PORT OF **WEIPA**

SUMMARY

2019 Turbidity Monitoring

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Port of Weipa, 2019 Maintenance Dredging

Summary of Turbidity Monitoring

Report No. P020_R2F1

NORTH QUEENSLAND BULK PORTS CORPORATION

Technical Report
September 2019

Port of Weipa, 2019 Maintenance Dredging

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North Queensland Bulk Ports Corporation Ltd

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North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions (PCS) to analyse turbidity data collected as part of the water quality monitoring undertaken for the Port of Weipa 2019 maintenance dredging program. The aims of this report are as follows:

- to analyse the turbidity and metocean conditions over the entire dredge program and the following 28 days post dredging;
- to assess the relative contribution of the maintenance dredging and placement activities on the natural turbidity at the measurement sites; and
- to better understand the spatial extent of any plumes resulting from the maintenance dredging and placement activities based on satellite-derived turbidity data.

PCS has analysed and interpreted turbidity data collected during the Port of Weipa 2019 maintenance dredging program and the results are presented in this report. The 2019 maintenance dredging program was undertaken by two dredgers and involved the relocation of 2.4 million m^3 of sediment in-situ from the dredged areas of the Port to the Albatross Bay Dredge Material Placement Area (DMPA). The data showed that during the 2019 maintenance dredging program the turbidity around the Port of Weipa was generally controlled by the natural conditions (tidal currents and wind/wave conditions), with higher turbidity occurring during spring tides (due to their stronger tidal currents) and periods with larger waves. The key findings from the turbidity data analysis undertaken are as follows:

- the benthic and surface turbidity data were found to show similar patterns (with the exception of WQ4, where the benthic turbidity data was erroneous), albeit with higher peaks in the benthic turbidity. The duration of time that the benthic and surface turbidity intensity thresholds were exceeded were similar. The surface turbidity thresholds calculated by PCS (2019c) can therefore suitably be considered along with surface turbidity measurements to estimate the duration of time the benthic turbidity thresholds are exceeded;
- the dredging and placement activities associated with the 2019 maintenance dredging program have been found to result in clearly visible plumes with slightly increased turbidity which can extend along much of the length of the South Channel and cover the majority of the Albatross Bay DMPA area. The plumes generally remained close to where they were generated showing that little residual transport occurs in the region, as was previously suggested by PCS (2018). It can therefore 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 maintenance dredging was found to have the potential to result in increases in the natural short-duration peaks in turbidity which occur at certain stages of the tide. These increases resulted in the turbidity thresholds being exceeded more regularly than would naturally have been expected. However, based on the natural variability in turbidity in the region (the wet season 95th percentile at WQ2 and WQ4 is approximately 10 times higher than during the dry season (PCS, 2019b)), these short-duration increases in turbidity are unlikely to impact the natural environment;
- the data showed that following completion of the 2019 maintenance dredging program, the turbidity quickly (within days) returned to natural conditions with no remaining areas with elevated turbidity due to the maintenance dredging and placement activities; and
- the Port of Weipa 2019 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to the dredged areas of the Port and the Albatross Bay DMPA.

1. Introduction

North Queensland Bulk Ports Corporation (NQBP) commissioned Port and Coastal Solutions (PCS) to analyse turbidity data collected as part of the water quality monitoring undertaken for the Port of Weipa 2019 maintenance dredging program. The aims of this report are as follows:

- to analyse the turbidity and metocean conditions over the entire dredge program and the following 28 days post dredging;
- to assess the relative contribution of the maintenance dredging and placement activities on the turbidity at the measurement sites; and
- to better understand the spatial extent of any plumes resulting from the maintenance dredging and placement activities based on satellite-derived turbidity data.

Three previous technical notes have been prepared to provide updates on the turbidity monitoring for the 2019 maintenance dredging program (PCS, 2019a, 2019b, 2019c). This report provides a final summary of all the turbidity data collected as part of the Port of Weipa 2019 maintenance dredging program.

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 2016/17 financial year, the Port of Weipa handled approximately 36 million tonnes of commodities, including bauxite (>95%), 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 has been undertaken annually by the *Trailing Suction Hopper Dredge* (*TSHD*) *Brisbane*, with volumes ranging from approximately 300,000 m^3 to 980,000 m^3 (although the 980,000 m^3 dredged in 2002 was because dredging had not been undertaken in 2001). The sediment, which has historically been removed by maintenance dredging, has been relocated to the offshore DMPA located in Albatross Bay (Figure 1).

Investigations undertaken as part of the Port of Weipa Sustainable Sediment Management (SSM) Project found that very high rates of sedimentation occurred at the Port of Weipa during the 2018/2019 wet season with more than 2 million cubic metres (Mm^3) of sediment deposited in the South Channel. This is approximately three times higher than the previous highest annual sedimentation volume. The very high sedimentation was found to be a result of multiple large wave events occurring over the wet season, which included two tropical cyclones and a prolonged tropical low (PCS, 2019d). As a result of the high levels of accretion within the area, the 2019 annual maintenance dredging program for the Port of

Weipa was calculated to require the removal of a larger volume of sediment than any previous annual programs, with approximately 2.5 Mm^3 planned.

Due to the large volume of sediment which was required to be relocated as part of the 2019 maintenance dredging program, it was necessary for a second dredge vessel to assist the *TSHD Brisbane* to ensure the dredging could be completed in a single dredge program in 2019. In addition to the *TSHD Brisbane,* the larger *TSHD Oranje* (hopper capacity of 16,000 m^3 compared to the *TSHD Brisbane* hopper capacity of 2,900 m^3) was also commissioned to undertake the maintenance dredging.

The 2019 maintenance dredging program commenced on the 4th June 2019, with the *TSHD Oranje* starting the dredging in the South Channel. On the 13th June 2019 the *TSHD Brisbane* commenced dredging, with both dredgers working concurrently from this time until the 6th July 2019, when the *TSHD Oranje* completed its component of the dredging. The *TSHD Brisbane* continued to undertake maintenance dredging until the 13th July 2019 when it completed the 2019 maintenance dredging program. The final in-situ volume of sediment removed from the South Channel and Inner Harbour regions of the Port of Weipa was calculated by Maritime Safety Queensland to be in the region of 2.4 Mm^3, with approximately 95% of this being from the South Channel. The *TSHD Oranje* was responsible for relocating approximately 80% of the sediment which was dredged, while the *TSHD Brisbane* relocated the remaining 20%.

1.2. Report Structure

The report herein is set out as follows:

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

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.

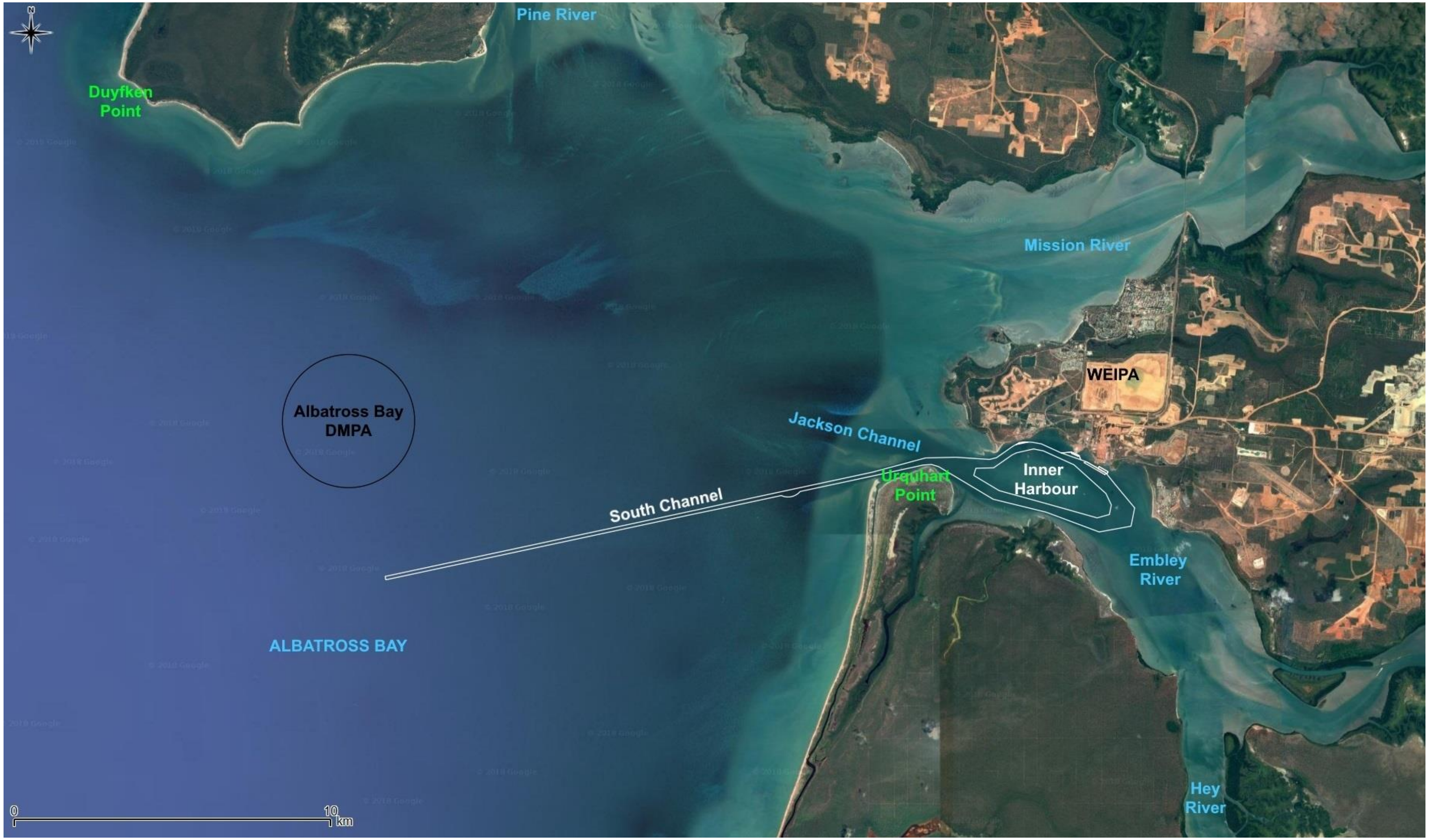


Figure 1. Layout of the Port of Weipa.

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

2. 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 a number of monitoring sites around the Port of Weipa. 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).

Surface turbidity data were collected by Vision Environment (VE) pre, during and post the 2019 maintenance dredging program at the same locations as the three existing benthic monitoring sites (WQ1, WQ2 and WQ4). These surface turbidity loggers were telemetered so that the data were available in real-time to allow NQBP to monitor the turbidity via an online dashboard throughout the maintenance dredging program.

Details of the benthic and surface turbidity data available for this assessment are provided in Table 1. Benthic turbidity data have been, and continue to be, collected by JCU at three sites around the Port of Weipa as part of the ongoing ambient water quality monitoring. The surface turbidity data were collected as part of the 2019 maintenance dredging program by VE with the data collection ending on the 13th August 2019, 31 days after the end of the dredging program.

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

Location	Approx. Depth (m MSL)	Benthic (JCU) Data Period	Surface (VE) Data Period
WQ1	5 m	19/01/18 to 13/08/19	24/05/19 to 13/08/19
WQ2	4 m	16/03/18 to 13/08/19	24/05/19 to 13/08/19
WQ4	4 m	19/01/18 to 13/08/19	24/05/19 to 13/08/19

2.1. Previous Analysis

Benthic turbidity data from the ongoing ambient monitoring were analysed by PCS (2019a) to understand the natural variability in turbidity at the three monitoring sites. Based on the analysis, the 95th percentile turbidity for the dry season period was selected as a representative benthic turbidity threshold for the 2019 maintenance dredging program (Table 2). The first three weeks of surface turbidity data collected as part of the 2019 maintenance dredging program (approximately two weeks pre-dredging and one week during dredging) were compared with the benthic turbidity data over the same period to allow representative surface turbidity thresholds to be adopted (Table 2) (PCS, 2019b). The surface turbidity thresholds at WQ1 and WQ2 were found to be approximately 50% of the benthic turbidity threshold. Over the 2019 maintenance dredging program the benthic turbidity data at WQ4 were found to consistently be unrealistically high. As a result it was not possible to define the surface turbidity threshold in the same way as at WQ1 and WQ2. Instead, the surface turbidity threshold at WQ4 was defined so that the duration of time the surface turbidity threshold was exceeded was comparable to the durations at WQ1 and WQ2 which ranged from 83 to 92 hours. Based on this a surface turbidity threshold of 10.2 NTU was defined at WQ4 as this resulted in a duration of exceedance of 87 hours.

Table 2. Benthic and surface dry season turbidity thresholds derived by PCS (2019a, 2019b).

Location	Benthic Turbidity Threshold (NTU)	Surface Turbidity Threshold (NTU)
WQ1	20.6	11.1
WQ2	25.3	13.2
WQ4	28.2	10.2

Figure 3. Location of the Port of Weipa ambient monitoring sites (WQ1, WQ2, WQ4 & WQ5), Albatross Bay waverider buoy (WRB) and South Channel markers (SC2 to SC24).

3. Data Analysis

This section provides an analysis of the turbidity data collected as part of the 2019 maintenance dredge program monitoring and a quantification of the duration of time that the turbidity intensity thresholds were exceeded.

3.1. Turbidity Analysis

The measured surface turbidity data at the three monitoring sites, along with the predicted water level for the Port of Weipa (calculated by the Bureau of Meteorology (BoM)), measured wind conditions at Weipa Airport (from BoM) and the wave conditions in Albatross Bay (from the Department of Environment and Science (DES) waverider buoy (WRB) in Albatross Bay) are shown in Figure 4[1]. The figure shows that there is generally a tidal signal within the turbidity data at the three monitoring sites, with increased turbidity correlating with the larger tidal range over the spring tides. The turbidity at WQ2 is also influenced by the wave conditions, with peaks in turbidity of more than 30 NTU corresponding to periods when the significant wave height (H_s) exceeded 0.75 m. The turbidity data at the three sites show similar patterns with increased turbidity during spring tides and reduced turbidity during neap tides.

At WQ1 and WQ2 the benthic and surface turbidity data are similar, with corresponding peaks occurring, but with the intensity of the peaks being higher in the benthic data (Figure 5 and Figure 6). However, at WQ4 although the benthic and surface turbidity data typically experience peaks in turbidity at the same time, the relative magnitude of the peaks are not comparable (Figure 7 and Figure 8). The surface turbidity data at WQ4 show a tidal signal similar to the other two sites, with higher turbidity occurring during the larger spring tides. In contrast, the data at WQ4 has regular very high peaks in benthic turbidity (>500 NTU) occurring from the 30th May 2019 onwards, which do not correlate with the turbidity at the other sites, the metocean conditions (except for the peaks in turbidity occurring around high water and there being a slight reduction in turbidity around neap tides) or the 2019 maintenance dredging program. The peaks in turbidity at WQ4 reach close to 3,000 NTU (Figure 8), which based on the turbidity at the other two sites (peaks generally less than 100 NTU) and previous data at WQ4 during comparable conditions, suggests that over this period there has been a very localised process (e.g. seagrass blocking the turbidity sensor during certain stages of the tide resulting in artificially high turbidity values) which has influenced the near-bed turbidity at WQ4[2].

Based on the benthic and surface turbidity data at WQ1 it appears that the turbidity both during the 2019 maintenance dredging program and over the 28 day period post dredging was predominantly controlled by the metocean conditions. The turbidity data at WQ2 also appears to be predominantly controlled by the metocean conditions, although the magnitude of some of the peaks in both the benthic and surface turbidity do not directly correspond to the metocean conditions during the dredging program which indicates that the maintenance dredging activity could be increasing the magnitude of the peak turbidity. Based on the surface turbidity data at WQ4 it appears that the turbidity during the dredge program and post-dredging was predominantly controlled by the metocean conditions.

[1] Rainfall data are not shown as there was very little rainfall over the period.

[2] The location of WQ4 was moved approximately 350 m to the south-east at the start of May and so the data collected at this position might differ to the previous WQ4 data (i.e. if seagrass are present) and the data used to determine the benthic turbidity threshold.

Figure 4. Predicted water level (top), measured wind (middle top), measured wave (middle bottom) and measured surface turbidity at the three Port of Weipa monitoring sites (bottom).

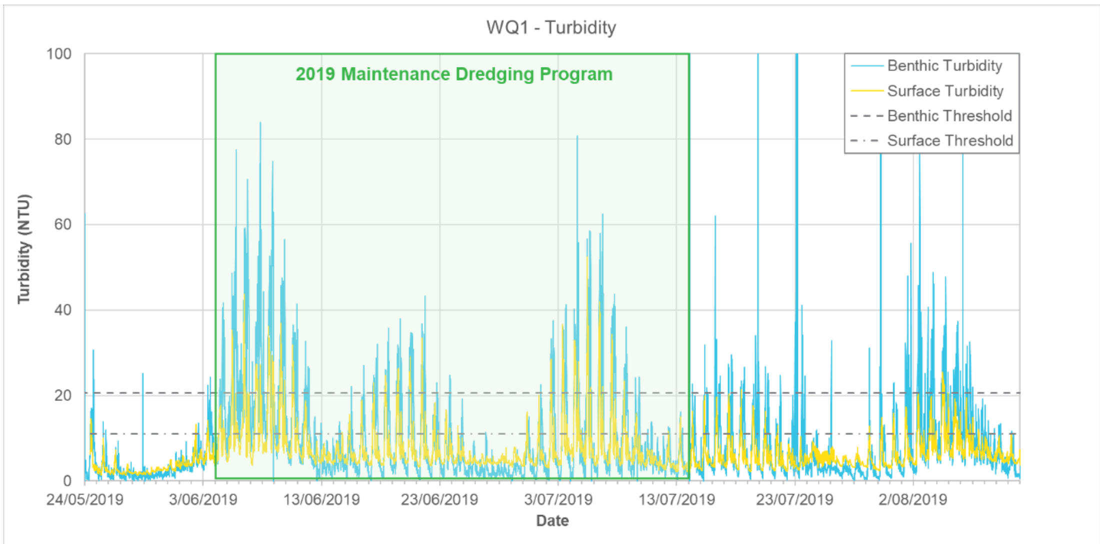


Figure 5. Measured benthic and surface turbidity at WQ1 and corresponding turbidity intensity thresholds.

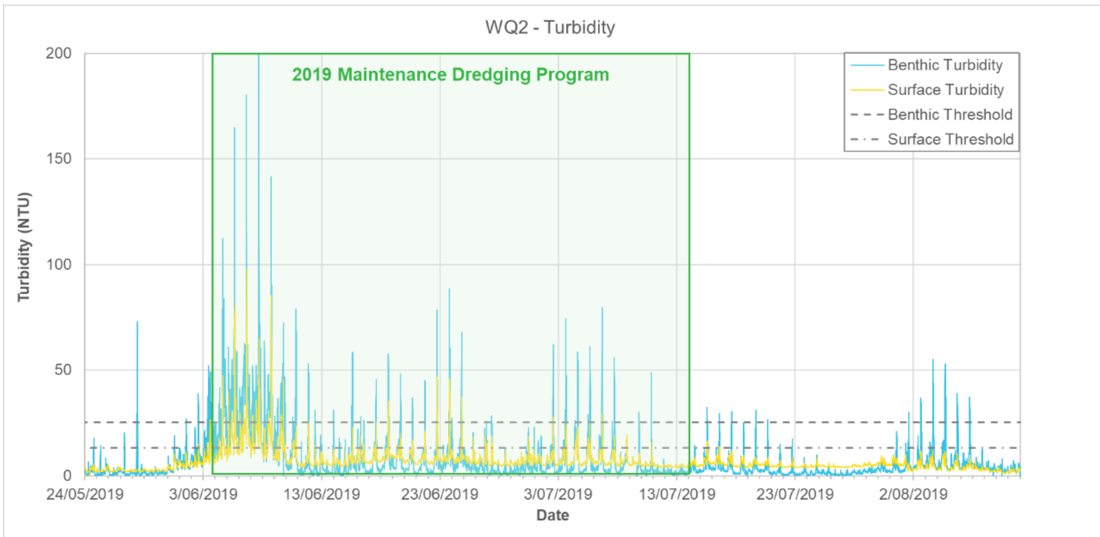


Figure 6. Measured benthic and surface turbidity at WQ2 and corresponding turbidity intensity thresholds. Note: the peak in benthic turbidity on 07/06/2019 was 460 NTU.

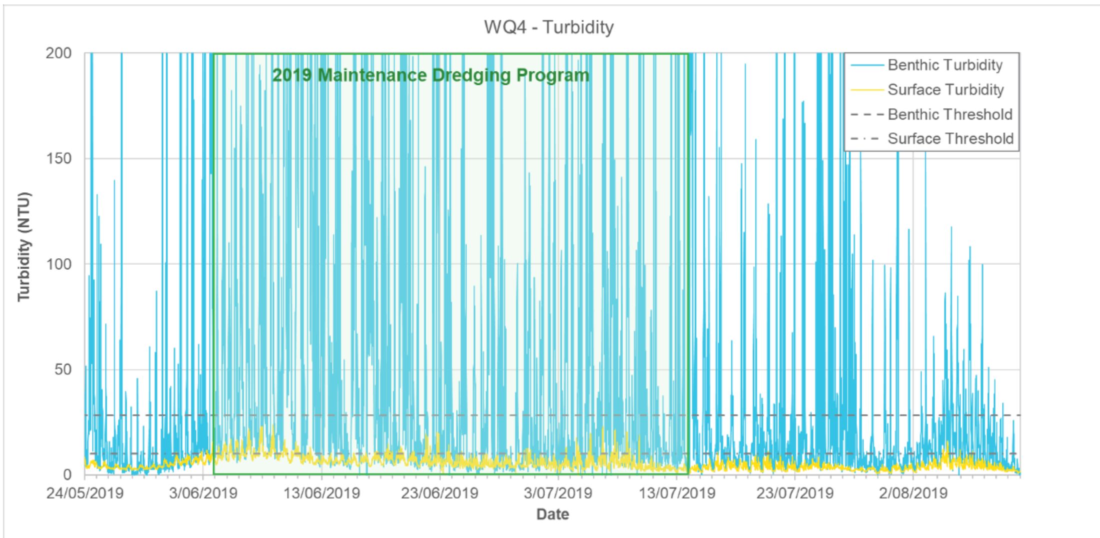


Figure 7. Measured benthic and surface turbidity at WQ4 and corresponding turbidity intensity thresholds.

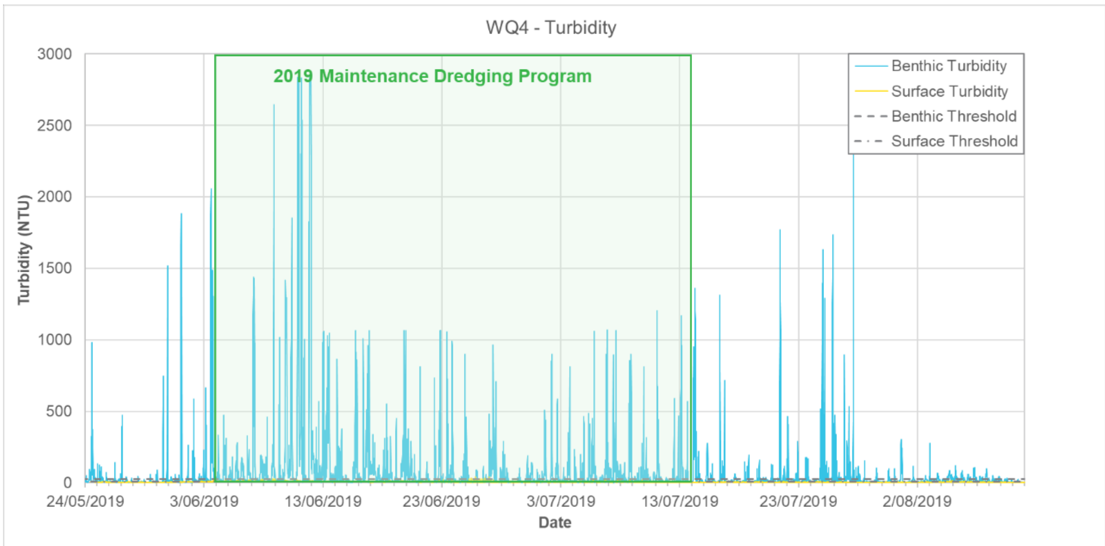


Figure 8. Measured benthic and surface turbidity at WQ4 showing the full intensity of the benthic turbidity.

As noted in Section 1.1, during the 2019 maintenance dredging program the *TSHD Oranje* and *TSHD Brisbane* were predominantly dredging the South Channel. More than 75% of the dredging in the South Channel occurred between markers SC8 and SC16 (see Figure 3 for channel marker locations). Over the duration of the dredge program the *TSHD Brisbane* and *TSHD Oranje* also removed 116,000 m^3 of sediment from the Inner Harbour area, with approximately two thirds of this being from the Departure Channel and the remainder from the Approach Channel (and a small volume from the berths). Although the turbidity data at WQ2 show that it was predominantly influenced by the tide and wave conditions, the data suggest that some of the short-duration peaks in turbidity which occurred each tide could have been increased by the maintenance dredging in the South Channel. Figure 9 shows that the peaks in turbidity correspond with the start of the flood tide. As the majority of the maintenance dredging activity occurred to the west of WQ2 (which is located mid-way between SC14 and SC16), any increases in turbidity due to the maintenance dredging would be expected to occur during the flooding tide when the tidal currents were in an eastward direction. This further indicates that the natural peaks in turbidity which occur during large spring tides and certain wind/wave conditions, are likely to have been increased during the

2019 maintenance dredging program due to suspended sediment released from the dredging activity in the South Channel.

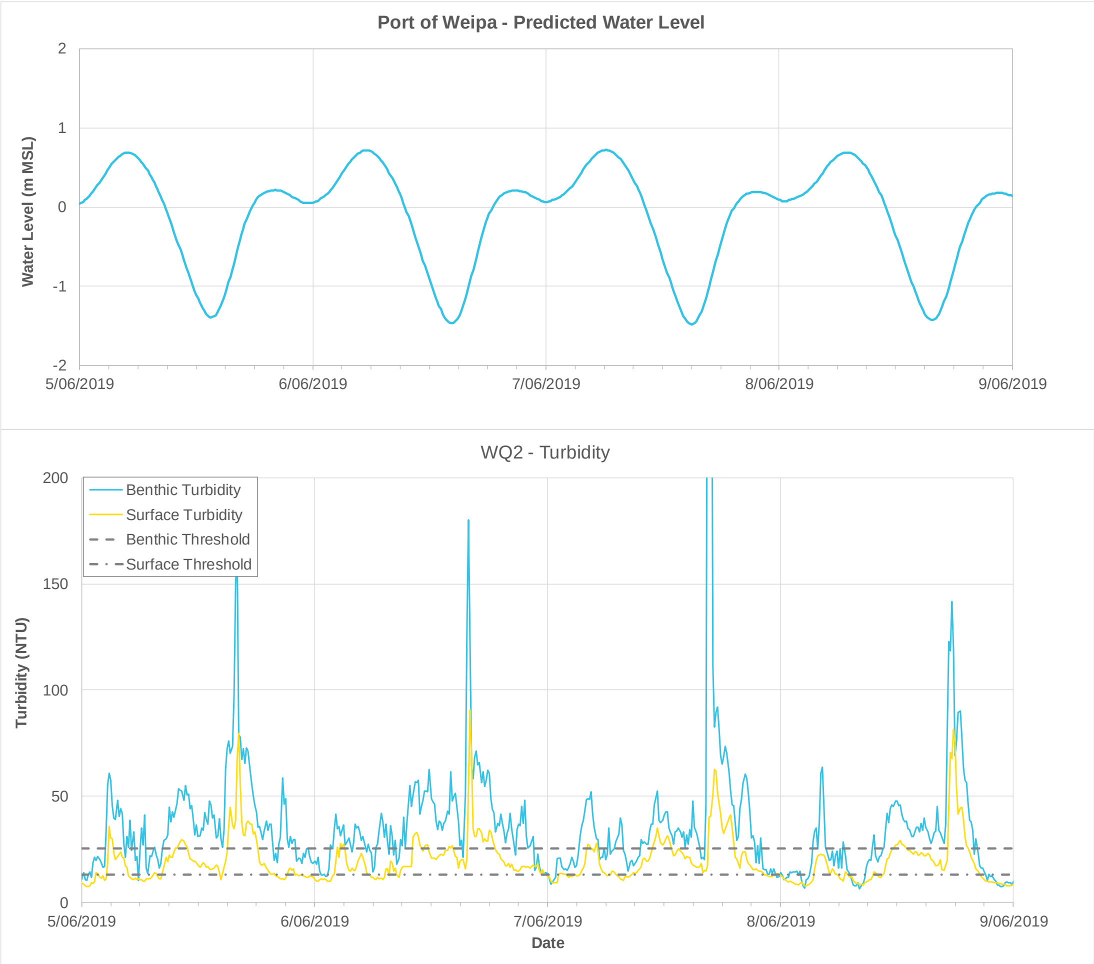


Figure 9. Predicted water level (top) and measured benthic and surface turbidity at WQ2 and corresponding turbidity intensity thresholds (bottom). Note: the peak in benthic turbidity on 07/06/2019 was 460 NTU.

3.2. Exceedance

The duration of time that the benthic and surface turbidity intensity thresholds were exceeded at the three monitoring sites was calculated during the 2019 maintenance dredging program and over the 28 days post dredging (Table 3). The results show that the benthic and surface duration exceedances are similar at WQ1 and WQ2. At WQ4 there are significant differences, but this is mainly due to the benthic data being erroneous over the whole period. The agreement at WQ1 and WQ2 demonstrates that the surface turbidity thresholds which were determined by PCS (2019c) can be applied to provide a realistic representation of the duration of time that the benthic turbidity thresholds were exceeded.

The benthic turbidity thresholds[3] were defined using the 95th percentile of the data measured during the dry season in 2018. As a result, the thresholds would typically be expected to be exceeded for 5% of time, which over the 40 day dredge program would equal 48 hours and over the 28 day post dredging period would equal 34 hours. The duration that the benthic and surface thresholds were exceeded is quantified in Table 3. The duration of exceedance

[3] the surface turbidity thresholds were calculated to result in a comparable duration exceedance as the benthic thresholds and therefore these can also be considered to be representative of the 95th percentile turbidity.

over the dredging program was between two and four times more than the average exceedance hours for the dry season (excluding the benthic data at WQ4 which are not considered to be realistic). As the metocean conditions over the period were relatively typical for the dry season, this provides further evidence to suggest that the maintenance dredging activity resulted in increased turbidity at all three sites.

Table 3. Exceedance of the benthic and surface turbidity intensity thresholds during and post the 2019 maintenance dredging program.

Location	Benthic Duration Exceeded (hrs)		Surface Duration Exceeded (hrs)	
	Dredging	Post-Dredging	Dredging	Post-Dredging
WQ1	169	63	172	61
WQ2	110	9	124	1
WQ4	466[1]	159[1]	135	3

[1] the benthic turbidity data at WQ4 is considered unreliable and as such the duration exceedances of 466 and 159 hours are not considered to be an accurate representation of the turbidity in this region. It is expected that the duration exceedance at WQ4 should be comparable to the duration exceedance at WQ1.

3.3. Satellite-Derived Data

To better understand the spatial extent of both the natural turbidity in the Weipa region and any plumes resulting from the maintenance dredging activity and the placement of dredged sediment at the Albatross Bay DMPA, real-time satellite-derived turbidity data were obtained pre-, during and post the 2019 maintenance dredging program. A combination of regional scale low-resolution (300 m) and local port scale high-resolution (10 to 30 m) satellite-derived turbidity data were obtained from EOMAP.

The regional scale low-resolution satellite-derived turbidity data can be used to better understand the spatial variability in turbidity at a regional scale and assess whether the maintenance dredging is having an influence at that scale. Plots of the regional scale satellite-derived turbidity are shown for the pre-dredge period in Figure 10 and Figure 11, for the dredging period in Figure 12 to Figure 16 and for the post-dredge period in Figure 17 and Figure 18. Analysis of the plots shows the following:

- during the wet season there is the potential for much higher natural widespread turbidity compared to the dry season. The largest wave events can occur during the wet season and these have the potential to result in elevated turbidity over the entire Weipa region (see Figure 10);
- higher turbidity often occurs around the entrances to the major rivers in the region. Generally, when there is higher turbidity around the rivers in Albatross Bay, there is also higher turbidity around the entrance to the Archer River, which is located south of Albatross Bay adjacent to Aurukun. This indicates that the increased turbidity is due to natural processes (e.g. increased tidal currents during spring tides) as opposed to local dredging influences around the Port of Weipa; and
- there is often elevated turbidity adjacent to the shoreline and within Albatross Bay, this pattern can be seen to occur pre-, during and post-dredging. Therefore, this regional scale elevated turbidity within Albatross Bay is not due to the 2019 maintenance dredging program at the Port of Weipa.

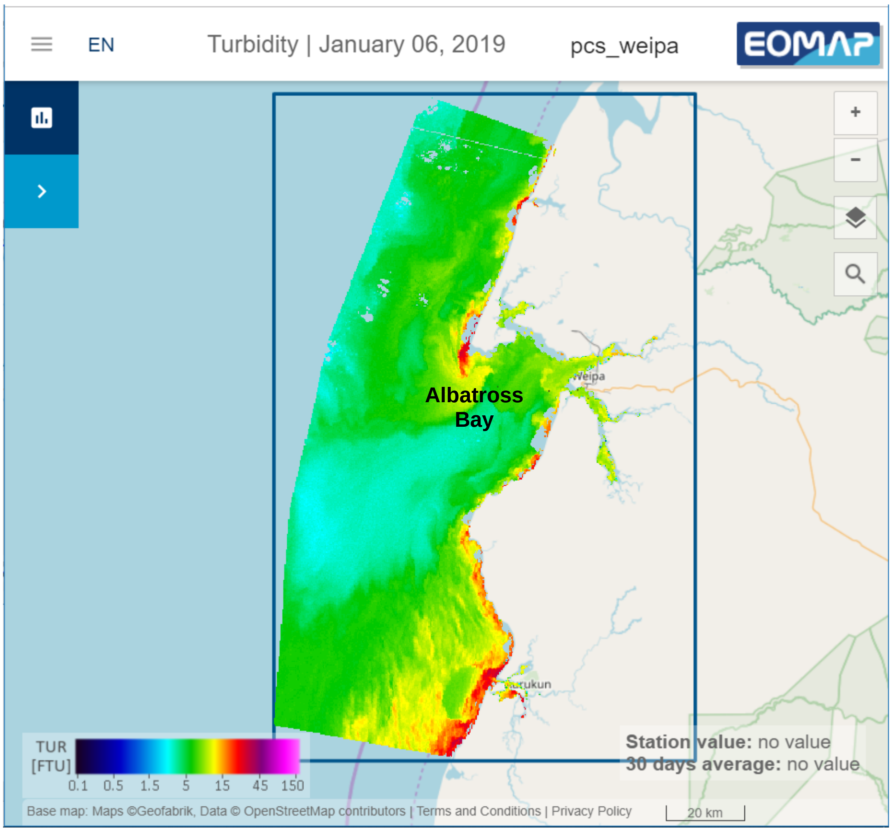


Figure 10. Regional scale satellite-derived turbidity for the Weipa region following a wave event during the wet season.

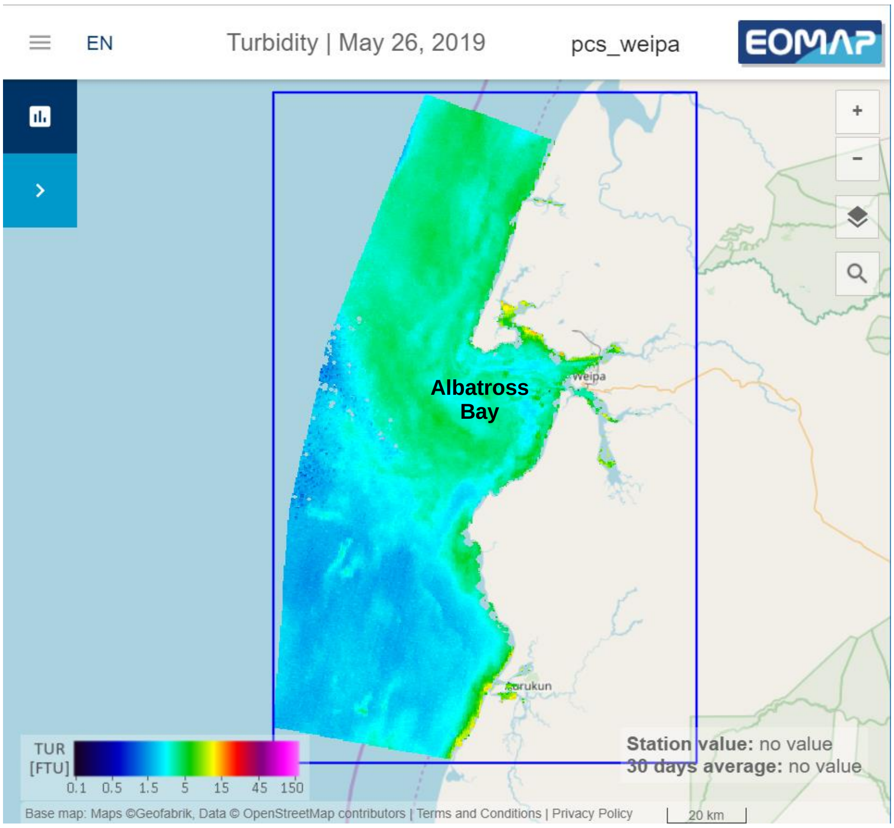


Figure 11. Regional scale satellite-derived turbidity for the Weipa region 9 days pre-dredging.

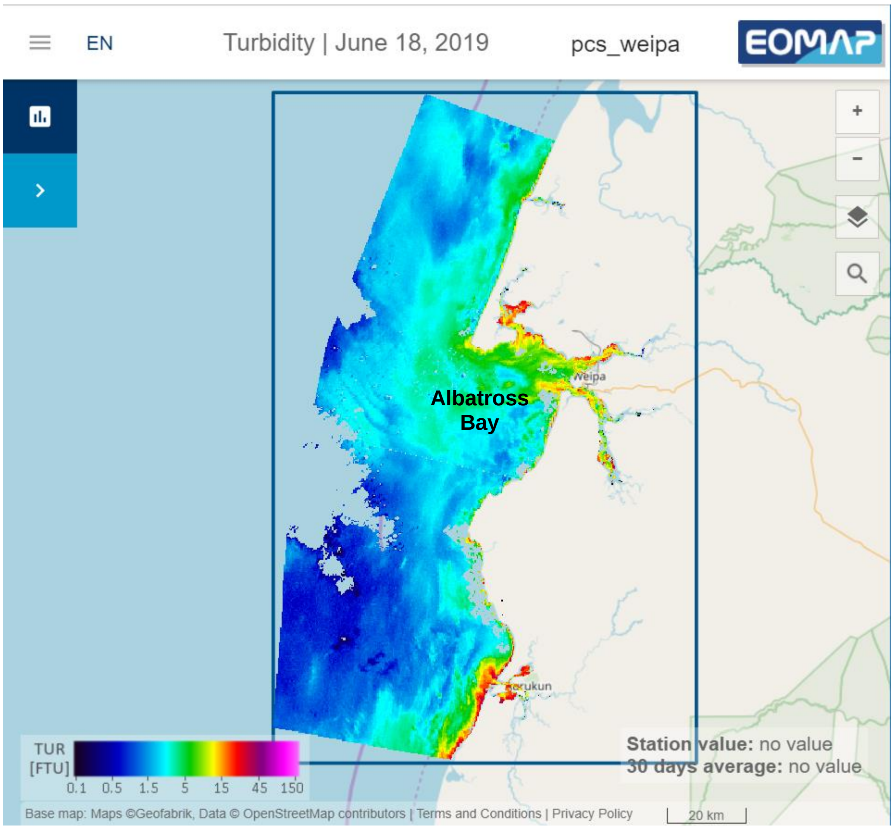


Figure 12. Regional scale satellite-derived turbidity for the Weipa region two weeks into dredging.

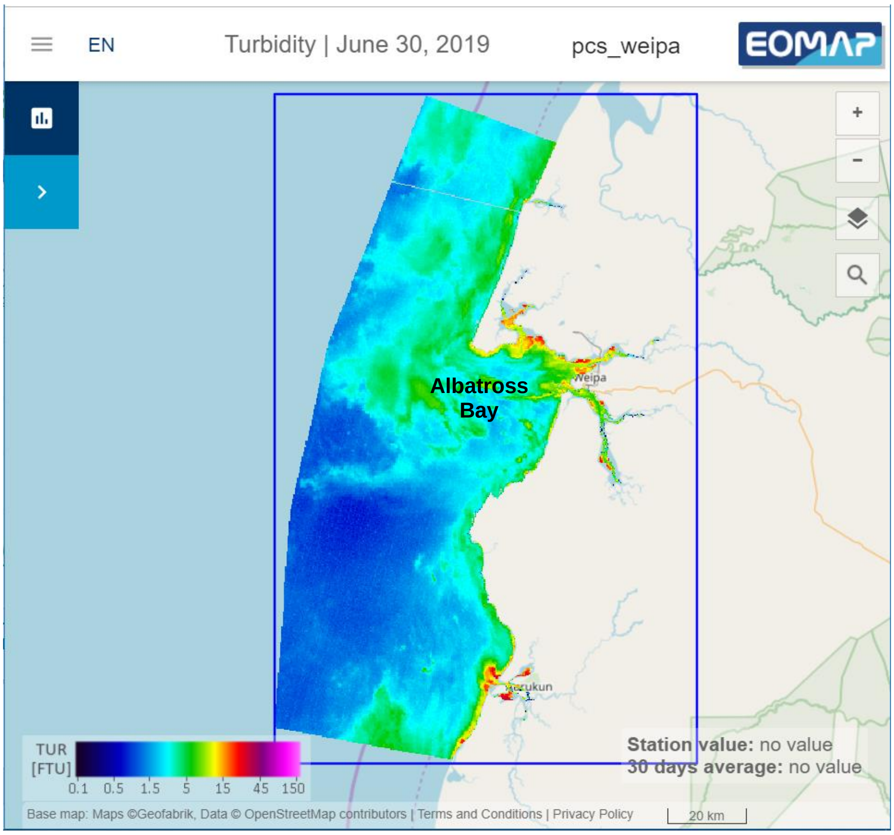


Figure 13. Regional scale satellite-derived turbidity for the Weipa region 3.5 weeks into dredging.

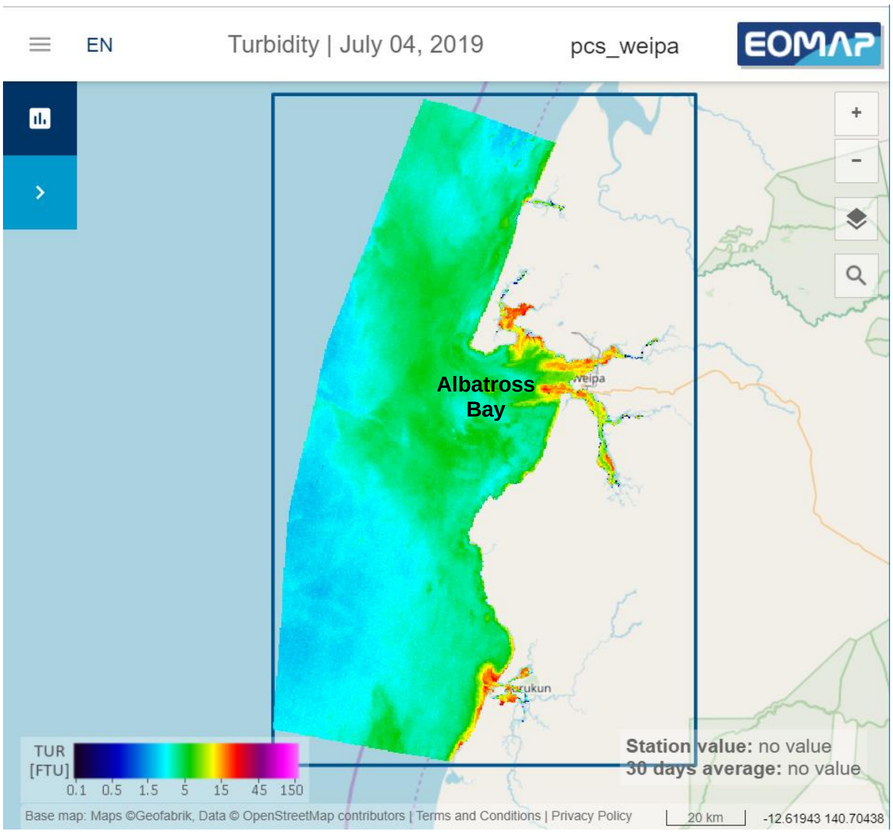


Figure 14. Regional scale satellite-derived turbidity for the Weipa region 4.5 weeks into dredging.

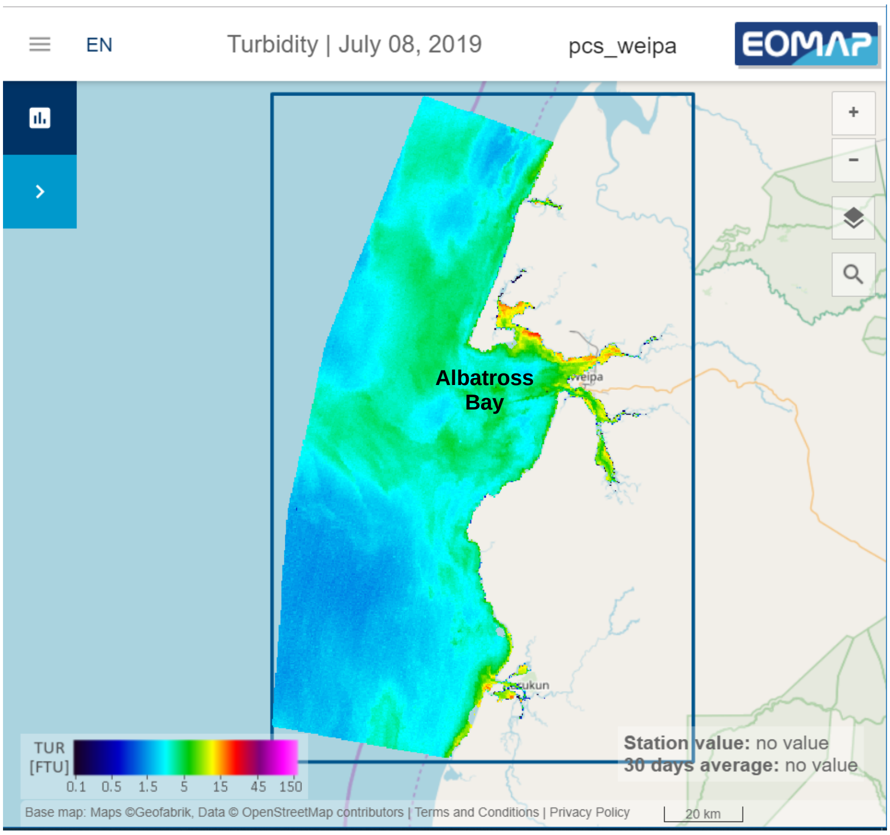


Figure 15. Regional scale satellite-derived turbidity for the Weipa region 5 weeks into dredging.

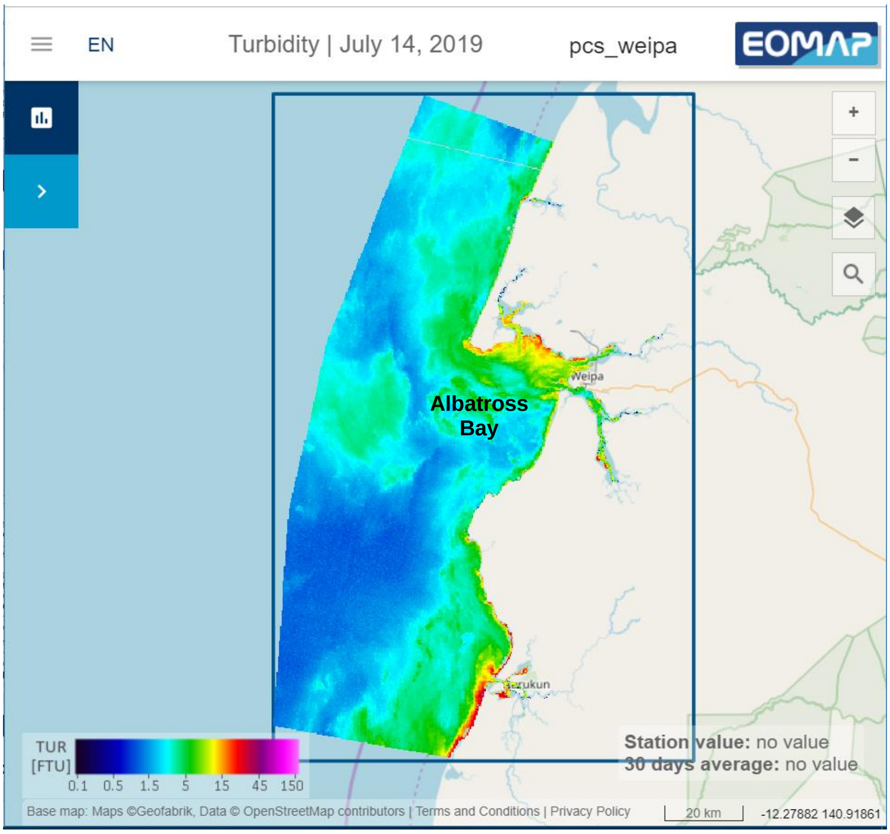


Figure 16. Regional scale satellite-derived turbidity for the Weipa region at the end of the dredging.

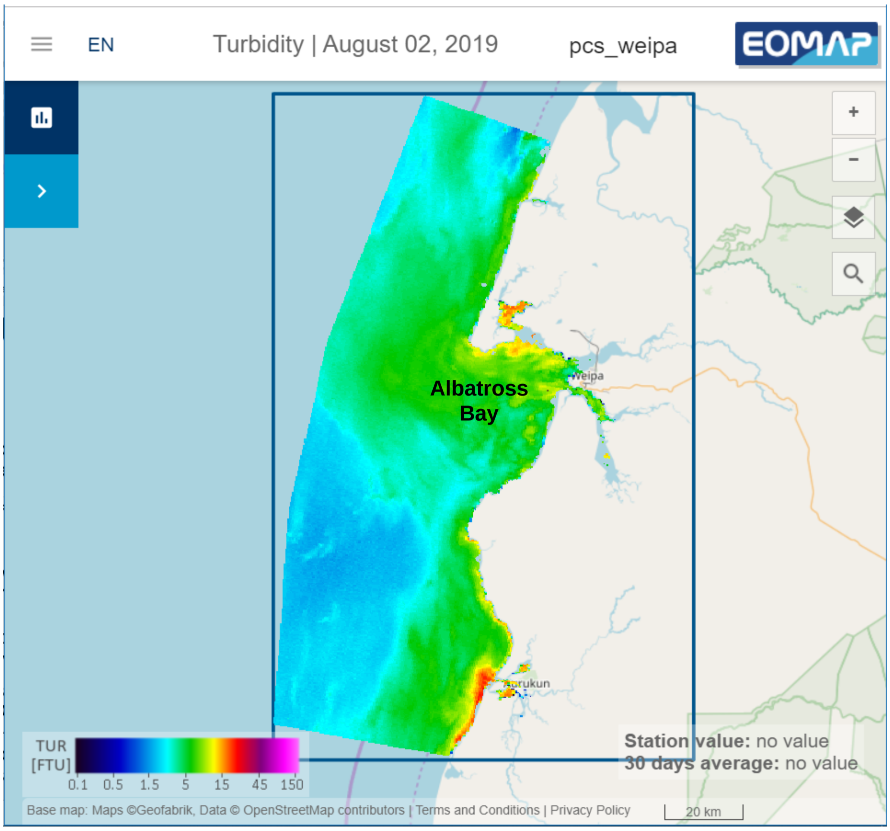


Figure 17. Regional scale satellite-derived turbidity for the Weipa region 2.5 weeks post dredging.

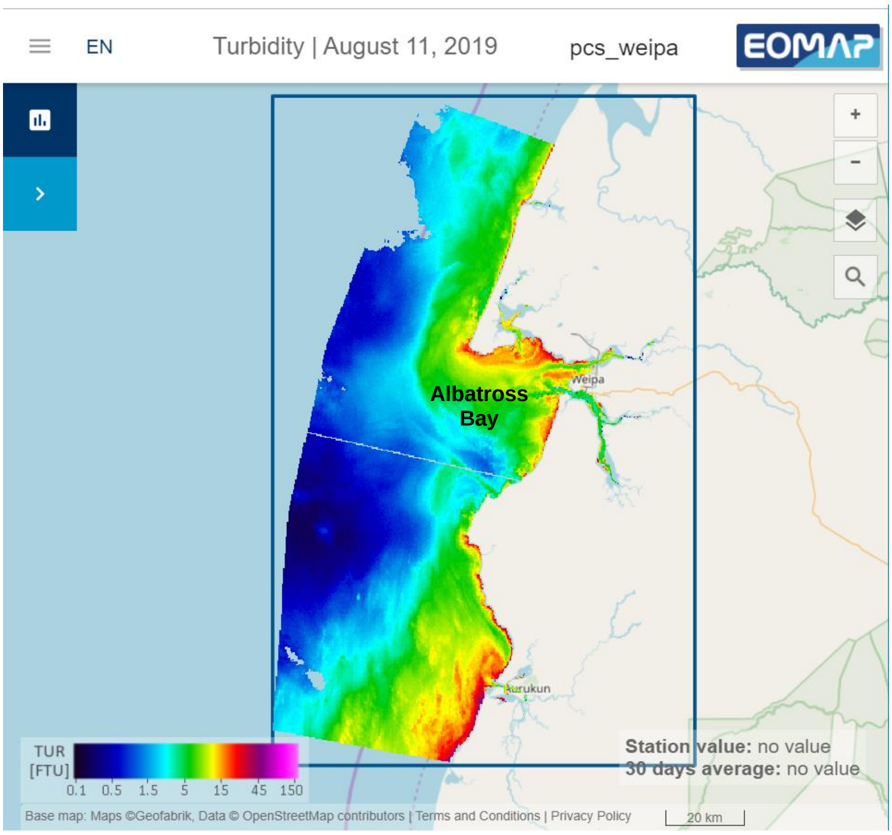


Figure 18. Regional scale satellite-derived turbidity for the Weipa region 4 weeks post dredging.

To better understand the spatial extent of plumes resulting from the maintenance dredging activity and the placement of dredged sediment at the Albatross Bay DMPA, the high-resolution satellite-derived turbidity data were analysed. Plots of the local scale satellite-derived turbidity are shown for the pre-dredge period in Figure 19 and Figure 20, for the dredging period in Figure 21 to Figure 27 and for the post-dredge period in Figure 28 and Figure 29. The local scale satellite data show the following:

- the natural turbidity patterns in Albatross Bay are spatially variable, with the potential for localised areas of elevated turbidity in the region of the South Channel and DMPA;
- the maintenance dredging activity in the South Channel by the *TSHD Oranje* and *TSHD Brisbane* resulted in visible plumes which at times extended to the WQ2 monitoring site. The higher concentration plumes (>15 FTU[4]) remained within the South Channel, while lower concentration plumes extended slightly beyond the South Channel (but still remained close to it). The plumes remained visible for multiple dredge cycles showing that some of the suspended sediment was taking several hours to settle out;
- the placement of dredged sediment at the Albatross Bay DMPA resulted in localised increases in turbidity, with the *TSHD Oranje* resulting in higher turbidity and larger spatial area increases relative to the *TSHD Brisbane* due to the larger capacity of the hopper (16,000 m^3 hopper capacity compared to 2,900 m^3). The satellite-derived turbidity data show that elevated turbidity was present at the Albatross Bay DMPA throughout much of the 2019 dredging program, but the plumes remained within or close to the DMPA suggesting that the majority of sediment placed at the site was retained;

[4] FTU stands for Formazin Turbidity Unit which is based on the measurement of light scattered within a 90° angle from a beam directed at the water. This is generally comparable to the Nephelometric Turbidity Unit (NTU) measured by in-situ loggers although it is important to note that the satellite-derived FTU and in-situ NTU may differ due to a number of reasons including the wavelength used.

- the clearly distinguishable higher concentration plumes resulting from the maintenance dredging activity in the South Channel were not clearly visible in the Inner Harbour region of the Port. However, it is possible that lower concentration plumes due to the dredging activity could have been transported into the Inner Harbour, but that these were not clearly visible in the satellite data;
- both the TSHD dredgers, as well as bulk carriers, have the potential to result in the resuspension of bed sediment due to their propeller wash when sailing along the South Channel, over the areas adjacent to the South Channel (to and from the DMPA and to the west of the South Channel) and through the approach channel in the Inner Harbour. This suggests that there is a layer of loosely consolidated fine-grained sediment present throughout the region which can easily be resuspended by increased near-bed currents (such as those caused by the propeller wash of a relatively large vessel); and
- following completion of the 2019 maintenance dredging program, the turbidity quickly (within days) returned to natural conditions with no remaining areas with elevated turbidity due to the maintenance dredging program.

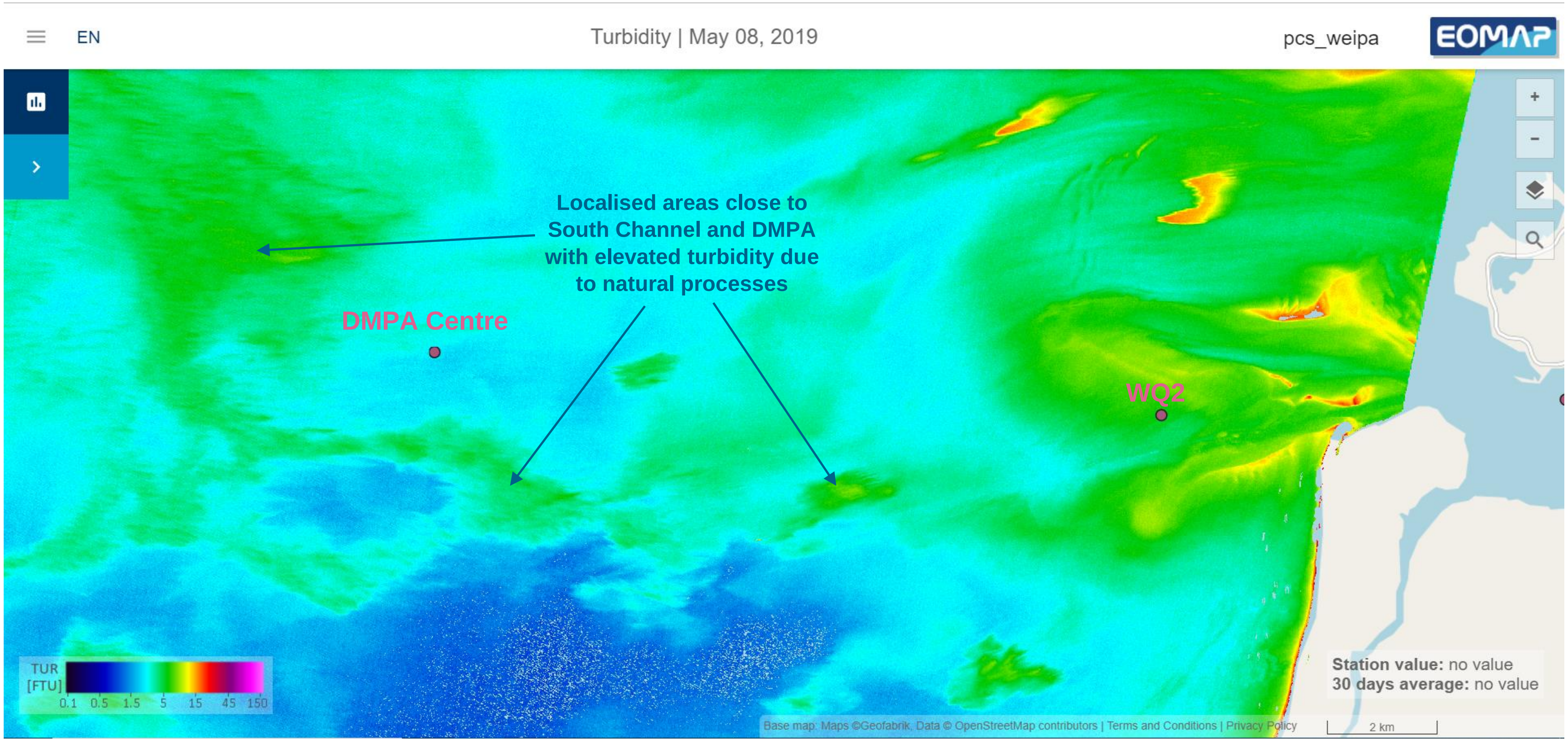


Figure 19. Satellite-derived turbidity of the South Channel and DMPA areas showing natural turbidity four weeks before the 2019 maintenance dredging program.

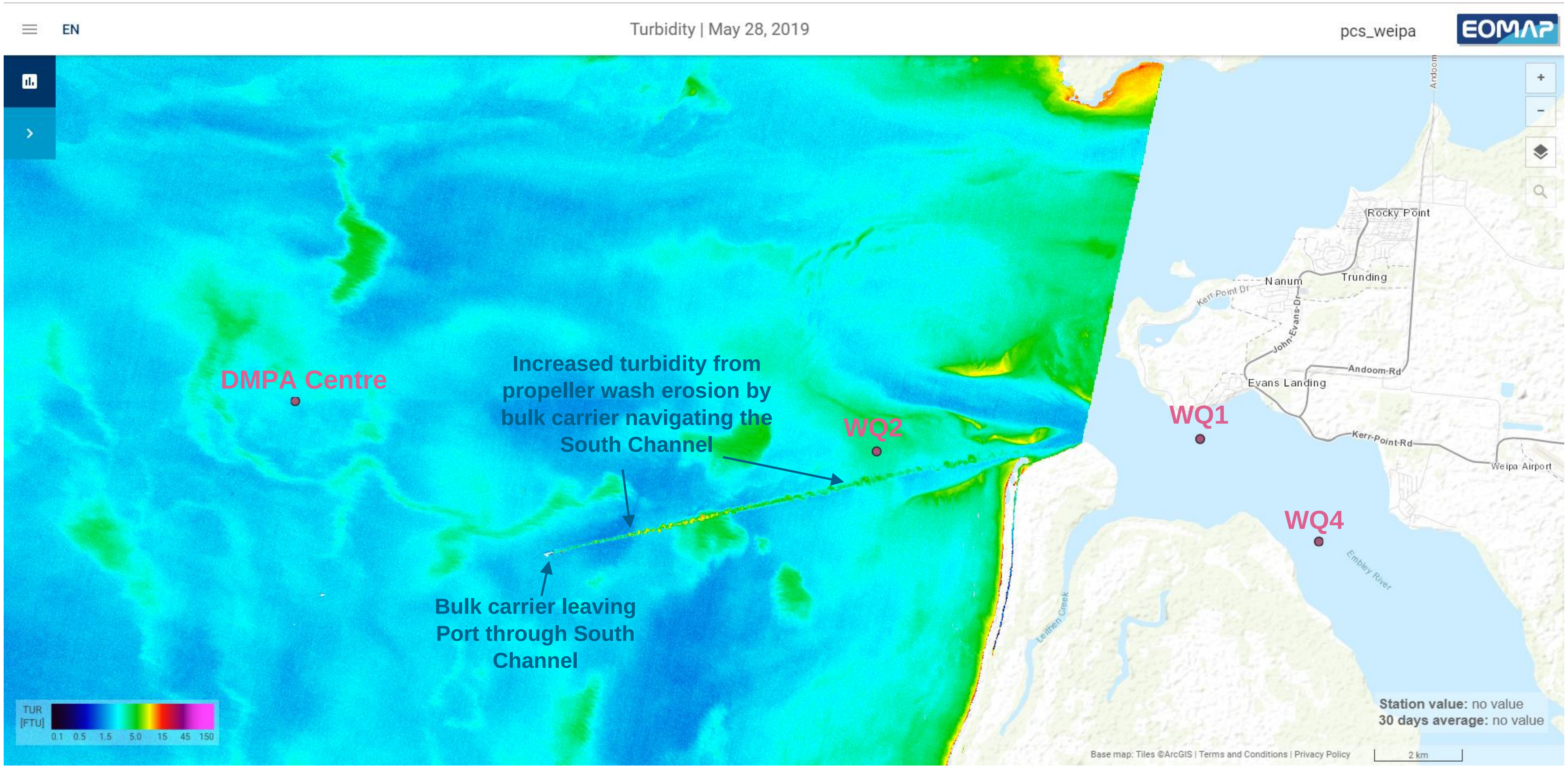
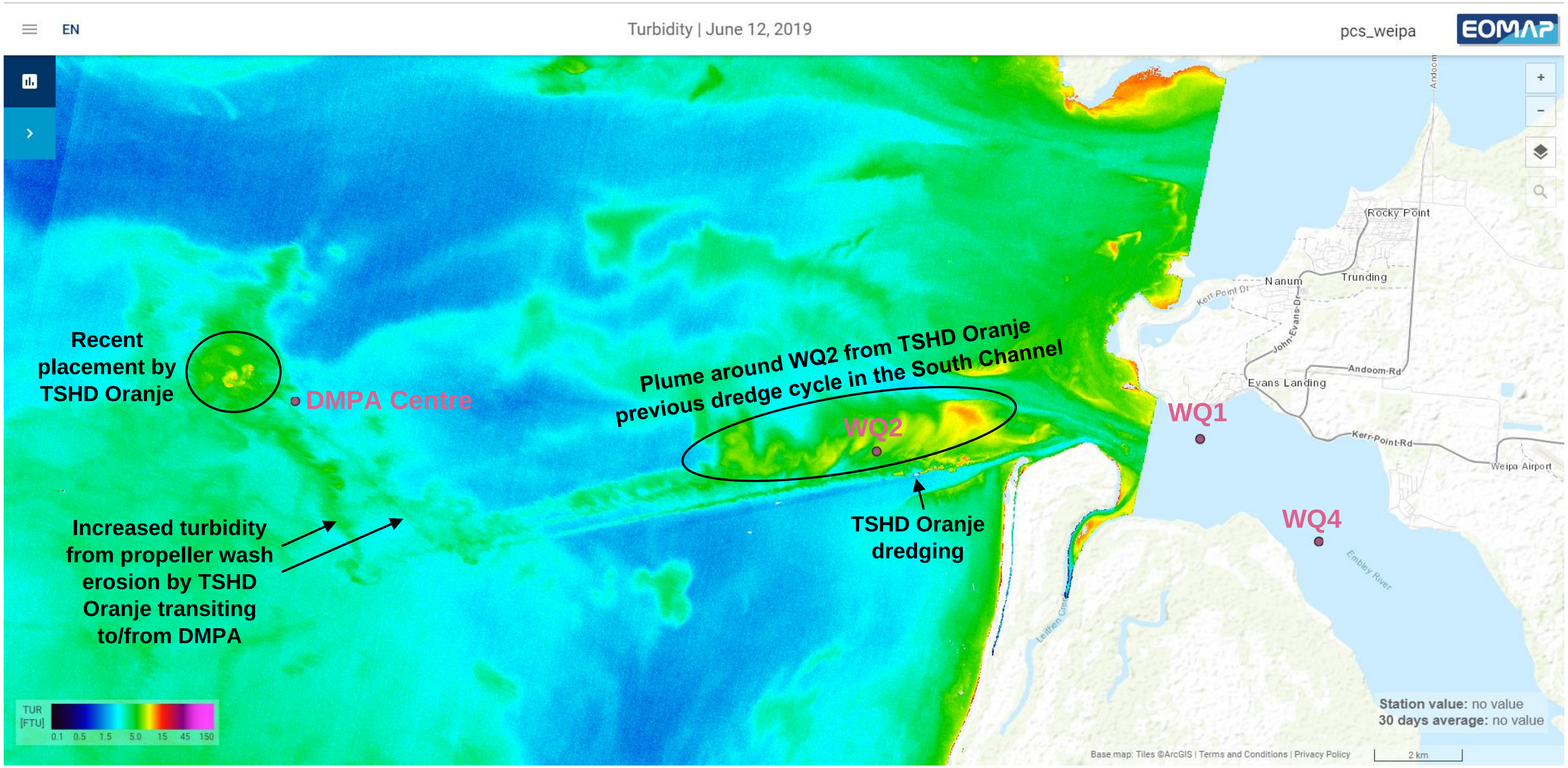
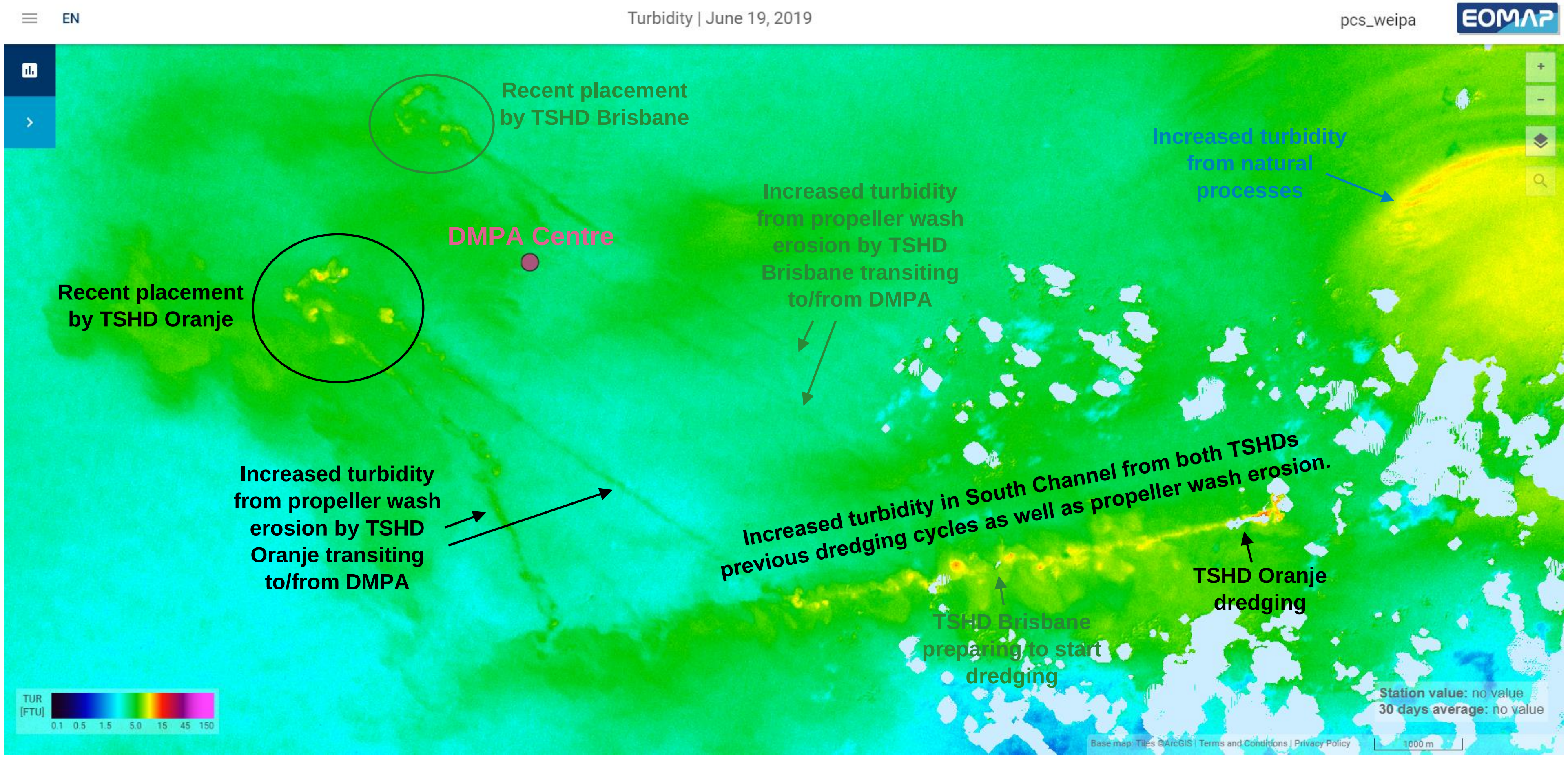


Figure 20. Satellite-derived turbidity of the Weipa region showing turbidity one week before the 2019 maintenance dredging program.



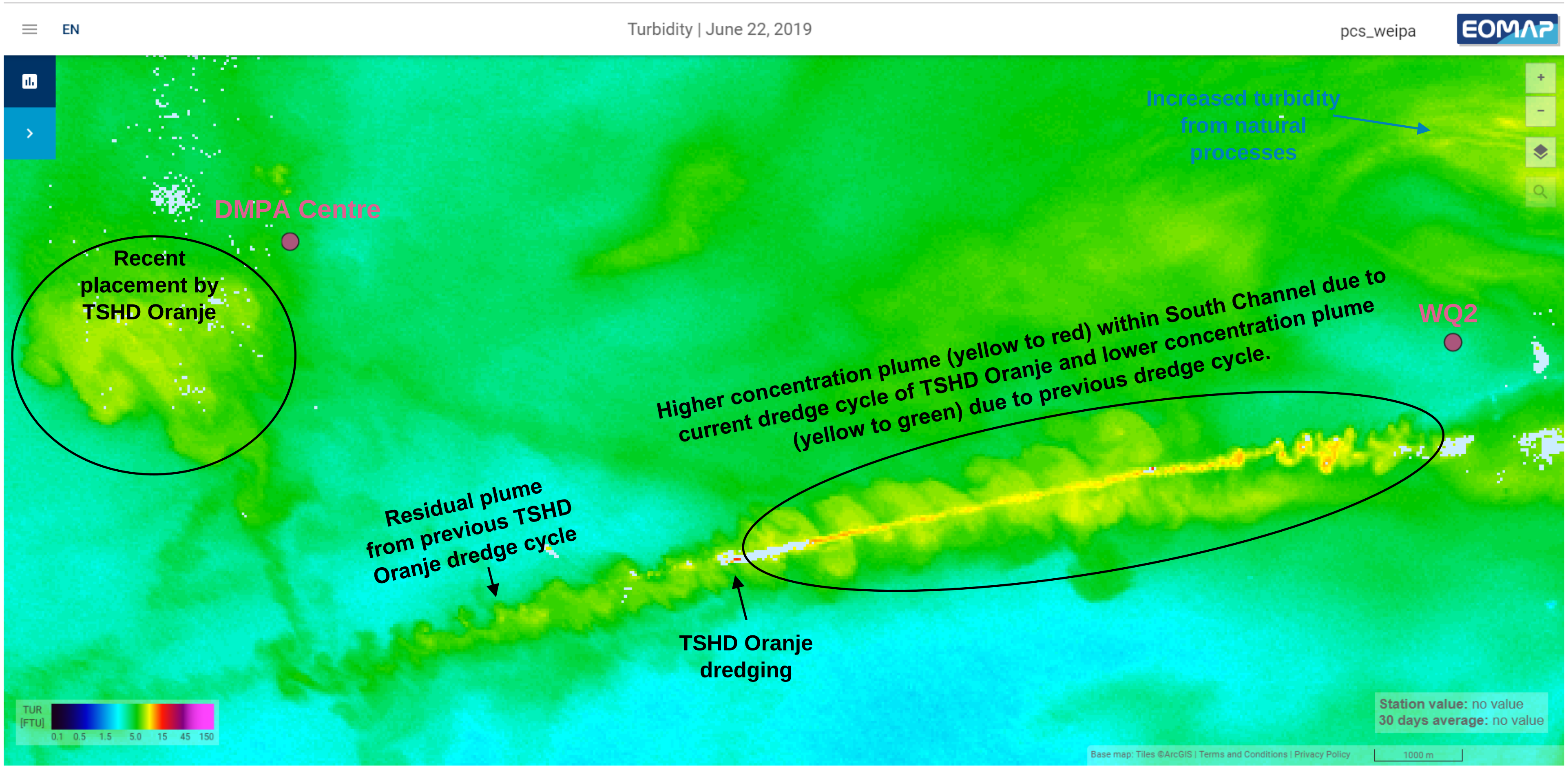
Note: Annotations in ***grey*** *are associated with TSHD Oranje.*

Figure 21. Satellite-derived turbidity of the Weipa region showing turbidity one week into the 2019 maintenance dredging program.



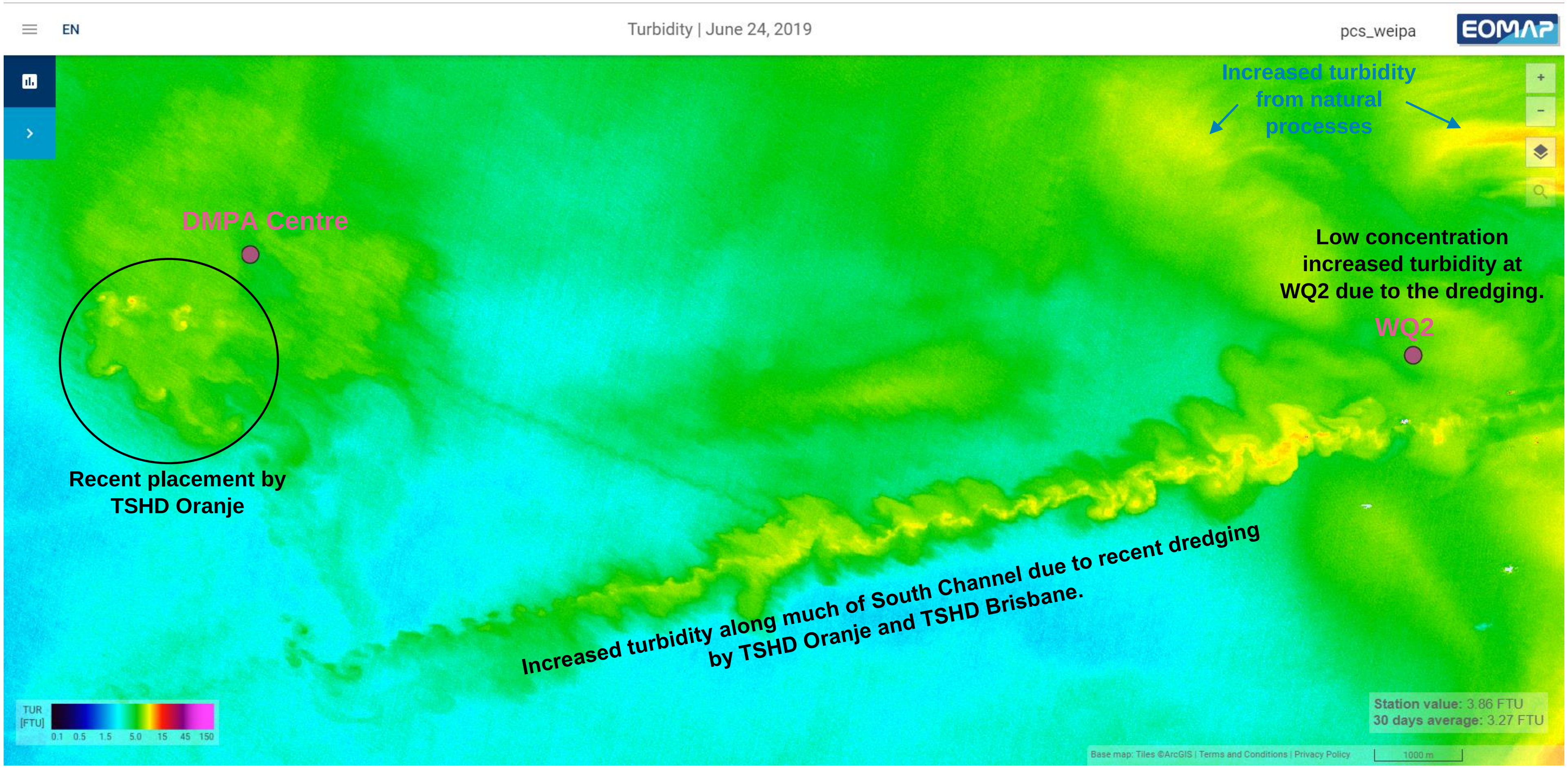
*Note: Annotations in **grey** are associated with TSHD Oranje, **green** with TSHD Brisbane and both TSHD's combined in **black**.*

Figure 22. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity two weeks into the 2019 maintenance dredging program.



Note: Annotations in ***grey*** *are associated with TSHD Oranje.*

Figure 23. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity 2.5 weeks into the 2019 maintenance dredging program.



Note: Annotations in ***grey*** *are associated with TSHD Oranje.*

Figure 24. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity three weeks into the 2019 maintenance dredging program.

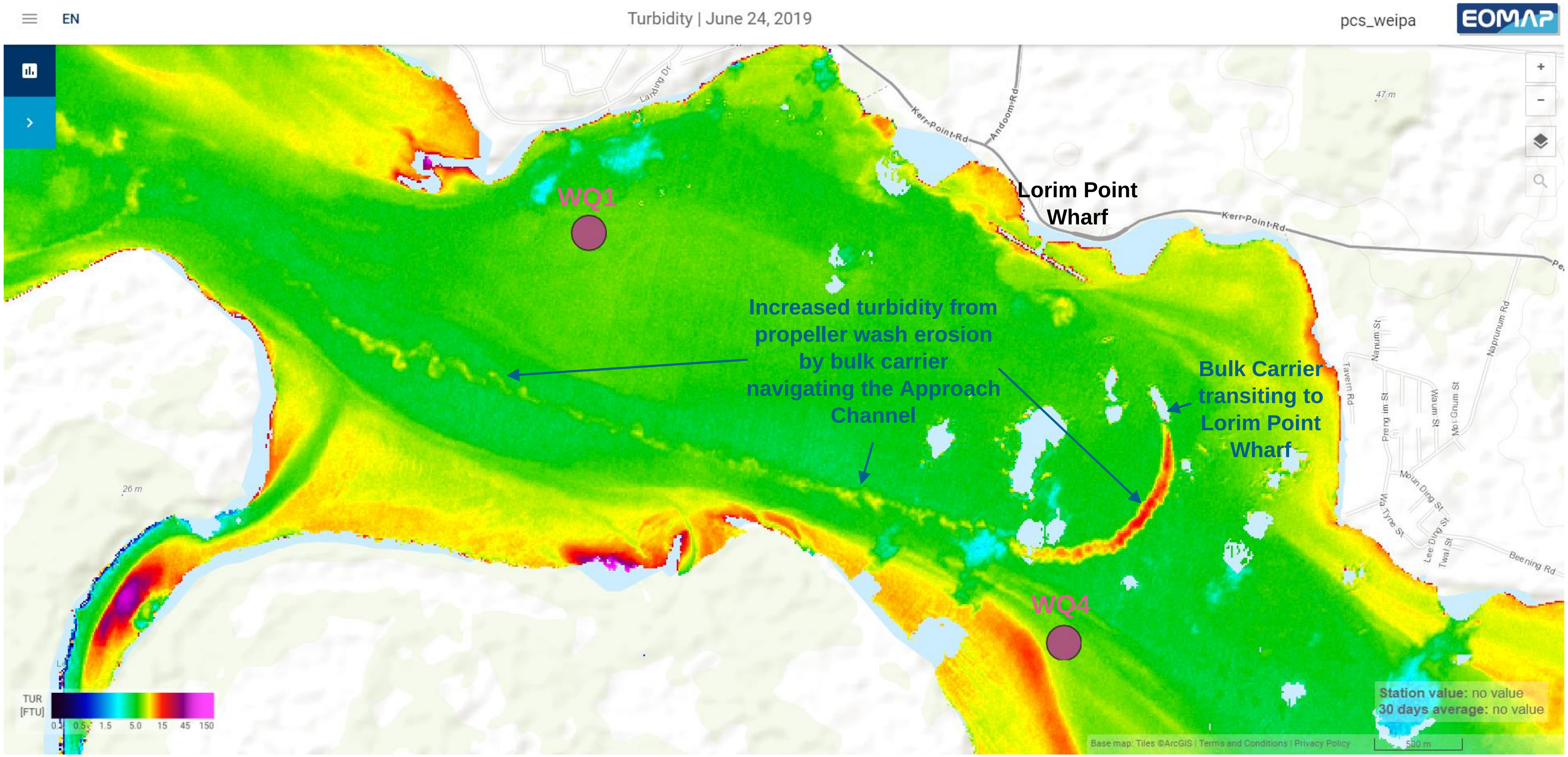
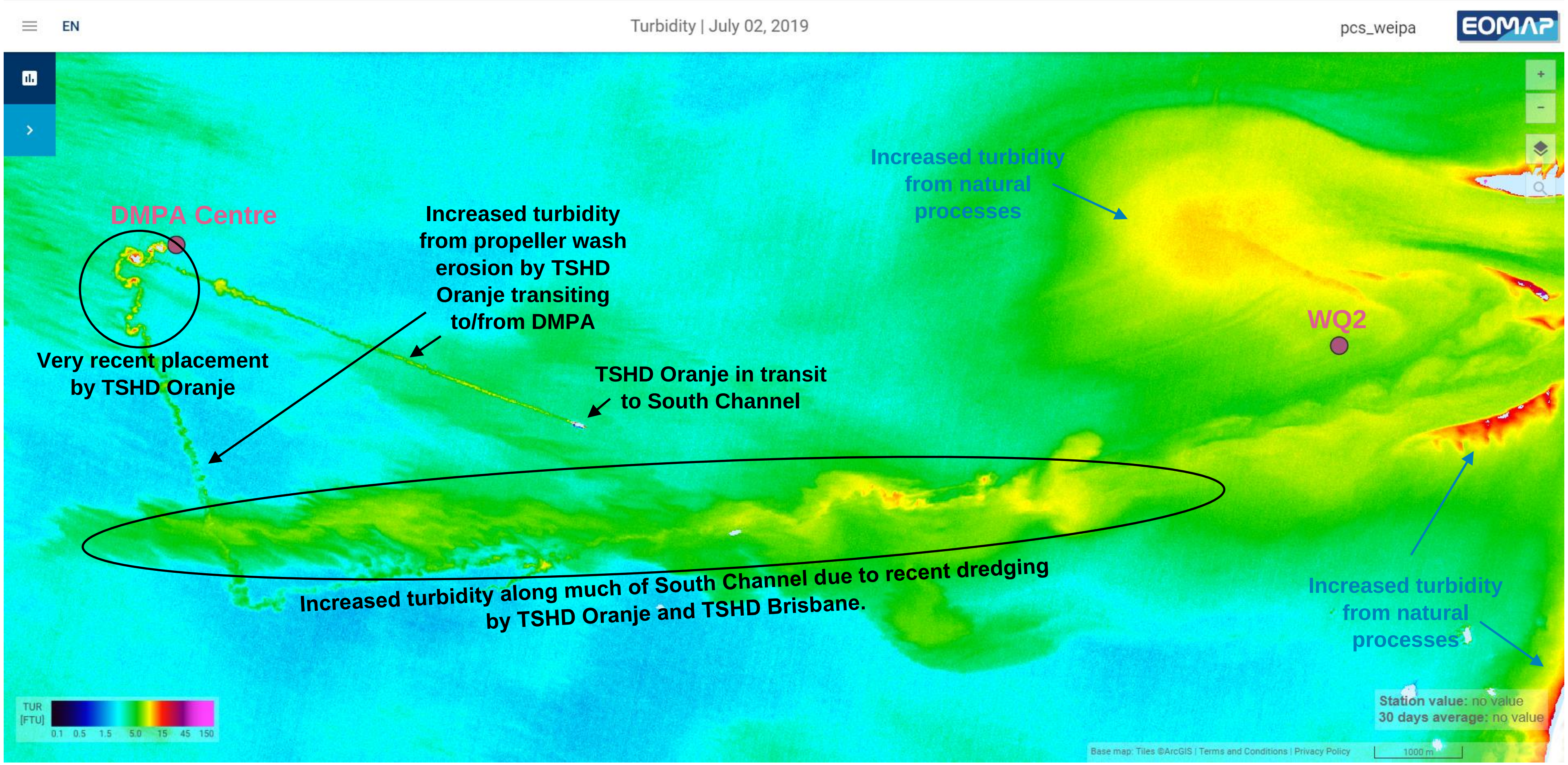
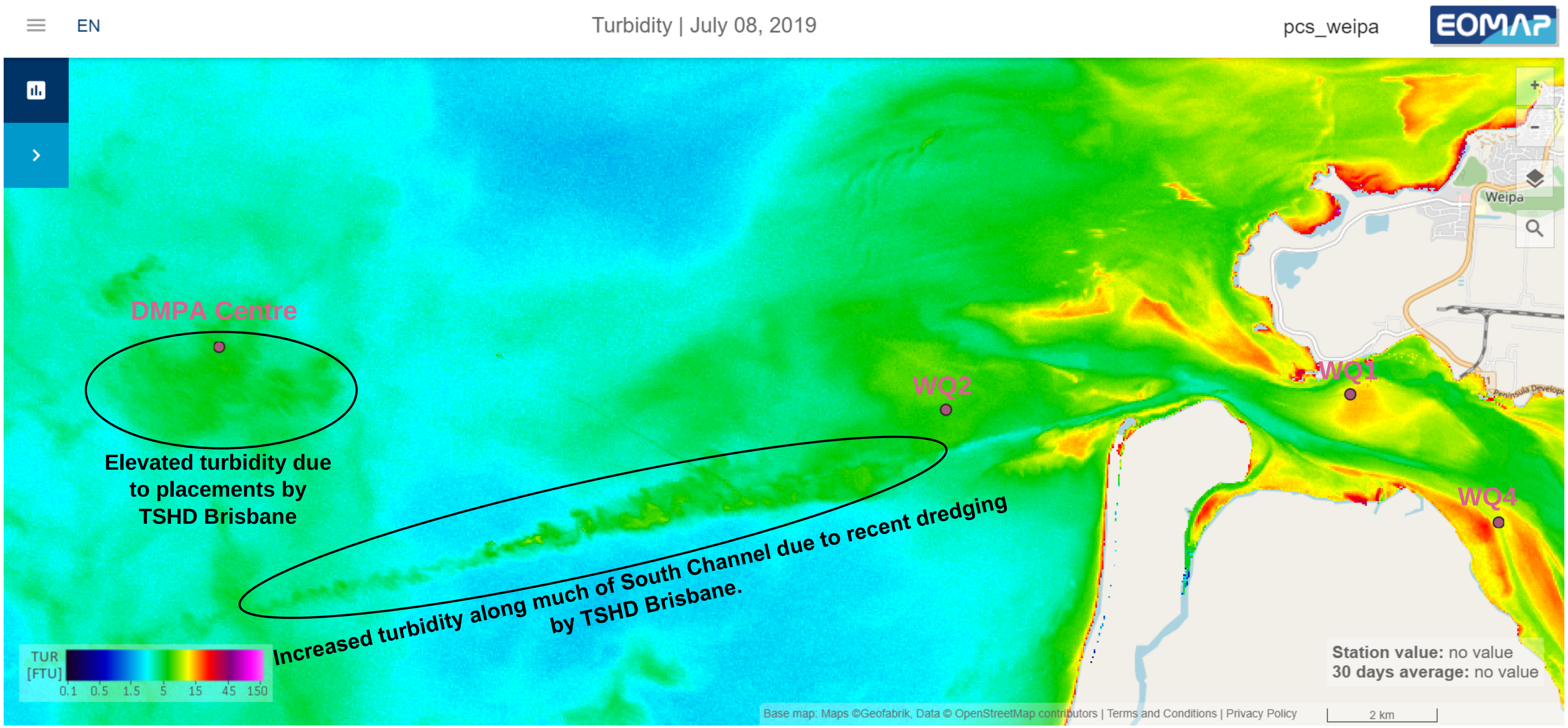


Figure 25. Satellite-derived turbidity of the Inner Harbour area showing turbidity three weeks into the 2019 maintenance dredging program.



*Note: Annotations in **grey** are associated with TSHD Oranje.*

Figure 26. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity four weeks into the 2019 maintenance dredging program.



Note: Annotations in ***grey*** *are associated with TSHD Brisbane.*

Figure 27. Satellite-derived turbidity of the Weipa region showing turbidity five weeks into the 2019 maintenance dredging program.

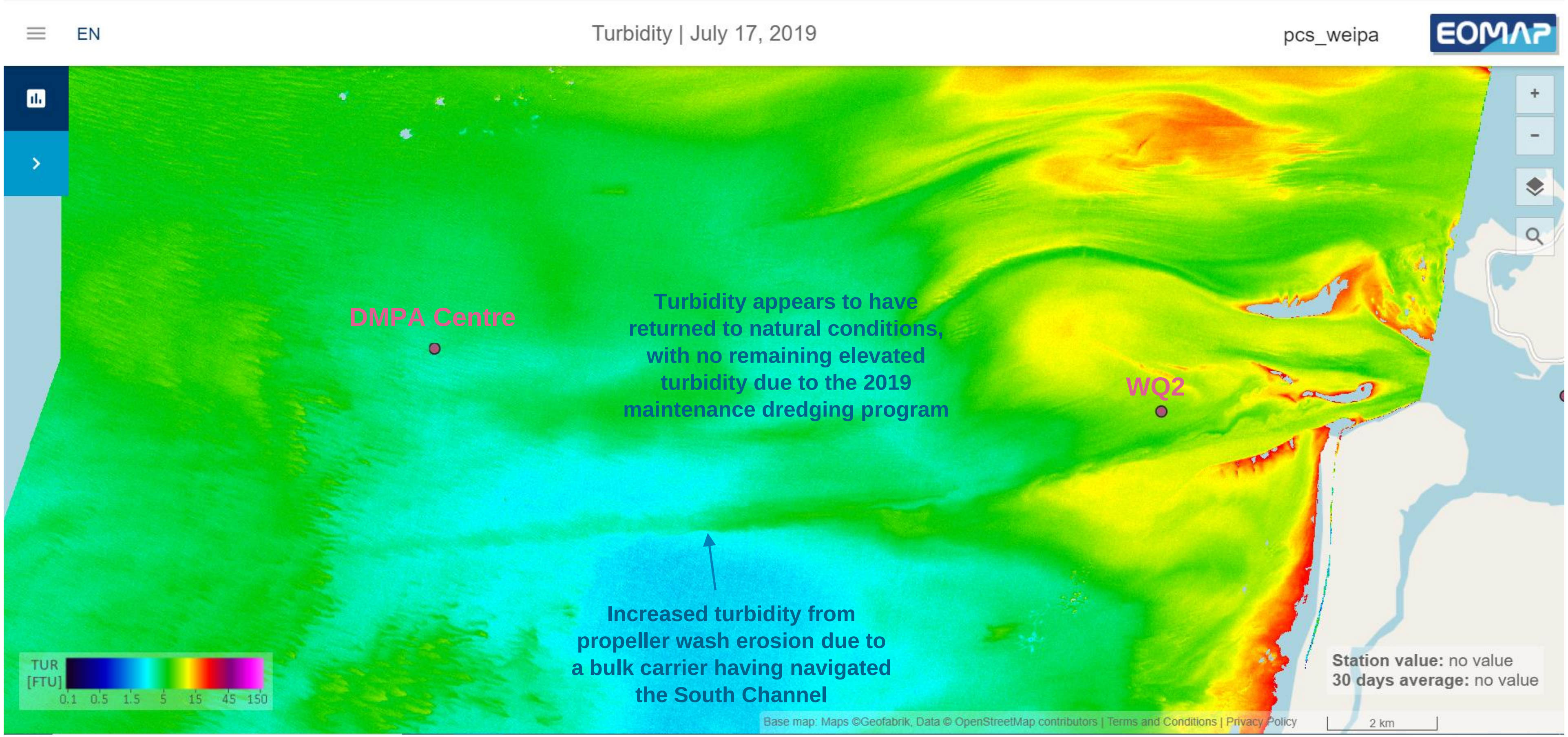


Figure 28. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity one week after the 2019 maintenance dredging program.

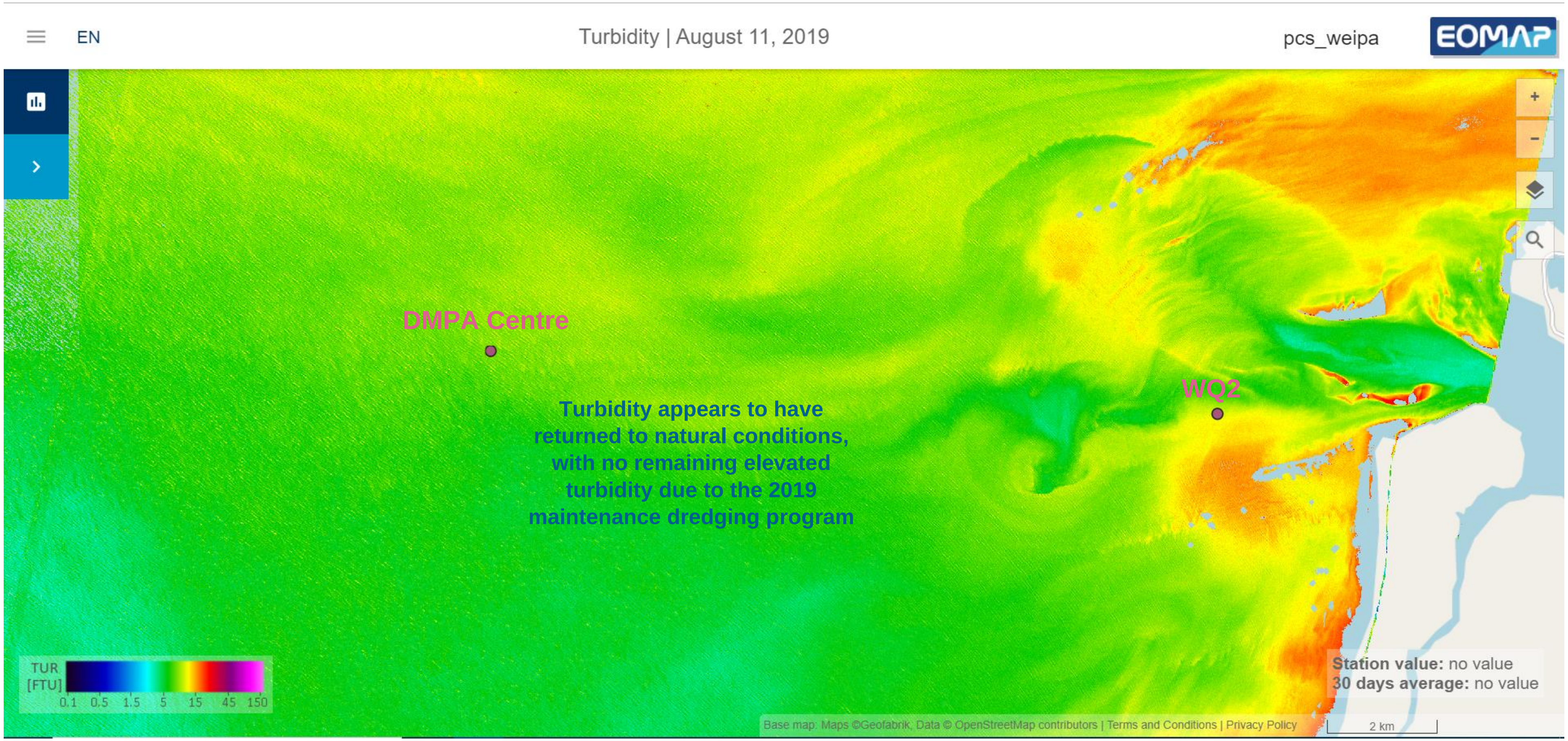


Figure 29. Satellite-derived turbidity of the South Channel and DMPA areas showing turbidity four weeks after the 2019 maintenance dredging program.

3.4. Influence of Maintenance Dredging

Based on the data from the turbidity loggers as well as the satellite-derived turbidity data it has been shown that the 2019 maintenance dredging program resulted in plumes with elevated turbidity due to both the dredging and placement activities. Although the plumes were found to remain visible for multiple hours, they were also found to be subject to limited residual transport which meant that over time they generally remained close to where they were originally generated. The in-situ turbidity monitoring showed that the short-duration peaks in turbidity which naturally occur on the flood tide at all three monitoring sites could be increased by the plumes generated by the maintenance dredging. These short-duration peaks were naturally highest during spring tides as the faster natural current speeds caused increased resuspension of natural bed sediment. Any increases in the turbidity due to the maintenance dredging was also found to be highest during spring tides as the higher tidal current speeds limit deposition of suspended sediment in the plumes, while also having the potential to transport the plumes further.

The observed increase in the short-duration peaks in turbidity due to the maintenance dredging also explains why the turbidity thresholds were exceeded more regularly than they would naturally have been expected to. However, based on the natural variability in turbidity which occurs in the region (the wet season 95th percentile at WQ2 and WQ4 is approximately 10 times higher than during the dry season (PCS, 2019b)), these short-duration increases in turbidity are unlikely to impact the natural environment.

The water quality monitoring and satellite-derived turbidity also showed that following completion of the 2019 maintenance dredging program, the turbidity quickly (within days) returned back to natural conditions with no remaining areas with elevated turbidity due to the maintenance dredging and placement activities.

4. Summary

This report has analysed and interpreted turbidity data collected during the Port of Weipa 2019 maintenance dredging program. The 2019 maintenance dredging program was undertaken by two dredgers and involved the relocation of 2.4 million m^3 of sediment from the dredged areas of the Port to the Albatross Bay Dredge Material Placement Area (DMPA). The data showed that during the 2019 maintenance dredging program the turbidity around the Port of Weipa was generally controlled by the natural conditions (tidal currents and wind/wave conditions), with higher turbidity occurring during spring tides (due to their stronger tidal currents) and periods with larger waves. The key findings from the turbidity data analysis undertaken are as follows:

- the benthic and surface turbidity data were found to show similar patterns (with the exception of WQ4 due to the erroneous benthic data), albeit with higher peaks in the benthic turbidity. The duration of time that the benthic and surface turbidity intensity thresholds were exceeded were similar. This shows that the surface turbidity thresholds which were calculated by PCS (2019c) can be considered suitable to use with surface turbidity measurements to estimate the duration of time the benthic turbidity thresholds are exceeded;
- the dredging and placement activities associated with the 2019 maintenance dredging program have been found to result in clearly visible plumes with increased turbidity which extend along much of the length of the South Channel and cover the majority of the Albatross Bay DMPA area. The plumes generally remained close to where they were generated showing that little residual transport occurs in the region, as was previously suggested by PCS (2018). It can therefore 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 maintenance dredging was found to have the potential to result in increases in the natural short-duration peaks in turbidity which occur at certain stages of the tide. These increases resulted in the turbidity thresholds being exceeded more regularly than they would naturally have been expected. However, based on the natural variability in turbidity which occurs in the region (the wet season 95th percentile at WQ2 and WQ4 is approximately 10 times higher than during the dry season (PCS, 2019b)), these short-duration increases in turbidity are unlikely to impact the natural environment;
- the data showed that following completion of the 2019 maintenance dredging program, the turbidity quickly (within days) returned to natural conditions with no remaining areas with elevated turbidity due to the maintenance dredging and placement activities; and
- the Port of Weipa 2019 maintenance dredging program did not influence the regional turbidity in the area. The dredging only influenced the local turbidity close to the dredged areas of the Port and the Albatross Bay DMPA.

5. References

PCS, 2018. Port of Weipa: Sustainable Sediment Management Assessment, Sediment Budget. September 2018.

PCS, 2019a. Port of Weipa 2019 maintenance dredging: turbidity analysis, Note 1. May 2019.

PCS, 2019b. Port of Weipa 2019 maintenance dredging: turbidity analysis, Note 2. June 2019.

PCS, 2019c. Port of Weipa 2019 maintenance dredging: turbidity analysis, Note 3. August 2019.

PCS, 2019d. Port of Weipa: Sustainable Sediment Management Assessment, Bathymetric model. June 2019.