Port of **Mackay**

Appendix F

Sediment Resuspension Assessment

PORT & COASTAL
SOLUTIONS

Technical Note

Date:	09/08/2021
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From:	Andy Symonds
Subject:	Mackay SSM Project, Sediment Resuspension Assessment
Classification:	Project Related
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1. Introduction

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions (PCS) to undertake a study to assess sediment resuspension at the Port of Mackay, as part of the Sustainable Sediment Management (SSM) Project at the Port. The overall aim of the study is to better understand the natural resuspension which can occur at the Port, to allow the potential resuspension of sediment due to maintenance dredging to be put into context with the natural environment.

The study has the following aims:

- to quantify the mass of sediment naturally resuspended in the Port of Mackay region during calm, energetic and extreme conditions;
- to estimate the annual natural resuspension of sediment in the region; and
- to develop a relationship between natural suspended sediment concentration (SSC) and wind speed for the region and compare this to the SSC resulting from a typical maintenance dredging program at the Port.

2. Approach

A sediment resuspension assessment was previously undertaken at the Port of Hay Point by RHDHV (2017). The assessment utilised a combination of measured and modelled SSC data to allow predictions of sediment resuspension to be made. For consistency, a similar approach has been adopted as part of this assessment which has involved analysis of the following data to estimate sediment resuspension:

- in-situ water quality data collected in the Hay Point and Mackay region since July 2014 as part of NQBPs ambient water quality monitoring program. Data have been collected at numerous sites with the two closest to the Port of Mackay being Slade Islet and Round Top Island (Figure 1); and
- numerical modelling results of the natural SSC which occurs in the region for a range of metocean conditions and the excess SSC which results from a typical maintenance dredging program. Two maintenance dredging programs have been undertaken at the Port of Mackay since 2010; (i) in 2013 approximately 100,000 m^3 of sediment was dredged and (ii) in 2020 approximately 120,000 m^3 of sediment was dredged. Therefore, for this assessment a typical maintenance dredging program has been assumed to be the higher of the two historic volumes (i.e. 120,000 m^3). The numerical model had been calibrated and validated using in-situ water quality data collected as part of the ongoing ambient water quality monitoring at the Ports of Mackay and Hay Point, as well as satellite derived turbidity data (see PCS (in prep) for further details).

Approaches using the in-situ measured SSC data and the modelled SSC data have been adopted to estimate the mass of sediment naturally resuspended in the region during calm, energetic and extreme conditions and the annual natural resuspension in the Mackay region. Further details of the approaches adopted are provided in the following section along with the results.

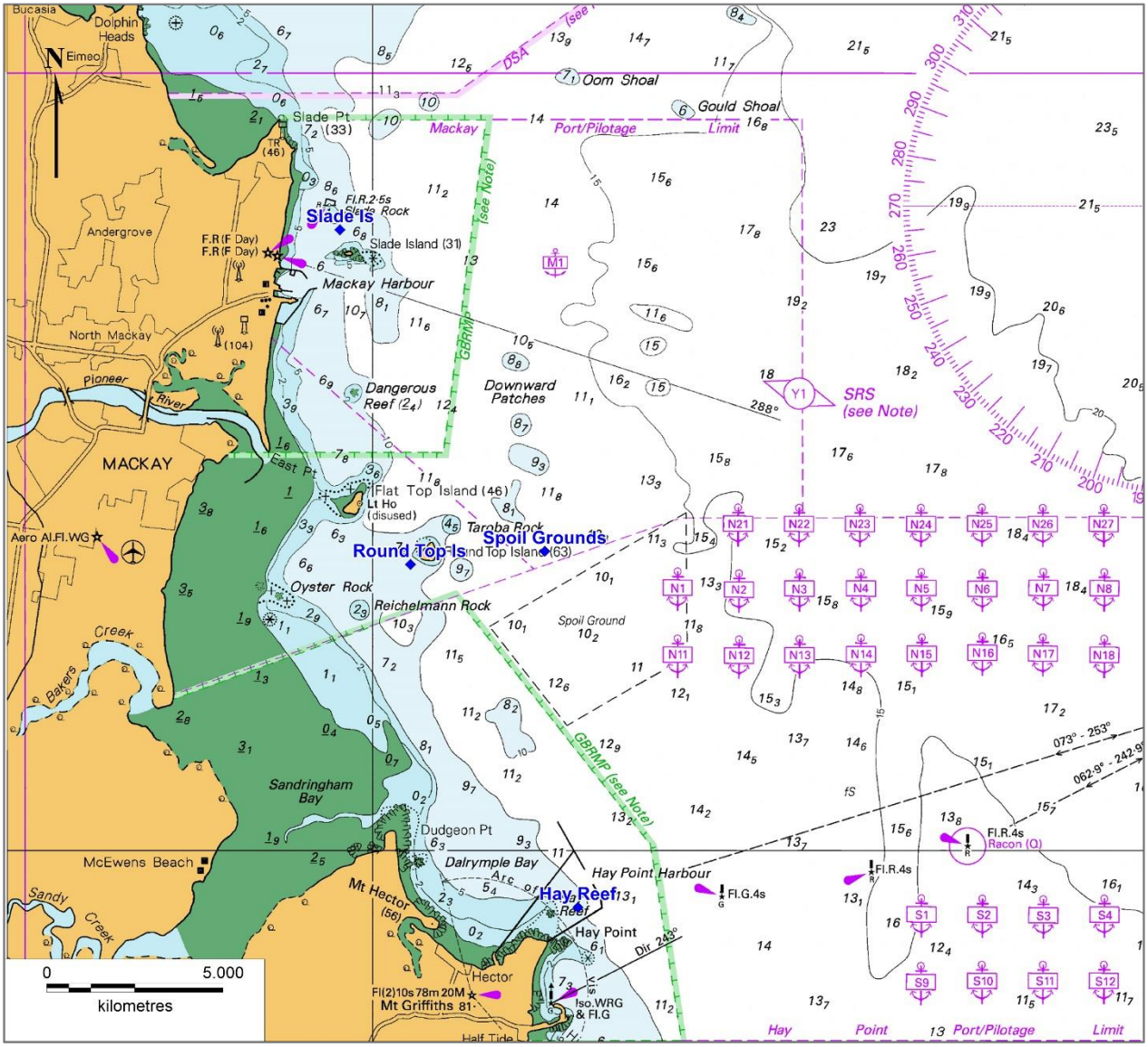


Figure 1. Long-term ambient water quality monitoring sites closest to the Port of Mackay.

3. Results

3.1. Measured SSC Estimate

Measured SSC data from Slade Islet, Round Top Island, Hay Reef and the Hay Point Spoil Grounds have been used to represent the SSC within the Mackay Region. These four sites were selected for the Mackay region as they provide a good representation of the spatial variability in SSC. The Mackay region is assumed to extend approximately 20 km to the south (approximately to Hay Point) and north-west of the Port (approximately 8 km to the north-west of Shoal Point) (Figure 2). This region is considered to encompass where the majority of suspended sediment which influences the sensitive receptors close to the Port (coral at Slade Islet and Round Top Island and seagrass meadows located between Slade Point and Hay Point) will be naturally resuspended and the region where any plumes generated by maintenance dredging could potentially impact.

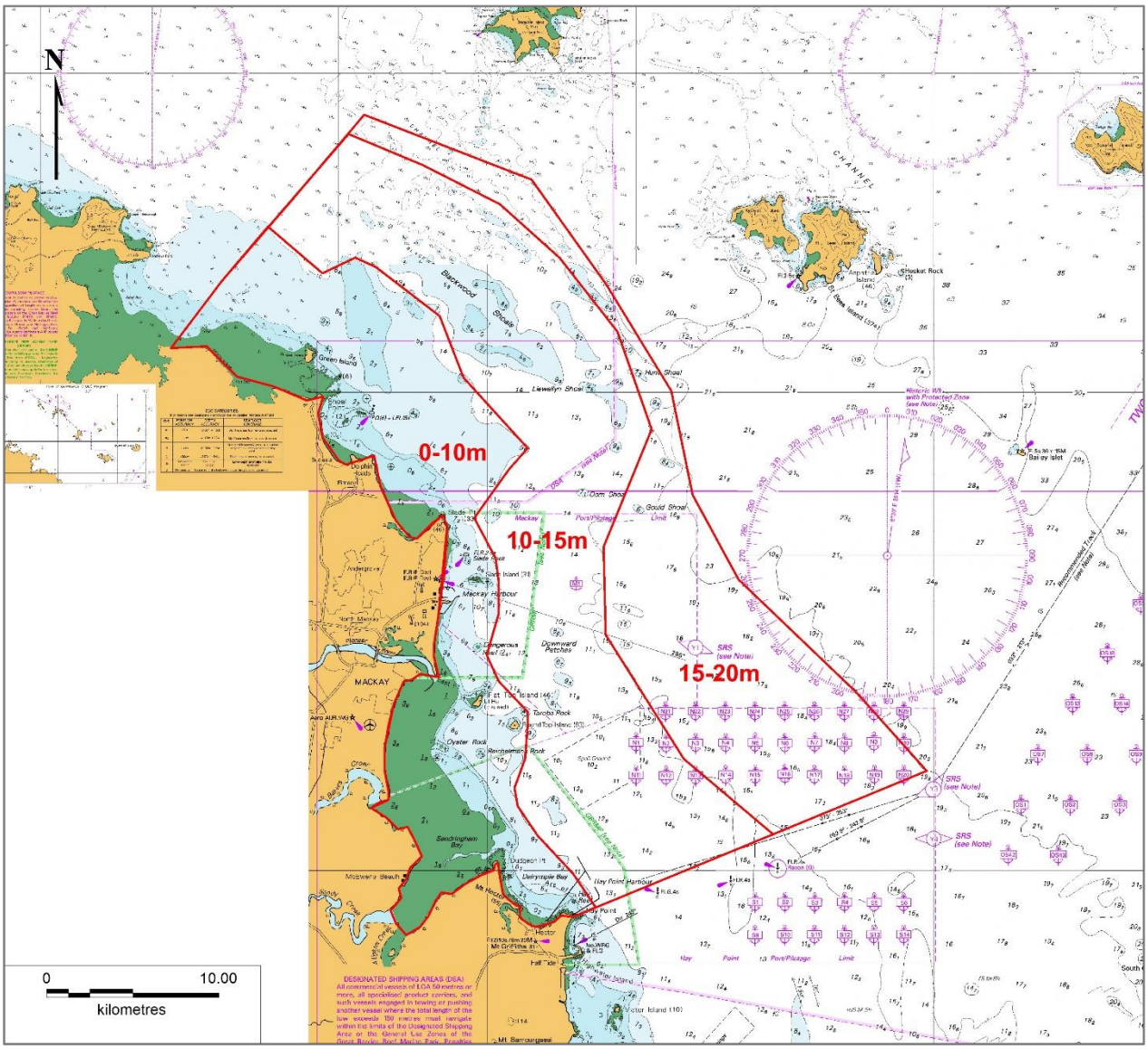


Figure 2. Extents of the different depth regions assumed for the Port of Mackay resuspension mass calculations.

The available measured SSC data from the four sites (data duration of just under seven years, although significantly less data when data capture is considered) were processed to determine the following averaged SSC for the Mackay region:

- the average 50th percentile SSC between the sites has been 2.3 mg/l, with SSC at the deeper water site being negligible during these conditions (approximately 1 mg/l). This can be considered to be representative of ambient wind/wave conditions and regular resuspension by spring tides;
- the average 95th percentile SSC between the sites has been 46.4 mg/l. This can be considered to be representative of infrequent large wave events; and
- during a tropical cyclone (TC) event (TC Debbie in March 2017) the peak SSC was only measured at one nearshore site (Hay Reef) in the Mackay region, with a peak instantaneous value of 2,500 mg/l recorded. However, the measured data showed large fluctuations in SSC (with values fluctuating from close to 0 mg/l to over 2,000 mg/l) over short durations (one to two hours), suggesting some uncertainty in the peak SSC value. Numerical modelling of the TC Debbie event has been undertaken as part of the Mackay SSM Project, with the model validated using the available measured data. The model was able to provide a reliable representation of the increase in SSC during the event, but was

not able to replicate the peak SSC values which were recorded during the short duration spikes (i.e. the model provides a reliable representation of the smoothed SSC over the event). Based on the modelled SSC the average peak SSC during the event at the four sites (located in depths of 0 to 10 m) was approximately 750 mg/l, but the SSC further offshore (10 to 20 m depth) was approximately 250 mg/l. Therefore, an averaged SSC of 500 mg/l has been applied for the entire area.

These concentrations can be used to estimate the total mass of sediment resuspended in the Mackay region by assuming the frequency that the resuspension events occur:

- as the 50th percentile SSC conditions occur for half of the year (182 days) it can be assumed that the sediment in suspension is resuspended 182 times per year; and
- the natural SSC exceeds the 95th percentile value for five percent of the year (18 days). Previous investigations have shown that increased resuspension due to waves occur in the Hay Point and Mackay area when the significant wave height (H_s) at the Hay Point waverider buoy (WRB) exceeds 0.9 m (RHDHV, 2016). The measured wave data at the Hay Point WRB shows that there are typically between 15 and 20 discrete events each year when the H_s exceeds 0.9 m and as a result a frequency of 18 times is considered to provide a realistic representation of the number of wave events when increased resuspension occurs.

The area selected as being representative of the Port of Mackay region extends offshore to a maximum depth of 20 m below LAT as this is the maximum depth that could potentially be impacted by any resuspension from maintenance dredging at the Port. The following sub areas were adopted for the resuspension calculations (Figure 2):

- to a depth of 10 m below LAT for spring tides and ambient resuspension calculations;
- to a depth of 15 m below LAT for larger wave event calculations; and
- to a depth of 20 m below LAT for extreme wave event calculations (e.g. TCs).

The areas of the three separate sub areas were 300, 690 and 925 km^2, respectively.

Based on the information provided above, the natural resuspension in the Mackay region was estimated to be:

- 3,450 tonnes of sediment per event resuspended by ambient wind/wave conditions and spring tides;
- 240,000 tonnes of sediment per event resuspended by large wind/wave events;
- 4,625,000 tonnes of sediment per event resuspended by an extreme wind/wave event; and
- in the order of 5,000,000 tonnes of sediment naturally resuspended in the Mackay region each year for a year without an extreme event and just under 10,000,000 tonnes for a year with an extreme event.

3.2. Modelled SSC Estimate

To assess the level of confidence that can be placed in the approach of estimating the mass of sediment resuspended in the Mackay region using measured in-situ SSC data, the Mackay numerical model was also used (see PCS (in prep) for further details). Outputs from the model were used to calculate the mass of sediment resuspended in the Mackay region during the following conditions:

- a spring tide,
- a large wave event; and
- during TC Debbie.

The model has been calibrated to measured SSC data collected at the ambient water quality monitoring sites for a range of conditions including a cyclonic event (PCS, in prep). The model was shown to provide a good representation of the natural resuspension processes at the sites with reliable data over the calibration period. The model is not able to represent the peaks in short duration spikes in SSC which can occur during wind and wave events at the nearshore sites. As such, although the model is considered to

provide a good representation of the timing and magnitude of the typical SSC which occurs naturally, the model does underestimate the short duration peaks in SSC which occur during cyclonic events and so is likely to underestimate the total resuspension during extreme events.

The spatial distribution in SSC around the Port of Mackay (with the same polygons plotted as in Figure 2) during a spring tide with low wind speeds, a strong wind/large wave event and a tropical cyclone (TC Debbie) are shown in Figure 3 to Figure 5. The peak mass of sediment in suspension during these events in the overall polygon shown in the figures (which extends from 0 to 20 m below LAT) was as follows:

- Spring tide = 3,100 tonnes;
- Large wave event (30 knot peak wind speed) = 230,000 tonnes; and
- TC Debbie = 4,100,000 tonnes.

Assuming the same number of resuspension events in a year as adopted in the approach for the measured SSC estimate (i.e. resuspension due to strong wind/large events occurs 18 times per year and resuspension due to ambient wind/wave conditions and regular resuspension by spring tides occurs 182 times per year), the mass of sediment indicated to be resuspended is 4,700,000 tonnes per year.

There is a small difference between the two approaches when estimating the mass of sediment resuspended by TC Debbie (measured data approach = 4,625,000 tonnes and model approach = 4,100,000 tonnes).

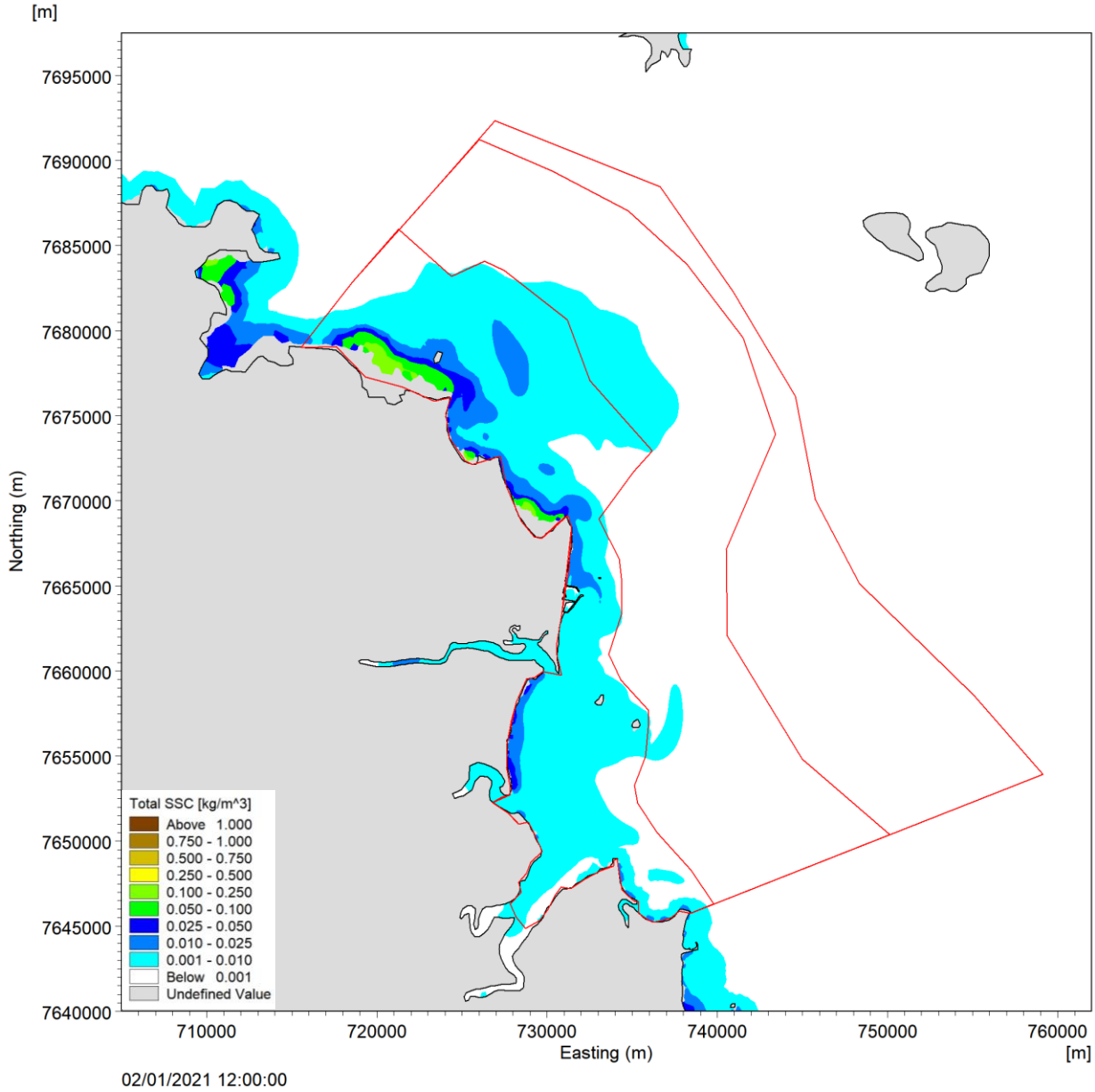


Figure 3. Modelled SSC during a large spring tide with low wind speeds.

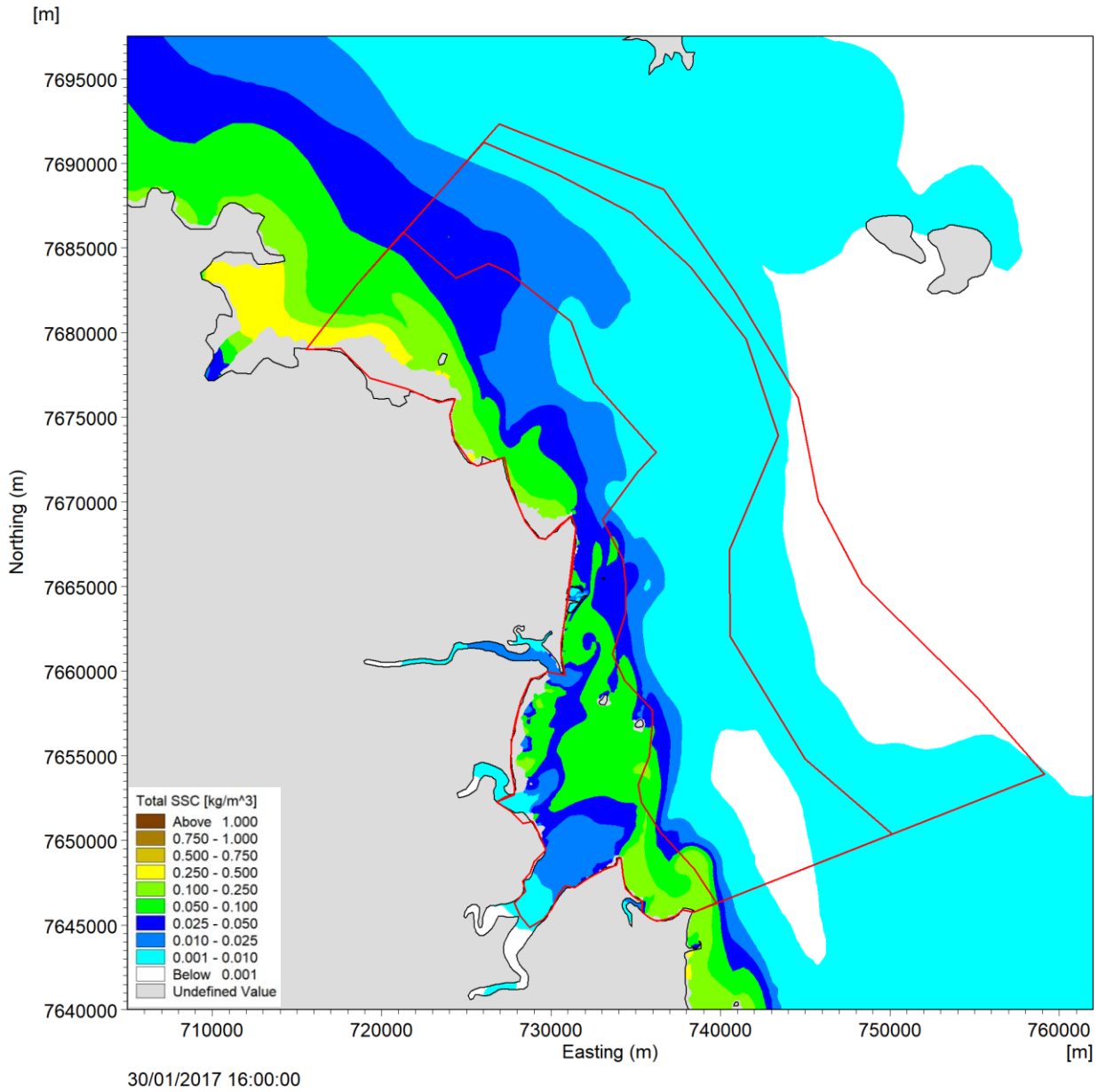


Figure 4. Modelled SSC during a high wind/large wave event.

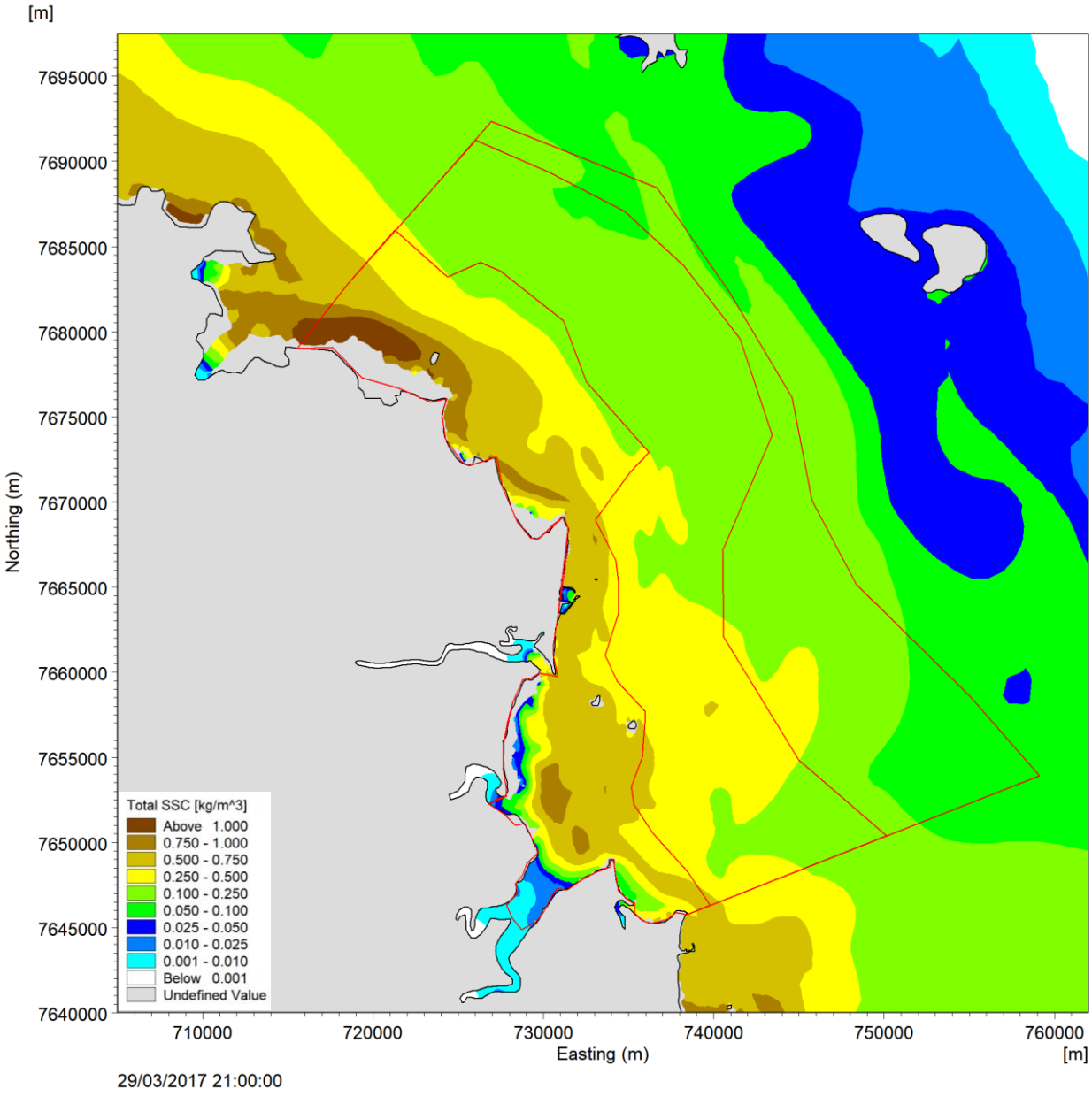


Figure 5. Modelled SSC during a TC extreme event.

3.3. SSC and Wind Speed Relationship

A relationship between wind speed and wave height was previously developed by RHDHV (2017) for the Hay Point and Mackay region (Figure 6). The plot shows that there is a strong relationship between wind speed and significant wave height (H_s) measured at the Hay Point wave rider buoy (which is also representative of nearshore wave conditions at Mackay).

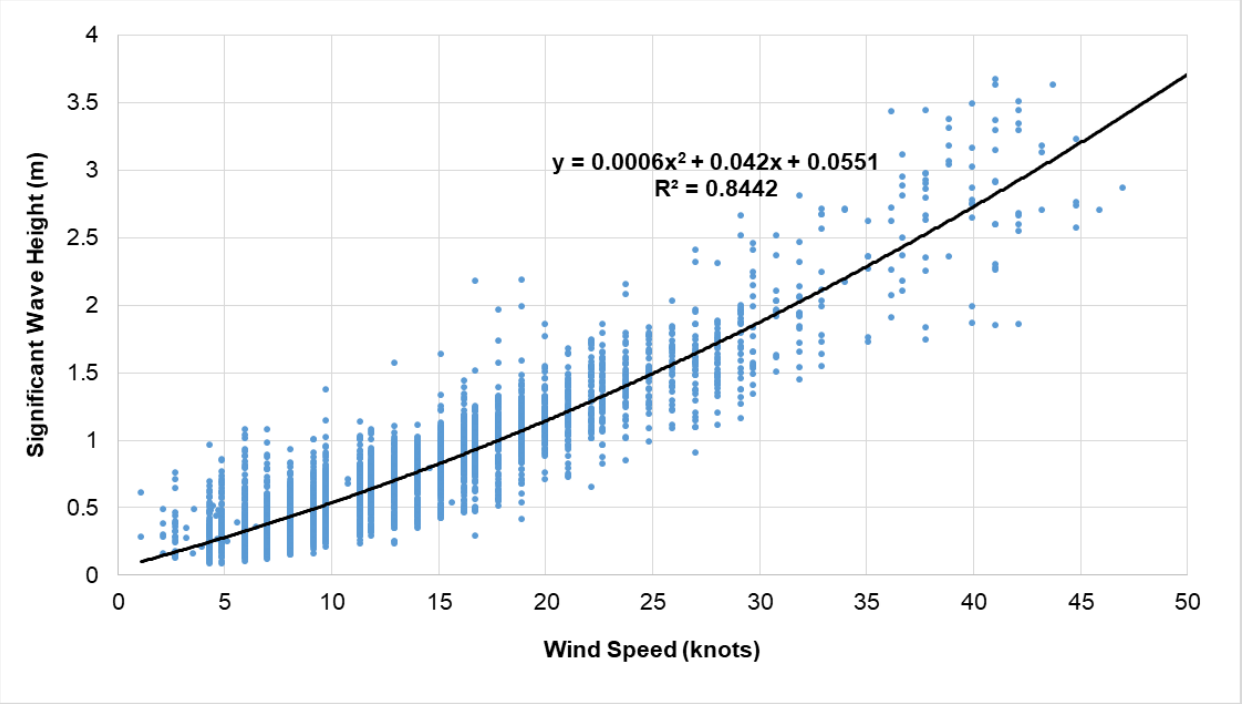


Figure 6. Relationship between wind speed and significant wave height at the Port of Hay Point (RHDHV, 2017).

The Mackay numerical model, developed by PCS for the Mackay SSM Project, was setup to simulate a six day period of either spring or neap tides (to understand the relative influence of the tide) which coincided with a range of representative wind and wave conditions. A typical onshore wind event (wind directions from the east to south-east) was scaled so that the peak wind speed of the event was equal to a range of eight wind speeds between 5 knots and 40 knots (every 5 knots). The wave boundary conditions were scaled relative to the wind speed according to the relationship shown in Figure 6. It is important to note that the results from the modelling can be applied to onshore wind directions ranging from the south-east to the north-east, but the results will not be representative for wind directions from cross-shore (northerly or southerly) or offshore (westerly) directions.

Results from the simulations have been processed to calculate the peak mass of sediment predicted by the numerical model to be in suspension within the Mackay region (0 to 20 m below LAT area shown in Figure 2) for each wind condition during both spring and neap tidal conditions (Figure 7 and Figure 8). The plots show the following:

- a linear increase in the mass of sediment resuspended relative to wind speed for wind speeds of up to 25 knots and an exponential relationship for wind speeds of more than 25 knots; and
- tidal currents are also an important process in terms of sediment resuspension, where in the order of double the mass of sediment is resuspended during spring tides compared to neap tides, when wind speeds exceed 20 knots.

To understand how the SSC in the Mackay region varies with wind speed, the peak SSC at Slade Islet and Round Top Island have been averaged for each of the wind speeds modelled. The relationships between wind speed and the averaged peak SSC at the two sites for spring and neap tidal conditions are shown in Figure 9 and Figure 10.

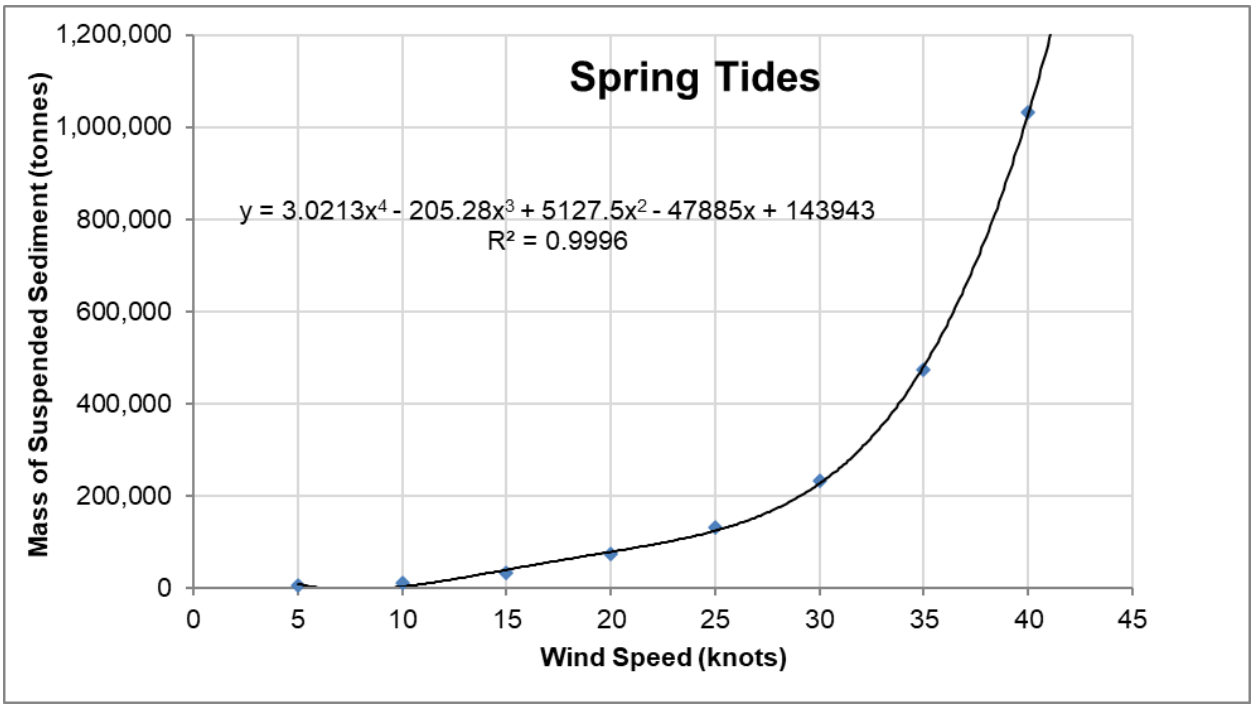


Figure 7. **Relationship between wind speed and the mass of sediment in suspension within the Mackay region during spring tides.**

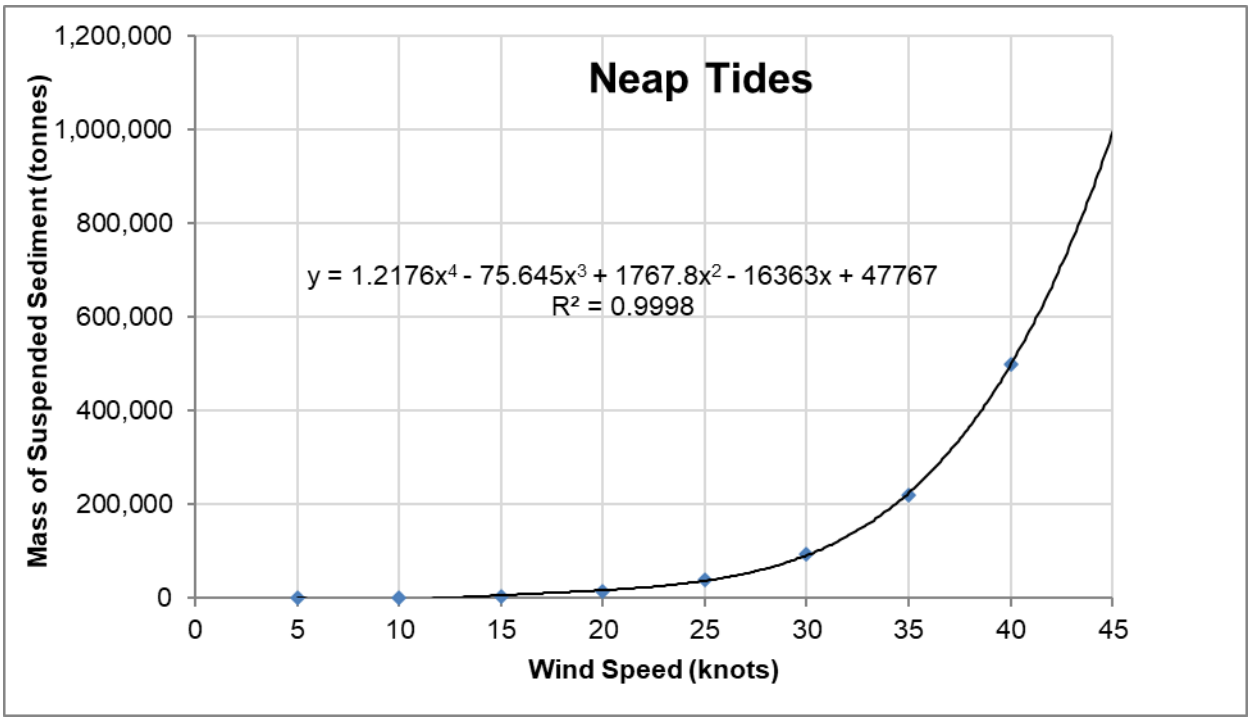


Figure 8. **Relationship between wind speed and the mass of sediment in suspension within the Mackay region during neap tides.**

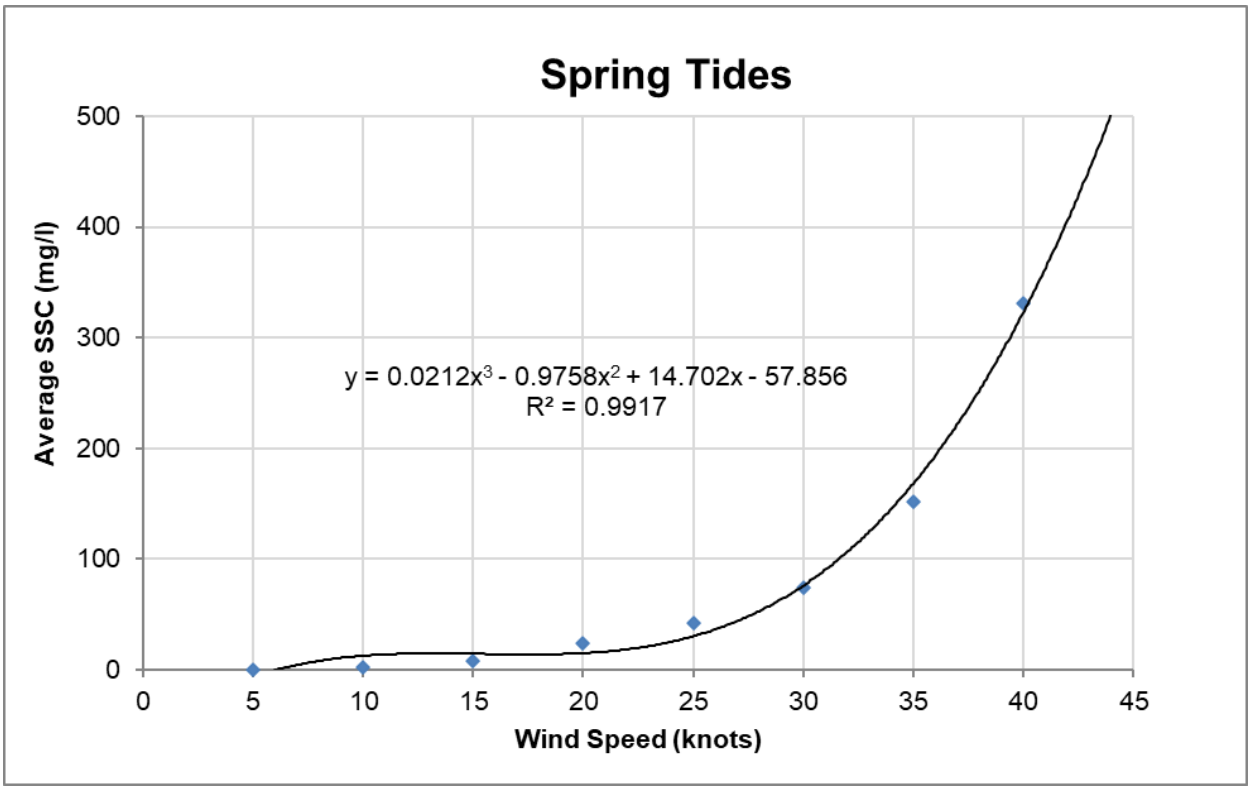


Figure 9. Relationship between wind speed and the averaged peak in SSC (averaged from Round Top Island and Slade Islet) during spring tides.

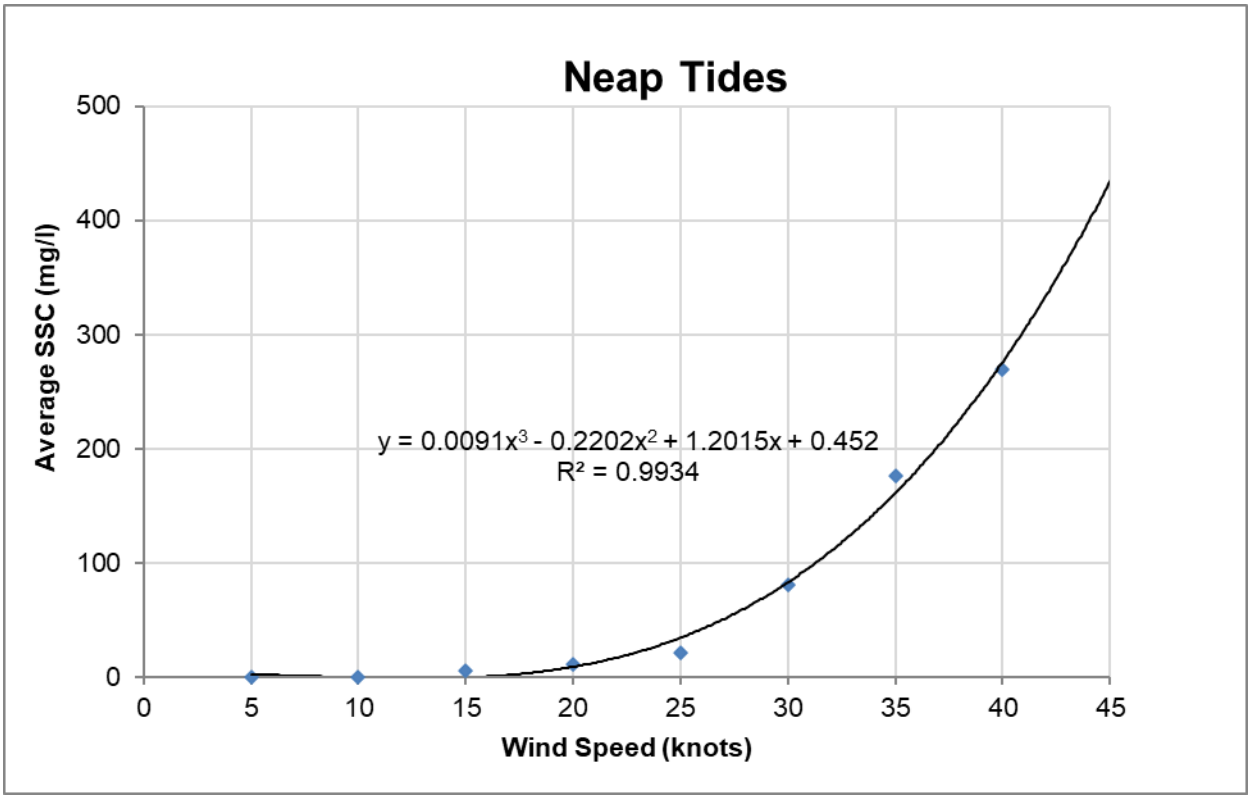


Figure 10. Relationship between wind speed and the averaged peak in SSC (averaged from Round Top Island and Slade Islet) during neap tides.

Measured wind data from the Bureau of Meteorology (BoM) weather station located at Half Tide Tug Harbour (Station Name: Hay Point, ID: 033317) provides the best representation of the wind conditions over water for the Hay Point and Mackay region. Measured data from the station has been processed to provide a better understanding of the wind conditions in the region (Table 1, Figure 11 and Figure 12). The wind speeds are less than 10 knots for approximately 40 percent of the time, and greater than 20 knots for approximately 8 percent of the time. The average and median wind speeds are approximately 12.5 knots. The wind data show that the dominant wind direction is from the south-east quadrant but there is some seasonal variability in wind conditions:

- Dry Season: during autumn and winter the dominant wind direction is from the south, although in the autumn winds from the entire south-east quadrant are common; and
- Wet Season: during spring and summer winds predominate from north clockwise through to south-east.

Table 1. Joint frequency table for wind speed and direction at the BoM Hay Point weather station.

Joint Frequency Table (%) Showing Wind Sp Against Direction for the Period 24-Nov-2005 14:00:00 to 09-Aug-2018 14:30:00

N=225246	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Total	Cumul.
0–5	0.27	0.21	0.26	0.28	0.34	0.21	0.25	0.24	0.47	1.02	1.38	1.07	1.17	0.48	0.29	0.17	8.12	8.12
5–10	1.58	1.55	2.13	2.63	3.67	2.19	2.22	2.08	3.12	4.63	3.06	1.07	1.26	0.69	0.70	0.58	33.17	41.28
10–15	1.60	1.23	1.32	1.66	3.91	3.08	2.86	2.71	3.65	1.65	0.19	0.05	0.04	0.02	0.08	0.30	24.34	65.63
15–20	2.22	0.62	0.40	0.65	3.36	4.66	4.06	5.05	4.60	0.83	0.04	0.02	0.02	0.01	0.01	0.20	26.76	92.39
20–25	0.23	0.02	0.03	0.10	0.59	1.34	1.17	1.41	0.79	0.04	*	*	*	*	*	0.02	5.76	98.14
25–30	0.03	0.01	0.01	0.02	0.10	0.20	0.16	0.38	0.11	*	*	–	–	–	*	*	1.03	99.17
30–35	*	*	*	*	0.01	0.02	0.01	0.06	0.01	*	–	–	–	–	–	*	0.15	99.32
35–40	*	0.01	*	*	*	*	*	0.01	*	–	–	–	–	*	–	–	0.07	99.39
40–45	*	*	*	*	*	*	–	*	*	–	–	–	–	–	–	*	0.03	99.42
45–50	–	*	*	–	–	*	–	–	–	–	–	–	–	–	–	–	*	99.42
Total	5.95	3.67	4.17	5.37	12.01	11.70	10.74	11.93	12.75	8.19	4.68	2.21	2.49	1.20	1.08	1.27		
Cumul.	5.95	9.62	13.79	19.16	31.16	42.87	53.61	65.54	78.30	86.48	91.16	93.37	95.86	97.07	98.15	99.42		

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

Metadata:
Project: P033
Data period: 24-Nov-2005 14:00:00 to 09-Aug-2018 14:30:00
Data source: BoM
Data summary: All Records
Number of Records: 225246
Missing data (%): 0.02
Calms (% <1.0kn): 0.56

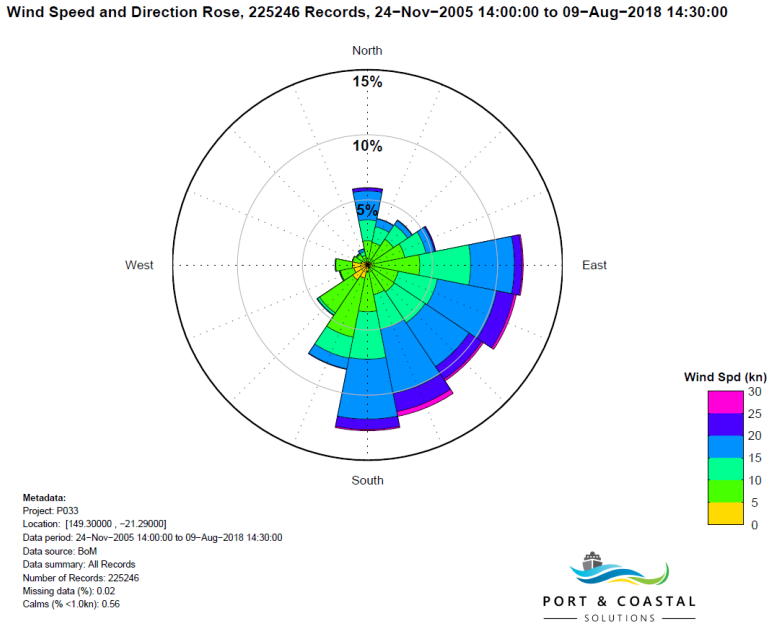
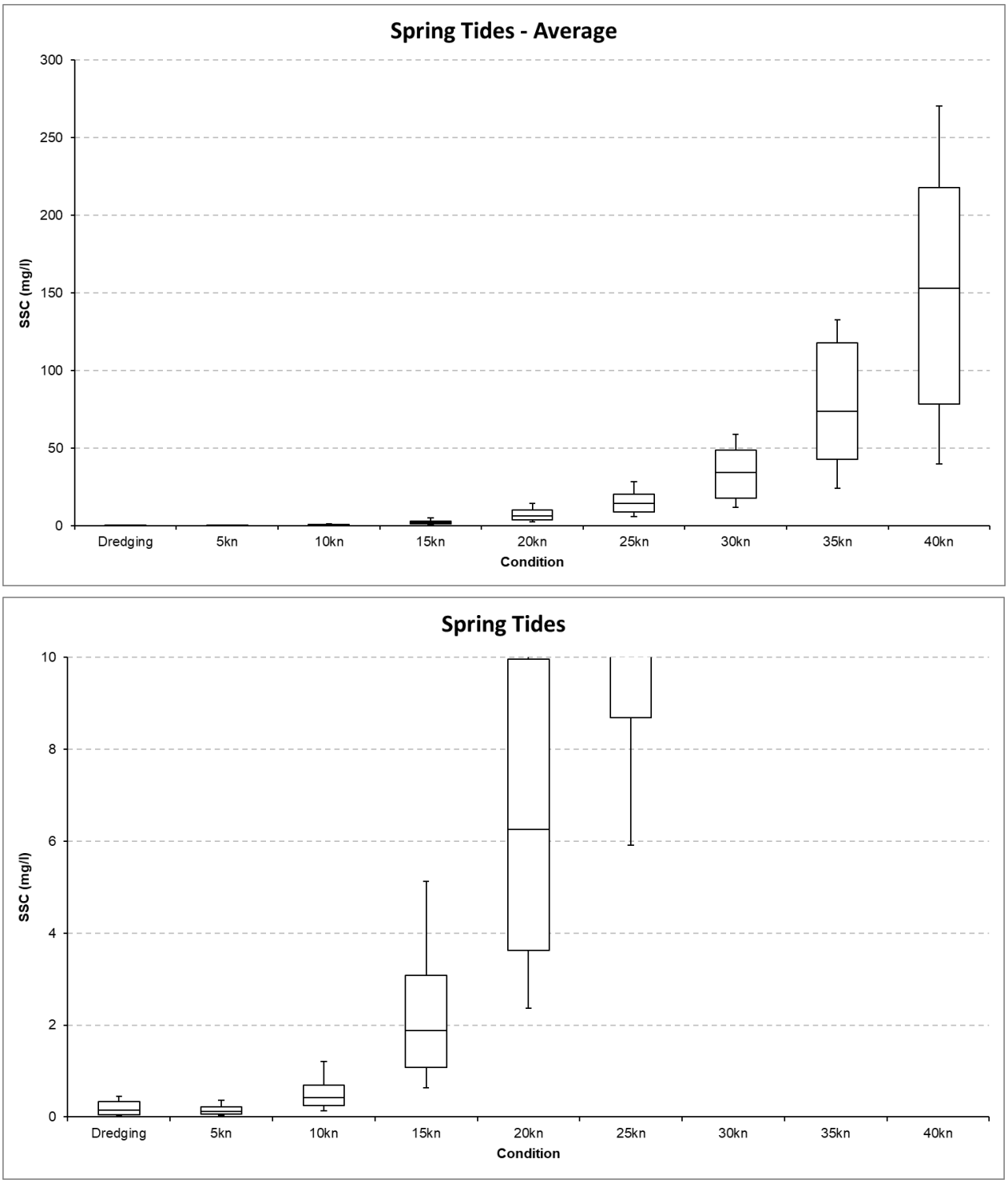


Figure 11. Annual wind rose for the BoM Hay Point weather station.

Figure 12. Seasonal wind roses for the BoM Hay Point weather station.

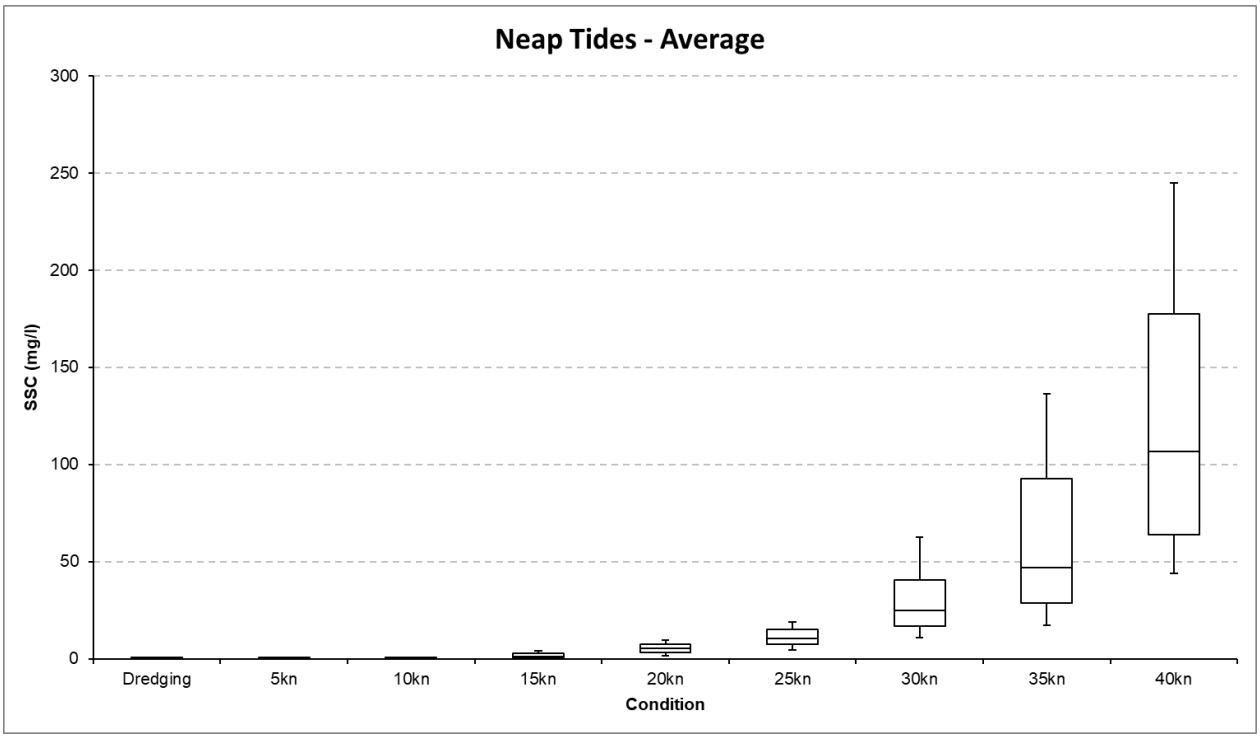
To show how maintenance dredging compares to the natural variability in SSC, numerical modelling results from the 12 day maintenance dredging program in 2020 where approximately 120,000 m^3 of maintenance dredging was undertaken using the existing material placement site have been used (for further details see PCS (in prep)). The modelled excess SSC (i.e. greater than natural ambient conditions) resulting from the maintenance dredging activity and placement at the existing material placement site was processed to calculate the 5^{th}, 20^{th}, 50^{th}, 80^{th} and 95^{th} percentile values that occurred during the spring and neap tide conditions over the simulated dredging duration.

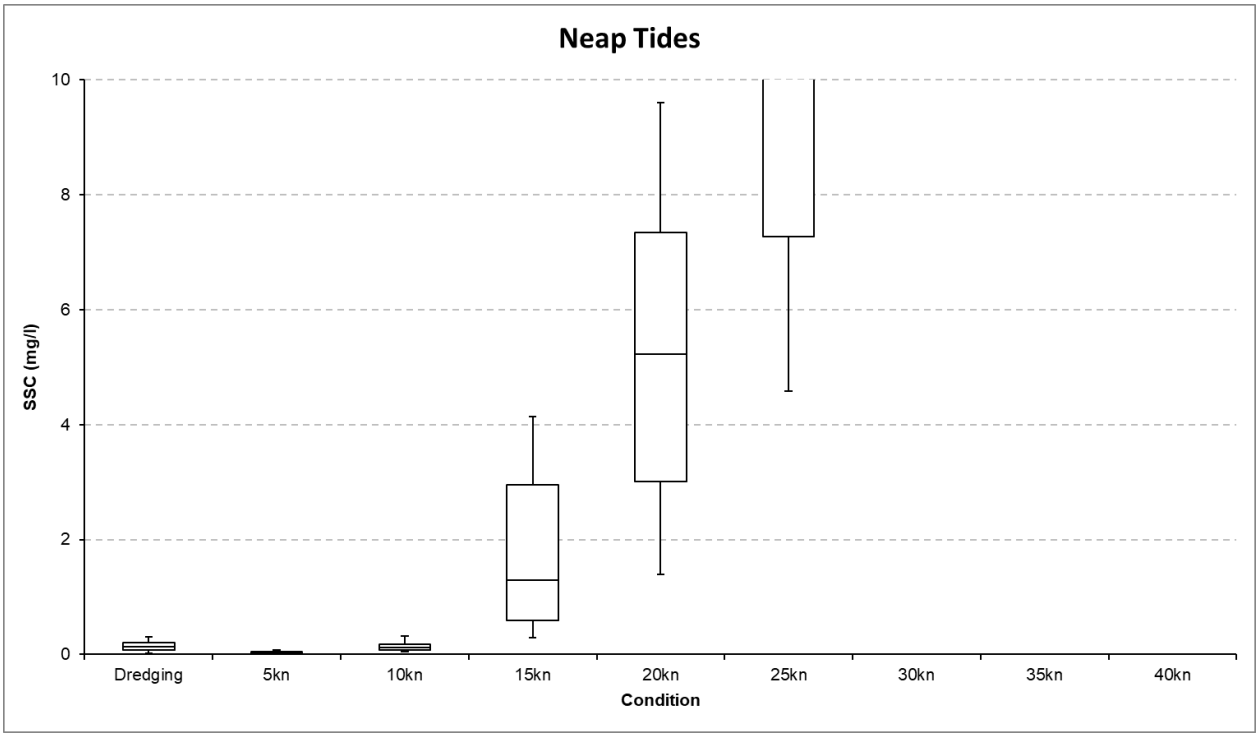
The dredging related excess SSC percentiles have been compared to the same percentiles calculated from the simulations used to develop the wind speed to natural SSC relationship described above. The natural SSC percentiles were based on three days during the peak of the eight wind speeds for both spring and neap tide conditions. The spatially averaged SSC percentiles from dredging and natural resuspension for the two sites considered (Slade Islet and Round Top Island) during spring and neap tides are shown in Figure 13 and Figure 14, while site specific plots are included in Appendix A. The plots demonstrate that the maintenance dredging results in low excess SSC at the two sites, with the 95^{th} percentile (upper limit of the whiskers) during both spring and neap tide conditions remaining below 1 mg/l. Based on this, the increase in SSC due to maintenance dredging is approximately comparable to the natural SSC, which occurs at the sites during very calm conditions (wind speeds of 10 knots and below). Results from the numerical modelling of the 2020 maintenance dredging showed that the SSC remained elevated within Mackay Harbour throughout the dredging program and then reduced to less than 1 mg/l within 24 hours of the dredging finishing. To put the elevated SSCs during the maintenance dredging within Mackay Harbour into context with the natural SSC, a box and whisker plot showing the SSC percentiles is shown in Figure 15. The plot shows that the SSC due to maintenance dredging within Mackay Harbour is comparable to the natural SSC which can be attributed to the 20 to 25 knot winds. This highlights how the Harbour acts to retain a lot of the sediment suspended by maintenance dredging (explaining why the SSC at the sites outside the Harbour are so low) and how the Harbour is sheltered from direct resuspension due to wind and wave conditions, meaning that natural SSC within the Harbour is constrained by the import of naturally suspended sediment during the flood stage of the tide.



The box is represented by the 20th, median (middle line) and 80th percentiles, while the whiskers are represented by the 5th and 95th percentiles.

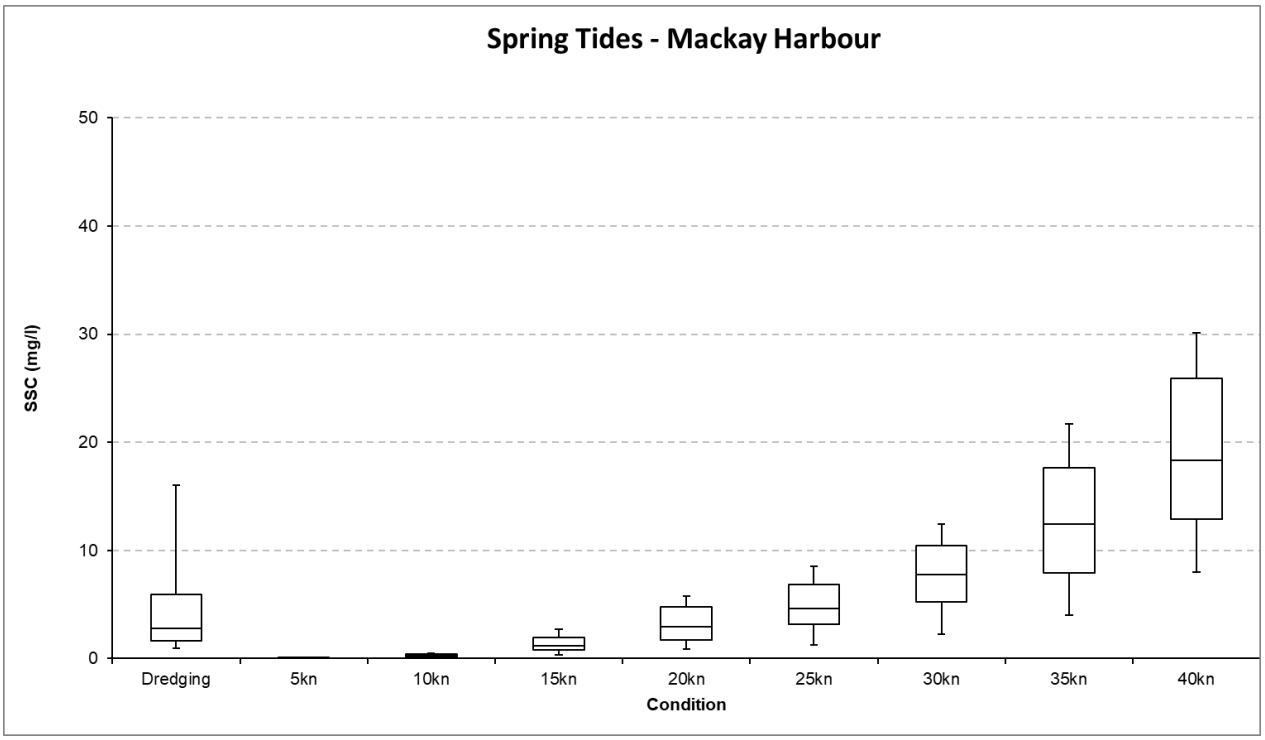
Figure 13. Box and whisker plot showing average percentiles (over the two sites) during spring tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m³ using the existing placement site. *The top plot shows the entire SSC range (0 – 300 mg/l) and the bottom plot is zoomed in on the lower SSC values (0 – 10 mg/l) so the relative impact of dredging can be seen.*





The box is represented by the 20th, median (middle line) and 80th percentiles, while the whiskers are represented by the 5th and 95th percentiles.

Figure 14. **Box and whisker plot showing average percentiles (over the two sites) during neap tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m³ using the existing placement site.** *The top plot shows the entire SSC range (0 – 300 mg/l) and the bottom plot is zoomed in on the lower SSC values (0 – 10 mg/l) so the relative impact of dredging can be seen.*



The box is represented by the 20th, median (middle line) and 80th percentiles, while the whiskers are represented by the 5th and 95th percentiles.

Figure 15. Box and whisker plot showing average percentiles within Mackay Harbour during spring tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m³ using the existing placement site.

4. Summary

This technical note has provided details of the natural resuspension of sediment in the Port of Mackay region. The assessment has found that:

- the annual mass of sediment resuspended by typical conditions is in the order of 5,000,000 tonnes per year in the Mackay region (to 20 m LAT and 20 km north and south of the Port); and
- between 4,100,000 and 4,600,000 tonnes of sediment was estimated to have been resuspended within the Mackay region (to 20 m LAT and 20 km north and south of the Port) during TC Debbie. As such, during a year when a tropical cyclone results in very strong winds and very large waves in the region the natural resuspension could increase to just under 10,000,000 tonnes per year.

Relationships between resuspension mass/SSC and wind speed for the Mackay region have been developed for both spring and neap tide conditions. The relationships show a relatively linear increase in SSC for wind speeds of less than 25 knots, with more of an exponential increase in SSC when wind speeds increase above 25 knots.

A comparison of maintenance dredging relative to the natural SSC has been undertaken. This shows that the 2020 maintenance dredging program (120,000 m³ placed at the existing placement site) resulted in very low excess SSC at the closest water quality monitoring sites (95th percentile SSC of less than 1 mg/l), which is approximately comparable to the natural range in SSC during calm conditions (wind speeds of 10 knots and under). The results have also shown that the SSC in Mackay Harbour during maintenance dredging remains higher than at the nearby water quality monitoring sites of Slade Islet and Round Top Island, showing that the Harbour acts to retain a lot of the sediment suspended by the maintenance dredging activity.

5. References

PCS, in prep. Port of Mackay SSM, Dredge Plume Modelling.

RHDHV, 2016. Hay Point Port: Bathymetric Analysis and Modelling. Reference: M&WPA1163R001F01, February 2016.

RHDHV, 2017. Port of Hay Point, Natural Sediment Resuspension Assessment. November 2017.

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Appendix A – Individual Site Plots

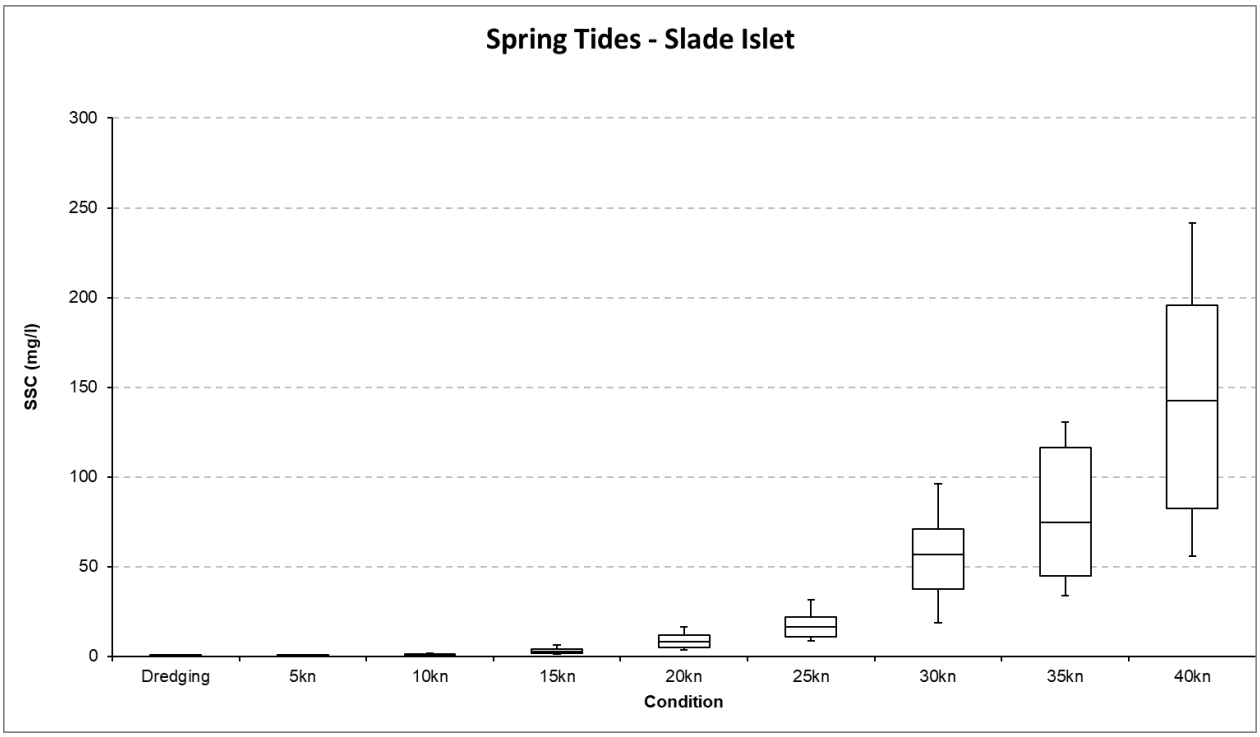

Figure A1. **Box and whisker plot showing percentiles at Slade Islet during spring tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m^3 using the existing placement site.**

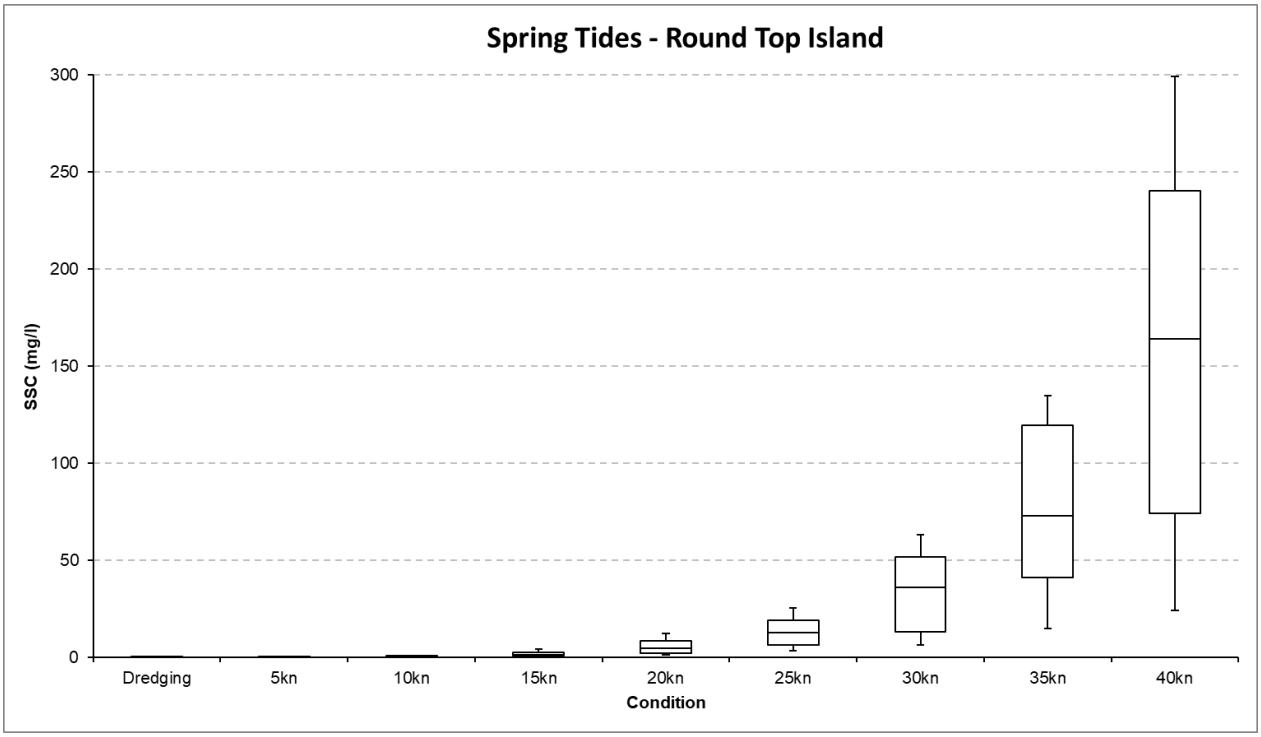

Figure A2. **Box and whisker plot showing percentiles at Round Top Island during spring tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m^3 using the existing placement site.**

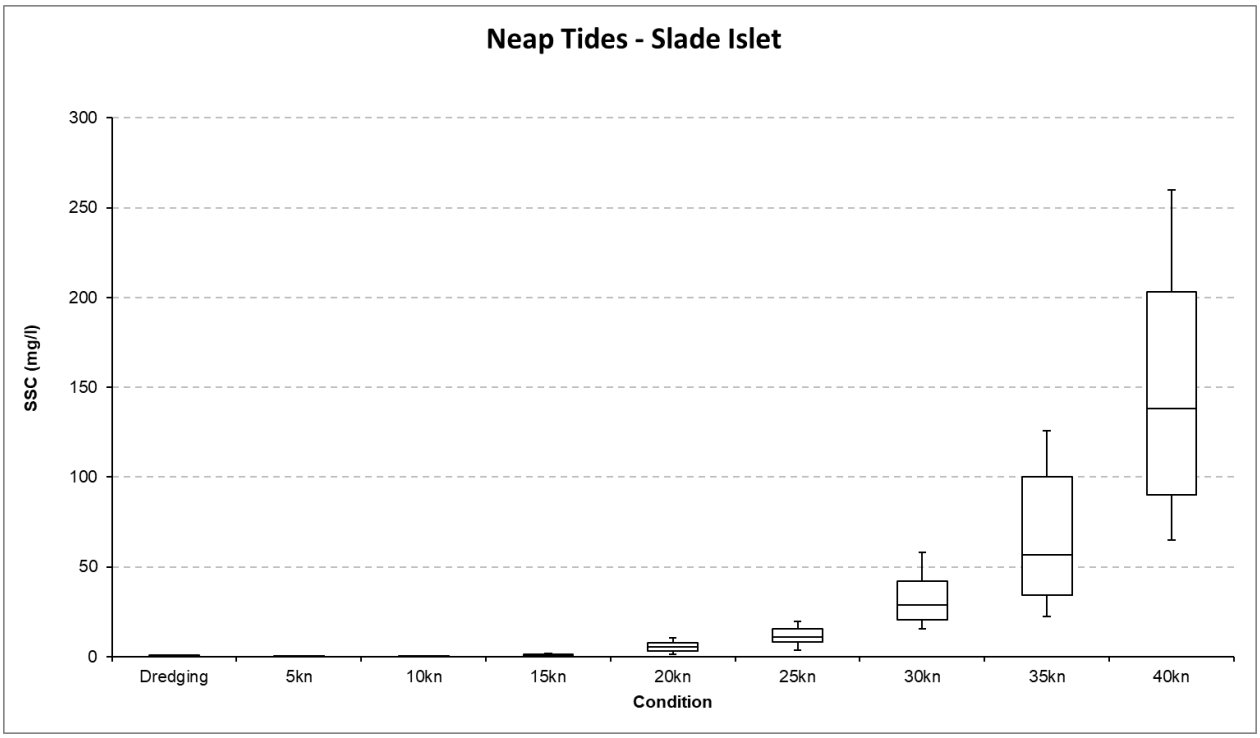

Figure A3. **Box and whisker plot showing percentiles at Slade Islet during neap tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m^3 using the existing placement site.**

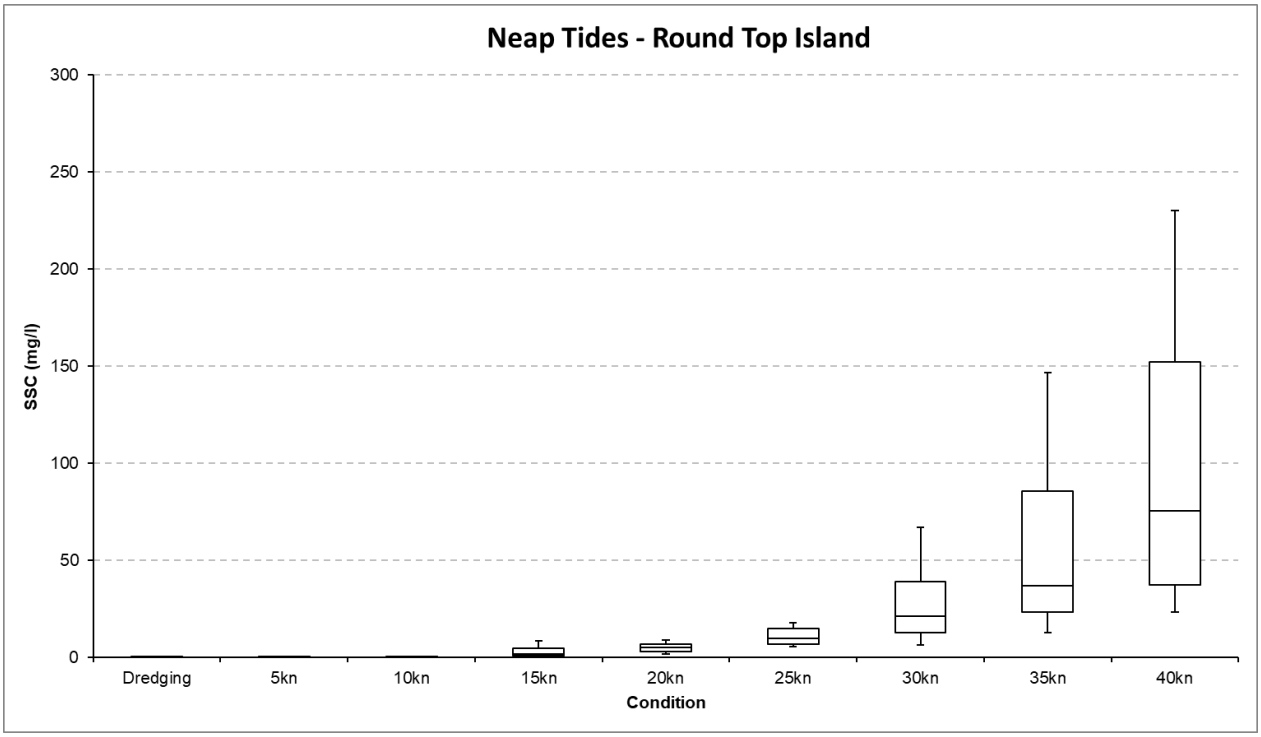

Figure A4. **Box and whisker plot showing percentiles at Round Top Island during neap tidal conditions for natural SSC during different wind speeds and excess SSC from maintenance dredging of 120,000 m^3 using the existing placement site.**