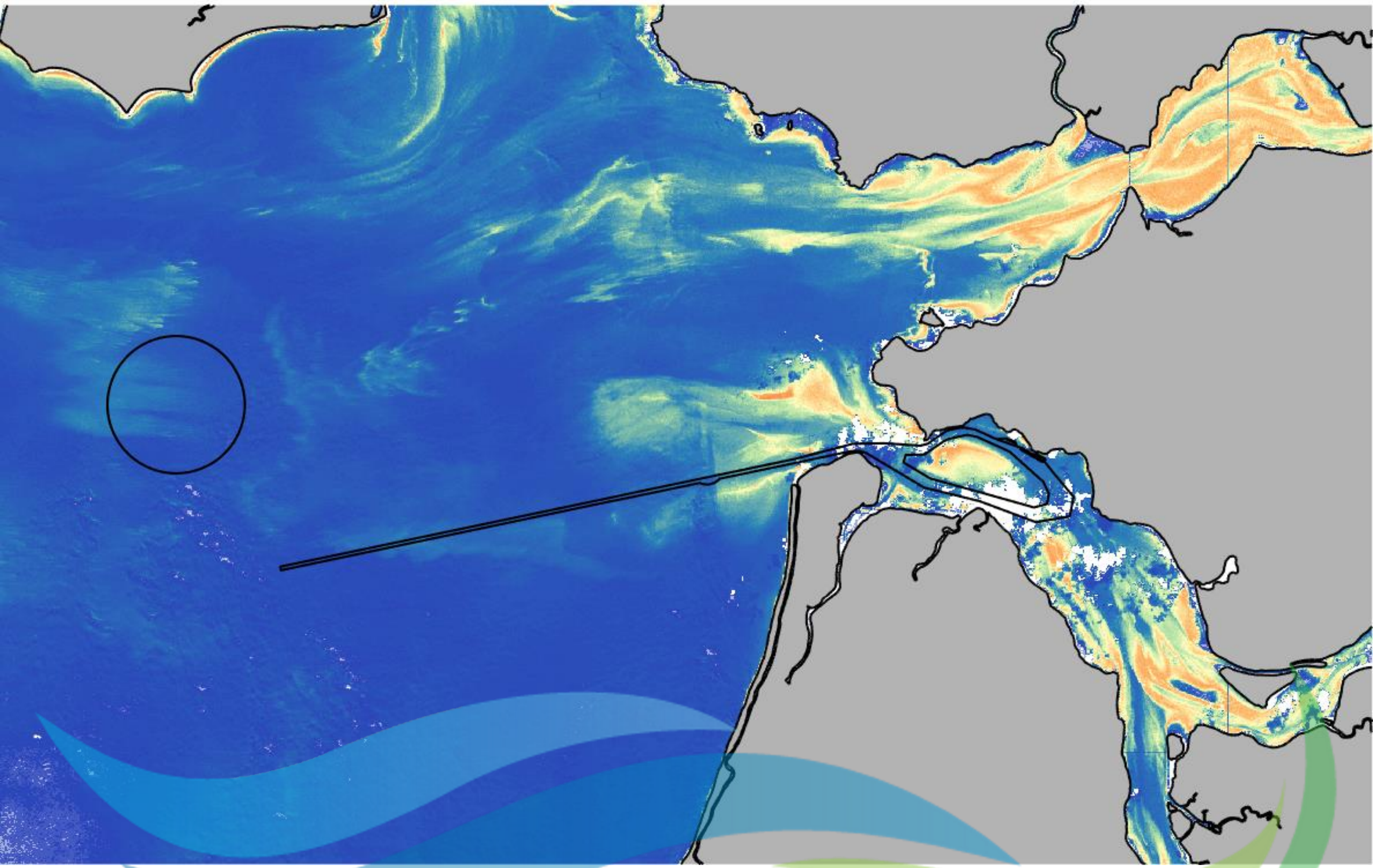
PORT & COASTAL SOLUTIONS

Port of Weipa, 2022 Maintenance Dredging

Summary of Turbidity Monitoring

Report No. P049_R02v02



NORTH QUEENSLAND BULK PORTS CORPORATION

Technical Report

November 2022

PORT & COASTAL SOLUTIONS

Port of Weipa, 2022 Maintenance Dredging

Summary of Turbidity Monitoring

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North Queensland Bulk Ports Corporation Ltd

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Executive Summary

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions Pty Ltd (PCS) to undertake work to support the 2022 maintenance dredging program at the Port of Weipa. This included the following:

1) to analyse the turbidity and metocean conditions over the duration of the dredge program, including 7 days pre- and post-dredging;
2) to assess the relative contribution of the maintenance dredging and placement activities on the natural turbidity at the measurement sites;
3) to better understand the spatial extent of any plumes resulting from the maintenance dredging and placement activities based on satellite-derived total suspended matter (TSM) data; and
4) provide a technical report which presents and interprets both the in-situ benthic turbidity data and satellite-derived TSM data collected over the entire pre-, during and post-dredging periods.

The 2022 maintenance dredging program was undertaken by the TSHD Brisbane and involved the relocation of 782,000 m^3 of sediment from the dredged areas of the Port to the Albatross Bay DMPA. Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future. The data showed that during the dredging program the turbidity around the Port of Weipa was generally driven by the natural conditions (predominantly the astronomical tide), with higher turbidity occurring during periods of larger range spring tides. The key findings from the turbidity data analysis are detailed below:

- the exceedance analysis of the in-situ measured benthic turbidity data shows that the duration exceedances were below the average duration exceedance at WQ1 and WQ2 while at WQ4 the exceedance duration was above the average duration exceedance but below the 90th percentile duration exceedance. The results therefore show that the turbidity at WQ4 was still higher than the turbidity at the other sites relative to the updated turbidity intensity thresholds. Based on this it would be beneficial to undertake a further analysis and revisit updating the turbidity intensity thresholds, as all available evidence indicates that the reason for the increased exceedance at WQ4 was due to natural processes rather than the maintenance dredging program;
- as expected, the dredging and placement activities associated with the Port of Weipa 2022 maintenance dredging program were found to result in visible plumes. Plumes were observed close to the dredger when dredging, adjacent to the South Channel and within the Albatross Bay DMPA. The size and concentration of the plumes was variable;
  - the largest plume which was clearly due to the maintenance dredging and not natural processes was up to 4 km in length and 250 m in width with a concentration of up to 15 mg/l, occurring adjacent to the South Channel. Satellite imagery indicated that a plume was regularly present around the South Channel as this was where the majority of the maintenance dredging was undertaken; and
  - plumes in the DMPA from the placement of dredged sediment were typically less than 1 km in extent and only persisted for short durations (in the order of hours). The observed plumes were consistent with placement by the TSHD Brisbane during previous annual maintenance dredging programs prior to the Albatross Bay DMPA being moved.
- all of the plumes resulting from maintenance dredging (including those from both dredging and placement) were found to remain close to where they were created. This shows that little net residual transport occurs in the region, this was also noted during the 2019 to 2021 maintenance dredging programs and as part of the Port of Weipa Sustainable Sediment Management assessment (PCS, 2019b, 2020a, 2020b and 2021a). Based on this, it can be assumed that the majority of the sediment suspended

by the maintenance dredging is subsequently redeposited close to where it was either dredged or placed;

- the Port of Weipa 2022 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to where dredging was undertaken in the Port and in the Albatross Bay DMPA. Natural variations in turbidity driven by the tide and wave conditions over the monitoring period were larger than the variations in turbidity due to the maintenance dredging. The satellite imagery showed that the turbidity in the area of the seagrass meadows in the Inner Harbour was predominantly controlled by natural processes over the 2022 maintenance dredging program, with no visible plumes from the dredging activity observed in the Inner Harbour; and
- the post dredging satellite imagery showed that residual plumes were still present around the South Channel 12 hours after the dredging had finished and a possible low concentration plume was also present in the Albatross Bay DMPA which could have been due to the most recent placement (11 hours prior to the image being captured). The image captured five days after dredging ended did not show any indication of plumes from the dredging or placement activities. This is in agreement with findings from previous dredge programs (2020) where satellite imagery showed that the turbidity had returned to natural conditions within one to four days after the end of the dredging (PCS, 2020a).

1. Introduction

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions Pty Ltd (PCS) to undertake work to support the 2022 maintenance dredging program at the Port of Weipa. This included the following:

- source satellite imagery for the Port of Weipa region and process the imagery to output satellite-derived turbidity to show the spatial distribution of turbidity over the duration of the dredging program plus 7 days pre- and post-dredging;
- obtain metocean data for the Weipa region over the whole pre-, during and post-dredging period to help interpret the satellite-derived turbidity data;
- provide a pre-dredging technical note prior to the dredging commencing which presents the satellite-derived turbidity data and metocean conditions. The note will provide an overview of the natural turbidity and the relative influence of different drivers (e.g. waves and tidal currents) during the pre-dredging period;
- provide a during dredging technical note after 21 days of the maintenance dredging. The note will present results from the satellite-derived turbidity monitoring over this initial dredging period and discuss the potential impacts of the dredging on the turbidity in the region; and
- provide a post dredging technical report following completion of the maintenance dredging and the post monitoring period. This note will present both the satellite derived turbidity and in-situ benthic turbidity data for the pre-, during and post-dredge periods and discuss the metocean conditions, the associated natural variability in turbidity and potential impacts of the maintenance dredging to turbidity in the region.

Following completion of the 2022 maintenance dredging program and the 7 day post-dredging period, this technical report presents and discusses the metocean and turbidity data collected.

1.1. Project Overview

The Port of Weipa is located in the Gulf of Carpentaria, on the north-west coast of the Cape York Peninsula in Northern Queensland (Figure 1). The Port is within Albatross Bay, a large embayment, with the wharves and berths located in the Embley River (Figure 1 and Figure 2).

In the 2021/22 financial year, the Port of Weipa handled just over 16 million tonnes of commodities, including bauxite, fuel, cattle and general cargo. Rio Tinto Alcan (RTA) currently operates most of the port facilities for the export of bauxite (aluminium ore) from the nearby RTA mine.

The layout of the Port of Weipa is shown in Figure 1. The Port consists of:

- a main shipping channel in Albatross Bay called South Channel; and
- an Inner Harbour, which is within the Embley River and consists of four shipping berths (Lorim Point East and West, Humbug Wharf and Evans Landing) and the Approach and Departure Channels (Figure 2).

The Port has approximately 622 hectares of channels, swing basins and berths where depths are maintained by maintenance dredging. NQBP currently has a 10-year Sea Dumping Permit for the Port of Weipa which allows for an average of 1,200,000 m^3 of sediment to be removed by maintenance dredging per annum, although this includes a contingency for events such as cyclones and so is not realised on an annual basis.

Since 2002 maintenance dredging at the Port of Weipa has been undertaken annually by the Trailing Suction Hopper Dredger (TSHD) Brisbane, with volumes ranging from approximately 300,000 m^3 to 2,400,000 m^3. The sediment, which has historically been removed by maintenance dredging, has been relocated to the offshore Dredge Material Placement Area (DMPA) located in Albatross Bay (Figure 1). Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future.

Based on detailed bathymetric analysis by PCS (2018) it was found that the annual sedimentation at the Port was highly variable depending on the wave conditions which occurred during the wet season, with the occurrence of Tropical Cyclones (TCs) in the region being a key driver for larger waves and increased sedimentation. The analysis also found that the majority of the sedimentation occurred in the South Channel, with limited sedimentation occurring in the Inner Harbour region (see Figure 3 for locations).

Multiple TCs and tropical lows occurred in the Gulf of Carpentaria during the 2021/22 wet season, with two wave events having a peak in significant wave height of more than 2.0 m and one of these having a peak of 3.7 m. As a result, higher rates of sedimentation in the South Channel were observed relative to the previous two years where wave conditions had remained relatively calm over the wet season. Due to the sedimentation, the declared depth in the South Channel had to be shallowed at the eastern end of the channel.

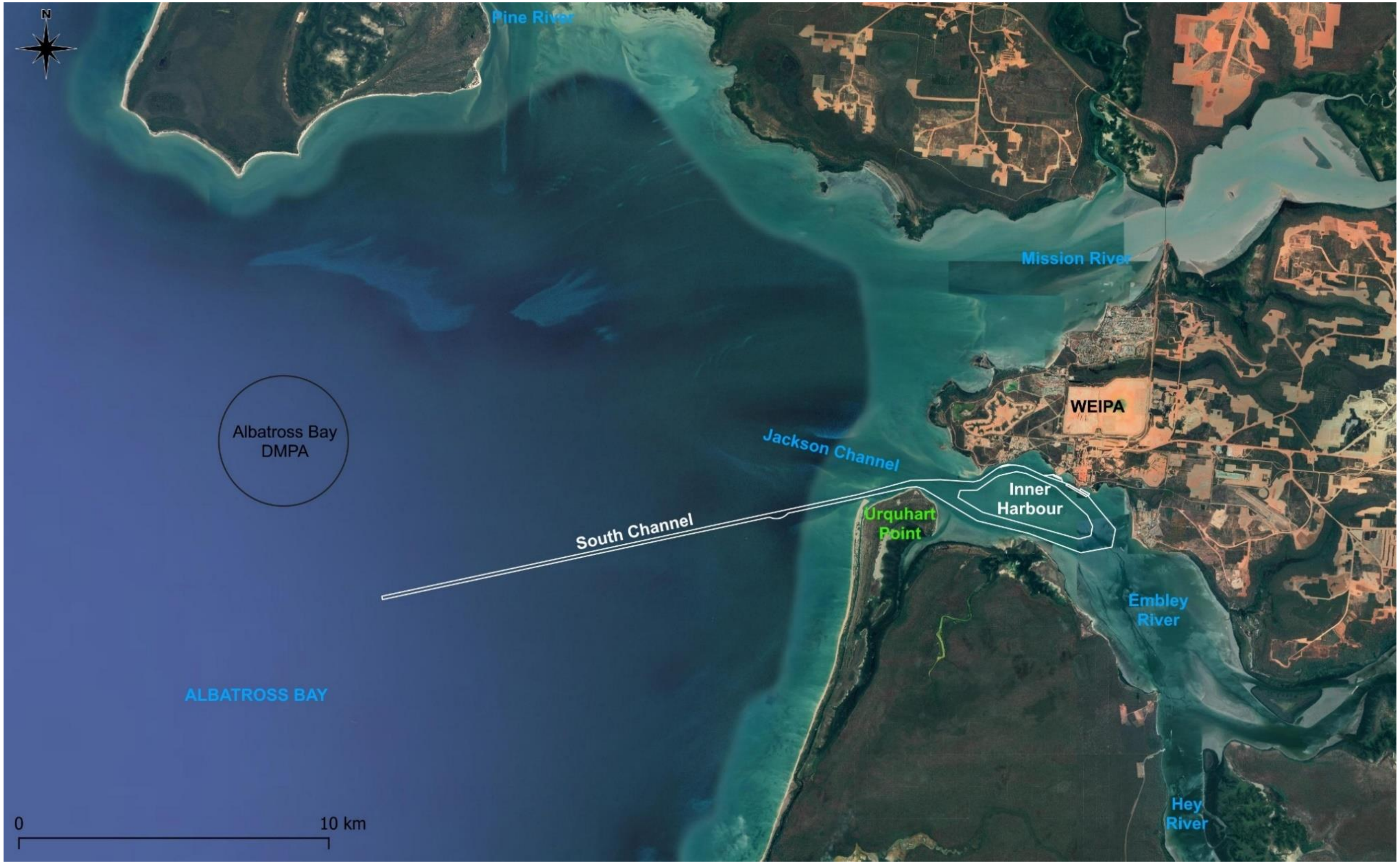

Figure 1. Layout of the Port of Weipa.

Figure 2. Close up of the Port of Weipa Inner Harbour area.

1.2. Report Structure

The report herein is set out as follows:

- a summary of the dredge program is provided in **Section 2**;
- details of the turbidity monitoring undertaken are provided in **Section 3**;
- analysis of the in-situ turbidity and satellite-derived data is presented in **Section 4**; and
- a summary of the findings is detailed in **Section 5**.

Unless stated otherwise, levels are reported to Chart Datum (CD). Zero metres CD is equal to the Lowest Astronomical Tide (LAT) at the Port of Weipa. Volumes presented throughout are in-situ cubic metres and time is presented in 24 hour format relative to Australian Eastern Standard Time (AEST).

2. Dredge Program

The Port of Weipa 2022 maintenance dredging program commenced at 07:15 Australian Eastern Standard Time (AEST) on the 1st May 2022 and was completed at 00:00 AEST on the 18th June 2022. Over the 49 day period a total of 430 dredge hopper loads were relocated to the Albatross Bay DMPA, with an average of just under nine loads per day. The total in-situ volume of sediment removed from the dredge areas of the Port of Weipa during the program was approximately 782,000 m^3 (PCS, 2022a). The majority of the maintenance dredging was focussed in the South Channel, with approximately 95% of the dredge loads from this area. It is important to note that the maintenance dredging requirement within the South Channel was not uniform, with almost 50% of the sediment removed from between SC10 and SC14 which represents approximately 20% of the total length of the South Channel (3.75 km of the total 17.5 km length of the channel). Although only 5% of the dredge loads were from the Inner Harbour, extensive bed levelling was also undertaken in the Inner Harbour. The bed levelling targeted sedimentation in the south-eastern section of the Approach Channel adjacent to Cora Bank, along sections of the Departure Channel adjacent to Cora Bank and within the berth pockets.

The following details the percentage of the total loads which were removed from the different port areas:

- South Channel, SC2 to SC6 (Figure 3): approximately 7% of the total number of dredge loads were removed from this area of the South Channel;
- South Channel, SC6 to SC10 (Figure 3): approximately 32% of the total number of dredge loads were removed from this area of the South Channel;
- South Channel, SC10 to SC14 (Figure 3): approximately 47% of the total number of dredge loads were removed from this area of the South Channel;
- South Channel, SC14 to SC18 (Figure 3): approximately 2% of the total number of dredge loads were removed from this area of the South Channel;
- SC18 to Urquhart Point (Figure 3): approximately 8% of the total number of dredge loads were removed from this area of the South Channel; and
- Inner Harbour (Figure 4): approximately 5% of the total number of dredge loads were removed from the Inner Harbour.

All of the dredged sediment was placed at the Albatross Bay DMPA, with the location of the placements within the DMPA being rotated between the five separate regions of the DMPA to ensure an even distribution over the DMPA.

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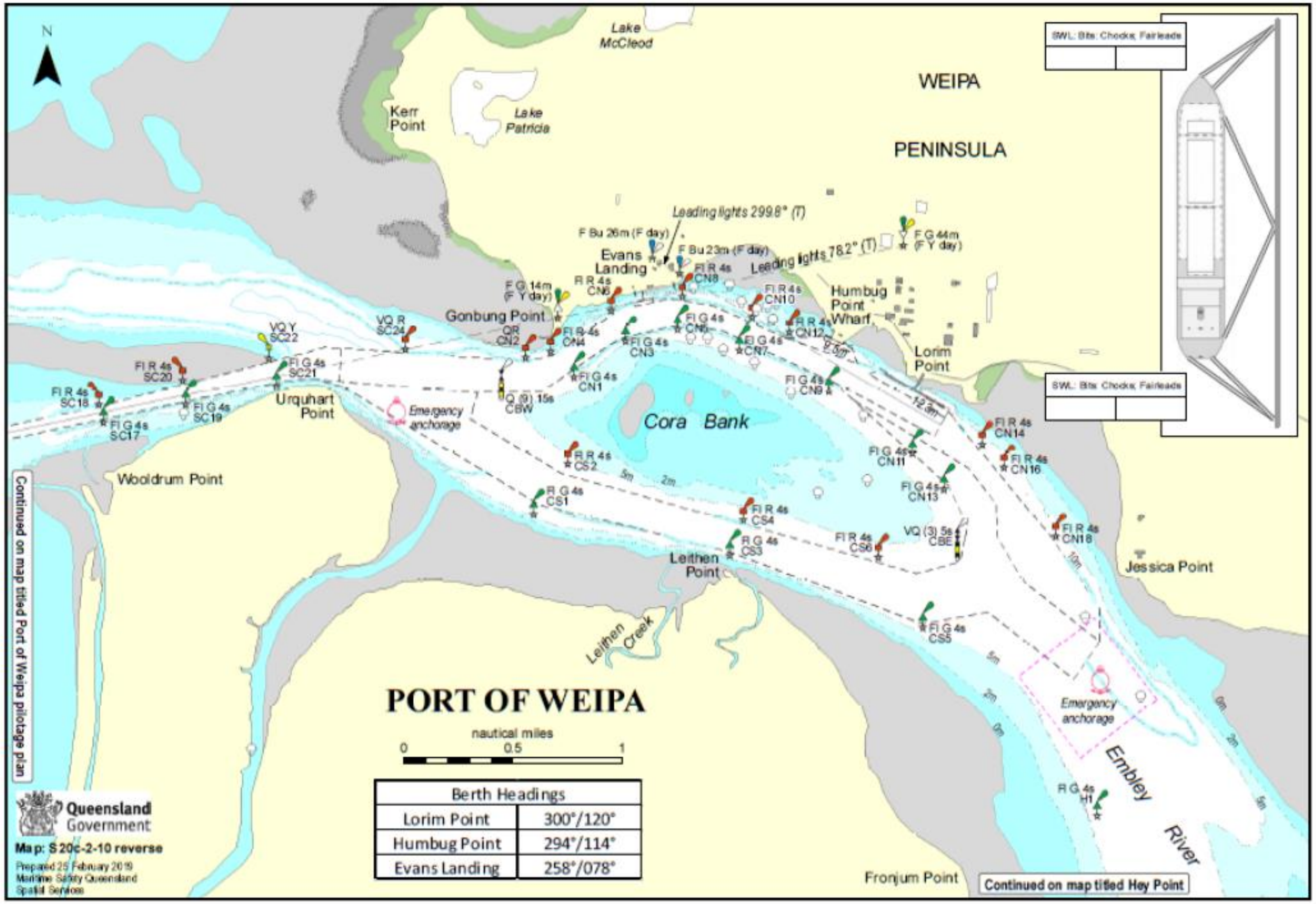
Figure 3. Location of the Port of Weipa ambient monitoring sites (WQ1, WQ2 and WQ4), DES waverider buoy (WRB) and South Channel (beacons SC2 – SC24).



Source: MSQ (2019)

Figure 4. Location of the Port of Weipa and beacons within the Inner Harbour.

2.1. Metocean Conditions

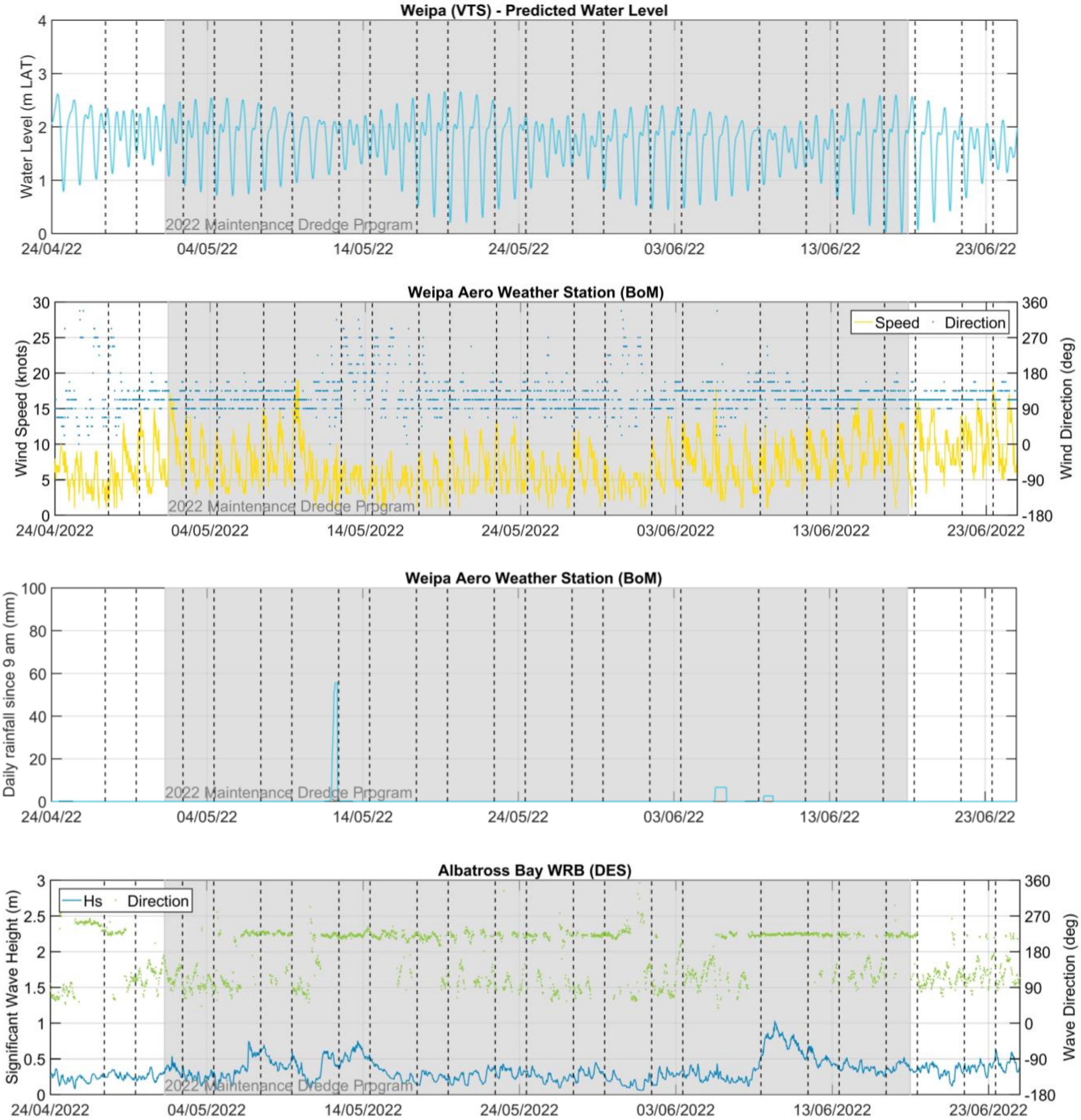
To provide an understanding of the metocean conditions over the pre-, during and post dredging periods, the following data have been sourced:

- Water Level: the predicted water level for the Port of Weipa (provided by the Bureau of Meteorology (BoM));
- Wind and Rain: measured wind and rainfall at the BoM Weipa Aero weather station (ID 027045); and
- Waves: measured wave conditions at the Albatross Bay waverider buoy (WRB) (Figure 3) (provided by the Department of Environment and Science (DES)).

The metocean conditions over the entire monitoring period are shown in Figure 5, with shading indicating the period of maintenance dredging. The dashed and dotted lines indicate when satellite images were captured (refer to Section 0). The figure shows the following:

- the metocean conditions are fairly consistent and can be considered to represent calm dry season conditions;
- the winds are consistent over the pre-dredge and dredge period, with peak speeds during the day of 10 to 15 knots and lighter winds overnight. Wind directions are typically from the east to south-east (i.e. from the coast at Weipa) throughout the period;
- rainfall was generally low throughout the pre-, during and post dredge periods. There was one day over the whole period when there was rainfall of more than 10 mm, this was during the dredging when approximately 55 mm of rainfall occurred. For reference, the mean monthly rainfall at Weipa is 107, 21 and 4 mm for April, May and June, respectively and with 7, 2 and 0.4 days per month experiencing more than 1 mm daily of rainfall; and
- the wave conditions over the whole pre-, during and post dredge periods varied between the south-east and south-west. The significant wave heights (H_s) were generally less than 0.5 m for the majority of the period. There were three occasions over the whole period when the H_s exceeded 0.5 m, these were all during the dredging with a wave direction from the south-west as a result of longer period swell waves when local winds were relatively calm.

Overall, the monitoring period is considered to be relatively calm in terms of wave conditions, although some localised resuspension of fine-grained sediment in shallow areas of Albatross Bay could have occurred during the three events during the dredging when the H_s was above 0.5 m.



Note: Dashed lines indicate times when satellite images were obtained and analysed, grey shaded area shows 2022 maintenance dredge program.

Figure 5. Metocean conditions at Weipa over the monitoring period, with water level (upper), winds (upper middle), rainfall (lower middle) and waves (lower).

3. Turbidity Monitoring

As part of the ongoing ambient water quality monitoring which NQBP have setup, benthic turbidity data have been collected by James Cook University (JCU) since January 2018 at monitoring sites around the Port of Weipa. The instruments measure near bed turbidity in Nephelometric Turbidity Unit equivalent (NTUe)[1]. There were originally two sites in Albatross Bay (WQ2 and WQ5), but one of these sites (WQ5) was decommissioned in July 2018 and there are currently two sites (WQ1 and WQ4) in the Inner Harbour (Figure 3).

The instruments were serviced a couple of weeks before the 2022 maintenance dredging program began and again during the maintenance dredging and finally retrieved for data download approximately two months after completion of the dredging program. Data up to the 24th August 2022 were provided by JCU.

Details of the benthic turbidity data available at the monitoring sites are provided in Table 1. The table also notes the data return for each site over the 2022 maintenance dredging monitoring period, which includes 7 days pre-dredging, 49 days during dredging and 7 days post dredging (63 days in total). The data return at all three of the sites was 100% over this period.

Table 1. Summary of ambient water quality monitoring data available for this assessment.

Location	Approx. Depth (m MSL)	Total Benthic Data Period	Data Return for 2022 Dredging Period
WQ1	5 m	19/01/18 to 24/08/22	100%
WQ2	4 m	16/03/18 to 24/08/22	100%
WQ4	4 m	19/01/18 to 24/08/22	100%

3.1. Previous Analysis

Benthic turbidity data from the ongoing ambient monitoring were analysed by PCS (2019a and 2020a) to understand the natural variability in turbidity at the three monitoring sites. The analysis undertaken prior to the 2019 maintenance dredging program suggested that the 95th percentile turbidity for the dry season period could be used as a representative benthic turbidity threshold for the 2019 maintenance dredging program. The subsequent more detailed analysis undertaken as part of the Environmental Thresholds component of the Port of Weipa Sustainable Sediment Management (SSM) Project recommended that the 90th percentile turbidity should be adopted as a turbidity intensity threshold as it approximately correlates with published benthic Photosynthetically Active Radiation (PAR) thresholds for the species of seagrass which are present in the Weipa region.

During the 2021 maintenance dredging program it was noted that the benthic turbidity threshold was exceeded significantly more at site WQ4 compared to sites WQ1 and WQ2 (PCS, 2021a). Based on the available information it was concluded that this was a result of a change in the natural turbidity at the site since the threshold was defined. Based on this, the benthic turbidity thresholds were reviewed and updated using data collected at the sites between January 2018 and August 2021. The resultant 90th and 95th percentile turbidity intensity thresholds for the dry season period at the three ambient water quality monitoring sites, which have been adopted for this assessment, are shown in Table 2. The table shows that all of the thresholds have increased as a result of the updated analysis.

[1] The international turbidity standard ISO7027 defines turbidity readings in NTU for 90 degree backscatter, while the JCU instrumentation uses 180 degree backscatter. In recognition of this fact, the units are reported as NTU equivalent (NTUe).

Table 2. Dry season benthic turbidity thresholds derived by PCS (2021b) along with previous values in brackets.

Location	90th Percentile Turbidity Threshold (NTUe)	95th Percentile Turbidity Threshold (NTUe)
WQ1	19 (17)	29 (21)
WQ2	23 (15)	47 (25)
WQ4	27 (18)	44 (28)

4. Data Analysis

This section presents in-situ turbidity data and satellite-derived turbidity data to provide an understanding of the variability in turbidity in the Weipa region and to determine the potential impact of the maintenance dredging activity on water quality in the region.

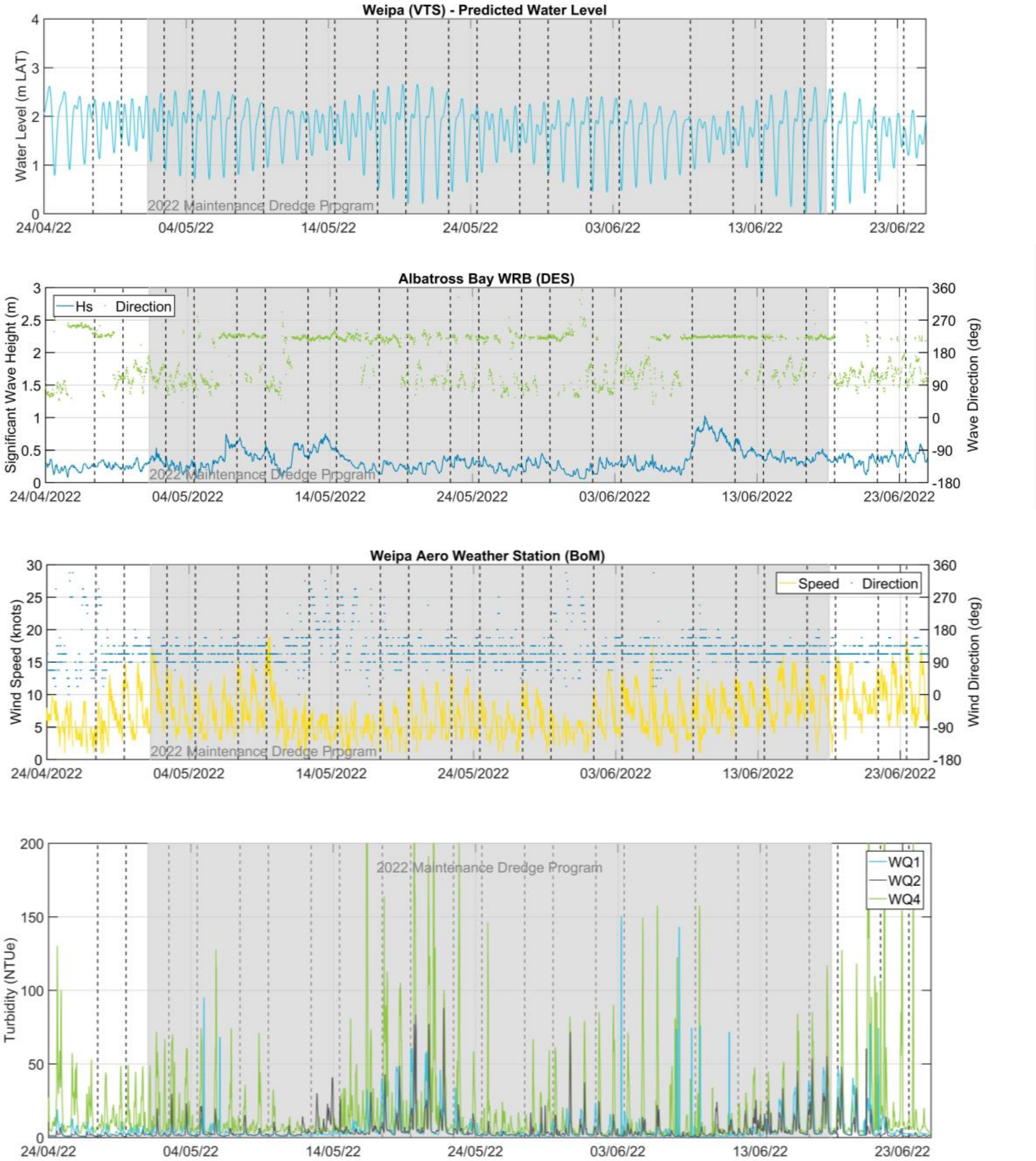
4.1. In-situ Turbidity Analysis

The measured benthic turbidity data at the three monitoring sites, along with the predicted water level for the Port of Weipa (calculated by BoM) and the measured wave conditions in Albatross Bay (from the DES WRB in Albatross Bay) are shown in Figure 6, while individual plots for each monitoring site are shown in Figure 7. The figure shows that there is a clear tidal signal in the turbidity data at the three sites (during the pre-, during and post dredge periods), with increased turbidity correlating with the larger tidal range over spring tides.

The turbidity data at WQ4 has regular peaks in turbidity which are much higher than at the other two sites throughout most of the monitoring period. These peaks regularly exceed 100 NTUe, and although the peaks do not always directly correspond with peaks at WQ1 (the other Inner Harbour site) they do tend to occur during larger spring tides. These peaks were observed in the data at WQ4 during the 2021 maintenance dredging program and as a result of them the turbidity intensity thresholds were updated (see Section 3.1). The 2022 maintenance dredging program is the first opportunity to review the updated threshold at WQ4 to check that it provides a more representative threshold.

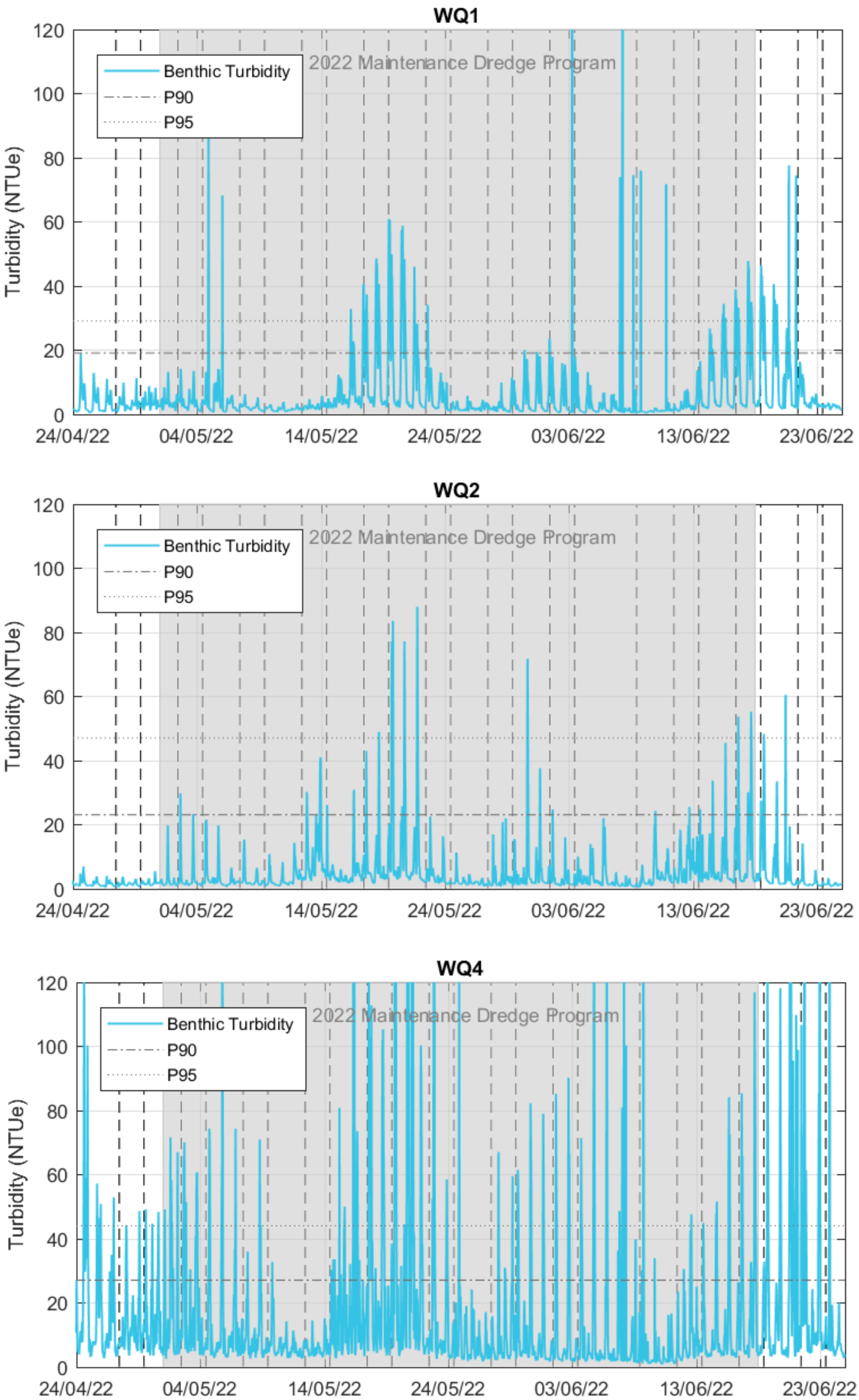
Based on the benthic turbidity data at the sites it appears that the turbidity during the pre-, during and post dredging periods of the 2022 maintenance dredging program was predominantly controlled by the metocean conditions. With the turbidity at all three monitoring sites increasing during spring tides and reducing during neap tides.

To further assess any potential increase in turbidity at the sites due to maintenance dredging the duration of time the updated benthic turbidity intensity thresholds, detailed in Table 2, were exceeded is analysed in the following section.



Note: Dashed lines indicate periods when Sentinel-2 satellite images were obtained and analysed, grey shaded area shows dredge period.

Figure 6. Metocean and turbidity conditions at Weipa over the monitoring period, with water level (upper), waves (upper middle), winds (lower middle) and turbidity at the three monitoring sites (lower).



Note: Vertical dashed lines indicate periods when Sentinel-2 satellite images were obtained and analysed, grey shaded area shows dredge period.

Figure 7. Measured turbidity data and percentile thresholds at the three Weipa monitoring sites over the monitoring period, with WQ1 (upper), WQ2 (middle) and WQ4 (lower).

4.1.1. Exceedance

The duration of time that both the 90th and 95th percentile benthic turbidity intensity thresholds were exceeded at the three monitoring sites was calculated over 7 days pre-dredging, the 49 days during dredging and 7 days post dredging for the 2022 maintenance dredging program (Table 3). The timeseries plots presented in Figure 5 show that the metocean conditions were relatively consistent and calm throughout the whole pre- during and post-dredging period. However, the plots also show that the 7 day pre-dredge period coincided with smaller range tides (mainly neaps), light winds (less than 10 knots for the majority of the time) and very small wave heights (H_s of less than 0.3 m) compared to the conditions during and post dredging.

The exceedance results show that the highest benthic duration exceedances occurred at WQ4 and the lowest at WQ2. During the dredging period the exceedance duration for both the 90th and 95th percentile thresholds at WQ4 was approximately double that at WQ1, while the duration exceedance for the 90th percentile threshold at WQ1 was approximately double that at WQ2. This suggests that either the maintenance dredging resulted in higher turbidity at WQ4 or that the natural turbidity was higher at this site.

The suggested duration triggers for the 90th percentile turbidity intensity threshold for a 40 day dredge period are presented in PCS (2021b). These duration triggers were suggested as possible adaptive management thresholds which could be adopted sequentially to minimise the risk of any impacts to sensitive receptors. If the dry season thresholds are scaled up to represent a 49 day period, then the exceedance durations during the dredging are less than the average duration of exceedance at WQ1 and WQ2 (118 hours), while at WQ4 they are more than the average duration (118 hours), but below the 90th percentile duration (185 hours) and well below the maximum duration (368 hours). At WQ1 and WQ2 where the average duration was not exceeded, the turbidity during the dredging period was well within the range of natural variability and as such no adaptive monitoring would have been implemented should real time monitoring have been undertaken at these sites. At WQ4 where the average duration was exceeded but the 90th percentile duration was not exceeded, an investigation into the cause of the elevated turbidity would have been required should real time monitoring have been undertaken at these sites.

Table 3. Duration of exceedance of the previously derived benthic turbidity intensity thresholds over the Port of Weipa 2022 maintenance dredging program.

Location	7 days Pre-Dredging (hrs)		49 days During Dredging (hrs)		7 days Post-Dredging (hrs)	
	90th %ile	95th %ile	90th %ile	95th %ile	90th %ile	95th %ile
WQ1	0	0	82.5	49.2	23.0	12.7
WQ2	0	0	40.0	9.0	6.2	1.0
WQ4	30.3	10.5	159.3	94.7	32.3	23.2

The results show that the turbidity at WQ4 was still higher than the turbidity at the other sites relative to the updated turbidity intensity thresholds. The updated thresholds were based on measured turbidity data from January 2018 to August 2021. However, the natural turbidity at WQ4 appears to have remained higher since November 2020 and so the updated analysis is based on a combination of lower and higher turbidity data. Based on this it would be beneficial to undertake a further analysis and revisit updating the turbidity intensity thresholds just using measured data since the natural turbidity increased at WQ4 (i.e. November 2020 to August 2022).

4.2. Satellite-Derived Data

Satellite-derived turbidity data are a valuable resource which can provide a reliable spatial overview of the variability in turbidity over a large area (Fearns et al., 2017). Analysis of repeat images can be used to assist in understanding how spatial variations in turbidity change over time.

To better understand the spatial extent of both the natural turbidity in the Weipa region and any plumes resulting from the maintenance dredging activity (including from the placement of dredged sediment at the Albatross Bay DMPA), satellite imagery was used. High-resolution imagery from the Sentinel-2 (10 m) sensor and low-resolution imagery (approximately 300 m) from the Sentinel-3 sensor were sourced over the 2022 maintenance dredge monitoring period.

In the Weipa region the repeat satellite coverage is high for the Sentinel-3 sensor (images captured 11 out of every 14 days) and relatively high for the Sentinel-2 sensor (images captured every 2 to 3 days). The reason the temporal coverage is relatively high for the Sentinel-2 sensor is because the area is partially covered by two separate satellite tracks, which means the entire region is not covered for each image (the Inner Harbour is only captured in every second image). The satellite data are restricted by cloud cover, and so imagery can only be used when there is little to no cloud cover in the areas of interest.

The available imagery was post processed to calculate the satellite-derived turbidity based on the approach of Brockmann et al. (2016). This approach provides an estimate of total suspended matter (TSM) and has been validated in various studies (Kyryliuk and Kratzer, 2019). An assessment of the accuracy of the satellite derived TSM against the in-situ near bed turbidity data was undertaken during the 2021 maintenance dredging program to allow a local calibration of the imagery. The results showed that the satellite derived TSM was able to provide a good representation of the benthic in-situ measured SSC data at the WQ1 and WQ2 monitoring sites.

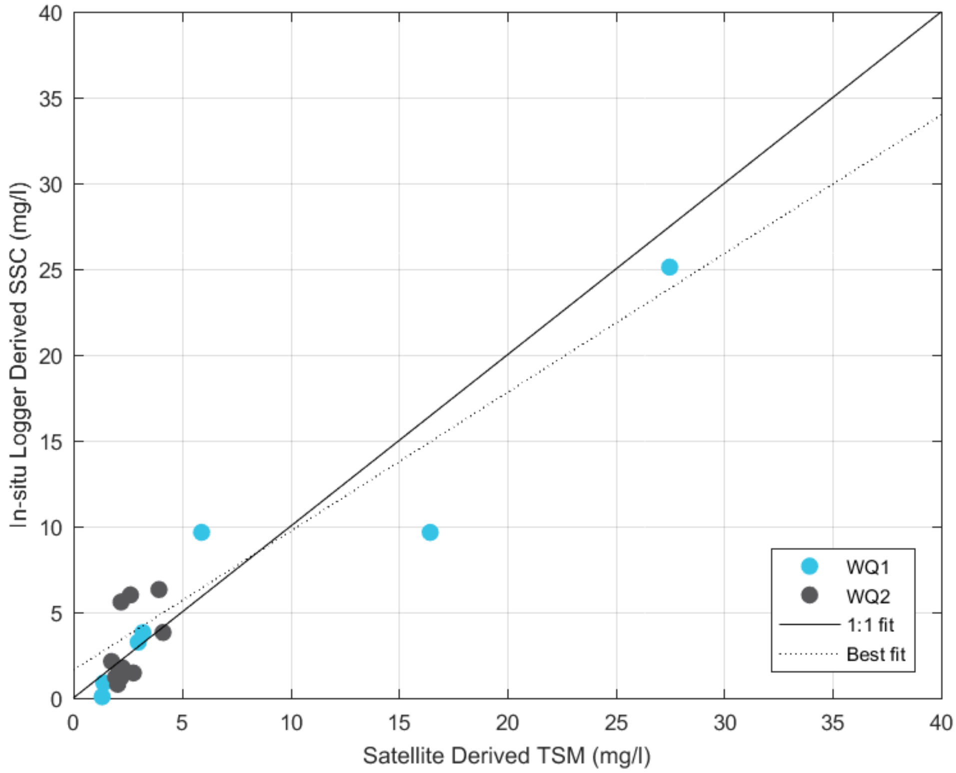


Figure 8. Correlation between satellite derived TSM from Sentinel-2 and in-situ logger derived SSC during the 2021 maintenance dredge monitoring period.

To ensure continuity between the satellite-derived TSM from different sensors a comparison between the TSM images derived from the Sentinel-2 and Sentinel-3 sensors was undertaken at the start of the 2022 dredge program (Figure 9). Both images have similar spatial patterns in TSM and magnitudes which gives confidence that both approaches were able to provide comparable TSM values during the dredge program.

Throughout the dredge period PCS provided NQBP with TSM from satellite imagery available from both satellite sensors to provide as much near real-time information about the natural turbidity and any plumes due to the maintenance dredging as possible. From the daily updates provided during the dredging it was noted that the plumes from the maintenance dredging were relatively small and localised and as such they can be difficult to identify from the lower resolution Sentinel-3 imagery. Based on that, the technical note provided during dredging focussed on satellite imagery from the Sentinel-2 sensor (PCS, 2022b). This post dredging report also focusses on imagery from the Sentine-2 sensor.

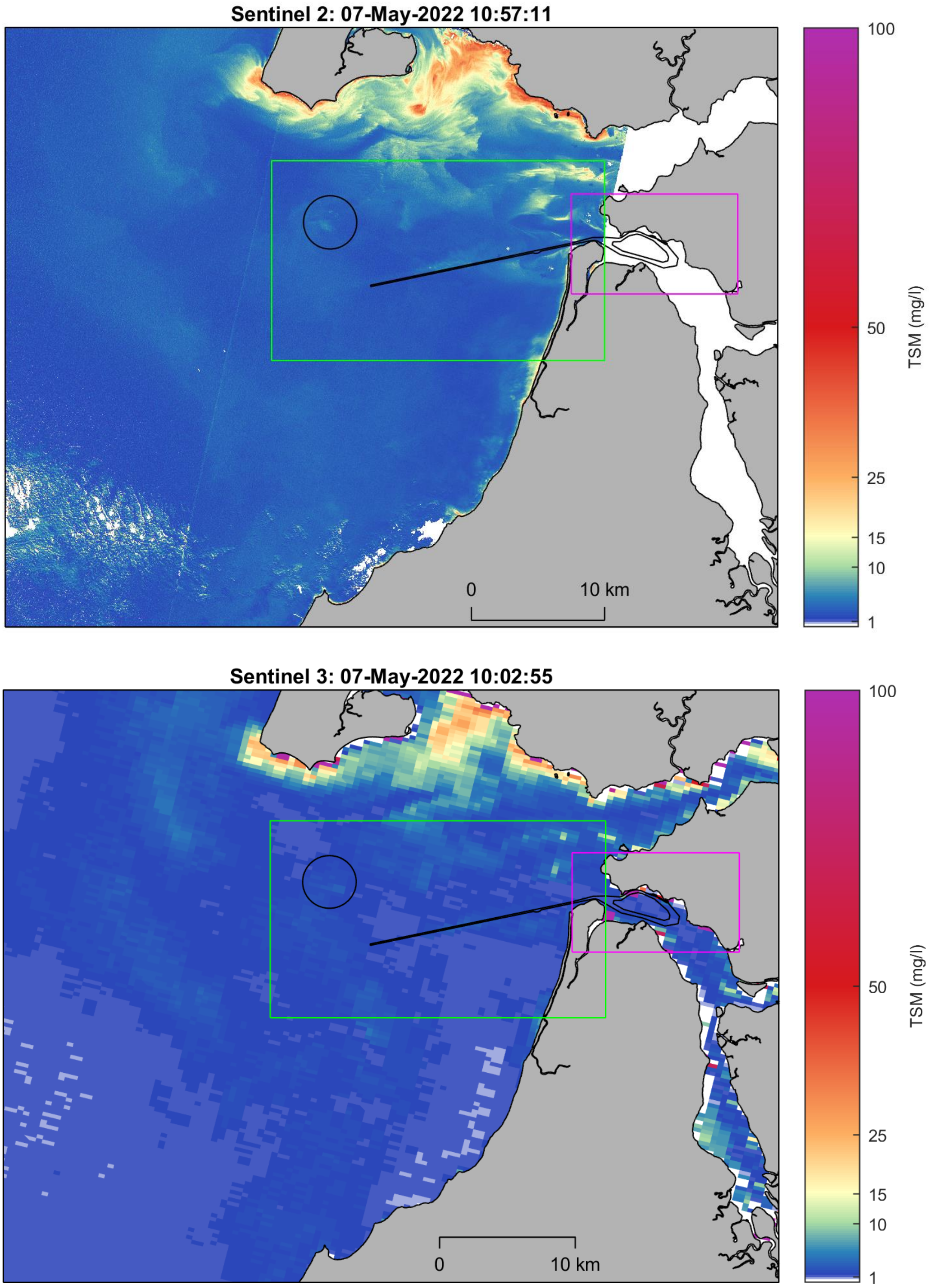


Figure 9. Comparison between satellite-derived TSM from the Sentinel-2 (top) and Sentinel-3 (bottom) sensors for images captured within 1 hour of each other.

Over the pre-, during and post-dredging monitoring periods a total of 23 high resolution satellite images were captured by the Sentinel-2 sensor. As a result of high cloud cover during some of the satellite passes four of the images were unusable (one during the pre-dredge, two during dredging and one post dredge), further the Inner Harbour region was only covered by ten of the Sentinel-2 images (some of these had cloud cover over the Inner Harbour and so did not show conditions anyway).

Details of the satellite images analysed as part of this assessment are provided in Table 4 for the pre-dredging monitoring period, Table 5 during dredging and Table 6 for the post-dredging monitoring period. Images presented are detailed in black text while other images are detailed in grey.

Table 4. Available satellite images for the pre-dredging monitoring period.

Date and Time	Satellite Name	Details
24/04/2022 10:46	Sentinel-2	Full cloud cover.
27/04/2022 10:57	Sentinel-2	No cloud, image excludes Inner Harbour area.
29/04/2022 10:46	Sentinel-2	Isolated patches of cloud, predominantly clear over Port.

Table 5. Available satellite images during dredging.

Date and Time	Satellite Name	Details
02/05/2022 10:57	Sentinel-2	High cloud cover, image excludes Inner Harbour area. The TSHD Brisbane was steaming to the DMPA at this time having finished dredging the Departure Channel adjacent to Evans Landing in the Inner Harbour at 9:38.
04/05/2022 10:47	Sentinel-2	Generally clear with some cloud cover over the Inner Harbour. The TSHD Brisbane was steaming to the South Channel at this time having just placed a hopper load at the DMPA at 10:28. Previous dredging was in the South Channel (SC10 to SC12) which finished at 09:36.
07/05/2022 10:57	Sentinel-2	No cloud cover, image excludes Inner Harbour area. The TSHD Brisbane was just about to start dredging the South Channel, having just placed a hopper load at the DMPA at 10:18. Previous dredging was in the South Channel (SC8 to SC10) which finished at 09:30.
09/05/2022 10:47	Sentinel-2	High cloud cover. TSHD Brisbane was steaming back to the South Channel (SC10 to SC12) having just placed a hopper load at the DMPA at 10:22.
12/05/2022 10:57	Sentinel-2	Patchy cloud cover around DMPA and adjacent to South Channel, image excludes Inner Harbour area. The image coincided with a crew change for the TSHD Brisbane. The most recent dredging activity finished at 04:34, with the subsequent placement at the DMPA finishing at 05:20.
14/05/2022 10:47	Sentinel-2	No cloud cover. The TSHD Brisbane was just about to start dredging the South Channel (SC8 to SC10), having just placed a hopper load at the DMPA at 10:37.
17/05/2022 10:57	Sentinel-2	Very low cloud cover, image excludes Inner Harbour area. The TSHD Brisbane was mid way through dredging in the South Channel (SC4 to SC6). The most recent placement at the DMPA was at 09:58.
19/05/2022 10:47	Sentinel-2	Very low cloud cover. The TSHD Brisbane started dredging in the South Channel (SC12 to SC14) at 10:32. The most recent placement at the DMPA was at 09:47.

Date and Time	Satellite Name	Details
22/05/2022 10:57	Sentinel-2	No cloud, image excludes Inner Harbour area. The TSHD Brisbane was steaming to Humbug Wharf (Inner Harbour) at this time having just placed a hopper load at the DMPA at 09:36. Previous dredging was in the South Channel (SC4 to SC6) which finished at 09:01 (placement at DMPA at 09:36).
24/05/2022 10:47	Sentinel-2	Patchy cloud over Albatross Bay, full cloud cover in Inner Harbour. The TSHD Brisbane was dredging Amrun Port on this day (also the afternoon of 23/05/22 and morning of 25/05/22).
27/05/2022 10:57	Sentinel-2	Patchy cloud, predominantly in north-west area of Albatross Bay. Image excludes Inner Harbour area. The TSHD Brisbane started dredging in the South Channel (SC6 to SC8) at 10:55. The most recent placement at the DMPA was at 10:16.
01/06/2022 10:57	Sentinel-2	No cloud, image excludes Inner Harbour area. The TSHD Brisbane started dredging in the South Channel (SC6 to SC8) at 10:43. The most recent placement at the DMPA was at 10:02.
03/06/2022 10:47	Sentinel-2	Moderate cloud cover in Albatross Bay, little cloud in Inner Harbour. The TSHD Brisbane was steaming back to the South Channel (SC6 to SC8) having previously finished dredging this area of the South Channel at 09:28 and placing the hopper load at the DMPA at 10:23.
08/06/2022 10:47	Sentinel-2	Patchy cloud cover in Albatross Bay, full cloud cover in Inner Harbour. The TSHD Brisbane was steaming back to the South Channel (SC10 to SC12) having previously finished dredging this area of the South Channel at 09:20 and placing the hopper load at the DMPA at 10:07.
11/06/2022 10:57	Sentinel-2	Little cloud, image excludes Inner Harbour area. The TSHD Brisbane was steaming to the DMPA having finished dredging the South Channel (SC18 to SC22) at 09:55 and with the most recent placement at the DMPA having been at 07:54.
13/06/2022 10:47	Sentinel-2	No cloud in Albatross Bay, patchy cloud cover in Inner Harbour. The TSHD Brisbane finished dredging the South Channel (SC12 to SC14) at 10:47, having previously finished dredging the same section of the South Channel at 08:26 and placing the hopper load at the DMPA at 09:28.
16/06/2022 10:57	Sentinel-2	Low cloud cover in Albatross Bay, image excludes Inner Harbour area. The TSHD Brisbane was steaming back to the South Channel (SC21 to Urquart Pt) having previously finished dredging SC10 to SC12 at 08:33 and placing the hopper load at the DMPA at 09:23.

Table 6. Available satellite images for the post-dredging monitoring period.

Date and Time	Satellite Name	Details
18/06/2022 10:47	Sentinel-2	No cloud in Albatross Bay, full cloud cover in Inner Harbour. The TSHD Brisbane completed its final dredge load at 22:54 on 17th June from the South Channel (SC10 to SC12) and the load was placed at the DMPA at 23:55 on 17th June.
21/06/2022 10:57	Sentinel-2	High cloud cover in Albatross Bay, image excludes Inner Harbour area.
23/06/2022 10:47	Sentinel-2	Patchy cloud cover in Albatross Bay and Inner Harbour.

4.2.1. Turbidity Analysis

To provide an understanding of natural turbidity levels within the study area and to identify the extent of potential increases in turbidity due to the 2022 maintenance dredging program, the turbidity analysis was undertaken at three different spatial scales, namely:

- regional (Albatross Bay region);
- local (Port of Weipa); and
- dredge vessel (in close proximity to the TSHD Brisbane).

4.2.1.1. Regional Scale

To provide an understanding of how the turbidity in Albatross Bay varied over the 2022 Maintenance Dredging Program, plots of the satellite-derived TSM in the Albatross Bay region for the usable satellite images are shown in Figure 10 to Figure 28. The plots show the following:

- Pre-Dredging: the pre-dredging images (Figure 10 and Figure 11) show that TSM throughout the majority of Albatross Bay was relatively low (less than 10 mg/l, equivalent to approximately 7 NTU), which corresponds to the calm metocean conditions over this period. The image on the 29th April 2022 shows that isolated patches of TSM of up to 10 mg/l can occur in Albatross Bay and adjacent to the DMPA and the South Channel;
- During Dredging: Although the TSM within the majority of Albatross Bay was relatively low over the whole period (less than 15 mg/l, equivalent to approximately 11 NTU), areas with higher TSM of 15 to 50 mg/l (approximately 11 to 35 NTU) did occur in the shallow areas of Albatross Bay and in the adjacent estuaries in the images captured during the dredge period (Figure 12 to Figure 26). For example, elevated TSM was widely visible in the shallow areas of the estuaries and adjacent to their mouths on the 19th May 2022 (Figure 17). The TSHD Brisbane was dredging the South Channel prior to the image being captured and so some localised plumes adjacent to the South Channel and DMPA could be due to the dredging, but the majority of the TSM in Albatross Bay was natural. This image was captured on the ebb stage of a large spring tide and it is therefore likely that strong tidal flows naturally resuspended sediments within the estuaries and in shallower areas of Albatross Bay during this period.

  The imagery has also shown plumes with TSM of up to 15 mg/l (approximately 11 NTU) and spatial extents of up to kilometres around the South Channel and DMPA occurred through the dredge period. Based on the spatial extent of the plumes, the dredge activity and the metocean conditions it is considered likely that the plumes were a result of the dredging activity. This will be further assessed in Section 4.2.1.2; and
- Post-Dredging: the post dredging images (Figure 27 and Figure 28) show that TSM in the broader Albatross Bay region during the post dredging period was similar to within the dredging period. The TSM was up to 10 mg/l (approximately 7 NTU) in the deeper areas of the bay and up to 50 mg/l (approximately 35 NTU) in the shallower areas and within the estuaries. The image from the 18th June 2022 shows a localised plume of 10 to

15 mg/l (approximately 7 to 11 NTU) present adjacent to the South Channel, with slightly elevated TSM of up to 10 mg/l (approximately 7 NTU) also being present within the DMPA. The image captured on the 23rd June 2022 does not show any indication of plumes from the dredging activity. The DMPA does have a TSM of up to 10 mg/l in the image, but as this extends the whole length of Albatross Bay this is a result of natural processes.

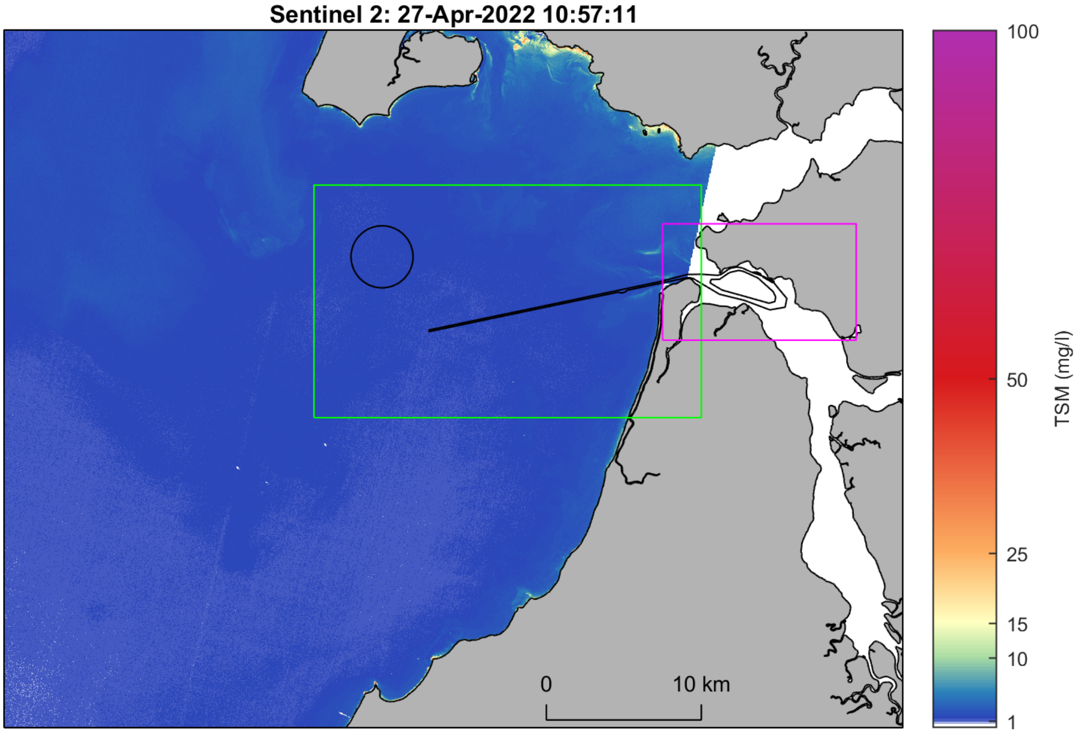


Figure 10. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 27/04/2022 at 10:57 AEST (pre-dredging).

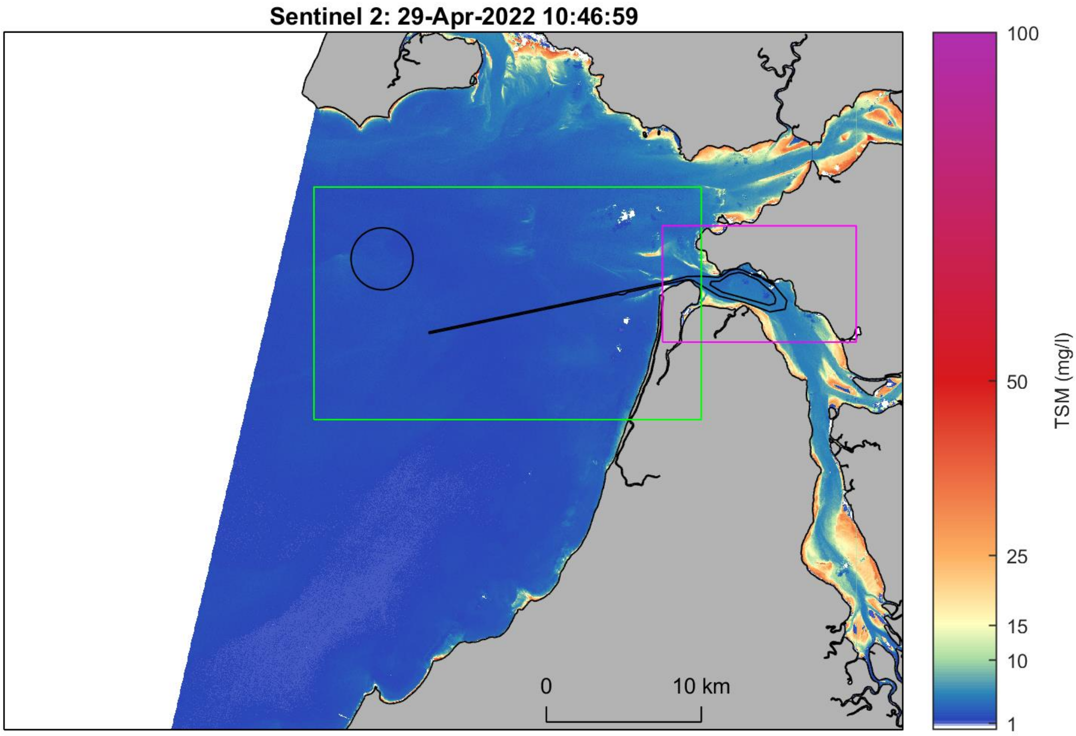
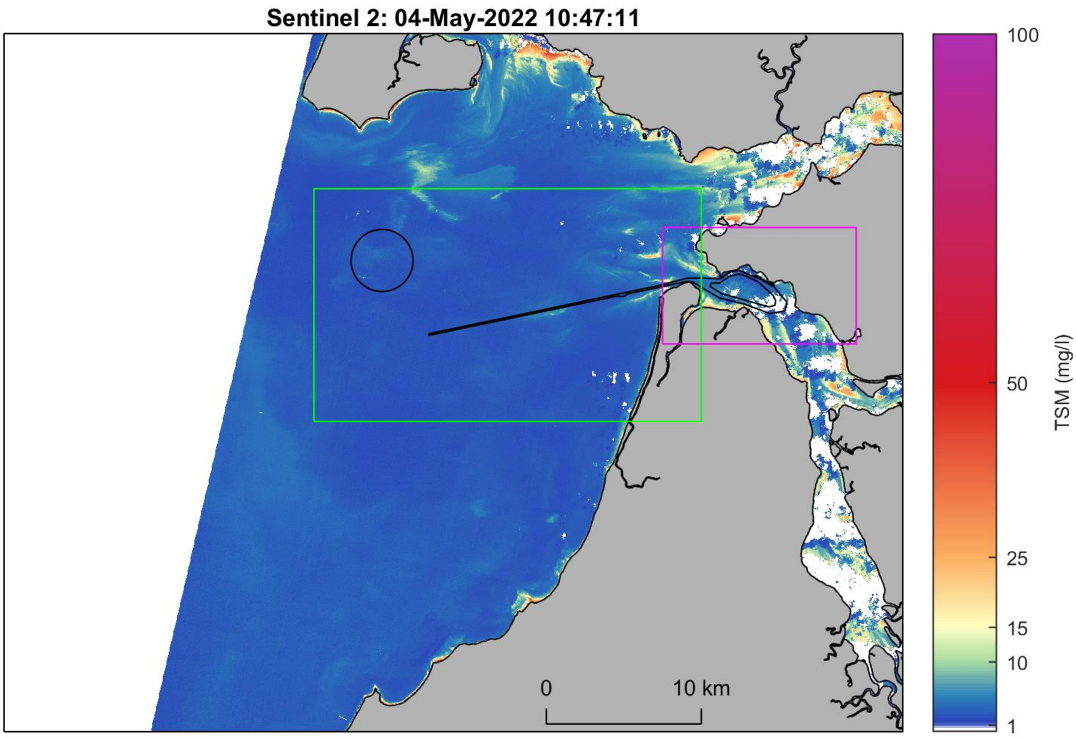
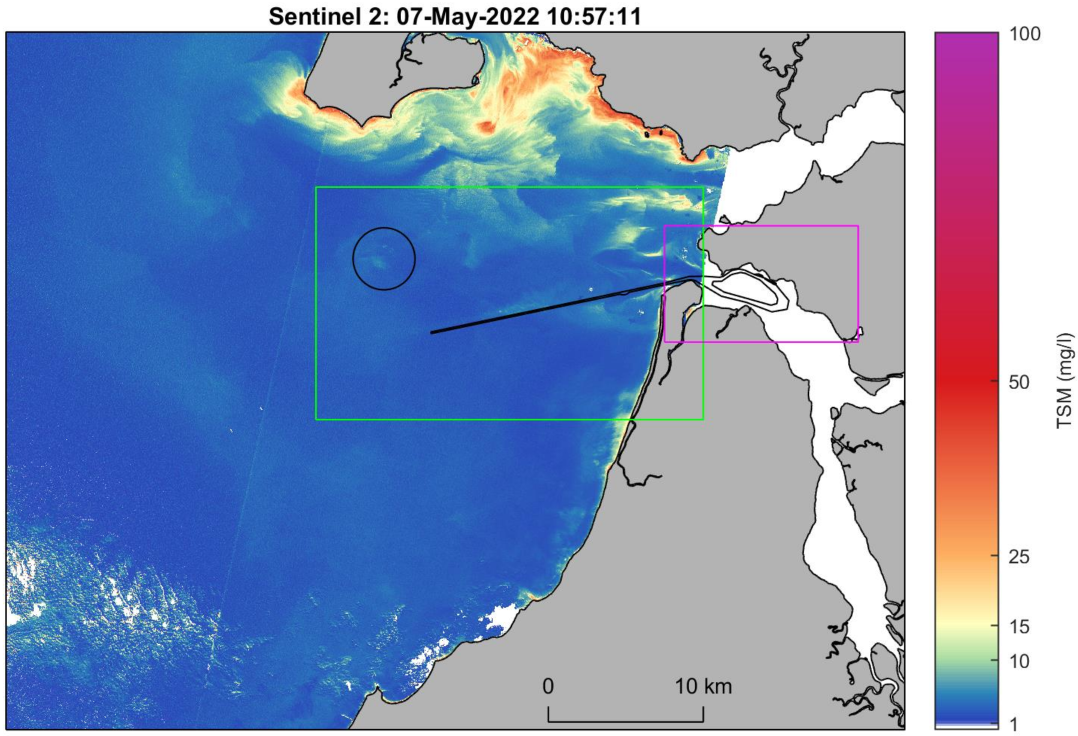


Figure 11. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 29/04/2022 at 10:46 AEST (pre-dredging).



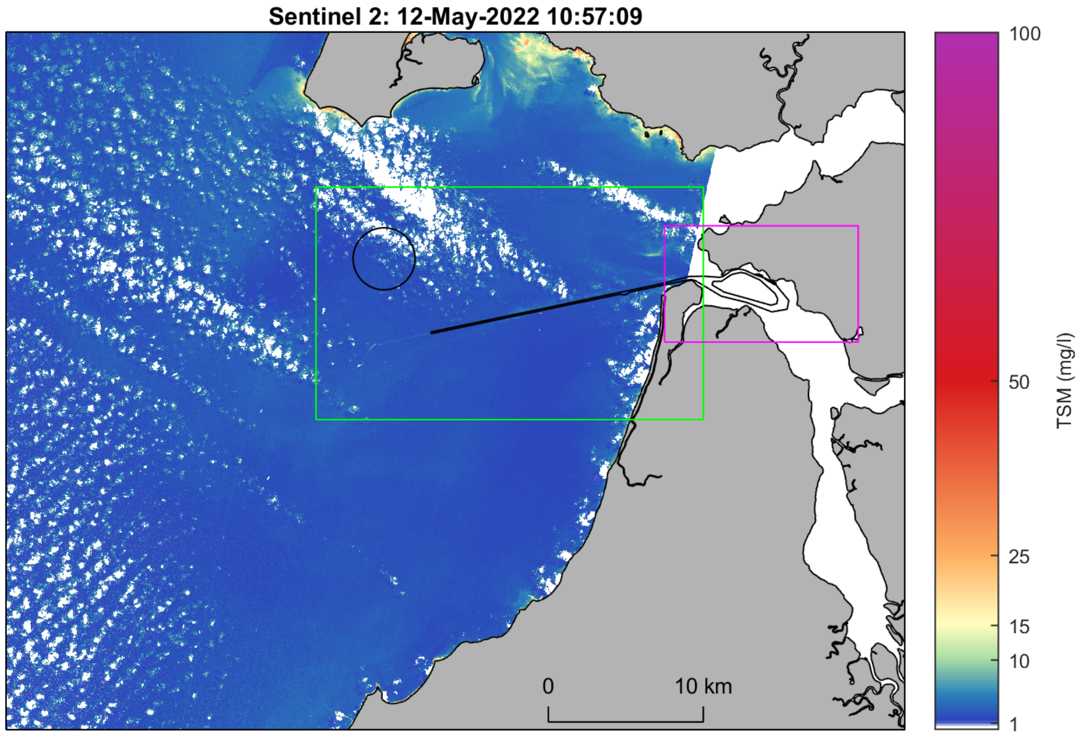
Note: the white areas represent cloud cover.

Figure 12. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 04/05/2022 at 10:47 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 13. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 07/05/2022 at 10:57 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 14. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 12/05/2022 at 10:57 AEST (dredging).

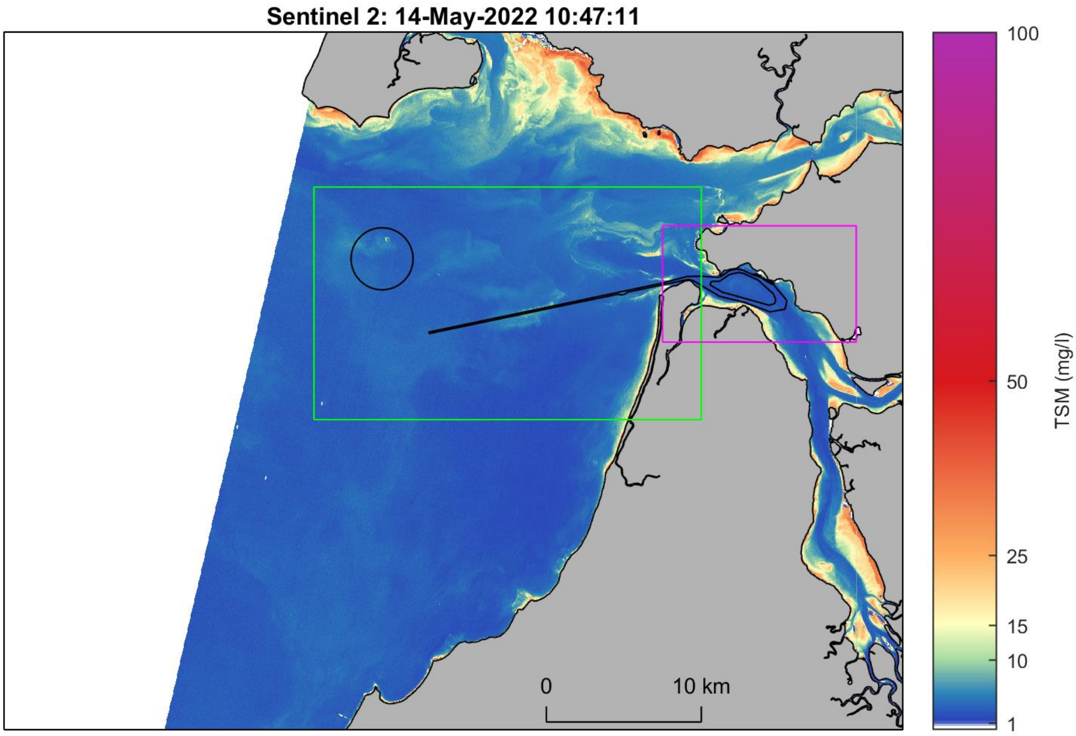


Figure 15. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 14/05/2022 at 10:47 AEST (dredging).

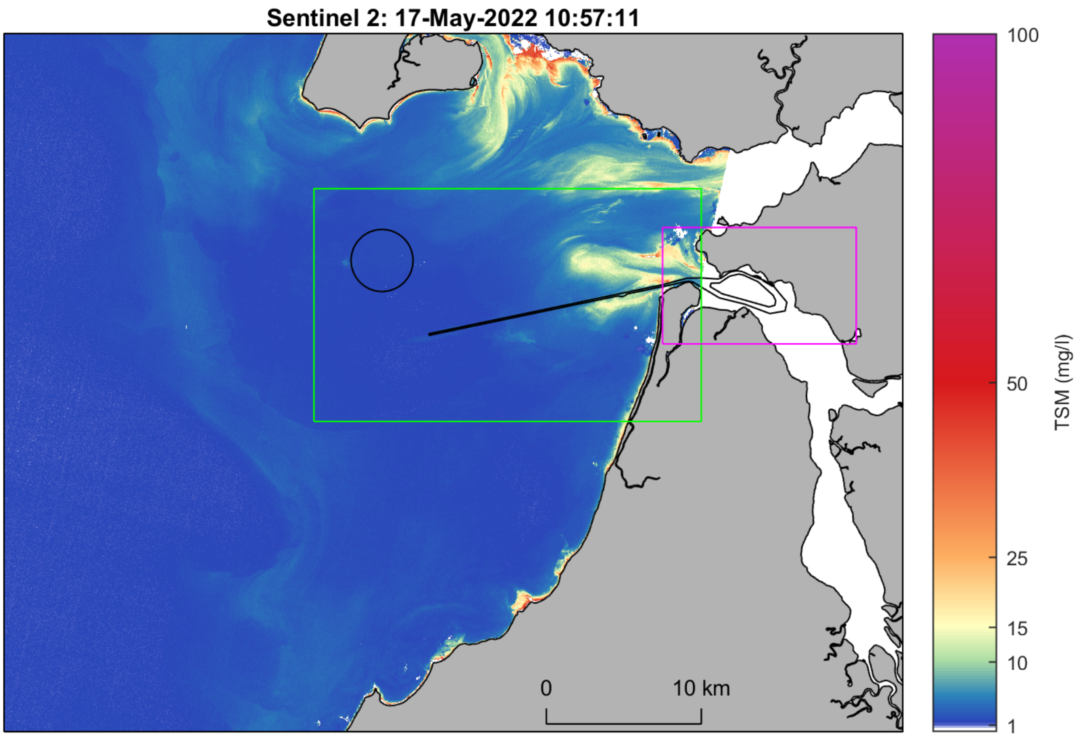


Figure 16. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 17/05/2022 at 10:57 AEST (dredging).

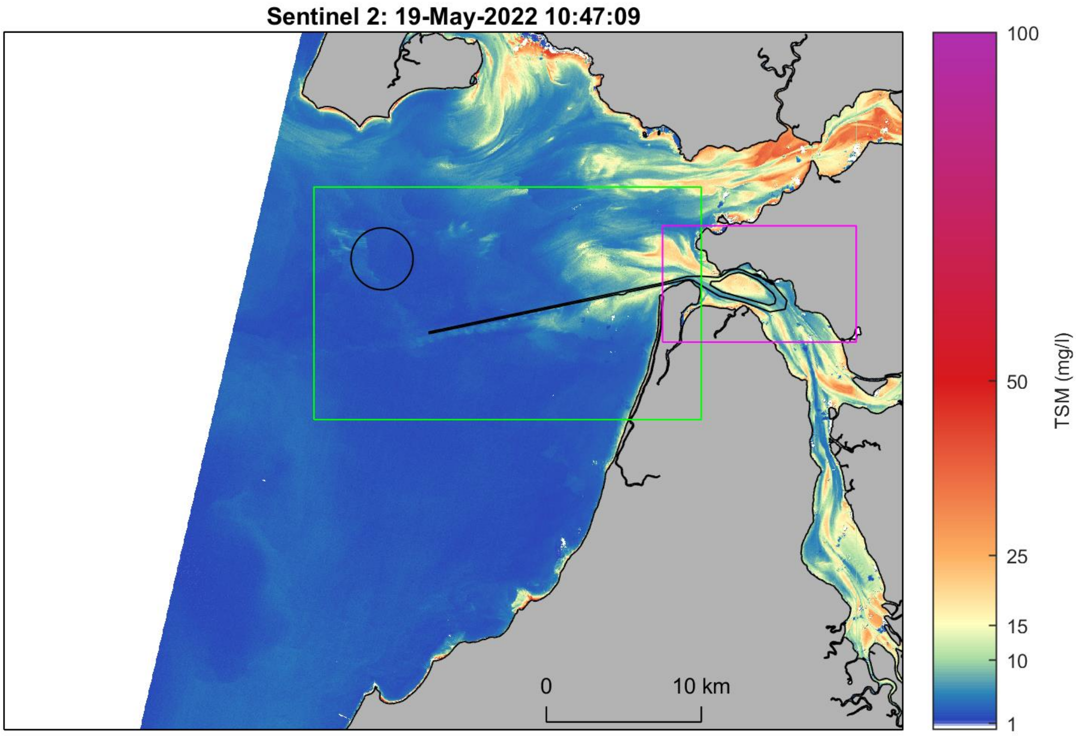


Figure 17. **Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 19/05/2022 at 10:47 AEST (dredging).**

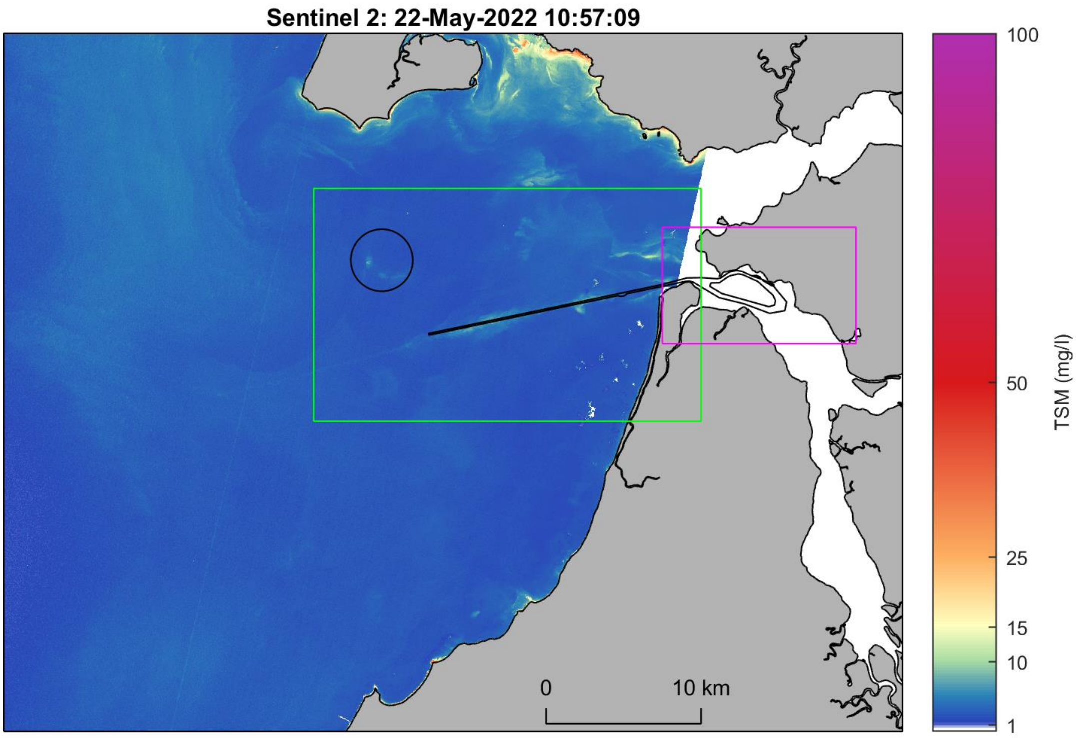
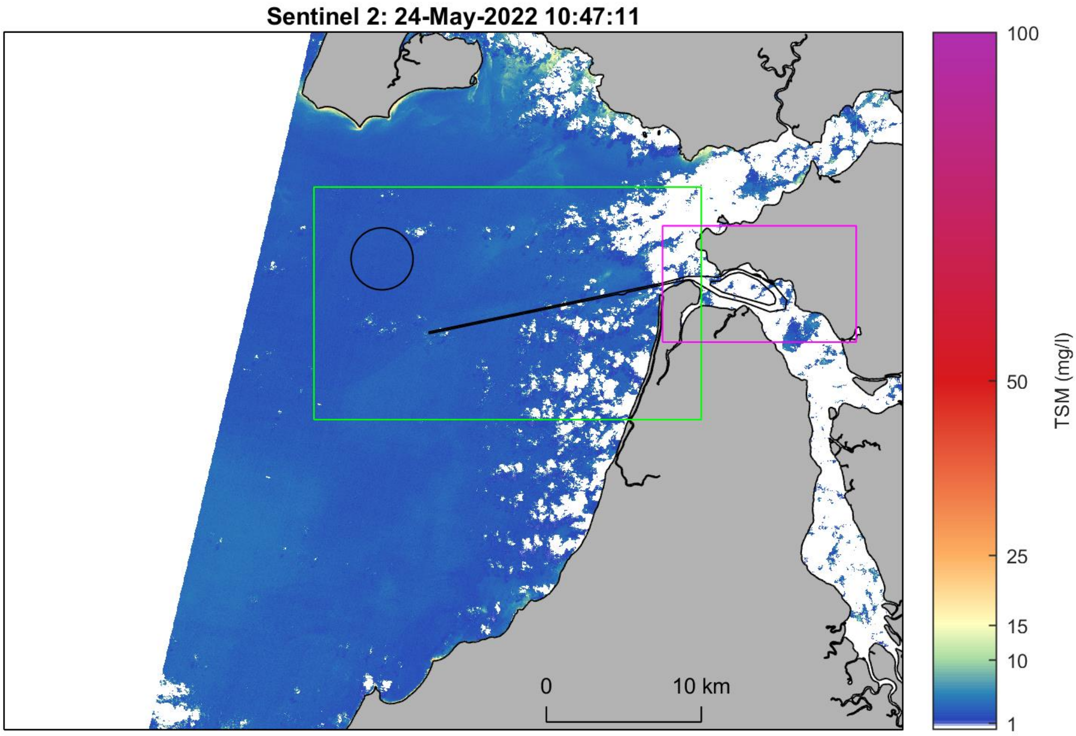
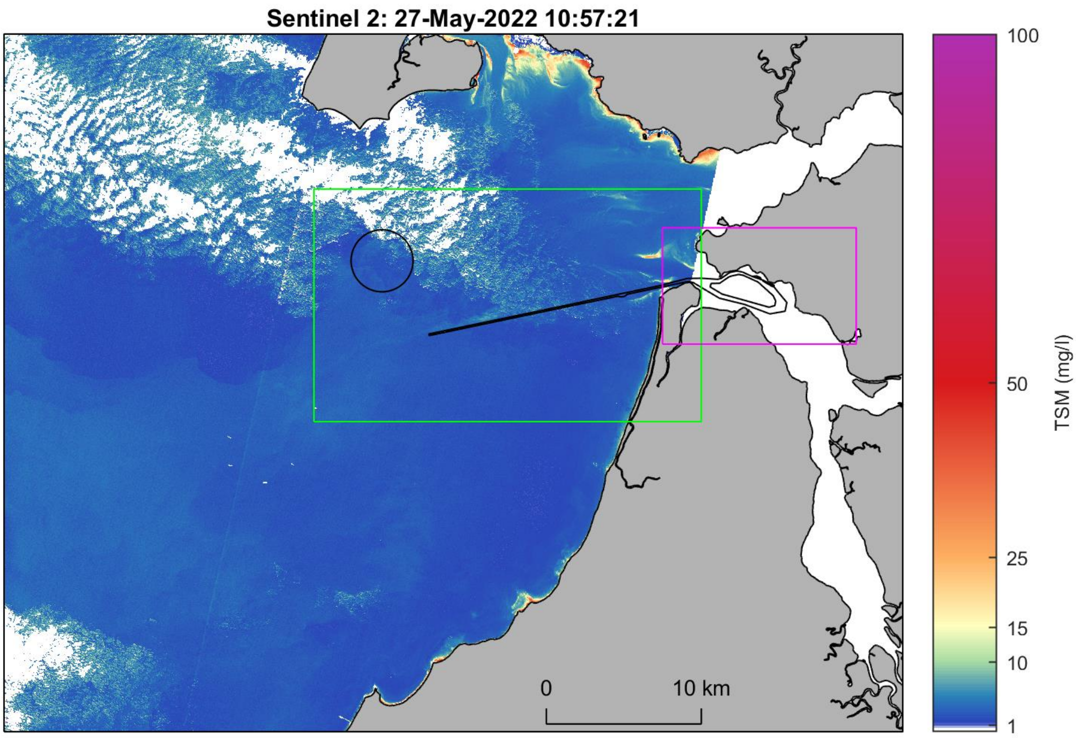


Figure 18. **Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 22/05/2022 at 10:57 AEST (dredging).**



Note: the white areas represent cloud cover.

Figure 19. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 24/05/2022 at 10:47 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 20. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 27/05/2022 at 10:57 AEST (dredging).

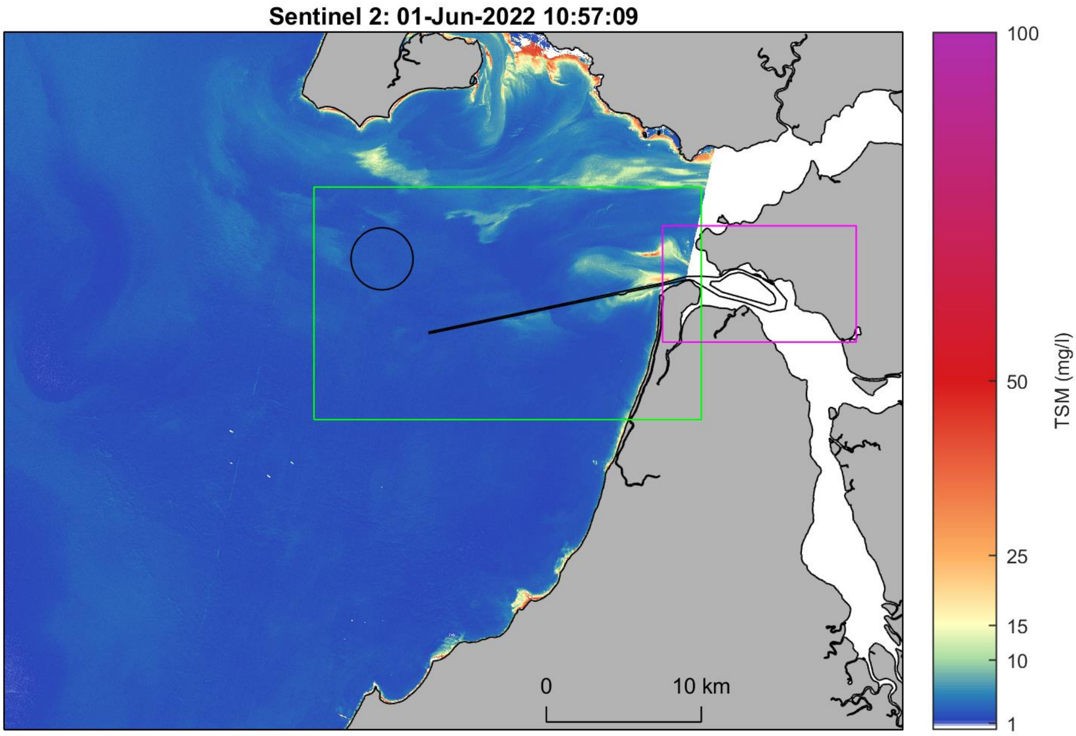
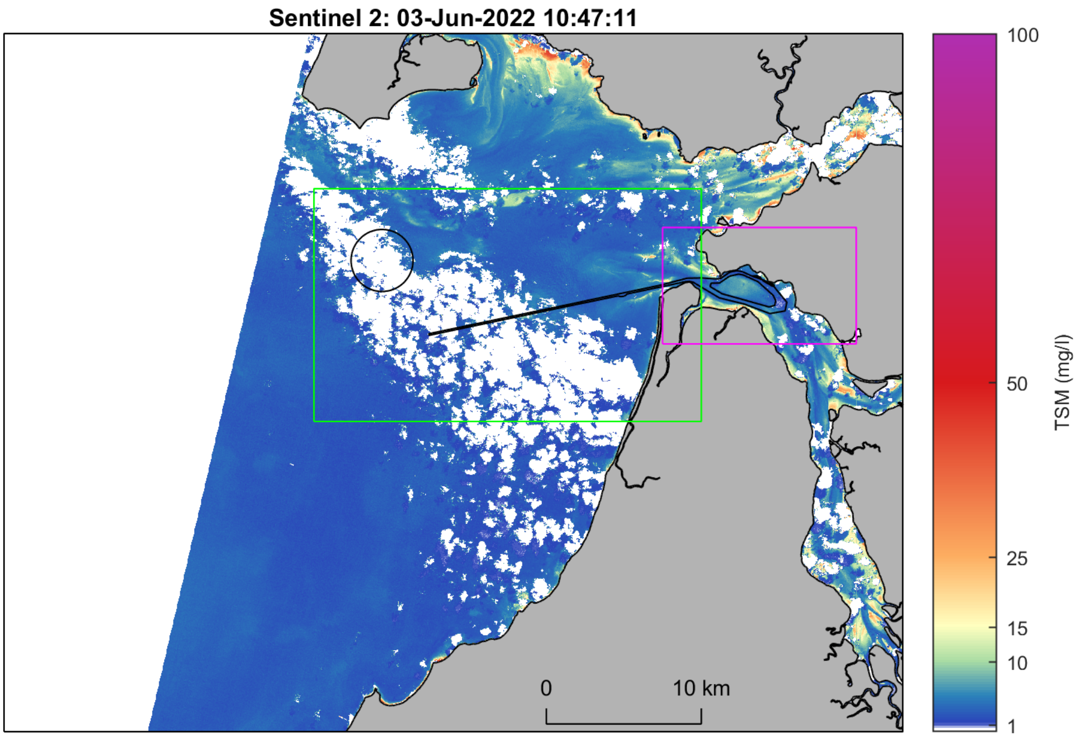
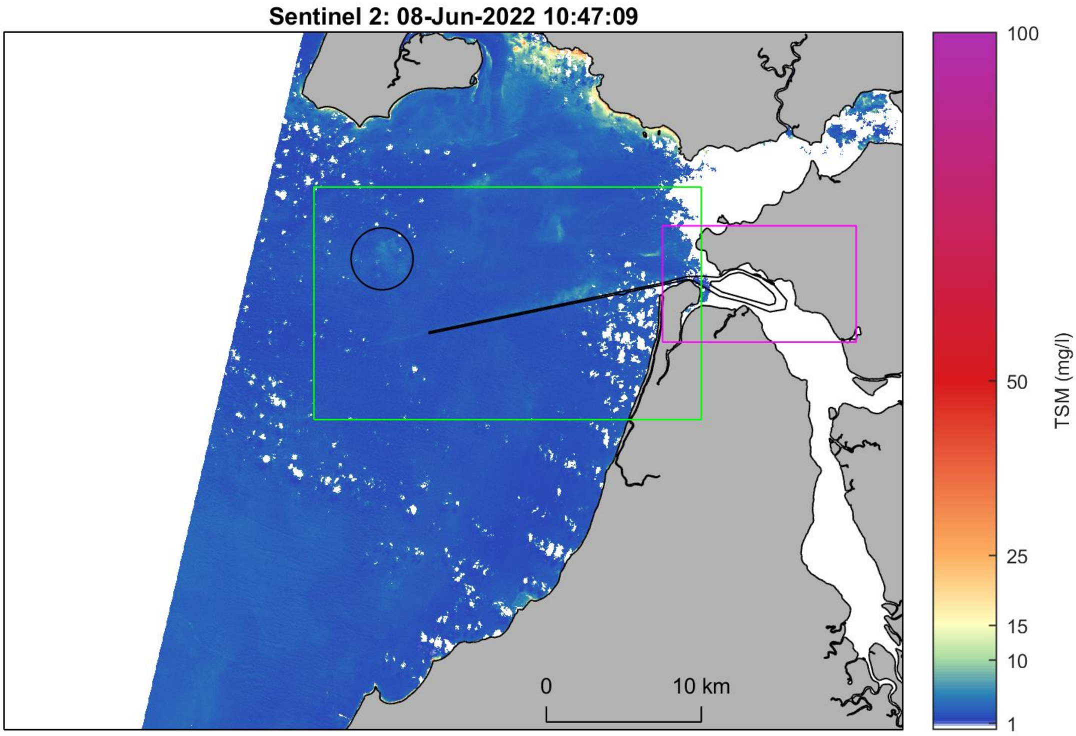


Figure 21. **Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 01/06/2022 at 10:57 AEST (dredging).**



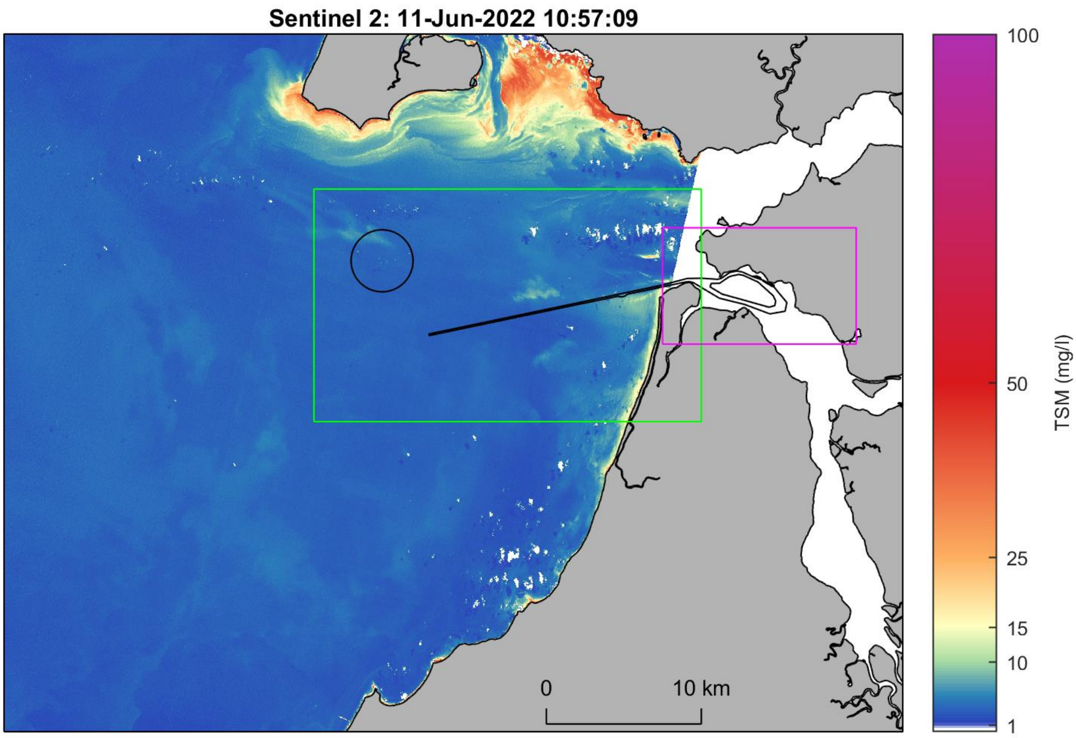
Note: the white areas represent cloud cover.

Figure 22. **Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 03/06/2022 at 10:47 AEST (dredging).**



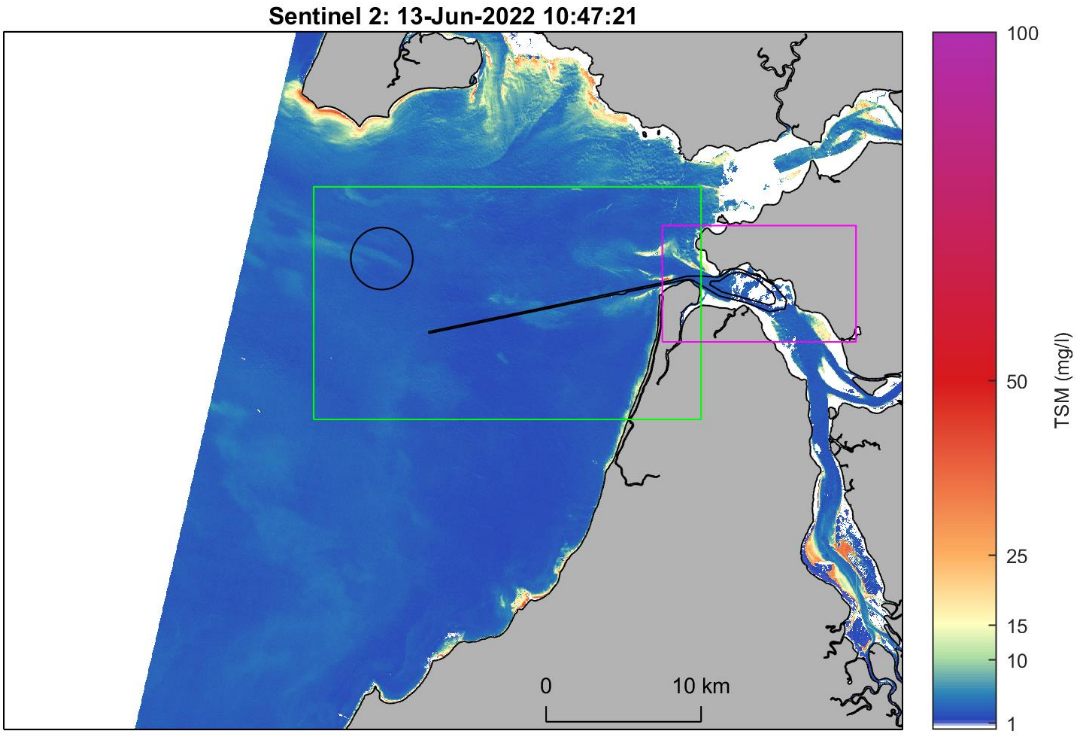
Note: the white areas represent cloud cover.

Figure 23. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 08/06/2022 at 10:47 AEST (dredging).



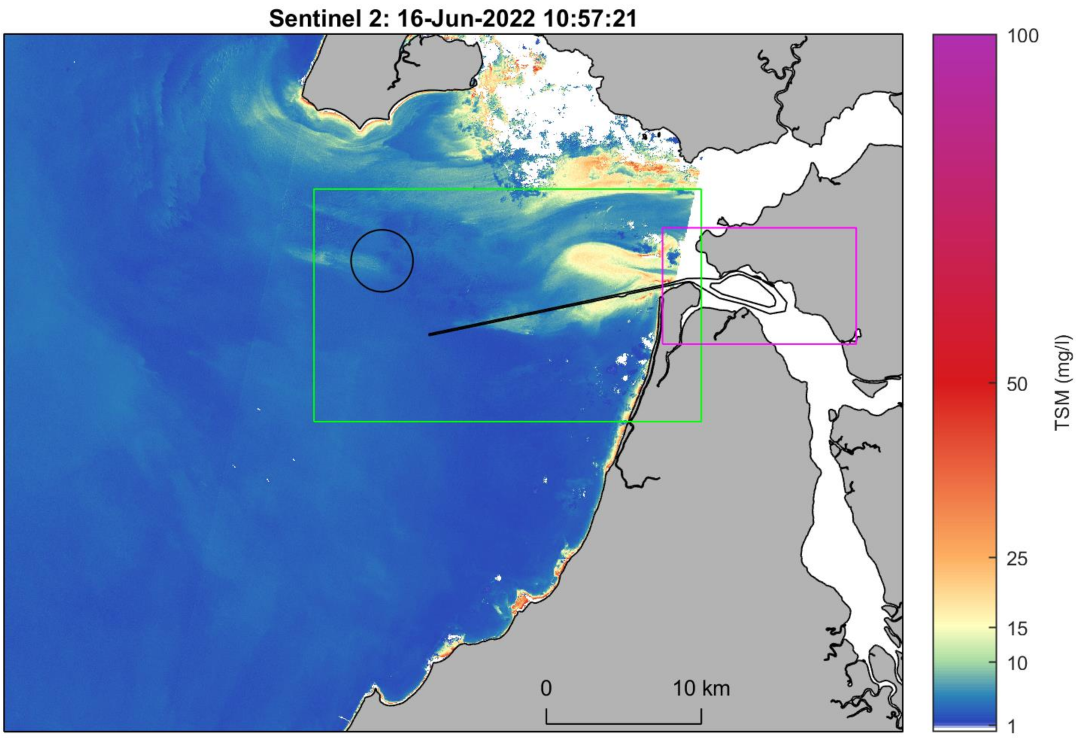
Note: the white areas represent cloud cover.

Figure 24. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 11/06/2022 at 10:57 AEST (dredging).



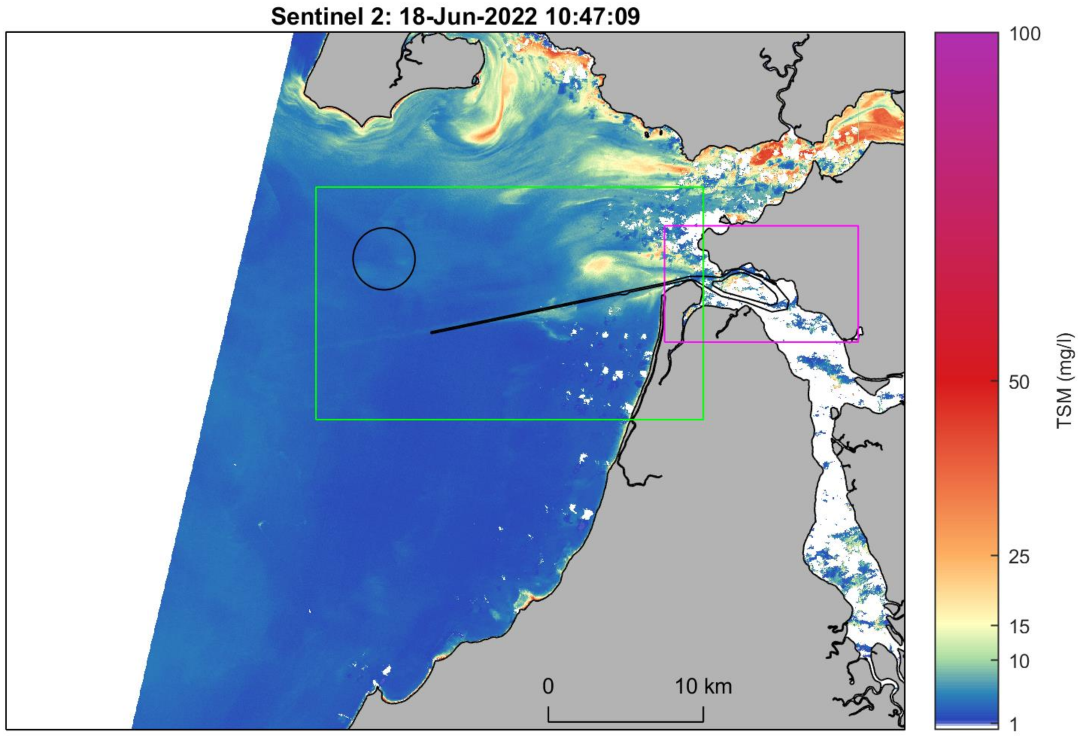
Note: the white areas represent cloud cover.

Figure 25. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 13/06/2022 at 10:47 AEST (dredging).



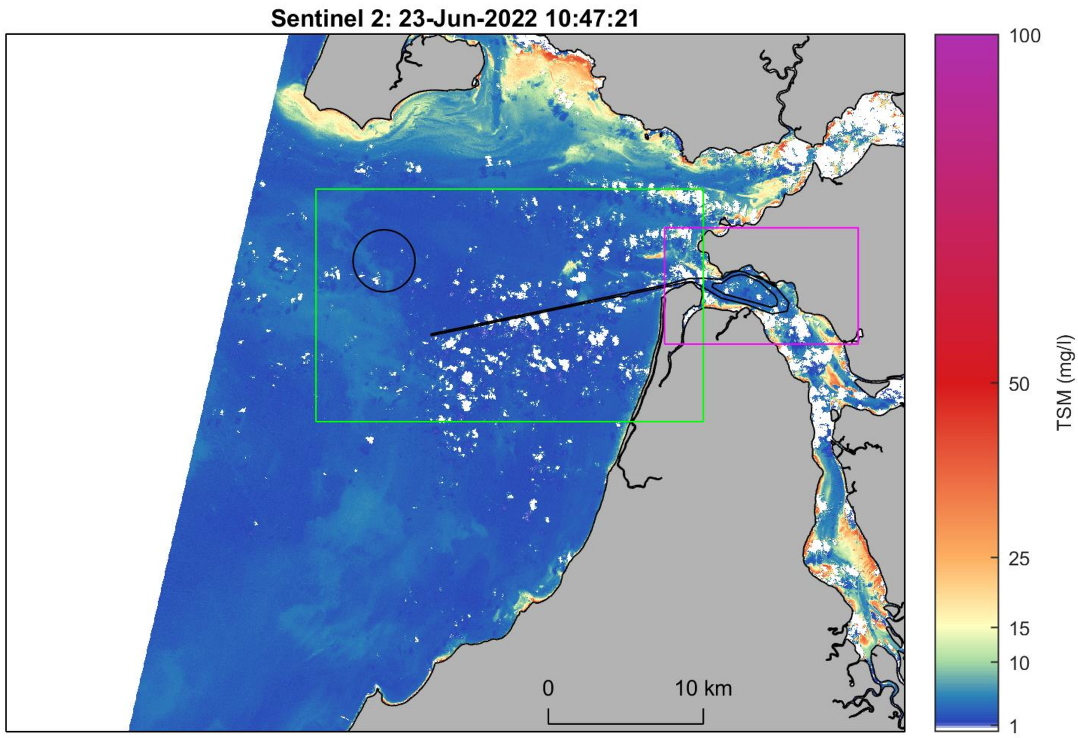
Note: the white areas represent cloud cover.

Figure 26. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 16/06/2022 at 10:57 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 27. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 18/06/2022 at 10:47 AEST (post-dredging).



Note: the white areas represent cloud cover.

Figure 28. Satellite-derived TSM from the Sentinel-2 sensor for Albatross Bay on 23/06/2022 at 10:47 AEST (post-dredging).

4.2.1.2. Local Scale

To show how the local turbidity around the Port of Weipa varied over the 2022 Maintenance Dredging program, plots of the satellite-derived TSM covering the South Channel and Albatross Bay DMPA and the Inner Harbour area are shown for the pre-, during and post-dredging periods in Figure 29 to Figure 47. The plots show the following:

- Pre-Dredging: the imagery from the pre-dredging period shows generally low TSM (less than 10 mg/l equivalent to approximately 7 NTU) across the South Channel and DMPA (Figure 29 and Figure 30). The image from the 29th April 2022 shows isolated plumes of up to 10 mg/l with spatial extents of 2 to 3 km present close to the South Channel and DMPA. The TSM in the Inner Harbour is slightly higher than in Albatross Bay, with background values of between 5 to 10 mg/l (approximately 4 to 7 NTU) in the channel and higher values along the shallow coastal areas (15 to 25 mg/l, approximately 11 to 18 NTU);
- During Dredging: the available images during the maintenance dredging program show localised plumes adjacent to the South Channel (mainly between SC6 and SC12), which are likely to be residual plumes predominantly due to the maintenance dredging and bed levelling activity (Figure 31 to Figure 45). Localised plumes were also visible within the Albatross Bay DMPA due to the recent placement of sediment within the DMPA. The plumes identified in the images attributed to dredging and placement activity remained close to where the placement or dredging activity occurred, showing that very little residual transport of the plumes away from where they were generated occurs. There were no visible plumes within the Inner Harbour as a result of maintenance dredging or bed levelling activity. The satellite images also did not show any visible plumes from maintenance dredging or bed levelling activities present at any of the three monitoring sites (WQ1, WQ2 and WQ4), indicating limited influence of the activities on the turbidity measurements at these sites. Further details of the observed plumes are provided below:
  - during dredging, up to 1 hour after dredging and within 30 minutes of placement at the DMPA, higher concentration plumes of up to 15 mg/l (approximately 11 NTU) were observed. The plumes of this concentration either remained within the South Channel or the DMPA where they were generated;
  - lower concentration residual plumes of up to 10 mg/l (approximately 7 NTU) were observed adjacent to the South Channel for up to 6 hours after dredging (following repeat dredging in one location) and within/adjacent to the DMPA for up to 3 hours after placement. Natural advection and dispersion of the plumes resulted in them being transported beyond the boundaries of the South Channel/DMPA, but these processes also acted to reduce the TSM of the plumes. Lower concentration plumes from the dredging of up to 5 km in length and 650 m in width were observed adjacent to the South Channel, while in the DMPA the lower concentration plumes were observed to be up to 750 m in diameter.
  - none of the processed images showed a localised plume in the Inner Harbour indicative of dredging or bed levelling. The areas of elevated TSM in the Inner Harbour appeared to be due to natural processes resuspending fine-grained sediment in the region;
  - the images indicate that the TSM in the area of the seagrass meadows in the Inner Harbour has been predominantly controlled by natural processes, with the natural TSM varying between 5 mg/l (along the northern shoreline, approximately 4 NTU) and 25 mg/l (along the southern shoreline, approximately 18 NTU) and remaining relatively consistent throughout the images. No persistent plumes that would be expected to impact seagrass beyond what they are normally exposed to have been observed as a result of the maintenance dredging program; and
  - the propeller wash from bulk carriers departing the Port resulted in plumes extending the majority of the length of the South Channel and offshore to the west. Within 2 km of a vessel a plume of up to 10 mg/l (approximately 7 NTU) and approximately 100 m

in width was observed while a lower concentration residual plume of up to 5 mg/l was present more than 2 km away from a vessel with a plume width of up to 500 m.

- Post-Dredging: the first post dredging image was captured approximately 12 hours after the dredging ceased and the second was more than five days after the dredging ceased (Figure 46 and Figure 47). The image from the 18th June 2022 shows a localised plume of 10 to 15 mg/l (approximately 7 to 11 NTU) present adjacent to the South Channel, with slightly elevated TSM of up to 10 mg/l (approximately 7 NTU) also present within the DMPA. The image was captured approximately 12 hours after dredging finished in the South Channel (in the approximate location of the plume) and 11 hours after the final load of sediment was placed. This indicates that that the plumes can remain in suspension for at least 12 hours once dredging and placement activities cease and provides further evidence that limited residual transport occurs. The image captured on the 23rd June 2022 does not show any indication of plumes from the dredging activity, showing that five days after dredging ended there is no residual plume remaining.

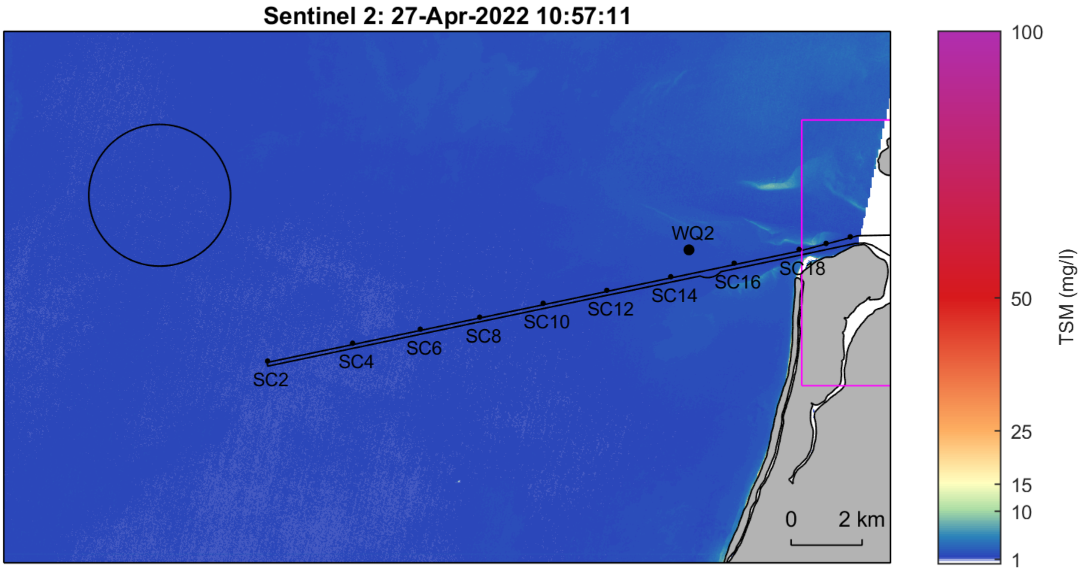
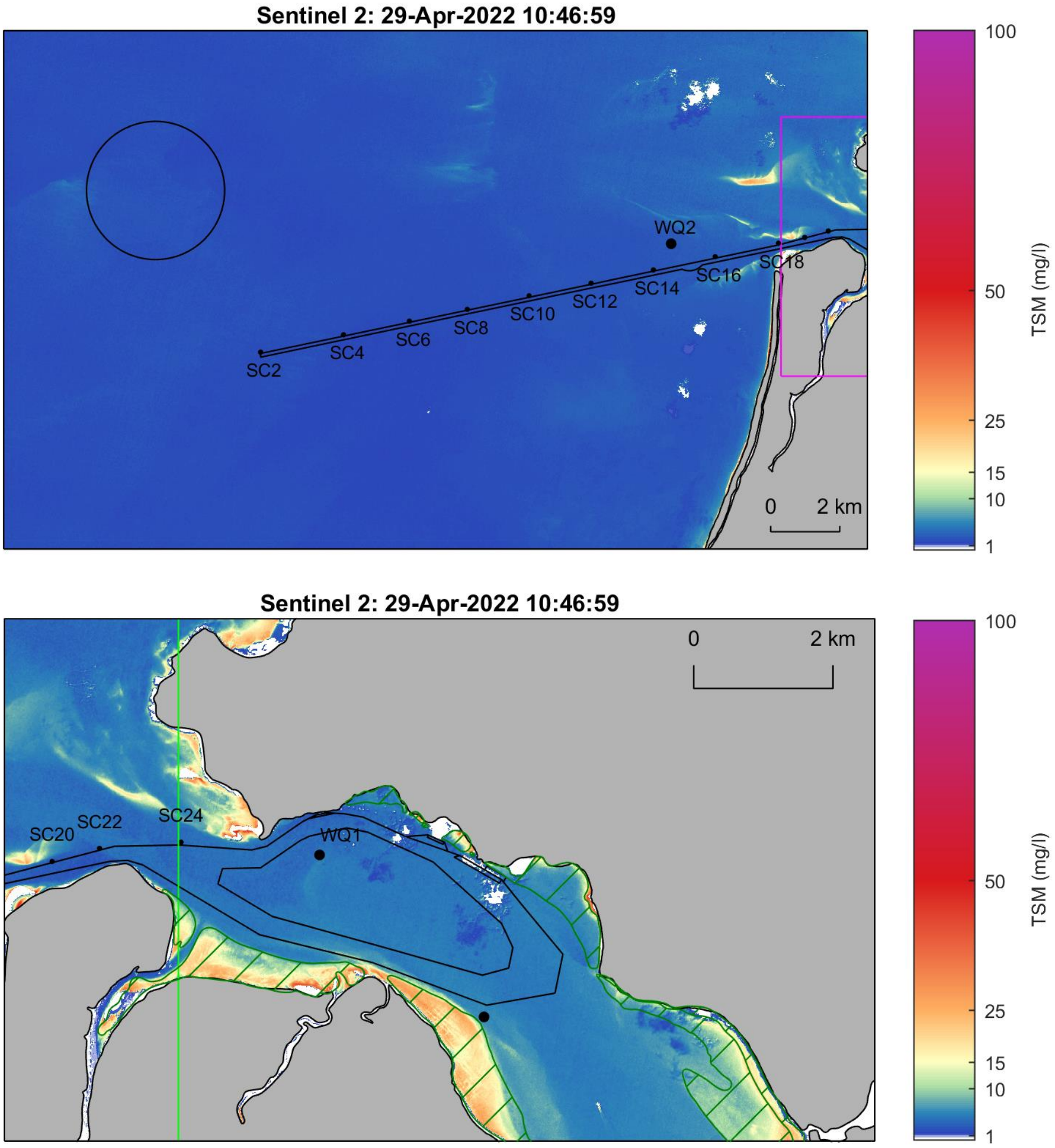
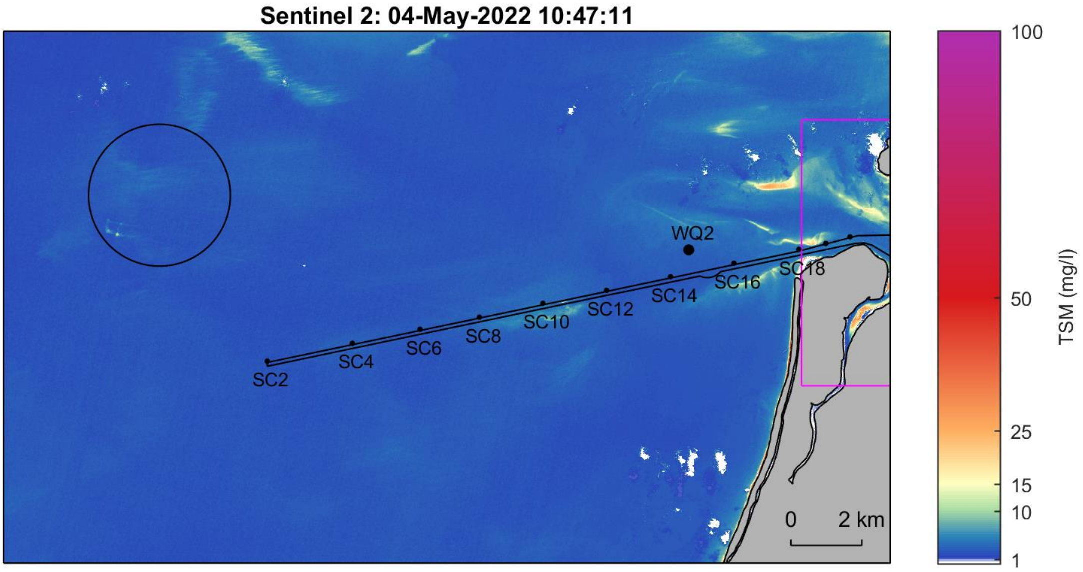


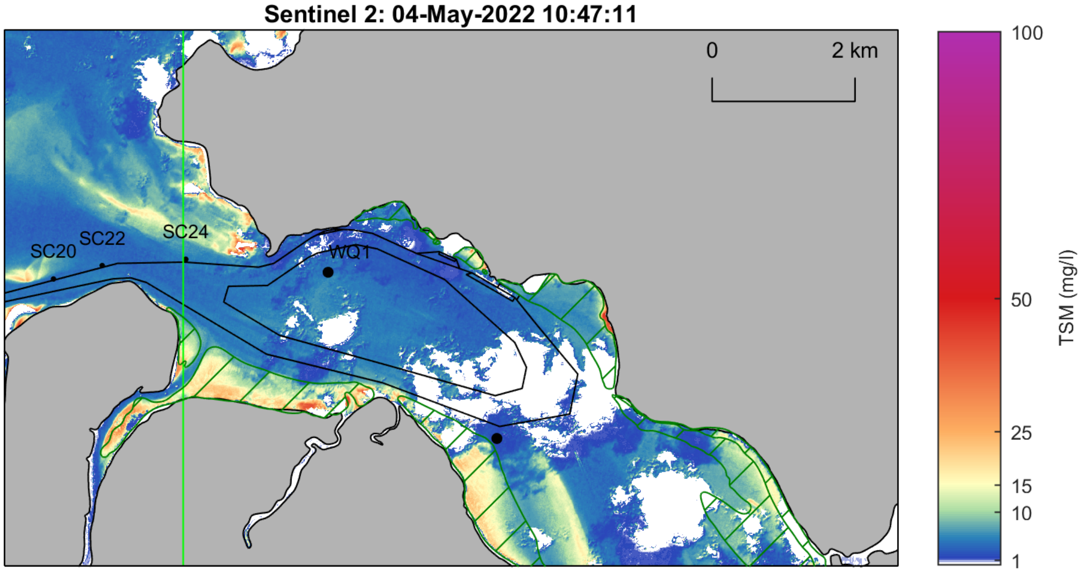
Figure 29. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 27/04/2022 at 10:57 AEST (pre-dredging).



Note: the white areas represent cloud cover.

Figure 30. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 29/04/2022 at 10:46 AEST (pre-dredging).





Note: the white areas represent cloud cover.

Figure 31. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 04/05/2022 at 10:47 AEST (dredging).

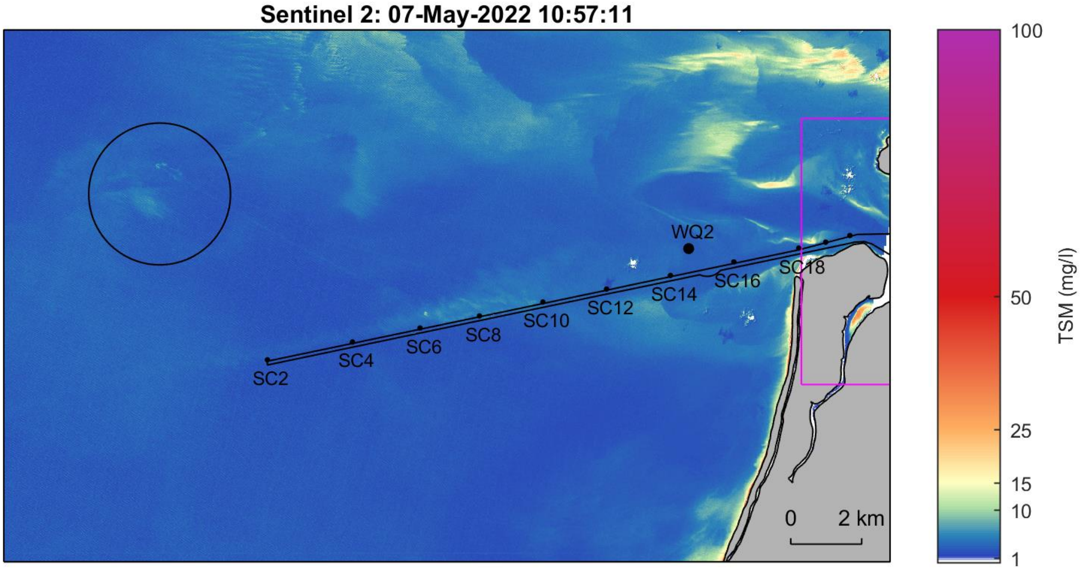
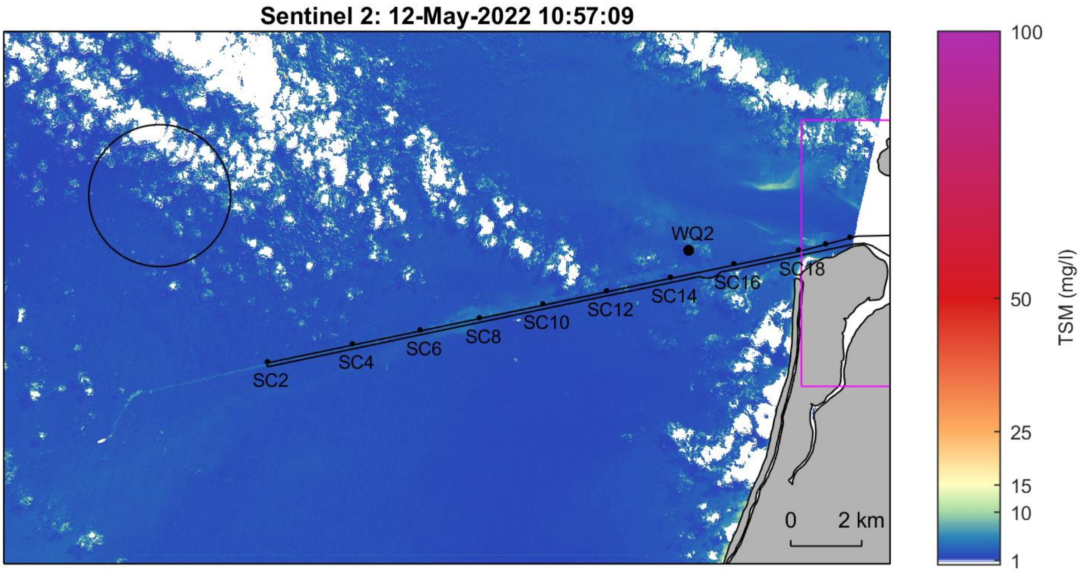
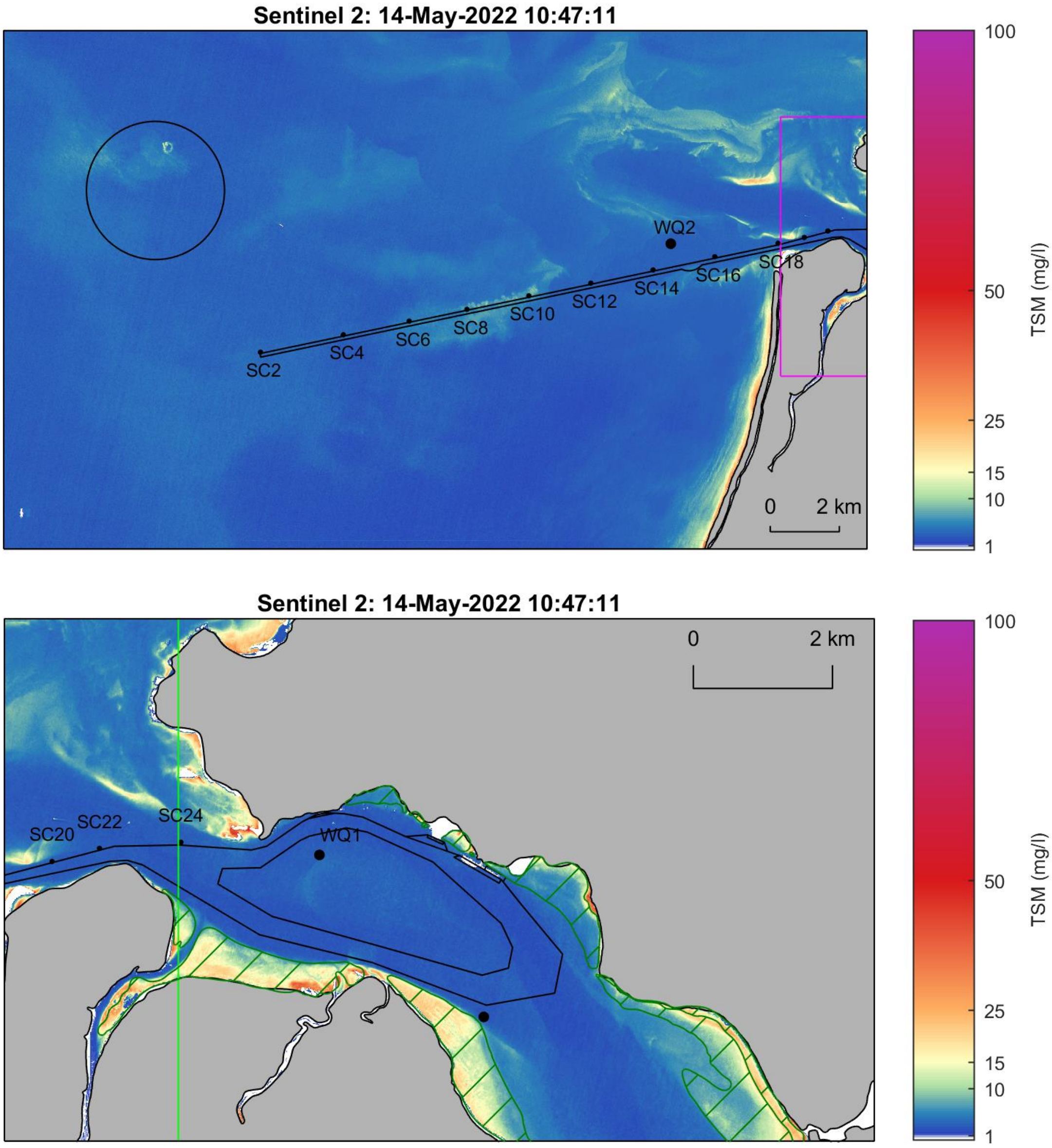


Figure 32. **Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 07/05/2022 at 10:57 AEST (dredging).**



Note: the white areas represent cloud cover.

Figure 33. **Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 12/05/2022 at 10:57 AEST (dredging).**



Note: the white areas represent cloud cover.

Figure 34. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 14/05/2022 at 10:47 AEST (dredging).

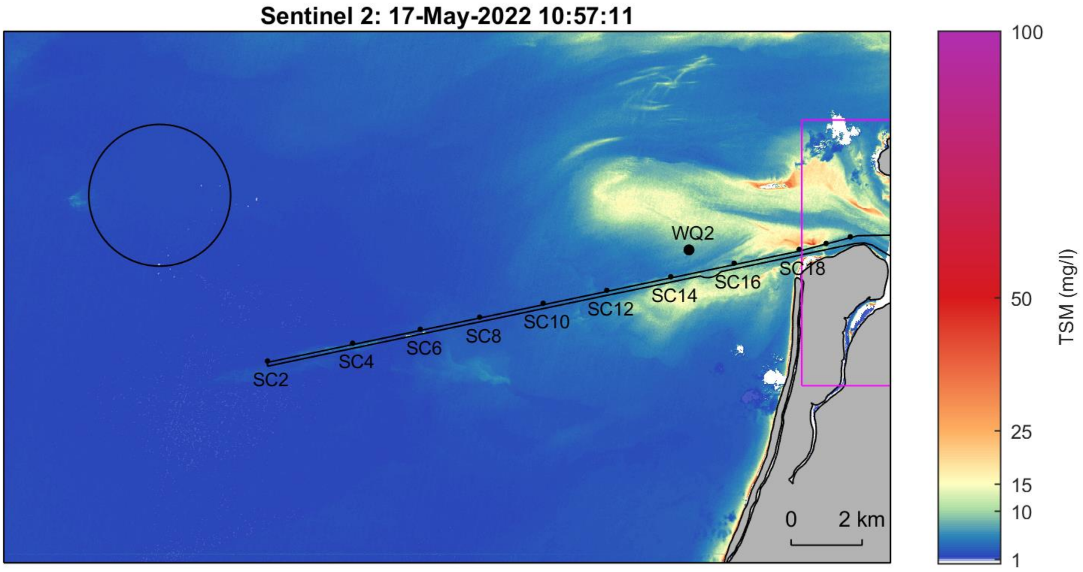
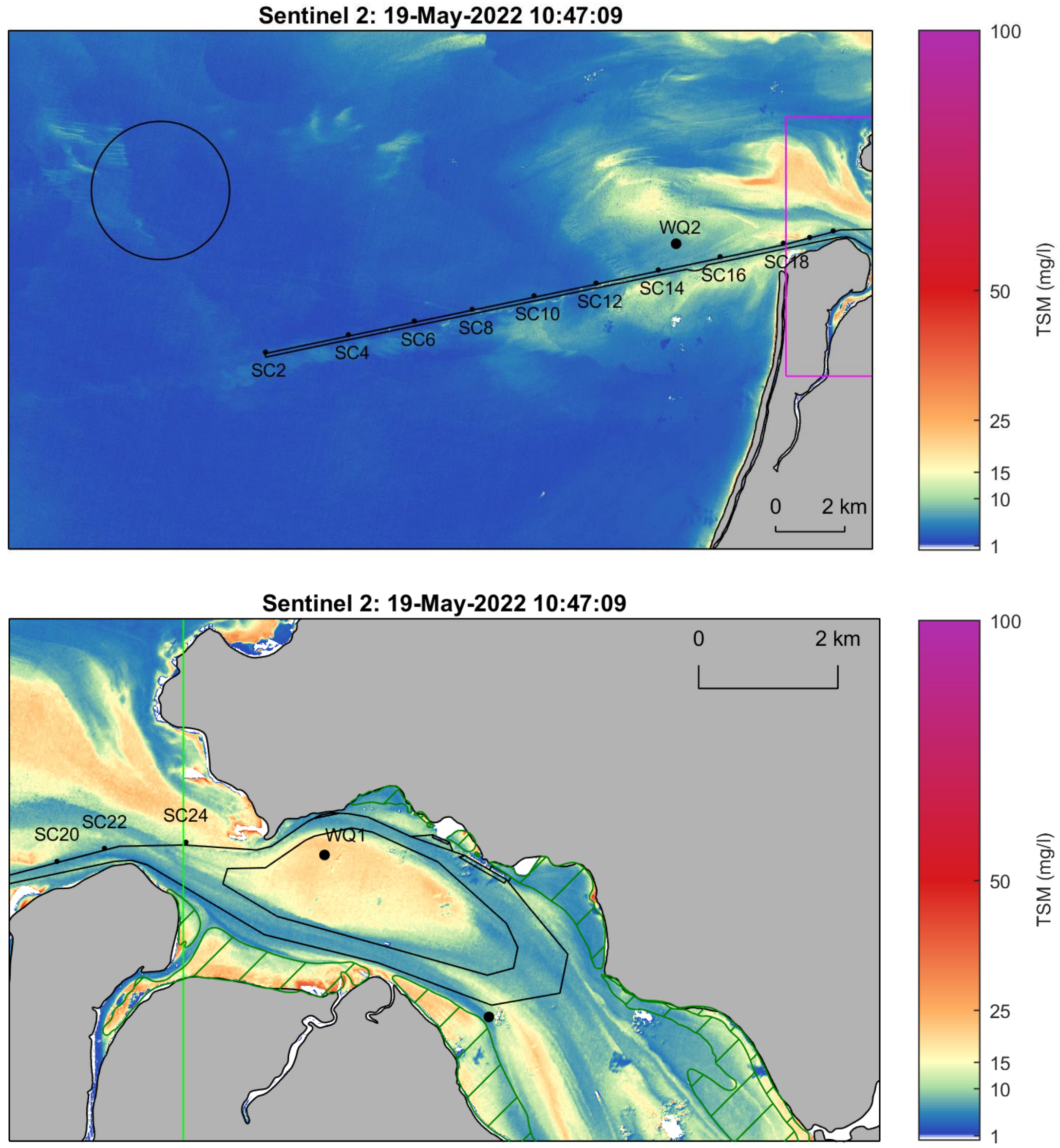


Figure 35. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 17/05/2022 at 10:57 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 36. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 19/05/2022 at 10:47 AEST (dredging).

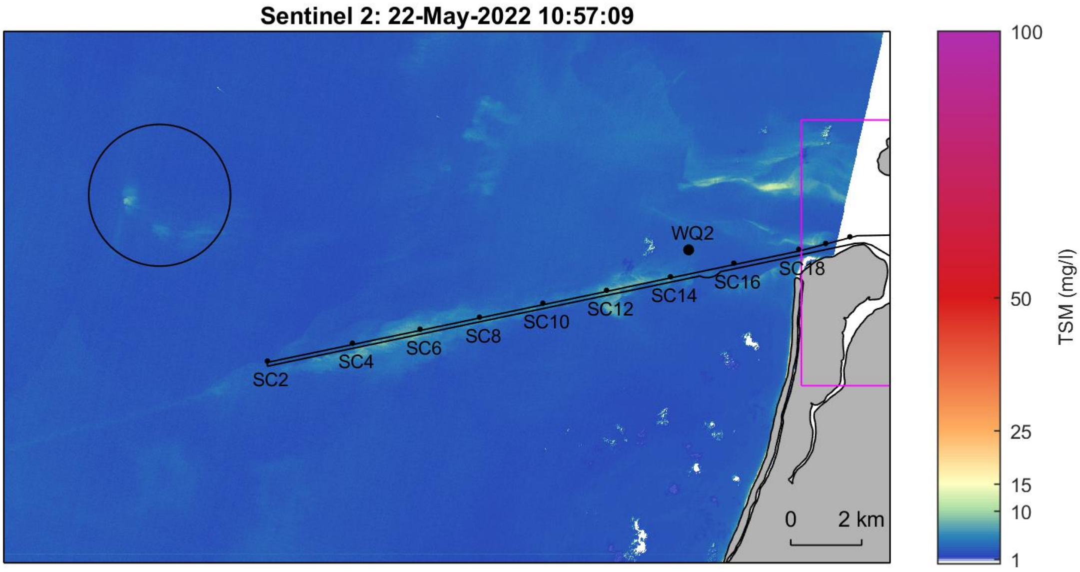
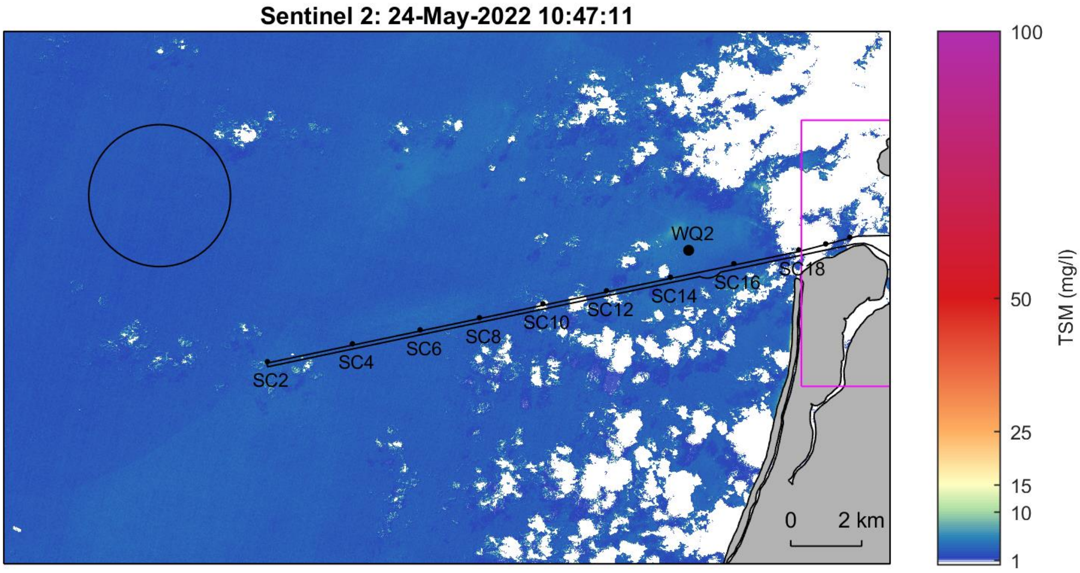
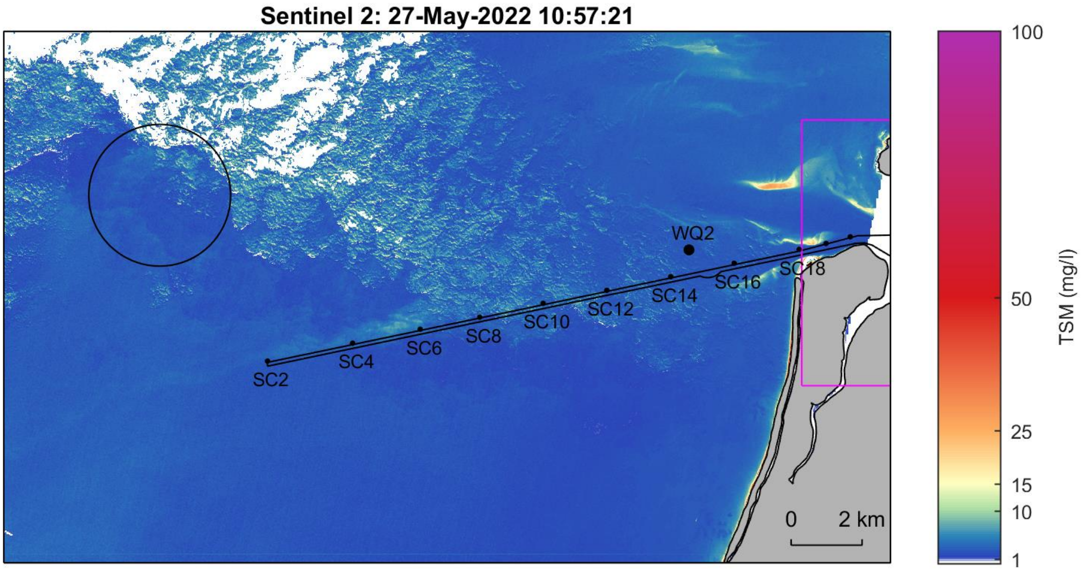


Figure 37. **Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 22/05/2022 at 10:57 AEST (dredging).**



Note: the white areas represent cloud cover.

Figure 38. **Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 24/05/2022 at 10:47 AEST (dredging).**



Note: the white areas represent cloud cover.

Figure 39. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 27/05/2022 at 10:57 AEST (dredging).

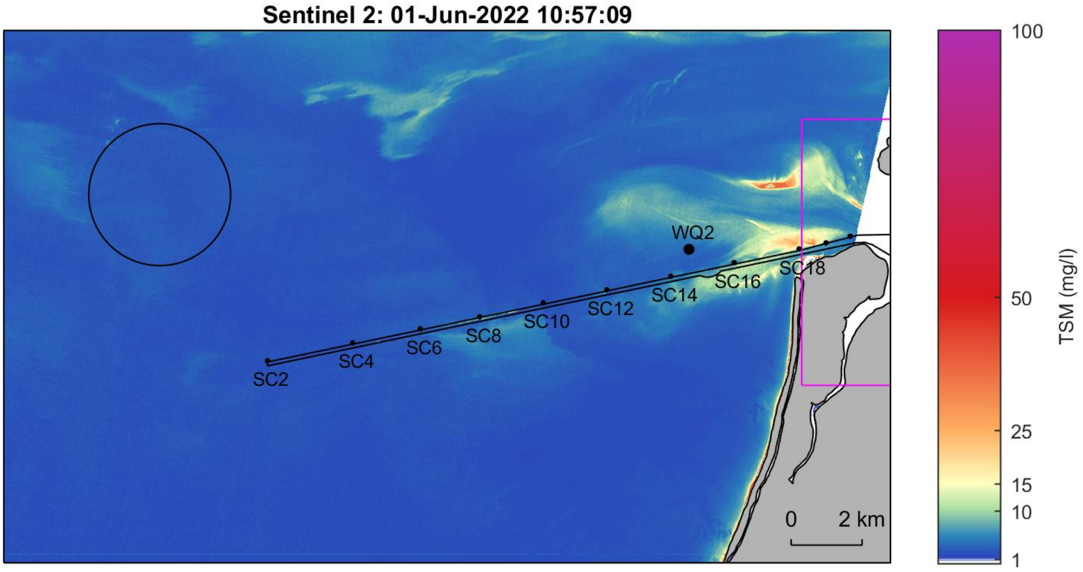
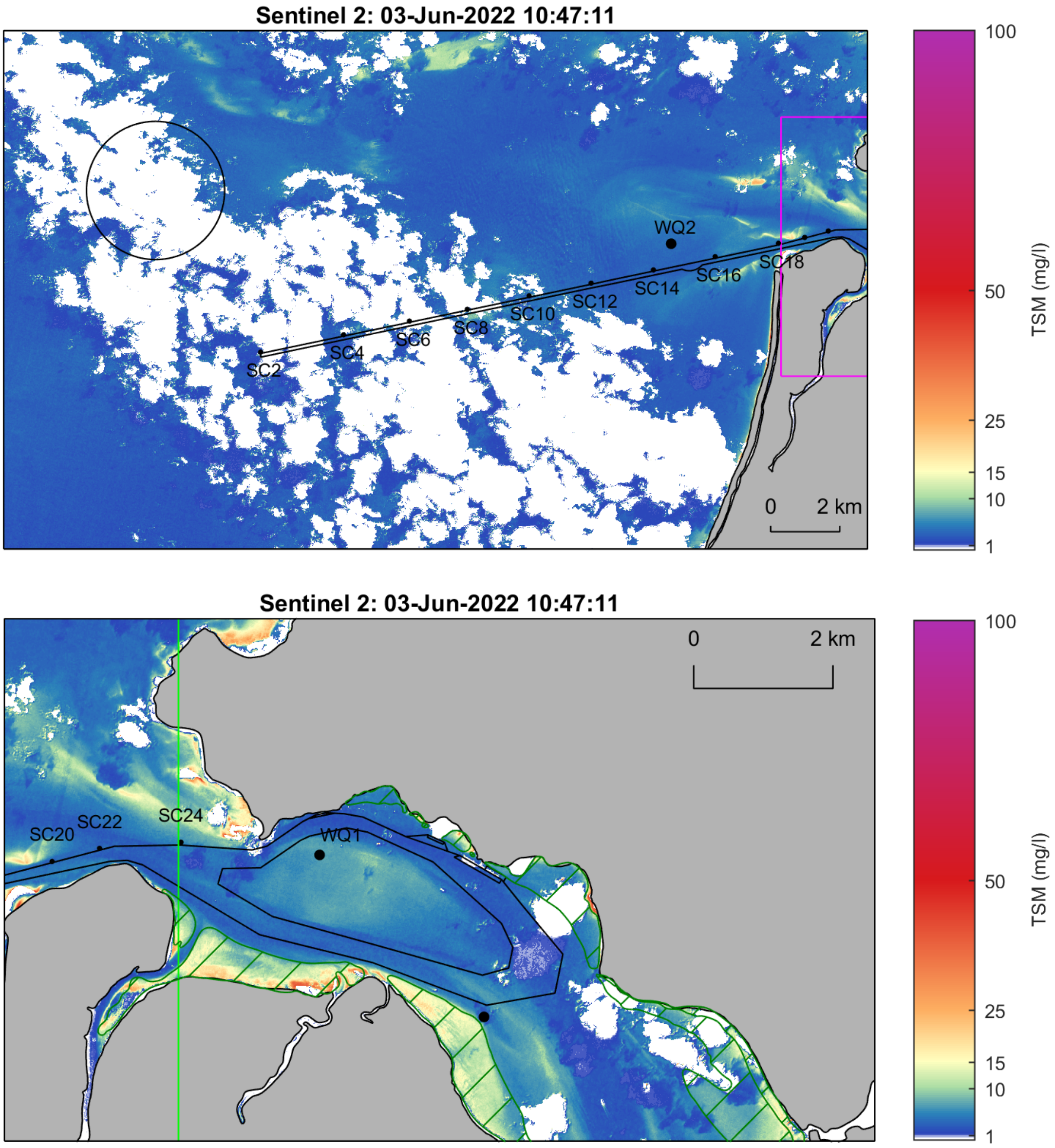
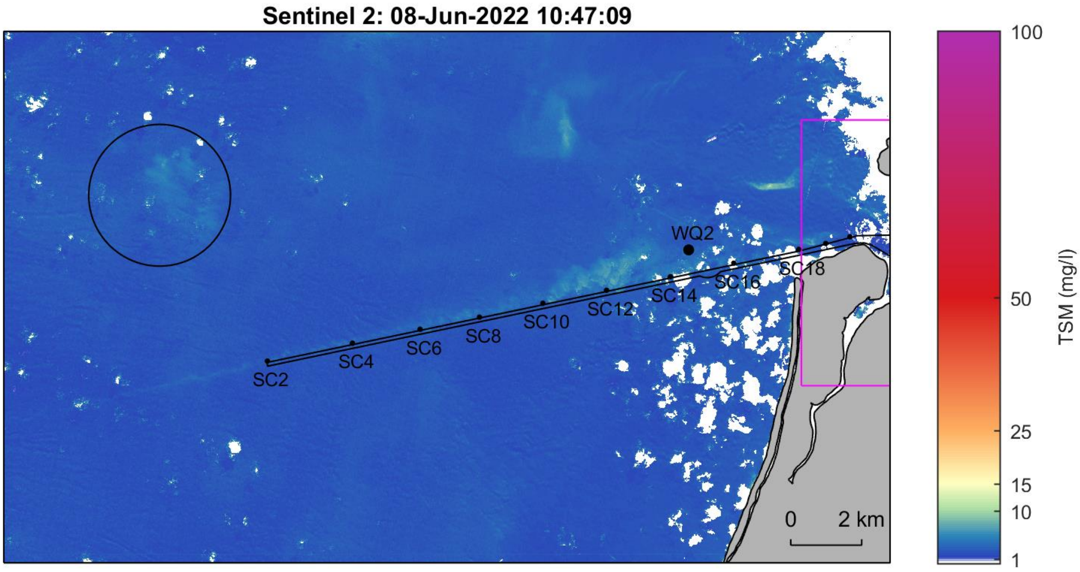


Figure 40. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 01/06/2022 at 10:57 AEST (dredging).



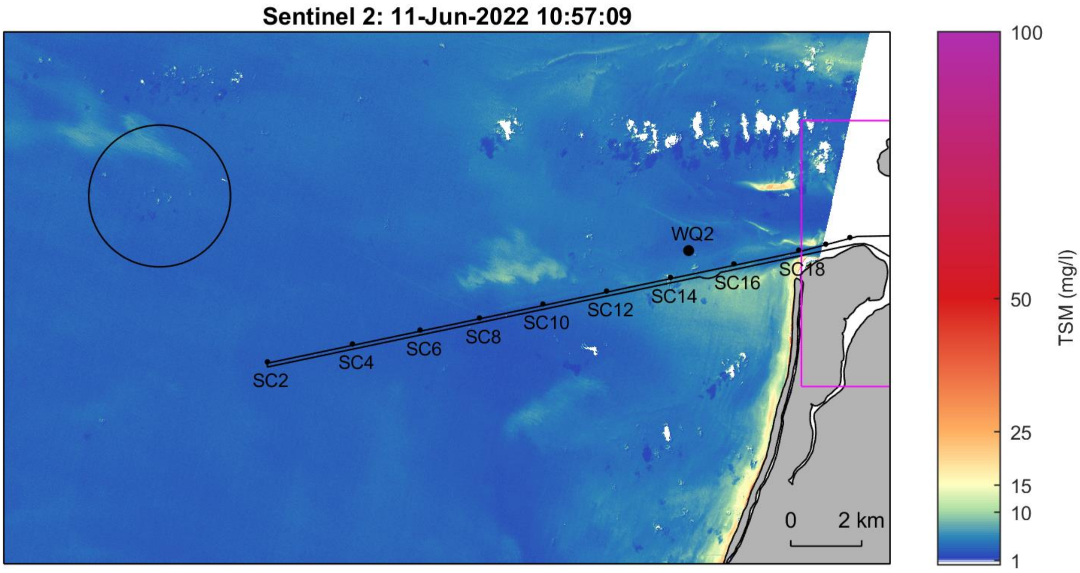
Note: the white areas represent cloud cover.

Figure 41. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 03/06/2022 at 10:47 AEST (dredging).



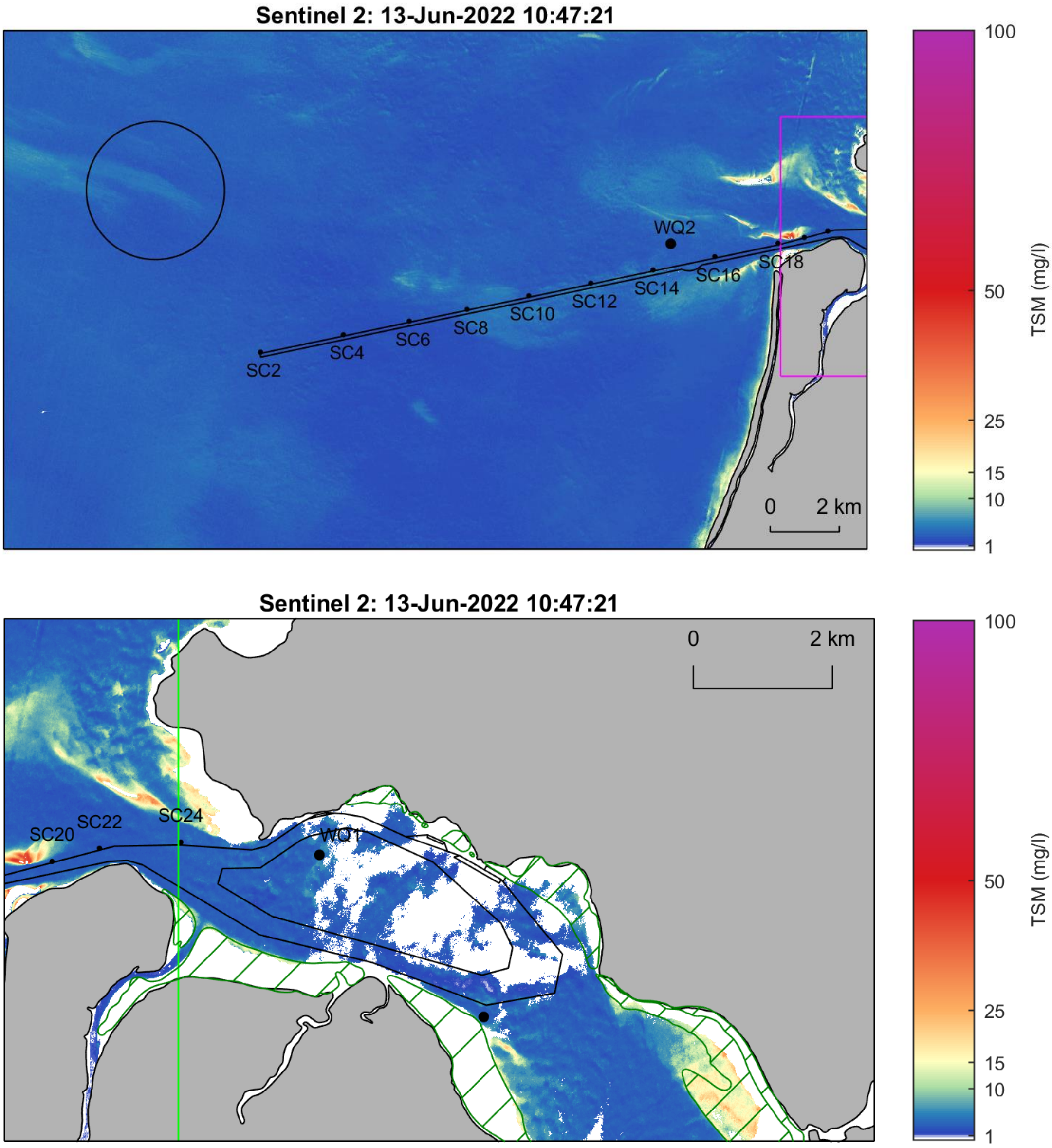
Note: the white areas represent cloud cover.

Figure 42. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 08/06/2022 at 10:47 AEST (dredging).



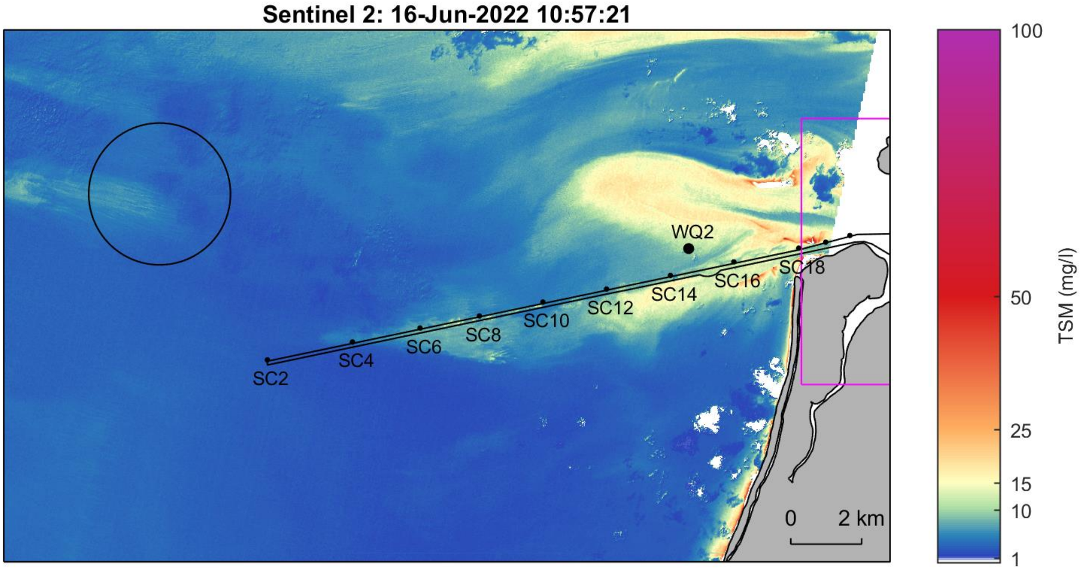
Note: the white areas represent cloud cover.

Figure 43. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 11/06/2022 at 10:57 AEST (dredging).



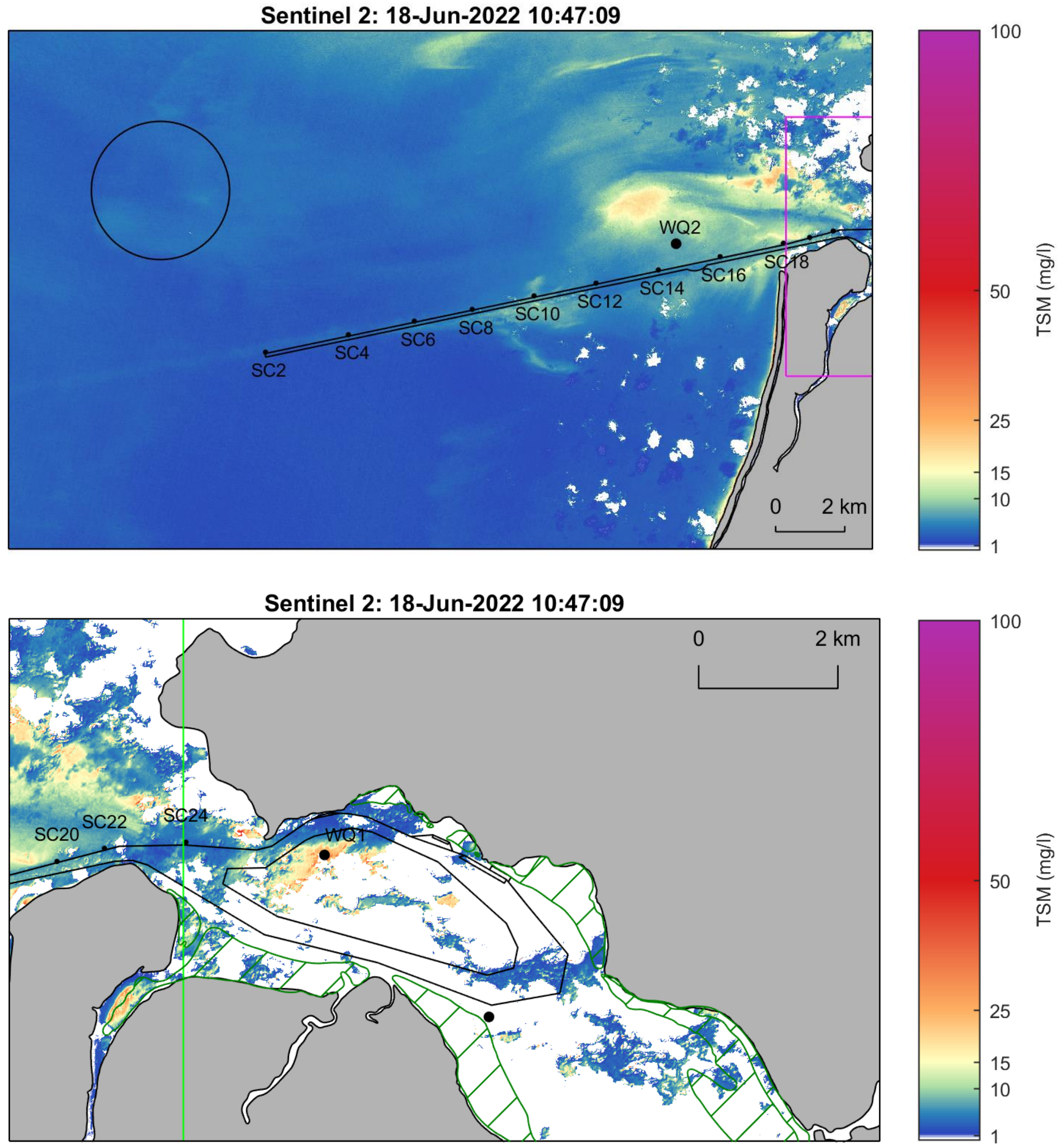
Note: the white areas represent cloud cover.

Figure 44. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 13/06/2022 at 10:47 AEST (dredging).



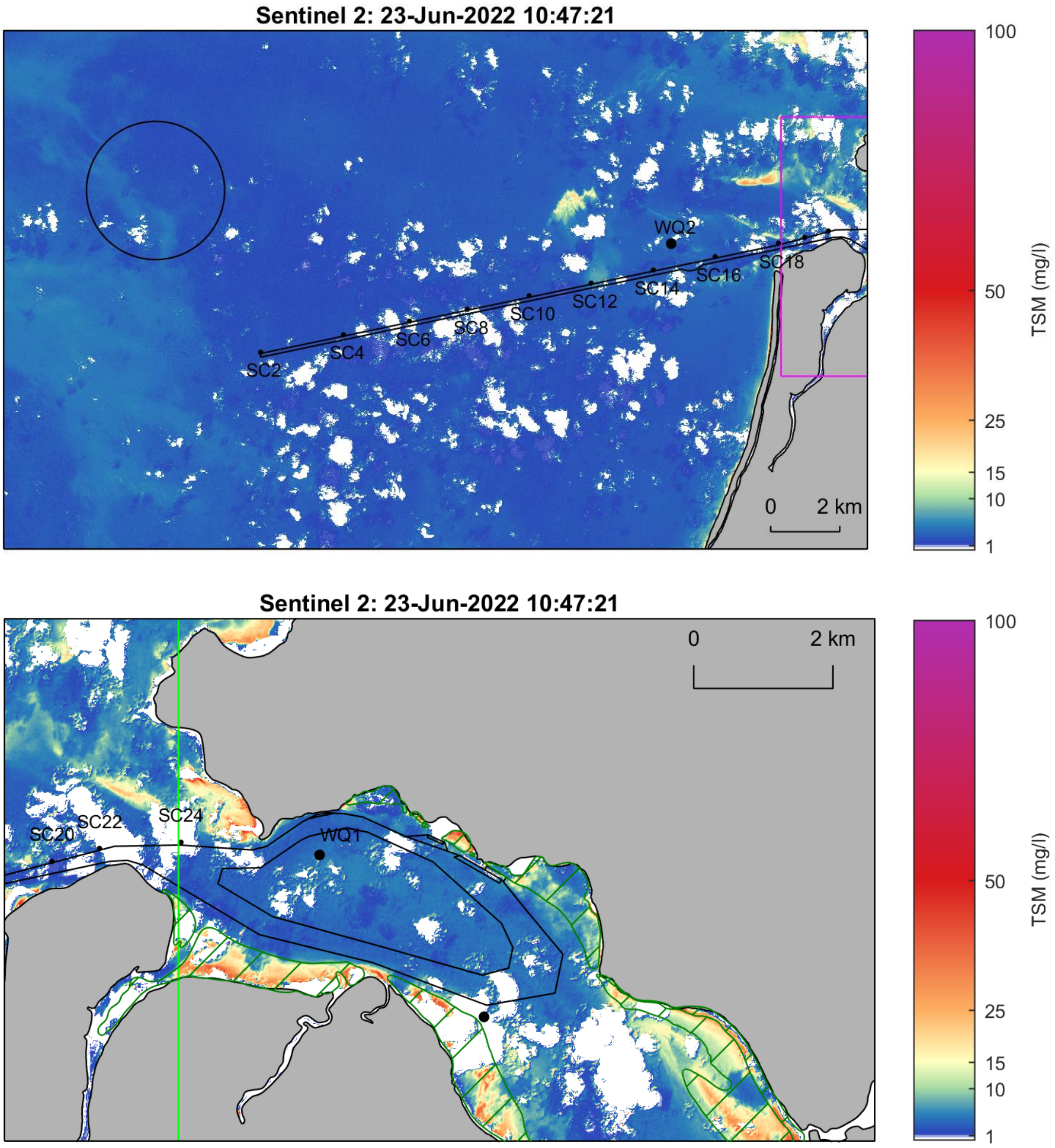
Note: the white areas represent cloud cover.

Figure 45. Satellite-derived TSM from the Sentinel-2 sensor for South Channel on 16/06/2022 at 10:57 AEST (dredging).



Note: the white areas represent cloud cover.

Figure 46. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 18/06/2022 at 10:47 AEST (post-dredging).



Note: the white areas represent cloud cover.

Figure 47. Satellite-derived TSM from the Sentinel-2 sensor for South Channel (top) and Inner Harbour (bottom) on 23/06/2022 at 10:47 AEST (post-dredging).

4.2.1.3. Dredge Vessel Scale

To further analyse the satellite-derived TSM for increases in TSM due to the maintenance dredging activity, zoomed in plots of the plume shown by Sentinel-2 imagery during periods when or soon after the TSHD Brisbane was dredging are shown for the following:

- 15 minutes after starting dredging (Figure 48 and Figure 49): the TSHD Brisbane was dredging silt from the South Channel in both images. The plots show similar plume extents and concentrations:
  - a higher concentration plume of up to 15 mg/l is present immediately behind the dredger (up to 1 km) which remains predominantly constrained within the South Channel (width of up to 80 m); and
  - a lower concentration plume of less than 10 mg/l, extending up to 4 km from the dredger, is visible with the potential for this plume to be either within or adjacent to the South Channel (width of up to 150 m).
- 2 hours 20 minutes after completion of dredging (Figure 50): this plot shows a plume of between 10 and 15 mg/l is present predominantly within the South Channel (width of up to 250 m) over a 4 km length of the channel.

The plots show how the maintenance dredging activity in the South Channel can result in a localised plume with a concentration of up to 10 to 15 mg/l in the location where the dredging is being undertaken. Although the plots show that some advection and dispersion of the plume occurs resulting in the plume extent increasing, the plume still remains predominantly within the dredged channel with the width increasing to up to 250 m.

To better understand the increases in TSM at the Albatross Bay DMPA, zoomed in plots of the plume shown by Sentinel-2 imagery soon after the TSHD Brisbane had placed sediment there are shown for the following:

- 10 minutes after placement (Figure 51): a plume of up to 15 mg/l with a radius of 350 m is clearly visible in the DMPA. The plume is in a circular pattern as the dredger sails in a circle during placement to ensure the sediment is placed where intended and the hopper is completely emptied;
- 20 minutes after placement (Figure 52): a plume of up to 10 mg/l with a radius of 500 m is clearly visible in the DMPA; and
- 40 minutes after placement (Figure 53): a plume of up to 6 mg/l with a radius of 800 m is visible in the DMPA. The natural background TSM is approximately 3.5 mg/l, indicating that the excess TSM from the plume is approximately 3 mg/l.

The plumes resulting from the placement of dredged sediment within the DMPA show how quickly the TSM of the plume reduces following placement, while the extent of the plume increases due to the advection and dispersion of the plume. The results show that 40 minutes after placement the concentration of the plume has more than halved and is only approximately 3 mg/l above the natural background TSM.

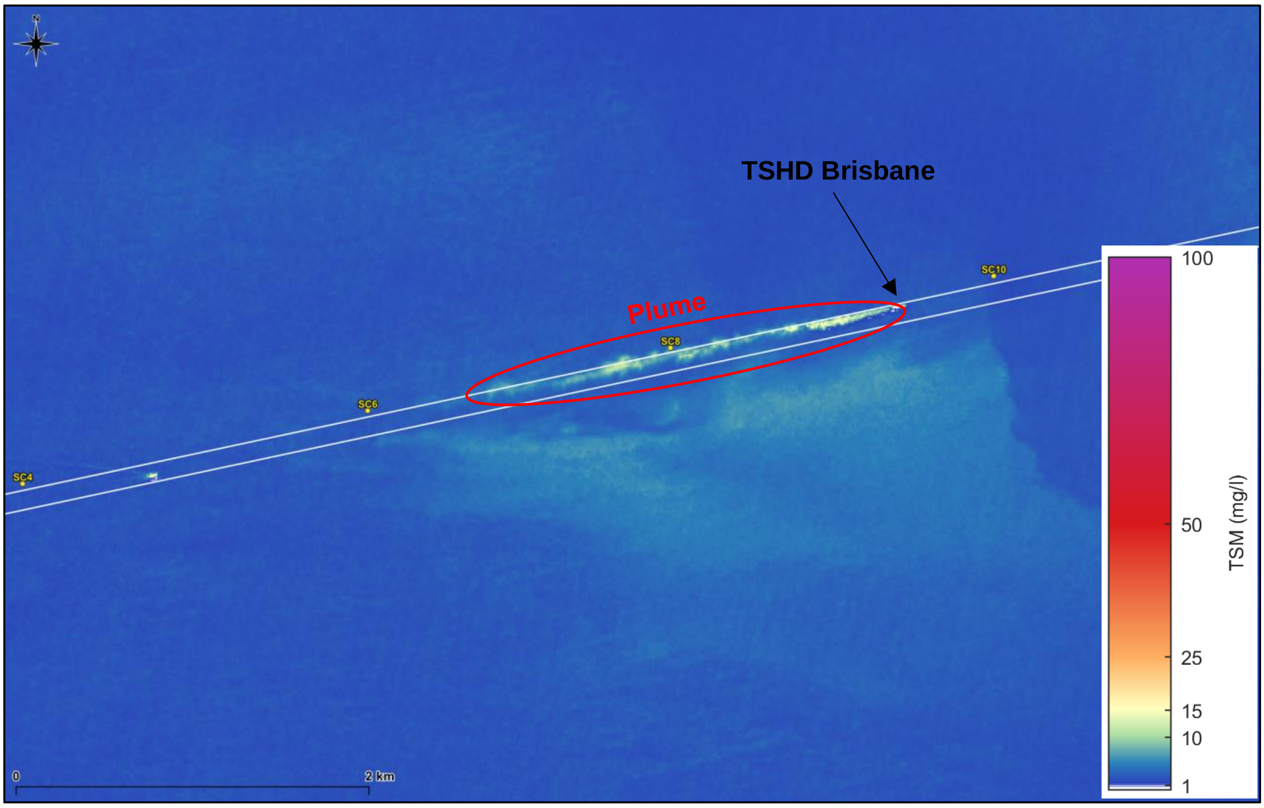


Figure 48. Satellite-derived TSM from the Sentinel-2 sensor showing the plume from the TSHD Brisbane 15 minutes after it started dredging on 01/06/2022 at 10:57 AEST.

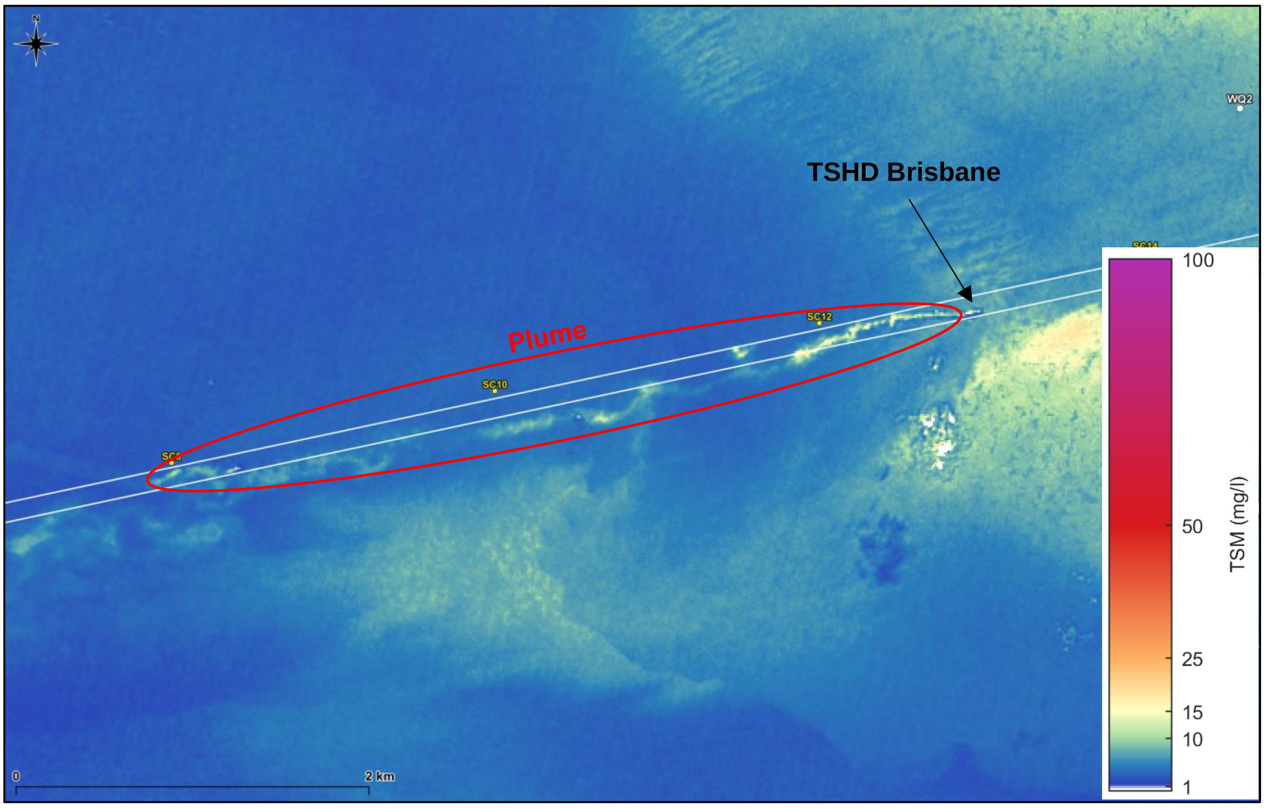


Figure 49. Satellite-derived TSM from the Sentinel-2 sensor showing the plume from the TSHD Brisbane 15 minutes after it started dredging on 19/05/2022 at 10:47 AEST.

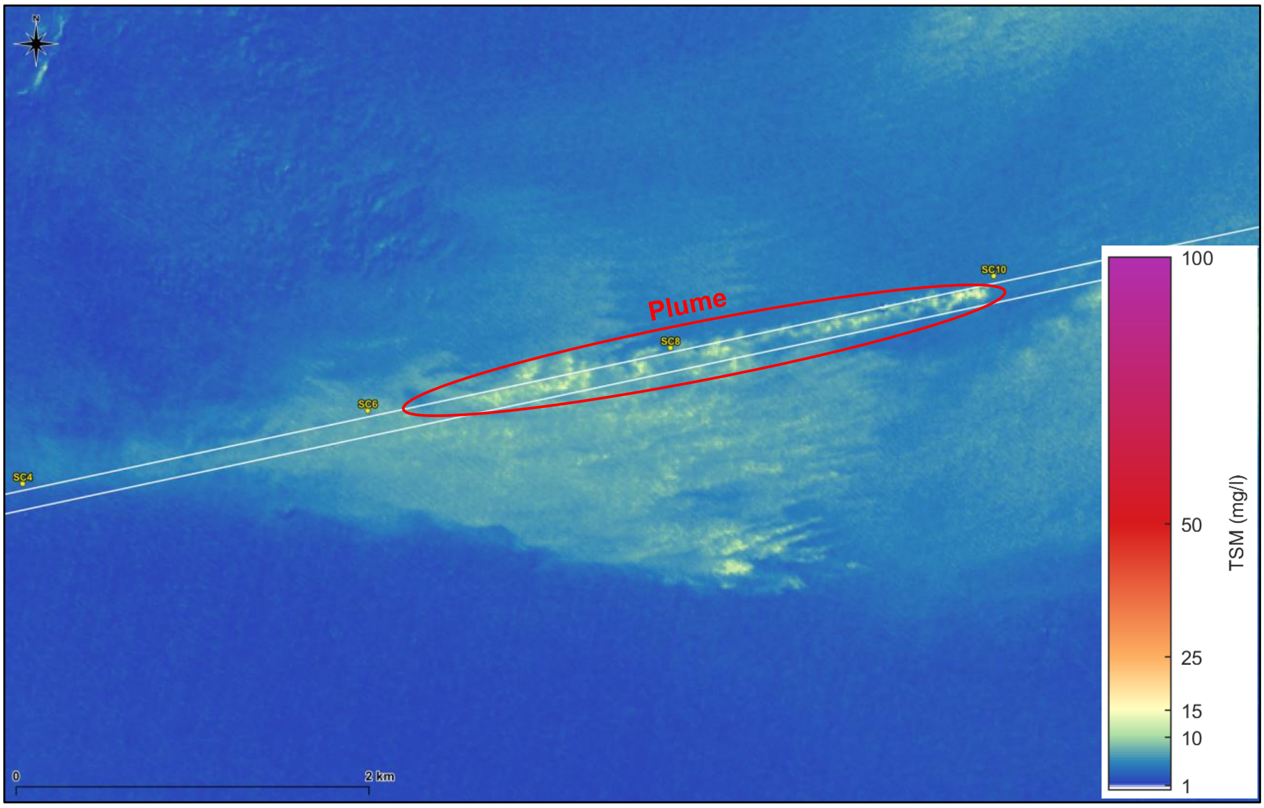


Figure 50. Satellite-derived TSM from the Sentinel-2 sensor showing the residual plume in the South Channel 2 hours and 20 minutes since dredging on 16/06/2022 at 10:57 AEST.

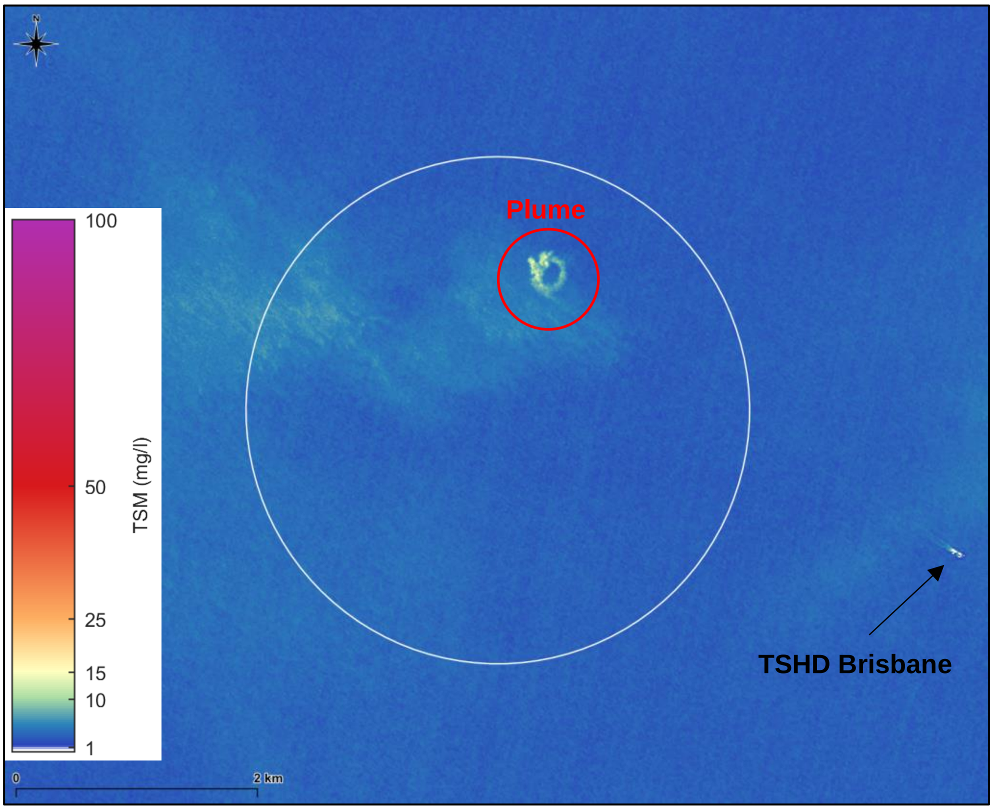


Figure 51. Satellite-derived TSM from the Sentinel-2 sensor showing the plume in the DMPA 10 minutes after placement by the TSHD Brisbane on 14/05/2022 at 10:47 AEST.

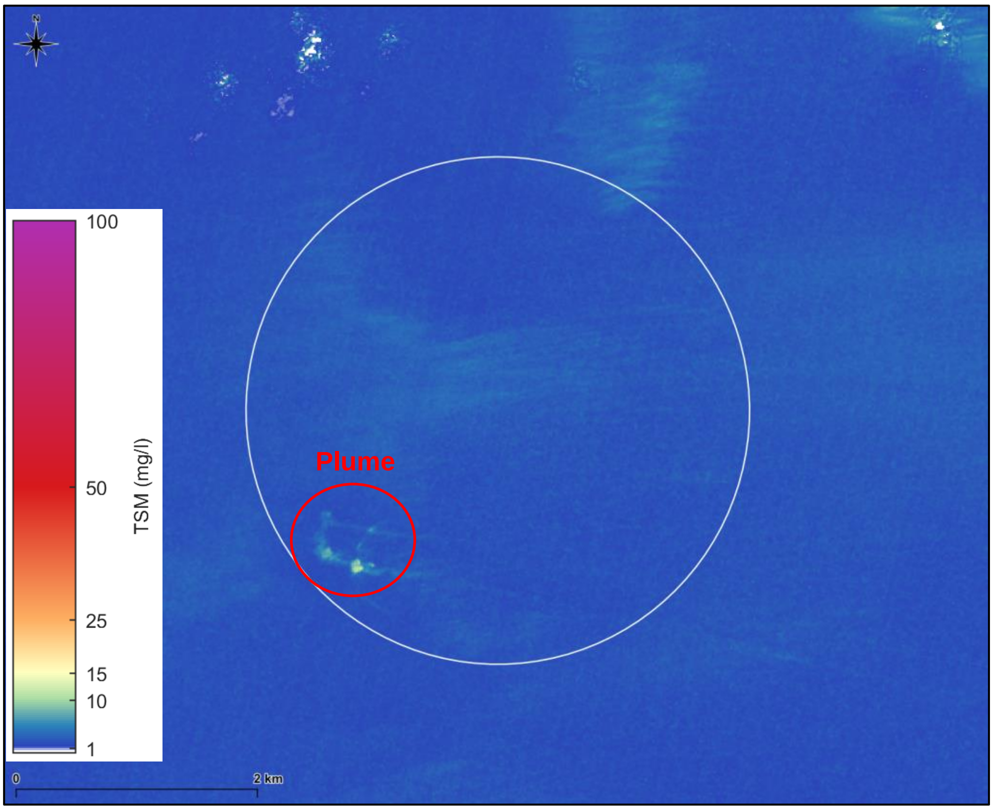


Figure 52. Satellite-derived TSM from the Sentinel-2 sensor showing the plume in the DMPA 20 minutes after placement by the TSHD Brisbane on 04/05/2022 at 10:47 AEST.

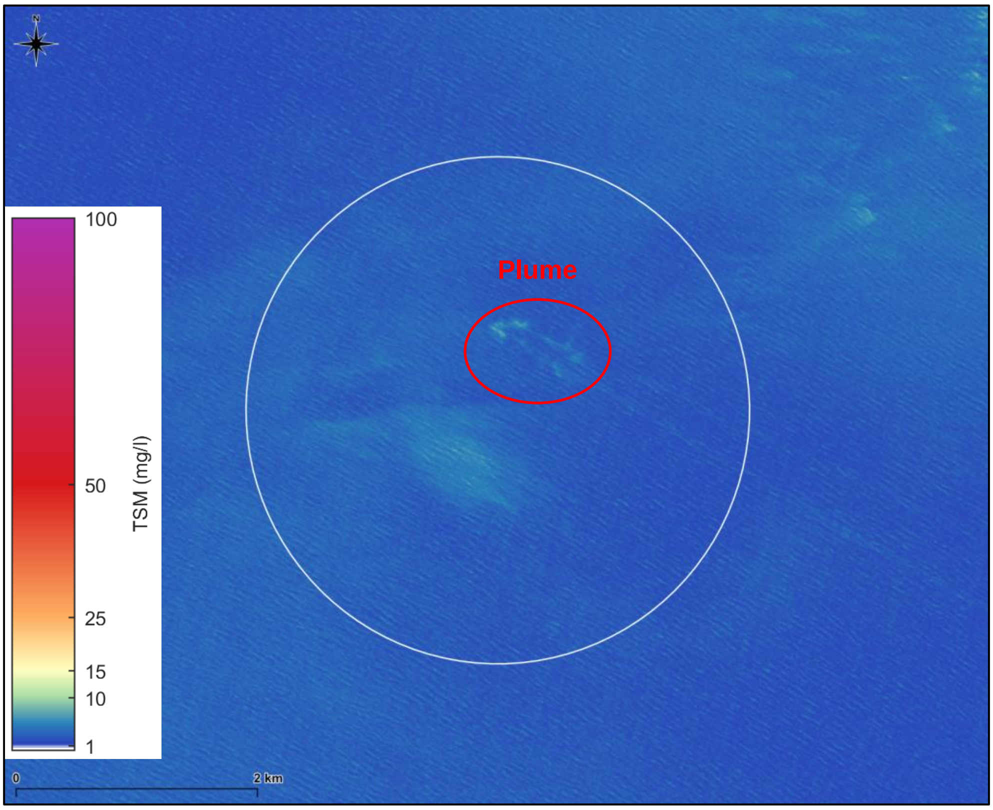


Figure 53. Satellite-derived TSM from the Sentinel-2 sensor showing the plume in the DMPA 40 minutes after placement by the TSHD Brisbane on 07/05/2022 at 10:57 AEST.

5. Summary

This report has analysed and interpreted turbidity data collected pre-, during and post the Port of Weipa 2022 maintenance dredging program. The 2022 maintenance dredging program was undertaken by the TSHD Brisbane and involved the relocation of 782,000 m^3 of sediment from the dredged areas of the Port to the Albatross Bay DMPA. Following the 2020 maintenance dredging program the DMPA was moved to the west, by the distance of its radius (1.1 nautical miles), to provide additional capacity for the future. The data showed that during the dredging program the turbidity around the Port of Weipa was generally driven by the natural conditions (predominantly the astronomical tide), with higher turbidity occurring during periods of larger range spring tides. The key findings from the turbidity data analysis are detailed below:

- the exceedance analysis of the in-situ measured benthic turbidity data shows that the duration exceedances were below the average duration exceedance at WQ1 and WQ2 while at WQ4 the exceedance duration was above the average duration exceedance, but below the 90th percentile duration exceedance. The results therefore show that the turbidity at WQ4 was still higher than the turbidity at the other sites relative to the updated turbidity intensity thresholds. Based on this it would be beneficial to undertake a further analysis and revisit updating the turbidity intensity thresholds, as all available evidence indicates that the reason for the increased exceedance at WQ4 was due to natural processes rather than the maintenance dredging program;
- as expected, the dredging and placement activities associated with the Port of Weipa 2022 maintenance dredging program were found to result in visible plumes. Plumes were observed close to the dredger when dredging, adjacent to the South Channel and within the Albatross Bay DMPA. The size and concentration of the plumes was variable;
  - the largest plume which was clearly due to the maintenance dredging and not natural processes was up to 4 km in length and 250 m in width with a concentration of up to 15 mg/l, occurring adjacent to the South Channel. Satellite imagery indicated that a plume was regularly present around the South Channel as this was where the majority of the maintenance dredging was undertaken; and
  - plumes in the DMPA from the placement of dredged sediment were typically less than 1 km in extent and only persisted for short durations (in the order of hours). The observed plumes were consistent with placement by the TSHD Brisbane during previous annual maintenance dredging programs prior to the Albatross Bay DMPA being moved.
- all of the plumes resulting from maintenance dredging (including those from both dredging and placement) were found to remain close to where they were created. This shows that little net residual transport occurs in the region, this was also noted during the 2019 to 2021 maintenance dredging programs and as part of the Port of Weipa Sustainable Sediment Management assessment (PCS, 2019b, 2020a, 2020b and 2021a). Based on this, it can be assumed that the majority of the sediment suspended by the maintenance dredging is subsequently redeposited close to where it was either dredged or placed;
- the Port of Weipa 2022 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to where dredging was undertaken in the Port and in the Albatross Bay DMPA. Natural variations in turbidity driven by the tide and wave conditions over the monitoring period were larger than the variations in turbidity due to the maintenance dredging. The satellite imagery showed that the turbidity in the area of the seagrass meadows in the Inner Harbour was predominantly controlled by natural processes over the 2022 maintenance dredging program, with no visible plumes from the dredging activity observed in the Inner Harbour; and
- the post dredging satellite imagery showed that residual plumes were still present around the South Channel 12 hours after the dredging had finished and a possible low

concentration plume was also present in the Albatross Bay DMPA which could have been due to the most recent placement (11 hours prior to the image being captured). The image captured five days after dredging ended did not show any indication of plumes from the dredging or placement activities. This is in agreement with findings from previous dredge programs (2020) where satellite imagery showed that the turbidity had returned to natural conditions within one to four days after the end of the dredging activity (PCS, 2020a).

6. References

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