over-land work (dry earth moving (DEM)) at Berth 6 (North End), and Component 2 involving over-water work at Berths 1 & 6.

The proposed equipment and methodology for each component is summarised as follows:

- Component 1, over-land work (DEM), use of long reach excavator(s):

  - Berth 6 (North End), removal of armour/rip-rap/fill and silty sand, and trucking to reclamation (depth from +3m CD to -5m CD),

- Component 2, over-water work, BHD supported by hopper or flat-top barges:

  - Berth 1, removal of OTR, crushed spill from previous CSD operations, pretreatment of more competent rock by ripping/hammering as required, loading into barges with capacity to match BHD production rates, unloading of barges alongside an existing wharf by long reach excavators in number and production to match BHD production rates, and trucking to reclamation (Berth 1 reclamation area [Old Tug Harbour area]). Overflowing of barges assumed to be allowed and accounted for in estimated losses to the water column (refer Section 5). BHD to operate within full depth silt curtain where required, subject to plume modelling,
  - Berth 6, BHD dredging below -5m CD, supported by hopper barges or flat-top barges as per Berth 1 above,

4.3 Berth 8 and New Tug Harbour

While, again, all supplied information has been reviewed, specific assessment has been made of the geotechnical reports relating to materials at Berth 8 and New Tug Harbour. These reports and the individual boreholes were as follows:

- Berth 8:
  - URS (2001), BHs PEP5, 7, 9, and 11 (for rock quality) and BHs PEP6, 8, and 10 (for interpolation and extension of harder rock layers).
- New Tug Harbour:
  - as for Berth 8.

At Berth 8, the available geotechnical information indicates it is likely that deepening to -13.0m CD would encounter a layer of medium to high strength rock. This layer would be expected to be encountered at a level between -10m CD and -11.5m CD.

At the New Tug Harbour, the available geotechnical information indicates that deepening to -7m CD would be unlikely to encounter competent rock.

The proposed equipment and methodology for dredging is summarised as follows. There would be no over-land (DEM) work envisaged for Berth 8 and New Tug Harbour:

- Over-water work:
  - Berth 8, BHD supported by hopper barges or flat top barges, removal of OTR, crushed spill from previous CSD operations, pretreatment of more competent rock by ripping/hammering as required, loading into barges with capacity to match BHD production rates, unloading of barges alongside an existing wharf by long reach excavators in number and production to match BHD production rates, and trucking to reclamation (Berth 1 reclamation area [Old Tug Harbour area]). Overflowing of barges assumed to be allowed and accounted for in estimated losses to the water column (refer Section 5). BHD to operate within full depth silt curtain where required, subject to plume modelling,
  - New Tug Harbour, either BHD supported by hopper barges or flat-top barges as per Berth 8 above, or use of small CSD pumping to New Tug Harbour reclamation area, subject to further assessment following SLR sediment investigation.

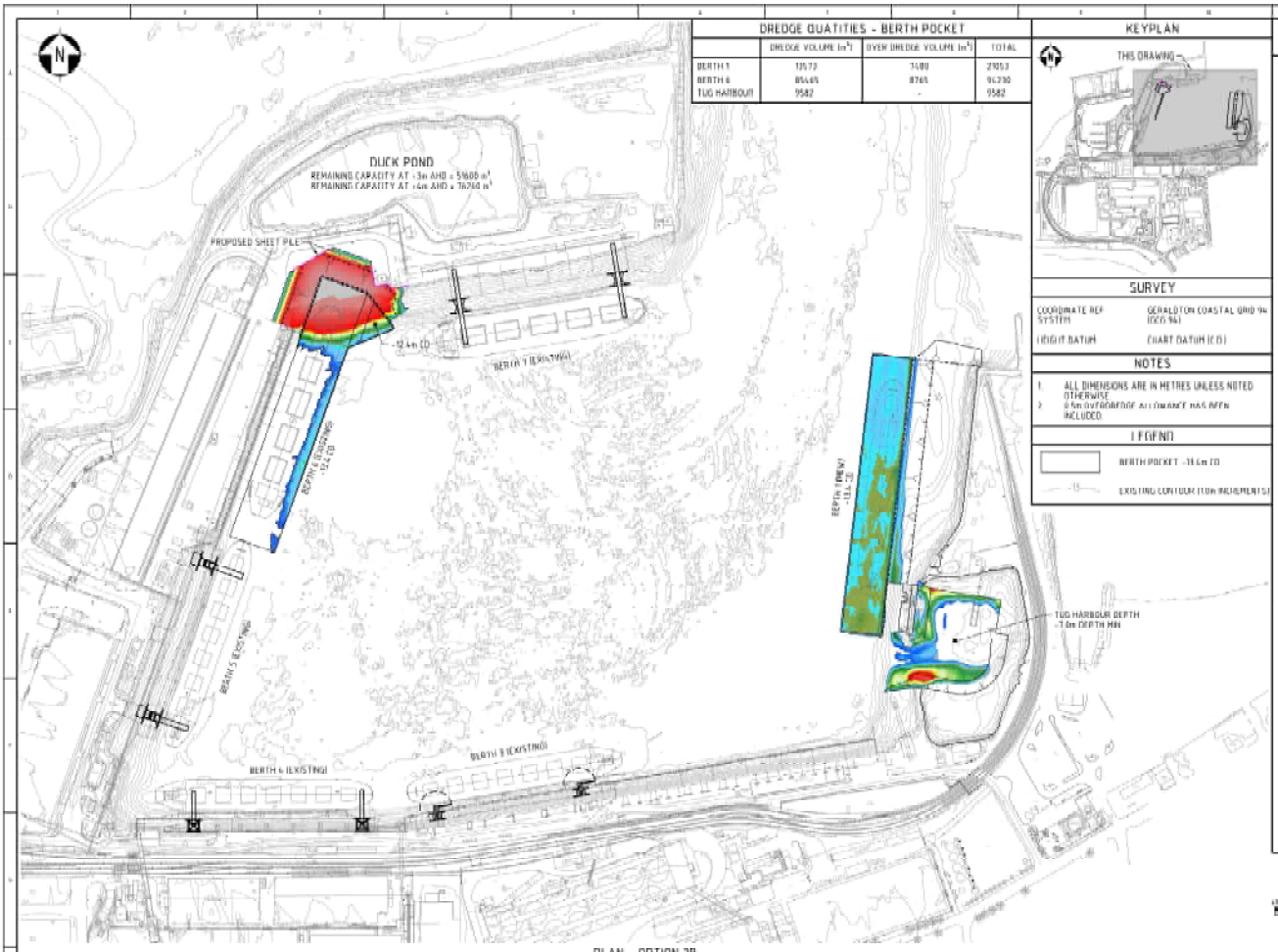
5 RECOMMENDATIONS FOR INPUT SOURCE TERMS FOR PLUME MODELLING

Recommendations for input source terms for modelling of plumes from dredging for Berths 1 & 6, and for Berth 8 and New Tug Harbour, have been prepared and are included within Tables in Attachment C and Attachment D respectively.

The recommendations are based on the BHD equipment and dredging methodologies outlined in the previous sections. More specifically, the assumptions set out below have been made. Note that source terms for the possible use of a small CSD for dredging within the New Tug Harbour would be established following the SLR sediment investigation.

- large to very large BHD, power 2,000 kW/weight 500t, using either 15m^3 medium bucket or 7.5m^3 rock bucket,
- dry earth moving (DEM) spread includes a number of long reach excavators, weight 30 to 50t,
- use of hopper barges with BHD, capacity 1400m^3,
- overflowing from barges allowed, release point to be taken at water surface for hopper barges without environmental overflow system, i.e., without green valve,
- release point of silt and clay fines for other operations, as per the Tables in Attachments C and D,
- overflow durations per ‘barge loading cycle’ as per the Tables in Attachments C and D.

ATTACHMENT A PROPOSED DREDGING FOR BERTHS 1 & 6



PLAN - OPTION 2B
SCALE 1:2000

DREDGE QUATITIES - BERTH POCKET

	DREDGE VOLUME (m³)	OVER DREDGE VOLUME (m³)	TOTAL
BERTH 7	13572	7480	21052
BERTH 6	85485	8765	94250
TUG HARBOUR	9582	-	9582

KEYPLAN

SURVEY

COORDINATE REF SYSTEM	GERALDTON COASTAL GRID 94 (GCG 94)
HEIGHT DATUM	CHART DATUM (CD)

NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE
2. 0.5m OVERDEPTH ALLOWANCE HAS BEEN INCLUDED

LEGEND

BERTH POCKET -13.6m CD

-15 EXISTING CONTOUR (1m INCREMENTS)

DEPTH FROM SEABED TO TARGET DREDGE LEVEL

LOWER VALUE		UPPER VALUE	COLOUR
0.0	TO	-0.2	
-0.2	TO	-0.4	
-0.4	TO	-0.6	
-0.6	TO	-0.8	
-0.8	TO	-1.0	
-1.0	TO	-1.2	
-1.2	TO	-1.4	
-1.4	TO	-1.6	
-1.6	TO	-1.8	
-1.8	TO	-2.0	
-2.0	TO	-2.2	
-2.2	TO	-2.4	
-2.4	TO	-2.6	
-2.6	TO	-2.8	
-2.8	TO	-3.0	
-3.0	TO	-3.2	
-3.2	TO	-3.4	
-3.4	TO	-3.6	
-3.6	TO	-3.8	
-3.8	TO	-4.0	
-4.0	TO	-4.2	
-4.2	TO	-4.4	
-4.4	TO	-4.6	
-4.6	TO	-4.8	
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-5.0	TO	-5.2	
-5.2	TO	-5.4	
-5.4	TO	-5.6	
-5.6	TO	-5.8	
-5.8	TO	-6.0	
-6.0	TO	-6.2	
-6.2	TO	-6.4	
-6.4	TO	-6.6	
-6.6	TO	-6.8	
-6.8	TO	-7.0	
-7.0	TO	-7.2	
-7.2	TO	-7.4	
-7.4	TO	-7.6	
-7.6	TO	-7.8	
-7.8	TO	-8.0	
-8.0	TO	-8.2	
-8.2	TO	-8.4	
-8.4	TO	-8.6	
-8.6	TO	-8.8	
-8.8	TO	-9.0	
-9.0	TO	-9.2	
-9.2	TO	-9.4	
-9.4	TO	-9.6	
-9.6	TO	-9.8	
-9.8	TO	-10.0	
-10.0	TO	-10.2	
-10.2	TO	-10.4	
-10.4	TO	-10.6	
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-11.2	TO	-11.4	
-11.4	TO	-11.6	
-11.6	TO	-11.8	
-11.8	TO	-12.0	
-12.0	TO	-12.2	
-12.2	TO	-12.4	
-12.4	TO	-12.6	
-12.6	TO	-12.8	
-12.8	TO	-13.0	
-13.0	TO	-13.2	
-13.2	TO	-13.4	
-13.4	TO	-13.6	
-13.6	TO	-13.8	
-13.8	TO	-14.0	
-14.0	TO	-14.2	
-14.2	TO	-14.4	
-14.4	TO	-14.6	
-14.6	TO	-14.8	
-14.8	TO	-15.0	
-15.0	TO	-15.2	
-15.2	TO	-15.4	
-15.4	TO	-15.6	
-15.6	TO	-15.8	
-15.8	TO	-16.0	
-16.0	TO	-16.2	
-16.2	TO	-16.4	

SCALE OF METRES 1:2000

PRELIMINARY
NOT FOR CONSTRUCTION
FOR INFORMATION ONLY

DRAWING NUMBER	REFERENCE DRAWING TITLE	REV	DATE	DESCRIPTION	BY DRN	CHK	AP APP
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MID WEST PORTS

BG&E RESOURCES

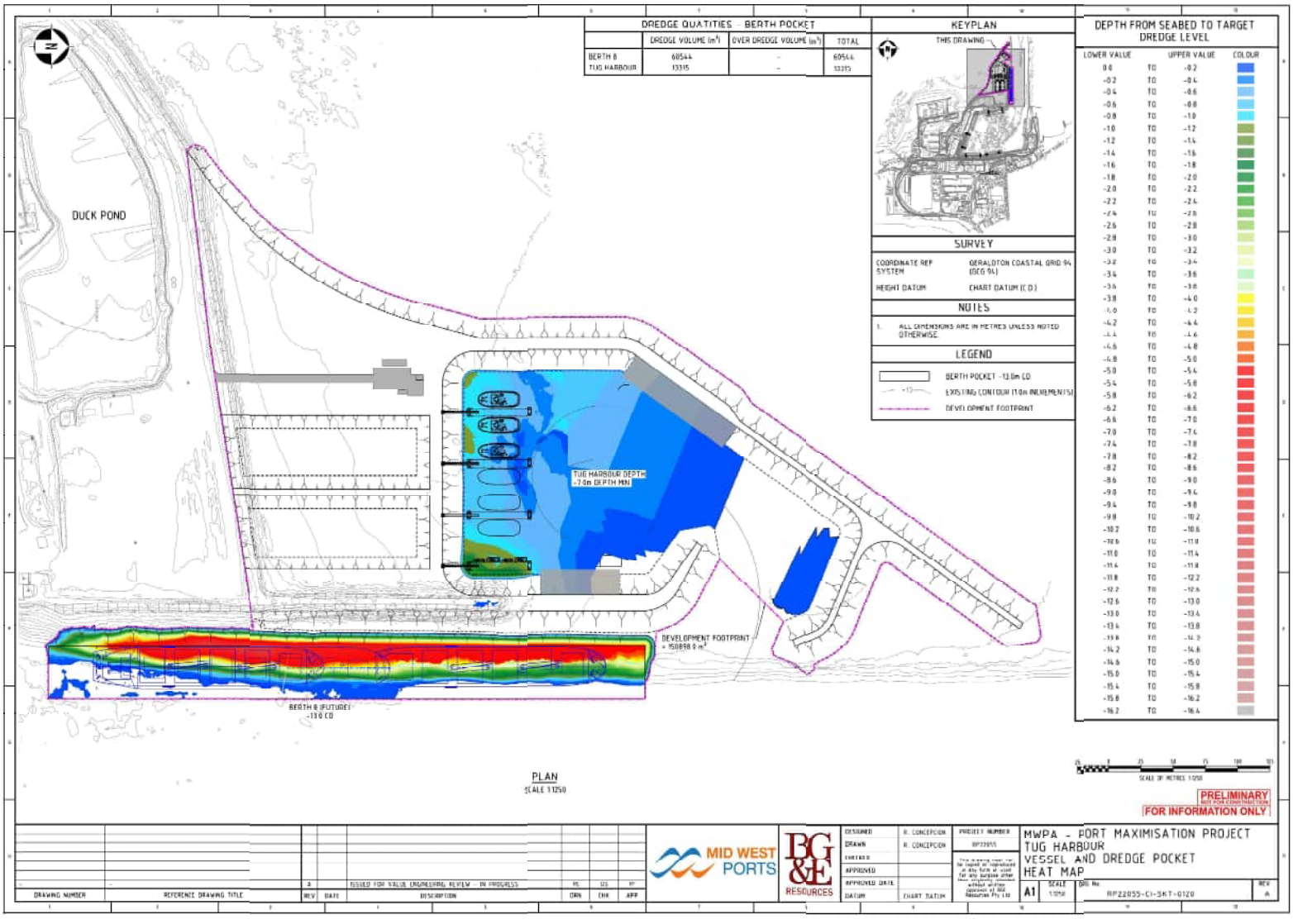
DESIGNED	K. CONCEPCION	PROJECT NUMBER	
DRAWN	K. CONCEPCION	BP22055	
CHECKED			
APPROVED			
APPROVED DATE			
DATUM	CHART DATUM		

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MWPA - PORT MAXIMISATION PROJECT
INNER HARBOUR
VESSEL AND DREDGE POCKET - OPTION 2B
HEAT MAP

SIZE	SCALE	DRG No.	REV
A1	1:2000	BP22055-CI-SKT-0100	A

ATTACHMENT B PROPOSED DREDGING FOR BERTH 8 AND NEW TUG HARBOUR



PLAN
SCALE 1:1250

DREDGE QUATITIES - BERTH POCKET

	DREDGE VOLUME (m³)	OVER DREDGE VOLUME (m³)	TOTAL
BERTH 8	60544	-	60544
TUG HARBOUR	13315	-	13315

KEYPLAN

SURVEY

COORDINATE REF SYSTEM	GERALDTON COASTAL GRID 94 (GCG 94)
HEIGHT DATUM	CHART DATUM (C.D.)

NOTES

1. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE.

LEGEND

- BERTH POCKET -13.0m CD
- -13- EXISTING CONTOUR (1.0m INCREMENTS)
- DEVELOPMENT FOOTPRINT

DEPTH FROM SEABED TO TARGET DREDGE LEVEL

LOWER VALUE		UPPER VALUE	COLOUR
0.0	TO	-0.2	
-0.2	TO	-0.4	
-0.4	TO	-0.6	
-0.6	TO	-0.8	
-0.8	TO	-1.0	
-1.0	TO	-1.2	
-1.2	TO	-1.4	
-1.4	TO	-1.6	
-1.6	TO	-1.8	
-1.8	TO	-2.0	
-2.0	TO	-2.2	
-2.2	TO	-2.4	
-2.4	TO	-2.6	
-2.6	TO	-2.8	
-2.8	TO	-3.0	
-3.0	TO	-3.2	
-3.2	TO	-3.4	
-3.4	TO	-3.6	
-3.6	TO	-3.8	
-3.8	TO	-4.0	
-4.0	TO	-4.2	
-4.2	TO	-4.4	
-4.4	TO	-4.6	
-4.6	TO	-4.8	
-4.8	TO	-5.0	
-5.0	TO	-5.4	
-5.4	TO	-5.8	
-5.8	TO	-6.2	
-6.2	TO	-6.6	
-6.6	TO	-7.0	
-7.0	TO	-7.4	
-7.4	TO	-7.8	
-7.8	TO	-8.2	
-8.2	TO	-8.6	
-8.6	TO	-9.0	
-9.0	TO	-9.4	
-9.4	TO	-9.8	
-9.8	TO	-10.2	
-10.2	TO	-10.6	
-10.6	TO	-11.0	
-11.0	TO	-11.4	
-11.4	TO	-11.8	
-11.8	TO	-12.2	
-12.2	TO	-12.6	
-12.6	TO	-13.0	
-13.0	TO	-13.4	
-13.4	TO	-13.8	
-13.8	TO	-14.2	
-14.2	TO	-14.6	
-14.6	TO	-15.0	
-15.0	TO	-15.4	
-15.4	TO	-15.8	
-15.8	TO	-16.2	
-16.2	TO	-16.6	

SCALE OF METRES 1:1250

PRELIMINARY
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DRAWING NUMBER	REFERENCE DRAWING TITLE

REV	DATE	DESCRIPTION	BS	CG	EP
A		ISSUED FOR VALUE ENGINEERING REVIEW - IN PROGRESS	DRN	CHK	APP

MID WEST PORTS

B&E RESOURCES

DESIGNED	R. CONCEPCION
DRAWN	R. CONCEPCION
CHECKED	
APPROVED	
APPROVED DATE	
DATUM	CHART DATUM

PROJECT NUMBER: RP22055

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MWPA - PORT MAXIMISATION PROJECT
TUG HARBOUR
VESSEL AND DREDGE POCKET
HEAT MAP

SIZE	SCALE	DRG No.	REV
A1	1:1250	RP22055-CI-SKT-0120	A

ATTACHMENT C RECOMMENDATIONS FOR INPUT SOURCE TERMS FOR PLUME MODELLING – BERTHS 1 & 6

SUMMARY TABLES FOR LOSSES OF FINES TO THE WATER COLUMN Rev 3

TABLE 1

Berth 1 (N/S) – CONTINUOUS - BHD dredging – Losses from bucket

BHD DREDGING

CONTINUOUS - INPUT SOURCE ESTIMATES - BHD into barges, unloaded into trucks to reclamation within port areas LOSS OF FINES FROM BHD BUCKET *These flux losses apply to 168hrs/wk*							
Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – dense OTR	BHD-dredging	168hrs/wk	6,073	0.3	0.57	1.42	Water column from seabed (-12.4mCD) to surface Note- Includes ROM estimate for volume of fines from previous CSD operations
Very low strength ROCK	BHD-dredging		12,733	1.27	0.13	0.03	Water column from seabed (-12.9mCD) to surface
Low strength ROCK	BHD-dredging		1,498	0.3	0.07	0.01	Water column from seabed (-13.9mCD) to surface
Low-medium strength ROCK	BHD-ripping		599	0.08	0.08	0.02	Seabed (-13.9mCD)
	BHD-dredging		599	0.06	0.18	0.04	Water column from seabed (-13.9mCD) to surface
Medium strength ROCK	BHD-hammer		150	0.06	0.03	0.01	Seabed (-13.9mCD)
	BHD-dredging		150	0.01	0.16	0.04	Water column from seabed (-13.9mCD) to surface

Source Input Estimate for intermittent BHD bucket loss only

Production levels are based on 168hrs/wk – Flux levels are continuous/based on this production over 168 hrs/wk

OTR Silt PDF Sub-distribution		vl str Rock Sub-distr	l str Rock Sub-distr	l-m str Rock Sub-distr	Med str Rock Sub-distr	Please note that the strata of geotech units is as per above table (top to bottom) Ripping and hammering will cause increased fines content, as indicated in the SILT sub-distribution for particles size. Sub-distribution is approximate.
PSD 60-75mu	20%	50%	40%	10%	25%	
PSD 40-60mu	20%	25%	30%	20%	25%	
PSD 20-40mu	25%	15%	15%	30%	30%	
PSD 2-20mu	35%	10%	15%	40%	20%	

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TABLE 2

***BERTH 1 N/S – – INTERMITTENT** - BHD dredging – Losses from overflow of barges*

BARGE OVERFLOWING

See comments

INTERMITTENT INPUT SOURCE ESTIMATE – Overflow from hopper barges during BHD loading (if allowed)

Material	Equipment	Working Hours	Overflow Duration hrs	Barge cycle time incl overflow-hrs	FLUX SILT only Dry Kg/sec	FLUX CLAY only Dry Kg/sec	Remarks
Very loose – dense OTR incl LdV fines	Split Hopper Barges 1400m3	168hrs/wk	0.76	6.88	0.70	1.39	Note: Includes ROM estimate for volume of fines from previous CSD operations.
Very low strength ROCK	Split Hopper Barges 1400m3		3,57	13.76	0.61	0.20	Source Input applies to overflow period only Release point for fines – Water-Surface level.
Low strength ROCK	Split Hopper Barges 1400m3		13.76	27.52	0.25	0.07	
Low-medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.40	0.05	
Medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.53	0.06	
Source input for overflow from hopper barges based on overflow time only. Intermittent For sub-particle size distribution of SILT for TABLE 2 - see TABL 1							
Totals Berth 1	BHD	168hrs/wk	21,053m3	2.09wks			

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TABLE 3 RELATES TO OLD TUG BERTH NOT TO BE CONSIDERED FURTHER

TABLE 3

DRY EARTH MOVING

Tug Harbour (upper level) – Part A

INTERMITTENT - ***Losses from excavator bucket***

Dry Earth Moving (DEM) into trucks to reclamation within port areas

Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – dense OTR+Fill	DEM	60hrs/wk	1,916	0.48	0.31	0.10	Water column from seabed (-5mCD) to surface
Production levels are intermittent and based on 60hrs/wk – Flux levels are intermittent/based on this production over 60 hrs/wk							

TABLE 4

BHD DREDGING

Tug Harbour (lower level) - Part B

CONTINUOUS ***-Losses from BHD bucket***

BHD into barges, unloaded into trucks to reclamation within port areas

TABLE 4 RELATES TO THE OLD TUG BERTH - BEHIND Berth 1 Not to be considered further

Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – loose OTR	BHD-dredging	168hrs/wk	7,666	0.51	0.64	0.43	Water column from seabed (-7mCD) to surface
Production levels are based on 168hrs/wk – Flux levels are continuous/based on this production over 168 hrs/wk Source Input Estimate for BHD bucket loss only							

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TABLE 5 relates to old tug berth. Not to be considered further

TABLE 5

BARGE OVERFLOWING

Tug Harbour (lower level) – Part B ***BHD dredging – Losses from overflow of barges***

INTERMITTENT ***INPUT SOURCE ESTIMATE – Overflow from hopper barges during BHD loading (if allowed)***							
Material	Equipment	Working Hours	Overflow Duration hrs	Barge cycle time incl overflow hrs	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Remarks
Very loose – dense OTR	BHD-split hopper barges 1400m3	168hrs/wk	1.02	9.17	0.80	0.32	Source Input applies to overflow period only Release point for fines – Water-Surface level.

TABLE 6

DRY EARTH MOVING

Berth 6 Upgrade DEM - ***Dry Earth Moving (DEM) to reclamation within port areas***

INTERMITTENT - ***LOSS OF FINES FROM BUCKET OF SHORE-BASED LONG ARM EXCAVATOR (50T) working day-shifts only***

Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – dense OTR+Fill	DEM	60 hrs/wk	20,000	5.00	0.31	0.10	Intermittent – 12hrs/day and 5 days/week. Water column from seabed (-7mCD) to surface
Production levels are intermittent and based on 60hrs/wk – Flux levels are intermittent/based on this production over 60 hrs/wk							

DEM Materials are mainly fill materials

Best guess for sub-distribution of particle size for SILT only, would be :

PSD 60-75mu 35%
PSD 40-60mu 25%
PSD 20-40mu 25%
PSD 2-20mu 15%

TABLE 7

BHD DREDGING

Berth 6 Upgrade BHD

BHD into barges, unloaded into trucks to reclamation within port areas

CONTINUOUS - ***LOSS OF FINES FROM BHD BUCKET***

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TABLE 7

Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – dense OTR	BHD-dredging	168 hrs/wk	13,000	0.65	0.57	1.71	Note: Includes ROM estimated volume of fines from previous CSD operations. Water column from seabed (-12.4mCD) to surface
Very low strength ROCK	BHD-dredging		30,616	3.06	0.13	0.03	Water column from seabed (-12.9mCD) to surface
Low strength ROCK	BHD-dredging		11,328	2.27	0.07	0.01	Water column from seabed (-13.9mCD) to surface
Low-medium strength ROCK	BHD-ripping		18,369	2.45	0.08	0.02	Seabed (-13.9mCD)
	BHD-dredging			1.84	0.18	0.04	Water column from seabed (-13.9mCD) to surface
Medium strength ROCK	BHD-hammer		918	0.37	0.03	0.01	Seabed (-13.9mCD)
	BHD-dredging			0.09	0.16	0.04	Water column from seabed (-13.9mCD) to surface
Totals BHD only			74,231	10.72			
BERTH 6			Total m3	Total wks			
Totals DEM+BHD			94,231	15.72			
Production levels are based on 168hrs/wk – Flux levels are continuous/based on this production over 168 hrs/wk Source Input Estimate for BHD bucket loss only.							

For sub-particle size distribution of SILT for TABLE 7 - See Table 1

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TABLE 8

BARGE OVERFLOWING

Berth 6 Upgrade BHD

INPUT SOURCE ESTIMATE – Overflow from hopper barges during BHD loading (if allowed)							
Material	Equipment	Working Hours	Overflow Duration hrs	Barge cycle time incl overflow-hrs	FLUX SILT only Dry Kg/sec	FLUX CLAY only Dry Kg/sec	Remarks
Very loose – dense OTR	Split Hopper Barges 1400m3	168hrs/wk	0.76	6.88	0.87	1.88	Source Input applies to overflow period only
Very low strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.61	0.20	
Low strength ROCK	Split Hopper Barges 1400m3		13.76	27.52	0.25	0.7	
Low-medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.40	0.05	
Medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.53	0.06	
Source input for overflow from hopper barges only based on overflow time only.							

***INTERMITTENT** - LOSS OF FINES FROM OVERFLOWING BARGES*

For sub-particle size distribution of SILT only for TABLE 8 - SEE TABLE 2

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ATTACHMENT D RECOMMENDATIONS FOR INPUT SOURCE TERMS FOR PLUME MODELLING – BERTH 8 AND NEW TUG HARBOUR

GERALDTON – MID WEST PORT AUTHORITY

DEVELOPMENT: PORT MAXIMISATION PROGRAM (PMP) – INNER HARBOUR

BERTH 8 AND NEW TUG BERTH ONLY

SUMMARY TABLES FOR LOSSES OF FINES TO THE WATER COLUMN

TABLE 1

Berth 8 (N/S) – CONTINUOUS - BHD dredging – Losses from bucket

BHD DREDGING

CONTINUOUS - INPUT SOURCE ESTIMATES - BHD into barges, unloaded into trucks to reclamation within port areas ***LOSS OF FINES FROM BHD BUCKET***							
Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – dense OTR	BHD-big dredging	168hrs/wk	12,000	0.6	0.57	1.42	Water column from seabed (-6/-13.5mCD) to surface. Note: Includes ROM estimated volume of fines from previous CSD operations.
Very low strength ROCK	BHD-small dredging		15,000	1.5	0.13	0.03	Water column from seabed (-8/-13.5mCD) to surface
Low strength ROCK	BHD-small dredging		25,527	5.11	0.07	0.01	Water column from seabed (-13.5mCD) to surface
Low-medium strength ROCK	BHD-rock dredging		8,485	1.13	0.13	0.03	
Medium str ROCK	BHD – Rip Dredging		9,563	3.83	0.16	0.04	Seabed (-13.9mCD)
	BHD-dredging		9,563	0.96	0.28	0.6	Water column from seabed (-13.9mCD) to surface
Medium – High strength ROCK	BHD-hammer		2,250	0.9	0.16	0.04	Seabed (-13.9mCD)
	BHD-dredging		2,250	0.22	0.28	0.06	Water column from seabed (-13.9mCD) to surface
Total Gross Volume including overdredging			72,825	14.25			
Source Input Estimate for BHD bucket loss only Production levels are based on 168hrs/wk – Flux levels are continuous/based on this production over 168 hrs/wk. **For sub-particle size distribution of SILT only for the above able see Table 1 in Apppendix C of this memo and below: Medium-High Strength ROCK**							

Approx PSD SILT Sub-distribution

PSD	60-75mu	20%
PSD	40-60mu	20%
PSD	20-40mu	30%
PSD	02-40mu	30%

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DEVELOPMENT: PORT MAXIMISATION PROGRAM (PMP) – INNER HARBOUR

BERTH 8 AND NEW TUG BERTH ONLY

TABLE 2

BERTH 8 N/S – INTERMITTENT - BHD dredging – Losses from overflow of barges

BARGE OVERFLOWING

INTERMITTENT INPUT SOURCE ESTIMATE – Overflow from hopper barges during BHD loading (if allowed)

Material	Equipment	Working Hours	Overflow Duration hrs	Barge cycle time incl overflow-time	FLUX SILT only Dry Kg/sec	FLUX CLAY only Dry Kg/sec	Remarks
Very loose – dense OTR incl LdV fines	Split Hopper Barges 1400m3	168hrs/wk	0.76	6.88	0.82	1.65	Note: OTR includes ROM estimated volume for fines from previous CSD operations
Very low strength ROCK	Split Hopper Barges 1400m3		3,57	13.76	0.61	0.20	
Low strength ROCK	Split Hopper Barges 1400m3		13.76	27.52	0.25	0.07	
							Source Input applies to overflow period only Release point for fines – Water-Surface level. No barge loading will take place during ripping, hammering
Low-medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.30	0.04	
Medium strength ROCK	Split Hopper Barges 1400m3		3.57	13.76	0.53	0.06	
Source inputs for overflowing from hopper barges based on overflow time only.							
Medium-High Strength Rock--same equipment			3.57	13.76	0.58	0.03	See Remarks above
Totals Berth 1	BHD	168hrs/wk	72,825m3	14.25wks			

For sub particle distribution of SILT only, for this table - See Table 2 in Appendix C of this memo and below. Medium-High Strength ROCK

Approx PSD SILT Sub-distribution

PSD	60-75mu	20%
PSD	40-60mu	20%
PSD	20-40mu	30%
PSD	02-20mu	30%

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TABLE 3

DRY EARTH MOVING

Tug Harbour NOT APPLICABLE

TABLE 4

BHD DREDGING

Tug Harbour

CONTINUOUS - Losses from BHD bucket

BHD into barges, unloaded into trucks to reclamation within port areas

Material	Equipment	Working Hours	Situ Qties m3 wet	Duration wks	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Release point of SILT and CLAY fines
Very loose – loose OTR	BHD-dredging	168hrs/wk	9,187	0.61	0.32	0.09	Water column from seabed (-5/-6.8mCD) to surface
Very low strength ROCK	BHD-Dredging	168 hrs/wk	21,438	2.14	0.13	0.03	Water column from seabed (-6.8/-7.5mCD) to surface
Total Gross Volume incl Overdredging			30,625				
Production levels are based on 168hrs/wk – Flux levels are continuous/based on this production over 168 hrs/wk Source Input Estimate for BHD bucket loss only							

For sub particle distribution of SILT only for this table - See Table 1 in Appendix C

TABLE 5

BARGE OVERFLOWING

Tug Harbour ***BHD dredging – Losses from overflow of barges***

INTERMITTENT ***INPUT SOURCE ESTIMATE – Overflow from hopper barges during BHD loading (if allowed)***							
Material	Equipment	Working Hours	Overflow Duration hrs	Barge cycle time incl overflow hrs	Flux SILT kg/sec dry	Flux CLAY kg/sec dry	Remarks
Very loose – dense OTR	BHD-split hopper barges 1400m3	168hrs/wk	1.02	9.17	0.96	0.16	Source Input applies to overflow period only Release point for fines – Water-Surface level.

For sub particle distribution for SILT only for this Table - See Table 2 in Appendix C

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A5 Capital Dredging Source Term Development – New Tug Harbour

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PORT MAXIMISATION PROGRAM (PMP)

NEW TUG HARBOUR

SUMMARY OF ROM ESTIMATES FOR INPUT SOURCE TERMS RELATING TO THE MODELLING OF PLUMES FROM DREDGING IN GERALDTON HARBOUR

OVERVIEW:

An assessment has been made of relevant geotechnical reports relating to capital dredging by small trailer suction hopper dredge (smTSHD) in future tug berth in the outer-harbour area, as part of the PMaxP (MWP) project, to inform and calculate a) the production estimate, b) drag-head loss, c) pump-out loss and d) prop-wash resuspension loss to the water column for silts and clays during the Works.

FINDINGS and ASSUMPTIONS:

There are several major assumptions relating to components of the proposed Works:

1) TSHD work is planned by MWP to remove sand with minor fines-content, as well as soft-stiff gravelly clays and possibly minor volumes of weathered / very low strength rock (calcareous/limestone) in an area (See Table 1 – Soil Model):
    - Due its configuration, the whole of the dredge area is not available to a small TSHD. It is assumed that these areas are finally dredged to line and level by BHD during other capital dredging works.
    - No overflow will be allowed
    - No jets on drag-heads will be allowed
    - No losses through hopper doors, valves or split hull will be allowed
    - Tug Harbour Breakwaters to be in place (restricting access to southern section of the harbour in particular the SE and SW corners)
    - The restricted dredge area will require additional manoeuvring of the vessel causing resuspension and scour.
    - Deployment of silt curtain around the TSHD dredger is not possible

2) TSHD discharge will be by pumping into a nearby reclamation site (Duck Pond).
    - Losses of material are released under the TSHD during pump-out through the water intake(s) at the pump-out station. See Figure 2.
    - No fines are to be contained in the discharge of transport water from the reclamation at the outlet weir of the settlement pond to the receiving environment. (No source input required).
      (The reclamation will be of adequate capacity to settle all fines and polish the returned waters without discharging until after the Works).

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3) Reference TSHD working 24hrs/7days.
    - DAMEN TSHD (modular series) 1500
        - LoA 70.00m
        - LbPP 66.90m
        - Beam 13.20m
        - Depth (Moulded) 5.40m
        - Draught (Dredging) 4.70m
        - Max dredging depth 20m
        - Propulsion (Twin Prop) 2x 700kW
        - Bow thruster 1x 280kW
        - Hopper Capacity (water) 1500-1800m (resp. sand-mud)
        - Speed (Loaded) 9 knots
        - Speed (Empty) 10 knots
        - Suction Pipe (single) 500mm
        - Adjustable overflow (incl green valve)
        - Pump ashore capability
        - Bottom door discharge
        - Available hours = 168hrs/wk
        - Dredging effective hours= 142.8hrs/wk at 85%

    Estimated losses of fines to the nearby receiving environment are calculated and provided for plume modelling purposes based on this standard design reference TSHD.

    Please note: The above reference dredge is slightly larger than TSHD Modi R (Rohde Nielsen – Denmark) and therefor production are slightly higher and flux inputs are slightly conservative.

4) Alternative methodologies
    - Lower turbidity levels than small TSHD methods can be achieved by using:
        - CSD within the sheltered area of the breakwaters pumping into reclamation. (Efficient and economic)
        - BHD loading barges within the sheltered area of the breakwaters. (Costly, efficient in removing all material above design within the footprint of the tug harbour)

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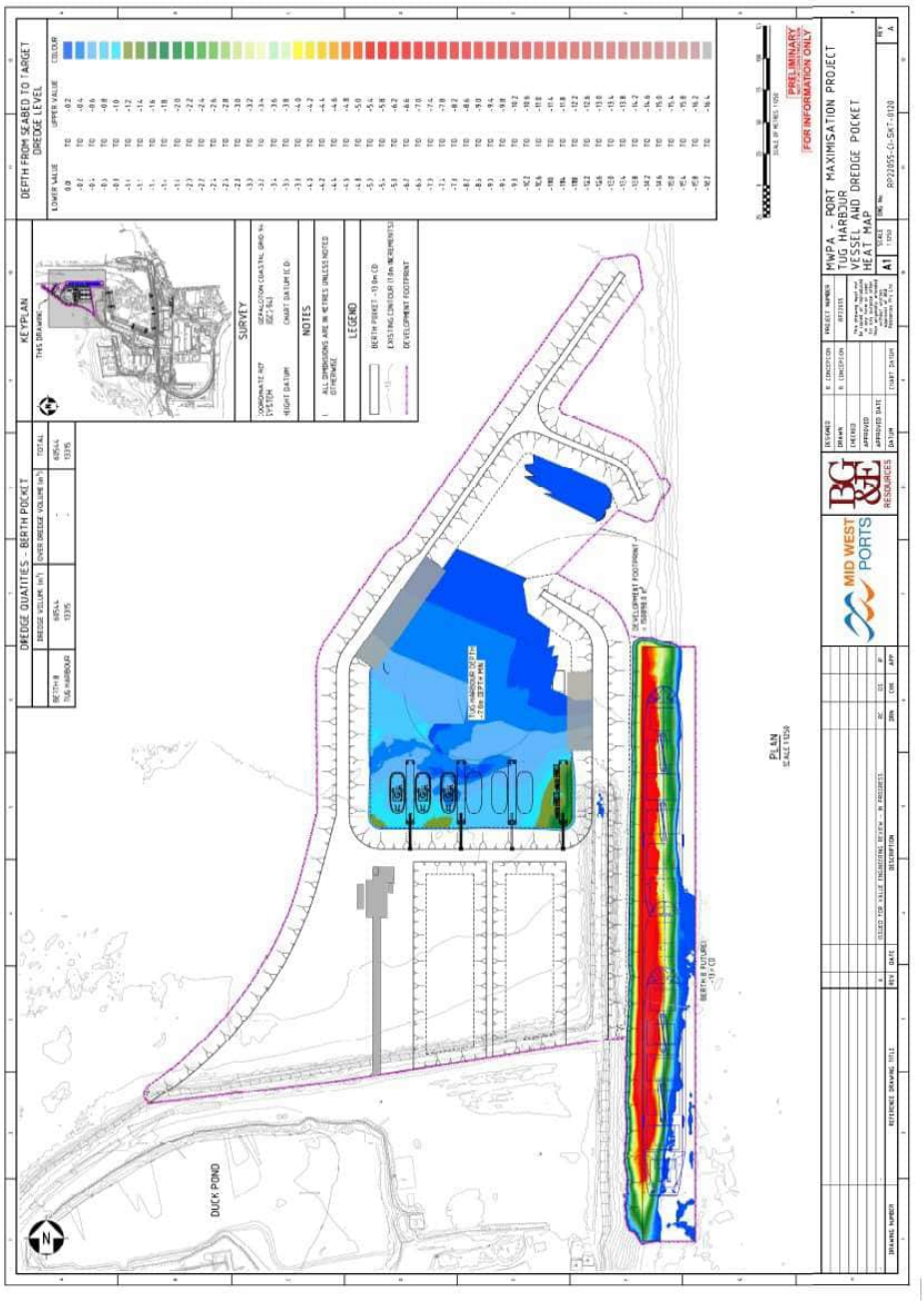
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PORT MAXIMISATION PROGRAM (PMP)

NEW TUG HARBOUR

PART 1 - CAPITAL DREDGE AREA AND NET VOLUMES

Figure 1 – Location of dredge area and net in-situ volume (exclusive of overdredging)



PART 2 - RECLAMATION AREA FOR DREDGED CAPITAL MATERIAL

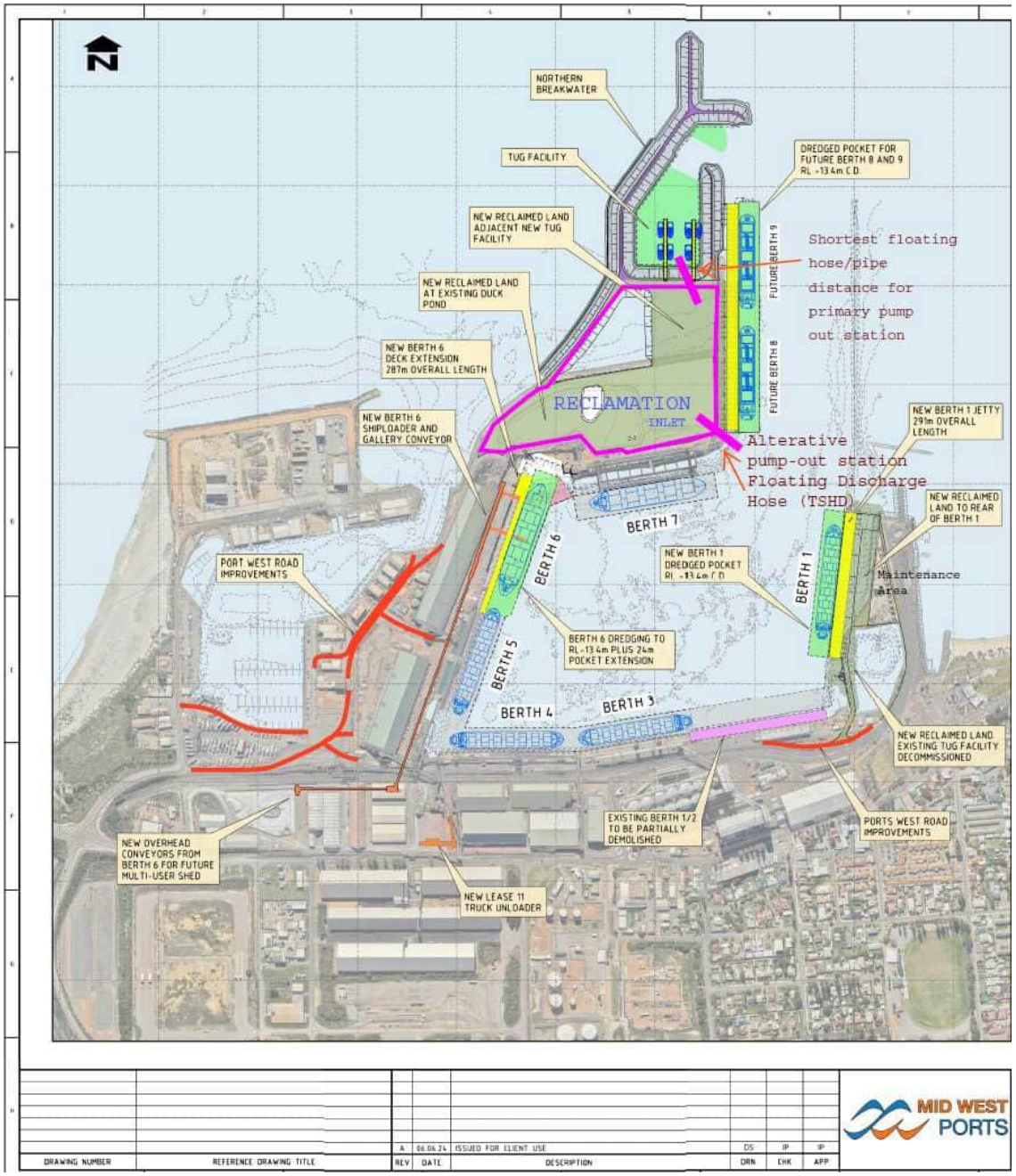


Figure 2 Reclamation Area, pump-out location and dredge area for TSHD (in Pink)

As can be noted: The pump-out discharge location for the small TSHD is assumed to be at the eastern end of the reclamation area. This may consist of a shore connection and floating

hose to an anchored buoy onto which the smTSHD moors by a single line over the bow during the discharge component of the dredge cycle.
Position control of the vessel can be further achieved by a small tug and/or by the combined use of bow-thruster and twin-propulsion.
Naturally, the above must be qualified in any contract, not to create any restrictions to the commercial shipping within the port.
Release area of mixture – Onshore within reclamation. (See Figure 2 - pink enclosure of Duck Pond, etc.)
Release point of clean tailwaters. If any, to be on the western side of the reclamation by gravity drainage through an adjustable weir box structure. Tailwaters from the reclamation to be clean and sediment free, when discharged or alternatively contained in the reclamation area.

Part 3 – ROM SUMMARY TABLES FOR ESTIMATED LOSSES OF FINES TO THE WATER COLUMN

New Tug Berth ***– CONTINUOUS LOSSES - THSD CAPITAL DREDGING – Losses from drag-head, TSHD losses during discharging and resuspension from prop-wash in a relatively small and shallow areas***

GEOTECHNICAL INFORMATION (Ex MWP)

Table 1 – SOIL MODEL – Capital dredging of new tug harbour

SURFACE SAMPLES	Identification	Coarse >75mu	Fines <75mu	Silt 2-75mu	Clay <2mu
	Tug1	96%	4%	2%	2%
	Tug2	92%	8%	5%	3%
	Tug4	94%	6%	3%	3%
	Tug7	95%	5%	2%	3%
	Tug9	94%	6%	4%	2%
Averages	**Harbour**	**94%**	**6%**	**3.5%**	**2.5%**
Dry densities	t/m3 dry	**1.67**		**1.35**	**1.25**

BORE HOLES	Identification	Gravelly Stiff Clay (mCD)		Very weak Rock (mCD)	
Dames+Moore 2002 BHS		from	to	from	To
	N3	-6.2	-7.8	-7.8	Above design
	N10	-6.5	-7.8	-7.8	
	N12	-7.0	-8.2	--8.2	
URS 1985 BH	PEP7	-7.1	-7.3	-7.3	
		Higher turbidity		Higher turbidity	
Dry densities	t/m3 dry	**1.85**		**2.35**	

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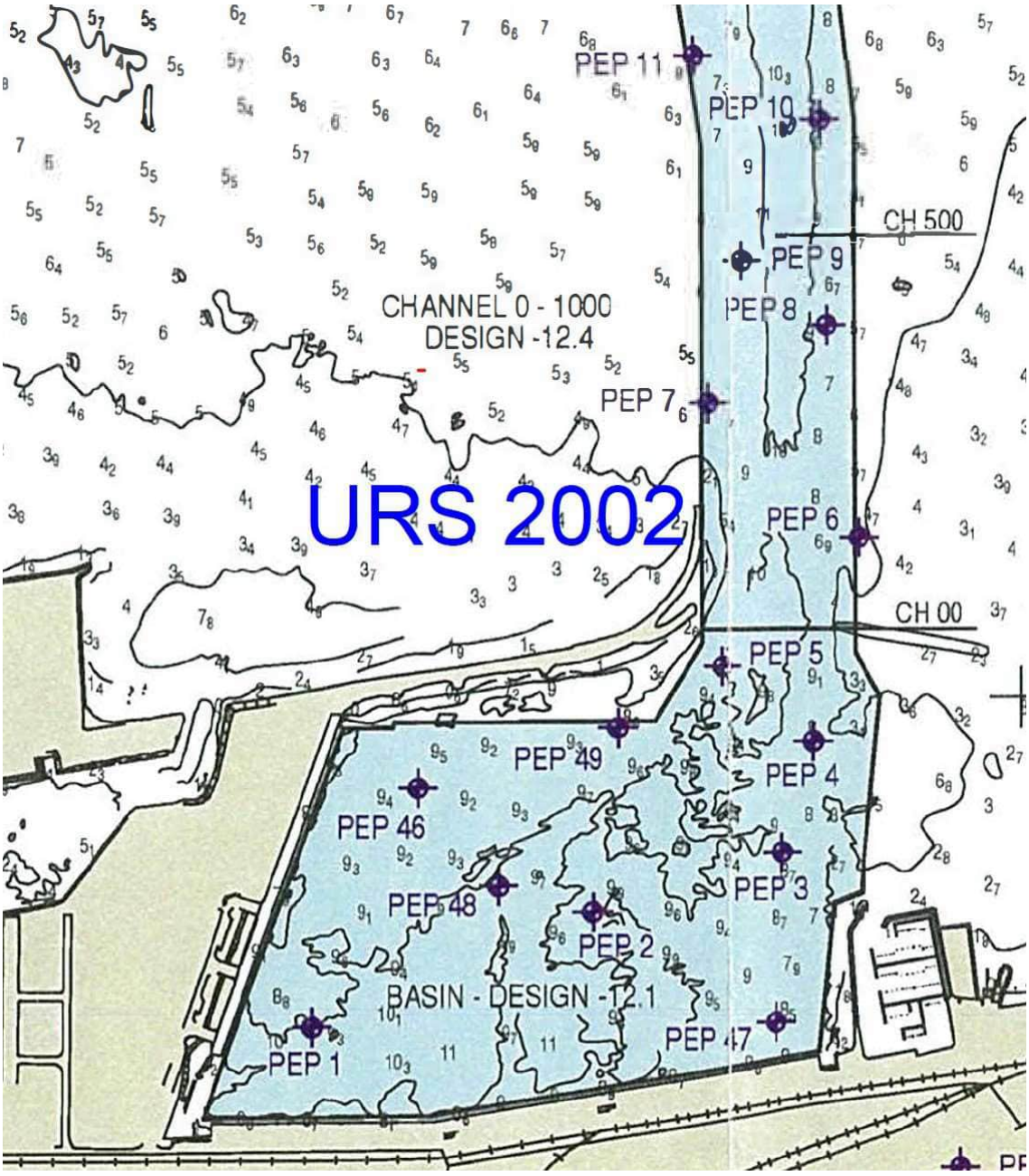
Figure 3 MWP - Diver Surface Sample Locations



Name	Site	Lat (GDA94)	Long (GDA94)
B1-1	Berth1	-28.7732416	114.6012393
B1-2	Berth1	-28.7727275	114.6012062
B1-3	Berth1	-28.7727566	114.6014321
B1-4	Berth1	-28.7738641	114.6010440
B1-5	Berth1	-28.7745964	114.6010359
B1-6	Berth1	-28.7748477	114.6013190
B1-7	Berth1	-28.7724398	114.6013881
B6-1	Berth6	-28.7719155	114.5954533
B6-2	Berth6	-28.7728451	114.5952026
B6-3	Berth6	-28.7719065	114.5958080
B6-4	Berth6	-28.7734314	114.5949512
B6-5	Berth6	-28.7720816	114.5951506
B6-6	Berth6	-28.7721850	114.5954165
B6-7	Berth6	-28.7719594	114.5949970
B8-1	Berth8	-28.7671095	114.5994746
B8-2	Berth8	-28.7679602	114.5994591
B8-3	Berth8	-28.7707386	114.5994217
B8-4	Berth8	-28.7698809	114.5993713
B8-5	Berth8	-28.7693505	114.5995979
B8-6	Berth8	-28.7681952	114.5993834
B8-7	Berth8	-28.7687011	114.5995173
B8-8	Berth8	-28.7701938	114.5993620
Tug-1	Tug	-28.7656249	114.5989566
Tug-2	Tug	-28.7677473	114.5975288
Tug-3	Tug	-28.7672932	114.5978104
Tug-4	Tug	-28.7671533	114.5983580
Tug-5	Tug	-28.7654923	114.5986569
Tug-6	Tug	-28.7677100	114.5985464
Tug-7	Tug	-28.7668804	114.5986618
Tug-8	Tug	-28.7677291	114.5982004
Tug-9	Tug	-28.7664579	114.5980293
Tug-10	Tug	-28.7668729	114.5978242

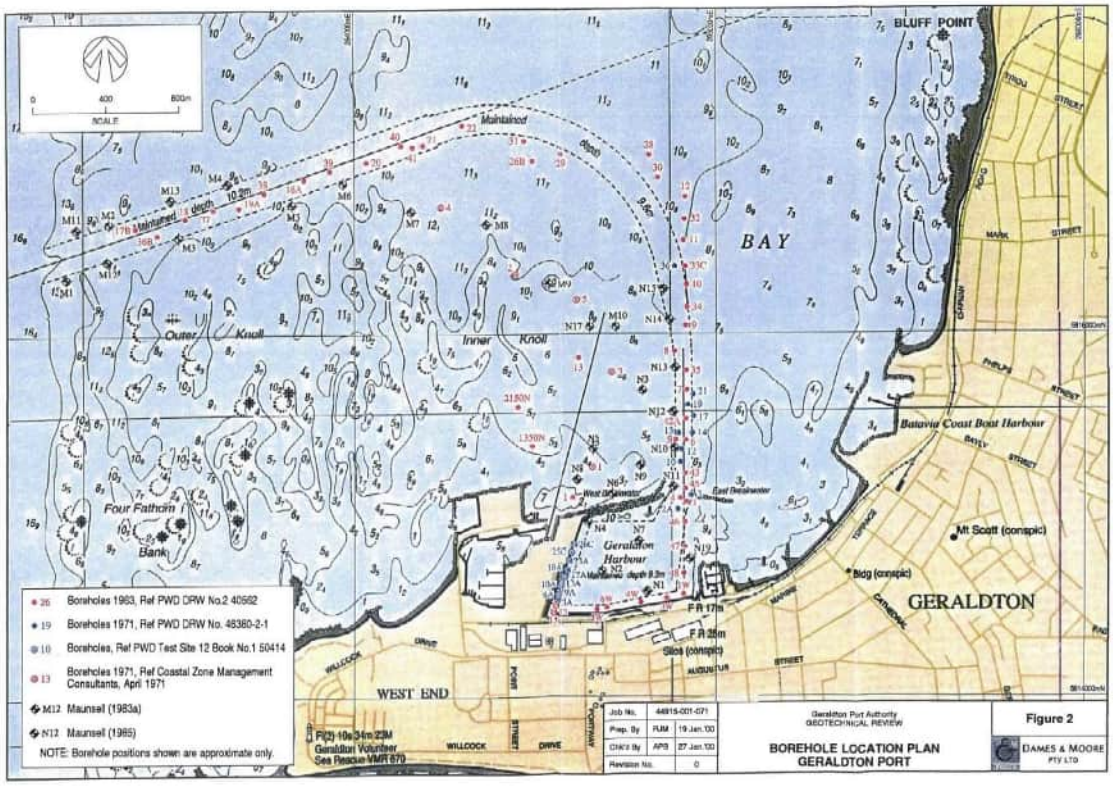
See Sample Locations Tug1, 2, 4 7 and 9 for which PSDs are available

Figure 4 – URS 2002 – Boreholes drilled in 1985



See Bore Hole PEP 7, which is near the New Tug Harbour Site.

Figure 5 – Dames and Moore 2002 – Boreholes - N- Series



See Bore Holes N3, N5, N10, N11, N12 and N13

Notes:

1) As the description indicates, the surface samples are not representative of underlaying materials, such as likely higher content of fines (<75mu) than 6%. For stiff clays or weathered rock, higher losses of predominantly clay fines has been incorporated for PHASES 2, 3 and 4.
2) Bore hole date in the Dames and Moore 2002 and URS 2002/1985 Reports are indicative of the fact that stiff gravelly clays and possibly very low strength rock might be encountered above the design (including of overdredging). Naturally, stiff clays and weak rock, when dredged by TSHD will cause an increased source input rates.

PART 4 – ROM SUMMARY PRODUCTION and DURATION INFORMATION

Production based on DAMEN 1500 - small trailer hopper suction dredge

Table 2 – SUMMARY of THSD PRODUCTION level for dredging and pump-out methodology and DURATION

THSD	Hopper Capacity and Effective Hrs		Over flow	Jets on DH	Solids	Volumes	Duration
DAMEN 1500	**Hopper m3**	**Eff Hours**	Nil	Nil	**Situ m3/wk**	**13,315m3 in situ NET**	**Wks**
	1500	85% of 168hrs per week				**Gross incl O/dredging**	
						24,459m3	
						Available to smTSHD	
						18,752m3 exclusive of spotting	
Phase 1					29,500	7,662m3	0.26
Phase 2					26,300	5,130m3	0.20
Phase 3					20,500	5,960m3	0.29
Spotting					4,500	1,000m3	0.22
Totals	**Average Production** **Total TSHD Volume** **Total Duration**				**20,000**	**19,252m3**	**0.97**

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PART 5 - ROM SUMMARY TABLE of SOURCE INPUTS for MODELLING

Table 3 – FLUX Inputs for selected dredging methodology

Calculated continuously over 168hrs/wk or a continuous part thereof.

POINT of RELEASE and FLUX	Total Loss of Fines kg/sec	Silt Fines only kg/sec	Clay Fines only kg/sec	Release Level	Distribution of fines
	<75mu	2-75mu	<2mu	from/to	%
PHASE 1					
Draghead	0.08	0.05	0.03	Seabed to +2m	See below
Prop wash	0.18	0.09	0.09	Seabed-Surface	See below
Pump-out Station	0.04	0.02	0.02	Draft@4m to Seabed	See below
PHASE 2					See below
Draghead	0.29	0.06	0.23	Seabed to +2m	See below
Prop wash	0.77	0.18	0.59	Seabed-Surface	See below
Pump-out Station	0.04	0.02	0.02	Draft@4m to Seabed	See below
Phase 3					See below
Draghead	0.46	0.08	0.38	Seabed to +2m	See below
Prop wash	1.78	0.40	1.38	Seabed-Surface	See below
Pump-out Station	0.04	0.02	0.02	Draft@4m to Seabed	See below
Spotting Phase 4					See below
Draghead	0.10	.02	0.08	Seabed to +2m	See below
Prop wash	1.78	0.40	1.38	Seabed-Surface	See below
Pump-out Station	0.04	0.02	0.02	Draft@4m to Seabed	See below
PHASE 1 SOIL Sub-distribution for clays+ silts **PSD 60-75mu** **PSD 40-60mu** **PSD 20-40mu** **PSD 2-20mu**		20% 20% 20% 40%			

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Phases 2-4 **SOIL Sub-distribution for clays+ silts** **PSD 60-75mu** **PSD 40-60mu** **PSD 20-40mu** **PSD 2-20mu**	 10% 20% 20% 50%	

Table 4 – Flux Distribution over water depth from TSHD Operations

Average height of water column	**Av mCD start**	**Av mCD End**	**ML tide**	**Av Water Depth**	**Remarks**
Seabed Change TSHD ops	-6.5	-7.5m incl O/D	-0.5m	-7.5m	
Release Point	**Release Layer**		**Distribution of flux**		
Draghead	from	to			
	Surface	-1.5m	0%		
	-1.5m	-3.0m	0%		
	-3.0m	-4.5m	0%		
	-4.5m	-6.0m	30%		
	-6.0m	-7.5m	70%		
Propwash+Scour	**from**	**to**	**Distribution**		
	Surface	-1.5m	10%		
	-1.5m	-3.0m	15%		
	-3.0m	-4.5m	20%		
	-4.5m	-6.0m	25%		
	-6.0m	-7.5m	30%		
Pump-out under TSHD (Applies to Tug Harbour Pump-out Station only)	**from**	**to**	**Distribution**		
	Surface	-1.5m	0%		
	-1.5m	-3.0m	0%		
	-3.0m	-4.5m	20%		
	-4.5m	-6.0m	30%		
	-6.0m	-7.5m	50%		
Overflow TSHD	**No overflow allowed**				

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