Port of Gladstone Sustainable Sediment Management Project

October 2018 – February 2019

Gladstone Ports Corporation (GPC)

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CITATION

This report should be cited as: *Vision Environment (2019). Port of Gladstone Sustainable Sediment Management Project. Report for Gladstone Ports Corporation.* Vision Environment, Gladstone, Australia.

DOCUMENT CONTROL

Document draft	*Originated by*	*Edit and review*	*Date*
Draft issued to Client	FM, JS	LA	08/03/2019
Final issued to client	GPC	FM LA	04/04/2019

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FILE REFERENCE

04042019_FINAL POG Sustainable Sediment Managment Project_VE

Executive Summary

Gladstone Ports Corporation Ltd (GPC) conducts regular maintenance dredging of the harbour channels with relocation of most spoil material to the East Banks Sea Disposal Site (EBSDS). In order to gain a better understanding of overall sediment movement, a variety of both GPC and Vison Environment (VE) benthic equipment was deployed before, during and after dredging at five sites in the vicinity of the EBSDS. Results of the deployment of altimeters (measuring sediment flux and bed level change) and benthic Photosynthetic Active Radiation (PAR) loggers (measuring the amount of light reaching the benthos) are reported here. Other data gained from the VE Acoustic Current Doppler Profiler (ADCP) and GPC monitoring equipment (LISST-100X, LISST-STX, AWAC and Wetlabs) during the field deployment is being examined and interpreted under a different GPC project scope.

During the equipment deployment period from 23 October 2018 to 11 February 2019, 213 mm of rainfall was recorded predominantly in mid-December. Wind gusts ≥ 50 km/h were recorded on 44 days of the 112-day deployment period and along with changes in wind direction, had a noticeable impact on sediment flux.

Approximately 211,102 m^3 of material was dredged across Gladstone Harbour shipping channels and disposed at the EBSDS between 14 November and 16 December 2018. Sediment flux was more volatile across the monitoring period at the shallower sites of EBE, EBW and OH02 compared to OH04 and OH06. A deeper water column tends to limit the expression of wind-driven seafloor sediment disturbance resulting in less sediment resuspension. At all sites, sediment resuspension increased in response to elevated wind speed events, particularly around 5 December when maximum wind gusts for the monitoring period were recorded. Although this event occurred during dredge operations, similar increases in sediment flux were also recorded during the pre- and post- dredge periods in response to regular elevated wind speed events.

Sites EBE and EBW located within the EBSDS trended similarly to one another across the monitoring period, although EBW was less responsive to wind driven events due to greater water depth. Sites OH02 and OH04 located further to the north west and north east of the EBSDS respectively, also exhibited similar patterns to each other regarding sediment flux and sediment accumulation. OH06 located to the south east of the EBSDS and adjacent to the outer shipping channel (Wild Cattle Cutting) where approximately 29,000 m^3 of material was dredged, remained reasonably stable in terms of sediment flux compared to the other sites, despite not being the deepest site.

Sediment accumulation occurred at all sites across the monitoring period resulting in overall increases in bed level at all sites. Deposition was not restricted to the dredge period, with most occurring during the post-dredge period when wind speeds were generally higher. The lowest overall accumulation occurred during pre-dredge when wind speeds were the lowest. Small periods of erosion were generally associated with changes in wind direction.

Lowest overall accumulation (~20 mm) occurred at the EBE and EBW sites located within the EBSDS. Net accumulation at sites OS02 and OS04 resulted in similar bed level change of 30 and 47 mm, respectively. Site OH06 accumulated 147 mm of sediment over the deployment period. Bed level at this site had remained stable up until the 5 December high wind speed event shortly before the end of dredging operations, when a steady and consistent increase in bed level occurred to the end of the monitoring period. It is unknown what contribution

dredging of the adjacent channel may have had on sediment movement at this site, however highest accumulation at this site occurred during the post-dredge period.

Three major environmental factors can affect BPAR: the available ambient light, water depth and water clarity. The impact of these key driving factors on the amount of light reaching the benthos was apparent during the monitoring period. Highest Total Daily PAR (TDP) at the benthos was measured at the shallowest sites EBE and EBW located within the EBSDS (although minimal data was retained from EBE due to instrument malfunction), compared to remaining sites. This is due to lower attenuation (reduction in intensity due to scattering/absorption) of ambient light with shorter distances to the benthos. Periods of rainfall (and therefore associated cloud cover) resulted in decreases in ambient sunlight and thus BPAR at all sites, particularly in mid-December at the end of dredge operations when the highest precipitation for the monitoring period was recorded.

Although water clarity was not directly measured by the VE instruments on this occasion, it has been historically recorded that increases in wind speeds result in increased sediment resuspension (as recorded by the altimeters) and thus decreased water clarity. There was a period of minimal light (< 0.01 mol/m^2/day) recorded at the benthos from approximately 5 December 2018 to 11 January 2019 at all sites. Although rainfall and associated low ambient light would have contributed to minimal BPAR up until 19 December, wind speeds from this point forward were much higher than during the remainder of the monitoring period when BPAR once again was recorded at > 0.01 mol/m^2/day. Ambient light during both periods was similar, thus suggesting elevated turbidity may have reduced BPAR.

There appears to be no clear relationship with increases in sediment flux and/or sedimentation with dredge material relocation to the EBSDS during the period of dredge activities for the 2018 GPC maintenance dredge operations. Sediment resuspension appeared to be more influenced by increased wind speeds and changes in wind direction.

Sediment accumulation at most sites began towards the end of dredge operations but continued throughout the post-dredge period, with lowest net accumulation at the EBSDS sites. Similarly, decreases in light reaching the benthos were affected by a combination of the available ambient light, water depth and potentially water clarity. The period of lowest BPAR occurred mostly during the post-dredge period.

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Acronyms

ADCP	Acoustic Current Doppler Profiler
BOM	Bureau of Meteorology
BPAR	Benthic Photosynthetically Active Radiation
EBSDS	East Banks Sea Disposal Site
GBRMP	Great Barrier Reef Marine Park
GBRWHA	Great Barrier Reef World Heritage Area
GPC	Gladstone Ports Corporation Ltd
HSEQ	Health Safety Environment and Quality
MS	Management System
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
PoG	Port of Gladstone
QA/QC	Quality Assurance/Quality Control
SCUBA	Self Contained Underwater Breathing Apparatus
TDP	Total Daily PAR
VB	Vision Base
VE	Vision Environment
WBDDP	Western Basin Dredge and Disposal Project

1 INTRODUCTION

Gladstone Ports Corporation Ltd (GPC) conducts maintenance dredging of the Gladstone harbour channels on at least an annual basis, to provide and operate effective and efficient port facilities and services. Most dredge material is placed at the East Banks Sea Disposal Site (EBSDS) located within Port limits. The Port of Gladstone (PoG) dredging and disposal activities occur within the Great Barrier Reef World Heritage Area (GBRWHA), but outside the Great Barrier Reef Marine Park (GBRMP).

In alignment with the Reef 2050 Long-term Sustainability Plan for the GBR and during the most recent maintenance dredging period, GPC sought to build information on a sediment budget and associated model to better understand the contribution of maintenance dredging activities to the overall sediment system. Approximately 211,102 m^3 of material was dredged across Gladstone harbour shipping channels and disposed at the EBSDS between 14 November and 16 December 2018. VE deployed GPC monitoring equipment (LISST-100X, LISST-STX, AWAC and Wetlabs) and VE monitoring equipment (altimeters, Benthic Photosynthetic Active Radiation (BPAR) loggers and Acoustic Doppler Current Profilers (ADCPs)) on the benthos from 24 October 2018 to 11 February 2019, in order to measure varying aspects of water quality and sediment movement.

This report provides a brief interpretation of altimeter and PAR data measured during the project. As per the scope of services, data from GPC equipment and the VE ADCPs were to be processed by GPC. Validated data for altimeters and PARS and raw ADCP data (ASCii format) was provided to GPC upon submission of this report.

2 METHODOLOGY

2.1 Fieldwork

A variety of equipment were deployed at five monitoring sites within and adjacent to the EBSDS for an approximate 112 day/16-week period (Table 1, Figure 1).

Table 1 Location, equipment and deployment period at each site.

Site	GPS Location	GPC Equipment	VE Equipment	Deployment Period
EBE	23.53.132; 151.29.332	LISST-100X, LISST-STX, Wetlab BPAR + NTU, AWAC	ADCP Dual altimeters Dual odyssey PAR loggers	23/10/18 - 11/02/19
EBW	23.52.229; 151.27.607	LISST-100X, LISST-STX, Wetlab BPAR + NTU, AWAC	ADCP Dual altimeters Dual odyssey PAR loggers	23/10/18 - 12/02/19
OH02	23.51.693; 151.26.582	-	Dual altimeters Dual odyssey PAR loggers	24/10/18 - 11/02/19
OH04	23.51.531; 151.29.287	-	Dual altimeters Dual odyssey PAR loggers	24/10/18 - 11/02/19
OH06	23.53.665; 151.30.364	-	Dual altimeters Dual odyssey PAR loggers	24/10/18 - 11/02/19

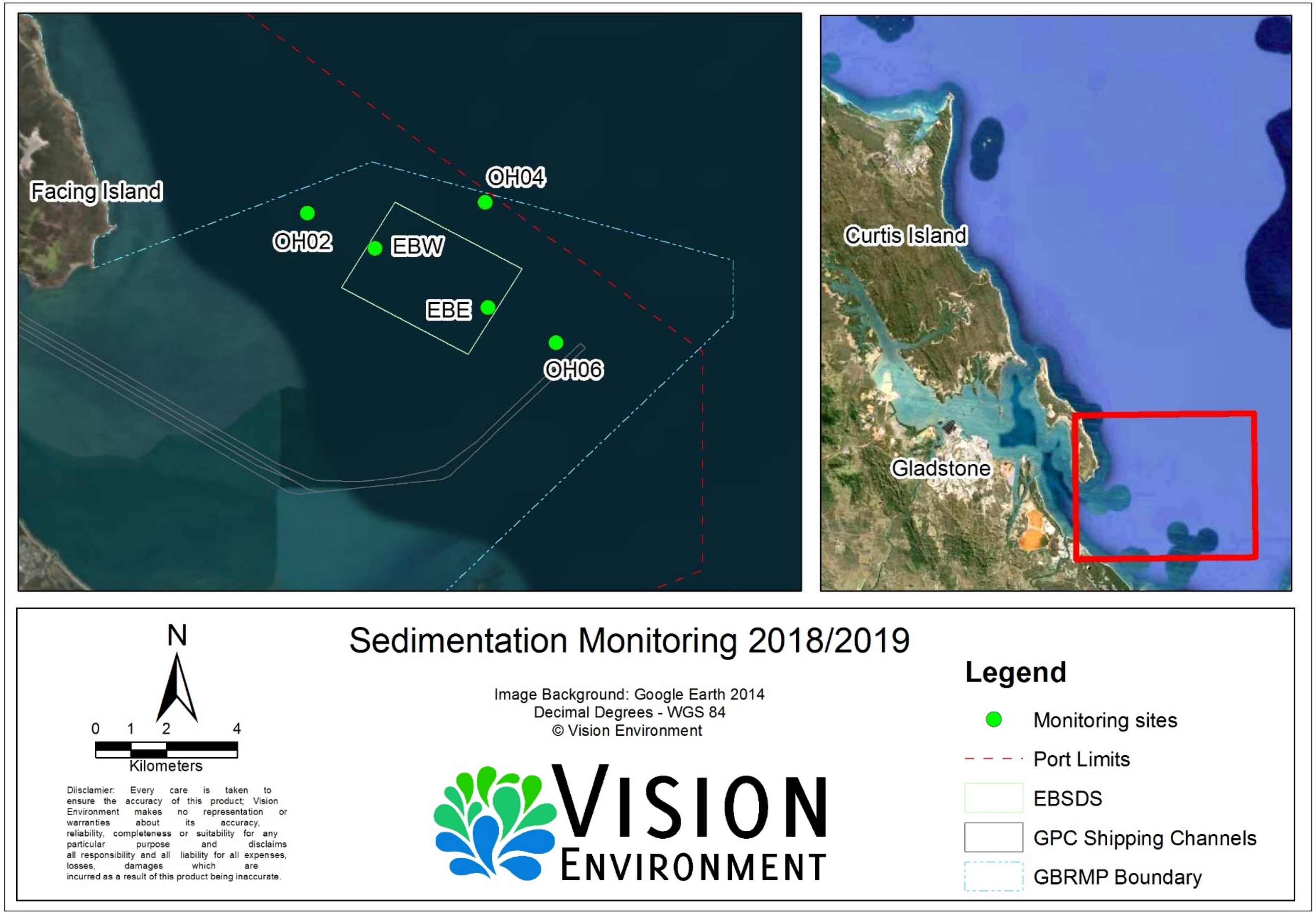

Figure 1 Monitoring sites for deployment of equipment for the sustainable sediment monitoring program.

VE equipment was deployed at each of the five sites (Table 1). Dual altimeters and dual Odyssey PAR loggers were mounted on a VE custom-built frame, deployed at approximately 300 mm above the benthos by VE SCUBA divers. A subsurface marker buoy was deployed within close proximity of the equipment (Figure 2).

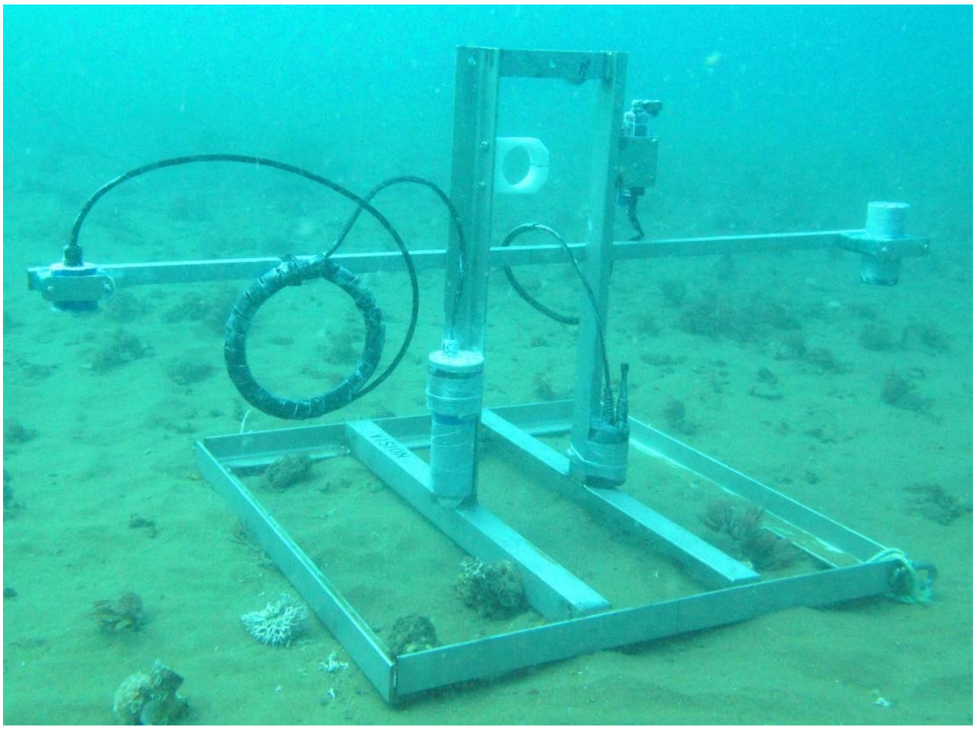

Figure 2 Custom dual PAR, dual altimeter monitoring frame deployed on the benthos.

ADCP were deployed at sites EBE and EBW by VE SCUBA divers. The ADCP were downward facing at 2.5 m distance from the seafloor, mounted on a 2.8 m tall, four-legged quadpod frame, with articulated foot pads that were staked into the benthos (Figure 3). Quadpods were additionally secured with a guideline to an anchored frame.

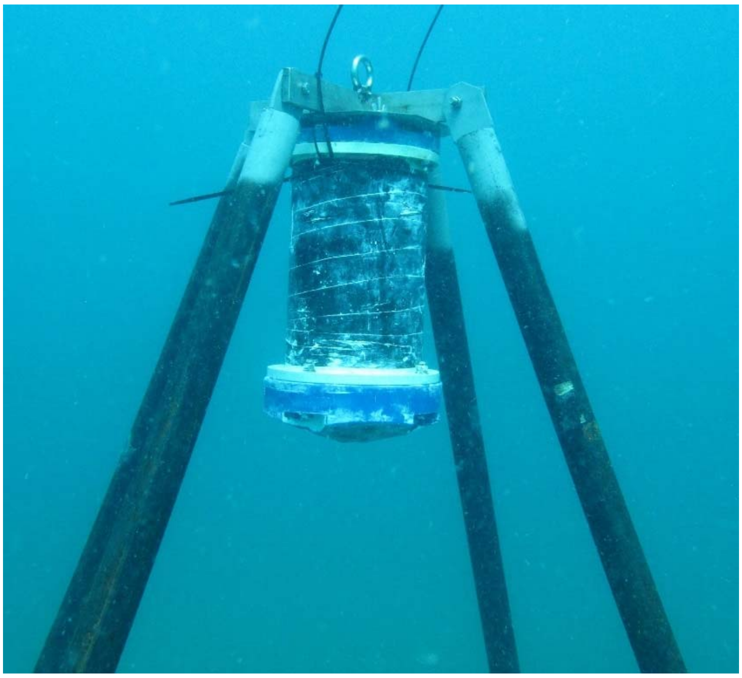

Figure 3 ADCP mounted downward facing to the benthos on a custom quadpod frame.

Retrieval of the units, downloading of data and redeployment of the GPC monitoring equipment was scheduled bimonthly, while monthly download and/or equipment exchange/maintenance of the VE equipment was scheduled to occur in November and December. Due to adverse weather conditions from December to February, not all scheduled fieldwork was possible. The following fieldwork was undertaken (Table 2):

Table 2 Fieldwork undertaken during monitoring program.

Date	GPC equipment	VE equipment
23/10/18 & 24/10/18	Initial deployment	Initial deployment
05/11/18 & 07/11/18	Retrieve, download & redeploy	-
20/11/18, 21/11/18 & 23/11/18	Retrieve, download & redeploy	Retrieve, download & redeploy
13/12/18 & 20/11/18	Retrieve, download & redeploy	
11/02/19 & 12/02/19	Demobilise	Demobilise

On return to shore the GPC equipment was downloaded by GPC personnel directly, prior to redeployment a few days later (weather dependent). Not all GPC equipment was available for redeployment on all occasions. All VE equipment was downloaded on the vessel by VE personnel during the scheduled visit and immediately redeployed or exchanged. Any VE units requiring maintenance were replaced with alternate units prior to redeployment.

2.2 Altimeter

The Altus altimeter (NKE Instrumentation) is an autonomous instrument that obtains very high precision bed level measurements (millimetre scale) at user set intervals using a high frequency acoustic sensor and an inbuilt data logging device. Distance to seabed data is recorded on four separate channels, each with unique detection threshold settings (11%, 23%, 39% and 70%). Threshold 1 (11%) is considered most useful in measurement of a non-homogenous medium such as that likely to be found in Port Curtis (mix of silt, sand and gravel sediment fractions).

Management of altimeter data is undertaken as per VE Health, Safety, Environment and Quality (HSEQ) Management System (MS) protocols. When insufficient echo is received back from the seafloor to produce a valid altitude reading, negative readings are logged. These readings are removed prior to further examination of the data. Other erroneous data is removed from the dataset using the following identifiers:

- Instantaneous sediment change > 30 mm in 10 minutes;
- Rapid cumulative change beyond an acceptable level expected to be triggered by environmental factors; and
- Problems with the deployed unit observed by divers upon altimeter retrieval and download (e.g. fallen over, rope entanglement). The date upon which this occurred can usually be identified in the dataset using the points above.

When interference with marine organisms occurs, the period of erroneous data removal is often small, with data returning to expected levels within a short period. Longer term interferences, such as deployment unit problems generally result in the data being removed for the remaining deployment period.

Subsequent calculations are based on the mean altitude recorded from both altimeters. Both instantaneous (change in 10 minutes) and cumulative bed level change (change from original 'baseline' reading) is calculated, in order to gain long-term sediment erosion or deposition patterns.

2.3 Benthic PAR

The Odyssey submersible photosynthetic irradiance autonomous recording system provides high resolution data in the required wavelength range of 400 to 700 nm. Duplicate Odyssey loggers were placed on the benthic frame alongside the altimeters and programmed to record at 10-minute intervals. A single self-cleaning wiper (Hydro-Wiper) is programmed to clean both sensors at regular intervals to prevent fouling.

In order to record daily ambient changes in total available PAR, duplicate telemetered LiCor loggers are operating at Vision Base (VB) Gladstone. Solar powered dual LI-COR LI192SA Quantum Sensors log the mean ambient PAR every 15 minutes (averaged from 1 min readings), with data transferred via General Packet Radio Service (GPRS) to the VECloud every 30 minutes. The inclusion of the Vision Base data allows for variation in daily ambient PAR (e.g. due to cloud cover) to be accounted for, thus aiding in the interpretation of benthic PAR levels and acting as a 'control' PAR. While small scale daily weather patterns such as scattered cloud would not be consistent throughout the harbour, substantial overall daily changes are recorded and significant reductions in PAR can be accounted for in this manner.

Management of BPAR logger data is undertaken as per VE HSEQ MS protocols. BPAR values from each Odyssey logger during the non-daylight period (according to sunrise and sunset times reported by Bureau of Meteorology), are zeroed. Subsequent calculations are based on the mean PAR recorded from both Odyssey loggers. Mean Odyssey data recorded for each day was summed to calculate total daily PAR (TDP) (mol/m²/day) for each site.

3 RESULTS & DISCUSSION

3.1 Dredge Volumes

The Trailing Suction Hopper Dredge (TSHD) "Brisbane" operated from 14 November to 16 December 2018. Approximately 211,102 m^3 of material was dredged across Gladstone harbour shipping channels (Figure 4) and disposed at the EBSDS (Figure 5). Data was provided by GPC.

3.2 Metocean Conditions

Approximately 213 mm of rainfall was recorded over the monitoring period from 23 October 2018 to 11 February 2019 (Figure 6), with the majority (126 mm) of the precipitation recorded in mid-December (BOM, 2019). Less than 55 mm of precipitation was recorded during both January and February 2019.

Maximum wind gusts across the period reached 69 km/h (5 December 2018), with wind gusts ≥ 50 km/h recorded on 44 days of the 112-day deployment period (Figure 6). Winds were generally in an easterly or north-easterly direction, although there were occasional days where winds were recorded from a south-westerly direction during the deployment period (BOM, 2019). Wave heights paralleled wind speeds, with highest significant wave heights (1.70 m) recorded on 8 December 2018. Significant wave heights ≥ 1 m were recorded on 42 days of the deployment period (DSITIA, 2019).

Spring tides associated with the full and new moons occurred on 8 and 23 November 2018 (3.81 and 3.85 m tidal ranges, respectively), 7 and 23 December 2018 (3.60 and 4.09 m tidal ranges, respectively), 6 and 21 January 2019 (3.28 and 4.30 m tidal ranges, respectively) and 5 February 2019 (3.23 m tidal range) (Figure 6).

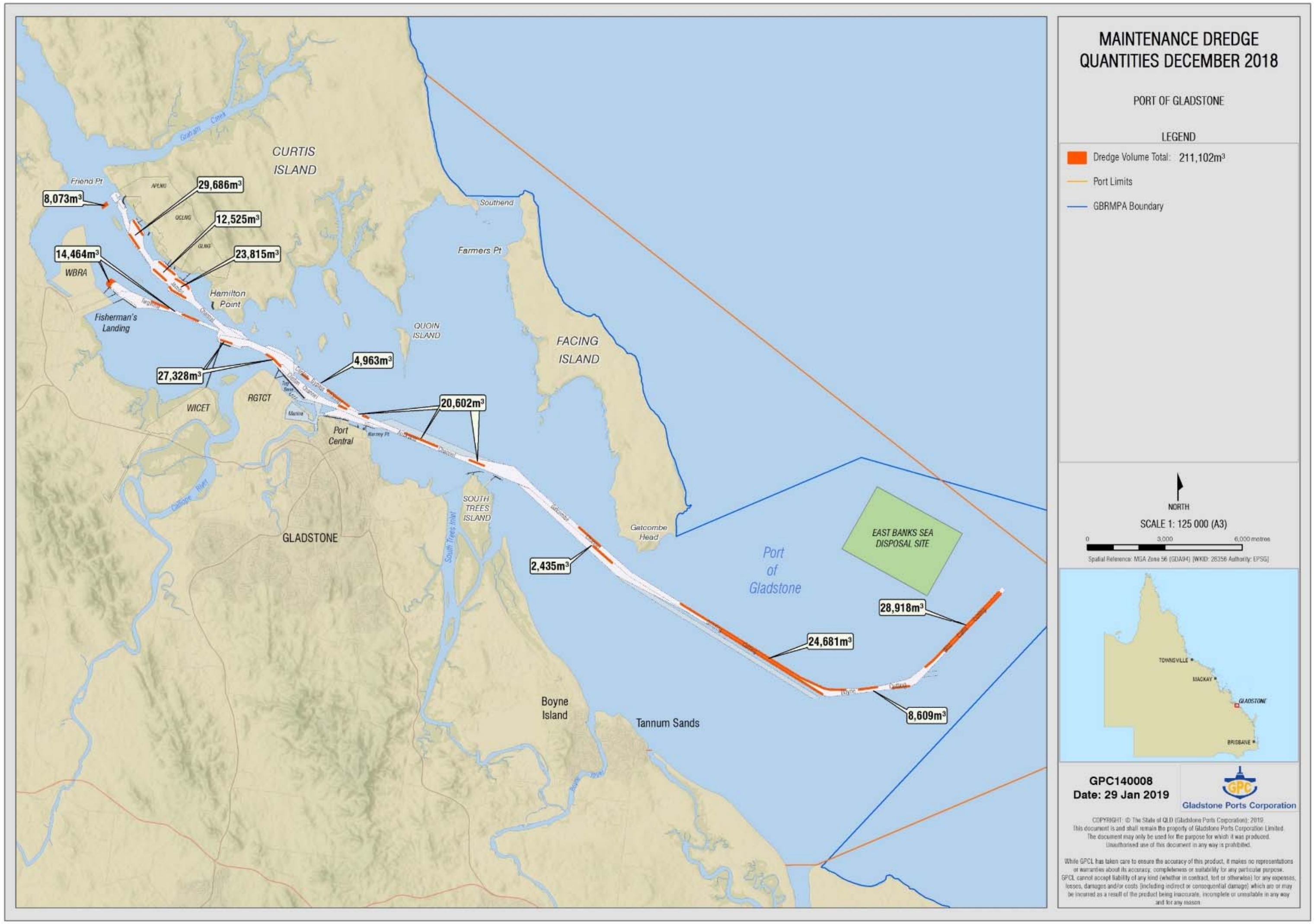

Figure 4 Maintenance dredge areas and volumes during operations 14 November to 16 December 2018.
Image provided by GPC.

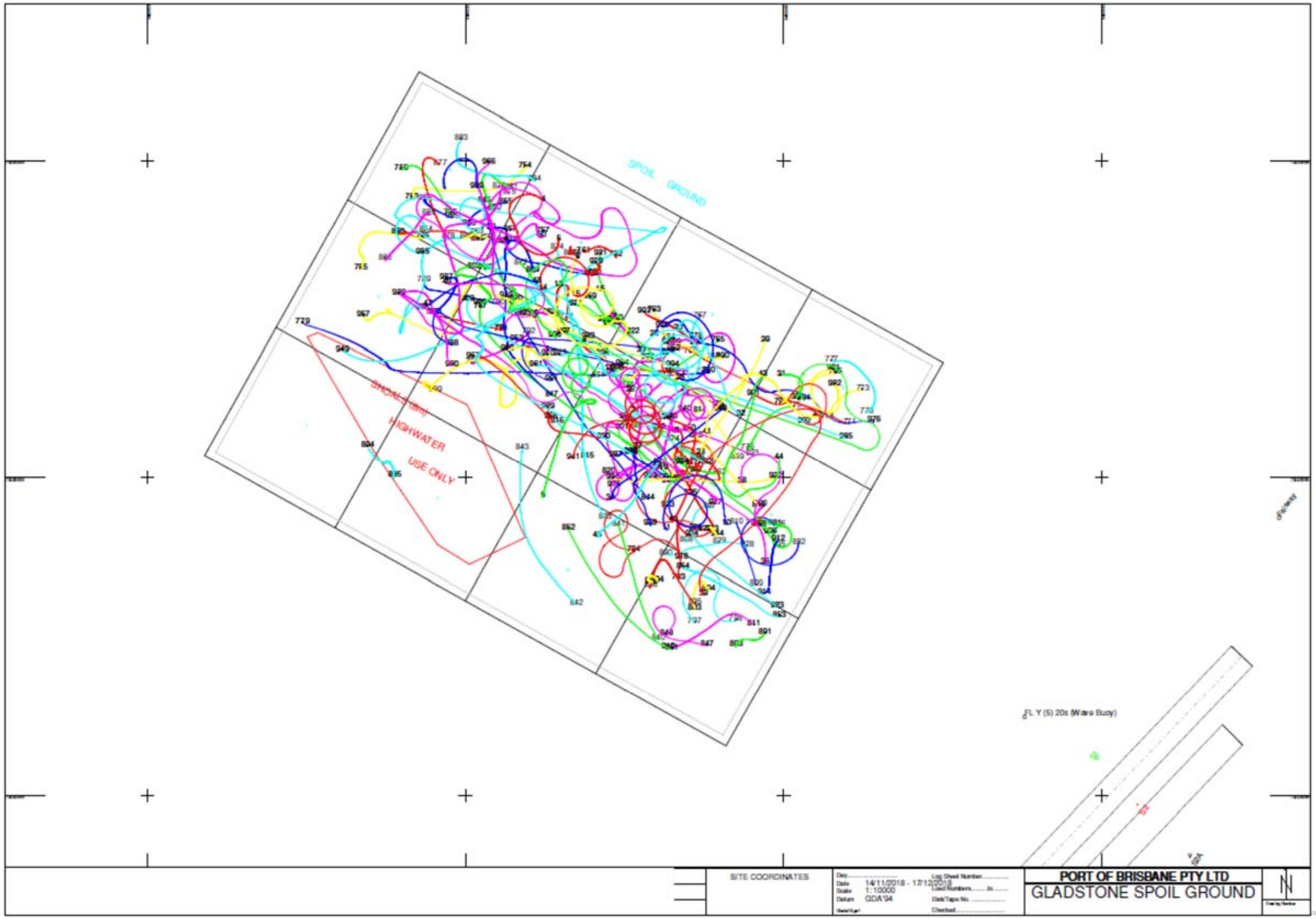

Figure 5 Maintenance dredge spoil disposal at EBSDS during operations 14 November to 16 December 2018.
Image provided by GPC.

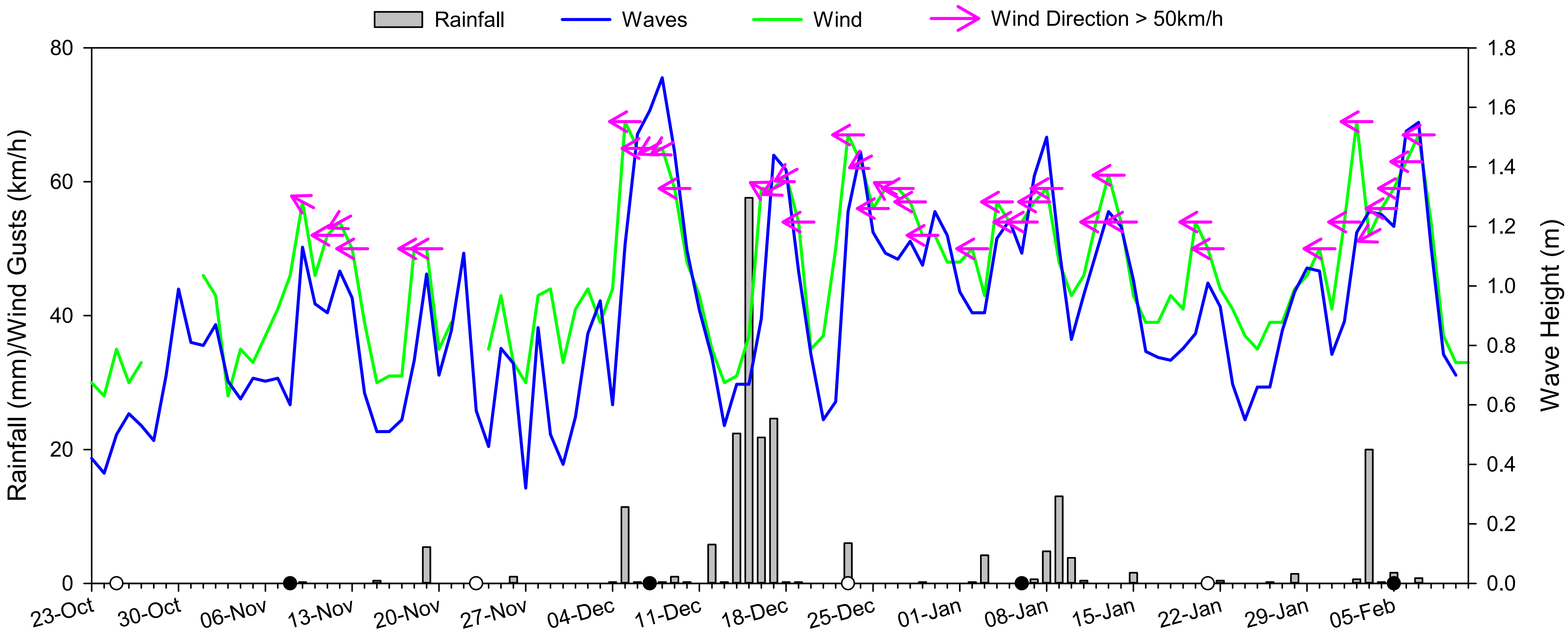

Figure 6 Rainfall, wind and wave conditions during sedimentation deployment period
White and black circles indicate full and new moon periods, respectively.

3.3 Altimeter

Changes in energy from wind, waves and currents, in addition to anthropogenic impacts such as the relocation of dredged material, can result in variation in sedimentation movements and patterns. This can result in deposition of sediments originating from another location, resuspension of sediments with no net change in the seabed and/or the resuspension of sediments and transportation to another location. Altimeters provide two forms of information to help identify these processes:

- Instantaneous bed level change calculated every 10 minutes indicating the level of sediment flux occurring at a set point in time; and
- Net cumulative change in bed level over a given period.

Instantaneous bed level change, in addition to net cumulative change over the deployment period is plotted in comparison to wind and rainfall in Figures 7 to 9. Net cumulative bed level change compared to baseline levels of 0 mm upon deployment in late October, is tabulated for each day of the monitoring program (Table 5 in Appendix), with the final net cumulative change and bed level change for each dredge phase tabulated in Table 3 (and Table 5 in Appendix). Note that at most of the sites, insufficient echo return was gained in the last few days of the deployment period before decommissioning of units. Therefore, data only up until 8 February 2019 has been reported.

Table 3 Net Bed Level Change at sedimentation monitoring sites during deployment period (October 2018 to February 2019) and during each dredge phase including number of days in each phase.
Note that (+) accumulation indicates sediment deposition, while (–) accumulation indicates sediment erosion.

Site	Depth below LAT (m)	Net bed level change (mm)	Pre-dredge bed level change (mm) 22 days	Dredge bed level change (mm) 33 days	Post-dredge bed level change (mm) 54 days
EBE	10.0	+20	+2	+12	+6
EBW	12.5	+22	+27	+11	-16
OH02	12.5	+30	+3	+21	+6
OH04	17.5	+47	-7	+37	+17
OH06	14.0	+147	+2	+65	+80

The relocation of dredged sediment material from the shipping channel to the EBSDS occurred from 14 November to 16 December 2018. All five monitoring sites exhibited overall accumulation over the entire deployment period. Sites EBE and EBW which were located within the EBSDS (Figure 1), recorded the lowest net accumulation (~ 20 mm). Moderate deposition was recorded at sites OH02 and OH04 (30 and 47 mm, respectively), which were located outside of the EBSDS (Figure 1). Highest overall accumulation was recorded at site OH06 located further east from the EBE and the EBSDS. Although this site was located furthest to the south east of the EBSDS, it was located adjacent to the outer shipping channel (Wild Cattle Cutting), where 28,918 m^3 of material was dredged intermittently (Figure 4) from the 15th November to 16 December 2018.

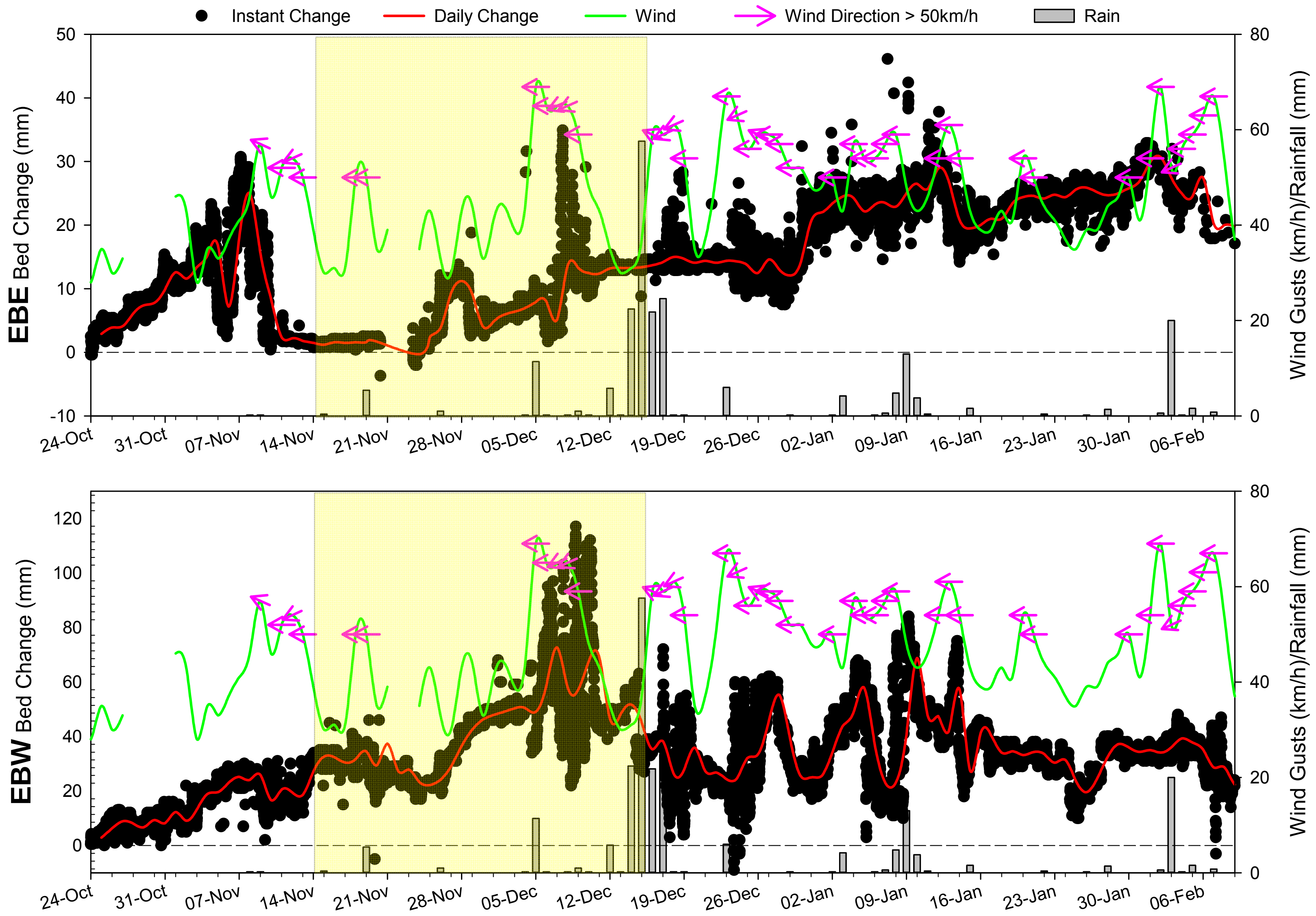

Figure 7. Mean instantaneous and daily averaged bed level change at EBE and EBW from 24 October 2018 to 8 February 2019 compared to wind and rain. *Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS.*

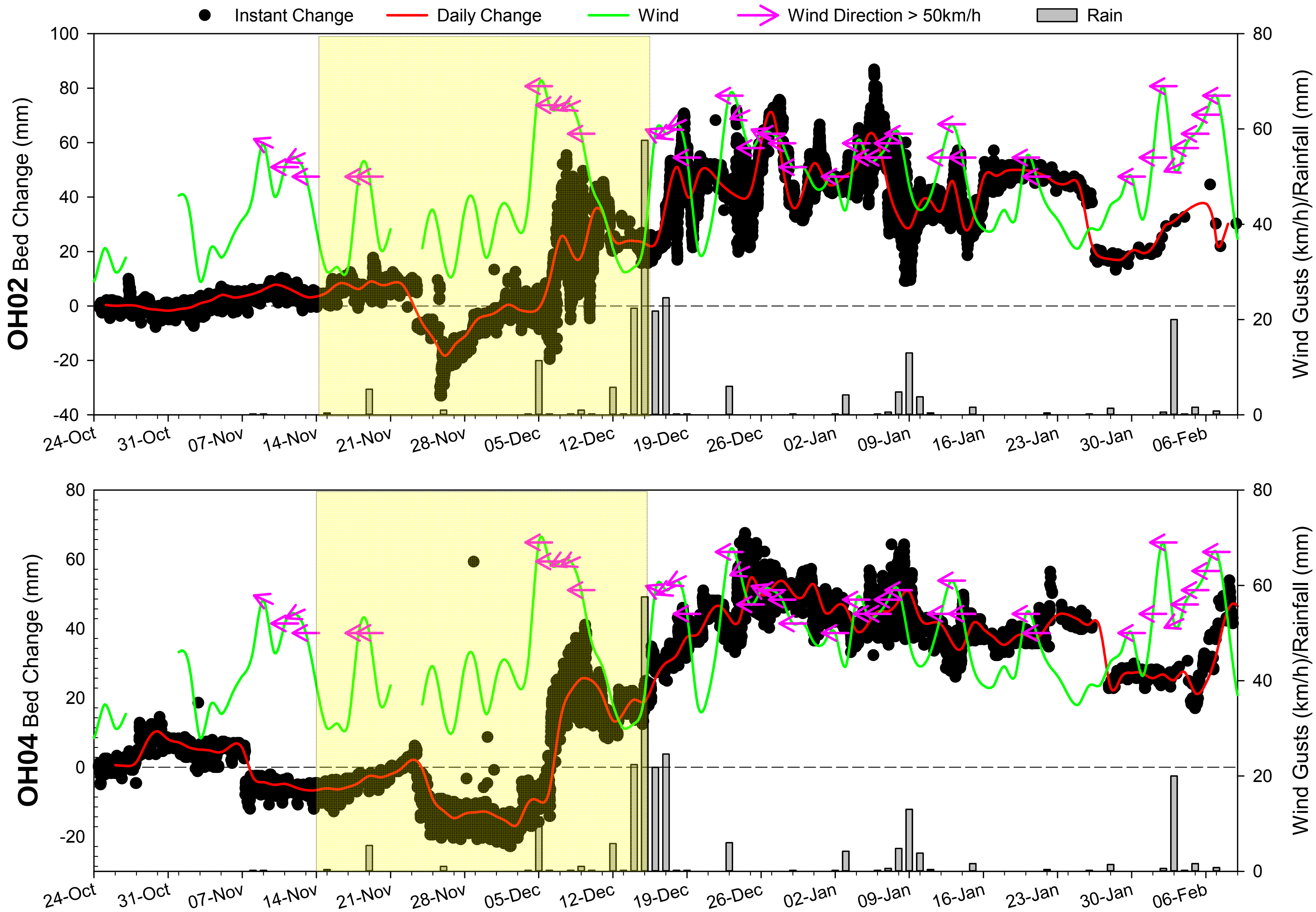

Figure 8. Mean instantaneous and daily averaged bed level change at OH02 and OH04 from 25 October 2018 to 8 February 2019 compared to wind and rain. *Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS.*

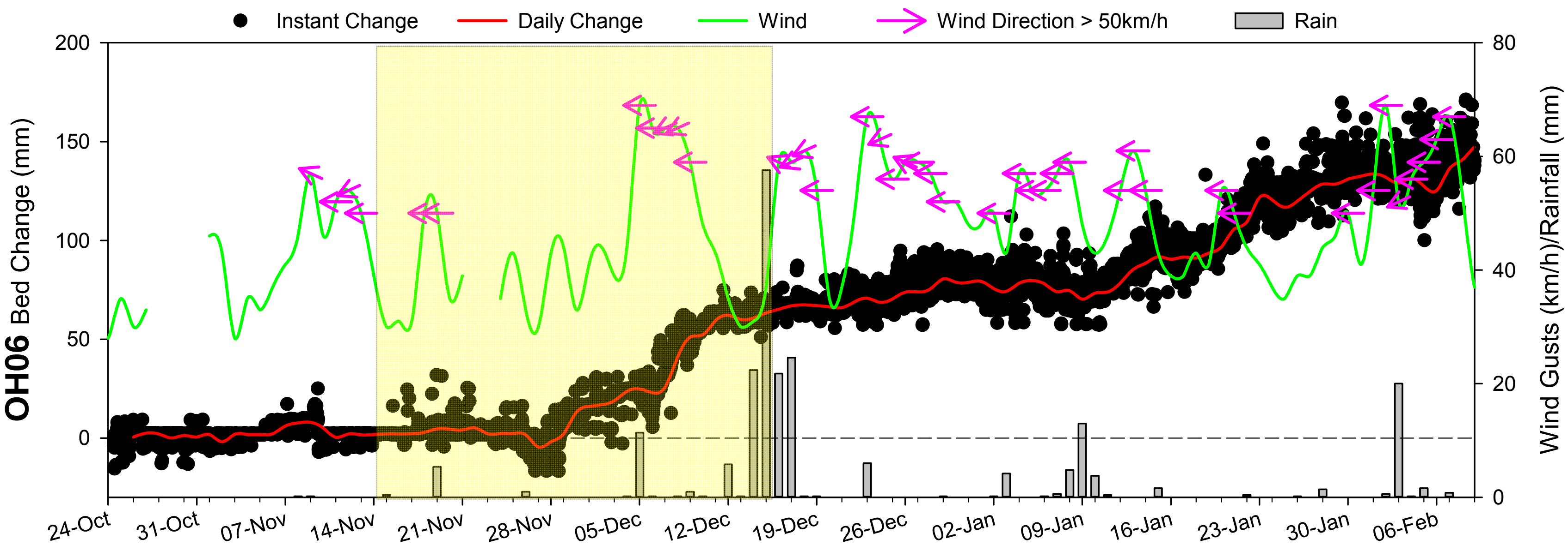

Figure 9. Mean instantaneous and daily averaged bed level change at OH06 from 24 October 2018 to 8 February 2019 compared to wind and rain. *Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS.*

Comparisons were also made of bed level change between each dredge phase at each site. Accumulation occurred during all phases of the monitoring period (Table 3), apart from sites OH04 during pre- and EBW during post-dredge, where 7 mm and 16 mm of erosion (negative accumulation) were recorded, respectively (Table 3). The trend of accumulation among sites was different for each separate phase of the dredging period. Although accumulation among sites was similar during the dredge (and to a lesser extent the post-dredge) period to that which occurred overall, the pre-dredge period recorded a contrasting result. The highest accumulation was recorded at EBW whereas lowest accumulation (erosion) occurred at OH04 during pre-dredge. It must be noted that the number of days within each dredge phase, and the number of days of high wind within each phase varied greatly. Wind speeds during the pre-dredge period (mean of 40 km/h, range of 28 to 57 km/h) were overall lower than both the dredge (mean of 43 km/h, range of 30 to 59 km/h) and post-dredge (mean of 49 km/h, range of 33 to 54 km/h) periods. Although it was apparent that high wind speeds resulted in sediment resuspension, no clear pattern of sediment movement could be clearly attributed to any one dredge phase.

At site EBE, sediment flux (Figure 7) increased during periods of elevated wind speed, particularly on 4 to 7 November (north-easterly winds), the 7, 18, 24 and 30 December (south-easterly winds), and 1, 11 and 31 January (north-easterly winds). During the early November north easterly elevated wind speeds, bed levels increased up to 25 mm, prior to declining to close to baseline levels within a few days. The change from deposition to erosion may have been triggered by the change in wind direction to south-westerly on the 8 November.

Bed levels stabilised during the period of lower north-easterly and easterly winds, prior to increasing during each period of higher easterly or north-easterly wind speeds remaining reasonably stable at the new higher bed level for the remainder of the deployment period. Minor decreases in net bed level were sometimes evident after periods of sediment flux. Once again, this may have been due to a change in wind direction, with the decrease in bed level in late November, potentially attributable to the prevailing south westerly winds on 29 November.

This also appeared to be the case at site EBW (Figure 7), located north west of EBE (Figure 1), with large sediment flux periods from 6 to 10, 16 to 19, 23 to 27 December, and 3 to 4, 8 to 9 and 13 January coinciding with higher wind speed periods. Of note, was the limited response from higher winds in early November, where sediments appeared to accumulate consistently without periods of noticeable flux. In contrast, sediment flux was marked and variable during December and January coinciding with large variations in wind speeds. South westerly winds throughout the period appeared to have no noticeable impacts at this site, perhaps due to the slightly deeper water column at EBE limiting expressions of wind driven seafloor sediment disturbance.

Site OH02 was located to the north west of the EBSDS (Figure 1), with approximately 30 mm sediment accumulated during the deployment period (Table 3, Figure 8). Like the EBSDS sites, sediment flux was most apparent during the December and January easterly and north-easterly high wind speed periods. After deployment, bed level remained reasonably stable until late November when a period of erosion was evident from 21 to 25 November. This did not appear to be associated with any recorded metocean conditions. After this, bed level exhibited an overall steady increase, particularly during the high wind speed periods of 7 December. Of note was the erosion in late January, prior to a slight increase in bed level in early February, when easterly wind speeds again increased to > 50 km/h.

Site OH04 was located to the north-east of the EBSDS (Figure 1), with net accumulation of 47 mm recorded over the deployment period (Table 3, Figure 8). Trending very similarly to OH02, bed level remained reasonably stable until early November when two periods of erosion were apparent during the predominantly north-easterly winds. A net bed level loss of ~ 20 mm was recorded at this stage. However, with the advent of higher wind speeds in early December, which were primarily easterly and south-easterly, accumulation of sediment became evident in a similar pattern to OH02. Sediment flux however appeared to be less reactive at OH04 than the three prior sites (EBE, EBW and OH02), and remained relatively consistent for the remainder of the deployment period. This may also be due to this site being much deeper than the three prior sites (Table 3), thus less responsive to elevated wind speed events. Following the same trend as at OH02, erosion was recorded in late January, followed by an increase in bed level in early February with increased wind speeds (Figure 8).

Site OH06 was located south-east of EBSDS (Figure 1) and adjacent to the outer shipping channel which was dredged. This site accumulated a higher level of sediment (147 mm) than all other sites (Table 3, Figure 9). Bed level remained consistent for the first month of deployment, prior to consistently increasing by between 3 to 10 mm daily for the remainder of the deployment period from 28 November to 8 February 2019, despite dredge operations ceasing on 16 December 2018. Highest accumulation at this site occurred during the post-dredge period (Table 3). Sediment flux at this site was less volatile than at all other sites despite this site not being the deepest.

There appears to be no clear relationship with increases in sediment flux and/or sedimentation with dredge material relocation during the period of dredge operations. Sediment resuspension appeared to be more influenced by increased wind speeds and changes in wind direction.

3.4 Benthic PAR

Benthic PAR, or the amount of light reaching the benthos that can be utilised for photosynthesis, was measured at the five sites, and compared to ambient PAR and metocean conditions (Table 4, Figures 10 to 12). Total Daily PAR (TDP) was tabulated for each day of the monitoring program (Table 6 in Appendix), with the PAR statistics tabulated in Table 4.

Table 4 Total Daily PAR (TDP) statistics at sedimentation sites and Vision Base (VB) from 24 October 2018 to 10 February 2019.

Note data from the BPAR exchange day on 20 or 23 November 2018 were not utilized in plots or statistics. Depth calculated from altimeter measurements.

Site	Depth below LAT (m)	Total Daily PAR (mol/m2/day)		
		Mean ± SE	Range	No. values
EBE	10.0	0.08 ± 0.01	0.03 – 0.13	27
EBW	12.5	0.02 ± 0.00	<0.01 – 0.07	109
OH02	12.5	0.02 ± 0.00	<0.01 – 0.07	108
OH04	17.5	0.01 ± 0.00	<0.01 – 0.05	108
OH06	14.0	0.01 ± 0.00	<0.01 – 0.05	108
VB PAR	-	48.7 ± 0.9	12.2 – 60.2	110

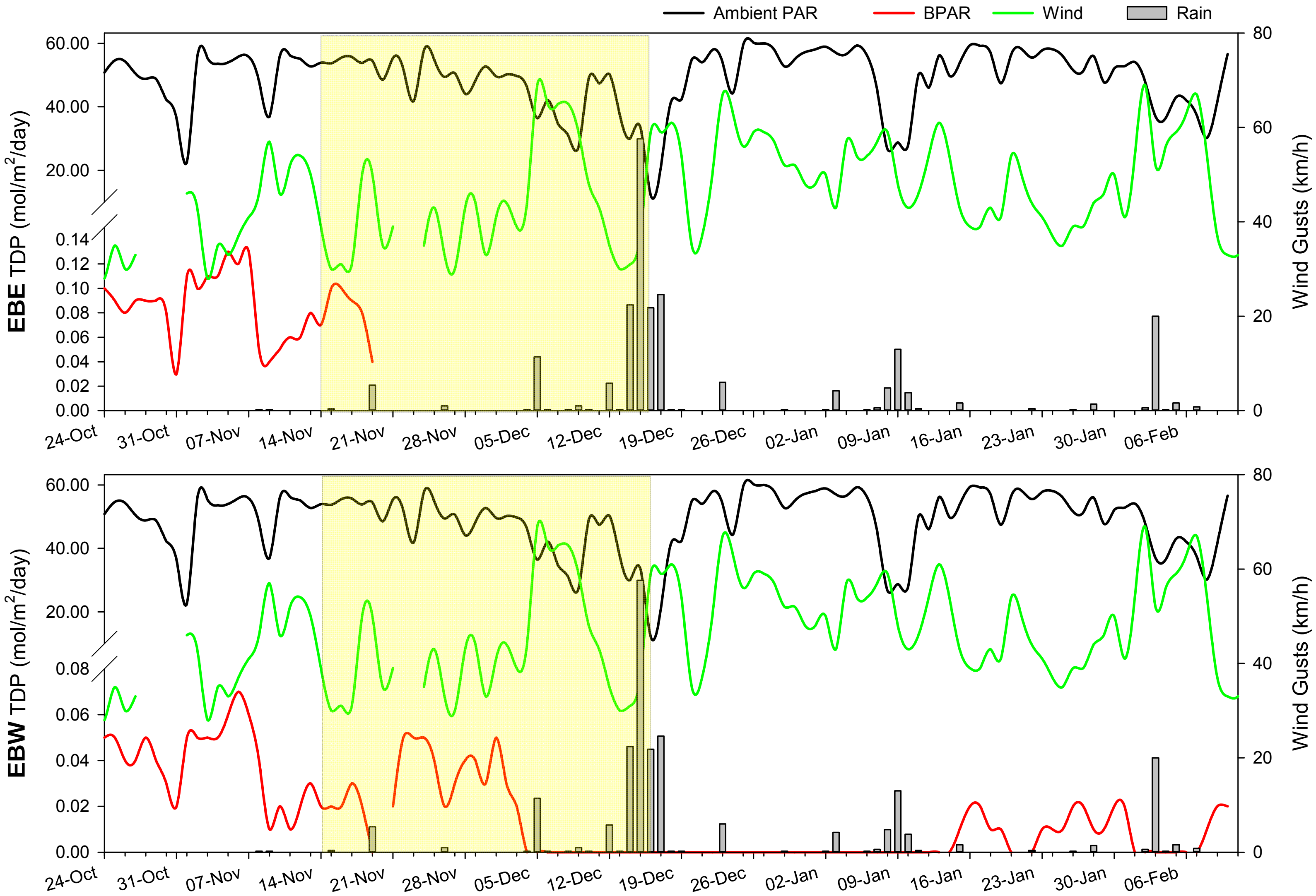

Figure 10. Total daily BPAR at EBE and EBW from 24 October 2018 to 10 February 2019 in comparison to ambient wind and rain.
Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS. Note data from the BPAR exchange day on 20 November were not utilized in plots or statistics.

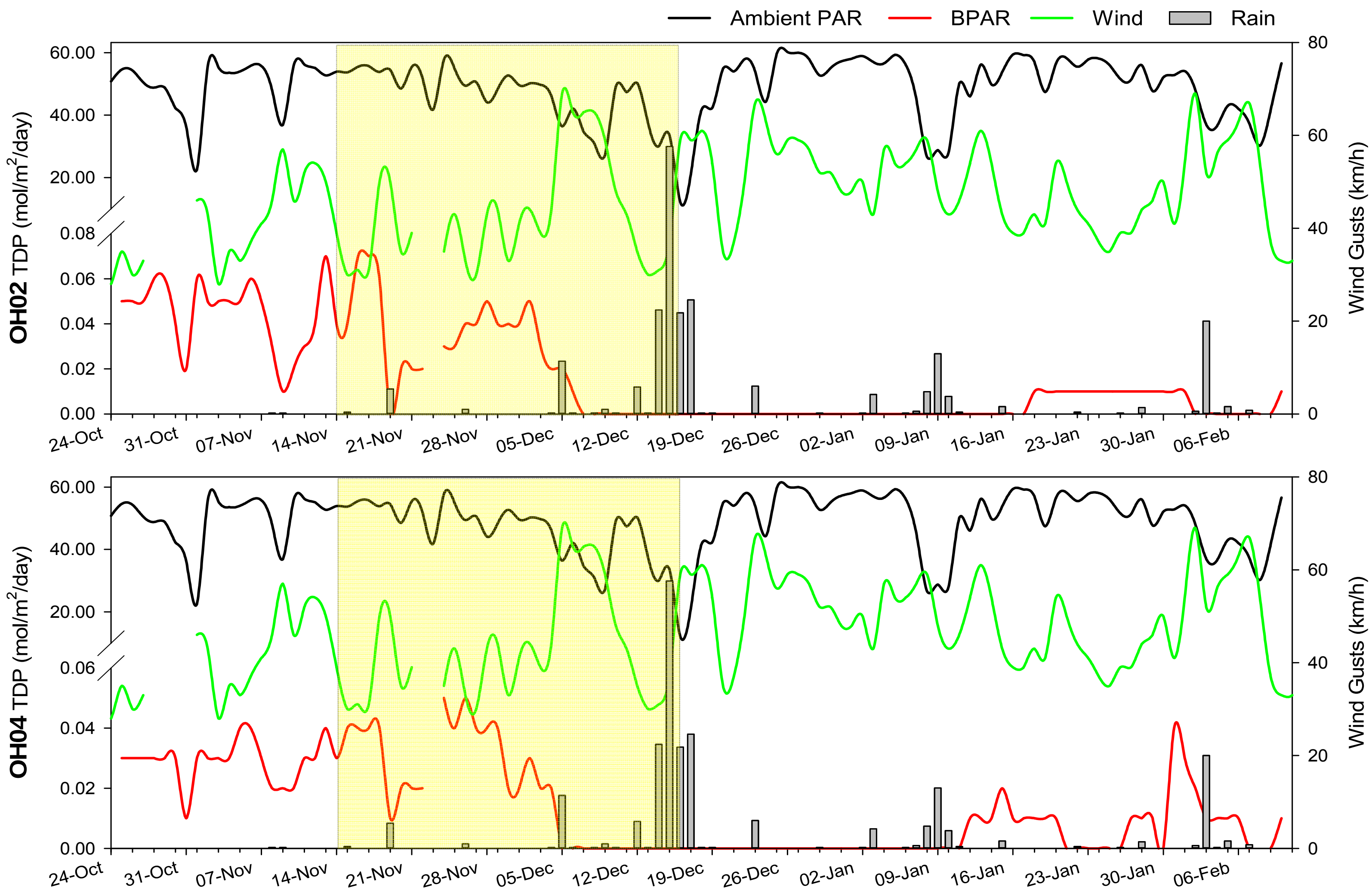

Figure 11. Total daily BPAR at OH02 and OH04 from 25 October 2018 to 10 February 2019 in comparison to ambient wind and rain.
Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS. Note data from the BPAR exchange day on 23 November were not utilized in plots or statistics.

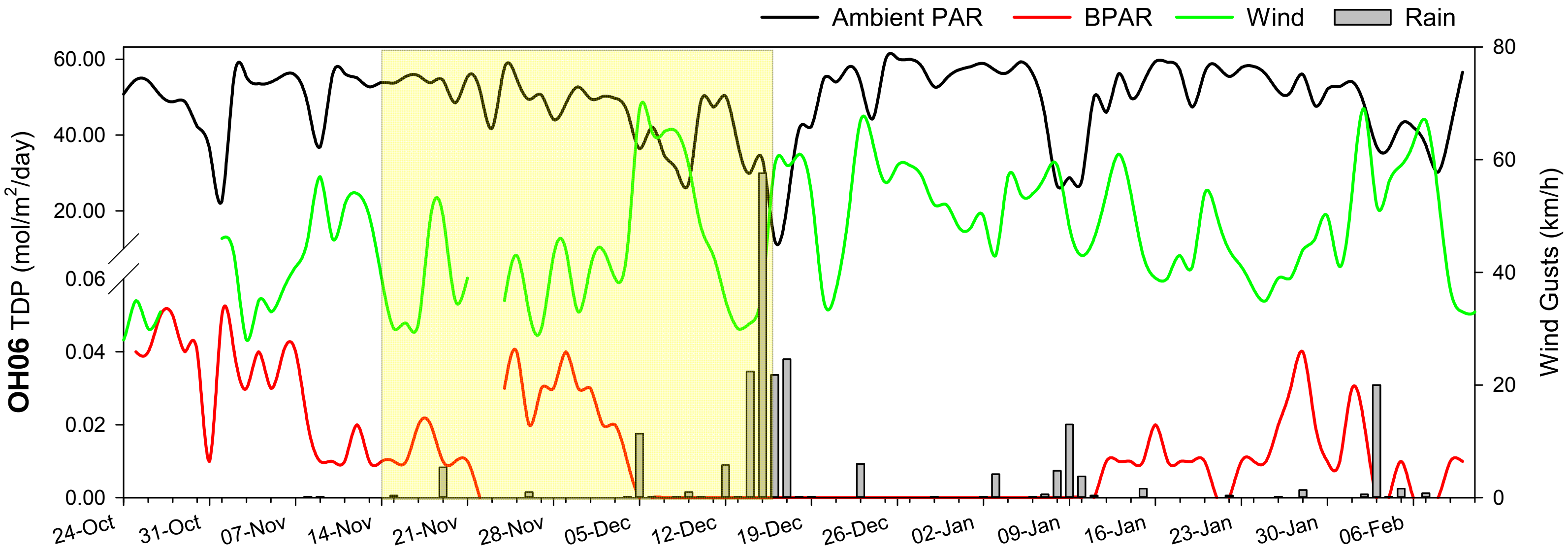

Figure 12. Total daily BPAR at OH06 from 25 October 2018 to 10 February 2019 in comparison to ambient wind and rain.
Yellow highlighted periods indicate when dredge spoil disposal was occurring at EBSDS. Note data from the BPAR exchange day on 23 November were not utilized in plots or statistics.

BPAR was only able to be measured at site EBE for the first month of the deployment period due to a malfunction (battery loss and instrument failure) of both Odyssey loggers deployed at this site from November to February. For the remaining sites, minimal light (< 0.01 mol/m^2/day) was recorded at the benthos from approximately 5 December 2018 to 11 January 2019, when TDP > 0.01 mol/m^2/day were again recorded.

There are three major environmental factors that can affect BPAR: the available ambient light, water depth and water clarity. Ambient light, as measured by VB PAR, ranged from 12.2 to 60.2 mol/m^2/day during the deployment period. During the period of minimal BPAR (5 December to 11 January) at all sites, average ambient TDP was ~ 45 mol/m^2/day, lower than mean ambient TDP during the deployment period prior to and after this period (~ 51 mol/m^2/day). Rainfall (and associated cloud cover) was recorded frequently from the 5 to 18 December lowering the average ambient TDP during this period to ~ 35 mol/m^2/day. A second period of rainfall (and associated cloud cover) from the 8 to 10 January when average ambient TDP dropped to ~ 28 mol/m^2/day, would have also contributed to lower overall minimal BPAR during this period.

Water clarity was not measured by VE instrumentation during this deployment period and the turbidity data collected by the GPC instruments is being processed separately. Therefore, it cannot be ascertained whether the period of minimal BPAR was also impacted by changes in water clarity. However, monitoring in the EBSDS and other offshore Port Curtis sites over several previous programs (Vision Environment, 2015, 2016, 2017, 2018, 2019) has ascertained that elevated wind speeds and waves often result in higher turbidity, and thus lower water clarity, due to resuspension of benthic sediments. Wind speeds from 19 December 2018 to 14 January 2019 (during the period of minimal BPAR not impacted by rainfall) averaged 52 km/h, which were much higher than wind speeds from 15 to 31 January (43 km/h). Average ambient TDP for the two periods were similar (51 and 55 mol/m^3/day, respectively). The results of the altimeter data demonstrated a high level of sediment movement during this time period (Figures 7 and 8) suggesting that water clarity was likely to be low.

Of the four sites where BPAR data was gained for the entire deployment period, mean Benthic TDP was slightly higher at the shallower sites of EBW and OH02 (12.5 m depth) than at OH04 and OH06 (14 to 17.5 m depth). The shallowest site of EBE (10 m depth) exhibited higher TDP than the other sites during its one month of operation. Higher BPAR at shallower sites is due to the lower distance for light to travel to the benthos and thus the less light attenuation that can potentially occur than at the deeper sites.

There appeared to be no clear correlation between decreased BPAR and dredge material relocation during the period of dredge operations. The lowest period of recorded BPAR occurred generally during the post dredging period. As typically observed, BPAR is affected by a combination of the available ambient light (impacted by rainfall and associated cloud cover), water depth and water clarity (impacted by turbidity, which is in turn impacted by increasing wind speeds and changing wind direction). These driving factors appeared to be more influential on light availability to the benthos than dredge activities during the 2018 GPC maintenance dredge operations.

4 REFERENCES

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5 APPENDIX

Table 5 Net Bed Level Change statistics from data collected from altimeters
Note altimeters permitted to settle for 12 to 24h prior to setting baseline bed level based on depth readings.

Phase	Date	Net cumulative bed level change from initial deployment (mm)				
		EBE	EBW	OH02	OH04	OH06
Pre-dredge 22 days	23/10/2019	Deployment		-	-	-
	24/10/2018	3	3	Deployment		
	25/10/2018	4	6	0	1	1
	26/10/2018	4	9	0	0	2
	27/10/2018	6	8	0	2	2
	28/10/2018	7	7	0	7	0
	29/10/2018	8	9	-1	10	1
	30/10/2018	10	8	-1	8	1
	31/10/2018	13	12	-2	7	2
	1/11/2018	12	9	-1	6	-2
	2/11/2018	13	13	-1	5	2
	3/11/2018	15	19	1	5	2
	4/11/2018	17	20	2	4	2
	5/11/2018	7	23	4	6	2
	6/11/2018	18	25	3	6	6
	7/11/2018	25	24	4	-3	8
	8/11/2018	16	26	5	-4	8
	9/11/2018	8	17	6	-5	5
	10/11/2018	2	21	8	-5	0
	11/11/2018	2	20	7	-6	2
	12/11/2018	2	19	5	-7	2
	13/11/2018	2	27	3	-7	2
Total pre-dredge		**2**	**27**	**3**	**-7**	**2**
Dredge 33 days	14/11/2018	1	33	4	-6	2
	15/11/2018	2	32	5	-6	2
	16/11/2018	2	31	8	-6	2
	17/11/2018	2	32	8	-4	3
	18/11/2018	2	35	6	-3	5
	19/11/2018	2	29	9	-3	5
	20/11/2018	2	37	8	-2	4
	21/11/2018	2	27	8	0	5
	22/11/2018	2	28	8	2	2
	23/11/2018	0	23	1	0	2
	24/11/2018	2	22	-7	-9	2
	25/11/2018	4	24	-12	-12	2
	26/11/2018	9	29	-18	-15	-5
	27/11/2018	11	36	-14	-13	-2
	28/11/2018	9	43	-11	-13	2

Phase	Date	Net cumulative bed level change from initial deployment (mm)				
		EBE	EBW	OH02	OH04	OH06
	29/11/2018	4	46	-5	-13	13
	30/11/2018	5	48	-3	-14	16
	1/12/2018	6	49	-2	-16	17
	2/12/2018	6	50	0	-17	19
	3/12/2018	7	50	-1	-10	24
	4/12/2018	8	49	-2	-10	25
	5/12/2018	8	59	0	-7	23
	6/12/2018	5	73	11	13	26
	7/12/2018	14	58	26	22	41
	8/12/2018	13	57	20	26	51
	9/12/2018	13	68	19	25	52
	10/12/2018	12	69	34	21	59
	11/12/2018	13	47	33	14	62
	12/12/2018	13	48	24	16	60
	13/12/2018	13	52	24	20	61
	14/12/2018	13	45	24	19	63
	15/12/2018	14	35	23	25	65
	16/12/2018	14	38	24	30	67
Total dredge		**12**	**11**	**21**	**37**	**65**
Post-dredge 54 days	17/12/2018	15	27	39	32	67
	18/12/2018	15	28	51	38	67
	19/12/2018	14	36	40	38	66
	20/12/2018	14	27	49	44	66
	21/12/2018	14	27	50	47	69
	22/12/2018	14	24	45	43	71
	23/12/2018	14	25	42	43	69
	24/12/2018	14	32	40	55	70
	25/12/2018	12	33	43	50	74
	26/12/2018	15	46	62	52	74
	27/12/2018	13	55	71	54	76
	28/12/2018	12	40	50	50	80
	29/12/2018	14	26	36	49	79
	30/12/2018	21	25	44	53	79
	31/12/2018	22	25	52	45	79
	1/01/2019	23	34	46	46	76
	2/01/2019	25	44	45	46	74
	3/01/2019	24	49	48	39	78
	4/01/2019	22	58	52	41	80
	5/01/2019	23	37	63	45	78
	6/01/2019	23	23	59	45	74
	7/01/2019	23	23	42	48	75
	8/01/2019	25	40	32	51	70

Phase	Date	Net cumulative bed level change from initial deployment (mm)				
		EBE	EBW	OH02	OH04	OH06
	9/01/2019	27	69	29	43	73
	10/01/2019	26	48	38	42	74
	11/01/2019	29	48	38	41	78
	12/01/2019	27	42	35	36	85
	13/01/2019	21	58	46	34	89
	14/01/2019	19	28	30	42	92
	15/01/2019	20	41	33	40	91
	16/01/2019	21	40	48	37	92
	17/01/2019	21	34	48	35	91
	18/01/2019	23	35	50	38	94
	19/01/2019	24	33	50	38	97
	20/01/2019	25	34	50	37	106
	21/01/2019	24	34	49	41	109
	22/01/2019	25	30	47	44	122
	23/01/2019	24	31	45	44	121
	24/01/2019	26	24	45	43	117
	25/01/2019	26	20	44	41	120
	26/01/2019	25	25	24	40	125
	27/01/2019	25	32	18	23	129
	28/01/2019	25	37	17	26	128
	29/01/2019	26	36	17	27	131
	30/01/2019	27	34	21	27	132
	31/01/2019	30	35	19	26	134
	1/02/2019	31	34	22	27	132
	2/02/2019	28	36	29	25	129
	3/02/2019	25	39	32	28	131
	4/02/2019	24	38	32	21	128
	5/02/2019	27	35	32	24	125
	6/02/2019	20	29	37	33	136
	7/02/2019	20	29	22	45	141
	8/02/2019	20	22	30	47	147
Total post-dredge		**6**	**-16**	**6**	**17**	**80**

Table 6 Total Daily PAR (TDP) at sedimentation sites and Vision Base (VB) from 24 October 2018 to 10 February 2019.
Note data from the BPAR exchange day on 20 or 23 November 2018 were not utilized in plots or statistics.

Phase	Date	TDP (mol/m²/day)					
		EBE	EBW	OH02	OH04	OH06	VB
Pre-Dredge	24/10/2018	0.10	0.05				51
	25/10/2018	0.09	0.05	0.05	0.03	0.04	55
	26/10/2018	0.08	0.04	0.05	0.03	0.04	54
	27/10/2018	0.09	0.04	0.05	0.03	0.05	51
	28/10/2018	0.09	0.05	0.06	0.03	0.05	49
	29/10/2018	0.09	0.04	0.06	0.03	0.04	49
	30/10/2018	0.08	0.03	0.04	0.03	0.04	42
	31/10/2018	0.03	0.02	0.02	0.01	0.01	36
	1/11/2018	0.11	0.05	0.06	0.03	0.05	23
	2/11/2018	0.10	0.05	0.05	0.03	0.04	56
	3/11/2018	0.11	0.05	0.05	0.03	0.03	55
	4/11/2018	0.11	0.05	0.05	0.03	0.04	54
	5/11/2018	0.13	0.06	0.05	0.04	0.03	54
	6/11/2018	0.12	0.07	0.06	0.04	0.04	56
	7/11/2018	0.13	0.06	0.05	0.03	0.04	56
	8/11/2018	0.05	0.04	0.03	0.02	0.02	48
	9/11/2018	0.04	0.01	0.01	0.02	0.01	37
	10/11/2018	0.05	0.02	0.02	0.02	0.01	56
	11/11/2018	0.06	0.01	0.03	0.03	0.01	56
	12/11/2018	0.06	0.02	0.04	0.03	0.02	55
	13/11/2018	0.08	0.03	0.07	0.04	0.01	53
Dredge	14/11/2018	0.07	0.02	0.04	0.03	0.01	54
	15/11/2018	0.10	0.02	0.04	0.04	0.01	54
	16/11/2018	0.10	0.02	0.07	0.04	0.01	55
	17/11/2018	0.09	0.03	0.07	0.04	0.02	56
	18/11/2018	0.08	0.02	0.06	0.04	0.02	54
	19/11/2018	0.04	0.00	0.00	0.01	0.01	54
	20/11/2018			0.02	0.02	0.01	48
	21/11/2018		0.02	0.02	0.02	0.01	55
	22/11/2018		0.05	0.02	0.02	0.00	52
	23/11/2018		0.05				42
	24/11/2018		0.05	0.03	0.05	0.03	58
	25/11/2018		0.04	0.03	0.04	0.04	55
	26/11/2018		0.02	0.04	0.05	0.02	49
	27/11/2018		0.03	0.04	0.04	0.03	51
	28/11/2018		0.04	0.05	0.04	0.03	44
	29/11/2018		0.04	0.04	0.04	0.04	48
	30/11/2018		0.03	0.04	0.02	0.03	53
	1/12/2018		0.05	0.04	0.02	0.03	50
	2/12/2018		0.03	0.05	0.03	0.02	50

Phase	Date	TDP ($mol/m^2/day$)					
		EBE	EBW	OH02	OH04	OH06	VB
	3/12/2018		0.02	0.03	0.02	0.02	50
	4/12/2018		0.00	0.02	0.02	0.01	46
	5/12/2018		0.00	0.02	0.00	0.00	36
	6/12/2018		0.00	0.01	0.00	0.00	42
	7/12/2018		0.00	0.00	0.00	0.00	35
	8/12/2018		0.00	0.00	0.00	0.00	31
	9/12/2018		0.00	0.00	0.00	0.00	27
	10/12/2018		0.00	0.00	0.00	0.00	49
	11/12/2018		0.00	0.00	0.00	0.00	47
	12/12/2018		0.00	0.00	0.00	0.00	50
	13/12/2018		0.00	0.00	0.00	0.00	38
	14/12/2018		0.00	0.00	0.00	0.00	30
	15/12/2018		0.00	0.00	0.00	0.00	34
	16/12/2018		0.00	0.00	0.00	0.00	12
Post-dredge	17/12/2018		0.00	0.00	0.00	0.00	21
	18/12/2018		0.00	0.00	0.00	0.00	42
	19/12/2018		0.00	0.00	0.00	0.00	42
	20/12/2018		0.00	0.00	0.00	0.00	55
	21/12/2018		0.00	0.00	0.00	0.00	54
	22/12/2018		0.00	0.00	0.00	0.00	58
	23/12/2018		0.00	0.00	0.00	0.00	54
	24/12/2018		0.00	0.00	0.00	0.00	44
	25/12/2018		0.00	0.00	0.00	0.00	60
	26/12/2018		0.00	0.00	0.00	0.00	60
	27/12/2018		0.00	0.00	0.00	0.00	60
	28/12/2018		0.00	0.00	0.00	0.00	58
	29/12/2018		0.00	0.00	0.00	0.00	53
	30/12/2018		0.00	0.00	0.00	0.00	55
	31/12/2018		0.00	0.00	0.00	0.00	57
	1/01/2019		0.00	0.00	0.00	0.00	58
	2/01/2019		0.00	0.00	0.00	0.00	59
	3/01/2019		0.00	0.00	0.00	0.00	57
	4/01/2019		0.00	0.00	0.00	0.00	57
	5/01/2019		0.00	0.00	0.00	0.00	59
	6/01/2019		0.00	0.00	0.00	0.00	56
	7/01/2019		0.00	0.00	0.00	0.00	45
	8/01/2019		0.00	0.00	0.00	0.00	27
	9/01/2019		0.00	0.00	0.00	0.00	29
	10/01/2019		0.00	0.00	0.00	0.00	28
	11/01/2019		0.00	0.00	0.00	0.00	50
	12/01/2019		0.00	0.00	0.01	0.01	46
	13/01/2019		0.00	0.00	0.01	0.01	56

Phase	Date	TDP (mol/m²/day)					
		EBE	EBW	OH02	OH04	OH06	VB
	14/01/2019		0.00	0.00	0.01	0.01	50
	15/01/2019		0.01	0.00	0.02	0.01	54
	16/01/2019		0.02	0.00	0.01	0.02	59
	17/01/2019		0.02	0.00	0.01	0.01	59
	18/01/2019		0.01	0.01	0.01	0.01	57
	19/01/2019		0.01	0.01	0.01	0.01	47
	20/01/2019		0.00	0.01	0.01	0.01	56
	21/01/2019		0.00	0.01	0.00	0.00	58
	22/01/2019		0.00	0.01	0.00	0.00	55
	23/01/2019		0.01	0.01	0.00	0.01	58
	24/01/2019		0.01	0.01	0.00	0.01	58
	25/01/2019		0.01	0.01	0.00	0.01	56
	26/01/2019		0.02	0.01	0.00	0.02	52
	27/01/2019		0.02	0.01	0.01	0.03	51
	28/01/2019		0.01	0.01	0.01	0.04	56
	29/01/2019		0.01	0.01	0.01	0.02	48
	30/01/2019		0.02	0.01	0.00	0.01	52
	31/01/2019		0.02	0.01	0.04	0.01	53
	1/02/2019		0.00	0.01	0.03	0.03	54
	2/02/2019		0.00	0.00	0.02	0.02	48
	3/02/2019		0.00	0.00	0.01	0.00	37
	4/02/2019		0.00	0.00	0.01	0.00	37
	5/02/2019		0.00	0.00	0.01	0.01	43
	6/02/2019		0.00	0.00	0.01	0.00	42
	7/02/2019		0.00	0.00	0.00	0.00	37
	8/02/2019		0.01	0.00	0.00	0.00	30
	9/02/2019		0.02	0.00	0.00	0.01	42
	10/02/2019		0.02	0.01	0.01	0.01	57