PORT OF **WEIPA**

APPENDIX F

Sediment resuspension technical note

PORT & COASTAL SOLUTIONS

Technical Note

Date:	05/12/2019
To:	Jennifer Miller, Kevin Kane, Damian Snell, Tom Kaveney
From:	Andy Symonds
Subject:	Sediment Resuspension in the Weipa region
Classification:	Project Related

1. Introduction

North Queensland Bulk Ports (NQBP) commissioned Port and Coastal Solutions (PCS) to undertake a study to better understand the natural sediment resuspension in the Weipa region and to compare this to the resuspension resulting from maintenance dredging at the Port of Weipa. The aims of this study are as follows:

- to develop relationships between the suspended sediment concentration (SSC) and the wave conditions at the long-term ambient water quality monitoring sites adjacent to the Port of Weipa; and
- to use results from dredge plume modelling simulations to compare the natural resuspension at the monitoring sites to the resuspension resulting from maintenance dredging.

2. Monitoring Sites

To better understand both the wave and the water quality conditions in the Weipa region, measured data have been used. Details of the data used as part of this assessment are provided in the following sections.

2.1. Waves

The Department for Environment and Science have been maintaining a directional waverider buoy (WRB) in Albatross Bay measuring wave conditions since 2008 (Figure 1). The available wave data (November 2008 to August 2019) have been analysed to better understand the long-term wave conditions and how the wave conditions vary seasonally (Figure 2, Figure 3, Table 1 and Table 2). The analysis shows the following:

- Annual climate: for the majority of the time the waves are from the south-west to west-north-west (waves propagating onshore towards the Weipa shoreline), although for approximately 30% of the time the waves are from the east-north-east to south-east (wave propagating offshore away from the Weipa shoreline). The largest waves occur from the west-south-west to west-north-west directions where significant wave heights (H_s) can exceed 3 m, with H_s of less than 1.5 m from all other directions;
- Seasonal climate: there is a marked seasonal variability in the wave climate, with larger waves propagating in an onshore direction occurring predominantly from the west to the west-north-west during the wet season, while during the dry season there are smaller waves propagating in an onshore direction predominantly from the south-west as well as waves propagating in an offshore direction from the east-north-east to south-east. The relative durations that different wave heights occur at the Albatross Bay WRB vary between the wet and dry seasons as follows;
  - Wet Season: during the wet season (November to April inclusive) the H_s is less than 0.5 m for 74% of the time and less than 1 m for 91% of the time; and
  - Dry Season: during the dry season (May to October inclusive) the H_s is less than 0.5 m for 85% of the time and less than 1 m for 99% of the time.

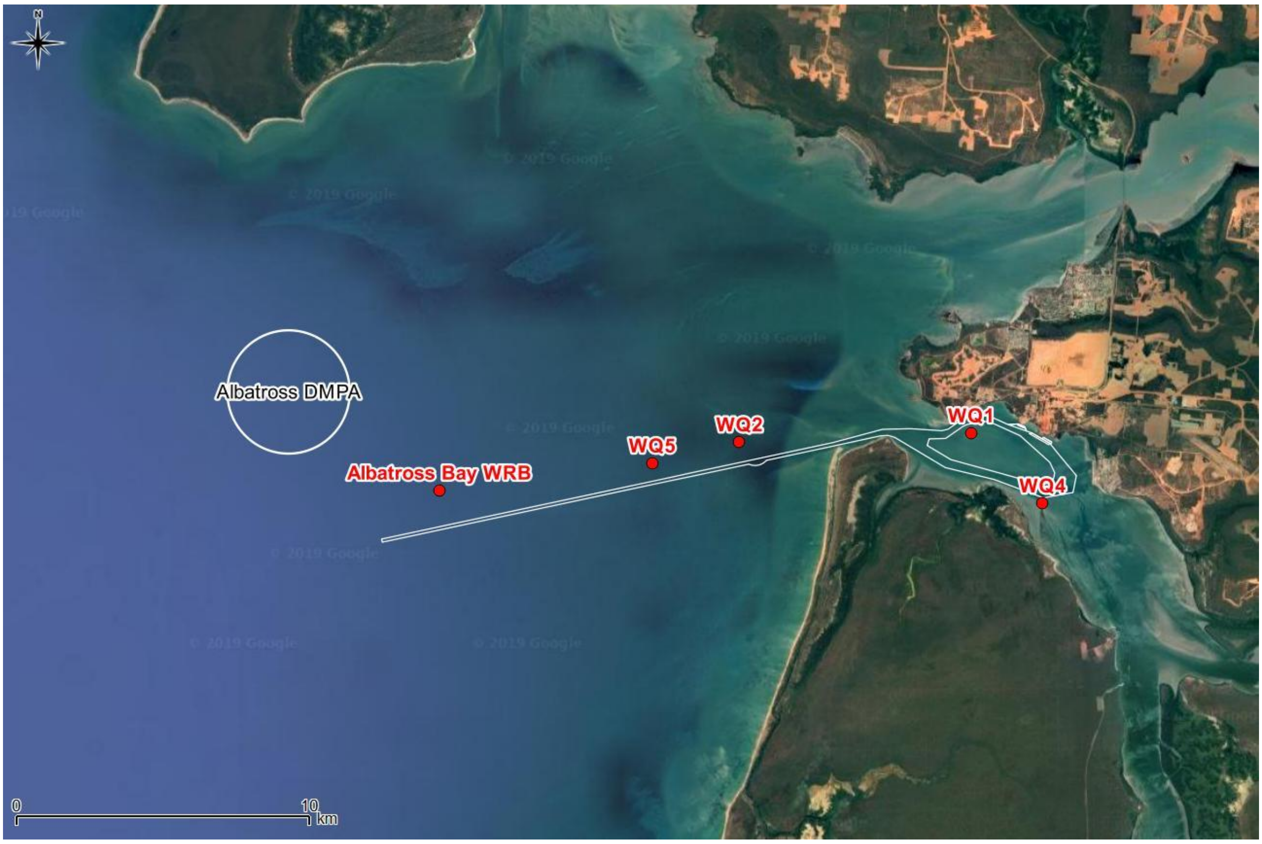

Figure 1. Location map of the water quality monitoring sites.

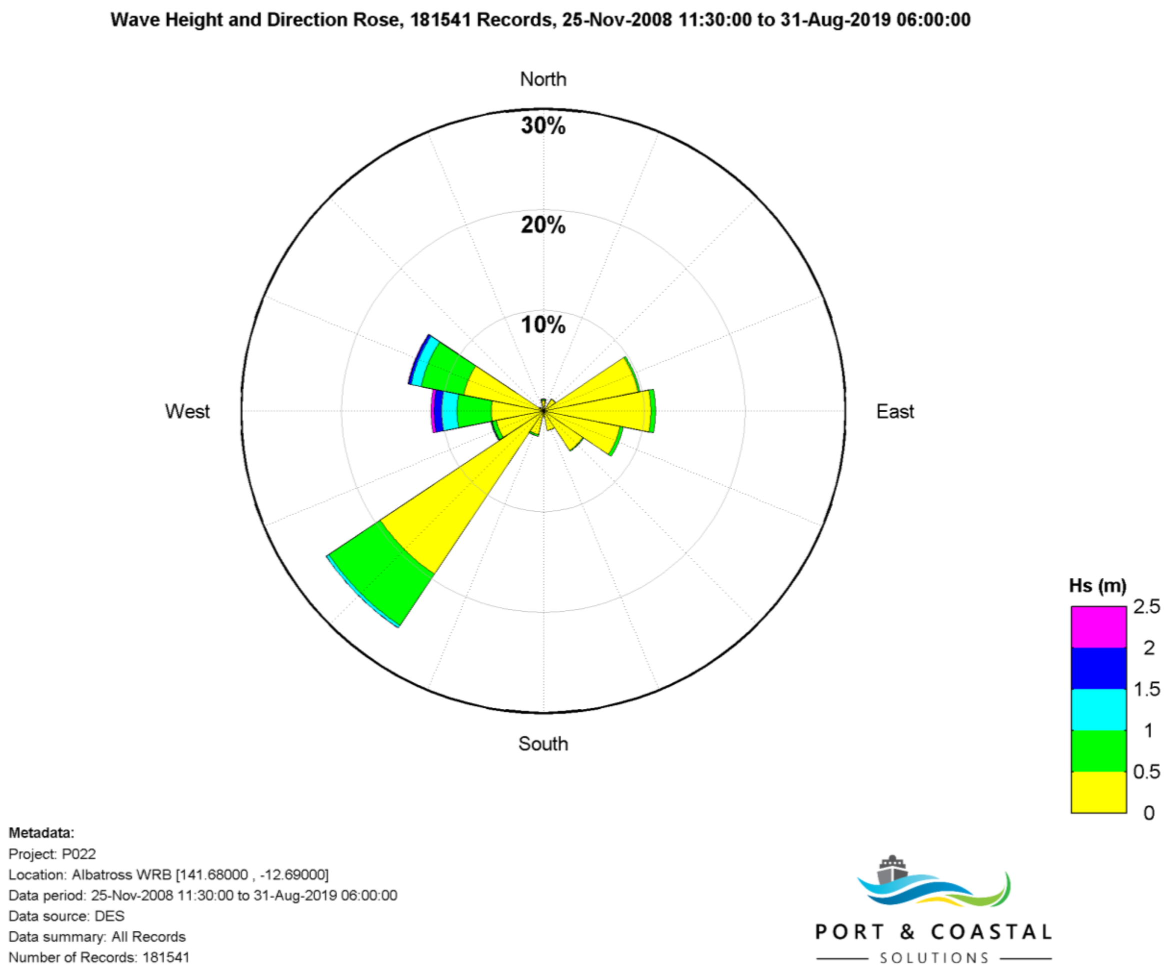

Figure 2. Annual wave rose for measured wave data at the Albatross Bay WRB (2008 to 2019).

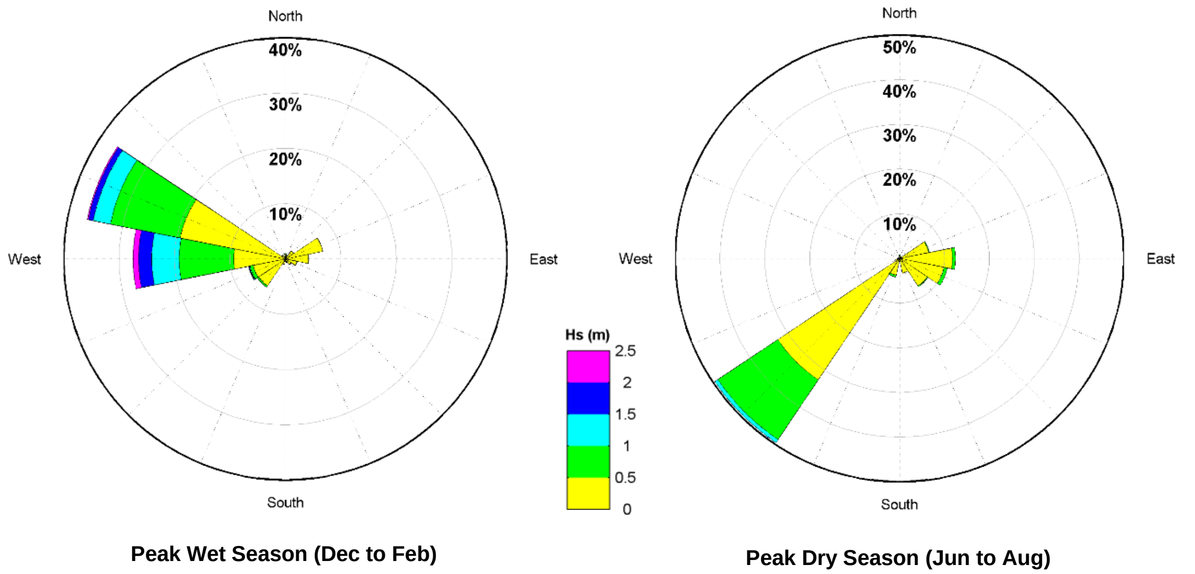

Figure 3. Seasonal wave roses of measured wave data at the Albatross Bay WRB (2008 to 2019).

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Table 1. Joint frequency table for significant wave height and wave direction at the Albatross Bay DMPA during the wet season.

Joint Frequency Table (%) Showing Hs Against Direction for the Period 25−Nov−2008 11:30:00 to 31−Aug−2019 06:00:00

N=181541	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0−0.25	0.65	0.32	1.23	5.45	3.63	2.01	1.32	0.63	0.30	0.90	5.07	2.55	2.78	5.29	0.38	0.13	32.61	32.61
0.25−0.5	0.42	0.15	0.72	5.04	3.70	1.41	0.52	0.18	0.11	0.48	6.50	5.09	6.26	9.96	0.35	0.07	40.94	73.55
0.5−0.75	0.09	0.01	0.02	0.15	0.22	0.05	0.02	*	*	0.05	1.01	0.55	3.58	5.94	0.03	*	11.74	85.29
0.75−1	0.05	−	*	*	0.01	−	*	−	−	0.01	0.16	0.11	3.13	2.62	*	*	6.10	91.40
1−1.25	0.03	−	−	−	−	−	−	−	−	*	0.02	0.07	1.90	1.41	−	−	3.43	94.83
1.25−1.5	0.03	−	−	−	−	−	−	−	−	*	0.01	0.06	1.14	0.66	−	−	1.90	96.73
1.5−1.75	0.02	−	−	−	−	−	−	−	−	−	*	0.05	0.91	0.37	−	−	1.35	98.08
1.75−2	0.03	−	−	−	−	−	−	−	−	−	*	0.04	0.54	0.14	−	−	0.75	98.83
2−2.25	0.01	−	−	−	−	−	−	−	−	−	*	0.03	0.36	0.07	−	−	0.48	99.31
2.25−2.5	*	−	−	−	−	−	−	−	−	−	*	0.01	0.24	0.04	−	−	0.31	99.61
2.5−2.75	*	−	−	−	−	−	−	−	−	−	0.02	*	0.13	0.02	−	−	0.17	99.79
2.75−3	*	−	−	−	−	−	−	−	−	−	0.01	0.02	0.07	*	−	−	0.11	99.90
3−3.25	*	−	−	−	−	−	−	−	−	−	*	*	0.05	*	−	−	0.07	99.96
3.25−3.5	−	−	−	−	−	−	−	−	−	−	−	*	0.04	*	−	−	0.04	100.00
Total	1.33	0.48	1.97	10.64	7.56	3.47	1.87	0.81	0.41	1.43	12.84	8.58	21.12	26.53	0.76	0.20		
Cumul.	1.33	1.81	3.78	14.42	21.98	25.45	27.31	28.12	28.53	29.96	42.80	51.38	72.50	99.03	99.80	100.00		

* **denotes values less than 0.01%** − **denotes no records in bin**

Metadata:
Project: P022
Location: AlbatrossWRB [141.68000 , −12.69000]
Data period: 25−Nov−2008 11:30:00 to 31−Aug−2019 06:00:00
Data source: DES
Data summary: All Records
Number of Records: 181541

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Table 2. Joint frequency table for significant wave height and wave direction at the Albatross Bay DMPA during the dry season.

Joint Frequency Table (%) Showing Hs Against Direction for the Period 25−Nov−2008 11:30:00 to 31−Aug−2019 06:00:00

N=181541	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0−0.25	0.45	0.12	0.63	3.40	4.16	3.26	2.26	1.28	0.46	1.28	7.57	0.92	0.70	0.48	0.13	0.09	27.19	27.19
0.25−0.5	0.52	0.03	0.31	5.52	10.17	9.10	5.50	1.96	0.28	2.20	20.42	1.04	0.68	0.51	0.04	0.01	58.29	85.48
0.5−0.75	0.09	−	*	0.20	0.70	0.60	0.15	0.02	*	0.29	8.70	0.13	0.09	0.07	−	−	11.05	96.53
0.75−1	*	−	*	*	*	*	*	−	−	0.03	2.64	0.03	0.03	*	−	−	2.76	99.29
1−1.25	*	−	−	−	−	−	−	−	−	*	0.52	*	0.05	*	−	−	0.58	99.87
1.25−1.5	−	−	−	−	−	−	−	−	−	−	0.06	*	0.03	*	−	−	0.10	99.97
1.5−1.75	−	−	−	−	−	−	−	−	−	−	0.01	*	*	*	−	−	0.03	100.00
1.75−2	−	−	−	−	−	−	−	−	−	−	−	*	−	−	−	−	*	100.00
2−2.25	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
2.25−2.5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
2.5−2.75	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
2.75−3	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
3−3.25	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
3.25−3.5	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	−	100.00
Total	1.07	0.16	0.95	9.12	15.03	12.97	7.91	3.25	0.74	3.80	39.92	2.14	1.59	1.08	0.17	0.10		
Cumul.	1.07	1.23	2.18	11.30	26.33	39.30	47.21	50.46	51.20	55.00	94.92	97.06	98.64	99.72	99.90	100.00		

* **denotes values less than 0.01%** − **denotes no records in bin**

Metadata:
Project: P022
Location: AlbatrossWRB [141.68000 , −12.69000]
Data period: 25−Nov−2008 11:30:00 to 31−Aug−2019 06:00:00
Data source: DES
Data summary: All Records
Number of Records: 181541

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2.2. Water Quality

James Cook University (JCU) has been carrying out NQBP's ongoing ambient marine water quality monitoring around the coastal waters of the Port of Weipa since January 2018. As part of the program, water quality sensors were deployed at four locations around the Port of Weipa (see Figure 1 and Table 3), with each sensor returning data on turbidity, benthic light and deposition at a ten-minute temporal resolution. In addition, water sampling has also been undertaken to allow the turbidity data to be converted to suspended sediment concentration (SSC) in mg/l. The instrument at WQ5 was removed in July 2018.

Table 3. Summary of water quality data collected at the Port of Weipa.

Site Name	Latitude	Longitude	Period
WQ1	-12.6709° S	141.8475° E	19/01/2018 to 27/08/2019 (ongoing)
WQ2	-12.6736° S	141.7765° E	16/03/2018 to 28/08/2019 (ongoing)
WQ4	-12.6918° S	141.8693° E	19/01/2018 to 28/08/2019 (ongoing)
WQ5	-12.6798° S	141.7494° E	19/01/2018 to 13/07/2018

Time series of the available long-term water quality data at the three ongoing monitoring sites located adjacent to the Port of Weipa indicate that there is a relationship between wave height and turbidity (Figure 4). The figure shows elevated turbidity during periods with increased wave heights, with the turbidity exceeding 2,000 NTUe during the largest wave events. When the wave conditions are calm (e.g. H_s of less than 0.5 m) the turbidity shows a tidal signal, with increased turbidity during spring tides when higher tidal current speeds occur and lower turbidity during neap tides with lower tidal current speeds.

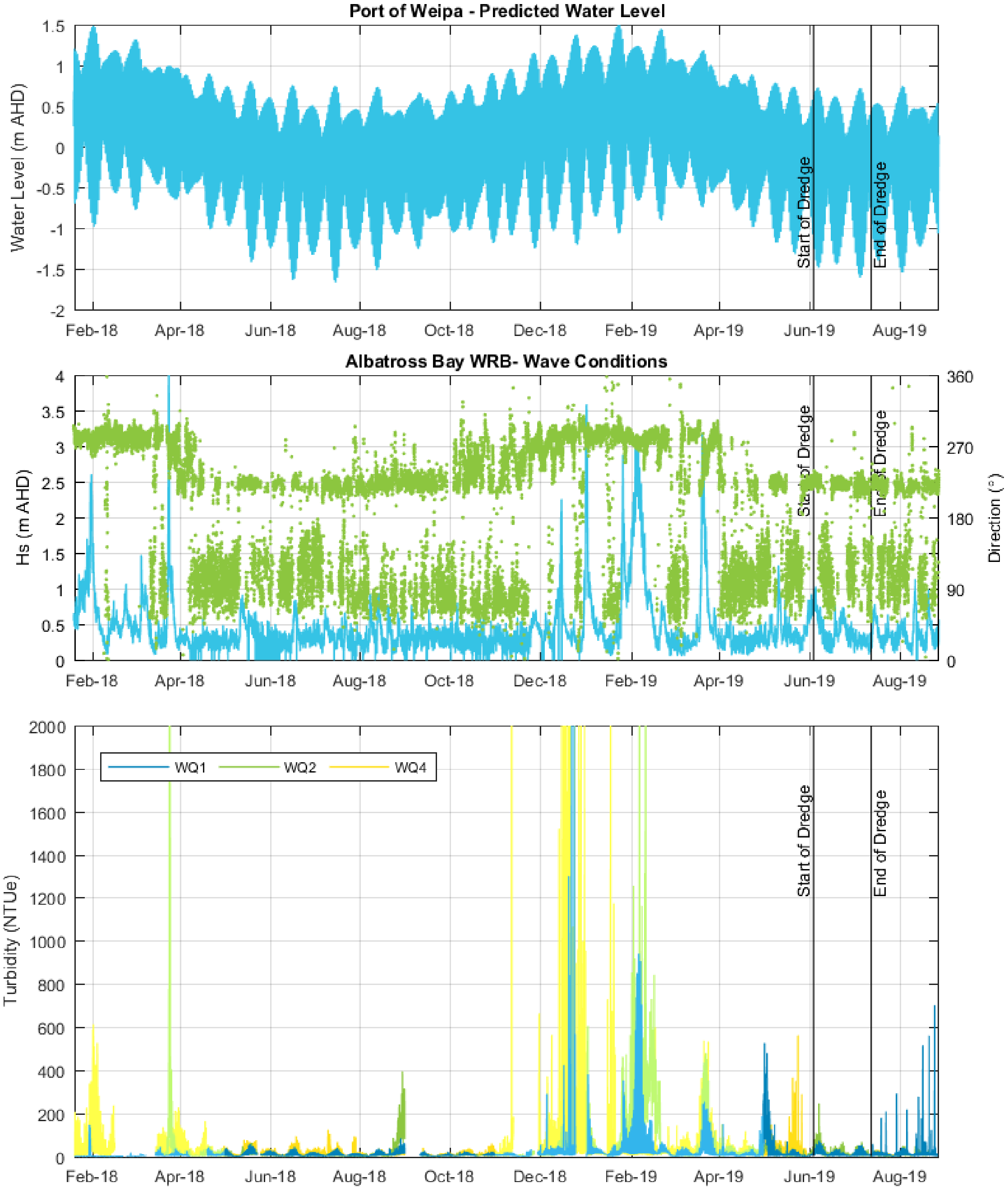

Figure 4. Predicted water level (top), measured waves (middle) and measured benthic turbidity data (bottom).
Note: for turbidity, data for the wet season is shown as a lighter colour and data for the dry season data as a darker colour.

3. Resuspension Analysis

This section provides details of the approach adopted to analyse the natural resuspension and the resuspension resulting from maintenance dredging. The analysis has been based on results from calibrated sediment transport and dredge plume models (see PCS (2019a & 2019b) for further details of the setup and calibration of the models).

3.1. SSC and Wave Height Relationship

As part of the Sediment Budget developed for the Port of Weipa SSM Project, it was found that in the Weipa region the measured SSC increased as the wave height increased (PCS, 2018). Additional analysis was undertaken as part of the Sediment Budget study using the calibrated sediment transport model to better understand how the SSC varies at the long-term water quality monitoring sites depending on the wave height at the Albatross Bay WRB. Results from the analysis are shown in Figure 5 and Figure 6. The plots show that there is an approximate exponential relationship between SSC and wave height at the sites and that the increase in SSC is relatively gradual up to an H_s of 2 m, and much more rapid when the H_s increases beyond this. During these periods of elevated wave heights (H_s > 2m) the results show that the SSC is much higher in Albatross Bay compared to the Inner Harbour. This is because the wave conditions directly affect the SSC in Albatross Bay as the waves resuspend the bed sediment in Albatross Bay, while the SSC in the Inner Harbour is indirectly effected by the wave conditions with the increase in suspended sediment resulting from sediment suspended from Albatross Bay being transported into the Inner Harbour (as opposed to sediment in the Inner Harbour being directly resuspended).

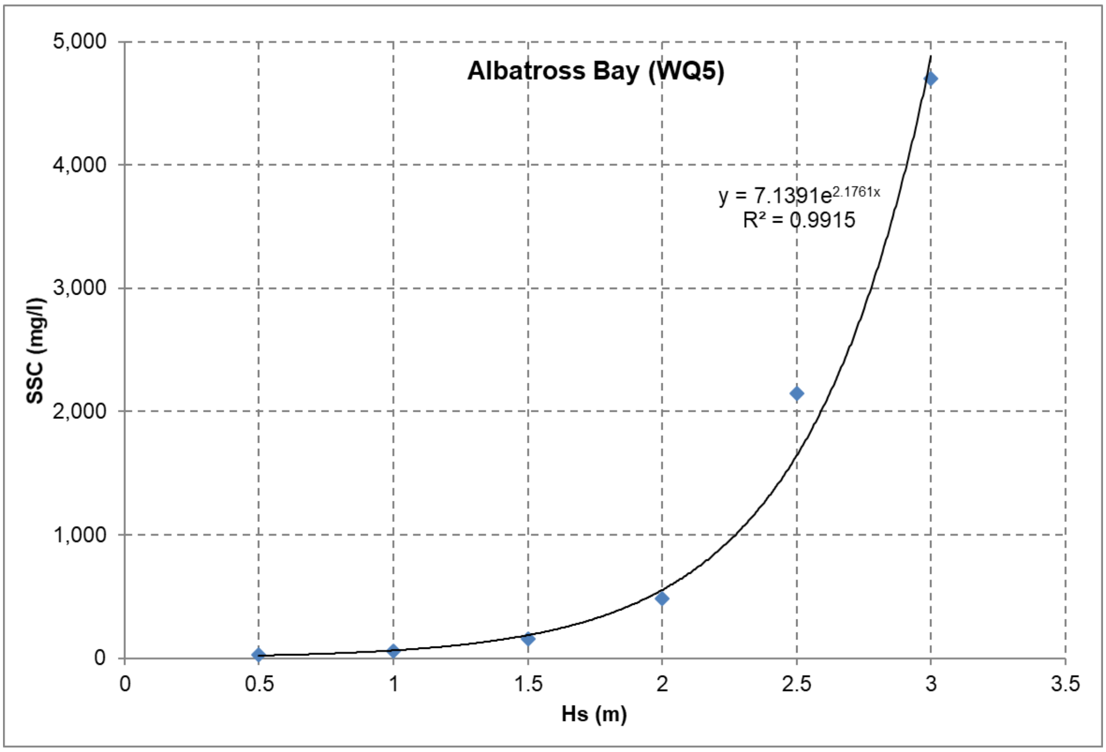

Figure 5. Relationship between H_s (at Albatross Bay WRB) and SSC in Albatross Bay (WQ5).

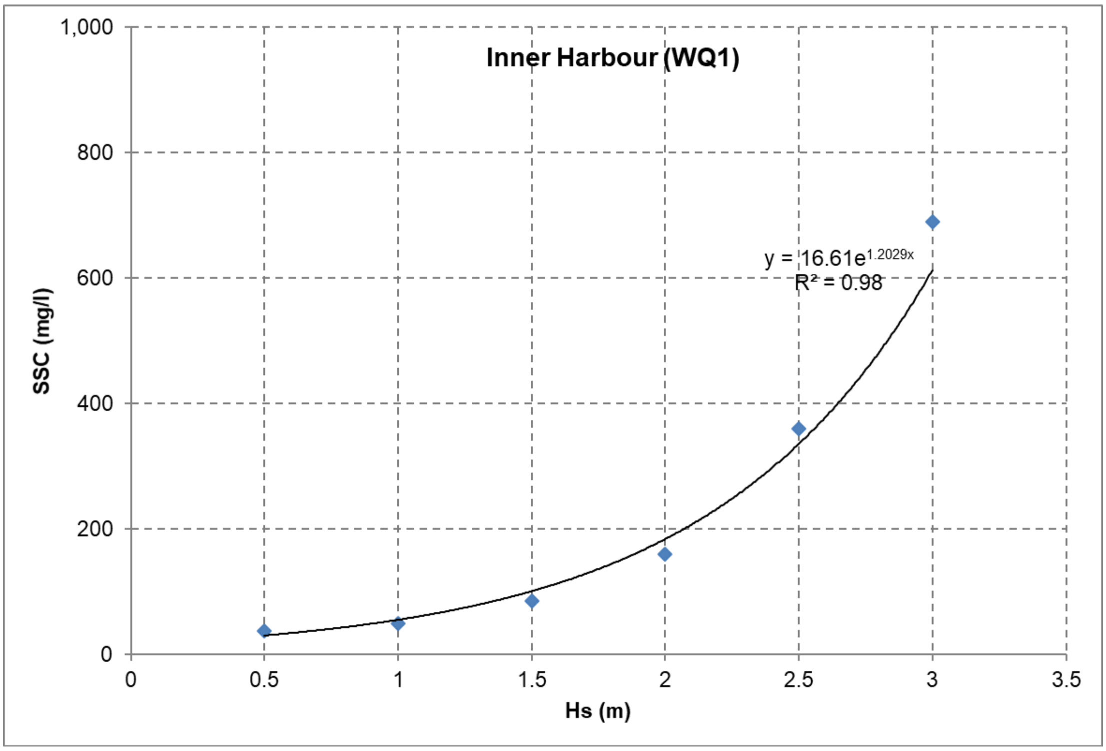

Figure 6. Relationship between H_s (at Albatross Bay WRB) and SSC in the Inner Harbour (WQ1).

3.2. Modelling Approach

The sediment transport model was configured to simulate a seven-day period, which started during spring tides and ended during neap tides and which coincided with a representative wave event. This representative wave event formed the basis of the model setup for seven different synthesised scenarios in which the wave boundary was scaled so that the peak H_s at the Albatross Bay WRB equated to a pre-defined value (from 0 m to 2 m). Results from the model simulations were analysed to calculate SSC percentiles for box and whisker plots (using the 5th, 20th, 50th, 80th and 95th percentiles) at each of the long-term monitoring sites over the seven-day period. As the period selected ranged from spring to neap tidal conditions the analysis can be considered to be representative of average tidal conditions.

Results from dredge plume model simulations undertaken as part of the Port of Weipa SSM (PCS, 2019a) were analysed to determine the relative increase in excess SSC at the long-term monitoring sites due to the placement of 400,000 m^3 (typical), 800,000 m^3 (cyclonic) and 2,500,000 m^3 (worst case) at the existing Albatross Bay dredge material placement area (DMPA). The typical and cyclonic dredge volumes were assumed to be undertaken by a single small dredger of a similar size to the Trailing Suction Hopper Dredger (TSHD) Brisbane, while the worst-case volume was assumed to be undertaken by a small and a large TSHD concurrently. The results were analysed to calculate the same SSC percentiles as for the natural simulations at each of the long-term monitoring sites over the duration of the dredging program. The dredge plume model simulations were all over a dry season period (dredging in June and July) to represent the conditions when maintenance dredging is likely to be undertaken.

3.3. Results

Box and whisker plots summarising the results from the analysis for the three long-term monitoring sites at the Port of Weipa are shown in Figure 7 to Figure 15. The plots show how the SSC naturally varies depending on the wave height at each site and the relative contribution of maintenance dredging during typical, cyclonic and worst-case years. The plots also show a wave rose to represent the wave conditions at the Albatross Bay WRB during the dry season for context as to the duration of time that the various wave heights are likely to occur. The plots show the following:

- the sensitivity of the three sites to the wave conditions at the Albatross Bay WRB location is variable. The monitoring site located in Albatross Bay (WQ2) is the most sensitive, with the median SSC increasing from less than 5 mg/l with no waves to more than 60 mg/l during a wave event with a peak in H_s of 2 m. The monitoring sites within the Inner Harbour (WQ1 and WQ4) are less sensitive to the wave conditions, with the site at WQ4 being the least sensitive as it is located further from the entrance of the estuary than WQ1;
- at all three sites the increase in SSC due to maintenance dredging during typical and cyclonic years is predicted to be small compared to the natural variability. In addition, for these two dredge programs the relative increase is predicted to be similar, showing that the longer duration of the cyclonic program does not result in higher SSC compared to a typical program (although the duration of increased SSC would be longer); and
- the increase in SSC due to maintenance dredging is noticeably higher for the worst-case dredge programs compared to the typical and cyclonic programs. This is because it has been assumed that two dredgers will be working concurrently and that one of these dredgers will be significantly larger than the single dredger assumed for the typical and cyclonic programs (approximately five times larger). However, even for the worst-case dredge programs the increase in SSC due to maintenance dredging remains below the natural SSC with no waves. Of the three monitoring sites, the contribution from maintenance dredging is closest to (but still notably less than) the natural SSC at WQ2. This is due to the close proximity of WQ2 to the South Channel where the majority of the maintenance dredging is undertaken (and by the large TSHD).

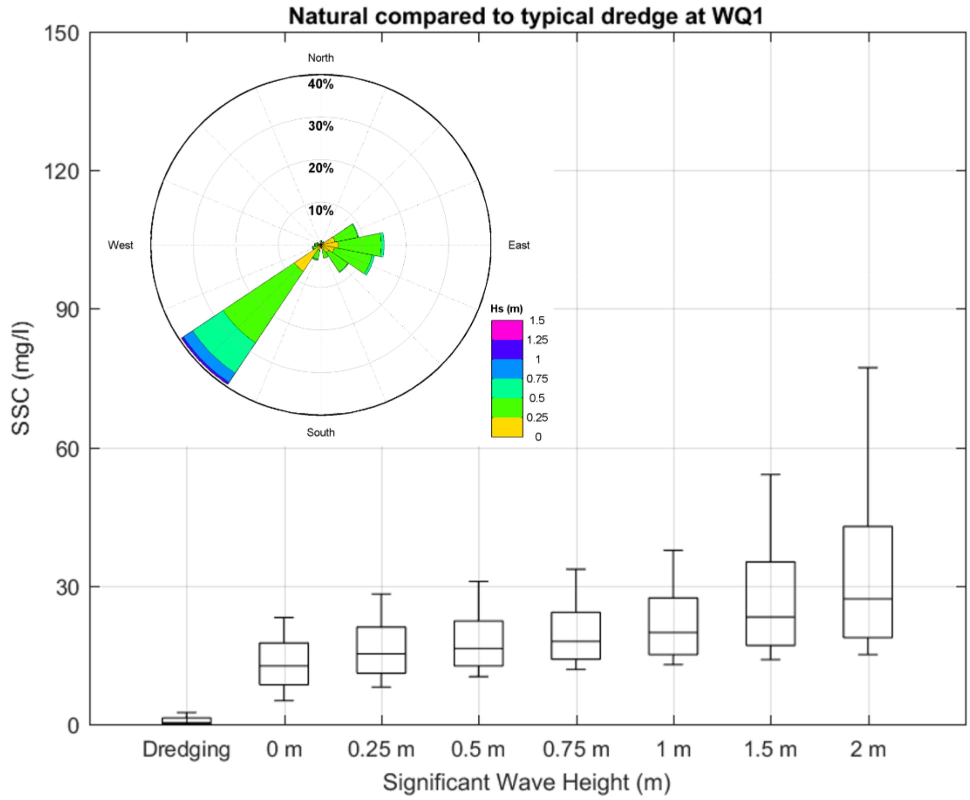

Figure 7. Box and whisker plot showing how SSC at WQ1 naturally varies depending on wave height and the relative contribution of a typical year dredge program. *Note: wave rose represents dry season conditions.*

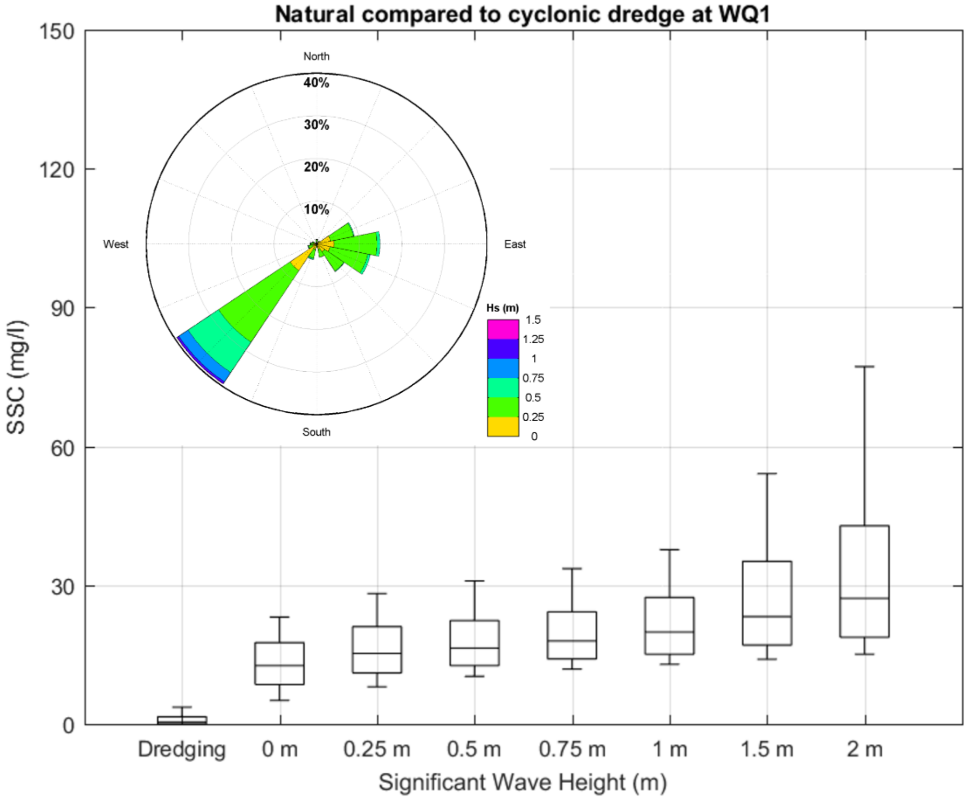

Figure 8. Box and whisker plot showing how SSC at WQ1 naturally varies depending on wave height and the relative contribution of a cyclonic year dredge program. *Note: wave rose represents dry season conditions.*

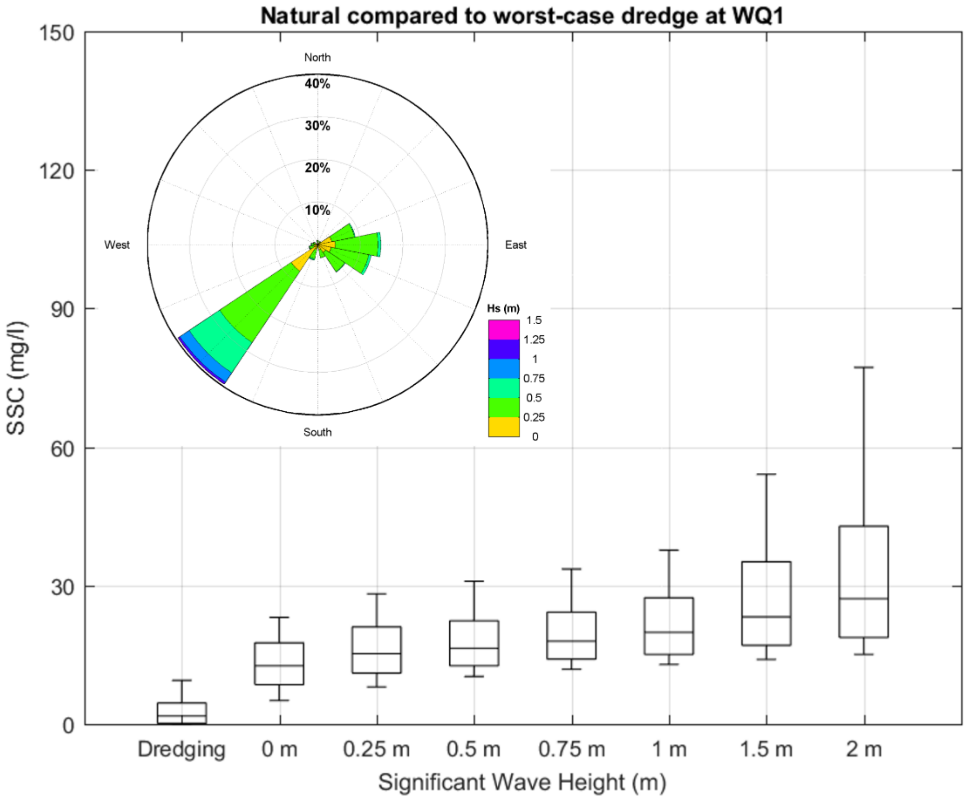

Figure 9. Box and whisker plot showing how SSC at WQ1 naturally varies depending on wave height and the relative contribution of a worst-case dredge program. *Note: wave rose represents dry season conditions.*

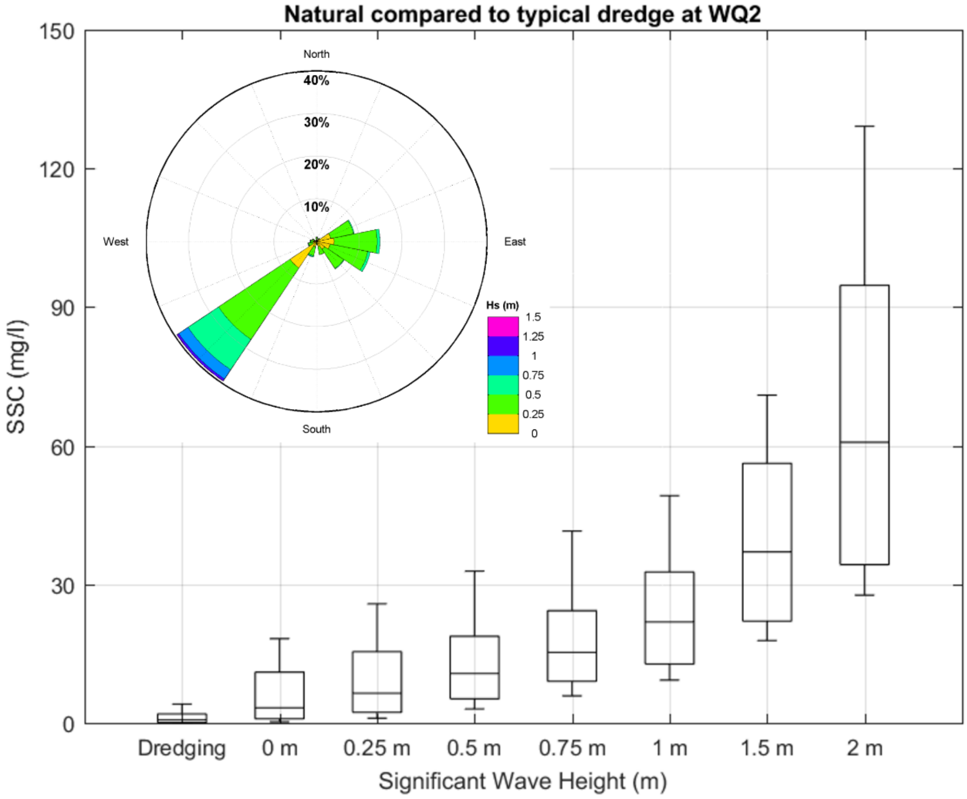

Figure 10. Box and whisker plot showing how SSC at WQ2 naturally varies depending on wave height and the relative contribution of a typical year dredge program. *Note: wave rose represents dry season conditions.*

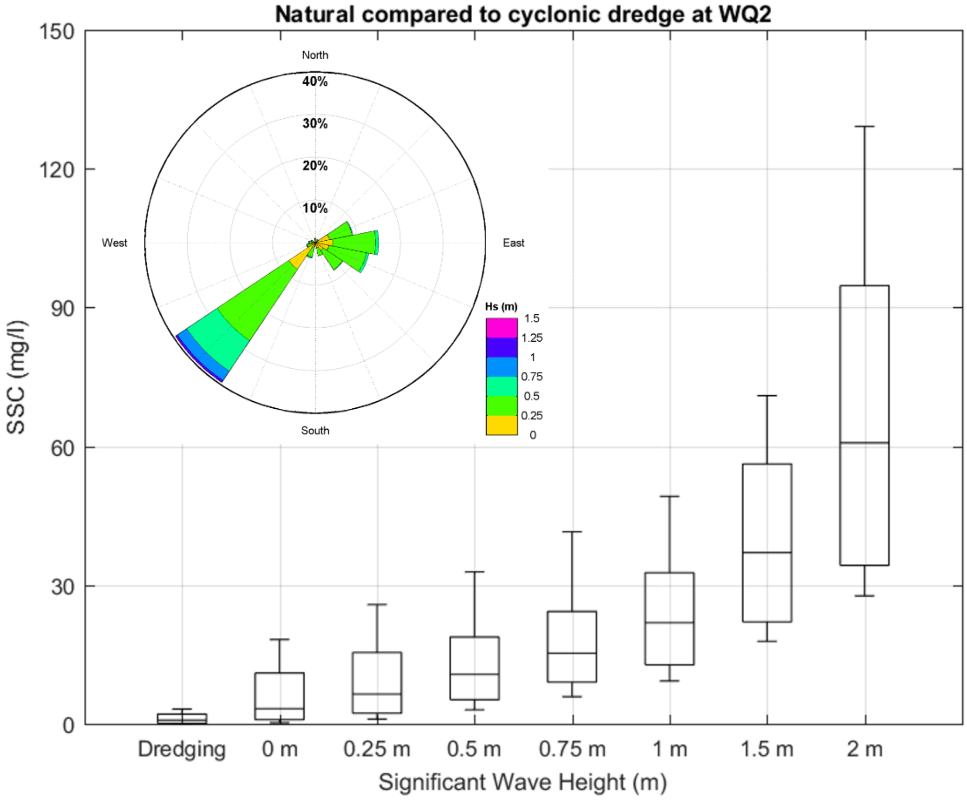

Figure 11. Box and whisker plot showing how SSC at WQ2 naturally varies depending on wave height and the relative contribution of a cyclonic year dredge program. *Note: wave rose represents dry season conditions.*

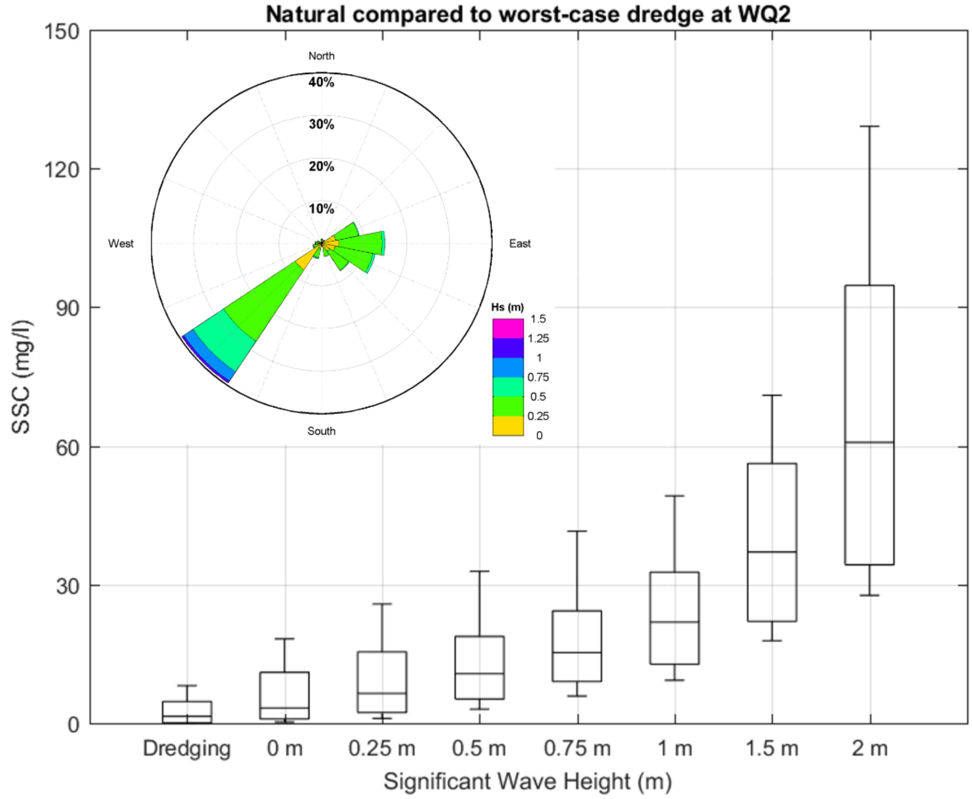

Figure 12. Box and whisker plot showing how SSC at WQ2 naturally varies depending on wave height and the relative contribution of a worst-case dredge program. *Note: wave rose represents dry season conditions.*

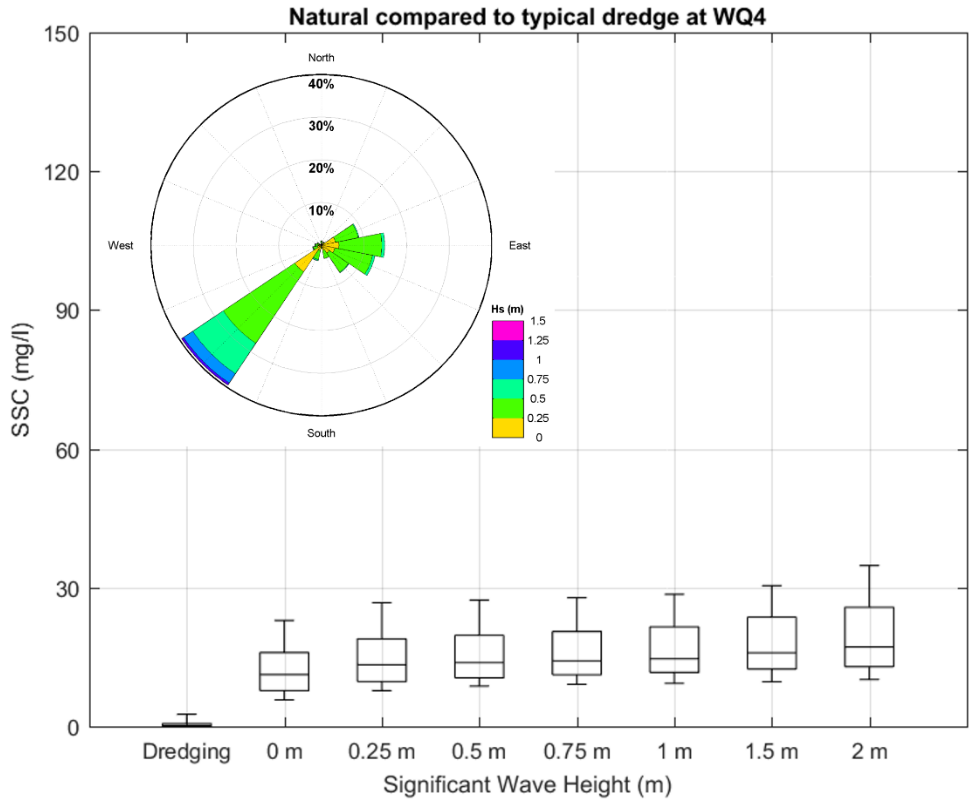

Figure 13. Box and whisker plot showing how SSC at WQ4 naturally varies depending on wave height and the relative contribution of a typical year dredge program. *Note: wave rose represents dry season conditions.*

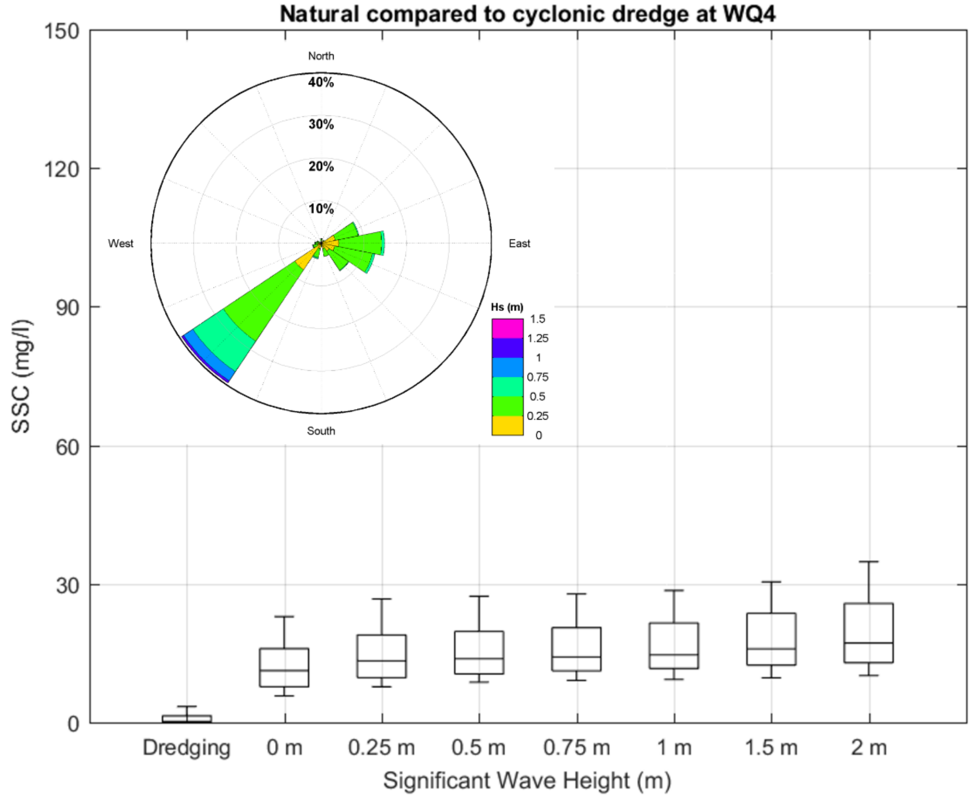

Figure 14. Box and whisker plot showing how SSC at WQ4 naturally varies depending on wave height and the relative contribution of a cyclonic year dredge program. *Note: wave rose represents dry season conditions.*

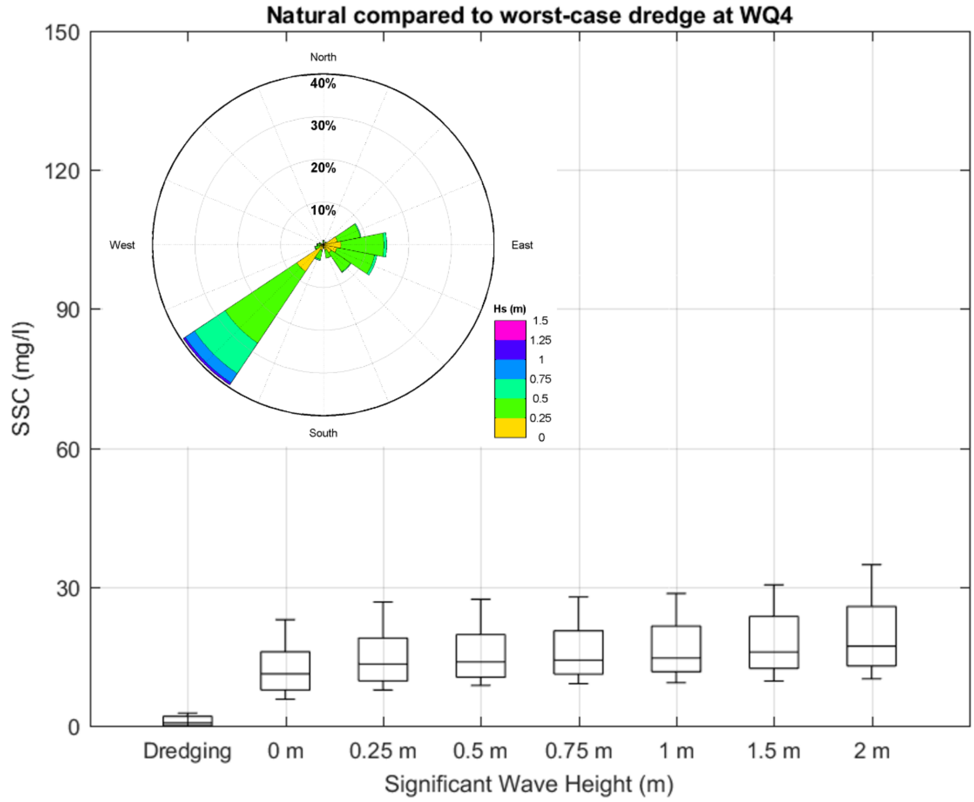

Figure 15. Box and whisker plot showing how SSC at WQ4 naturally varies depending on wave height and the relative contribution of a worst-case dredge program. *Note: wave rose represents dry season conditions.*

4. Summary

This assessment has been undertaken to better understand the natural sediment resuspension in the Weipa region and to put the predicted increases in SSC due to maintenance dredging at the Port of Weipa into context with the natural variability in SSC.

The assessment has included analysis of measured wave and turbidity data as well as numerical modelling to predict the SSC which occurs naturally and which occurs due to maintenance dredging activity. The analysis has shown that the natural environment around the Port of Weipa is naturally turbid and as a result any increase in SSC due to maintenance dredging is predicted to be less than the natural variability.

5. References

PCS, 2018. Port of Weipa Sustainable Sediment Management Assessment, Sediment Budget. Report No. P007_R03F1. September 2018.

PCS, 2019a. Port of Weipa Sustainable Sediment Management Project, Dredge Plume Modelling Assessment. Report No. P022_R05D01. December 2019.

PCS, 2019b. Port of Weipa 2019 Maintenance Dredging, Dredge Plume Model Validation. Report No. P020_R3D01. December 2019.