South Thomson Bay Barge Development

Dredge Plume Modelling Assessment

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Dredge Plume Modelling Assessment

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Executive Summary

We acknowledge the Traditional Custodians of this Island, the Whadjuk people of the Noongar Nation, their ancestors and their Elders past, present and emerging. We acknowledge and respect their continuing culture and the contribution they make to the life of this Island and this region.

Wadjemup (Rottnest Island) is an A-class nature reserve of ecological, cultural, and social significance, with the island currently supplied with bulk cargo via the roll-on-roll-off vessel which docks at the barge ramp located near the base of the Main Ferry Wharf. Following identification in the Rottnest Island Master Plan – 20 Year Vision (RIA 2019) of the need to improve the functionality and efficiency of transporting bulk cargo to and from Wadjemup, investigations and studies have been undertaken to determine a design and method to convert the former Army Jetty site in South Thomson Bay into a barge landing development to move these activities away from the Main Ferry Wharf site.

The dredge plume modelling assessment examines the Value Engineering Concept Design reported by AECOM in 2020 and includes the following design aspects:

- Extending the existing groyne by approximately 150m, which includes a 90m (nominal) breakwater that will run approximately parallel to the shoreline.
- A RoRo facility, consisting of an LCT Barge Ramp in the lee of the shore perpendicular section of the new breakwater structure, and including a laydown area of approximately 2,300 m^2.
- Dredging the approach to and footprint within the new breakwater structure to a declared depth of -3.0m Chart Datum (CD), which will include a turning basin with a nominal diameter of 80 m, resulting in a required dredging volume of approx. 16,000 m^3 when considering an overdredge requirement of 0.6m

Prior to commencement of the dredge plume modelling, Baird liaised with the specialist dredging consultancy in2Dredging Pty Ltd (i2D) to determine the most suitable methodology to dredge the material, as well as to determine the required schedule and budget estimate related to the chosen methodologies The dredging methodology used in this assessment relates to the use of a backhoe dredger BH EX05 setup and the P50 rock quality parameters assumed in i2D's reporting. The dredging requirements are considered in relation to the proposed barge landing footprint to be dredged in 6 sections across the dredge footprint according to the proximity of these areas to the sediment samples captured by Douglas Partners in their 2019 reporting.

The dredge plume model simulations were executed with no background suspended sediment concentration (SSC) and the raw model results represent excess above the background SSC. For the analysis of the model results and predicted extent, severity and duration of dredging impacts a background SSC was applied in the post processing of results. With no long-term dataset available within Thomson Bay to determine the most appropriate background SSC to use during a winter dredging campaign, analysis has been made of data available offshore of Wadjemup and at a location closer to shore within Cockburn Sound to make an estimate of the most appropriate background SSC to assume for this investigation. The background SSC taken from this interpretation is 3 mg/L.

The modelling process simulates dredge plume generation from their source and examines the fate of fine sediments in suspension, as suspended sediment concentration (SSC) both spatially and vertically through the water column in 3D. Sediment plumes are driven in the model by the hydrodynamic forcing (water levels, winds, waves, currents) with erosion, resuspension and deposition of the dredge material permitted in the model based on bed shear stress. The overall current direction trend from west to east along Thomson Bay has had an impact upon the dredge plume generated in the modelling program, with plumes

generally directed east along South Thomson Bay away from the existing Army Groyne, with occasional periods of direction change directing the plume west and around the Army Groyne.

The calculation of the Zones of Impact (ZoI) defined by this study follow the method of calculation used by BMT in their analysis of the dredge plume and passive plume impacts from the placement of dredged sediments on Port Beach. This assessment determined nominal values of SSC that would have detrimental impact on local seagrass species, including the predominant species within South Thomson Bay, Posidonia.

The calculated zones of impact (ZoI, ZoMI and ZoHI) have been compiled based on the complete winter dredging program and are presented spatially in Section 5.5. Each of the zones that are considered to have an impact on benthic communities and habitat (BCH, including seagrasses), the ZoHI and ZoMI, are contained to small spatial extents adjacent to the dredge footprint, with extents based on conservative buffers around the dredge footprint as well as impacts from the modelling. It should be noted that the model impacts only influenced the spatial extents landward of the dredge footprint (i.e., impacts do not extend into Thomson Bay and are bounded by the dredge footprint, the Army Groyne and the Beach. The extent and coverage of the ZoI (representing the maximum predicted extent of visible plumes with the important consideration that these changes would not result in a measurable impact on BCH) stretching east along the beach in South Thomson Bay demonstrates the influence of the prevailing currents on this side of Wadjemup.

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1. Introduction

Wadjemup (Rottnest Island), located approximately 20 kilometres west of the port of Fremantle in Western Australia, is an A-class nature reserve of ecological, cultural, and social significance. The island is a remnant of southwest Western Australia's Pleistocene dune ridges and is surrounded by large quantities of reef platforms and rock formations. It is a popular tourist attraction with over 780,000 visitors to the Island annually enjoying short stay accommodation and recreational activities including snorkelling, bike riding and site seeing (WA Govt 2019). Tourists enter Wadjemup via ferry services disembarking on the island's Main Ferry Wharf located in Thomson Bay, with the Bay located on the north east side of the island, spanning approximately 2.5 km, and sheltered from the prevailing south westerly swell conditions (Figure 1.1).

The island is currently supplied with bulk cargo via the roll-on-roll-off vessel which docks at the barge ramp located near the base of the Main Ferry Jetty. Following identification in the Rottnest Island Master Plan – 20 Year Vision (RIA 2019) of the need to improve the functionality and efficiency of transporting bulk cargo to and from Wadjemup, to reduce noise levels for residents, and to improve safety and amenities for visitors arriving at the island, investigations and studies have been undertaken at the Army Groyne. This includes studies to determine a design and method to convert the former Army Jetty site in South Thomson Bay into a barge landing, freight handling and associated storage area to aid in reducing heavy vehicle traffic around Wadjemup's main jetty in the Main Settlement area.

Figure 1.1: Site location showing Wadjemup /Rottnest Island and location of Thomson Bay on the Northeast side of the Island, with the Army Groyne location shown in the southern section of Thomson Bay

Initial concept designs for the proposed new barge landing site prepared by Wallbridge Gilbert Aztec (WGA) in late 2018 were used by MP Rogers and Associates (MRA) in their South Thomson Bay Coastal Processes Assessment (MRA 2019), with further development of the first option being undertaken by BMT in 2020. Following these assessments, AECOM were engaged by the Rottnest Island Authority (RIA) to undertake a high-level value engineering assessment of this concept design, aiming to identify opportunities to reduce capital costs, while maintaining the key functional/user requirements achieved by the initial concept design.

The concept developed by AECOM in their Value Engineering of Concept Design reporting (AECOM 2020) is the concept that has been used by Baird to develop an updated Coastal Processes Report (Baird 2023) and will be used in the dredge plume modelling scope covered in this report.

1.1 Project Location Summary

The local setting and metocean conditions for the project location are described in detail in Baird (2025). A brief summary follows.

The tides at Wadjemup are mainly diurnal with a spring tide range of approximately 0.7m and neap tide range of 0.5m. The tidal planes for Thomson Bay have been taken from the nautical chart for Rottnest Island WA412 (DoT 2011) with the vertical datum set to the Rottnest Island Sounding Datum. It is noted that the LAT level has not been established for Thomson Bay.

Wadjemup is the largest island along the Garden Island Ridge, a rocky remnant Pleistocene ridge forming a chain of submarine reef platforms and emergent islands approximately 12km offshore of the Swan Coastal Plain, with Wadjemup forming the northern terminus of the Ridge (Searle et al 1985). The Island sits on the middle shelf region of the narrow Rottnest Shelf (Brooke 2010), with bathymetry west of the island dropping to -55m MSL within 2km of the western most point of the island (Cape Vlamingh at West End). Flows around the island are largely driven by swell energy from the Indian Ocean that wrap around the island from west to east as they encounter the surrounding shallower waters and the emergent island itself.

The measured currents at the proposed barge landing site show:

- Depth averaged peak current speed of 0.05ms^{-1} - 0.1ms^{-1} in neaps and 0.1ms^{-1} – 0.15ms^{-1} in springs.
- Current direction (direction to) is relatively consistent across the tidal cycle at 80˚ - 100˚, with occasional brief changes in direction to come from more northerly directions.
- The low current speeds seen in this area appear to be strongly affected by increased wind speeds, with current speed peaks seen during periods of increased wind speed at Wadjemup.

In general, wave conditions at the proposed barge landing site are dominated by diffracted and refracted swell waves within the range of 0.4m to 0.7m (significant wave height) at peak wave periods around 12 to 18s arriving from the northern sector, with intermittent influence of wind sea resulting in higher waves around 0.8 to 0.9m at peak wave periods of 5 to 10s arriving from the northwestern sector.

1.2 Dredge Plume Modelling Scope

The methodology used to provide the requirements of scope is outlined here.

- A site visit was conducted to examine the key features at the project location that are important for consideration in the delivery of the study.
- A coupled hydrodynamic and wave mode was developed l at appropriate resolution for project site at south Thomson Bay (high resolution) and surrounding area of influence (lower resolution areas offshore). Model validation was provided to available measured water level, currents and wave data in Thomson Bay.

- Model was developed in 3D around the area of interest where dredge plumes are generated – plume dispersion will be modelled in 5 vertical layers.
- The dredging program characteristics was determined in discussion with dredge contractor and RIA. Inputs to the model were co-ordinated, specifying sources of dredge plume generation (incorporating dredge method, timing, production rates, schedule). Dredge volumes and sediment classification of dredged material (sand, fine sand, silt, clay content) were confirmed with RIA for input to the modelling process.
- The dredge program was executed in the model, adopting continuous simulation of hydrodynamics and wave conditions and dredge plume source/s. The model adopted a representative winter season condition in Thomson Bay.
- Analysis of the dredge plume impacts around the site based was carried out based on the methods detailed in the EPA and supported by analysis in BMT (2021) spatially based zonation scheme to describe the predicted extent, severity and duration of impacts associated with dredging proposals (EPA, 2016). The scheme consists of three zones that represent different levels of impact:

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

- The calculation of the ZoMI and ZoHI areas from the dredge plume modelling was completed based on analysis of the running mean of modelled SSC against different thresholds taken from BMT (2021). Baird would analyse dredge plume zones of impact (ZoMI, ZoHI, ZoI) based on receptor communities for seagrass consistent with threshold levels outlined in BMT (2021). The Zones of impact would be determined in GIS format and presented in spatial mapping to support the approvals process.

2. Background Information

The background reports referenced in the development of the hydrodynamic model and application in the dredge plume modelling program are outlined in Appendix A.

2.1 Measured Data Sources

The key measured data sources which have been applied in the Dredge Plume model program are summarised in Table 2.1.

Table 2.1: Data Summary – Key Datasets

Dataset	Description
Sediment Sampling	Geotechnical core samples with sediment sampling from seabed areas within and adjacent to the proposed dredging footprint were reported in Douglas Partners (2019). Further sediment samples from the same dredge footprint area with similar PSD results were collected by RPS in 2020.
Bathymetry Ordered Highest to lowest priority	There is a very good description of the bathymetry from around the Island captured in high resolution for the Department of Transport (DoT) in 2009 to approximately 30m depth (Figure 2.3). There are high resolution local bathymetric surveys in Thomson Bay captured in 2017 and 2020 by DoT which provide an excellent description of the seabed (Figure 2.3).

Baseline Metocean Data	Measured data relevant to the site and this modelling scope is available for a range of data types and dates. The full set of measured data is detailed in Baird's Coastal Processes Report (Baird 2025).
	The location of each of these datasets shown in Figure 2.1 and Figure 2.2. The key metocean datasets used for model setup and validation include:
	• Rottnest Island Wind
	  • 1983 – 2023
	  • Wind Speed and Direction
	• Rottnest Buoy DWR
	  • 2004 – 2023
	  • Waves (Hs, Tp, Dir)
	• Aquadopp Site 1
	Deployment 1: 25th June 2020 – 13th October 2020
	Deployment 2: 9th February 2021 – 6th August 2021
	  • Waves (Hs, Tp, Dir, Spread), Currents (Speed, Direction), Water Depth
	• Signature 1000 Site 2 ADCP
	  • 5th Nov 2020 – 9th Feb 2021
	  • Waves (Hs, Tp, Dir, Spread), Currents (Speed, Direction), Water Depth
	• AWAC_R1_01
	  • 8th Aug – 3rd Oct 2012
	  • Waves (Hs, Tp, Dir)

Figure 2.1: Locations of Measured Data around the Wadjemup Site

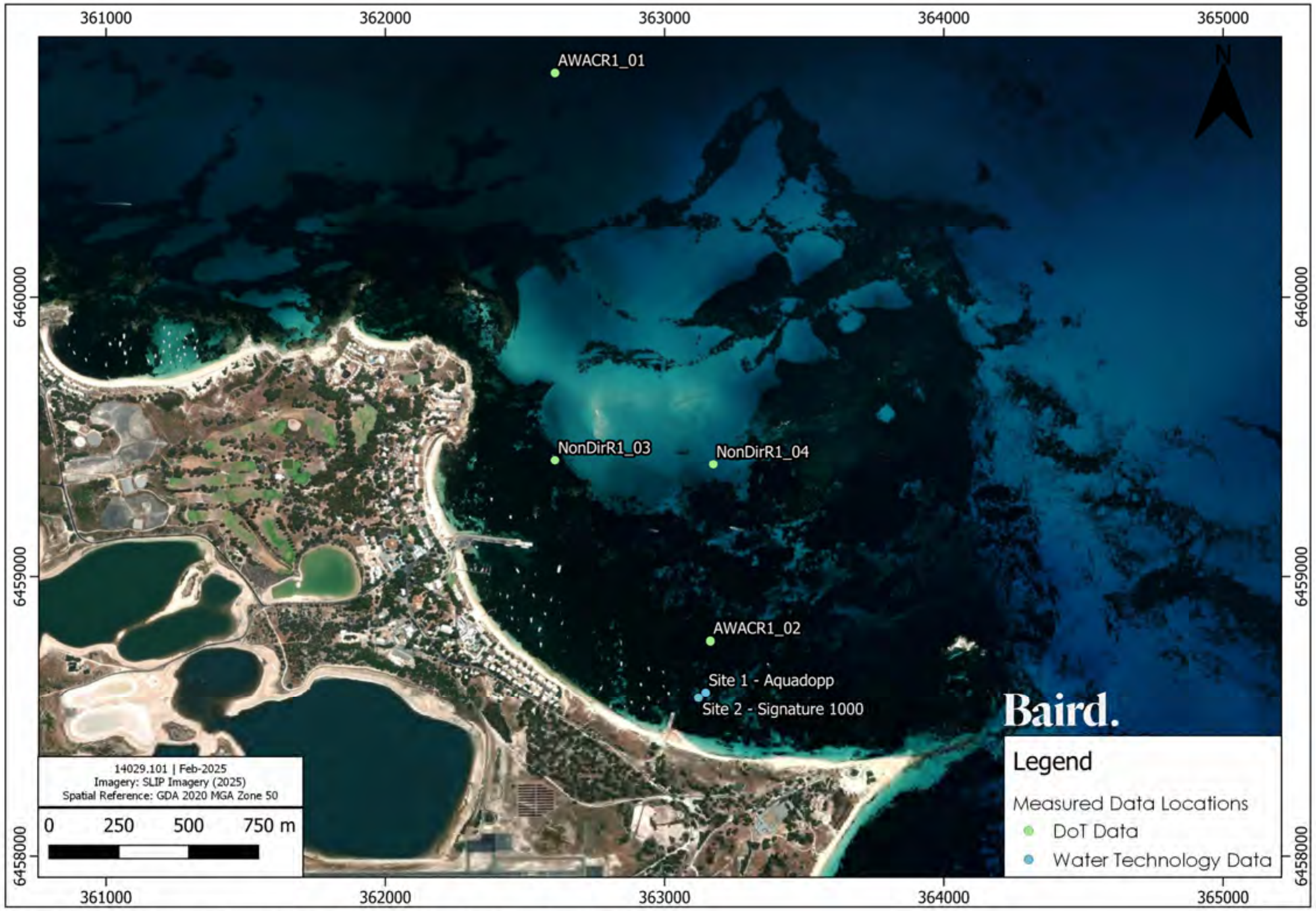

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Figure 2.2: Locations of Measured Data in Thomson Bay around the Army Groyne Site

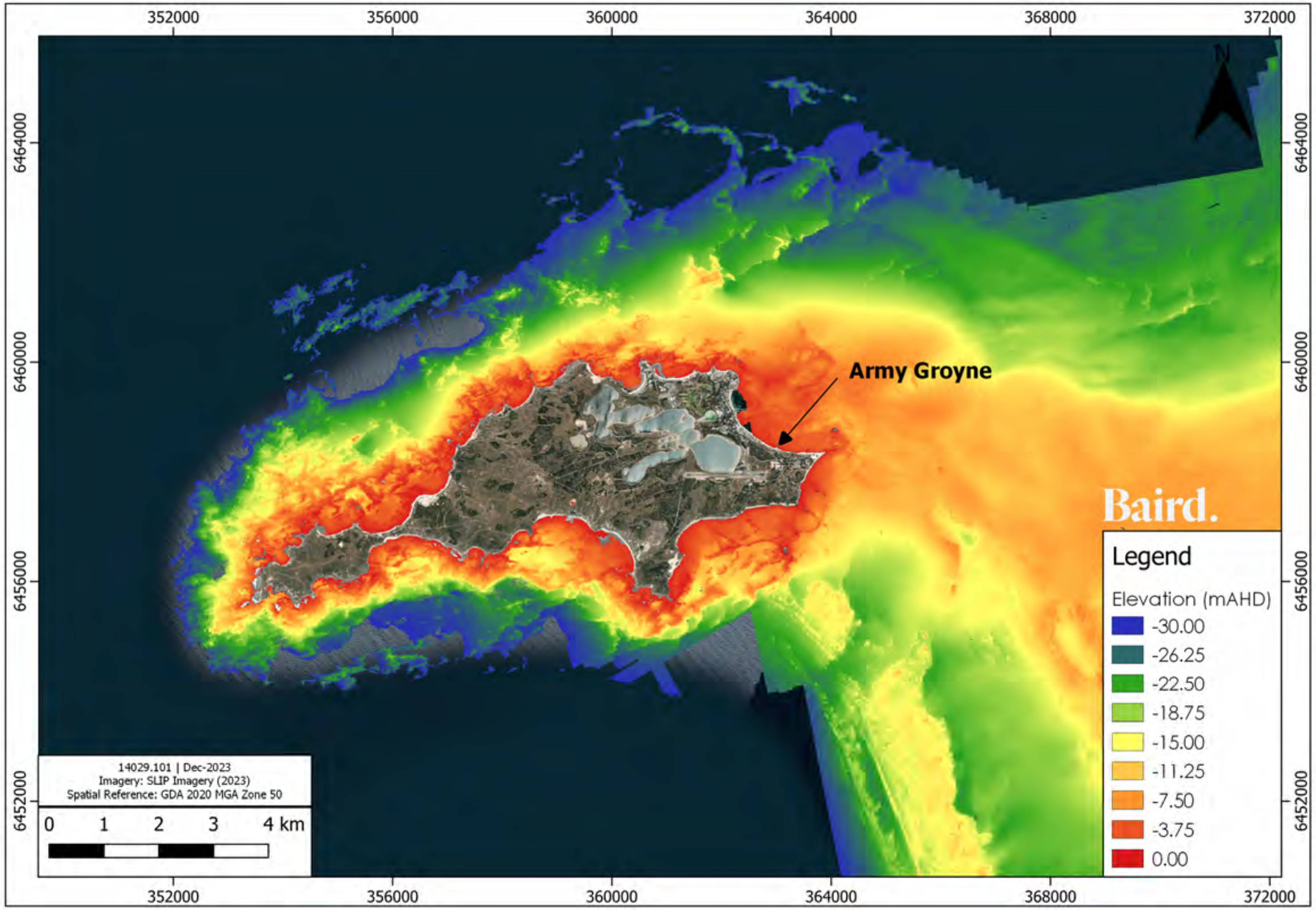

Figure 2.3: High resolution multibeam bathymetry captured by DoT around Wadjemup

3. Dredging Method

The area to be included in this dredge plume modelling assessment is based on the Value Engineering Concept Design reported by AECOM in 2020, shown below in Figure 3.1, and includes the following design aspects:

- Extending the existing groyne by approximately 150m, which includes a 90m (nominal) breakwater that will run approximately parallel to the shoreline.
- A RoRo facility, consisting of an LCT Barge Ramp in the lee of the shore perpendicular section of the new breakwater structure, and including a laydown area of approximately 2,300 m^2.
- Dredging the approach to and footprint within the new breakwater structure to a declared depth of -3.0m Chart Datum (CD), which will include a turning basin with a nominal diameter of 80 m.

This will require a volume of material to be removed from the site of approximately 16,000m^3, including an overdredging depth of 0.6m vertically, and accounting for the removal of both loose sediment and rock.

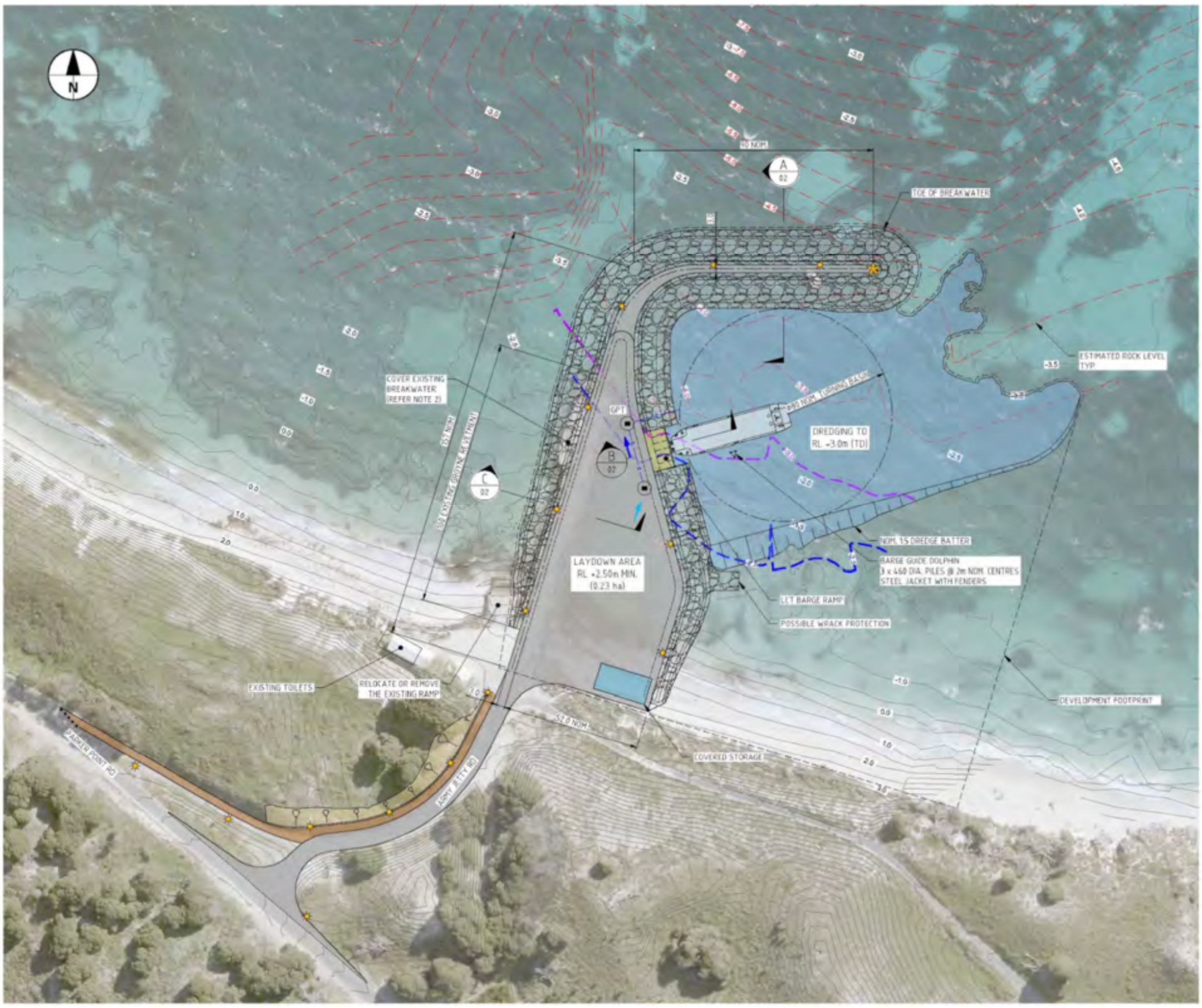

Figure 3.1: Value Engineering Concept 1 General Arrangement (AECOM 2020, RIA-2520-19180-MAR-01 RevE)

3.1 in2Dredging Methodology and Schedule

Prior to commencement of the dredge plume modelling, Baird liaised with the specialist dredging consultancy in2Dredging Pty Ltd (i2D) to determine the most suitable methodology to dredge the material, as well as to determine the required schedule and budget estimate related to the chosen methodologies outlined in i2D (2023). This analysis and reporting resulted in the estimation of dredging rates and schedules based on the use of a backhoe dredger (BHD), as shown in Figure 3.2, with dredging and schedule estimates for two small to medium BHDs included.

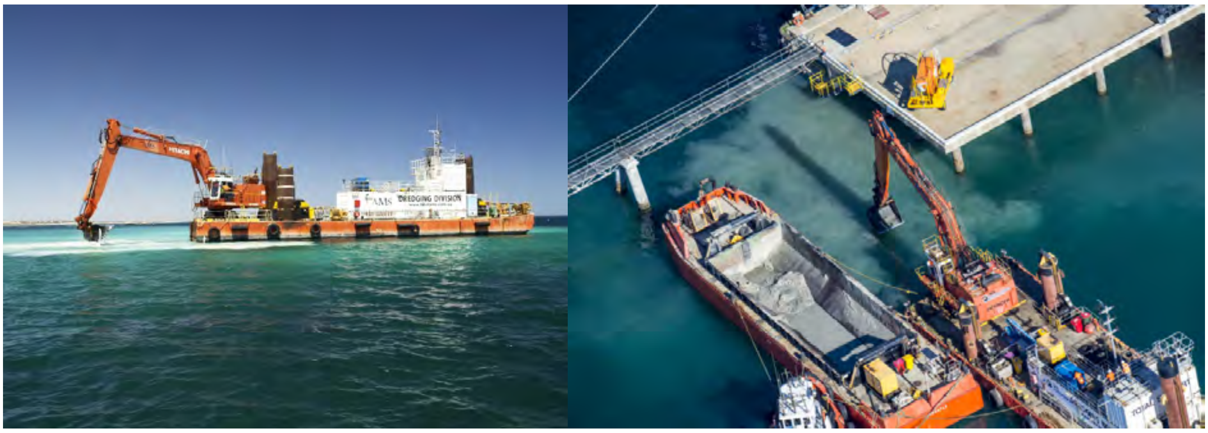

Figure 3.2: Backhoe dredger vessel example, the TAMS FT3 BHD (left), with associated hopper barge (right) (TAMS 2024)

This estimate resulted in the following production overview for the two selected example BHDs.

Table 3.1: Production Overview (adapted from i2D 2023)

Parameter	Unit	Sand		Rock (P50)		Rock (P80)	
		BHD FT3	BH EX05	BHD FT3	BH EX05	BHD FT3	BH EX05
Gross Volume	in situ m^3	14,033		2,017			
Operability	OH/wk	26	37	58	57	61	60
Productivity	in situ m^3/OH	150	67	21	20	3	3
Weekly Production	in situ m^3/wk	3,948	2,479	1,230	1,135	207	331
Duration per unit	weeks	3.6	5.7	1.6	1.8	9.7	6.1
Total duration for both units	weeks	N/A		5.2	7.5	13.6	11.8

3.2 Dredging Approach and Methodology

The dredging methodology has been defined based on the information provided by i2D, with the dredge plume model case developed based on a case in the mid-range of the timing estimates provided in the i2D reporting. The dredge plume modelling assumes the use of the BH EX05 setup and the P50 rock quality parameters outlined in Table 3.1 above, a realistic worst case scenario that considers the longer dredging campaign with rock parameters that are the most likely to be present at the site. If further investigation shows that the rock quality is closer to the P80 parameter update can be made to the dredging program to determine the impact of this on the predicted plumes. Inputs to be model are summarised in Table 3.2.

Table 3.2: Dredging Method - Summary Statement

Dredge Design	
Target Dredging	12,069 m^2 (Area, inc. batters) 16,000 m^3 (Volume, inc. overdredge requirement)
Design Depth	-3.0m CD
Batters (nom.)	1V:5H
Dredge Volume	A dredge volume of approximately 16,000m^3 has been included in model, using the schedule calculated for the BH EX05 scenario of 7.5 weeks. As the timing of the dredging operations across this 7.5 weeks is not yet decisively determined, the potential worst-case scenario of discharging sediment continuously into the marine environment has been assumed. This results in a target production rate of 302 m^3/day. Sediment is classified by volume in sediment fractions in the categories: • Gravel, Cobbles >2mm. • Medium to coarse Sand 0.25mm – 2mm. • Fine sand 62µm – 0.25mm. • Coarse Silt 16µm to 62µm. • Fine Silt 2µm to 16µm. • Clay < 2µm. The proportion of the respective sediment classes that will be modelled as a source term will be based on the information from latest sediment sampling, shown in Figure 3.3.
Over Dredge Allowance	Allowance of 0.6m over dredge in all areas being dredged (i.e., not where natural seabed level is already at design depth).
Dredge Method	
Dredge Plant	Backhoe Dredger BH EX05
Excavation Rate	302m^3/day, assumed to be undertaken on a 24/7 basis.
Dredge Disposal Sequence	Dredging undertaken by moving from the nearshore area (requires greater volume of dredging due to shallower natural seabed depth and therefore more material to be removed to reach design depth) to the offshore, as detailed in Section 3.3 and Figure 3.4.

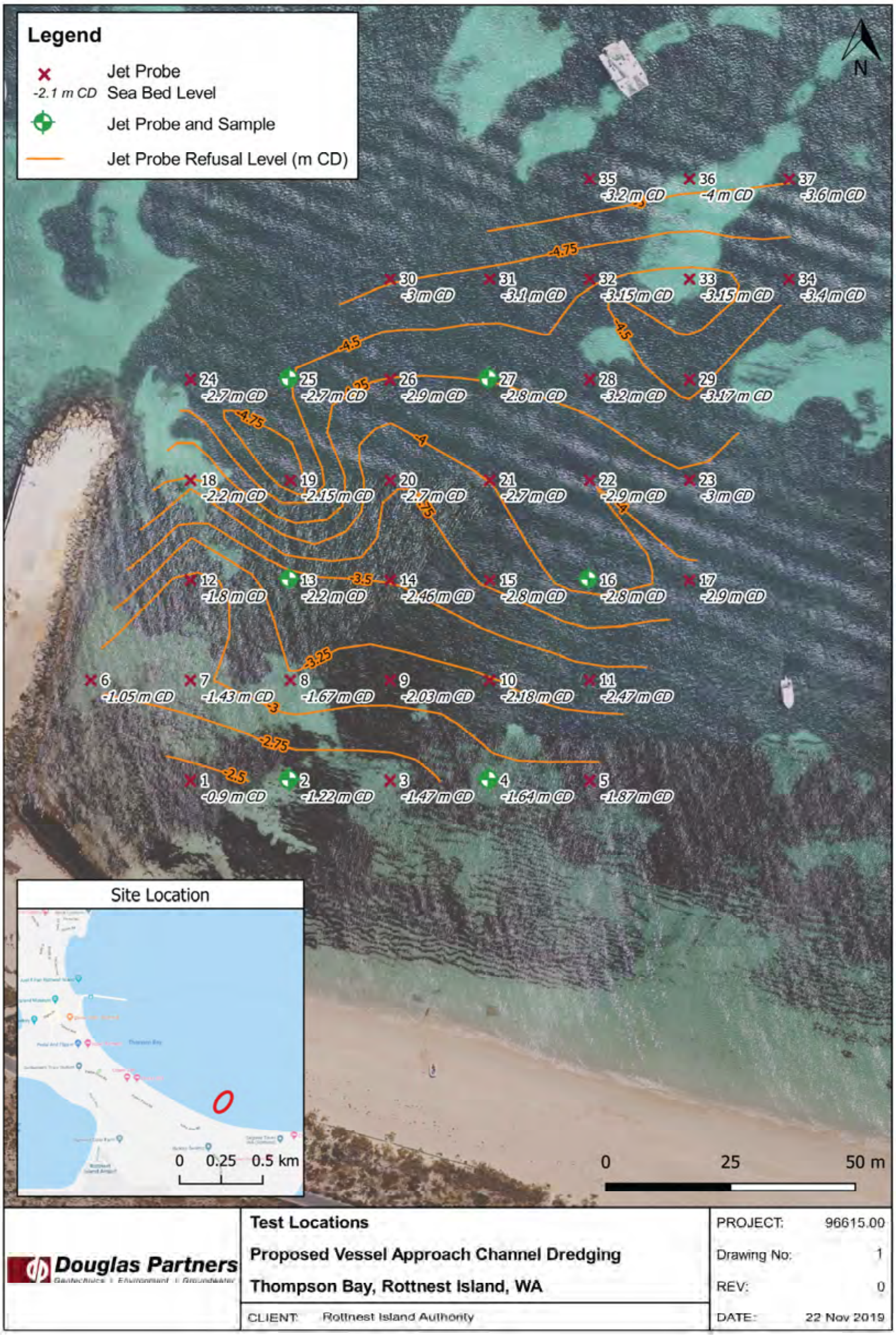

Figure 3.3: Geotechnical sediment sampling locations included in particle size distribution (PSD) analysis (Douglas Partners 2019) and adopted in dredge plume modelling program, with locations of samples included in PSD analysis shown in green.

3.3 Dredging Program

The dredging schedule included in this modelling program has been developed based on the schedule outlined in i2D (2023), and taking the assumptions related to use of the BH EX05 dredging plant, which includes the assumption that the dredging will take place prior to the construction of the breakwater structure due to difficulties in manoeuvring plant within the breakwater following construction, and the potential for impacts upon the structure toe if materials are removed from the vicinity following placement. The schedules aim to complete the requirements of the project in one continuous dredging program between late June to mid-August (nominal winter), with discussions held with RIA confirming that the winter period is the optimal time to complete dredging works as it avoids the peak tourist season of summer. The dredging program incorporates a range of assumptions for the plant and equipment (e.g., production rates, working hours) as shown in Table 3.2.

The dredging requirements are considered in relation to the proposed barge landing footprint to be dredged in 6 sections across the dredge footprint according to the proximity of these areas to the sediment samples shown in Figure 3.3 (dredge areas shown in Figure 3.4).

Within each dredge area, the sediment composition of dredge spoil is determined from available geotechnical information (Douglas Partners 2019) closest to each respective section. The dredge volume in each section to be included in the dredge plume model is then calculated in terms of fine sand and silt components, noting that no clay component was found in any of the 6 PSD samples, and assigned to plume sources in the numerical model based on the assumed dredging method of the BH EX05, as discussed above.

Table 3.3: Proposed Dredging Schedules Adopted in Model Program

Area Covered	Dredge Volume	Modelled Dates		Days
		Start	End	
Sample 2	2,114 m^3	24/06/2020	30/06/2020	7
Sample 4	2,114 m^3	01/07/2020	07/07/2020	7
Sample 13	4,530 m^3	08/07/2020	22/07/2020	15
Sample 16	2,718 m^3	23/07/2020	31/07/2020	9
Sample 25	3,020 m^3	01/08/2020	10/08/2020	10
Sample 27	1,510 m^3	11/08/2020	15/08/2020	5
TOTAL	**16,006 m^3**			**53**

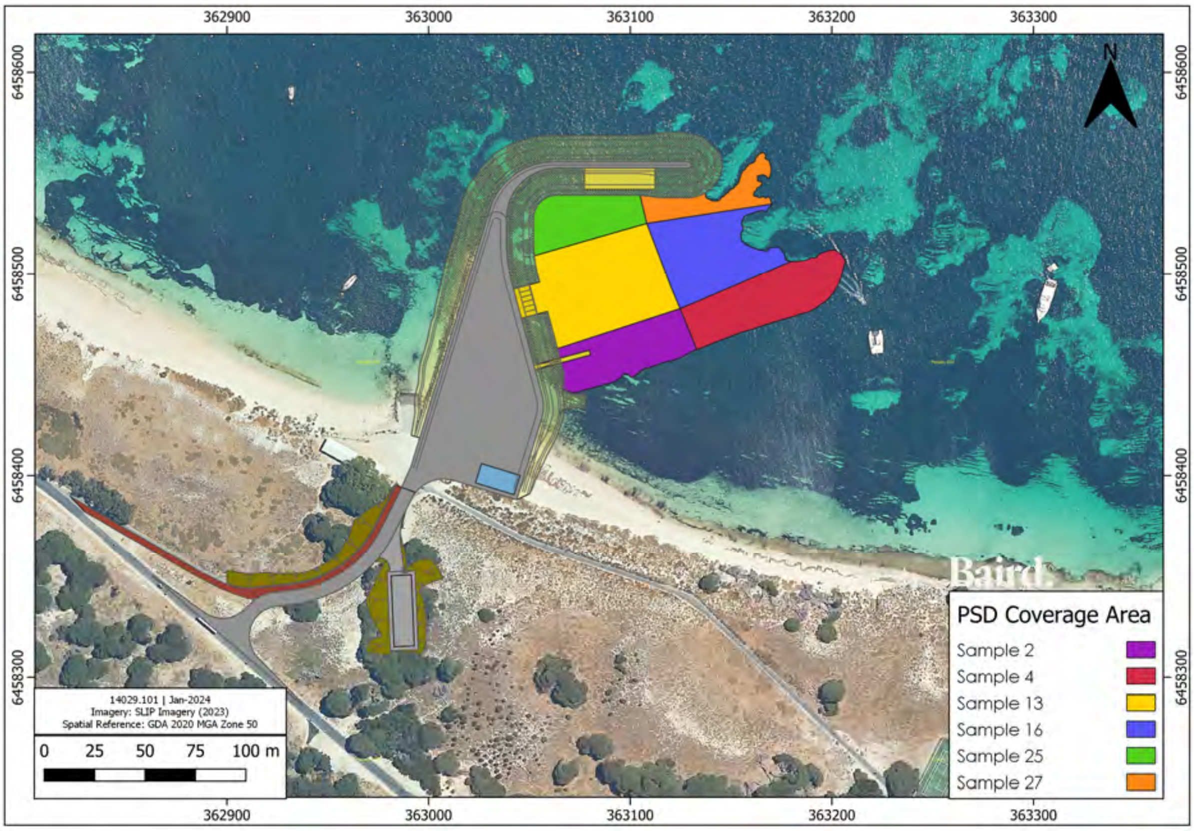

Figure 3.4:Dredge footprint split according to the closest sediment sample collected by Douglas Partners in 2019, showing the sediment size classification used for each section of the dredge footprint in the dredge plume modelling

3.4 Sediment Classifications in Model

Douglas Partners' (2019) detailed geotechnical investigation and sediment sampling program has informed understanding of the composition of the seabed material which will be dredged.

The sediment classifications considered in the modelling are based on the range of sizes described in Table 3.4. The dredge plume modelling examines fine cohesive sediments (silts only as no clays are present at the site) while also considering non-cohesive fine sand.

Table 3.4: Summary of Sediment Classes in Model (from Wentworth Scale)

Sediment Class	Size Range (µm)	Model Assumptions
Fine sand	62µm – 0.25mm	Modelled as non-cohesive sediment with Median Sediment D_{50} = 200µm
Coarse Silt	16µm to 62µm	Modelled as cohesive sediment, Settling Velocity 1.7mm/s
Fine Silt	2µm to 16µm	Modelled as cohesive sediment, Settling Velocity 0.06 mm/s

A key determinant of the dredge plume dispersion and settlement in the model is the settlement rate parameter for the fine fractions. According to Stokes' Law, the settling rate of particles is affected by the gravitational force exerted on the particle, the density of the particle relative to the density of the medium, and the viscosity (resistance to flow-settling) of the medium.

For the modelled fine fractions, the following settlement rates has been adopted according to Stokes' Law:

- Coarse Silt = 1.7 mm/s
- Fine Silt = 0.06 mm/s

These values fall within the ranges of settling velocity adopted in similar modelling studies as noted in Sun et al, 2016.

3.5 Dredge Material - Sediment Sampling and Analysis

The sediment sample locations collected through the alignment of the proposed barge landing dredge footprint are shown in Figure 3.3, with the interpretation of the areas covered by each sediment sample in the model shown in Figure 3.4. The sediment samples are taken from various depths, from -1.22m CD to -2.8m CD. The boreholes are considered to represent the sediment conditions of the dredged material in the channel.

There are six respective dredge areas shown as coloured polygon areas in Figure 3.4. The sequences are distinct areas considered across the dredging footprint in which the sediment composition and volume has been assessed and input into the model to determine the dredge plume impacts. The area covered by sample 13 is the largest due to the relative amount of the dredge footprint that aligns closely to this sediment sample location. This location is also relatively shallow requiring a greater volume of material to be removed to reach design depth, corresponding to an assumed 15 days of the dredge program being informed by the PSD from this location (Table 3.3). Conversely, as dredging operations move offshore to the area of the footprint informed by sample 27, the spatial area reduces as the dredging volume required to reach the design depth decreases and the days spent in this part of the dredge footprint will also be reduced (5 days of dredging are assumed to be informed by the PSD from this location).

Within each of the dredge areas informed by each sediment sample, sample 2 to sample 27, the particle size distribution of the dredged material for application in the model has been calculated based on the measured sediment size data. This process is summarised in Table 3.5, outlining the samples that have been considered for each of the areas and the calculation of the respective sediment fractions (silt, fine silt, and sand).

Table 3.5: Sediment Composition of dredged material by area – based on Douglas Partners 2019

Area Covered	Depth of Sample	Fine Silt %	Silt %	Fine Sand %
Sample 2	-1.22m CD	1	2	36
Sample 4	-1.64m CD	0	0	47
Sample 13	-2.2m CD	2	1	68
Sample 16	-2.8m CD	0	0	73
Sample 25	-2.7m CD	0	0	84
Sample 27	-2.8m CD	2	1	79

An overview of the incorporation of the Douglas Partners' (2019) sediment sampling results into the model is provided as follows:

- The sediment sampling has been applied to the model based on determining the most appropriate number of days spent in each part of the proposed dredge footprint and the most appropriate sediment sample PSD to use as input to the model for those respective days.
- The sediment samples show that the fines content is very low across all of the sample PSDs, with no clay content found in any sample. Silt content is also zero for half of the sample PSDs, with the combined silt fraction content at 3% for the other half of the sample PSDs. Fine sand (included in the model source terms), coarse sand and gravel (not included in the model source terms as these fractions are so large that they do not contribute to the generation of plumes) make up the majority of the sediment samples.

To illustrate the application of the geotechnical information, the core samples from sample 2 and sample 27 are shown below in Figure 3.5, demonstrating the very low fines content of the samples and the overall non-cohesive nature of the samples collected within the proposed dredge footprint.

Figure 3.5: Core Samples for sample 2 (top) and sample 27 (bottom) (Douglas Partners, 2019). Cores are collected to the target depth below seabed of 1m, and demonstrate very low fines content and non-cohesive nature of the sediments at these locations

3.6 Handling of Dredge Spoil

At the time of preparing this report (2023) and undertaking the modelling it was assumed that dredge material would be transferred onshore and trucked to a disposal site near the island's airport I2D(2023).

In the peer review by RPS (2024) it was noted the RIA has moved to disposal of dredge material onshore for the construction of the Barge Development structure's laydown area. This is likely to involve creation of a bunded area that is progressively backfilled with dredged material. The review in RPS (2024) noted because this method has the potential for return of finer dredged material to the ocean through dewatering and disturbance of temporary bunds, this potential should be assessed by Baird:

- for significance in the context of modelling already completed
- the potential for sediment losses to the ocean during construction of the breakwater itself should be assessed for significance in the context of modelling already completed.

Baird note the inclusion of these terms in the model is expected to have a minimal impact on the extent of the dredge plume zones shown in this report. This finding is due to the small percentage of fines present in the dredge spoil material, that will be placed within the bund following dredging from the seabed. Secondly the use of filter layers within the bund would allow for water to pass through the bund wall while trapping sediments which would limit the release of dredge spoil sediments (sand / silt) into the receiving waters.

4. Dredge Plume Modelling

Hydrodynamic, wave and sediment transport models have been developed for the South Thomson Bay project to model dredge plume development and dispersal. The model system is used for predicting the likely extent, severity, and persistence of environmental impacts by the proposed dredging activity. For this project the Delft3D modelling system (Deltares, 2020) has been adopted.

Delft3D is an industry leading integrated modelling suite, which simulates two-dimensional (in either the horizontal or a vertical plane) and three-dimensional flow, sediment transport and morphology, waves, water quality, and ecology and can handle the interactions between these processes. The model has been applied in many similar studies of dredging impacts at sites around Australia with modules for investigation of far-field water quality, mid-field water quality, ecological modelling, and cohesive and non-cohesive sediment transport (Sun et al 2016).

Prior to modelling the dredge plume impacts, the coupled hydrodynamic and wave model was validated to the measured data made available to this study. The details of these models, as well as the validation achieved for the coupled model systems, are presented below, followed by overview of the details of the sediment transport model that allows for the investigation of the dredge plume impacts that can be expected from the dredging program described in Section 3.

4.1 Hydrodynamic Model (Delft3D FLOW-WAVE-FLOW)

The hydrodynamic and wave models established for this phase of the South Thomson Bay project are summarised as follows:

1. A regional scale hydrodynamic model extending across the southwest of Australia using Delft-Flow Flexible Mesh (D-Flow FM) model (grid setup shown in Figure 4.1). The model is driven by tidal constituents along its open boundaries with bathymetry defined from hydrographic chart data and local scale bathymetry sources where available. For this project, winds and atmospheric pressure have been sourced from the NCEP Climate Forecast System (CFSR). The climatic conditions were then applied spatially in D-Flow FM and updated hourly across the regional model in conjunction with the tides, so their influence was captured in the determination of hydrodynamic forces acting in the domain.
2. A local scale Delft3D hydrodynamic model is established over the Wadjemup area with boundary conditions defined by the Regional model at the domain edge in Figure 4.2. A series of regular grids have been used in downscaling the Regional model currents to the site of interest for dredge plume modelling.
3. The local hydrodynamic model is setup in a domain decomposition grid arrangement to optimise the efficiency of the model performance. The outer grid extends along the shoreline approximately 84 km with a cross shore extent of approximately 40km. The outer grid is setup on a 500 m grid size, with smaller grids at resolutions of 250m and 50m included in the domain decomposition arrangement to balance required model resolution and computational efficiency. The model grids and model bathymetry are shown for the full model setup in Figure 4.2. For the dredge plume analysis, a smaller domain sized at 10 m resolution describes the area around the dredge footprint within South Thomson Bay (model grid coverage and bathymetry at Figure 4.4). This local scale model is setup with the following attributes:
    - The model is forced along the boundary of the outer grid by water level boundaries along the northern, western and southern boundaries as derived from the regional scale model described above. Water levels at the boundary are updated every 10 minutes.
    - The model is driven by local wind conditions derived from the Bureau of Meteorology (BoM) site on Rottnest Island (BOM Site 9193), scaled down from the height they are measured at (~43m MSL) to the standard 10m above mean sea level.

4. A SWAN wave model was developed to cover the local scale domain with the following attributes:
   - The model grids are setup to align with the four hydrodynamic grids described above, with model grid cell resolution increasing approaching the project site in Thomson Bay (500m x 500m, 200m x 200m, 50m x 50m, 10m x 10m). The grid and bathymetry setup is as shown in Figure 4.3.
   - The wave conditions inside the SWAN model develop under forcing from boundary conditions based on the Rottnest Directional WaveRider Buoy, with local seas for the South Thomson Bay model generated by input winds in the FLOW model.
   - Wave conditions are updated in the local hydrodynamic model every half hour using Delft3D coupled FLOW-WAVE-FLOW module.

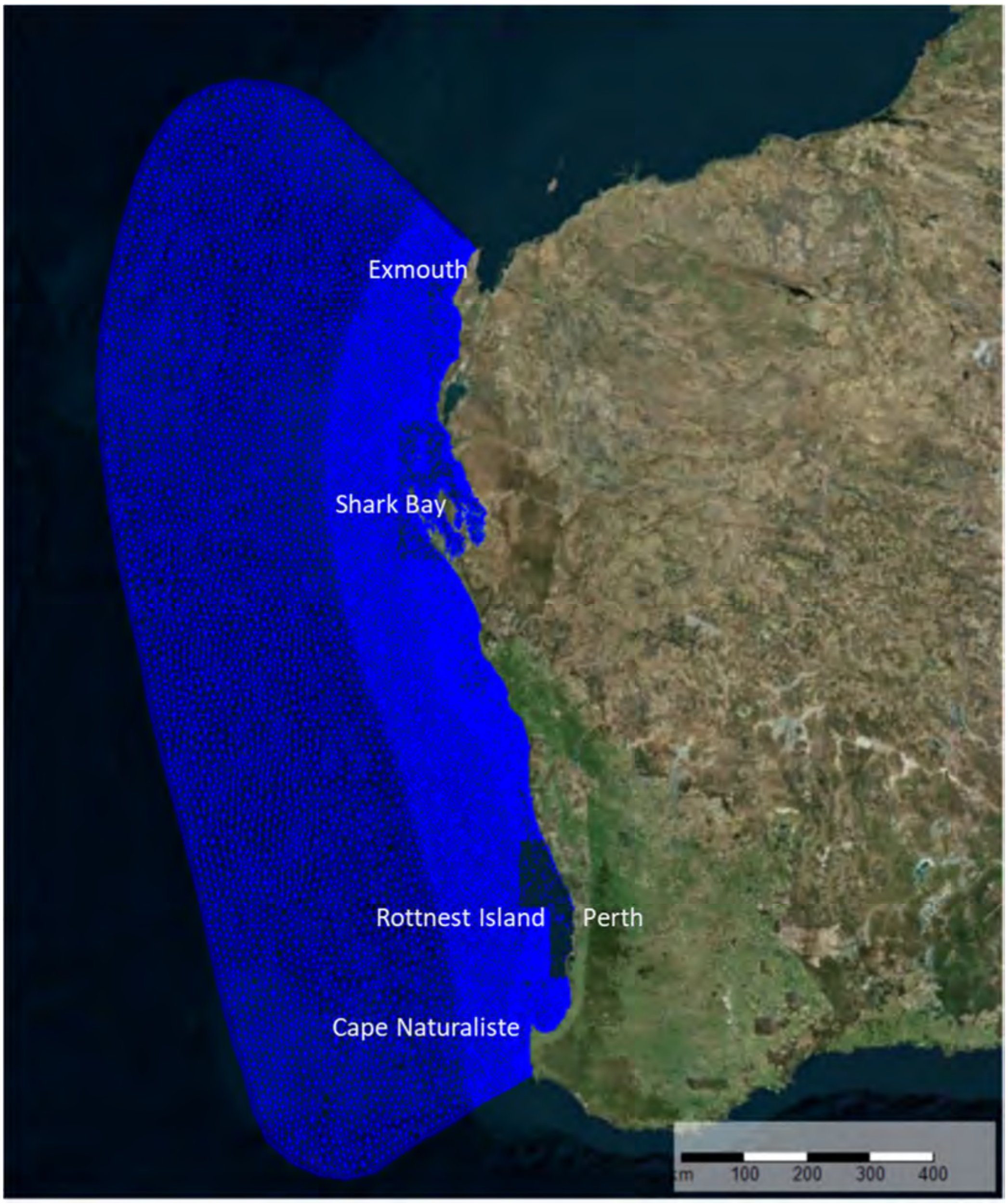

Figure 4.1: Regional Hydrodynamic Model Domain (DFM) covering southwest Western Australia.

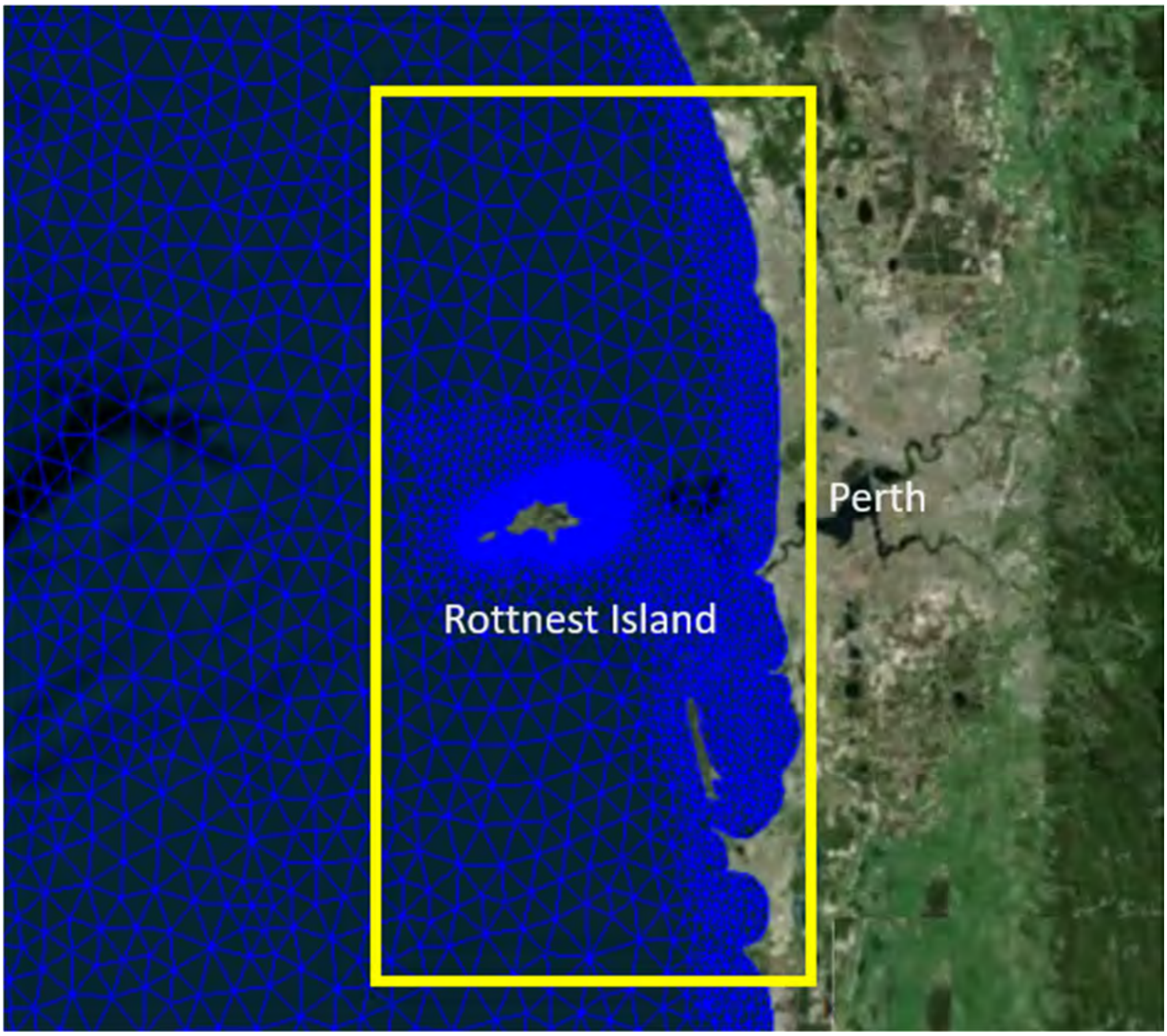

Figure 4.2: Local scale Delft3D model area (Yellow Rectangle). The boundary conditions for the local model are defined from the Regional model along the domain open boundaries.

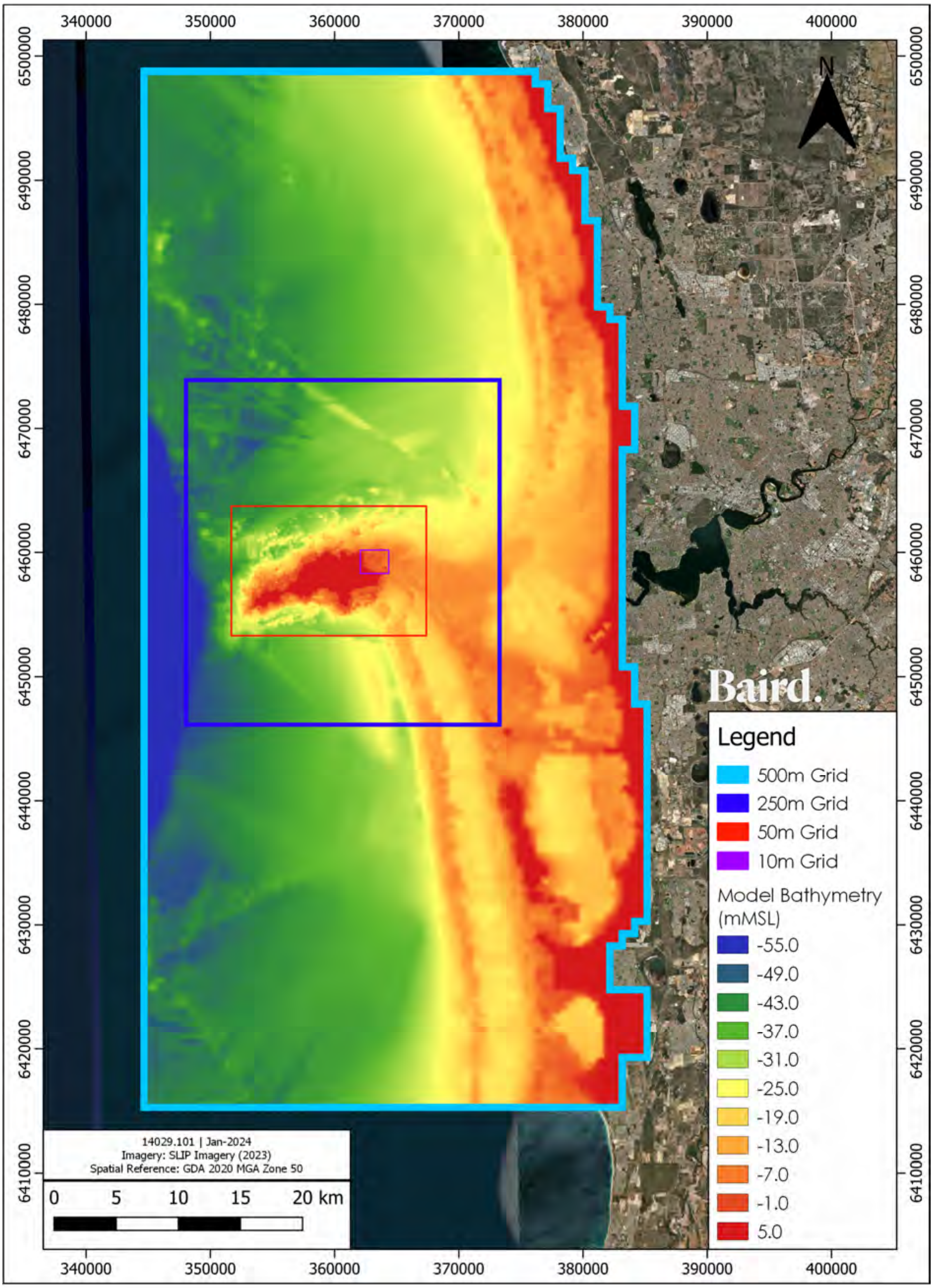

Figure 4.3: Local Delft3D Hydrodynamic Model grid setup applied for dredge plume modelling.

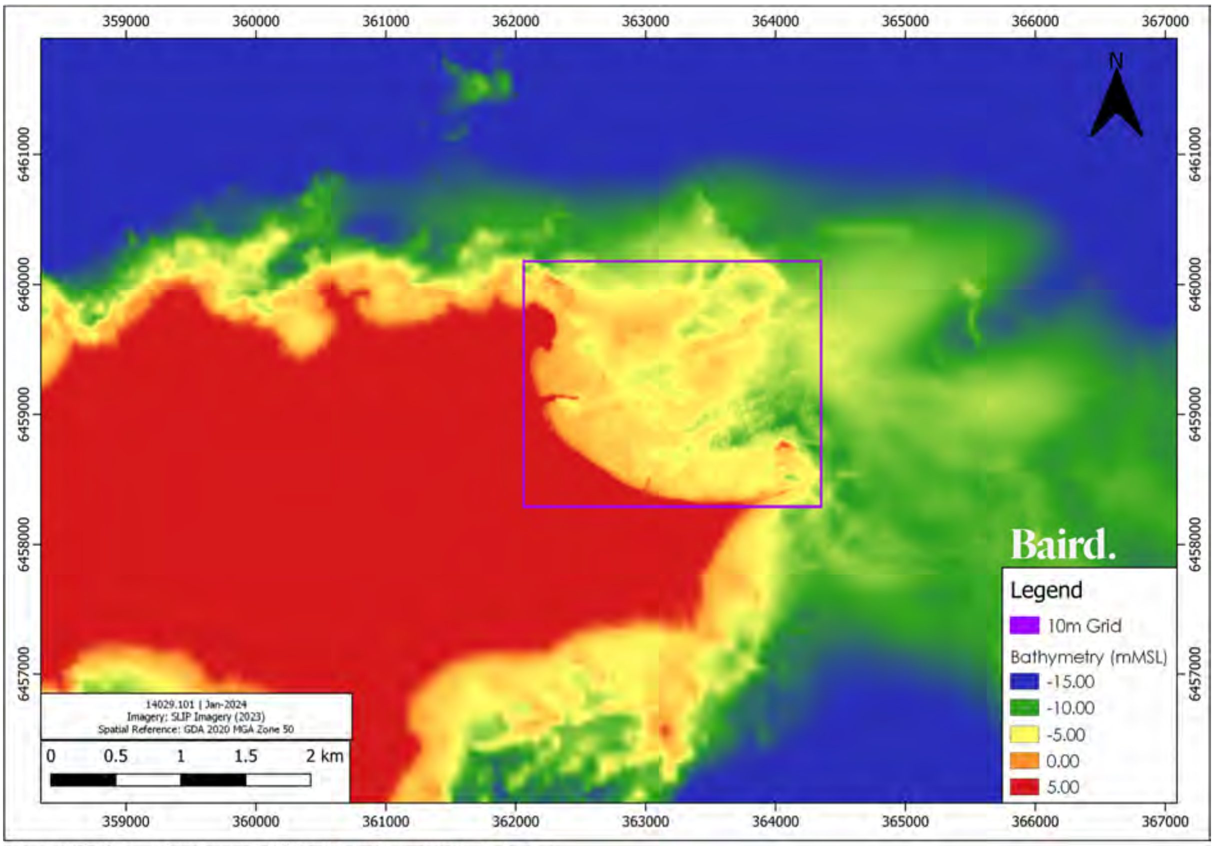

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Figure 4.4: Local Delft3D Hydrodynamic Model grid setup applied for dredge plume modelling, zoomed into the smallest grid (10m x 10m grid resolution) at South Thomson Bay.

4.2 Validation of Regional Model

Baird's regional scale hydrodynamic model has been applied in numerous projects across the southwest of Western Australia and comparison of the modelled water levels against the predicted astronomical tide at standard port locations across the south-west region shows very good agreement to tidal constants in both amplitude and phase.

A comparison of the modelled water level against predicted water levels (based on tidal constituents) for the full year of 2011 are shown in Figure 4.5. The modelling undertaken for this full year signal was carried out for a previous project, with the model validation undertaken for that project shown here to demonstrate the high level of accuracy that use of this regional model brings to this dredge plume model program. The comparisons for port locations nearby the South Thomson Bay site at Hillarys, Jurien Bay, Lancelin and Two Rocks Marina show excellent agreement.

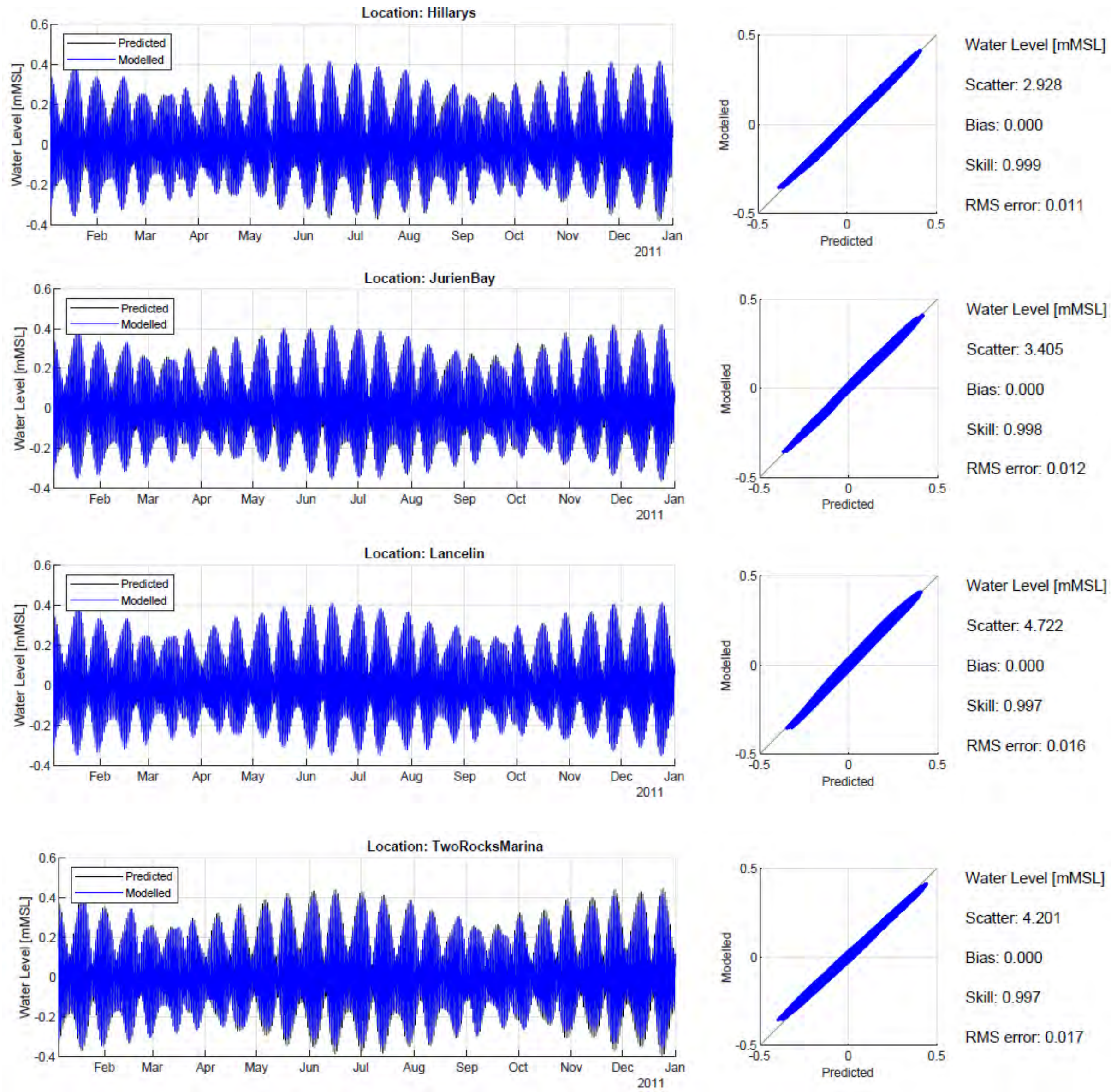

Figure 4.5: Regional Model Tidal Validation at nearby Port locations

The regional scale model was updated and executed over the 2018 – 2019 period to coincide with the metocean data collection campaign by Water Technology (2020). The regional model uses the TOPEX8 tidal constituents on the boundary with spatial wind and pressure fields from the NCEP Climate Forecast System (CFSR) updated across the model domain hourly throughout the entire model period.

4.3 Validation of Local Model

It is noted that the coupled hydrodynamic and wave model detailed in this report will be used as a basis for assessing impacts from dredging at the proposed South Thomson Bay barge facility site, which has been modelled based on the schedule related to the dredging of P50 rock and BH EX05 dredging plant referenced in i2D (2023) over a period of 7.5 weeks. Validation of the model has been completed for the winter of 2020, when measured data is available for both currents and waves, in this report.

The validation for both the hydrodynamic and wave model components of the coupled model has been undertaken over a 7.5-week period in the Winter where contemporaneous data was available from both the offshore and inshore locations (Aquadopp within South Thomson Bay and Rottnest DWR offshore of Wadjemup respectively).

The adopted period was:

- Winter: 16 July 2020 – 16 August 2020 with model warm-up period of 2 days prior.

The metocean data collection, detailed in Section 2.1, provides measured winds, waves, currents and water levels covering the validated model period. The selected date range for the modelled season validation period corresponds with a time where metocean data is available from both inshore and offshore sites (**Figure 2.2**) and where two full spring tides and two full neap tide cycles are completed through the duration.

For the validation of the model, the modelled and measured data is presented as graphical times series in the sections to follow.

4.3.1 Model Validation – Water Levels and Currents

The comparison of the modelled data against the measured data for the current speed (depth averaged) and direction is shown in Figure 4.6 for the nearshore location (Aquadopp Instrument). The current speed and direction components are separated into the X and Y components (U and V current) for the analysis shown in Figure 4.6.

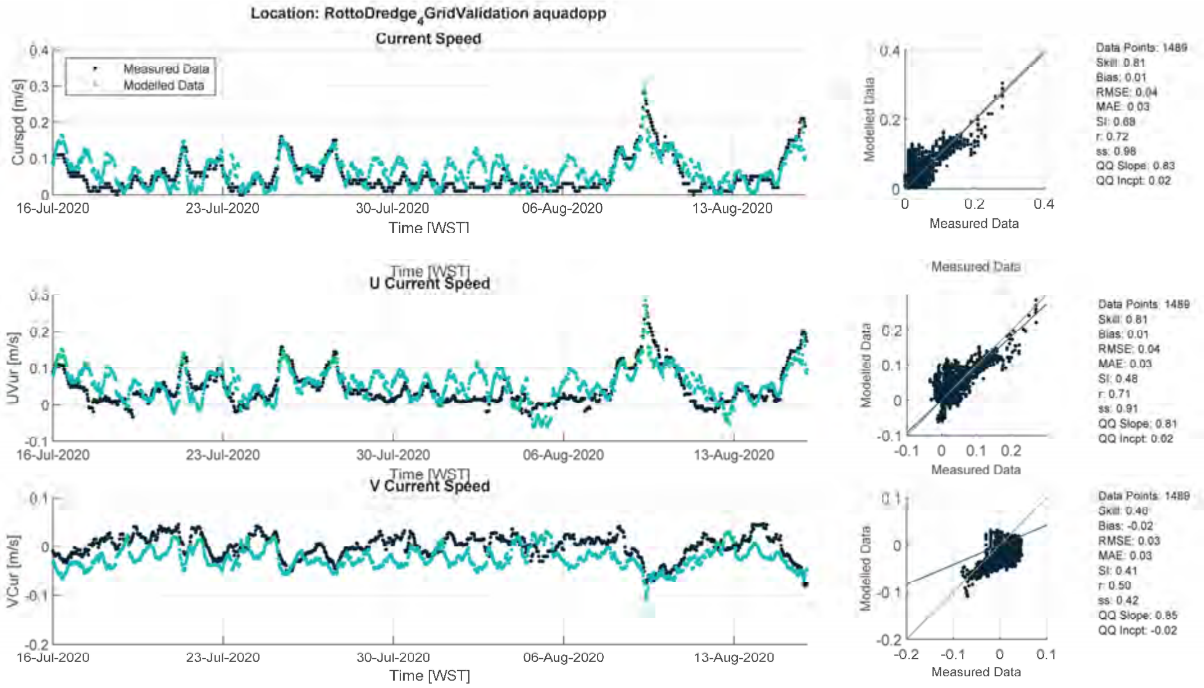

Figure 4.6: Comparison of Inshore Location Measured vs Modelled Data for Depth Averaged Current. Winter Validation Period, 16 July 2020 – 16 August 2020.

The model metrics have been calculated for the current speed and direction components (including X and Y directionality) against the measured data in the model cases presented in Figure 4.6 and are presented in Table 4.1.

Table 4.1: Model Metrics for depth-averaged current velocity, X axis and Y axis Current.

Location	Component	Skill	Bias	Scatter	RMS Error
Offshore Location Aquadopp WINTER	Current Velocity	**0.81**	0.01	0.68	0.04
	Current x axis (E-W)	**0.81**	0.01	0.41	0.04
	Current y axis (N-S)	**0.48**	-0.02	0.41	0.04

The measured current speeds within South Thomson Bay are very low, tending to a value less than 0.1m/s throughout the month of calibration. There is a build-up to a peak current speed value of approximately 0.3m/s on 11 August, and several lower peaks in the range of 0.2m/s. The Baird model current speeds match these higher peak values closely. For prolonged periods in the measured data (eg 30 July to 6 August) the current speed is negligible (<0.05m/s) and during these times of very low current the Baird modelled currents are higher by 0.05 to 0.1 m/s. This small over prediction of model current is not considered material for the application in the dredge plume modelling. Overall, the model skill for the current velocity over the four-week calibration period is good (0.81) and the bias is low (+0.01).

The extremely low current velocity presents difficulty in getting a close match in the current directions (indicated by the U and V current speeds in Figure 4.6). The model has the most difficulty with describing the currents in the y/V direction (i.e., in the cross-shore direction within South Thomson Bay) with current speeds consistently +/- 0.05m/s). The predominant direction of current movement is alongshore (i.e., the x/U current direction) with current speeds of up to 0.3m/s). The model is describing this direction well (model skill of 0.81 for U Current Speed) and Baird conclude that this U current which is the most influential on the movement of the dredge spoil are being described well by the model.

Given the low current speeds in this nearshore area, the validation metrics are good for both the current speed and direction, with good model skill and low bias and error metrics, indicating the suitability of this model for modelling of dredge spoil impacts related to the proposed barge facility dredging activities.

4.3.2 Model Validation – Waves

The wave conditions from the SWAN model developed through the winter validation case has been compared against the measured data from both the offshore directional waverider location and the nearshore Aquadopp location (Figure 2.2).

The winter results are compared from the model against the waverider data offshore in Figure 4.7. There is good agreement between the modelled and measured wave data at this location, with good validation metrics across wave height, period and direction.

The model results have also been compared to the measured data at the nearshore aquadopp location in South Thomson Bay, shown in Figure 4.8. There is also good agreement here between the modelled and measured wave data for this nearshore location, with consideration to be made of the complex nearshore reef structures that influence the transformation of waves from the offshore to the nearshore environment in this area. Note should be made that there has been discussion around the accuracy of the wave directions across the measured data campaign used in this validation analysis, with the modelled wave direction seen in the model sitting relatively consistently within the NNW sector, while the Water Technology (2020) measured data oscillates between the NNE to the NNW.

Comparison can be made to wave model validation completed for previous work within Thomson Bay in Baird (2025) at the Department of Transport's directional AWAC measurement point sitting approximately 200m north of the aquadopp site, shown in Figure 4.9. This location shows a good comparison of wave direction largely coming from the NNW in both the measured and modelled data, further supporting the assumption that wave directions in the Water Technology (2020) data measured at the aquadopp may be erroneously biased towards the NNE.

Inclusion of the AWAC data from 200m north of the South Thomson Bay site shows that waves are generally approaching this site from the NNE, even at this site that is further offshore and in an area more geomorphically predisposed to wave directions from the full range of potential wave directions (See Figure 2.1). The location of the Aquadopp at the Barge Landing site is such that the geomorphic features, and where it sits within South Thomson Bay, would lead to the transformation of offshore waves to largely approach the site from the N or NNE, rather than from the NNW direction that is shown in the measured data. This discrepancy in the measured wave directions between these two site has led Baird to believe that there may have been a deployment or processing error in the Water Tech data leading to the reporting of the predominant wave direction to come from the NNW. In line with this, as the model is predicting waves to come largely from the expected direction (NNE) Baird see that the model is reproducing the wave climate well and can be expected to predict the wave impacts on the dredge plume correctly.

While there is a slight overprediction of the wave height at the AWACR1_02 location, the wave height prediction at the location nearest the barge development (Aquadopp) are very close (within +/- 0.1m), indicating that the modelled waves both offshore and within the bay are well suited to apply to the dredge plume modelling cases for the dispersion of dredge spoil.

The model metrics have been calculated for the wave height, period and direction components against the measured data in the model cases presented in Figure 4.7 and Figure 4.8 and are presented in Table 4.2, showing overall good agreement between the measured and modelled data, indicating that the wave model component of the coupled hydrodynamic and wave system is suitable for modelling the dredge spoil impacts related to the proposed barge facility dredging activities.

Table 4.2: Model Metrics for wave height, period and direction for the Rottnest DWR and Aquadopp locations

Location	Component	Skill	Bias	Scatter	RMS Error
Offshore Location DWR	Wave Height	**0.98**	-0.11	0.07	0.18
	Wave Period	**0.90**	-0.10	0.10	1.42
	Wave Direction	**0.91**	2.69	0.03	6.55**
Nearshore Location Aquadopp	Wave Height	**0.88**	-0.02	0.16	0.08
	Wave Period	**0.36***	-0.25	0.24	3.48

* Note that while the wave period skill appears to be relatively low, this is due to the strong scatter in wave periods seen in the measured data. Overall patterns of sea and swell wave period across the measured data are replicated in the modelled data, ensuring that both energy types are reproduced in the model.

** note that this RMS error appears to be relatively high but is due to the relatively narrow band of directions the waves are arriving from at the RDWR (largely around 240-280 degN) and the large number of datapoints in the measured data signal.

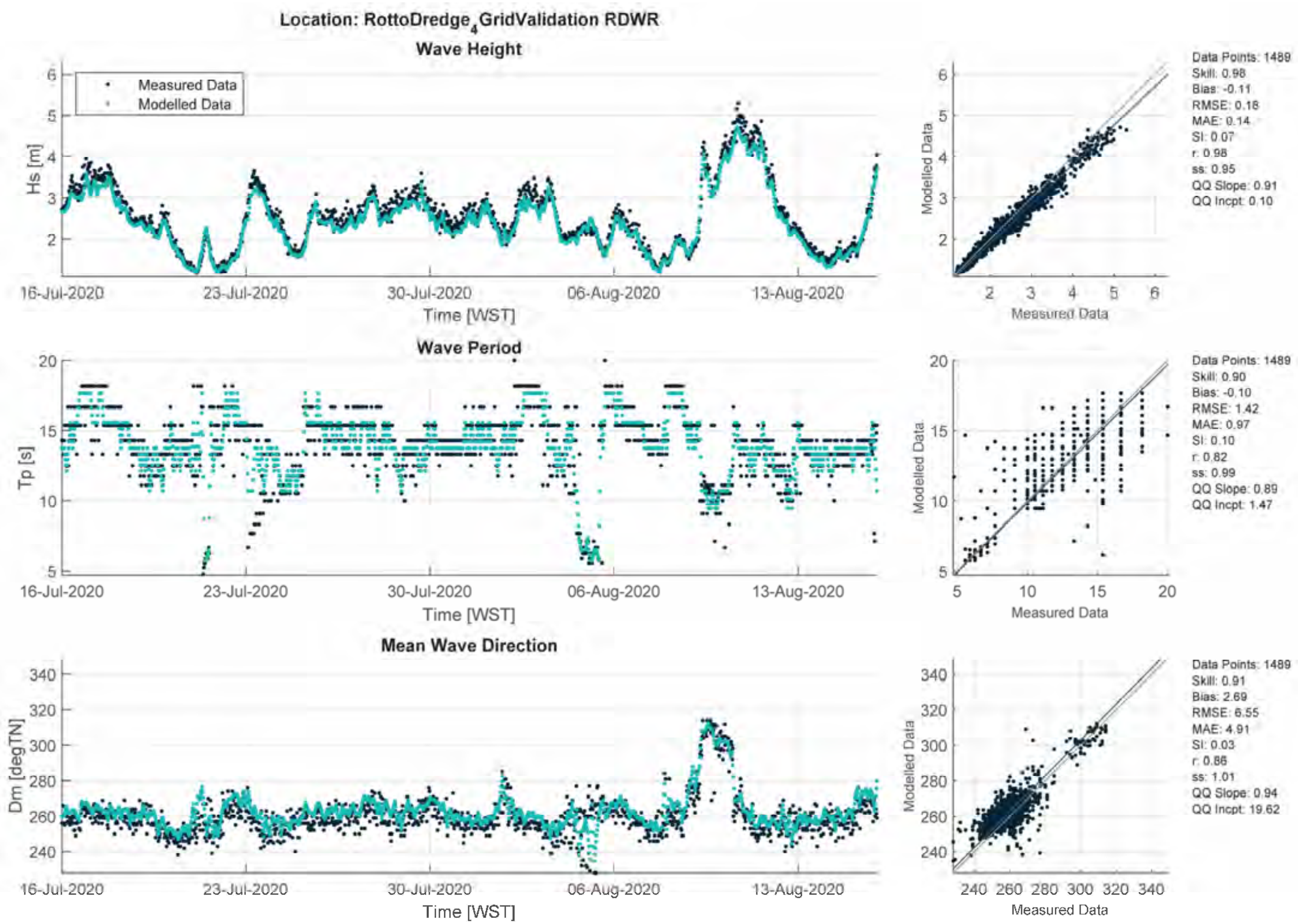

Figure 4.7: Winter Validation Case - Comparison of Wave Data Measured vs Modelled at the Rottnest Directional Waverider Buoy

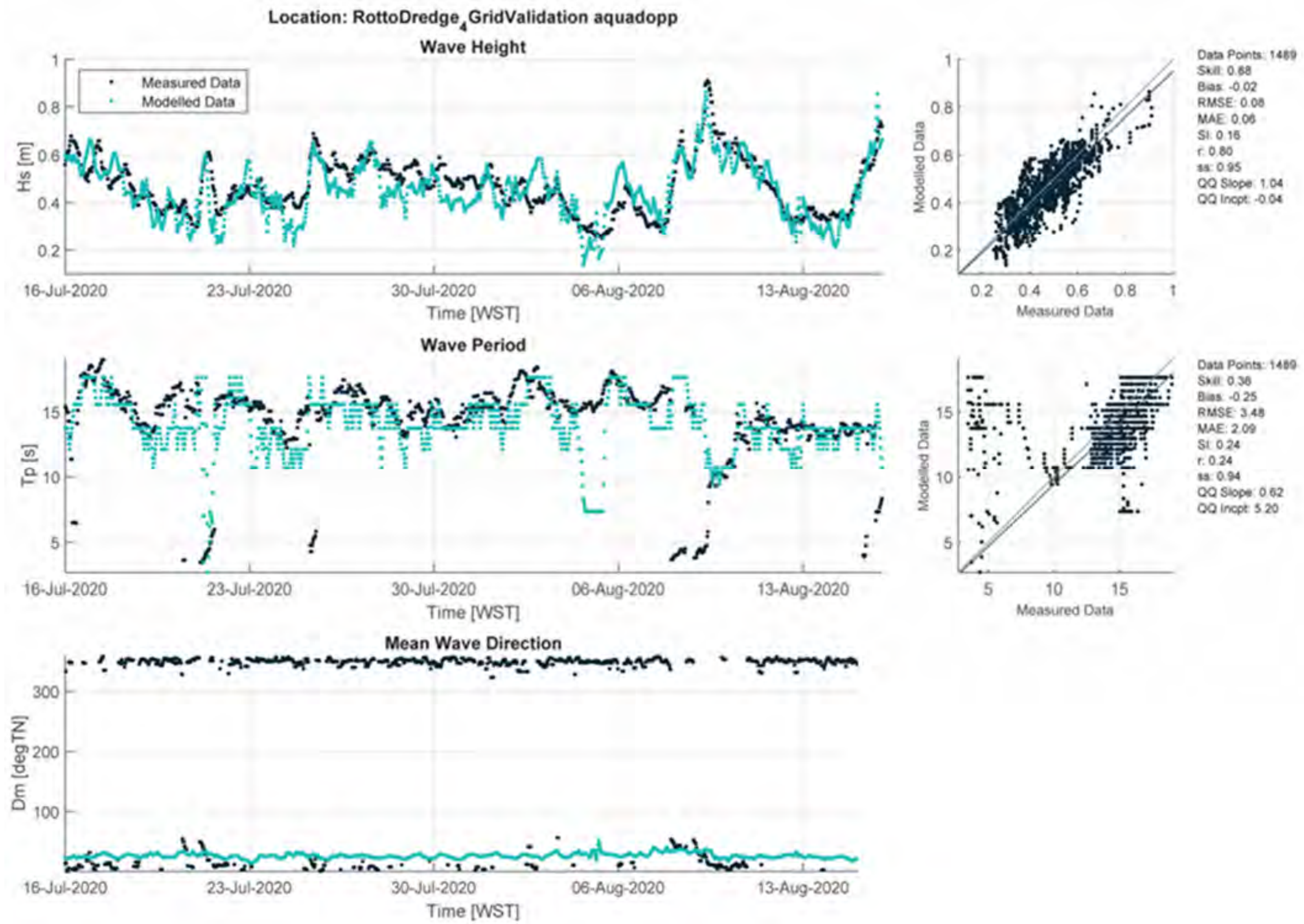

Figure 4.8: Winter Validation Case - Comparison of Wave Data Measured vs Modelled at the Aquadopp Location. Directional statistics are not included due to the uncertainty around the accuracy of the direction reported in the measured data.

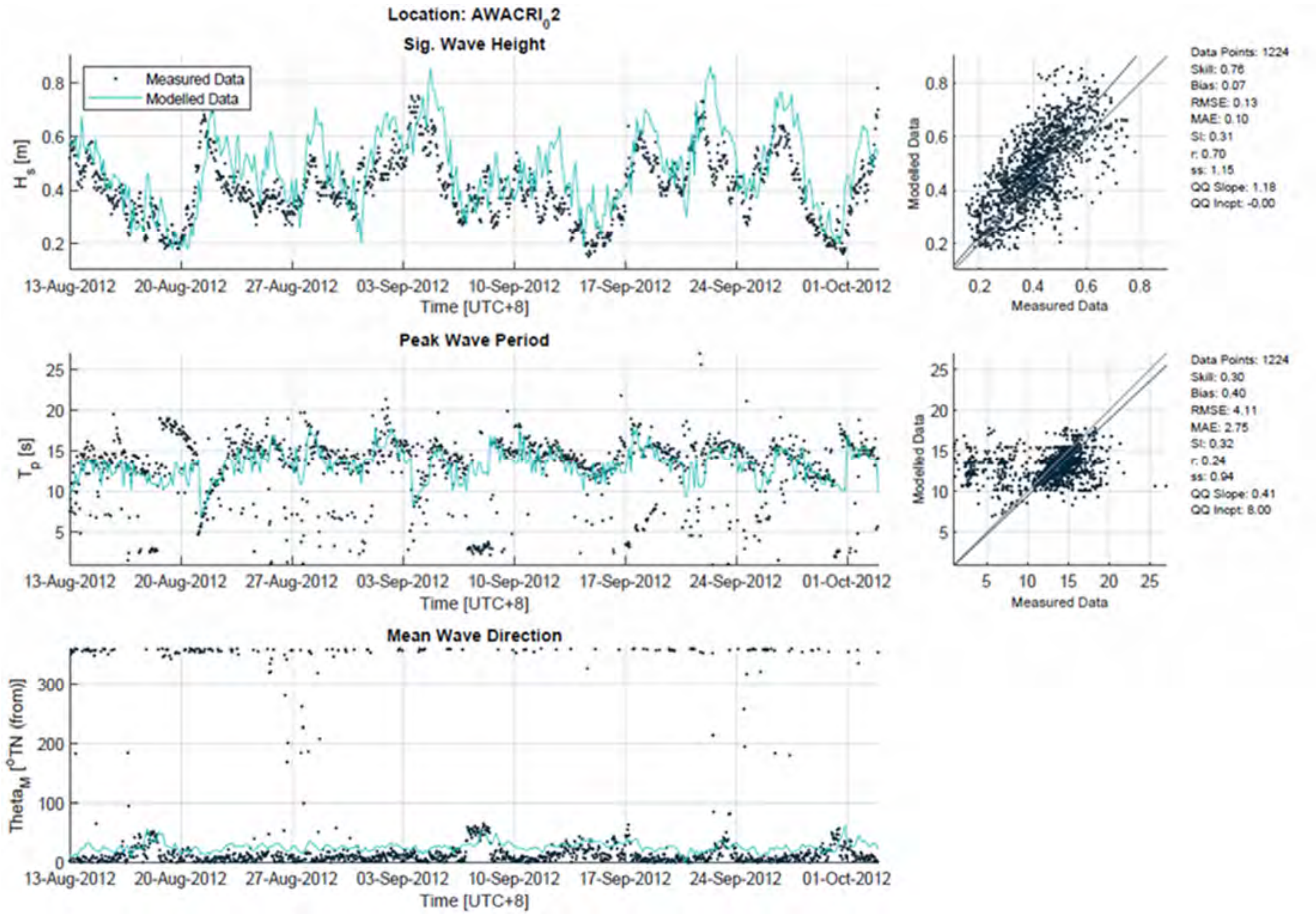

Figure 4.9: Winter Validation Case Previously Completed for 2012 - Comparison of Wave Data Measured vs Modelled at the AWACR1_02 Location

4.4 Dredge Plume Model Setup

Following validation of the coupled hydrodynamic and wave model, as presented above, the model system was updated to include the sediment transport module required to input sediment source terms to the model, as well as to run the inner grid (covering Thomson Bay where the dredge plumes will be generated) in 3D to allow for determination of the impacts of vertical sediment transport as well as horizontal.

Sediment inputs to the model have been schematised based on the dredging program outlined in Section 3.3 and the sediment fractions defined in Table 3.5, and the sediment transport module has been activated in the model to allow for inclusion of this parameter in the dredge plume modelling.

4.4.1 Sediment Transport Model - Delft3D Morphology Module (Online-MOR)

The Delft3D Online Sediment model (Online-MOR) is used to investigate the transport and fate of sediments released into the water column through the dredging program. The sediment transport module is part of the Delft3D suite developed by Deltares in the Netherlands and designed to simulate sediment transport of non-cohesive (sandy) or cohesive (silt) sediments under combined processes of wave propagation, currents and morphological developments in coastal, river and estuarine areas (Deltares 2020).

The Delft3D model system is one of the passive plume models reviewed in Sun et al (2016) and the model has been applied in similar dredging studies completed in Western Australia and many locations globally. The passive plume dispersal is managed through three separate model components, namely a hydrodynamic model, a sediment transport model and surface wave model. The validated Delft3D hydrodynamic and wave model system outlined in Section 4.1 has been adopted as the platform for hydrodynamics and waves, with the sediment transport module (Online-MOR) activated to investigate the release of sediments from dredge plume sources (mobilisation of fine material by the action of the BHD operations) and examine the diffusion, dispersion and resuspension processes of the plume.

The sediments released through the dredging program are assessed in the model in three sediment fractions –coarse silt, fine silt, and clay as discussed in Section 3.

4.4.2 Summary of Dredge Plume Model Parameters

An overview of the key model settings and characteristics is provided in Table 4.3.

Table 4.3: Delft3D Dredge Plume Model Settings

Feature	Description
Grid size / type	Domain Decomposition - Regular Grids at: - 500m - 250m - 50m - 10m
Grid Extent	Outer Grid: 84km x 40km
3D sigma layer model	Inner (10m) grid: 5-vertical sigma layers with layer thicknesses of 20% all the way through the water column.
Vertical Datum	Mean Sea Level (m MSL), 0.68m CD at Thomson Bay
Horizontal eddy diffusivity coefficient	Across the DD Grids 500m / 250m / 50m / 10m: 50 / 25 / 1 / 1 m^2/s

Feature	Description
Horizontal eddy viscosity coefficient	Across the DD Grids 500m / 250m / 50m / 10m: 50 / 25 / 1 / 1 m^2/s
Vertical eddy viscosity / diffusivity	k-ε turbulence closure model
Time step (3D sigma-layer)	0.1 mins (6 secs)
Bed friction	500m, 250m Grids: Chezy $65m^{1/2}/s$ 50m, 10m Grids: Chezy $55m^{1/2}/s$
Sediments Specific Density	2,650 kg/m^3
Fine Sand	D_{50} = 0.200mm, Dry Bed Density 1600kg/m^3
Silt	Settling Velocity 1.7mm/s, Dry Bed Density 500kg/m^3
Fine Silt	Settling Velocity 0.06mm/s, Dry Bed Density 500kg/m^3
Van Rijn's reference height factor	1
Threshold sediment thickness	0.005 m
Critical Bed Shear Stress for Sedimentation	0.1 N/m^2
Critical Bed Shear Stress for Erosion	0.5 N/m^2
Background Suspended Sediment	Modelled as zero. Background SSC is added into model results in post processing (refer Section 5)
Loss rate of dredged sediment to the water column.	The BHD will lose 2% of fine sediments (fine sand, silt) by volume in the process of raising the bucket from the seabed to the hopper. This is input to the model by volume as: • 40% at the bed layer • 30% at mid layer • 30% at surface layer The overflow loss from the hopper is assumed at 2.81% of the fine sediments (fine sand, silt). This is input to the upper layer of the model based on production rate.
Vertical distribution of sediment initially suspended in the water column (prior to far-field dispersion and settlement).	Assumed background SSC is 3mg/L. (Refer Section 5.1)

5. Modelling Outcomes

5.1 General Plume Behaviour

The overall current direction trend from west to east along Thomson Bay has had an impact upon the dredge plume generated in the modelling program, with plumes generally directed east along South Thomson Bay away from the existing Army Groyne, with occasional periods of direction change directing the plume west and around the Army Groyne. This is demonstrated in the spatial plots taken from specific points in time shown in Figure 5.1, with plots shown at three hourly timesteps from 26th June 2020 18:00 to 27th June 2020 3:00. These plots show the plume being directed strongly to the east away from the Army Groyne (top left) in the middle of a flood tide, less strongly away from the Army Groyne (top right) as the flood tide gets closer to its peak water level, directed weakly to the west around the Army Groyne (bottom left) as the flood tide is close to its peak water level and remaining close to the point of discharge in the peak of a tidal cycle as the tide turns from flood to ebb (bottom right). This behaviour is observed during both the neap and spring tidal cycles included in the full dredge model program.

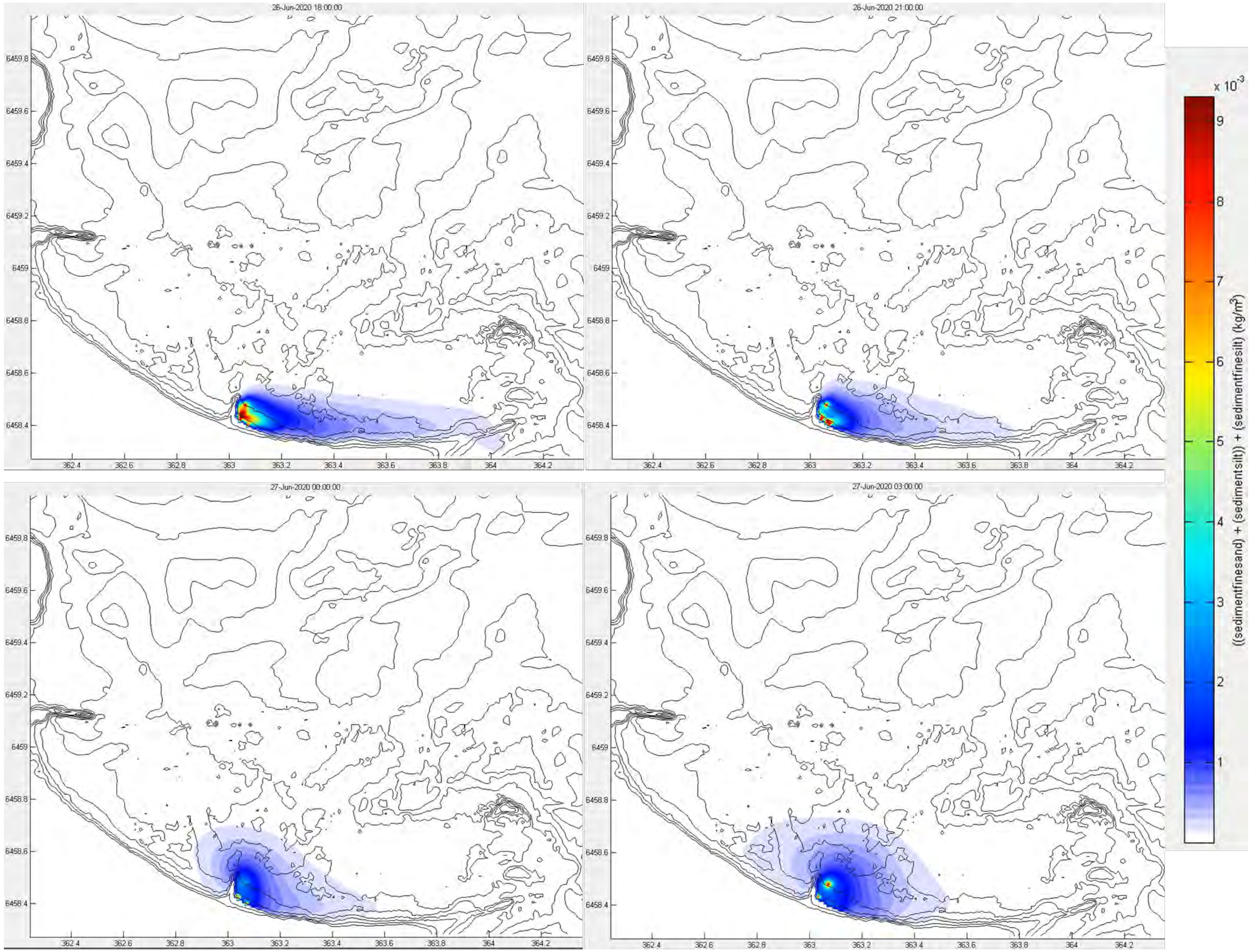

Figure 5.1: Spatial plots at three hourly spaced timepoints in the dredge program model, showing the plume directed strongly to the east away from the Army Groyne (top left), less strongly away from the Army Groyne (top right), directed weakly to the west around the Army Groyne (bottom left) and remaining close to the point of discharge in the peak of a tidal cycle as the tide turns from flood to ebb (bottom right)

5.2 Modelled Time Series Data through the Dredge Program

The modelled dredge sequence was evaluated in one continuous model simulation covering the dredging program based on the assumptions for the BH EX05 and the P50 rock quality (i2D 2023) and being carried out during the winter of 2020.

Timeseries data at four locations (Figure 5.2) in the vicinity of the dredge footprint are presented below, demonstrating the distribution of suspended sediments directly in the vicinity of the Army Groyne and dredge footprint, east along South Thomson Bay away from the Army Groyne, and at the Aquadopp location.

Figure 5.2: Locations where timeseries suspended sediment concentration (SSC) data is presented

5.2.1 Modelled Time Series – Winter

Time series data from the offshore disposal plume models across the 7.5 week winter program has been extracted close to the Army Groyne, two locations east along South Thomson Bay from the Army Groyne, and at the aquadopp location, as seen in Figure 5.2. The modelled SSC from the sediment fractions (sand and silts) for winter are combined in the time series plots shown in Figure 5.3 to Figure 5.6. Background SSC have been applied to the timeseries data from each island according to the chosen background SSC (discussed further in Section 5.3).

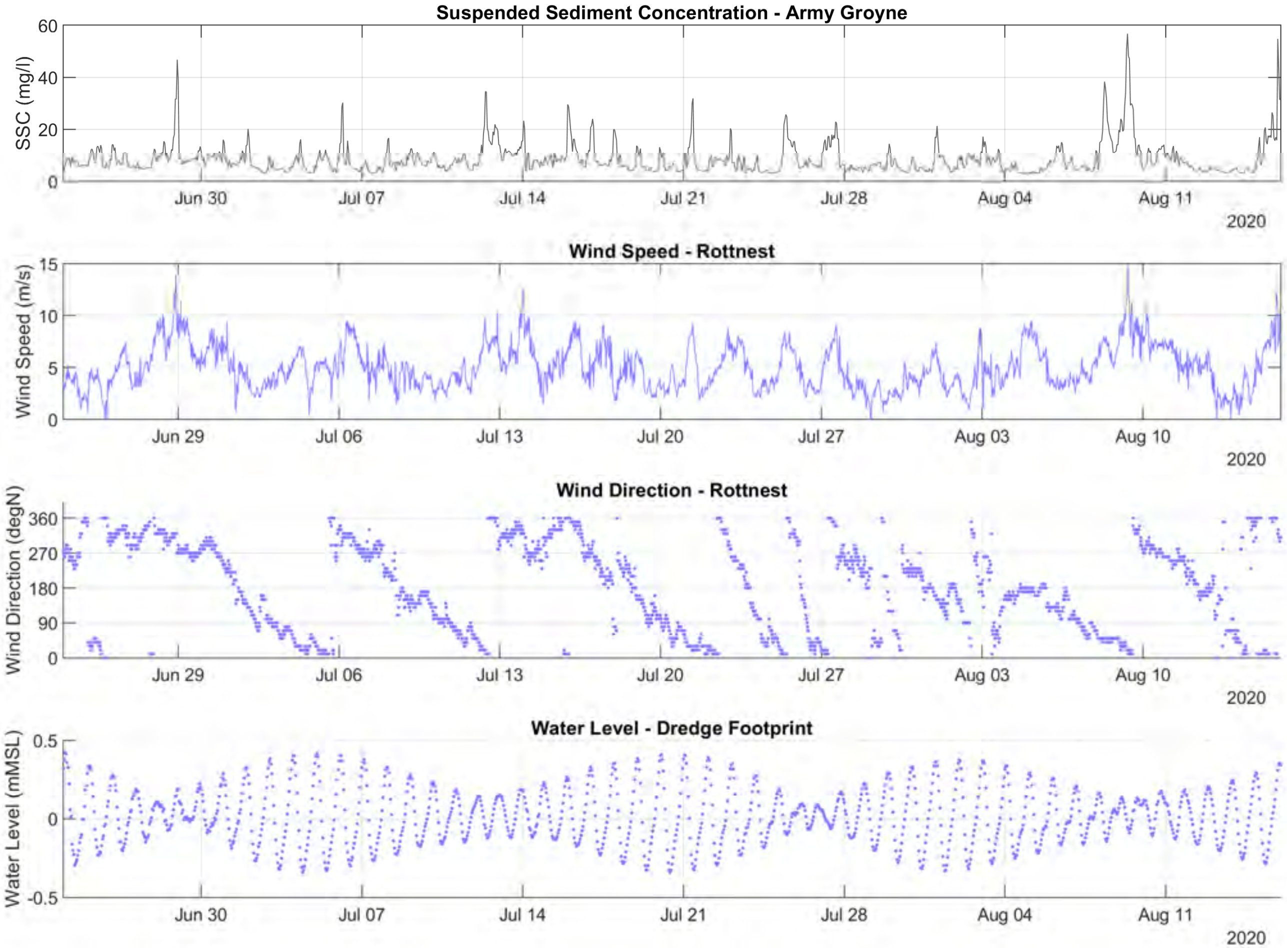

Figure 5.3: Modelled Suspended Sediment Concentration (mg/L) in close proximity to the dredge footprint (Army Groyne) over winter, with associated wind speed and direction and water level at the dredge footprint.

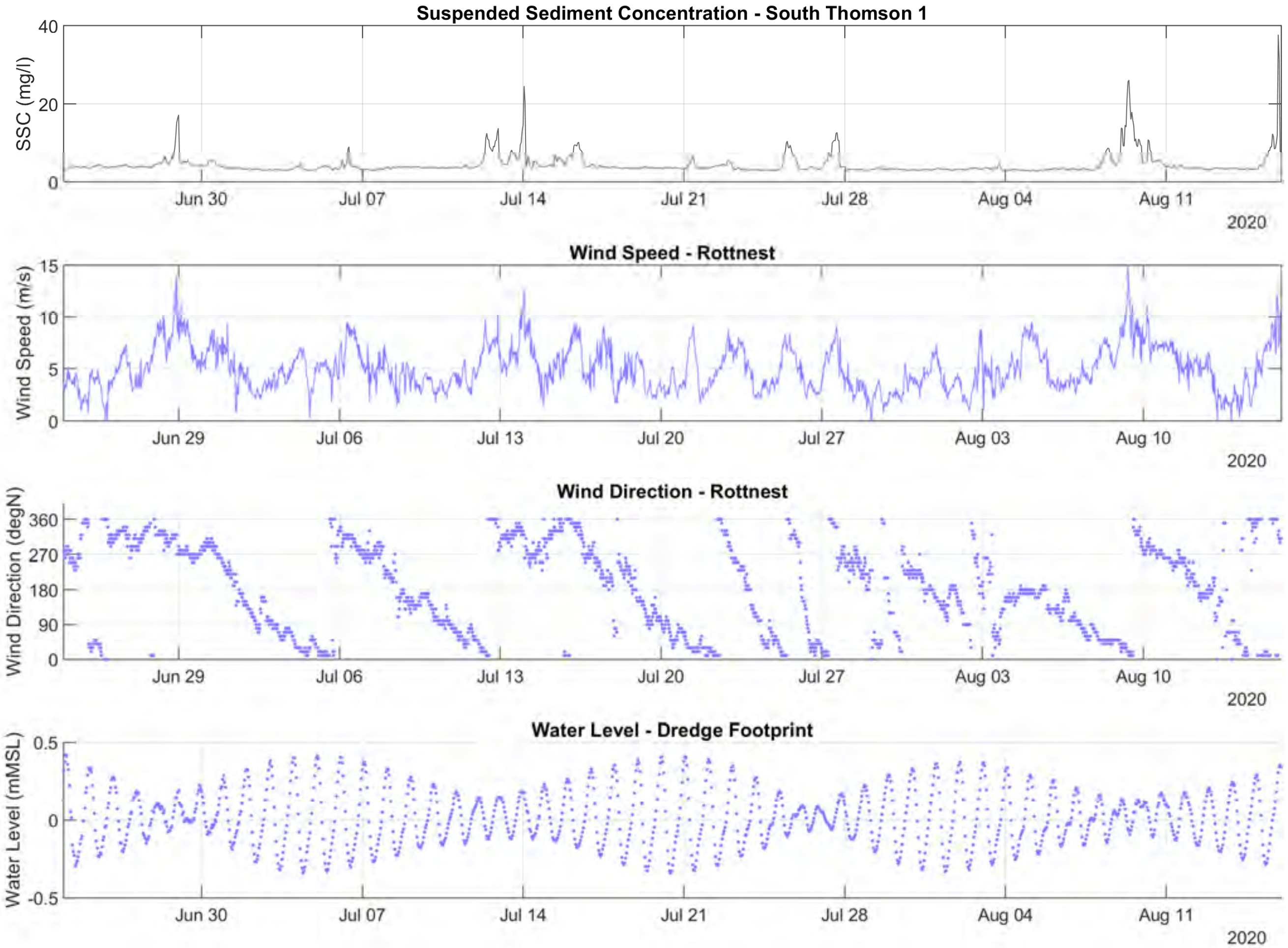

Figure 5.4: Modelled Suspended Sediment Concentration (mg/L) just east of the dredge footprint (South Thomson Bay 1) over winter, with associated wind speed and direction and water level at the dredge footprint.

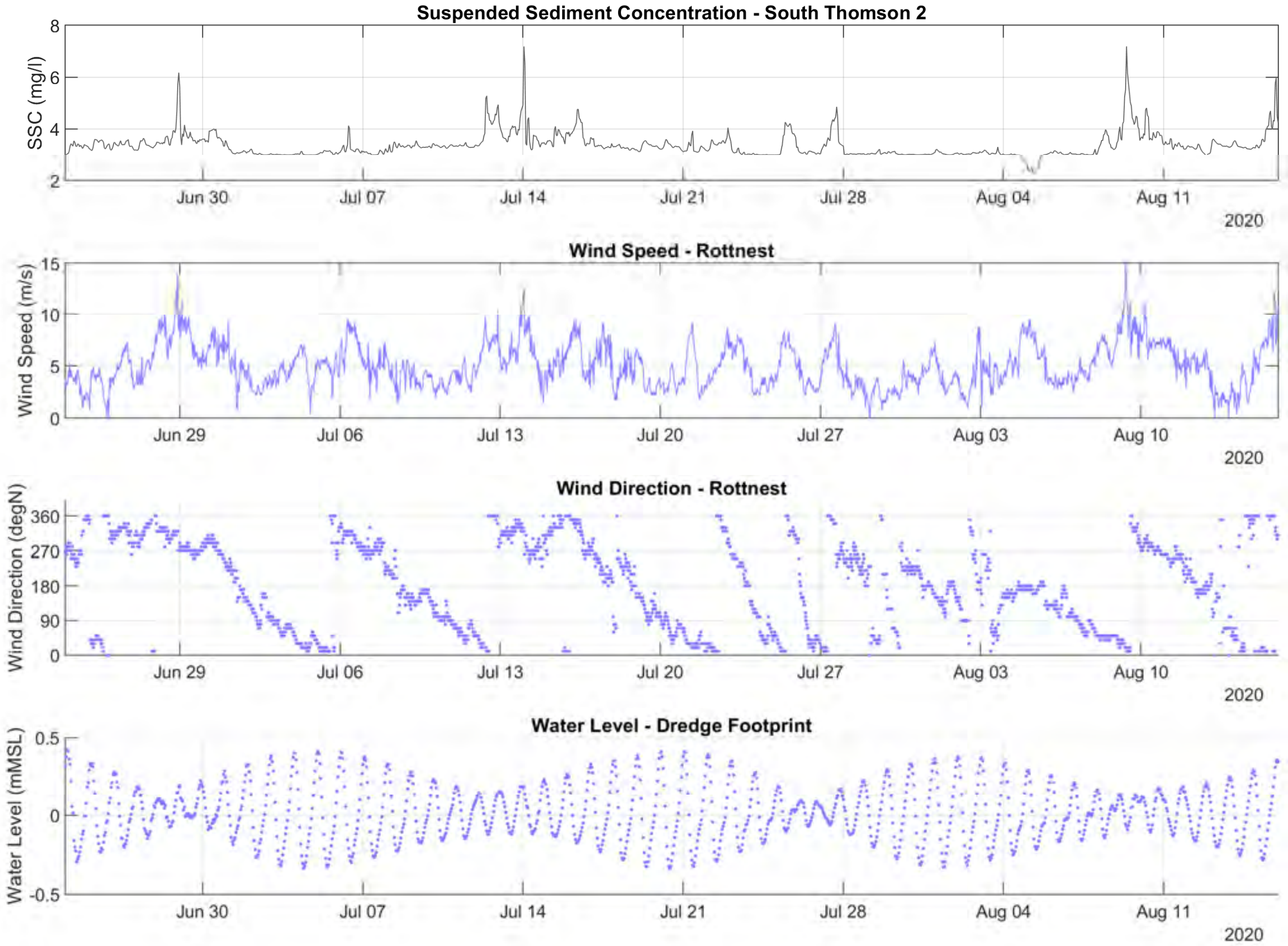

Figure 5.5: Modelled Suspended Sediment Concentration (mg/L) further east of the dredge footprint (South Thomson Bay 2) over winter, with associated wind speed and direction and water level at the dredge footprint.

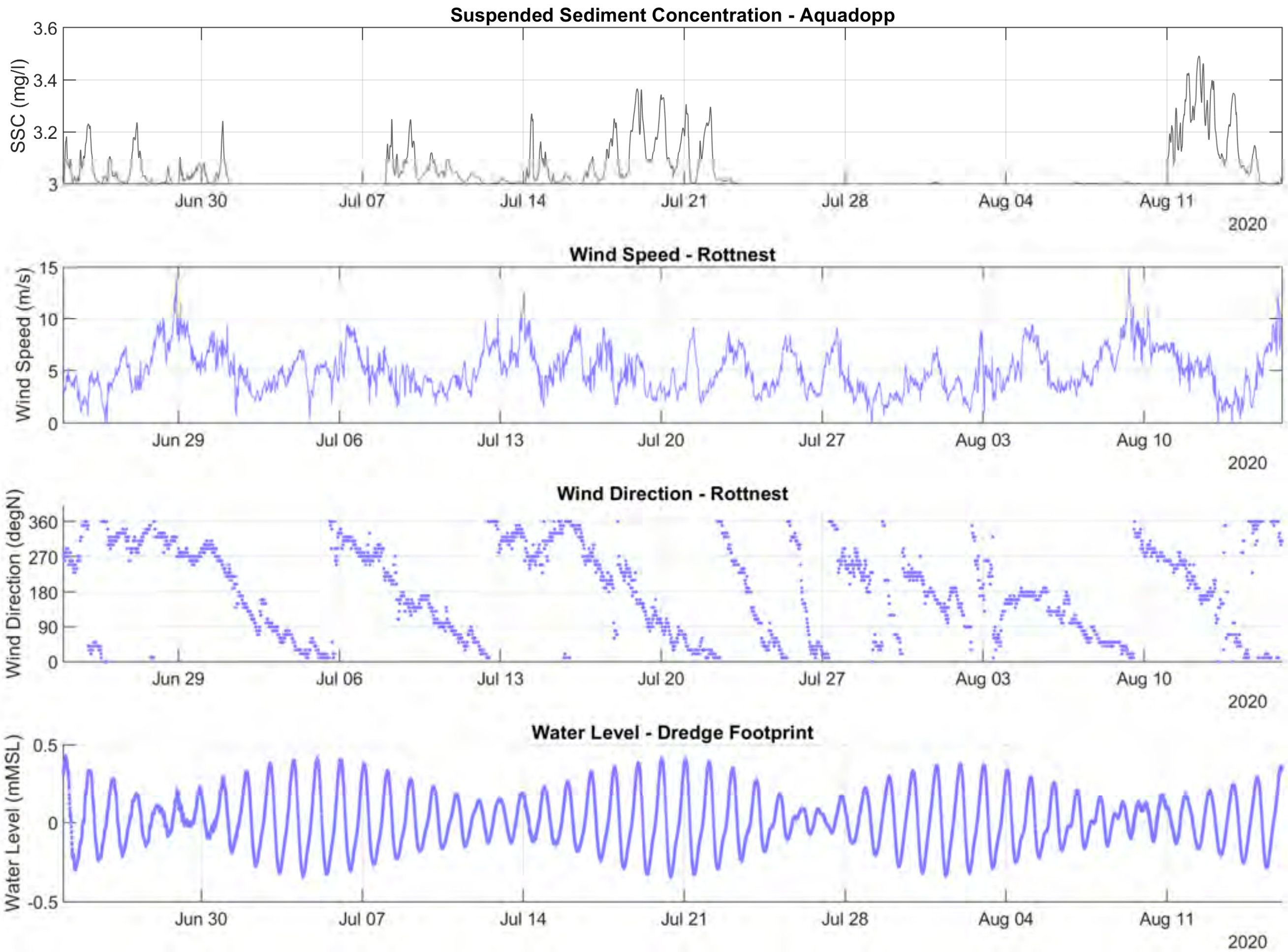

Figure 5.6: Modelled Suspended Sediment Concentration (mg/L) immediately north of the dredge footprint (aquadopp) over winter, with associated wind speed and direction and water level at the dredge footprint.

5.3 Background Suspended Sediment Concentration

The dredge plume model simulations were executed with no background suspended sediment concentration (SSC) and the raw model results represent excess above the background SSC. For the analysis of the model results and predicted extent, severity and duration of dredging impacts a background SSC was applied in the post processing of results.

As there is no long-term dataset available within Thomson Bay to determine the most appropriate background SSC to use during a winter dredging campaign, analysis has been made of data available offshore of Wadjemup and at a location closer to shore within Cockburn Sound to make an estimate of the most appropriate background SSC to assume for this investigation.

Data from the Rottnest IMOS National Reference Station (NRS) provides measured total suspended solids (TSS) offshore of Wadjemup, in approximately 35m water depth (Clementson et al 2020). The values included in that study are shown in the plot in Figure 5.7, with the range of measured TSS following normalising using a blank sample (orange line) sitting between 0.5 mg/L and 3.5mg/L.

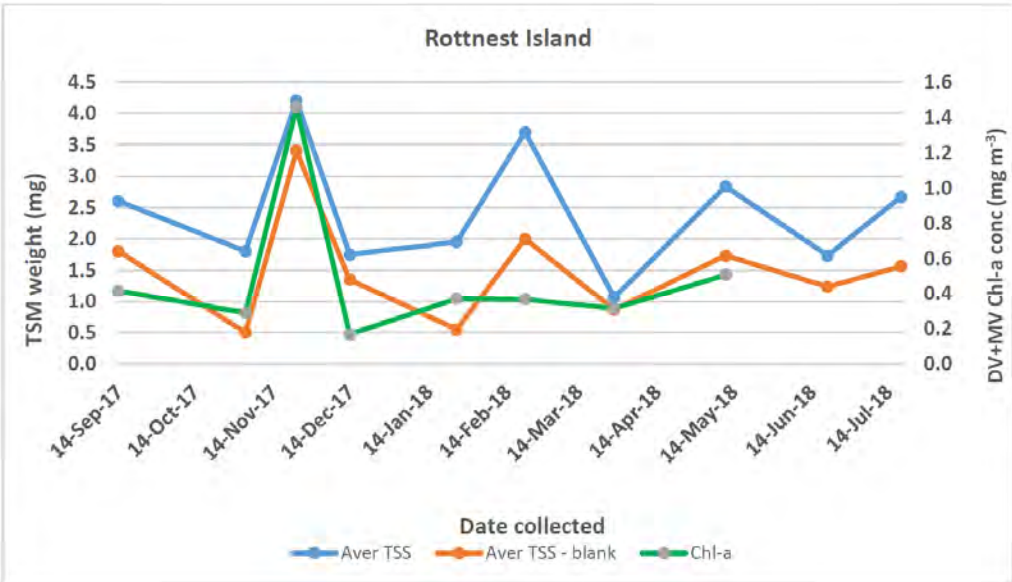

Figure 5.7: Average post-July 2017 TSM values with (orange line) and without (blue line) correction for the blank at Wadjemup between September 2017 and July 2018 (Clementson et al 2020)

Data from Cockburn Sound has been taken from an analysis of TSS data measured at the Perth Seawater Desalination Plant (PSDP) in approximately 10m water depth (Cockburn Sound Management Council 2023). The values included in that study are shown in Figure 5.8, with the range of TSS sitting between 2.5mg/L and 6.5mg/L.

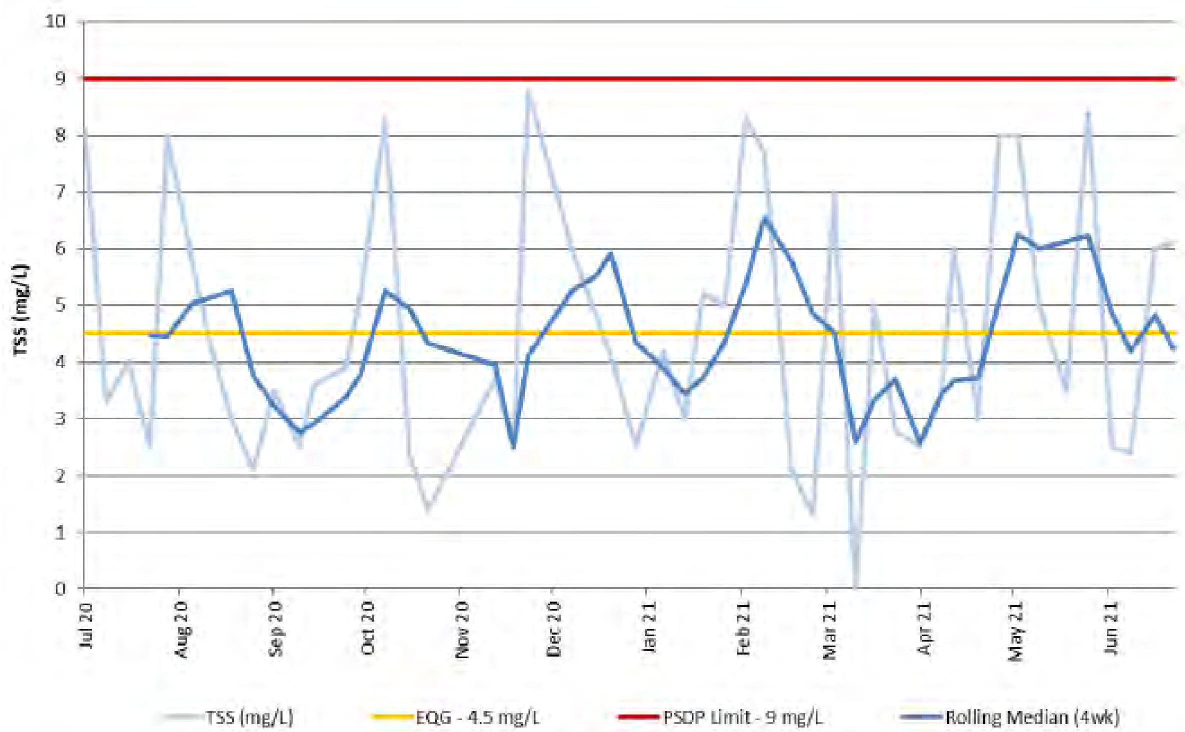

Figure 5.8: Weekly and rolling four-weekly median total suspended solids (TSS) concentration in the intake seawater for the Perth Seawater Desalination Plant between July 2020 and June 2021 (Cockburn Sound Management Council 2023)

Comparison of the PSD analysis of data collected in South Thomson Bay by Douglas Partners in 2019 and data collected in Cockburn Sound as part of the PSDP study in 2021 shows that the average fines percentage in South Thomson Bay sits at 2.2%, while the average fines found in Cockburn Sound sits at 27%. When this analysis is taken to just look at the clay fraction, South Thomson Bay experiences 0% clay, while Cockburn Sound experiences 46% clay.

In line with this, while the Wadjemup data is taken from a relatively pristine offshore location and the location within Cockburn Sound where the TSS data was collected may seem to be a more representative location for South Thomson Bay (e.g., closer to shore), it can be seen that sediments close to shore within South Thomson Bay contain much less fines than Cockburn Sound and so a background SSC value between those measured offshore of Wadjemup and within Cockburn Sound will be the most appropriate for this study. The background SSC value chosen is 3mg/L and has been used for the timeseries analysis presented in Section 5.2.1 and the spatial plots presented below in Section 5.5.

This SSC value is considered a suitably conservative assumption. The waters around Rottnest are reported to have low turbidity, however wave and current resuspension of sediments in the nearshore environment in South Thomson Bay may lead to higher SSC in the water column under certain conditions. For this reason, the conservative assumption of higher SSC within the bay rather than the value from the offshore IMOS location is considered appropriate.

5.4 Zones of Impact Calculation

The EPA has developed a spatially based zonation scheme for proponents to use as a common basis to describe the predicted extent, severity and duration of impacts associated with their dredging proposals (EPA, 2016g). The scheme consists of three zones that represent different levels of impact:

1. Zone of High Impact (ZoHI) is 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.
2. Zone of Moderate Impact (ZoMI) is 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 immediately outside of, the zone of high impact. The outer boundary of this zone is coincident with the inner boundary of the next zone, the Zone of Influence.
3. Zone of Influence (ZoI) is the area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota. These areas can be large, but at any point in time the dredge plumes are likely to be restricted to a relatively small portion of the Zone of Influence.

5.4.1 Calculation Method for Zones of Impact

Consideration of the impacts from the dredge plume modelling on the most important benthic species within South Thomson Bay, seagrass, is calculated in the work carried out by Statton et al (2017) from the Dredging Science Node of the WAMSI via the measurement of Daily Light Integral (DLI), a measurement of the cumulative amount of light that is experienced during daylight hours (EPA 2021). As dredge plume modelling is undertaken by determining the extent of suspended sediment plumes generated via a source of sediment in the water column, a relationship would need to be derived between SSC and DLI to be able to interpret the results of dredge plume modelling and their impact upon seagrass species using the thresholds defined by Statton et al (2017). As this is a highly site-specific relationship (EPA 2021), calculations carried out for other locations would not be suitable for interpretation of the relationship at South Thomson Bay.

In the absence of site-specific measurements to define the SSC and DLI relationship in Thomson Bay, the calculation of the Zones of Impact (ZoI) defined by this study will follow the method of calculation used by BMT (2021a) in their analysis of the dredge plume and passive plume impacts from the placement of dredged sediments on Port Beach. In BMT (2021a), nominal SSC values of 2, 5, 10 and 20 mg/L were selected to define 'visible', 'low risk', 'moderate-risk' and 'high-risk' categories on the basis of site-specific sampling which allowed a relationship between SSC and light attenuation coefficient (LAC) to be derived.

The use of the BMT (2021a) assessment methodology for the South Thomson Bay site in this report is considered applicable in the absence of site-specific data, due to the similarity of the benthic habitat. The site of the BMT (2021a) study at Port Beach exhibits a benthic area largely covered by Posidonia seagrass, the seagrass type which is dominant in South Thomson Bay based on the RPS (2019a) assessment.

For the dredge plume modelling analysis, the nominal values of SSC that would have detrimental impact on local benthic communities and habitat (BCH) (e.g., seagrass species), including the predominant species within South Thomson Bay, Posidonia are adopted as:

- 2 mg/L, approximating a potentially visible plume.
- 5 mg/L, approximating a value that may post a low risk to seagrasses.
- 10 mg/L, approximating a value that may post a moderate risk to seagrasses.
- 20 mg/L, approximating a value that poses a high risk of impacts to seagrass health.

From the above nominal values, the Zones of Influence used within this study are defined in Table 5.1.

Table 5.1: Impact zones, definitions and boundary thresholds (based on BMT 2021a)

Impact Zone	Definition	Boundary Threshold(s)
Zone of High Impact (ZoHI)	The area where impacts on benthic communities and habitats (BCH) 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 the ZoHI.	• Boundary of the dredging and placement area.
Zone of Moderate Impact (ZoMI)	The area within which predicted impacts on BCH are recoverable within a period of five years following completion of the dredging and placement activities. The ZoMI abuts and lies immediately outside of the ZoHI.	• The 95th percentile of the area where a TSS concentration of >10 mg/L was exceeded.
Zone of Influence (ZoI)	The area within which changes in environmental quality associated with turbid plumes are predicted and anticipated during dredging and placement activities, but where these changes would not result in a measurable impact on BCH.	• The 100th percentile of the area where a TSS concentration of >2 mg/L above background was exceeded (representing the maximum predicted extent of visible plumes).

Examples of the analysis for winter of the total SSC and daily running mean SSC against the nominal thresholds outlined above are presented in Figure 5.9 to Figure 5.12, using the chosen background SSC. The locations analysed are the points shown in Figure 5.2 as 'Army Groyne, 'South Thomson Bay 1, 'South Thomson Bay 2' and 'Aquadopp'. From the analysis of these figures:

- The observation location in closest proximity to the dredge footprint, Army Groyne (Figure 5.9), demonstrates the relatively high level of SSC experienced at the dredge footprint, and finds the SSC in this location to exceed the nominal thresholds related to moderate risk (i.e., the 10mg/L threshold that places this location within the ZoMI) and on occasional to high risk (20mg/L). It should be noted that this location is within the buffer zone used for to conservatively apply the boundary of the ZoMI.
- The South Thomson Bay 1 location immediately east of the dredge footprint along South Thomson Bay (Figure 5.10) also experiences occasional periods of exceedance of the nominal thresholds related to moderate risk (10mg/L) and high risk (20mg/L). It should be noted that this location is also within the buffer zone used for to conservatively apply the boundary of the ZoMI;
- The South Thomson Bay 2 location further east of the dredge footprint along South Thomson Bay (Figure 5.11) crosses the two lower thresholds of 5mg/L and 2mg/L, with the 5 mg/L threshold demonstrating that this location may occasionally experience sediment plumes that could pose moderate risk to seagrass.
- The Aquadopp location immediately north of the dredge footprint into wider Thomson Bay (Figure 5.12) only experiences levels of SSC that cross the threshold related to the potential for a visible sediment plume but with no measurable impact on BCH (seagrass).

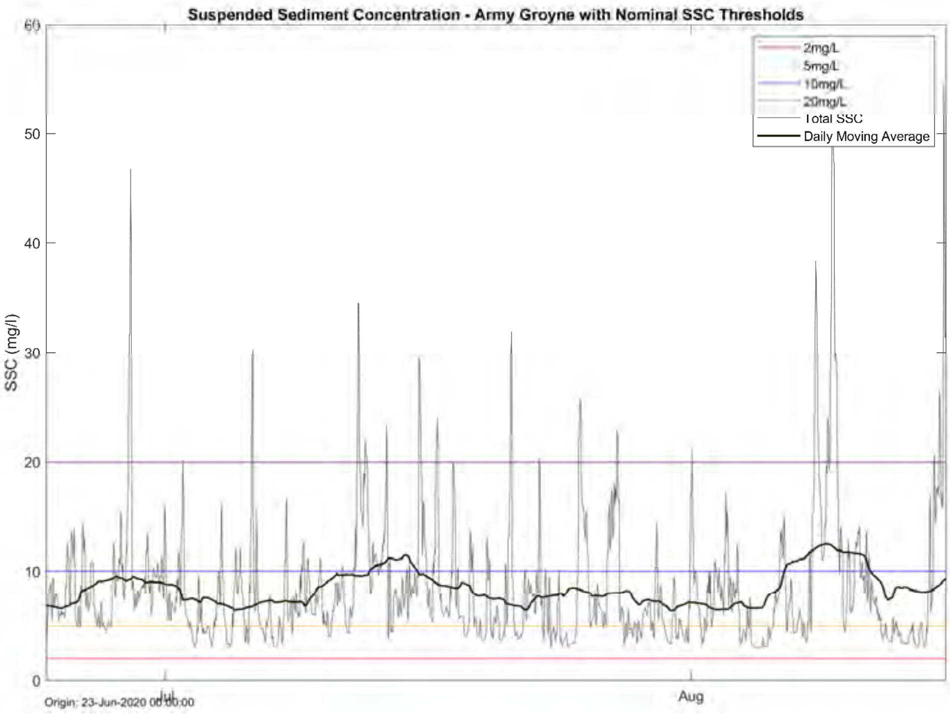

Figure 5.9: Calculation of total SSC and daily mean values of modelled SSC analysed against nominal seagrass impact thresholds (based on BMT 2021a) at the Army Groyne location. Analysis shown for the background SSC of 3mg/L.

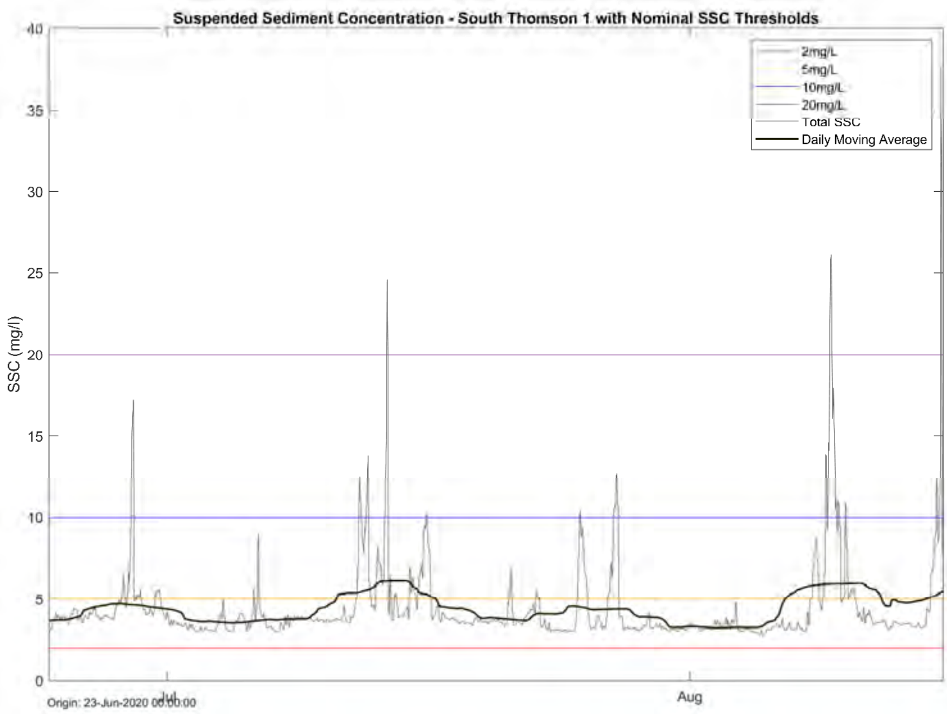

Figure 5.10: Calculation of total SSC and daily mean values of modelled SSC analysed against nominal seagrass impact thresholds (based on BMT 2021a) at the South Thomson Bay 1 location. Analysis shown for the background SSC of 3mg/L.

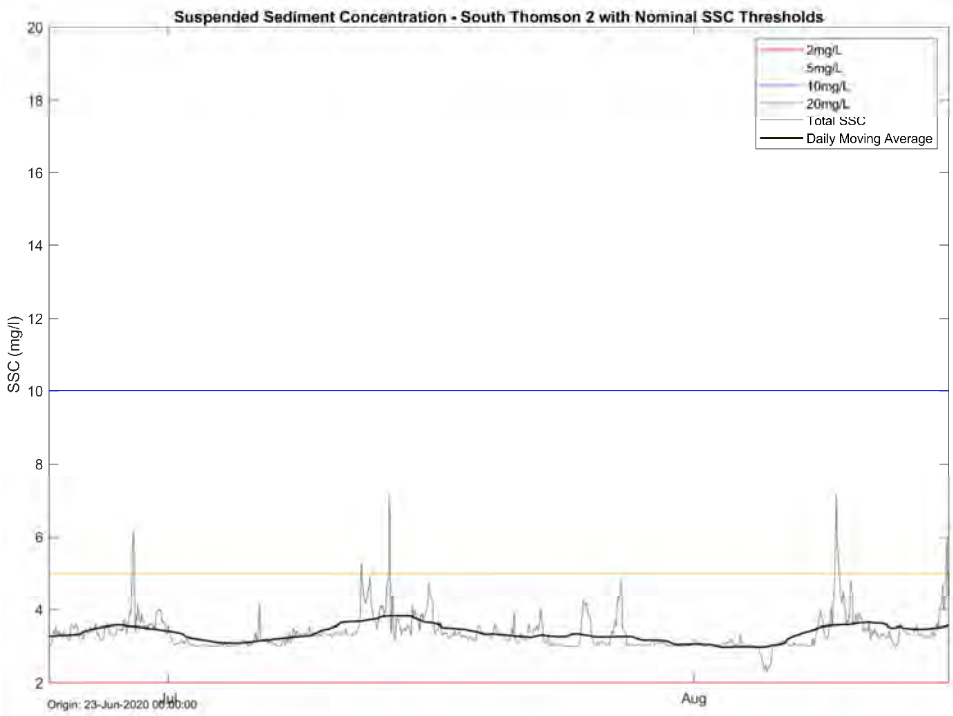

Figure 5.11: Calculation of total SSC and daily mean values of modelled SSC analysed against nominal seagrass impact thresholds (based on BMT 2021a) at the South Thomson Bay 2 location. Analysis shown for the background SSC of 3mg/L.

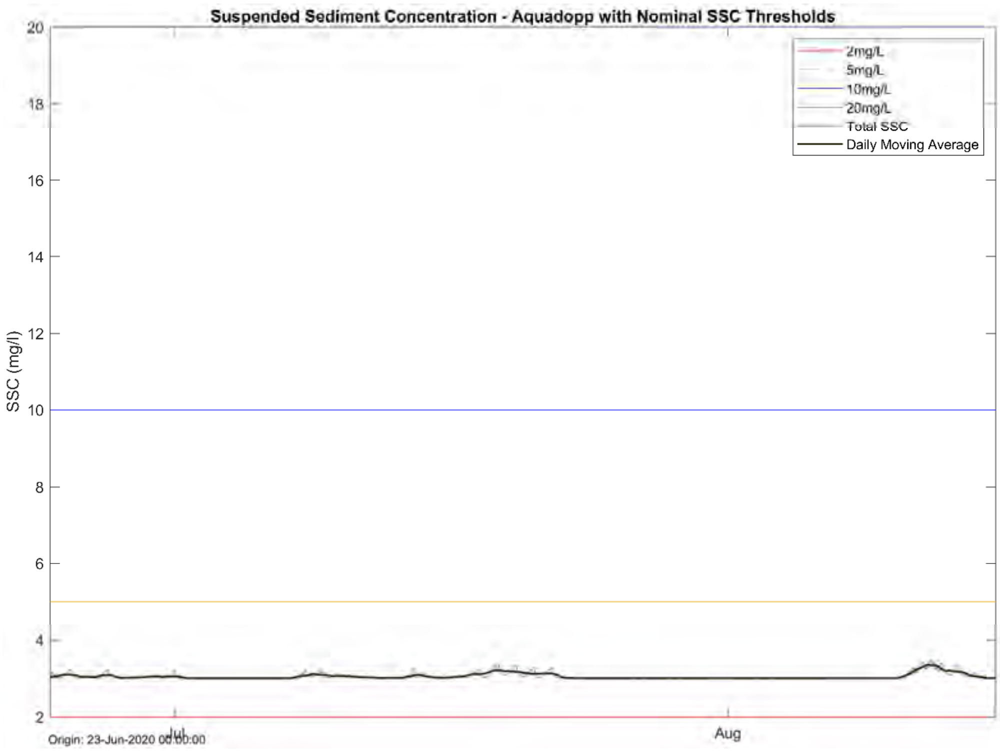

Figure 5.12: Calculation of total SSC and daily mean values of modelled SSC analysed against nominal seagrass impact thresholds (based on BMT 2021a) at the Aquadopp location. Analysis shown for the background SSC of 3mg/L.

5.5 Calculated Zones of Impact

The calculated zones of impact (ZoI, ZoMI and ZoHI) have been compiled based on the complete winter dredging program. The zones of impact are presented in Figure 5.13 with consideration of the chosen background SSC of 3mg/L. It should be noted that the ZoHI spatial extent adopts a minimum distance from the dredged footprint of 25m, and the ZoMI adopts a minimum distance from the dredged channel of 150m. These distances have been set as a conservative basis for including consideration of the coarse sand fractions assumed to fall out of suspension close to the source of dredging. Both the ZoHI and ZoMI have made consideration of the depositional thresholds defined in Table 5.1, but noting that the majority of sedimentation takes places in the swash zone or on the beach to the east of the Army Groyne, at distances from the dredged footprint that fall within the conservative buffers mentioned for each zone. The ZoI, shown in yellow in Figure 5.13, represents the maximum predicted extent of visible plumes with the important consideration that these changes would not result in a measurable impact on BCH. The extent and coverage of the ZoI stretching east along the beach in South Thomson Bay demonstrates the influence of the prevailing currents on this side of Wadjemup.

The areas encompassed by each of the zones are:

- ZOI: 0.17 km^2
- ZOMI: 0.07 km^2
- ZOHI: 0.02 km^2

The standard buffers used to formulate the ZOMI and the ZOHI areas have a much more significant impact upon the areas detailed above and shown in Figure 5.13 due to the relatively low impact of the dredge plume itself. As shown in Figure 5.9 to Figure 5.12, the only locations that showed SSC signals that regularly reached the SSC thresholds outlined in Table 5.1 sat within the dredge footprint itself. Figure 5.1 also shows that elevated SSC levels within the dredge plume were only regularly seen to the south (landward) of the dredge footprint, away from the sensitive seagrass receptors further out in Thomson Bay. The significantly greater influence of the conservative buffers when compared to the dredge plume itself on the ZOHI and ZOMI areas demonstrates that these zones are not going to be sensitive to marginal changes in the key assumptions, including the background SSC assumed and the season in which the dredging takes place (the season used in this dredging campaign can be considered a worst case scenario as it takes place during the winter, typically more stormy and higher energy than summer or transitional periods – see further discussion of seasonality at Wadjemup in Baird’s Coastal Processes Assessment (2023a)).

As the calculation method for the ZOI does not include consideration of what the background SSC is, but just looks at the plume that experiences an SSC of 2mg/L above the background at any one time in the dredge program, this zone is not sensitive to changes in the background SSC assumption. Similar to the ZOHI and ZOMI, as this dredge program was undertaken during a winter period, it can be considered that this ZOI area is a worst case scenario in regards to seasonal influence.

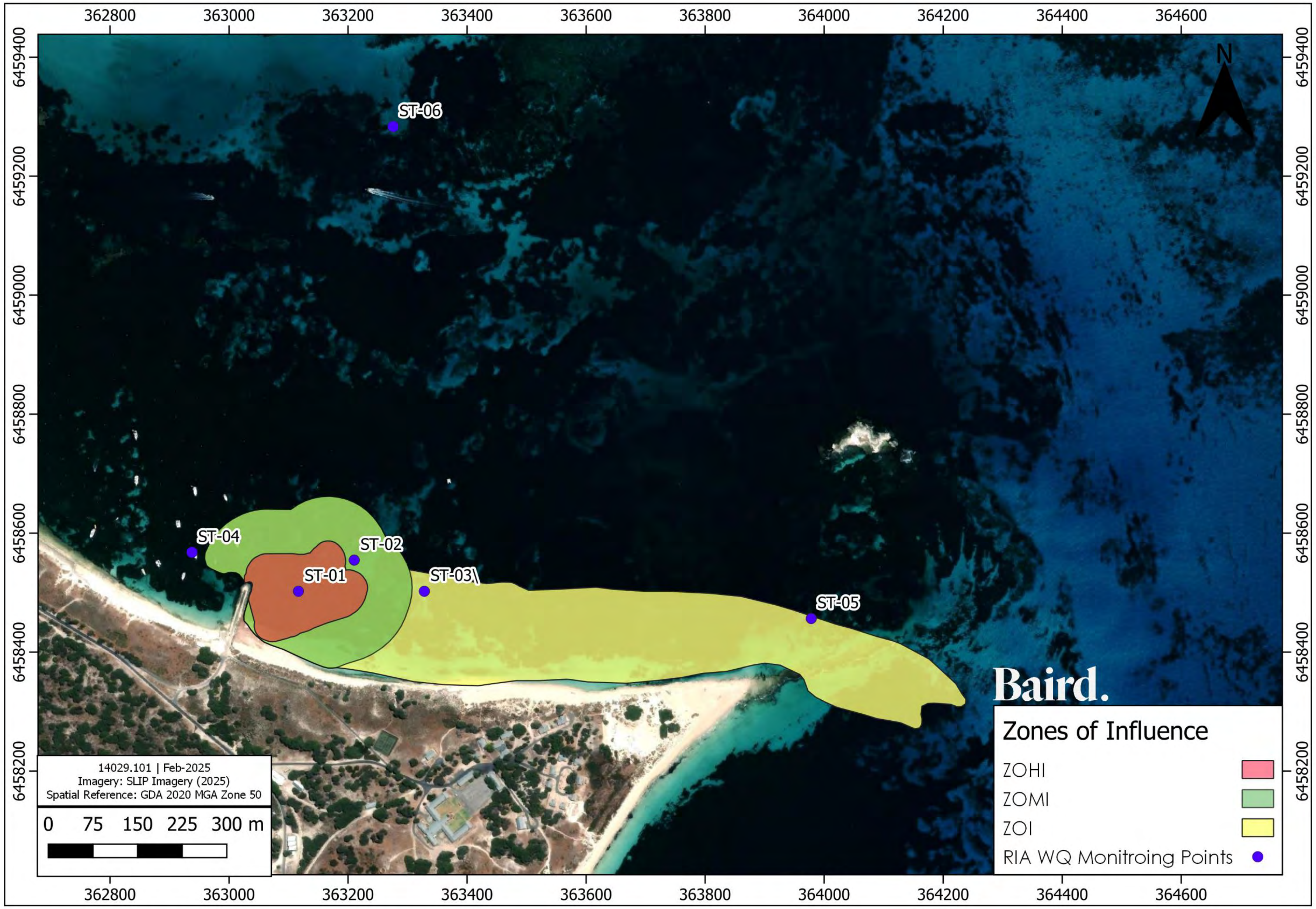

Figure 5.13: Calculated Zones of Impact (ZoI, ZoMI and ZoHI) based on a background SSC of 3mg/L for the 7.5 week winter dredging program.

6. Conclusions

This report presents the analysis of the comprehensive numerical modelling campaign that has been undertaken to determine the potential extent of impacts from dredging activities in South Thomson Bay related to the proposed South Thomson Barge Development at the Army Groyne site. Modelling has been undertaken based on a set of assumptions taken from reporting provided by in2Dredging Pty Ltd (i2D), a specialist dredging consultancy that was engaged to determine the most suitable methodology to dredge the material, as well as to provide an estimated required schedule for the dredging method. A range of potential methods were outlined in the reporting, with the assumptions related to the use of the backhoe dredger BH EX05 and the requirement to dredge rock at an assumed P50 rock quality based on available geotechnical data used in the modelling and analysis presented in this report. The dredging program used in this modelling study covered 7.5 weeks in winter.

Following the modelling of the potential dredge plume that may be generated as a result of dredging activities in South Thomson Bay as part of the proposed South Thomson Bay Barge Development, analysis to determine the zones of influence (ZoIs) was carried out following the method of calculation used by BMT in their analysis of the dredge plume and passive plume impacts from the placement of dredged sediments on Port Beach. This assessment determined nominal values of SSC that would have detrimental impact on local seagrass species, including the predominant species within South Thomson Bay, Posidonia.

The calculated zones of impact (ZoI, ZoMI and ZoHI) have been compiled based on the complete winter dredging program and are presented spatially in Section 5.5. Each of the zones that are considered to have an impact on benthic communities and habitat (BCH, including seagrasses), the ZoHI and ZoMI, are contained to small spatial extents adjacent to the dredge footprint, with extents based on conservative buffers around the dredge footprint as well as impacts from the modelling. It should be noted that the model impacts only influenced the spatial extents landward of the dredge footprint (i.e., impacts do not extend into Thomson Bay and are bounded by the dredge footprint, the Army Groyne and the Beach. The extent and coverage of the ZoI (representing the maximum predicted extent of visible plumes with the important consideration that these changes would not result in a measurable impact on BCH) stretching east along the beach in South Thomson Bay demonstrates the influence of the prevailing currents on this side of Wadjemup.

The areas encompassed by each of the zones are:

- ZOI: 0.17 km^2
- ZOMI: 0.07 km^2
- ZOHI: 0.02 km^2

7. References

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Appendix A

Key Reports

A.1 Key Reports

A.1.1 Site Specific Reports Prepared for the South Thomson Barge Development

- AECOM (2020), South Thomson Bay Barge Facility; Value Engineering of Concept Design. Doc. No. 606370980-MA-REP-0001 Rev 0.
- Douglas Partners (2019). Geotechnical Investigation, Proposed Vessel Approach Channel Dredging. Prepared for Rottnest Island Authority, R.001.Rev0
- in2Dredging (2023). South Thomson Bay Development: Dredging Budget and Schedule Estimate. Technical Note prepared for Baird, i2D-BAIRD-TN-001.
- Baird (2025) South Thomson Barge Development Coastal Processes Assessment. Prepared for RIA, 14029.101.R1.RevA.
- RPS (2020) SAP Implementation Report, Rottnest Island Army Jetty Dredging. Prepared for RIA, EEC19032.011
- Water Technology (2021), Rottnest Island Wave & Current Monitoring, Data Report. Report prepared for Rottnest Island Authority, 31 August 2021

A.1.2 Western Australian Marine Science Institution (WAMSI) Dredging Node

- Statton J, McMahon KM, Armstrong P, Strydom S, McCallum R, Kendrick GA, Lavery PS (2017) Determining light stress bio-indicators and thresholds for a tropical multi-species seagrass assemblage. Report of Theme 5 - Project 5.5.1 prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 50 pp.
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- EPA (2018b), Instructions on how to prepare Environmental Protection Act Part IV Environmental Management Plans.
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A.1.4 Other Policy and Guidance

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