Quarterly Monitoring Report

Post Dredging

LPC Channel Deepening Project

Lyttelton Port Company
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Port
Company

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1 Introduction

Lyttelton Port Company (LPC) completed Stage 1 of the Channel Deepening Project (CDP) on the 29th of November 2018. LPC then undertook dredging associated with Stage 1 of the Te Awaparahi Bay Reclamation Project. Reclamation dredging commenced 12th March 2019 with the first disposal to the offshore ground on the 13th March. Typical daily dredge/disposal volumes were in the order of 1,200-1,800 cubic meters. This compared to daily volumes of 70,000-90,000 cubic meters during Channel Deepening with the *Fairway*. Reclamation dredging was completed on the 23rd of March 2020.

The seabed deposition and disposal activities associated with both the CDP and reclamation dredging are authorised under resource consents CRC172455 and CRC172522 (collectively, "the Consents") issued by the Canterbury Regional Council (CRC).

The reclamation is in Te Awaparahi Bay, Lyttelton Harbour. Ten hectares (10ha) has already been constructed out of earthquake rubble. The next section, Stage 1, will extend the reclamation southward to enable construction of a wharf (Figure 1). To reduce land settlement times, 12-15 m depth of soft seabed sediments under the southern edge of the reclamation need to be removed (Figure 2). This is being achieved via a backhoe dredge and attendant split hopper barges.

Figure 1 – Reclamation location and stages.

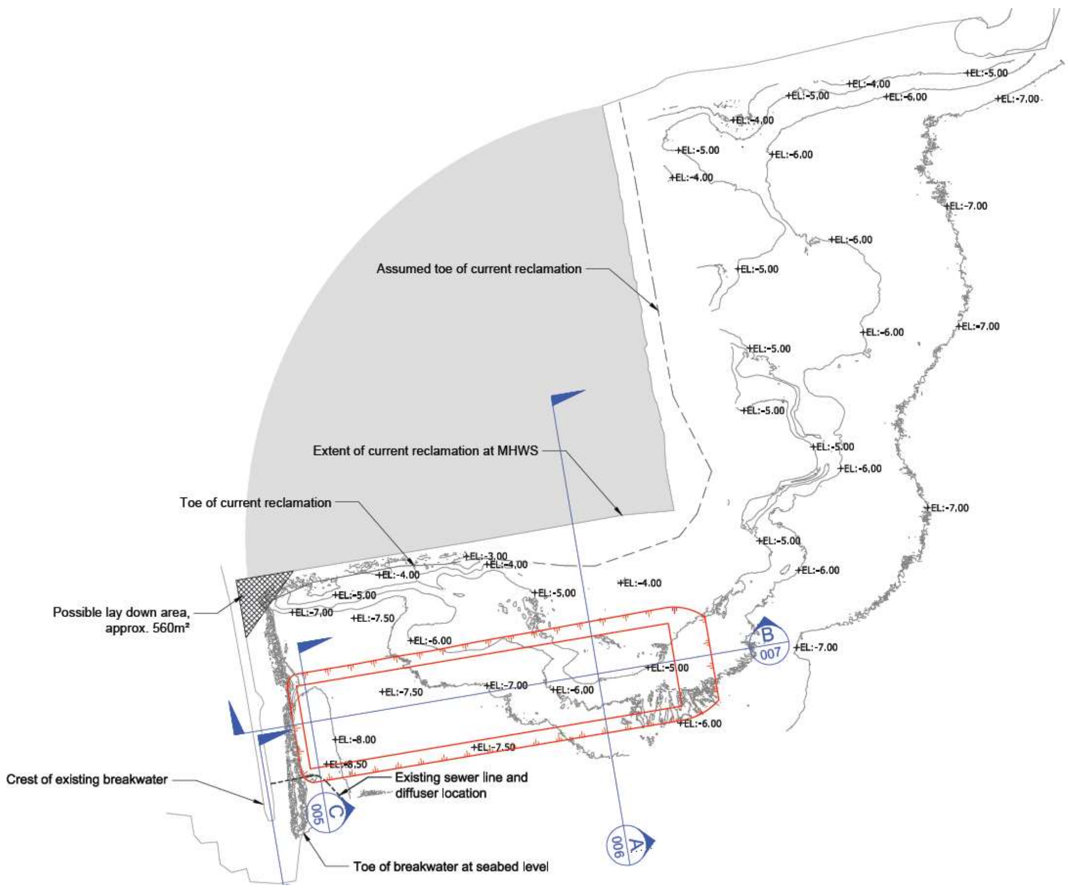

Figure 2 – Location of dredge area (in red) and surrounding bathymetry.

2 Consent Requirements

This report fulfils the requirement of Condition 8.16 of CRC172522/455, and covers the CDP and reclamation dredging from 1 April 2020 to 31 July 2020.

> *"8.16 During and after a Dredging Stage, the CHPT shall provide to the TAG, PRG, ALG and the Consent Authority, no later than the end of the third working week of the month, a quarterly report that reviews the monitoring and management response measures carried out during the previous four months and which shall include, but not be limited to, the following:*
>
> *8.16.1 Collation of all the monitoring undertaken; and*
>
> *8.16.2 Details of any triggers that have been exceeded, the management response measures carried out and the results of monitoring after the management response measures have been completed. "*

This report is the sixth quarterly report, detailing the findings in the post-dredging phase from April to July 2020 (dredging ceased on 23 March 2020).

Within 12 months of dredging ceasing, a post dredge report will be issued which will cover both channel deepening and reclamation dredging.

3 Dredge Stage Monitoring

The following monitoring has been undertaken in the preceding four months of the project:

- Water quality monitoring (including comments on any trigger exceedance) - Vision Environment
- Physical Shoreline Monitoring (undertaken in May/June 2020)- Tonkin and Taylor

Note that due to level 4 COVID-19 restrictions in New Zealand that were implemented on 25th March 2020, routine maintenance of continuous surface instruments could not be completed during this time. Therefore, rigorous cleansing of fouled raw data was undertaken resulting in some sites having periods of missing data. COVID-19 restrictions were lowered to level 3 on the 27th April allowing equipment maintenance and water sampling to recommence.

Ecological monitoring undertaken by Cawthron in July 2020 was not available for inclusion in this report at the time of issue. This data will be appended to this report when made available.

3.1 Water Quality Monitoring

Water quality monitoring was undertaken by Vision Environment.

The water quality monitoring included data collection of the climatic and oceanic conditions, real-time surface turbidity, benthic turbidity, benthic photosynthetically active radiation (BPAR), sedimentation, physiochemical parameters and water sample analyses, and depth profiling. Monitoring collection was undertaken via instrumentation located at 15 sites throughout Lyttelton Harbour/Whakaraupō and offshore Banks Peninsula. Monthly water sampling was also undertaken at these locations by Vision Environment staff.

A monthly monitoring report outlining the results of the water quality monitoring, climatic data, water sample testing is completed by Vision Environment for each month (April, May, June and July).

A copy of each report is included in **Appendix A**.

3.2 Physical Shoreline Monitoring

Tonkin+Taylor Ltd undertook the physical shoreline monitoring, comprising beach profiles, photo point monitoring and sediment size analysis. Note that in this report they refer to during dredging as the main dredging phase with the Fairway.

A copy of the report is included as **Appendix B**.

4 Dredge management

Due to the cessation of dredging operations on the 23rd of March, dredge management and comparison of turbidity against trigger levels were not required during this reporting period.

Water quality monitoring reports from Vision Environment do include comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 with that recorded during this reporting period (April – July 2020).

5 Recommendations

There are no recommendations at this stage.

6 Applicability

Enviser Ltd has prepared this report for Lyttelton Port Company in accordance with the agreed scope. No other party may rely on this report, or any conclusions or opinions within it, for any purpose without the express written permission of Enviser Ltd.

The opinions and conclusions within this report are based on the information that was viewed during preparation of the report.

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Appendix A: Water Quality Monthly Reports

Lyttelton Port Company Channel Deepening Project Environmental Monitoring Water Quality Environmental Monitoring Services – Monthly Report April 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring Water Quality Environmental Monitoring Services – Monthly Report May 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring Water Quality Environmental Monitoring Services – Monthly Report June 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring Water Quality Environmental Monitoring Services – Monthly Report July 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

April 2020

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Certified System Quality ISO 9001 SAI GLOBAL
Certified System ISO 45001 Occupational Health and Safety SAI GLOBAL
Certified System Environment ISO 14001 SAI GLOBAL

FILE REFERENCE

190620 FINAL LPC Water Quality Environmental Monitoring April 2020_VE

Summary

Since September 2016, Vision Environment (VE) has been undertaking water quality monitoring for the Environmental Monitoring and Management Plan (EMMP) associated with the Lyttelton Port Company (LPC) Channel Deepening Project (CDP) (Envisor, 2018). Baseline datasets were acquired from three spoil ground sites (SG1, SG2 and SG3), seven offshore sites (OS1 to OS7) and five inshore sites (UH1 to UH3, CH1 and CH2) to assess potential impacts of the dredging project.

Dredging operations for the CDP were undertaken from 29 August to 29 November 2018. Post-dredge monitoring was undertaken until 11 March 2019, when a smaller dredging operation began for the reclamation works at Cashin Quay and was completed on 23 March 2020. Channel maintenance dredging commenced at midday on 4 December 2019 and was completed 21 March 2020, thus commencing the post dredging monitoring phase, which will cease on project completion on 31 July 2020.

Post Dredge monitoring results collected during April 2020 are presented within this report. This monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018).

Note that due to level 4 COVID-19 restrictions in New Zealand that were implemented on 25 March, routine maintenance of continuous surface instruments could not be completed during this time. Therefore, rigorous cleansing of fouled raw data was undertaken resulting in some sites having periods of missing data. COVID-19 restrictions were lowered to level 3 on the 27 April allowing equipment maintenance and water sampling to recommence.

Climatic Conditions: During April lower rainfall was recorded at Cashin Quay (16.8 mm) than during March (25 mm), with highest daily rainfall recorded on 18 April at (14.9 mm). Peak flows from the Waimakariri River were recorded on the 28 April at a maximum flow rate of 273 m^3/s, similar to the low peak flow rate in March.

Monthly average air temperature (13.6°C) was lower than the mean air temperature of March (15.2°C) in line with seasonal cooling. Similar to previous months' inshore winds were generally from an easterly to north-easterly direction, with the highest mean daily wind speed of 19.7 kts recorded on 14 April. The highest offshore mean daily wind speeds (> 15 kts) were recorded on 4, 5 and 14 April, with greatest mean daily significant wave height also recorded on 12 April (3.3 m).

Currents: Current data was recorded at SG1, SG2a (WatchKeeper) and SG3 during April. Maximum near-surface current speeds at SG1, SG3 occurred on 4 April and at SG2a on 15 April. Maximum near-seabed current speeds were recorded on the 5, 14 and 28 April concurrent with dominant metocean forces of significant wave events (> 1m) and winds coming from a west south-westerly direction.

Near-surface predominant current movement for SG1 tended towards a west-northwest direction and SG3 tended to move in an east-southeast direction, while near-seabed currents at both locations predominantly moved in an east-southeast direction. In contrast, both near-surface and near-seabed currents at SG2a moved in eastward and westward direction, as consistently found.

Turbidity: Consistent with previous results, turbidity was higher overall at the inshore monitoring sites of the central and upper harbour than at the offshore and spoil ground monitoring locations. Mean turbidity values for April in addition to percentile statistics were lower than those recorded during the baseline monitoring period.

Short-lived elevated surface turbidity was recorded at all sites on multiple days in April coinciding with moderate to high inshore and offshore winds and significant wave heights >1 m. The majority of sites displayed increased turbidity around 5 to 7 April when strong offshore wind speeds and significant wave heights were recorded.

Benthic turbidity responded to both wind speed and wave height events in April. As typically observed, mean benthic turbidity was more elevated then their surface counterparts throughout the month.

Other Physicochemical Parameters: As expected mean monthly water temperatures were lower to those recorded in March with all sites displaying a seasonal decline. Unlike previous summer months, slightly lower temperatures are recorded in the upper and central harbour than the offshore sites, consistent with previous winter sampling periods. Benthic temperatures were consistent with those at the surface indicating a well-mixed water column.

Consistent with previous reports, surface and benthic pH during April was similar across all sites. As previously observed inner harbour sites recorded lower mean conductivity values than offshore and spoil ground sites.

Dissolved oxygen (DO) concentrations showed strong diurnal fluctuations at all sites during April. DO at inshore and offshore sites exhibited a similar pattern with declining DO (<90% saturation) at the beginning of the month followed by a period of stability before a gradual increase in DO concentrations after 19 April to the end of the month. These patterns may be following a cycle of degrading and recovering algal bloom populations. Benthic DO, although lower than surface counterparts followed similar trends.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 29 April 2020, and once again a well-mixed water column was indicated. DO displayed a decreasing gradient through the water column at nearshore and offshore sites due to lower photosynthesis at depth.

Turbidity and total suspended solids (TSS) measurements for surface waters were again elevated at inshore sites compared to the offshore areas, resulting in the shallowest estimations of euphotic depth as typically recorded during the monitoring program. Euphotic depths at the offshore monitoring locations were relatively high; estimated to be at 15.1 m at SG1. No exceedances of WQGs were observed for sub-surface turbidity during the April sampling period.

Unlike previous months, total phosphorous concentrations showed no particular spatial pattern though no exceedances of WQG were recorded across the sites. Dissolved reactive phosphorous concentrations were above the WQG at all sites in April as intermittently found. Both total nitrogen and total kjeldahl nitrogen (TKN) were below the limit of reporting (LOR) and below WQG at all sites. Total Ammonia was recorded above WQG at all but five sites, three of which were located in the upper harbor. Nitrogen oxide concentrations were above WQG at nearly half of the monitoring sites located both inshore and offshore. Concentrations of bioavailable nutrients were unusually high and this may be an anomaly related to the Covid19 delay in sampling processing.

Chlorophyll-*a* concentrations were moderate across all sites and exceeded the WQG value (4 µg/L) at three sites offshore, indicating higher than normal algal populations potentially due to the readily bioavailable nutrients.

As commonly reported, the majority of metals were reported as below the limit of reporting (LOR) and no dissolved metal fraction exceeded the designated WQG among the sites. Total aluminium concentrations did exceed the designated WQG at sites except three in the upper channel, but the dissolved and therefore readily bioavailable fraction, remained undetectable. Total aluminium, iron and manganese displayed a strong spatial difference with elevated concentrations found in the inshore locations (associated with increased suspended sediments). Total and dissolved chromium, vanadium and molybdenum were also detected during April but little spatial variability was noted.

Benthic Photosynthetically Active Radiation (BPAR): April's shorter days were reflected in the lower levels of ambient sunlight compared with recent months. Mean BPAR at both OS2 and OS3 were lower compared to the mean for March and almost negligible compared to summer months. However mean BPAR at OS3 was slightly higher than OS2, most likely as a result of lower turbidity at that site.

Sedimentation: Overall accumulation of sediments at OS2 and UH3 were evident during April, though data for OS2 was only available until 12 April. As observed in previous months, bed level within the sheltered upper harbour at UH3 was more stable than that at OS2. UH3 exhibited a gradual period of sediment accretion at the beginning of the month and a long period of stability mid-month, ending the month with short gradual periods of accretion and erosion.

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Acronyms

ADCP	Acoustic Doppler Current Profiler
BPAR	Benthic Photosynthetically Active Radiation
BSL	Benthic self-logging sonde
CDP	Channel Deepening Project
DO	Dissolved oxygen
ECan	Environment Canterbury
EMMP	Environmental Monitoring and Management Plan
K_d	Light attenuation coefficient
KZ filter	Kolmogorov-Zurbenko filter
LOR	Limits of Reporting
LPC	Lyttelton Port Company
LYT	Lyttelton Port of Christchurch
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
QA/QC	Quality Assurance/Quality Control
SL	Self-Logger
ST	Subsurface telemetry
ST/ADCP	Subsurface telemetry/Acoustic Doppler Current Profiler
TAG	Technical Advisory Group
TDP	Total daily PAR
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VBCC	Vision Base Christchurch
VE	Vision Environment
WK	WatchKeeper telemetered weather station
WQG	Water Quality Guidelines

1 INTRODUCTION

Lyttelton Port Company (LPC) is undertaking a Channel Deepening Project (CDP) to extend the existing navigational channel to allow larger vessels access to the Lyttelton Port of Christchurch (LYT), the South Island's largest port. Utilising background information provided by LPC and advice from the Technical Advisory Group (TAG) in relation to ambient conditions, locations of sensitive habitats and dredge impact hydrodynamic modelling scenarios, a water quality monitoring program was designed.

Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August 2018 with completion of works on 29 November 2018. Monitoring continued into a post-dredge phase up until 11 March 2019 when smaller scale dredging operations for the reclamation works commenced and was completed on 23 March 2020. Note that maintenance dredging of the channel was undertaken from 4 December 2019 to 21 March 2020, with spoil being relocated to the maintenance dredge spoil ground located off Godley Head. The interpreted environmental data provided by VE supports the process of the Environmental Monitoring and Management Plan (EMMP) for the LPC CDP (Envisor, 2018) and will assist to ascertain the potential impacts of the projects.

All dredge operations were completed on 23 March 2020. Post Dredge monitoring will continue until 31 July 2020 when monitoring for the Project will be completed.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for the baseline and operations phases of water quality monitoring is provided in this section. A more detailed description of the importance of the measured parameters and the specific methodology for the CDP data collection and processing protocols can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

2.1.1 Monitoring Locations and Equipment

Guided by the results of preliminary hydrodynamic modelling (MetOcean, 2016a, b) in addition to advice from the TAG, baseline and dredge operations, monitoring sites were located outside the area of predicted direct impact (i.e. dredge footprint and offshore disposal ground), but within the zone of dredging and dredge material placement influence, in addition to being in the vicinity of sensitive receptors (e.g. mussels farms and important mahinga kai sites). For ease of identification the harbour was divided into four areas: spoil ground (SG); offshore (OS); central harbour (CH); and upper harbour (UH), in which 15 locations were selected for monitoring (Figure 1). In each area, one to three monitoring sites were selected for the deployment of the various individual types of equipment, which are identified in Table 1. A total of 22 monitoring units were deployed across the 15 locations.

The offshore monitoring area (encompassing monitoring sites SG1 to SG3 and OS1 to OS7) is a deep water (generally >15 m) oceanic environment, where turbidity appears to be mostly driven by wind speeds and wave heights, resulting in resuspension of material from the benthos. A combination of both surface loggers and benthic loggers have been utilised at several offshore locations.

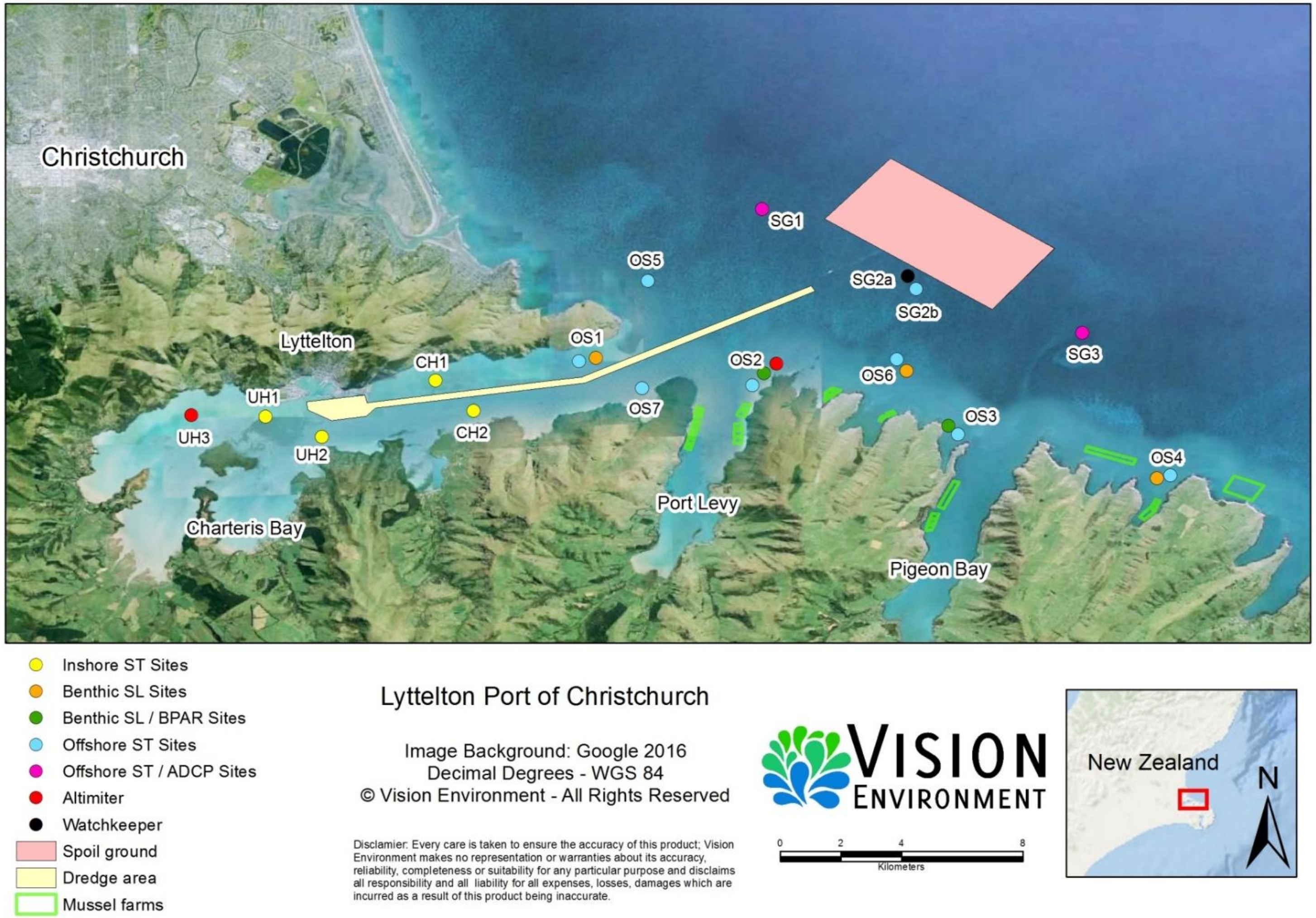


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

Table 1 Summary of monitoring sites and deployment equipment for the LPC Channel Deepening Project.
ST = subsurface telemetry, SL = self-logger, BSL = benthic self-logger, BPAR = benthic photosynthetically active radiation, and ADCP = Acoustic Doppler Current Profiler, WK = WatchKeeper telemetered weather station.

Site	WK	ST/ADCP	ST	BSL sonde	BSL sonde/BPAR	Altimeter
	WatchKeeper telemetered weather station with currents and waves	Subsurface telemetered dual physico-chemistry and currents	Subsurface telemetered dual physico-chemistry	Benthic self-logging dual physico-chemistry	Benthic self-logging dual physico-chemistry and self-logging BPAR	Benthic self-logging dual altimeter
SG2a	√					
SG2b			√			
SG1		√				
SG3		√				
OS1			√	√		
OS2			√		√	√
OS3			√		√	
OS4			√	√		
OS5			√			
OS6			√	√		
OS7			√			
CH1			√			
CH2			√			
UH1			√			
UH2			√			
UH3						√
Total	1	2	12	3	2	2

The inshore monitoring area (including monitoring sites CH1 and CH2, and UH1 to UH3) is a shallow (<10 m depth) marine environment that, in addition to wind speeds and wave heights, is also influenced by tides (~ 0.2 m/s). The water column is well mixed at these sites, with little to no stratification. Therefore, surface loggers only have predominantly been utilised at these sites.

The comprehensive water quality component of the program involves the monitoring of:

- Physicochemistry, including turbidity; temperature; pH; conductivity and DO;
- Light attenuation (Photosynthetic Active Radiation or PAR);
- Benthic light (Benthic Photosynthetic Active Radiation or BPAR);
- Total Suspended Solids (TSS);
- Sedimentation rates;
- Nutrients and chlorophyll *a*;
- Metals (total and dissolved); and
- Organic compounds (biannually).

This monthly report presents data collected from the 22 monitoring locations for April 2020 during the post-dredge phase of operations. Monthly water sampling and depth profiling was conducted on 29 April 2020. A summary of climatic conditions during this period is provided, in addition to the results of continuous and discrete water sampling with comparisons to the baseline monitoring period.

2.1.2 Water Quality Guidelines

Water quality monitoring data from LYT were compared to the Australian and New Zealand Water Quality Guidelines (WQG) default trigger values (ANZG, 2018). In the absence of specific trigger values for New Zealand estuarine or marine ecosystems, the WQG suggest the use of trigger values for south-east Australian estuarine and marine ecosystems.

Total metals represent the concentration of metals determined in an unfiltered sample (those bound to sediments or colloidal particles in addition to dissolved metals), while dissolved metals are defined as those which pass through a 0.45 µm membrane filter (APHA, 2005). Specific trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived for several metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZG, 2018). The LYT coastal environment could be described as slightly-to-moderately disturbed, therefore the 95% WQG trigger value was considered appropriate for comparison.

3 RESULTS & DISCUSSION

3.1 Metocean Conditions

3.1.1 Wind and precipitation

A total of 16.8 mm of rainfall was recorded at Cashin Quay during April 2020, which was lower to the precipitation recorded in March (25 mm). The highest recorded rainfall was on the 18 April at 14.9 mm (Metconnect, 2020) (Figure 2). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days' post flow. Flows for April were again low ranging between 26 m^3/s and 273 m^3/s with the maximum flow rate occurring on the 28 April (ECAN, 2020). These low rates were not expected to greatly impact harbour parameters.

Inshore winds during April were generally from an easterly to north-easterly direction (Metconnect, 2020). Highest mean wind speed (19.7 kts) was recorded on 14 April from a west south-westerly direction, with maximum wind gusts of 47 kts occurring on the 14, 15 and 27 April from a west and south-westerly direction. Elevated daily mean wind speeds over 15 kts were also recorded on the 4 and 5 April (15.8 and 17.7 kts) from an east north-easterly direction and again on 14 April (19.7 kts) from a westerly south-westerly direction.

Daily mean air temperatures at Cashin Quay ranged from 10°C to 18°C, resulting in a monthly mean temperature of 13.6°C, lower than the March mean temperature of 15.2°C (Metconnect, 2020) in line with seasonal cooling.

Offshore significant wave height peaked albeit short lived, at 3.3 m at 10:30 pm on 23 April, leading to a mean daily significant wave height of 1.7 m (Figure 3), which equated to the highest mean daily significant wave event in April. Significant wave heights >1m were recorded throughout the month of April. Highest mean daily offshore wind speed 20.6 kts was recorded on the 14 April with offshore winds predominantly being from a west north-westerly direction (Figure 29).

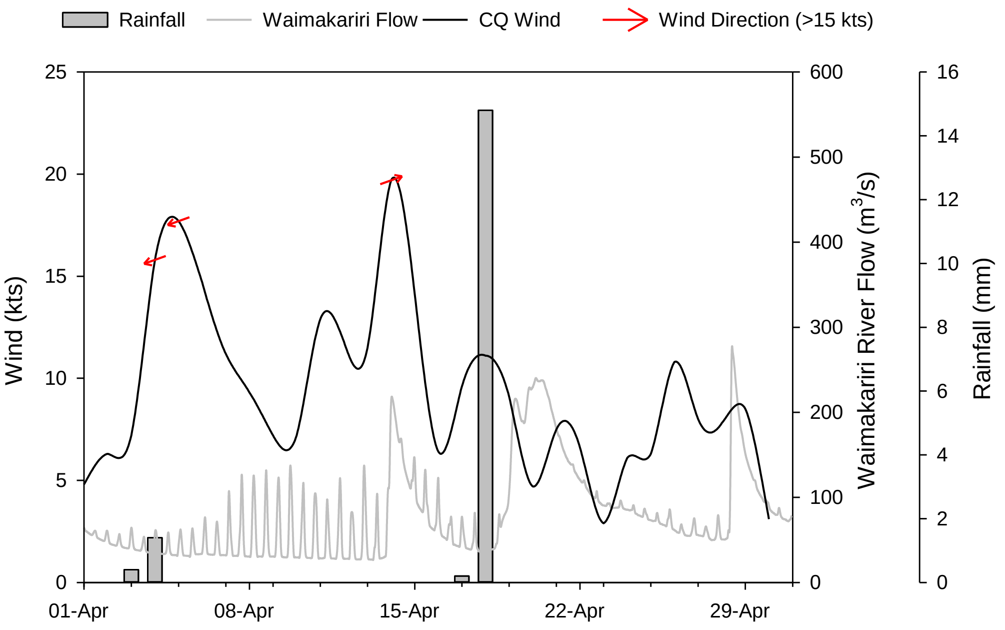


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during April 2020.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

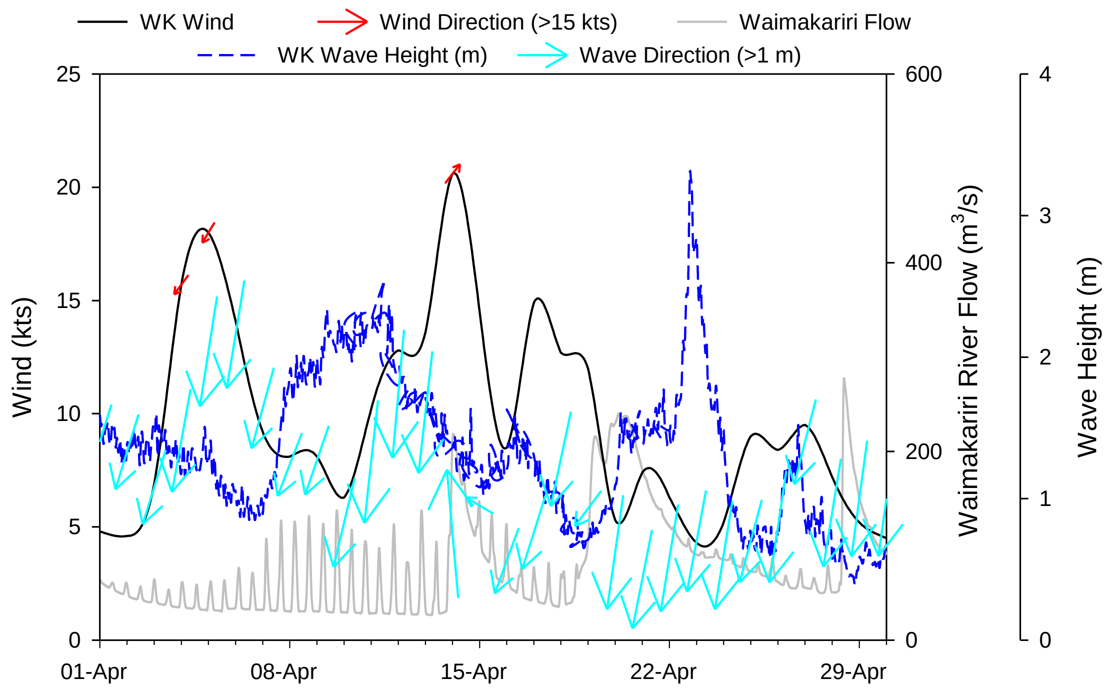


Figure 3 Offshore metocean conditions including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during April 2020.
Note: Arrows indicate the direction of travel for offshore winds greater than 15 knots and offshore waves above 1 m significant wave height. Directions from the WatchKeeper buoy have not been corrected for magnetic declination.

3.1.2 Currents

Acoustic Doppler Current Profilers (ADCPs) are deployed at the spoil ground monitoring sites SG1, SG2a (Watchkeeper) and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Summary ADCP statistics of available data are presented within Table 2, and Figures 4 to 6. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 30 to 35 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

Table 2 Parameter statistics for spoil ground ADCPs during April 2020.

Parameter	Depth	Site		
		SG1	SG2a	SG3
Minimum current speed (mm/s)	*Near-surface*	2	1	2
	Near-seabed	1	3	3
Maximum current speed (mm/s)	*Near-surface*	382	271	535
	Near-seabed	351	301	509
Mean current speed (mm/s)	*Near-surface*	87	59	125
	Near-seabed	92	79	119
Standard deviation of current speed (mm/s)	*Near-surface*	57	40	80
	Near-seabed	51	44	69
Current speed, 95^{th} percentile (mm/s)	*Near-surface*	203	137	291
	Near-seabed	189	156	251

Maximum near-surface current speeds at SG1 (382 mm/s), SG2a (271 mm/s) and SG3 (535 mm/s), were recorded on 4 April (SG1 and SG3) and 15 April (SG2a). These peaks coincide with periods of moderate to high inshore and offshore winds coming from west south-westerly directions from the 4 to 6 April and the 13 to 15 April. Significant wave heights >1m were experienced throughout the month.

Maximum near-seabed current speeds at SG3 (509 mm/s), SG2a (301 mm/s) and SG1 (351 mm/s), and were recorded on the 5, 14 and 28 April, respectively. Again these coincided with daily offshore and inshore wind speeds that were moderate to high from a west south-westerly direction with significant wave heights >1 m occurring throughout the month and possibly explaining the increased near-seabed currents recorded.

The time-series plots (Figures 30 to 35 in Appendix) illustrate time-varying current direction, whilst the current rose diagrams (Figures 4 to 6) depict the distribution of current direction and velocity in the near-surface and near-seabed layers. When interpreting the current data, note that the convention for defining current direction is the direction in which the current flows *towards*, which is the reference used throughout the Figures presented.

During April near-surface currents at SG1 tended to move in a west-northwest (31.2%) and southeast direction (14.4%). Near-bed currents at this site also moved predominantly in east-southeast (28.6%) and west-northwest (29.7%) directions. Near-surface currents located around SG3 primarily moved in an east-southeast (39.1%) and northwest (27.0%) direction, while near-bed currents at this site moved in an east-southeast (42.0%) and west-northwest (34.6%) direction.

Near surface current movements at SG2a moved in an eastward and westward direction (19.9% and 2.7% respectively). As previously observed at this site, near-seabed currents moved in an eastward (24.1%) and westward (21.8%) direction during April.

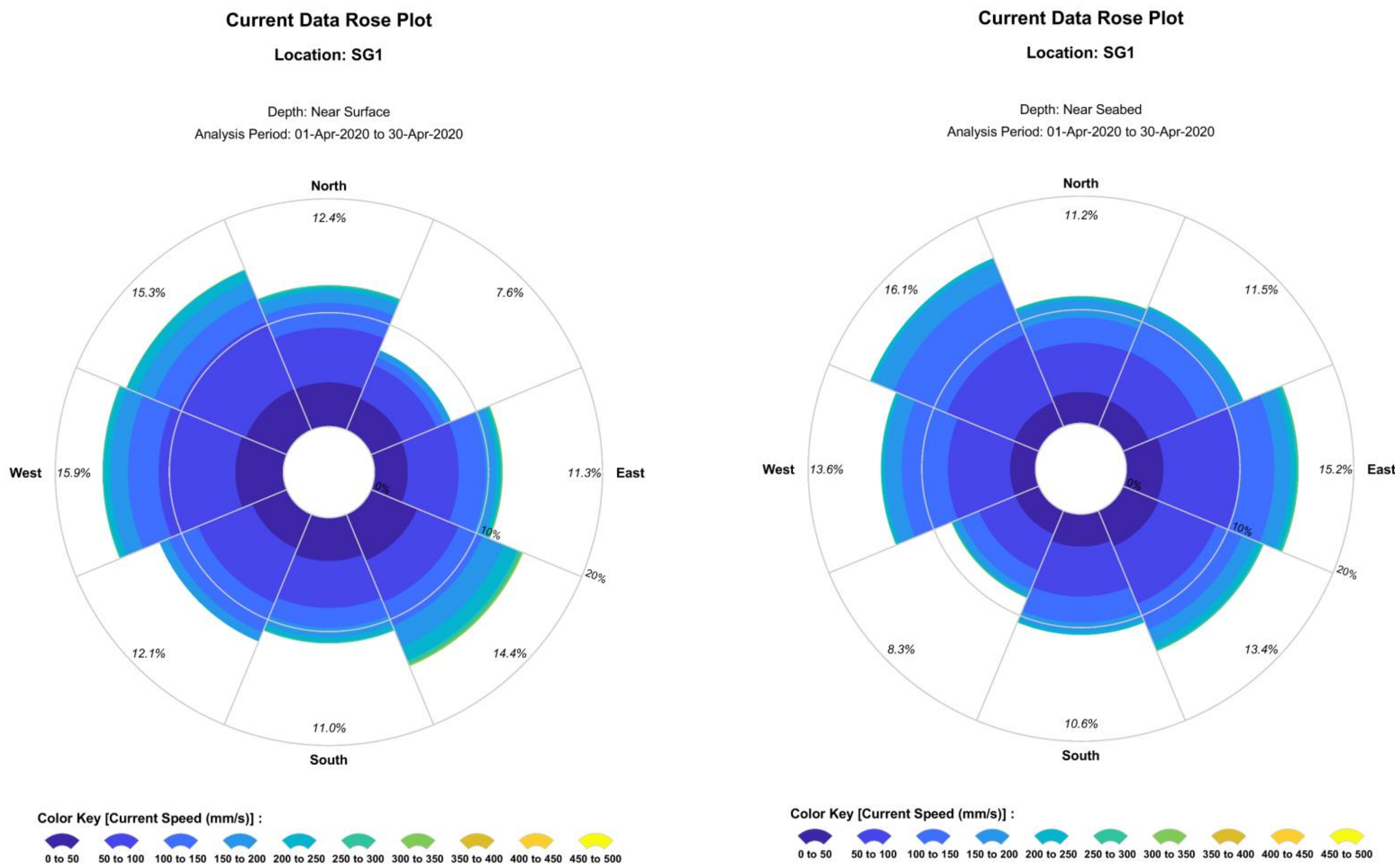
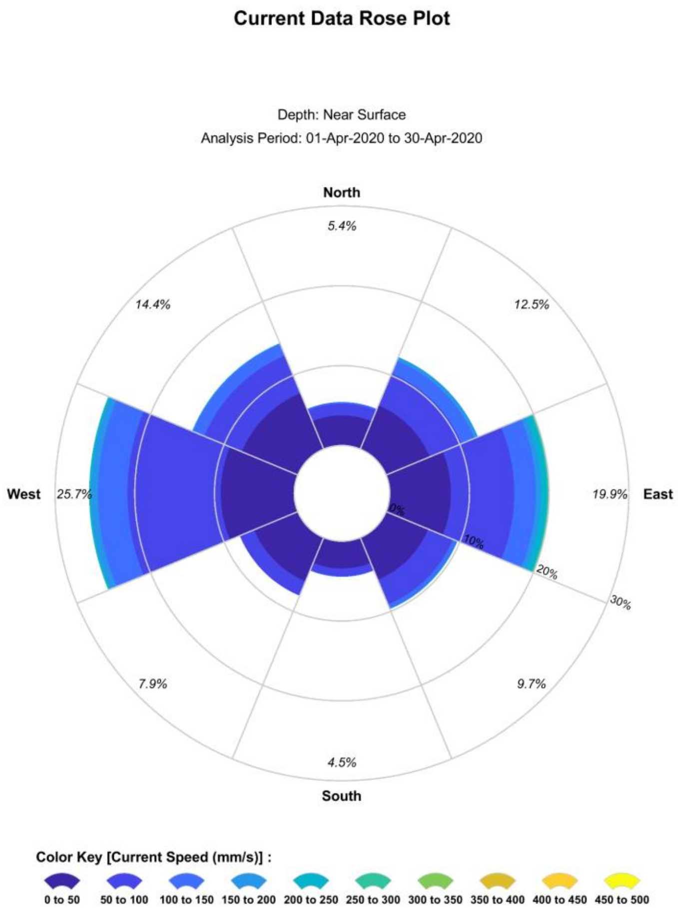


Figure 4 Near-surface and near-seabed current speed and direction at SG1 during April 2020.
Speed intervals of 50 mm/s are used.



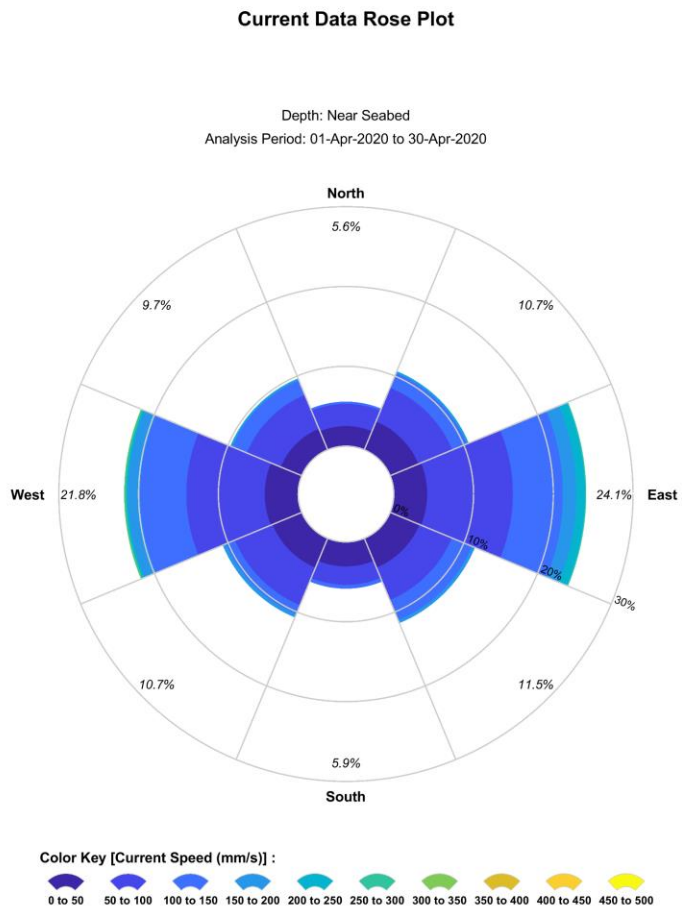
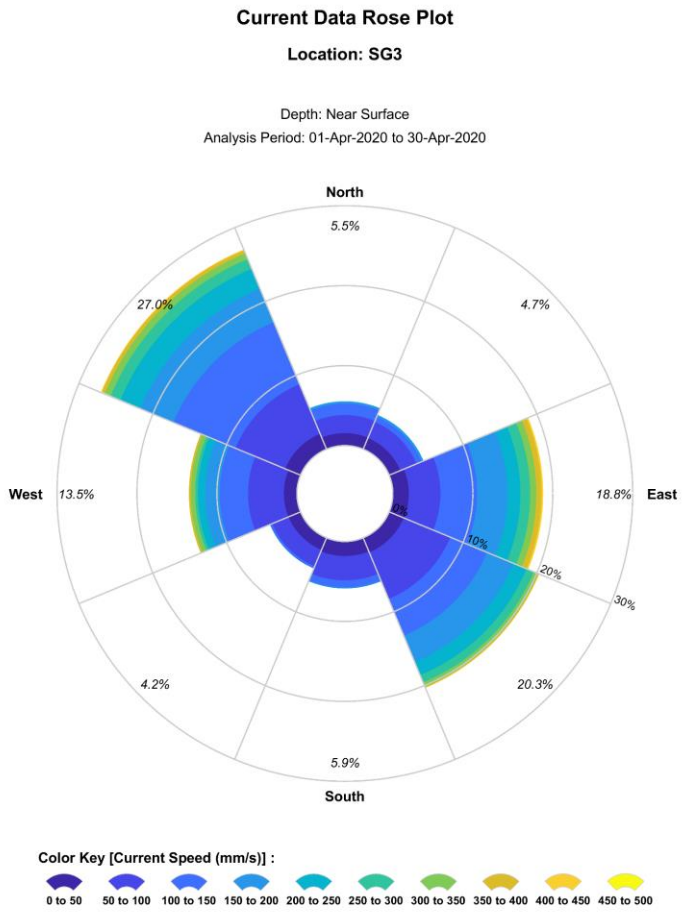


Figure 5 Near-surface and near-seabed current speed and direction at SG2a (Watchkeeper) during April 2020.
Speed intervals of 50 mm/s are used.



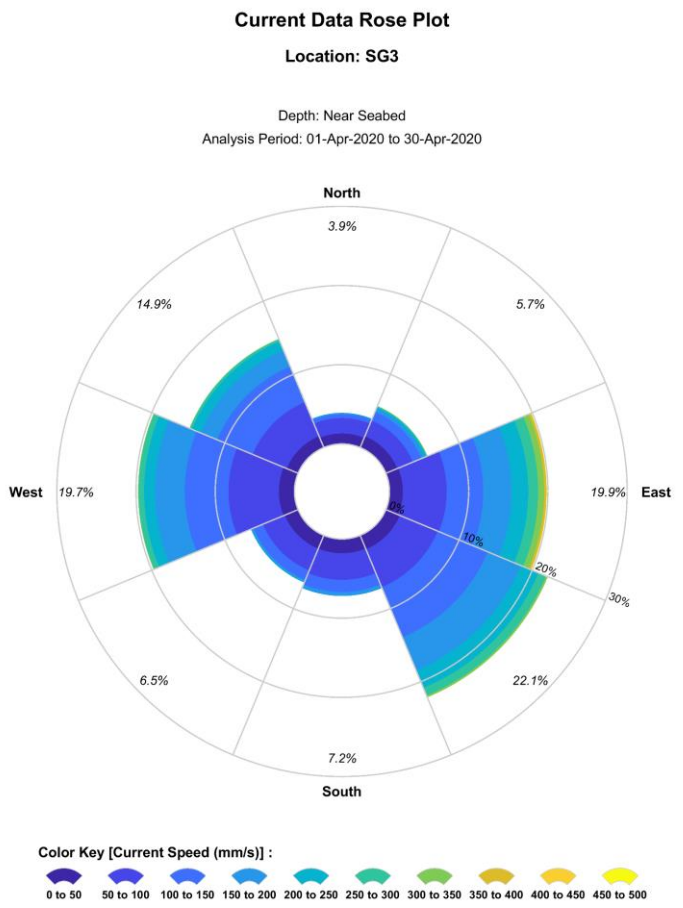


Figure 6 Near-surface and near-seabed current speed and direction at SG3 during April 2020.
Speed intervals of 50 mm/s are used.

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties of the water column are measured at monitoring sites every 15 minutes by dual telemetered surface loggers. Additional dual sets of benthic loggers have also been deployed at five offshore sites (OS1 to OS4 and OS6). In conjunction with the continuous loggers, discrete depth profiles of all physicochemical parameters were also conducted at all 15 monitoring sites on 29 April 2020. Further details regarding the methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Summary statistics for each physicochemical parameter recorded during April are presented in Tables 3 to 12. Validated datasets for surface and benthic measurements are also presented in Figures 7 to 23. Due to the inherent high level of variability in the turbidity datasets, a 24-hour rolling average has been calculated every 15 minutes to act as a smoothing technique and aid in data interpretation.

3.2.1 Turbidity

Note that due to level 4 COVID-19 restrictions in New Zealand that were implemented on 25 March, routine maintenance of continuous surface instruments could not be completed during this time. Therefore, rigorous cleansing of fouled raw data was undertaken resulting in some sites having periods of missing data. COVID-19 restrictions were lowered to level 3 on the 27 April allowing equipment maintenance and water sampling to recommence.

April Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 3.7 to 6.3 NTU) at the inshore monitoring sites (Table 3 and Figure 6). Further offshore, the spoil ground sites (Table 4) exhibited lower surface turbidity values (2.0 to 2.9 NTU). This can be attributed to the deeper water column limiting expressions of seafloor sediment resuspension at the sub-surface. Mean turbidity values at offshore sites ranged from 2.8 to 6.5 NTU (Table 5) during April.

Turbidity across the inner harbour was relatively low (< 10 NTU) during the majority of April. Slightly elevated short-lived turbidity peaks were noted at CH2 between 4 and 9 April and again on 3 April coinciding with increased inshore winds (> 15 kts).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) were again relatively low for April staying below 10 NTU for the majority of the monitoring period. Small peaks occurred from the 6 to 10 April and again from the 12 to 16 April at all nearshore surface sites. These episodes occurred in conjunction with, or just following, high winds and significant wave heights (> 1m).

Further offshore at OS5, OS6, SG1 peaks in turbidity were recorded during 5 to 9 April and 12 to 17 April. Short lived intermittent turbidity peaks were also observed at SG1 during the latter part of the month from 20 to 18 April. Turbidity at SG2 was typically low for the majority of the month. Available data for SG3 at the beginning and end of the month points to similar patterns found at SG1, with peaks during 5 to 6 April and the 28 April corresponding to higher wind speeds and elevated wave heights over 1m.

Benthic:

Data return was gained for all benthic sites during April, however interruption in data acquisition are noted for OS3 and OS4 due to longer sonde deployment. Benthic turbidity data corresponded with surface measurements, with elevated turbidity occurring during early to mid-April when high winds and waves dominated climatic conditions (Figure 7).

Table 3 Mean turbidity and statistics at inshore water quality logger sites during April 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for April are means ± se, range and percentiles (n = 1309 to 2880) Baseline values modified from Fox 2018. Note turbidity data for UH2 is only available from 1 to 15 April and 28 to 30 April.

Site	Turbidity (NTU)		
	Statistic	Surface April	Surface Baseline
UH1	Mean ± se	3.7 ± 0.0	12
	Range	1.6 – 9.9	-
	99th	8.7	39
	95th	6.7	22
	80th	4.7	15
UH2	Mean ± se	6.3 ± 0.0	10
	Range	2.1 – 10.0	-
	99th	9.9	32
	95th	9.3	20
	80th	8.1	13
CH1	Mean ± se	6.1 ± 0.0	9
	Range	2.2 – 10.0	-
	99th	9.6	29
	95th	8.7	18
	80th	7.5	12
CH2	Mean ± se	3.8 ± 0.0	8
	Range	1.8 – 10.0	-
	99th	8.1	24
	95th	6.8	16
	80th	5.0	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during April 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for April are means ± se, range and percentiles (n = 718 to 2865). Baseline values modified from Fox 2018.Note turbidity data for SG3 was only available from the 1 to 7 April and 28 to 30 April.

Site	Turbidity (NTU)		
	Statistic	Surface April	Surface Baseline
SG1	Mean ± se	2.0 ± 0.0	4.2
	Range	<1 – 10.0	-
	99th	8.6	14
	95th	6.8	10
	80th	3.5	6.2
SG2	Mean ± se	2.4 ± 0.0	4.6
	Range	< 1 – 7.9	-
	99th	6.1	20
	95th	4.8	11
	80th	3.1	7.0
SG3	Mean ± se	2.9 ± 0.0	3.6
	Range	<1 – 9.9	-
	99th	9.7	13
	95th	8.8	7.7
	80th	3.4	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during April 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for April are means ± se, range and percentiles (n = 1038 to 2721). Baseline values modified from Fox 2018. Note turbidity data for OS1 is only available from the 1 to 13 April and surface OS6 data only available until the 16 April.

Site	Statistic	Turbidity (NTU)		
		Surface April	Surface Baseline	Benthic April
OS1	Mean ± se	4.1 ± 0.0	7.5	41.9 ± 0.8
	Range	< 1 – 10.0	-	<1 – 199.2
	99th	9.7	24	184.3
	95th	8.3	16	184.3
	80th	5.9	10	76.2
OS2	Mean ± se	4.7 ± 0.0	6.4	58.8 ± 0.8
	Range	< 1-10.0	-	5.9 – 199.7
	99th	9.7	18	182.2
	95th	8.6	13	147.1
	80th	6.2	9.0	91.5
OS3	Mean ± se	7.0 ± 0.1	6.6	37.7 ± 0.6
	Range	1.1 – 28.6	-	2.6 – 199.8
	99th	17.7	27	155.6
	95th	13.6	15	103.5
	80th	9.6	8.9	58.1
OS4	Mean ± se	4.3 ± 0.0	5.9	51.8 ± 0.7
	Range	<1 -10.0	-	14.6 – 199.8
	99th	9.7	20	163.9
	95th	9.0	13	124.3
	80th	6.4	8.3	78.0
OS5	Mean ± se	2.8 ± 0.0	4.6	–
	Range	<1 – 10.0	-	–
	99th	9.2	19	–
	95th	7.3	11	–
	80th	4.7	6.4	–
OS6	Mean ± se	6.5 ± 0.0	4.7	41.2 ± 0.7
	Range	2.5 – 10.0	-	1.3 – 196.8
	99th	10.0	19	154.7
	95th	9.7	12	110.7
	80th	8.7	7.2	69.5
OS7	Mean ± se	5.3 ± 0.0	6.4	–
	Range	1.2 – 10.1	-	–
	99th	9.8	23	–
	95th	9.2	14	–
	80th	7.3	9.2	–

Comparison to Baseline:
Mean surface turbidity values and statistics during April were lower than the values calculated from the baseline monitoring period (Tables 3 to 5, Figures 7 to 12).

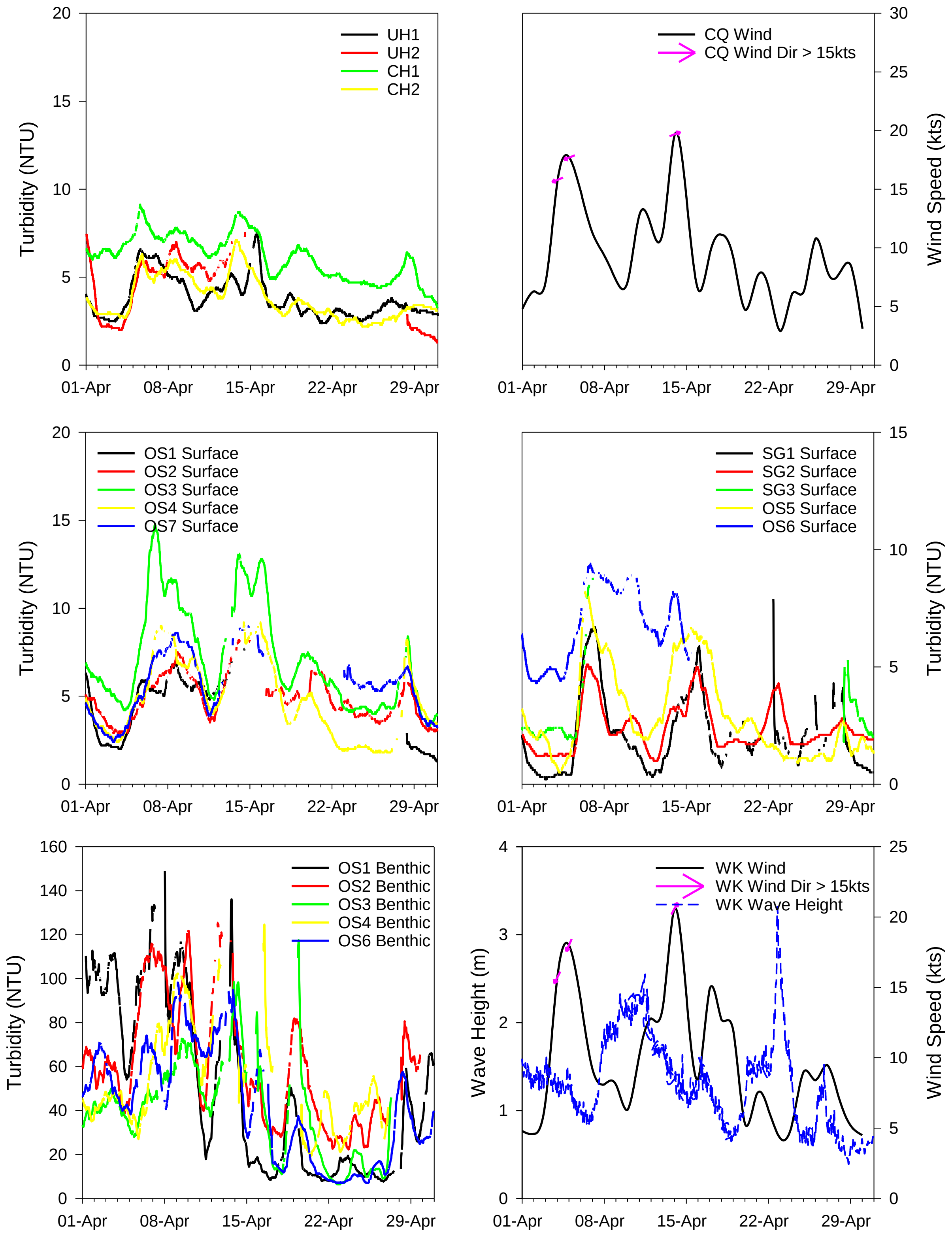


Figure 7 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations during April 2020.
Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 15 knots.

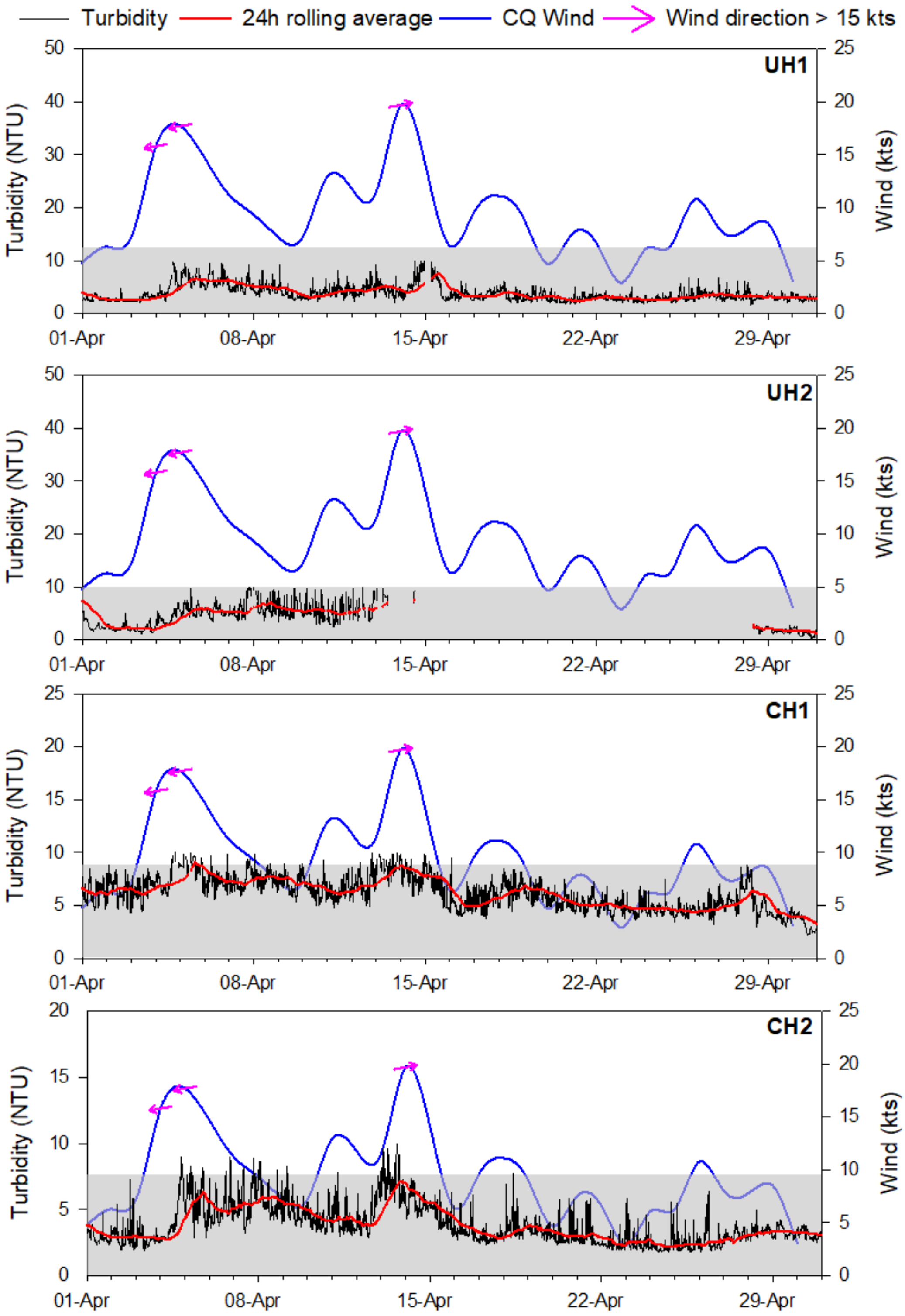


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during April 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

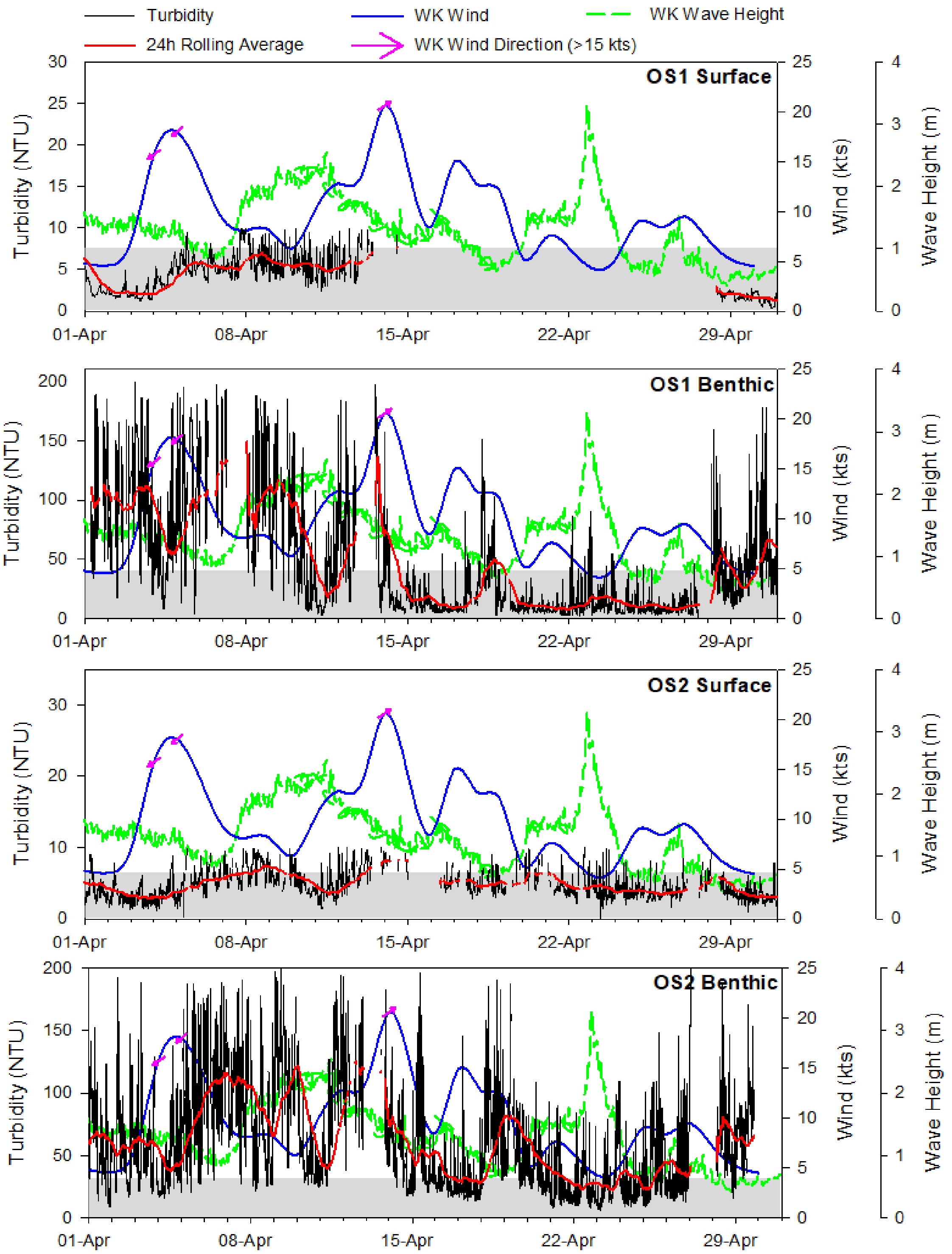


Figure 9 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS1 and OS2) during April 2020.

Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity

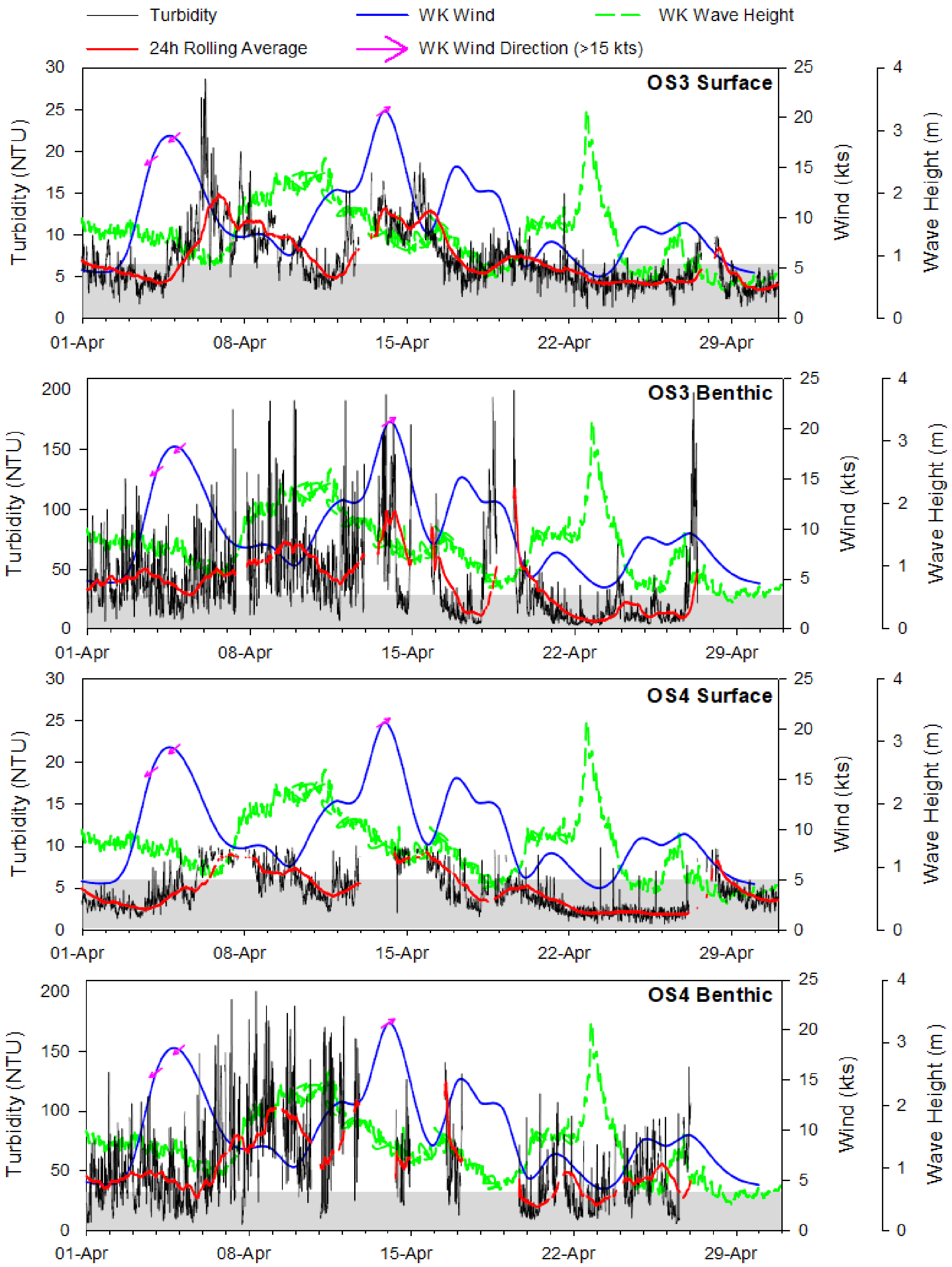


Figure 10 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS3 and OS4) during April 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

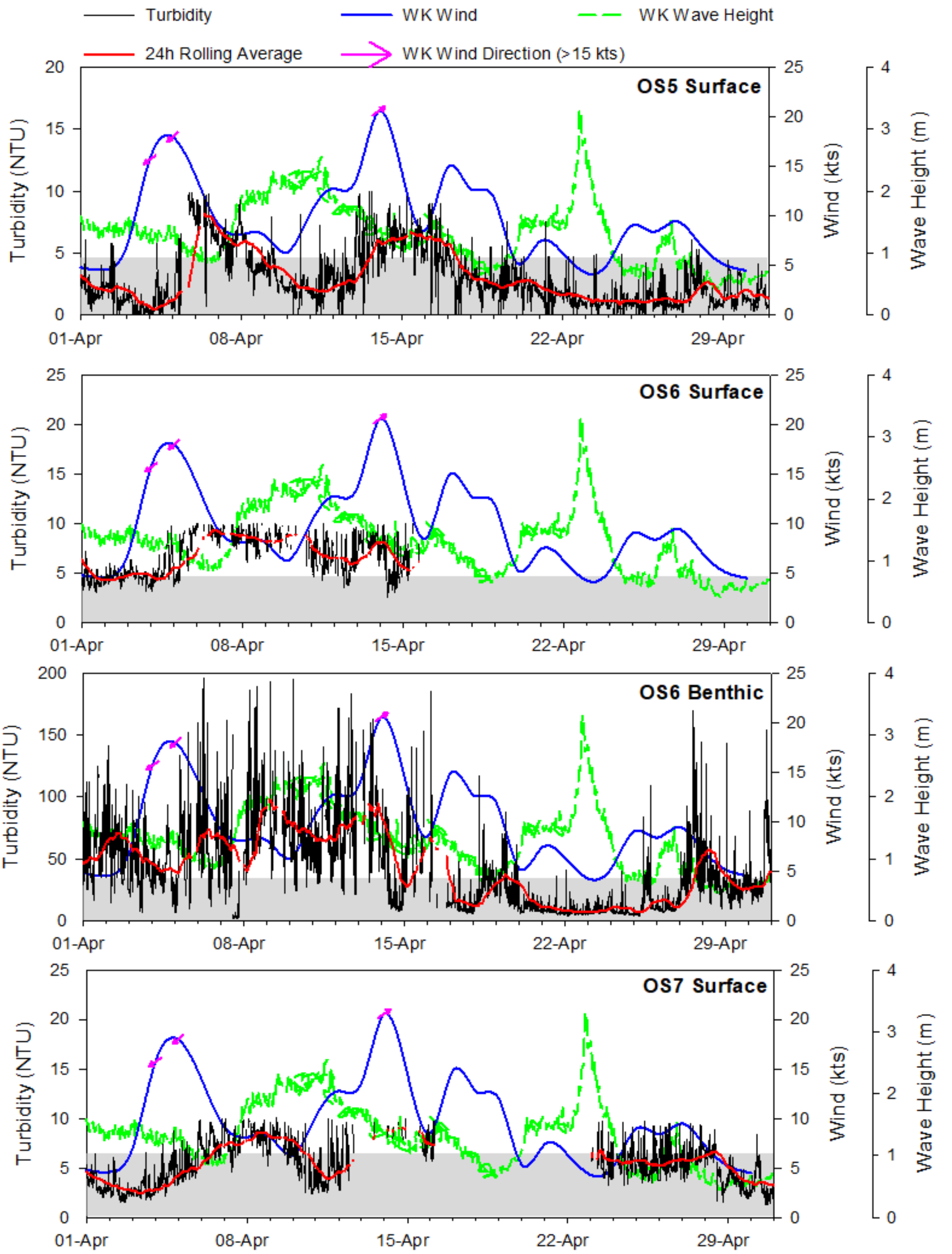


Figure 11 Surface and benthic turbidity and daily averaged winds at nearshore and offshore sites (OS5, OS6 and OS7) during April 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

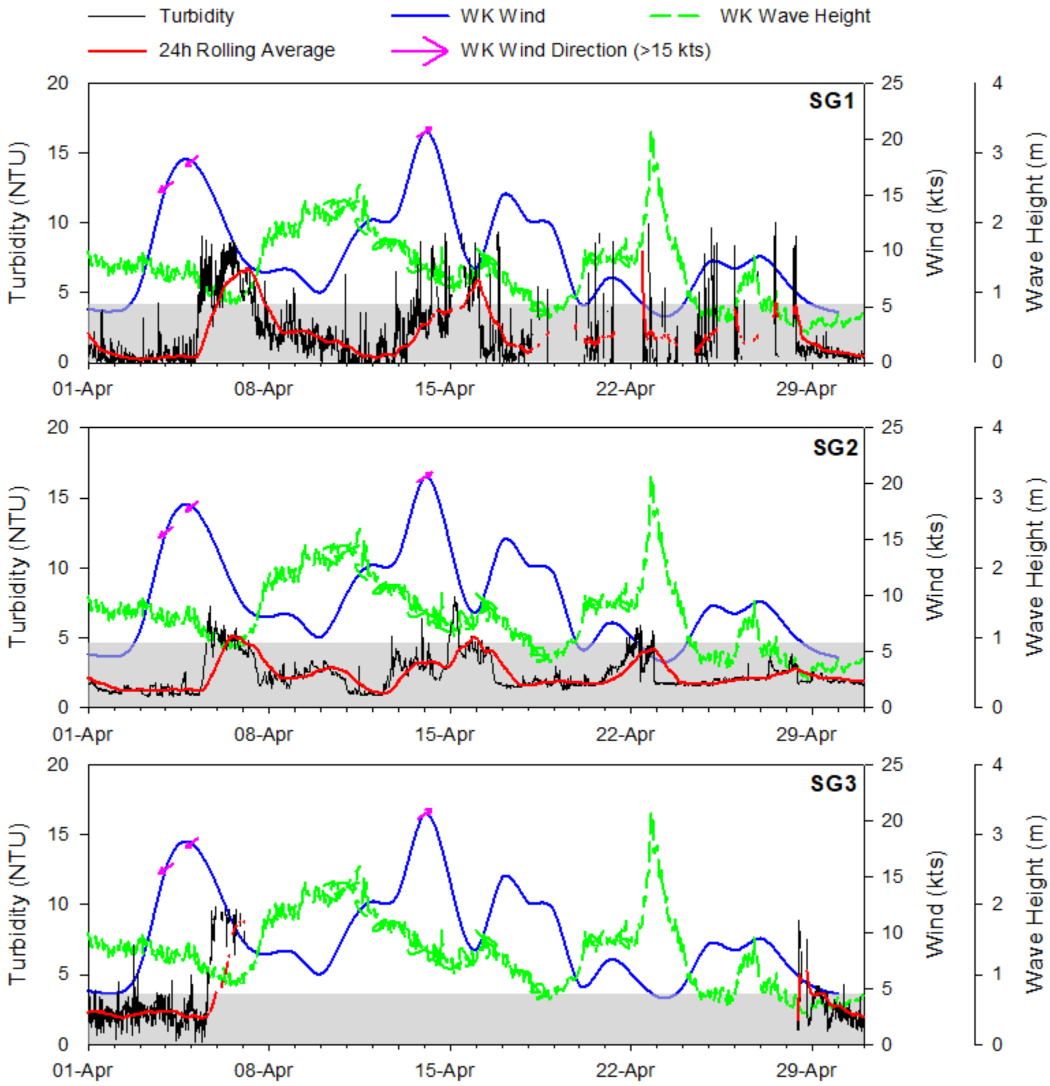


Figure 12 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during April 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

3.2.2 Temperature

Mean monthly sea surface temperatures during April (14.0 to 14.5 °C) (Table 6) were significantly lower to those experienced during March (16.0 to 16.4 °C) as would be expected due to seasonal cooling. The overall declining temperature trend was fairlyconsistent throughout April at all sites, except for a decline in temperatures recorded from the 13 to 15 April, which was most pronounced at inshore sites (Figures 13 and 14).

Table 6 Mean temperature at inshore, spoil ground and offshore water quality sites during April 2020. *Values are means ± se (n = 2552 to 2880).*

Site	Temperature (°C)	
	Surface loggers	Benthic loggers
UH1	14.0 ± 0.0	–
UH2	14.1 ± 0.0	–
CH1	14.2 ± 0.0	–
CH2	14.3 ± 0.0	–
SG1	14.2 ± 0.0	–
SG2	14.3 ± 0.0	–
SG3	14.3 ± 0.0	–
OS1	14.3 ± 0.0	14.2 ± 0.0
OS2	14.3 ± 0.0	14.2 ± 0.0
OS3	14.3 ± 0.0	14.2 ± 0.0
OS4	14.4 ± 0.0	14.2 ± 0.0
OS5	14.3 ± 0.0	–
OS6	14.5 ± 0.0	14.2 ± 0.0
OS7	14.2 ± 0.0	–

Similar to March and in contrast to previous summer months, slightly lower temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites during April. Semidiurnal variability (associated with tidal water movements and solar radiation) was again observed, particularly at the inner harbour and spoil ground sites. Benthic temperatures were lower than the overlying surface waters and generally displayed the same surface trends indicating a well-mixed water column.

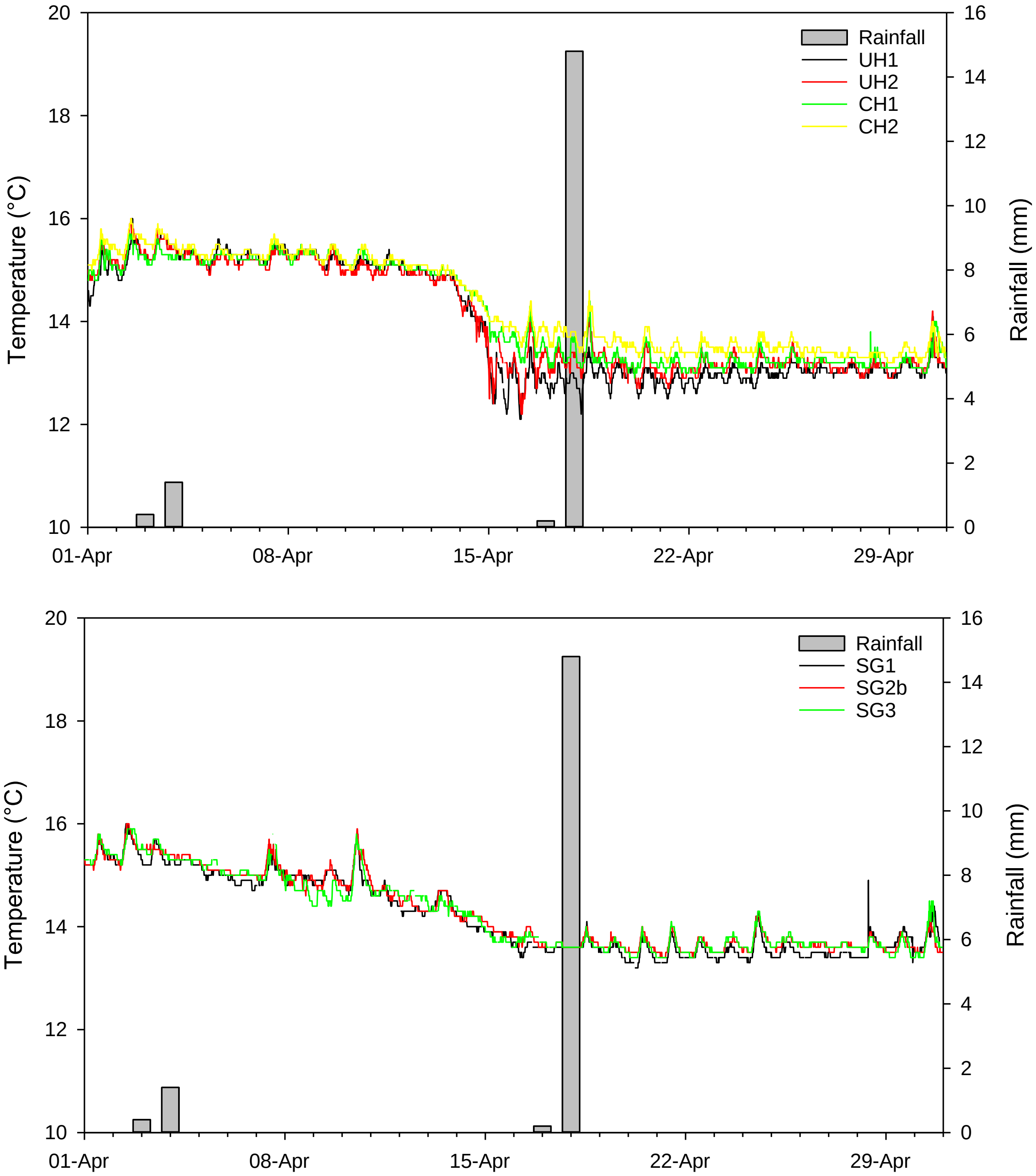


Figure 13 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during April 2020.

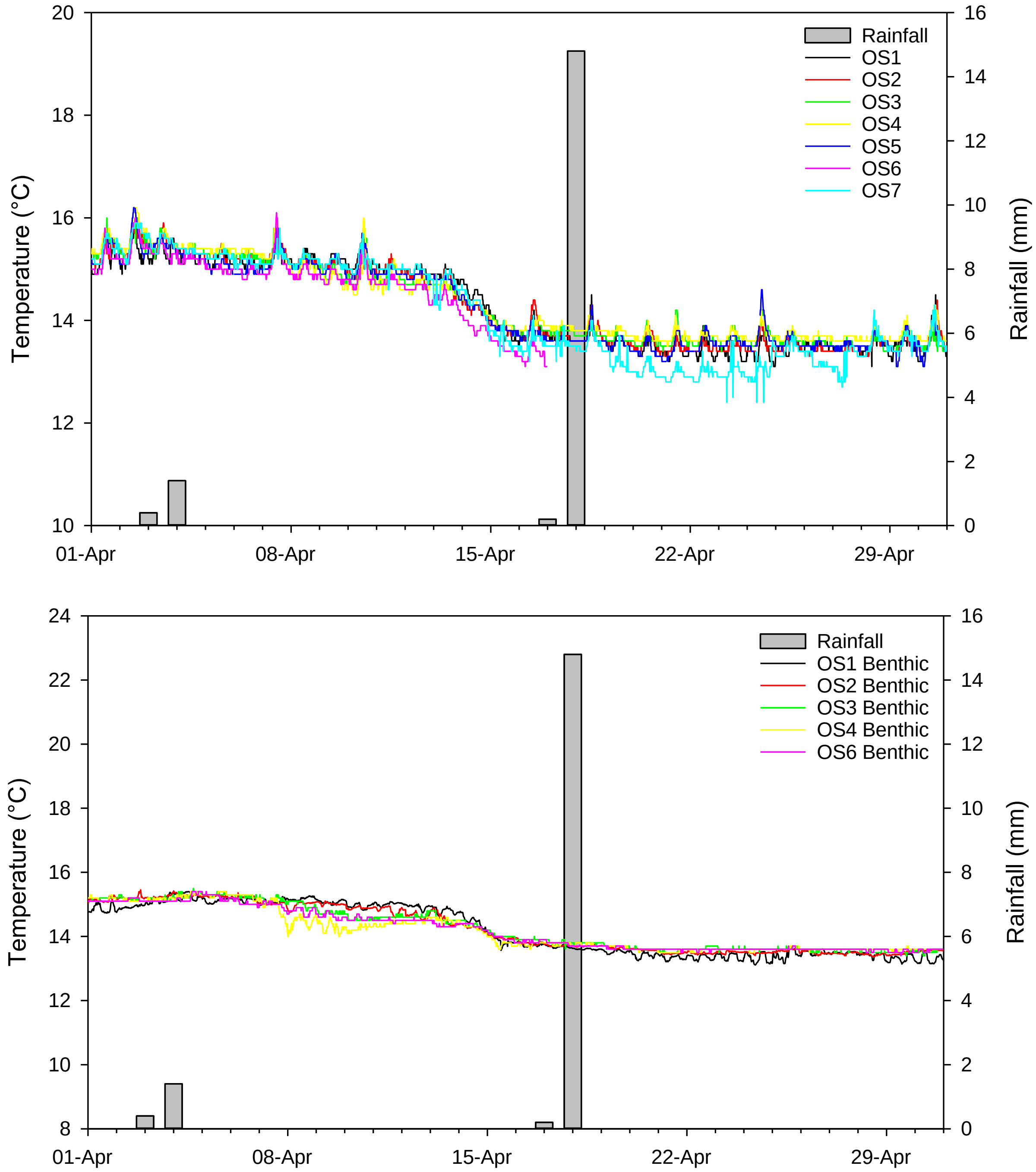


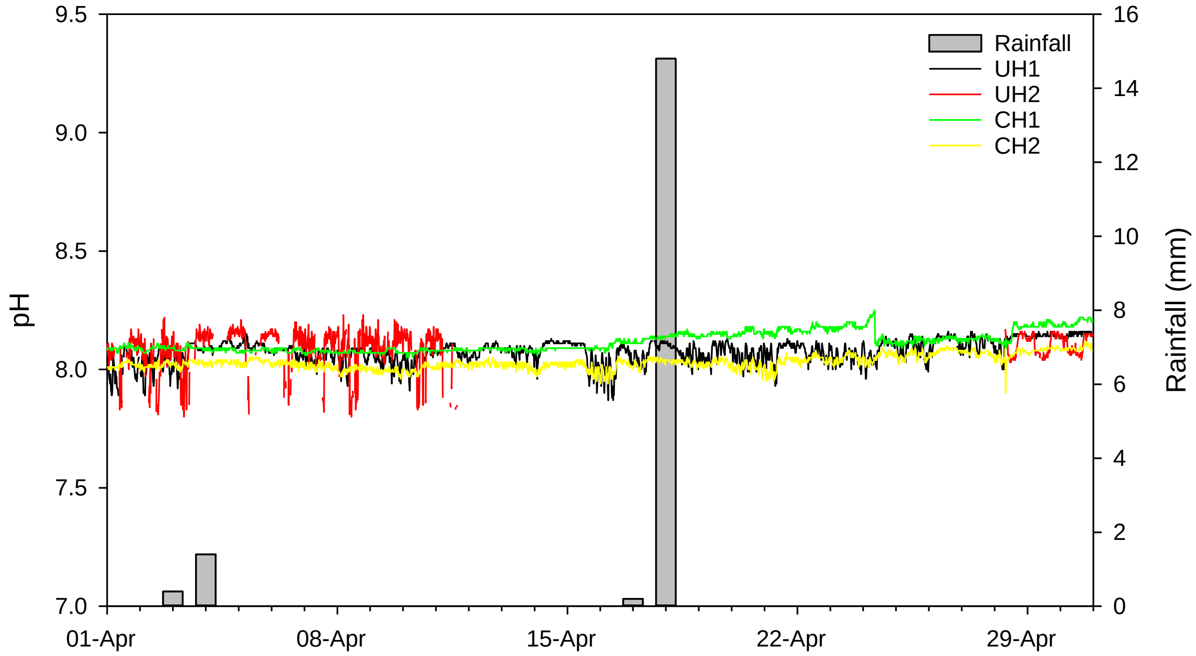
Figure 13 Surface temperature (OS1 to OS7) and benthic temperature (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during April 2020.

3.2.3 pH

The pH remained consistent across surface and benthic sites, with monthly means ranging between 7.9 and 8.2 (Table 7, Figures 15 and 16).

Table 7 Mean pH at inshore, spoil ground and offshore water quality sites April 2020. *Values are means ± se (n = 1806 to 2880).*

Site	pH	
	Surface loggers	Benthic loggers
UH1	8.1 ± 0.0	–
UH2	8.1 ± 0.0	–
CH1	8.1 ± 0.0	–
CH2	8.0 ± 0.0	–
SG1	8.2 ± 0.0	–
SG2	8.1 ± 0.0	–
SG3	8.1 ± 0.0	–
OS1	8.1 ± 0.0	8.2 ± 0.0
OS2	8.2 ± 0.0	7.9 ± 0.0
OS3	8.1 ± 0.0	8.1 ± 0.0
OS4	8.2 ± 0.0	8.1 ± 0.0
OS5	8.2 ± 0.0	–
OS6	8.0 ± 0.0	8.0 ± 0.0
OS7	8.1 ± 0.0	–



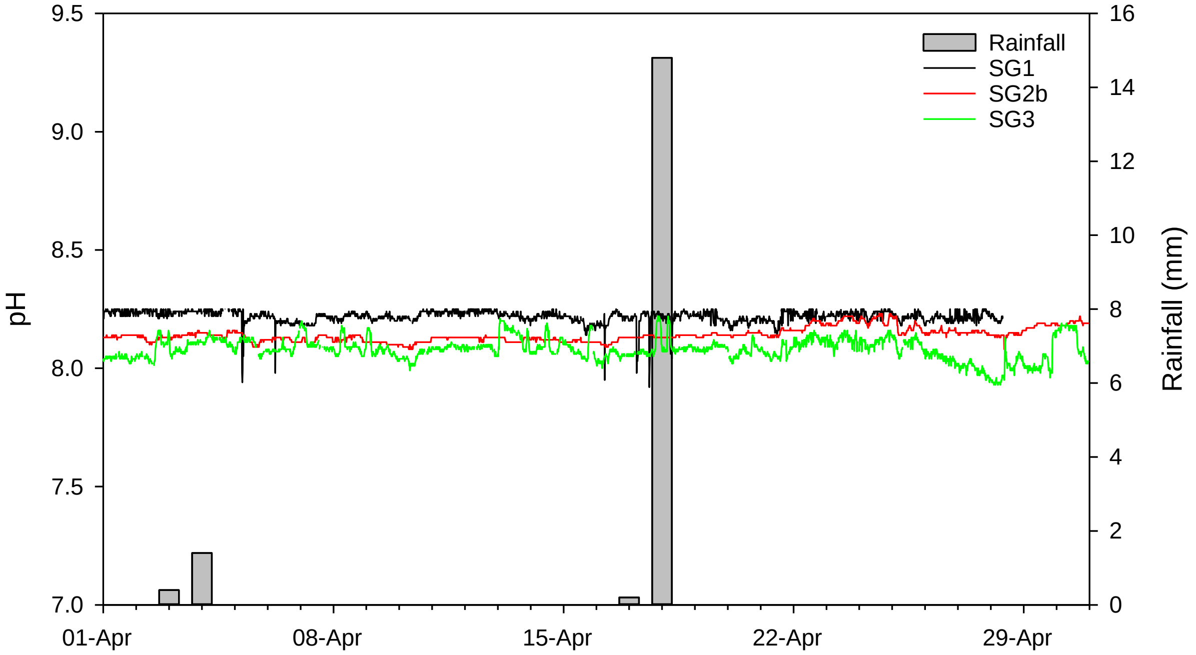
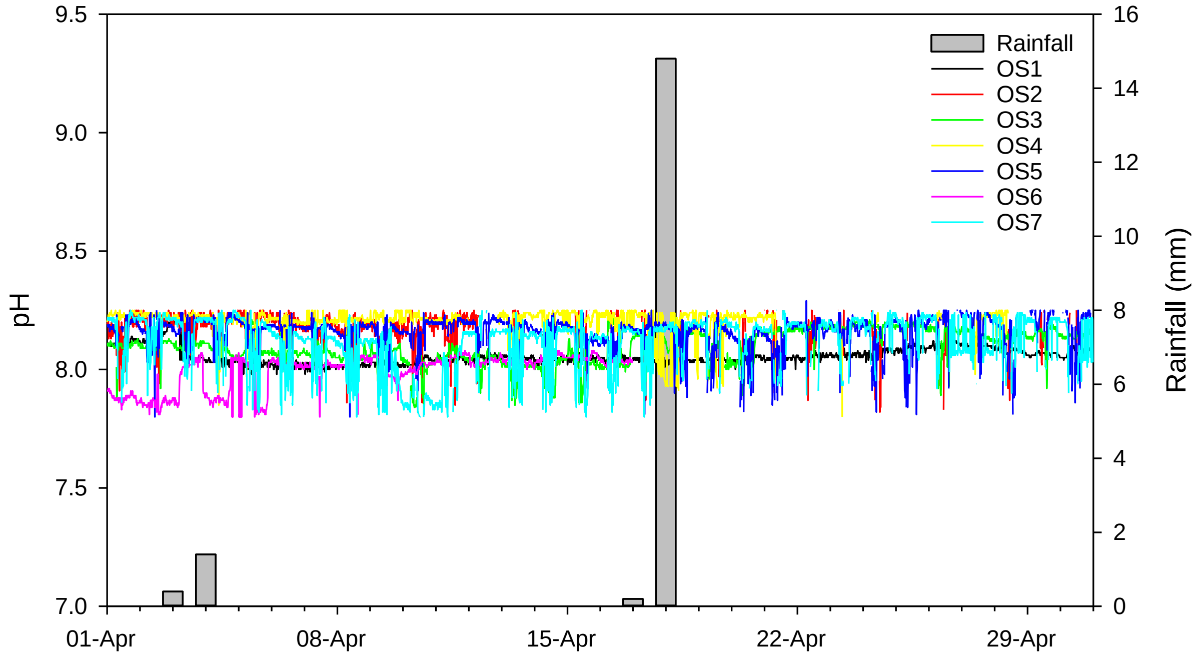


Figure 15 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during April 2020.



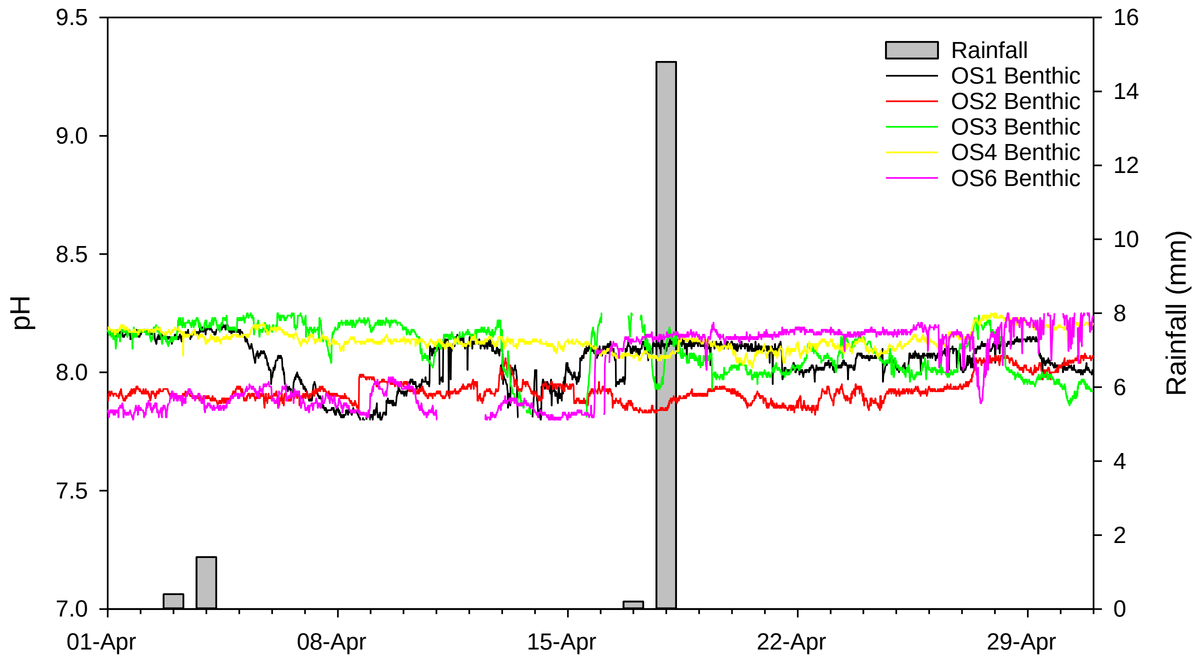


Figure 16 Surface pH (OS1 to OS7) and benthic pH (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during April 2020.

3.2.4 Conductivity

Surface conductivity in April ranged from 50.8 mS/cm to 54.1 mS/cm (Table 8, Figure 17 and 18), with benthic conductivity recorded at similar values, ranging from 51.5 mS/cm to 54.1 mS/cm.

As observed in previous months, inner harbour sites recorded slightly lower mean conductivity values than offshore and spoil ground sites due to previous localised freshwater influences compared to oceanic mixing. During April surface conductivity was relatively consistent across all sites with more variability recorded at benthic sites. Flow rates from the Waimakariri River did not exceed 300 m^3/s during April, which would account for the stability in surface conductivity observed through most of the month.

Table 8 Mean conductivity at inshore, spoil ground and offshore water quality sites during April 2020. *Values are means ± se (n = 614 to 2880).*

Site	Conductivity (mS/cm)	
	Surface loggers	Benthic loggers
UH1	51.4 ± 0.0	–
UH2	51.9 ± 0.0	–
CH1	50.9 ± 0.0	–
CH2	50.8 ± 0.0	–
SG1	53.9 ± 0.0	–
SG2	51.5 ± 0.0	–
SG3	53.4 ± 0.0	–
OS1	51.9 ± 0.0	52.6 ± 0.0
OS2	54.1 ± 0.0	51.5 ± 0.0
OS3	54.2 ± 0.0	54.1 ± 0.0
OS4	54.0 ± 0.0	53.0 ± 0.0
OS5	53.5 ± 0.0	–
OS6	53.5 ± 0.0	52.3 ± 0.0
OS7	53.2 ± 0.0	–

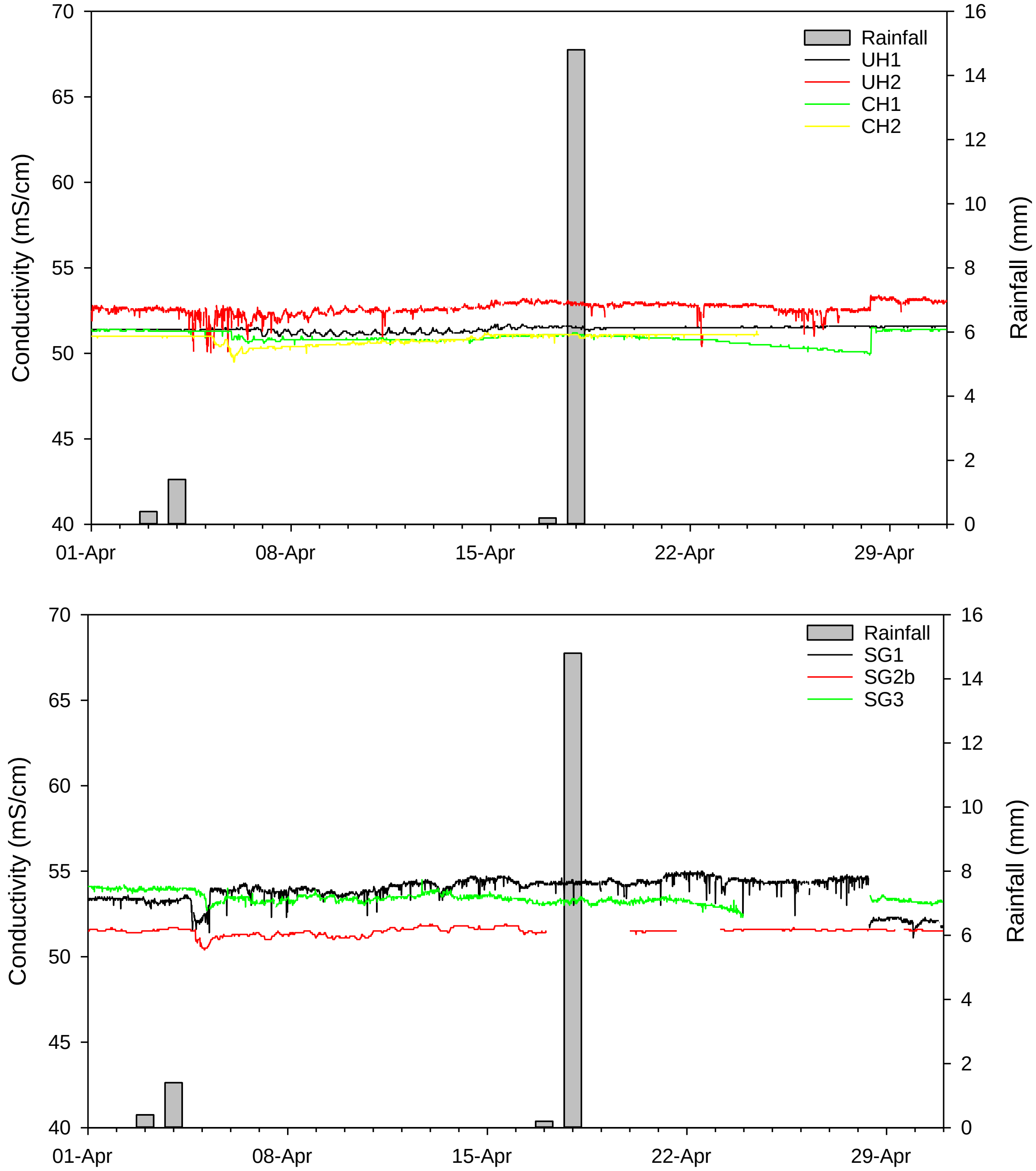
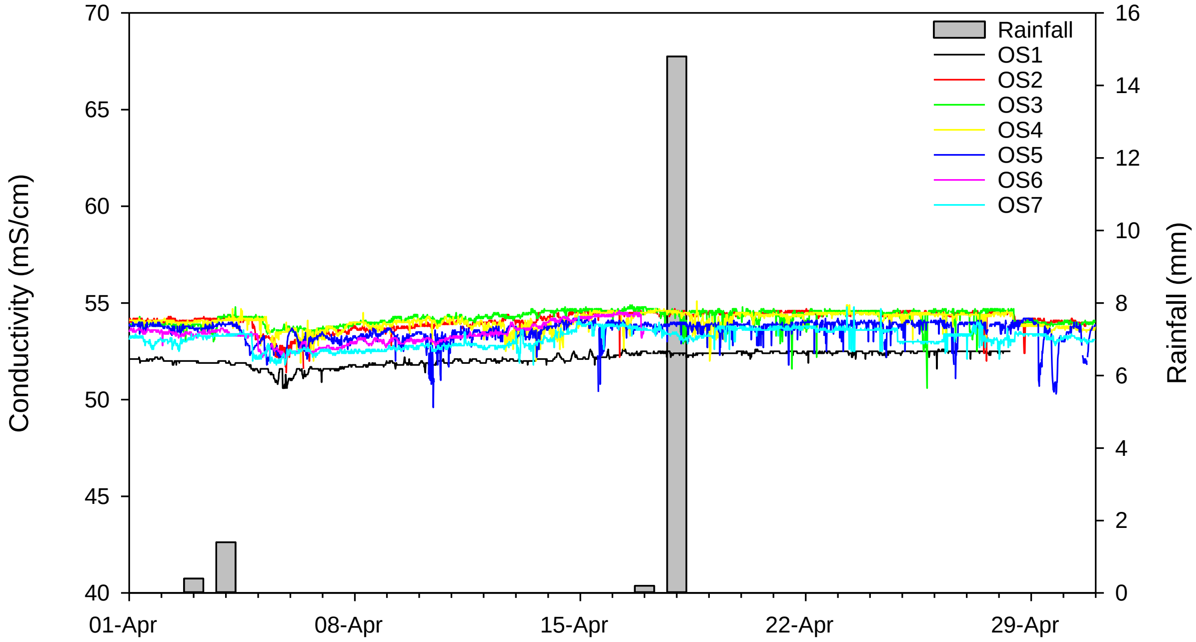


Figure 17 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during April 2020.



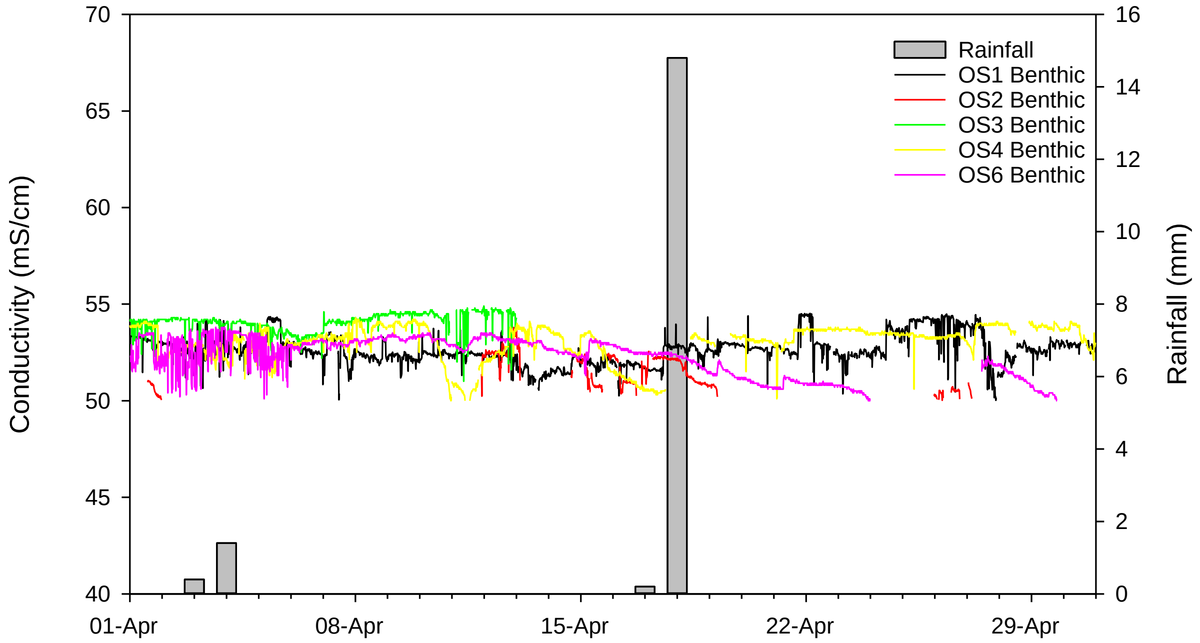


Figure 18 Surface conductivity (OS1 to OS7) and benthic conductivity (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during April 2020.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in April ranged from 91 to 101% saturation and demonstrated diurnal fluctuations at all sites, particularly those in the inshore area. DO concentrations at all sites appeared to be generally stable over the month. Offshore sites (OS7 and OS6) exhibited declining DO (< 90% saturation) from the 5 to 16 April before following a pattern exhibited by all offshore sites of generally increasing DO after the 19 April till the end of the month. Similar temporal patterns of DO concentrations were exhibited in the inshore and upper harbour sites. These declines in DO at the beginning of the month may have been associated with degrading algal blooms in which bacterial degradation results in respiration and oxygen consumption. In a cyclical pattern, warmer temperatures associated with increased sunlight following this period likely stimulated microalgal growth, leading to recovery of algal populations, increased photosynthesis, and therefore increased DO concentrations. Flows from the Waimakariri River may have also introduced nutrients contributing to algal growth.

Mean monthly benthic DO concentrations were generally lower than corresponding surface readings but followed similar trends, indicative of lower photosynthesis at the benthos (Table 9, Figures 20).

Table 6 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during April 2020.
Values are means ± se (n = 614 to 2880).

Site	Dissolved oxygen (% saturation)	
	Surface loggers	Benthic loggers
UH1	96 ± 0	–
UH2	101 ± 0	–
CH1	99 ± 0	–
CH2	98 ± 0	–
SG1	97 ± 0	–
SG2	101 ± 0	–
SG3	95 ± 0	–
OS1	101 ± 0	94 ± 0
OS2	98 ± 0	87 ± 0
OS3	94 ± 0	98 ± 0
OS4	94 ± 0	91 ± 0
OS5	95 ± 0	–
OS6	92 ± 0	86 ± 0
OS7	91 ± 0	–

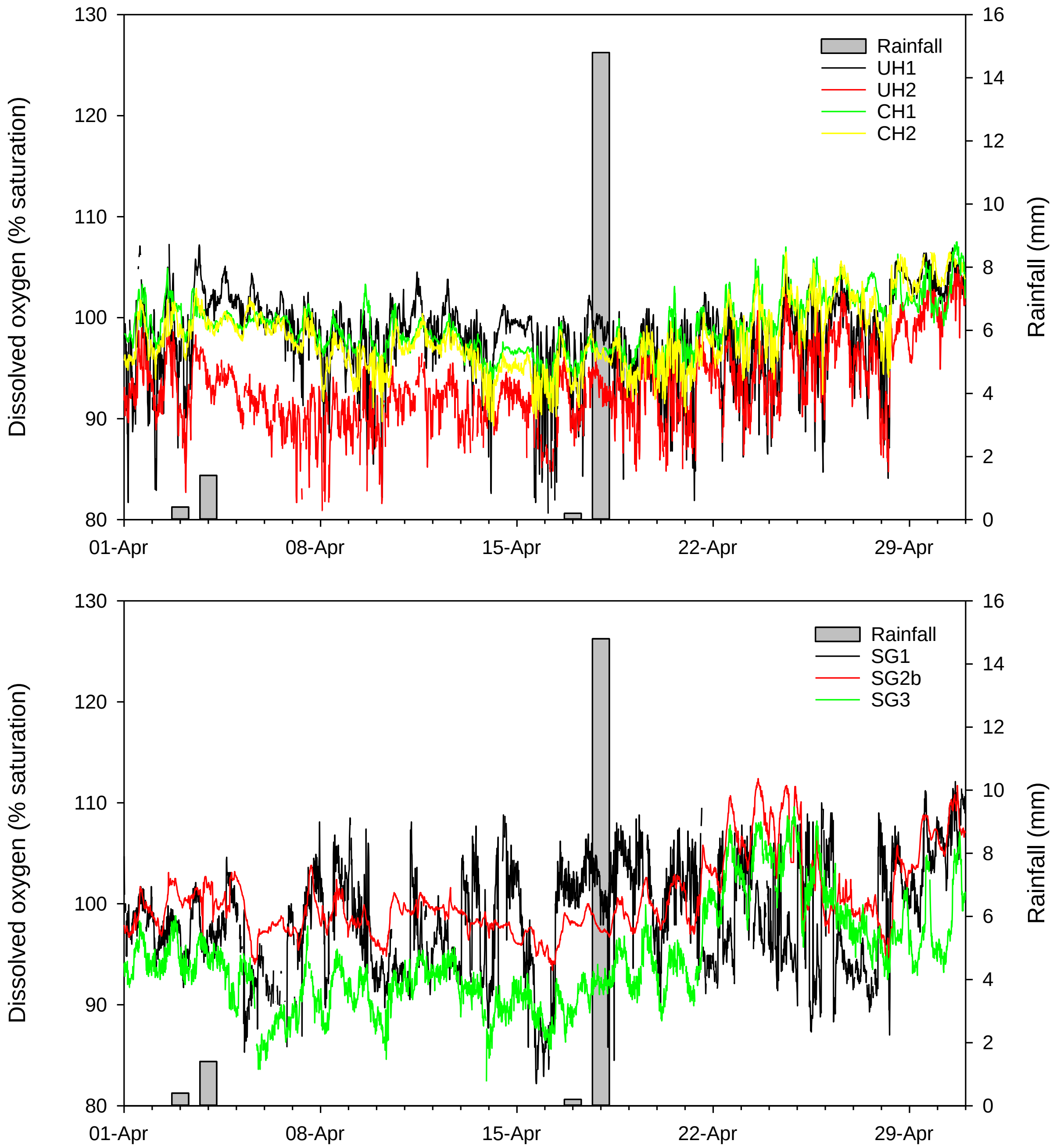
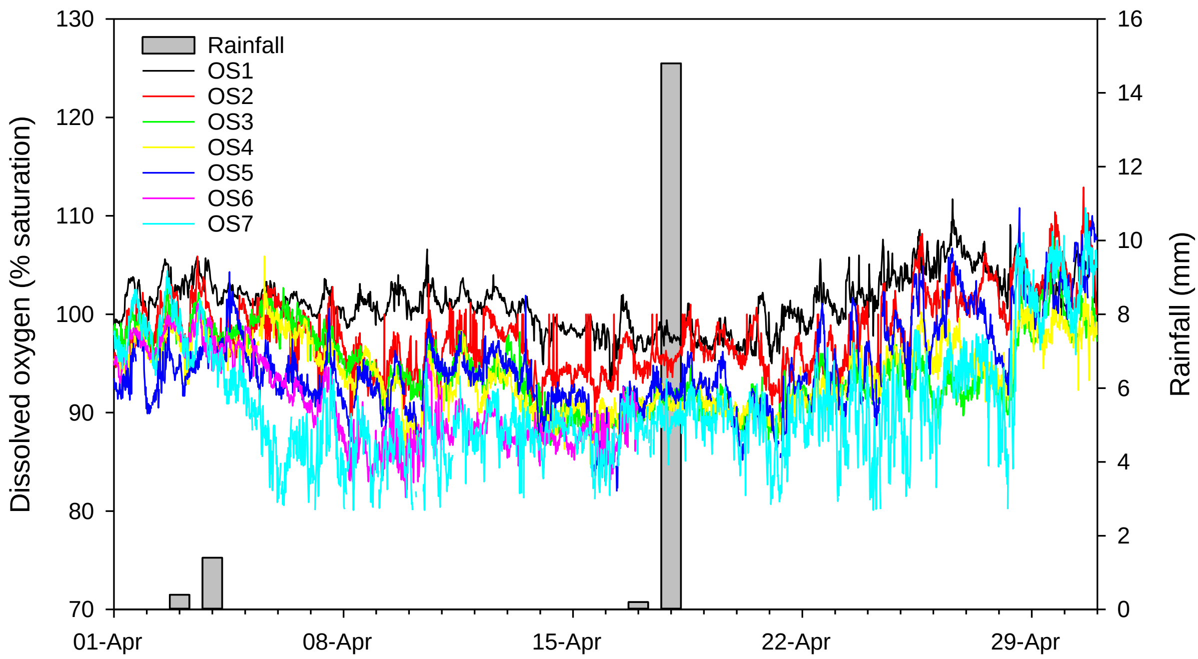


Figure 19 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during April 2020.



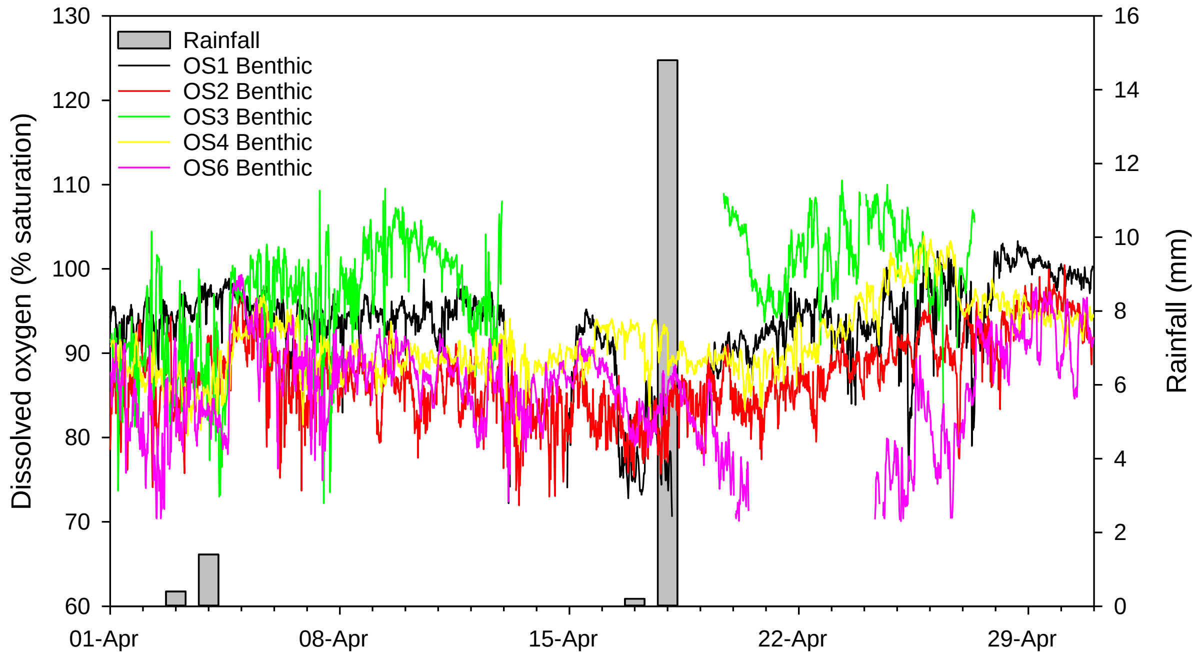


Figure 20 Surface DO (OS1 to OS7) and benthic DO (OS1 to OS 4 and OS6) at nearshore and offshore water quality sites during April 2020.

3.3 Physicochemistry Depth Profiling & TSS

Vertical depth profiling of the whole water column at each monitoring site was conducted in conjunction with monthly discrete water sampling on 29 April 2020. In addition to the previously discussed physicochemical parameters, the light attenuation rate (K_d, the rate at which light or PAR diminishes with depth through the water column) and resultant euphotic depth (the depth to which net photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were collected from three different depths (sub-surface, mid-column and approximately 1 m above the benthos) at the ten offshore and spoil ground sites. Due to the shallow water depths at the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, UH3, CH1 and CH2. Further information regarding the specific sampling methodology can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Statistical analyses of the resulting datasets are provided in Tables 10 to 12, with depth profile plots presented in Figures 21 to 23.

The relatively shallow sites of the upper and central harbour once again displayed well mixed conditions with little variability recorded in parameters through the water column (Figure 21). As commonly reported turbidity was higher at the three inshore sights with highest turbidity readings recorded at UH3, CH1 and CH2. Temperature, which is usually higher in the upper harbour was marginally lower in the upper harbour sites in April.

Within the nearshore region, physicochemical profiles for temperature and conductivity were relatively consistent throughout the water column at all sites, while pH showed a slight decrease at ~ 3 m at OS1, and OS3 (Figure 22). As commonly observed DO concentrations at all sites declined with depth most likely due to decreased photosynthesis at depth. Turbidity remained stable throughout the water column at all nearshore sites except near the benthos, particularly at OS4, most probably due to the resuspension of benthic sediments.

Within the offshore region of the spoil ground, the water column displayed relative consistent temperature, pH and conductivity profiles, although conductivity in surface waters at OS5 were lower than the other sites until ~ 1 m (Figure 23). DO concentrations, again tended to decrease among all spoil ground sites closer to the benthos, due to reduced photosynthetic activity at depth. Turbidity remained stable throughout the water column at all sites between 11 and 17 m, where it increased due to benthic resuspension.

The shallowest euphotic depth of 5.9 m occurred within upper harbour monitoring site UH3 (Table 10), which reflects the typically higher levels of turbidity experienced in this area (Figure 21). The deepest euphotic depth was calculated to be 15.2 m at SG1 (Table 12) where turbidity throughout the column was typically low. During April no exceedances of WQG were recorded at the sub-surface during depth profiling.

Table 10 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the April 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, n = 22 to 38 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/)	K_d	Euphotic Depth (m)
UH1	29/04/2020 05:37	Sub-surface	12.9 ± 0	8 ± 0	0.6 ± 0	101 ± 0	3.2 ± 0	6	0.6 ± 0	7.7
		Whole column	12.9 ± 0.5	8 ± 0	51.3 ± 0	101 ± 0	3.7 ± 0.4	-		
UH2	29/04/2020 06:21	Sub-surface	13 ± 0	8.1 ± 0	0.5 ± 0	104 ± 0	2.3 ± 0	<3	0.5 ± 0	10.0
		Whole column	13 ± 0.4	8.1 ± 0	51.3 ± 0	103 ± 0	2.3 ± 0	-		
UH3	29/04/2020 06:03	Sub-surface	12.8 ± 0	8 ± 0	51.3 ± 0	101 ± 0	3.6 ± 0	4	0.8 ± 0.1	5.9
		Whole column	12.8 ± 0.5	8 ± 0	51.3 ± 0	101 ± 0	3.6 ± 0	-		
CH1	29/04/2020 07:06	Sub-surface	13 ± 0	8.1 ± 0	51.3 ± 0	103 ± 0	3.5 ± 0.2	8	0.7 ± 0	6.9
		Whole column	13 ± 0.4	8.1 ± 0	51.3 ± 0	102 ± 0	3.6 ± 0.1	-		
CH2	29/04/2020 06:47	Sub-surface	13.3 ± 0	8.1 ± 0	51.4 ± 0	105 ± 0	4 ± 0.3	5	0.6 ± 0	8.0
		Whole column	13.3 ± 0.5	8.1 ± 0	51.4 ± 0	105 ± 0	3.4 ± 0.1	-		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 11 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the April 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 31 to 45 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS1	29/04/2020 07:37	Sub-surface	13.5 ± 0	8.1 ± 0	0.5 ± 0	106 ± 0	2.4 ± 0	5	0.5 ± 0	9.5
		Mid	13.4 ± 0	8.1 ± 0	51.4 ± 0	104 ± 0	2.6 ± 0.1	5		
		Benthos	13.4 ± 0	8.1 ± 0	51.4 ± 0	104 ± 0	4.3 ± 0.6	10		
		Whole column	13.5 ± 0.5	8.1 ± 0	51.3 ± 0	105 ± 0	2.9 ± 0.2	-		
OS2	29/04/2020 11:47	Sub-surface	13.6 ± 0	8.1 ± 0	51.3 ± 0	107 ± 0	2.4 ± 0	3	0.5 ± 0	9.2
		Mid	13.4 ± 0	8.1 ± 0	51.4 ± 0	106 ± 0	2.8 ± 0.1	11		
		Benthos	13.4 ± 0	8.1 ± 0	51.4 ± 0	105 ± 0	5.7 ± 0.8	5		
		Whole column	13.5 ± 0.5	8.1 ± 0	51.4 ± 0	106 ± 0	3.2 ± 0.2	-		
OS3	29/04/2020 10:59	Sub-surface	13.7 ± 0	8.1 ± 0	51.4 ± 0	105 ± 0	2.2 ± 0	<3	0.6 ± 0	8.2
		Mid	13.5 ± 0	8.1 ± 0	51.5 ± 0	102 ± 0	3.5 ± 0.1	8		
		Benthos	13.4 ± 0	8 ± 0	51.5 ± 0	99 ± 0	5.3 ± 0.2	8		
		Whole column	13.6 ± 0.5	8.1 ± 0	51.4 ± 0	102 ± 0	3.5 ± 0.2	-		
OS4	29/04/2020 10:12	Sub-surface	13.7 ± 0	8.1 ± 0	51.6 ± 0	103 ± 0	3.2 ± 0.1	3	0.5 ± 0	8.7
		Mid	13.6 ± 0	8.1 ± 0	51.6 ± 0	102 ± 0	3.3 ± 0.1	6		
		Benthos	13.6 ± 0	8.1 ± 0	51.6 ± 0	101 ± 0	6.2 ± 1.4	10		
		Whole column	13.6 ± 0.4	8.1 ± 0	51.6 ± 0	102 ± 0	3.8 ± 0.3	-		
OS7	29/02/2020 12:07	Sub-surface	13.7 ± 0	8.1 ± 0	51.3 ± 0	110 ± 0	2.6 ± 0	3	0.5 ± 0	8.9
		Mid	13.5 ± 0	8.1 ± 0	51.3 ± 0	109 ± 0	2.7 ± 0	5		
		Benthos	13.4 ± 0	8.1 ± 0	51.4 ± 0	106 ± 0	3.4 ± 0.1	4		
		Whole column	13.6 ± 0.5	8.1 ± 0	51.3 ± 0	109 ± 0	2.8 ± 0.1	-		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 12 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the April 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 43 to 56 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS5	29/02/2020 08:08	Sub-surface	13.4 ± 0	8.1 ± 0	50.6 ± 0.2	108 ± 0	1.9 ± 0.1	3	0.4 ± 0	11.3
		Mid	13.4 ± 0	8.1 ± 0	51.3 ± 0	107 ± 0	1.6 ± 0	<3		
		Benthos	13.6 ± 0	8.1 ± 0	51.6 ± 0	100 ± 0	3.9 ± 0.1	7		
		Whole column	13.4 ± 0.4	8.1 ± 0	51.2 ± 0.1	106 ± 0	2.1 ± 0.1	-		
OS6	29/02/2020 11:22	Sub-surface	13.7 ± 0	8.1 ± 0	51.3 ± 0	109 ± 0	2.6 ± 0.1	3	0.5 ± 0	9.0
		Mid	13.4 ± 0	8.1 ± 0	51.4 ± 0	106 ± 0	2.7 ± 0.1	5		
		Benthos	13.4 ± 0	8.1 ± 0	51.4 ± 0	103 ± 0	5.4 ± 0.4	25		
		Whole column	13.5 ± 0.4	8.1 ± 0	51.4 ± 0	107 ± 0	3.2 ± 0.2	-		
SG1	29/02/2020 08:39	Sub-surface	13.6 ± 0	8.1 ± 0	51.5 ± 0	104 ± 0	1.7 ± 0	5	0.3 ± 0	15.2
		Mid	13.5 ± 0	8.1 ± 0	51.5 ± 0	104 ± 0	1.5 ± 0	<3		
		Benthos	13.5 ± 0	8.1 ± 0	51.6 ± 0	104 ± 0	2.4 ± 0.5	<3		
		Whole column	13.5 ± 0.4	8.1 ± 0	51.5 ± 0	104 ± 0	1.7 ± 0.1	-		
SG2	29/04/2020 09:07	Sub-surface	13.5 ± 0	8.1 ± 0	51.4 ± 0	109 ± 0	1.9 ± 0	<3	0.4 ± 0	11.7
		Mid	13.5 ± 0	8.1 ± 0	51.4 ± 0	107 ± 0	1.8 ± 0	3		
		Benthos	13.5 ± 0	8.1 ± 0	51.5 ± 0	101 ± 1	5.3 ± 0.7	5		
		Whole column	13.5 ± 0.4	8.1 ± 0	51.4 ± 0	107 ± 0	2.4 ± 0.2	-		
SG3	29/04/2020 09:40	Sub-surface	13.6 ± 0	8.1 ± 0	51.5 ± 0	102 ± 0	2.4 ± 0	4	0.4 ± 0	12.4
		Mid	13.5 ± 0	8.1 ± 0	51.5 ± 0	100 ± 0	2.4 ± 0	3		
		Benthos	13.6 ± 0	8.1 ± 0	51.6 ± 0	98 ± 1	5.2 ± 0.8	10		
		Whole column	13.5 ± 0.4	8.1 ± 0	51.5 ± 0	100 ± 0	2.7 ± 0.2	-		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

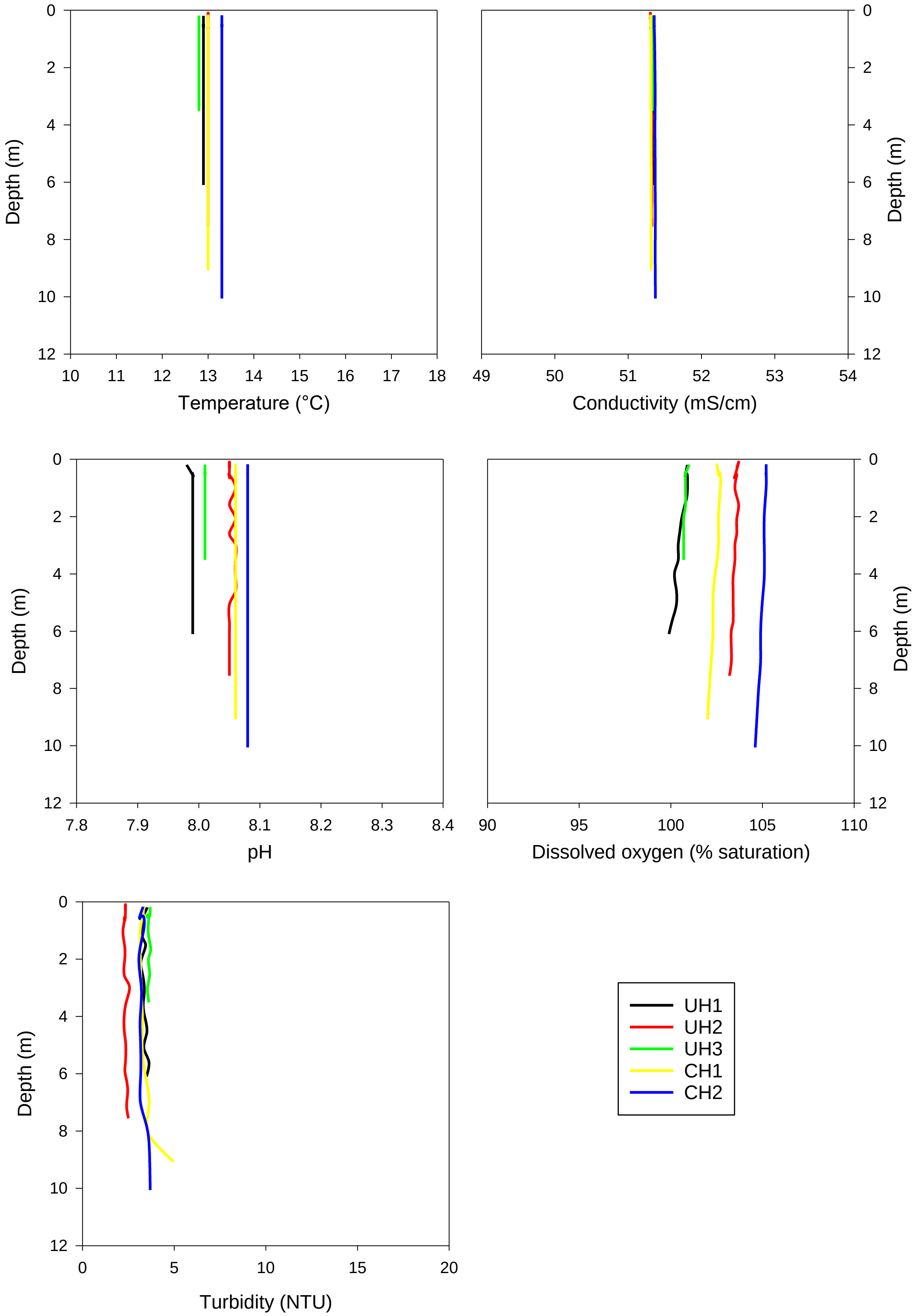


Figure 21 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 29 April 2020

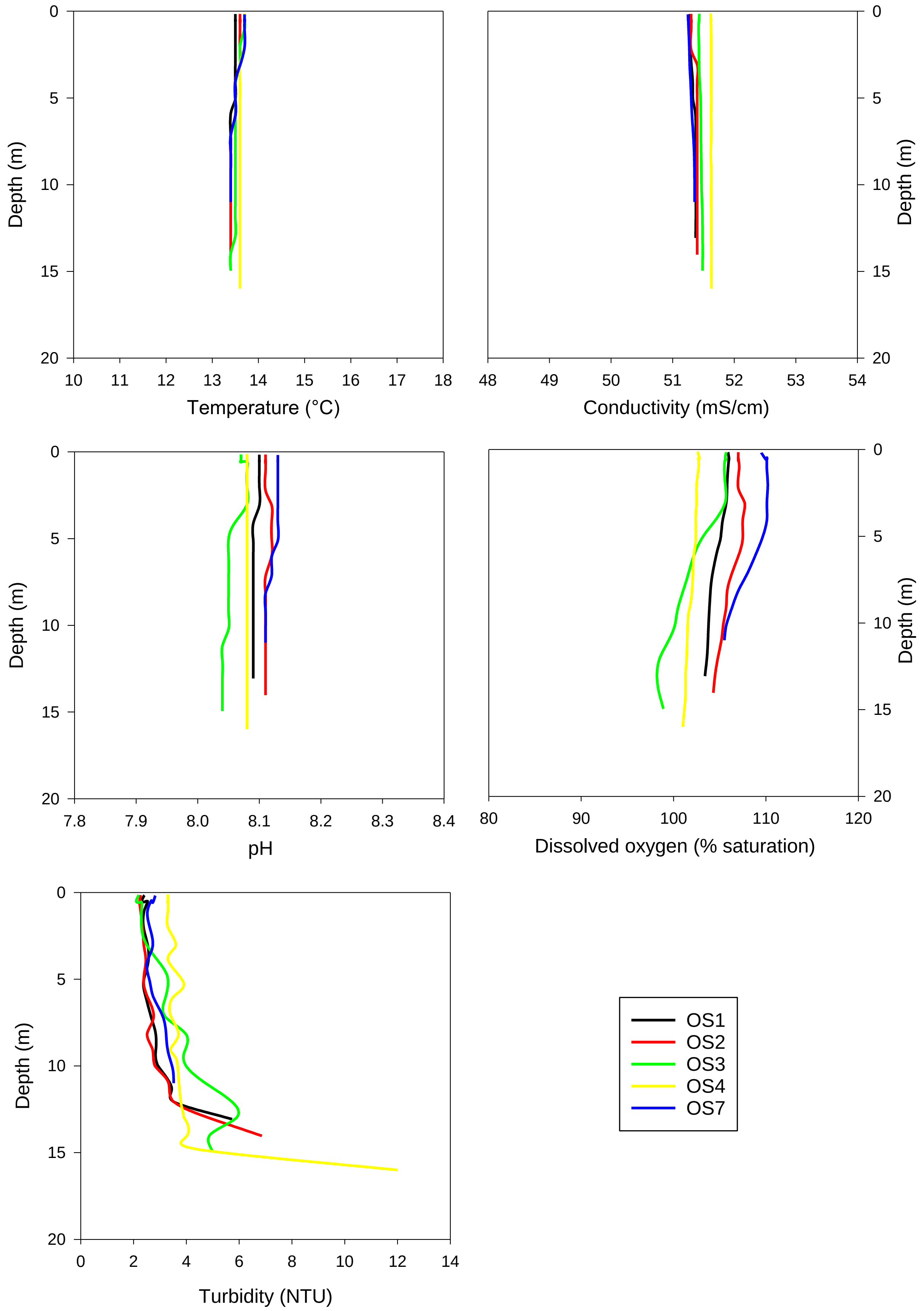


Figure 22 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 29 April 2020

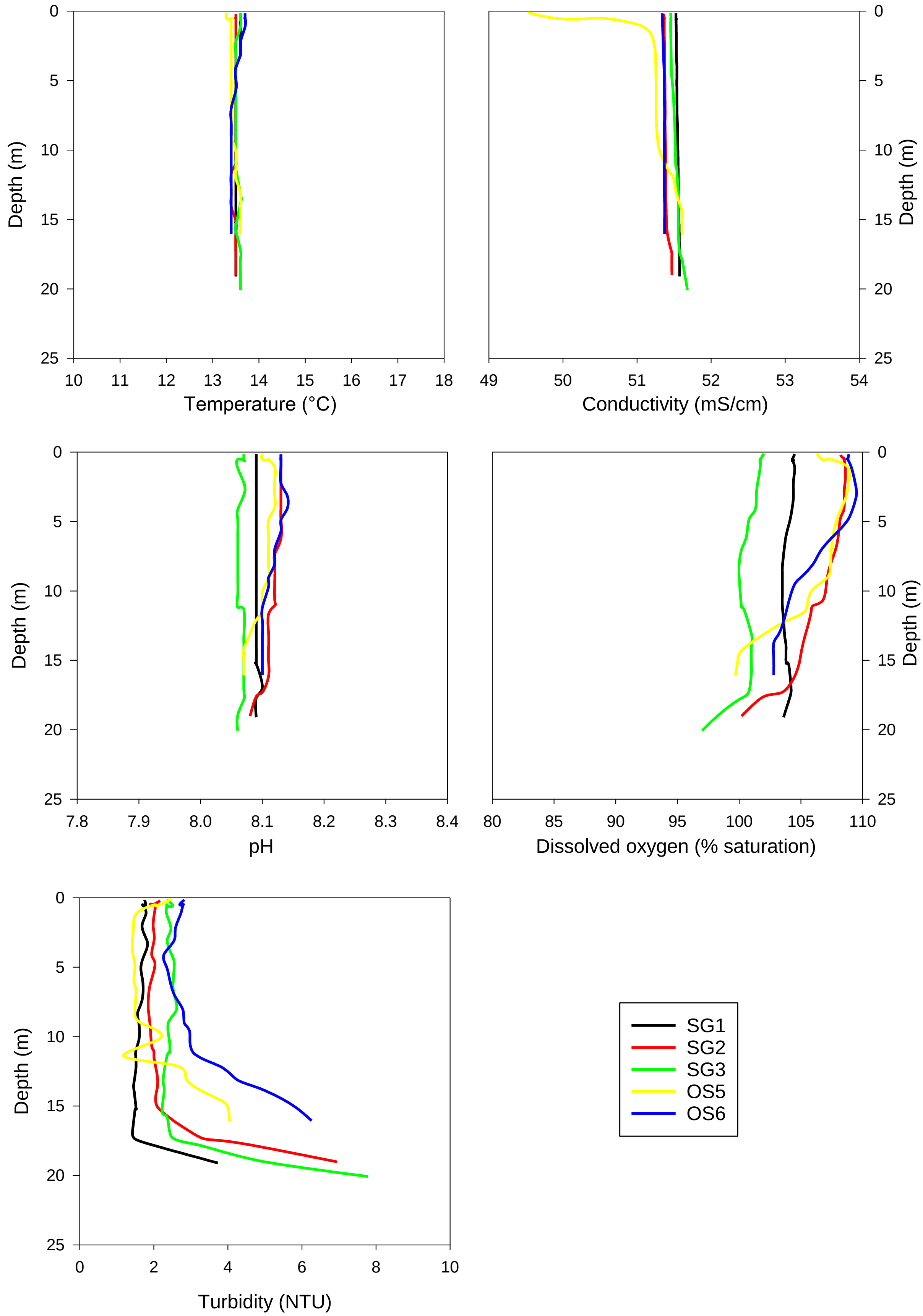


Figure 14 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 29 April 2020.

3.4 Continuous BPAR Loggers

Benthic PAR, or the amount of light reaching the benthos that can be utilised for photosynthesis, was measured at two offshore sites (OS2 and OS3) by autonomous dual PAR Odyssey loggers. Benthic PAR was compared to ambient PAR measured by telemetered loggers located at the Vision Environment office in Christchurch (Vision Base Christchurch, VBCC) in order to account for variations in daily light intensity such as those induced by cloud cover.

Further information on the specific methodology used in BPAR measurements can be obtained from the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

Statistical analyses on the monthly BPAR datasets are presented in Table 13, with the collected data from benthic and VBCC sensors presented in Figure 24.

Table 13 Total Daily PAR (TDP) statistics during April 2020.
Values are means ± se (n = 23 to 30). Note BPAR exchange days did not occur in April.

Site	Depth (m)	TDP (mmol/m^2/day)		
		Mean ± se	Median	Range
Base	-	15,273 ± 1062	15,164	5,892 – 33,747
OS2	17	22 ± 10.5	0	<0.1 – 253
OS3	14	174 ± 67	0	<0.1 – 1,421

Ambient PAR/total daily PAR (TDP, i.e., the amount of sunlight available to enter the water column), turbidity and the depth of the water column, all have a controlling factor on BPAR measurements. As typically observed in temperate regions with high levels of cloud cover, the amount of incoming solar radiation at VBCC was variable, ranging from 5,892 to 33,747 mmol/m^2/day (Table 16), which was slightly lower than the range recorded during March (7,965 to 42,895 mmol/m^2/day). With the reduction in daylight hours during April mean TPD during the month was extremely low and lower (15,164 mmol/m^2/day) than the previous months of March (27,524 mmol/m^2/day) and February (31,923 mmol/m^2/day).

As a result mean BPAR at OS2 was almost negligible, lower in April (22 mmol/m^2/day) compared to March (1,181 mmol/m^2/day). Similarly, OS3 mean BPAR was also lower in April (174 mmol/m^2/day) than levels recorded in March (596 mmol/m^2/day). Turbidity peak on the 5 to 11 and 12 to 18 April were experienced at both sites leading to low TDP values. Lower turbidity values during 20 to 27 April at OS3 related to higher TDP values over this period. However attempted interpretation of TDP data at these extremely low levels is of limited value.

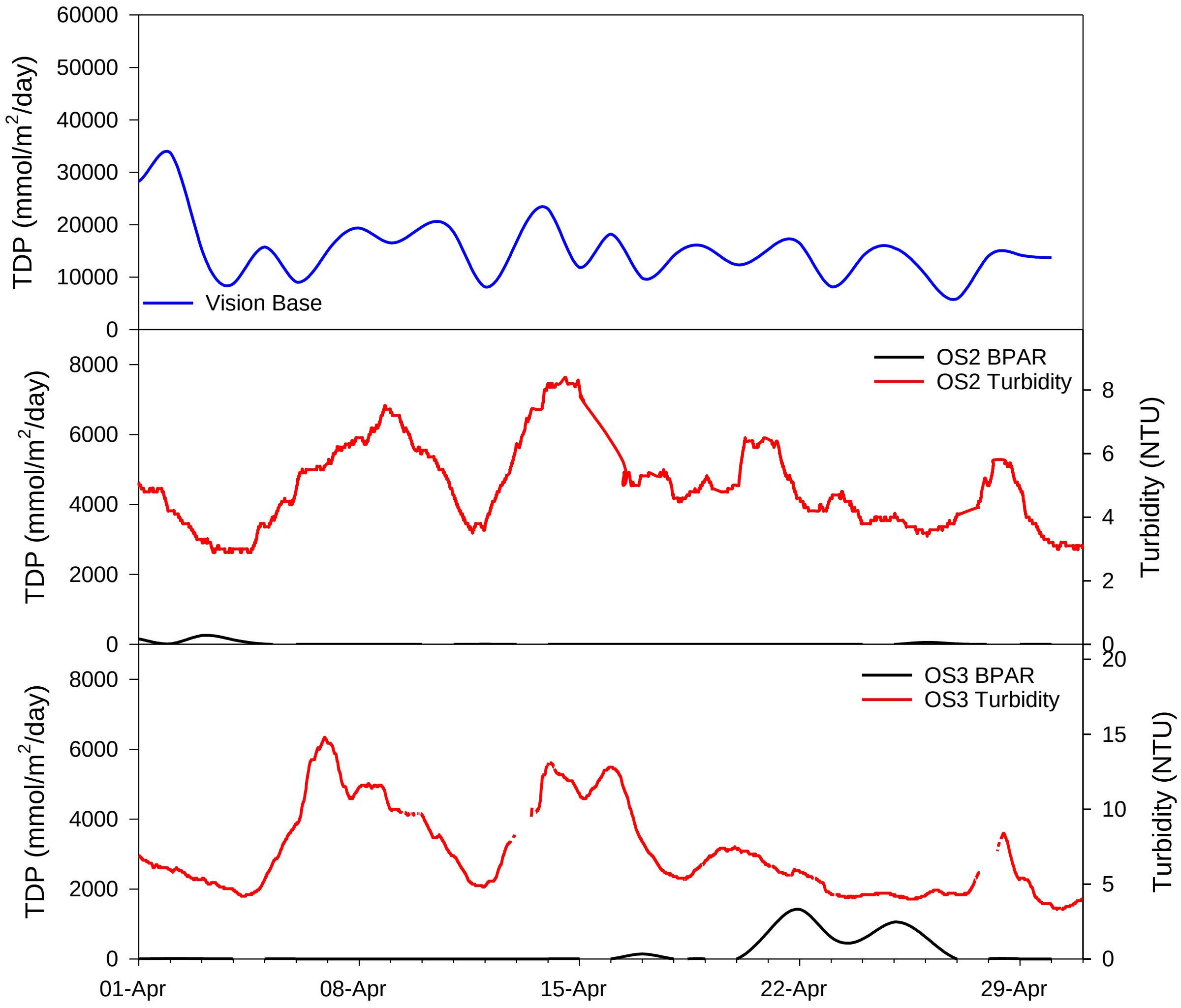


Figure 24 Total daily BPAR at OS2 and OS3 during April 2020 compared to ambient PAR and corresponding surface turbidity (24 hour rolling average).

3.5 Continuous Sedimentation Loggers

Data on sediment deposition/erosion rates were collected at the inshore site UH3 and offshore site OS2, using ALTUS acoustic altimeters located approximately between 200 and 600 mm above the seabed in drop down frames. Further details on the specific methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Changes in energy from wind waves, currents and/or tidally induced flows can result in variations in sedimentation patterns, ranging from deposition of sediments originating from another location, resuspension of sediments with no net change in the seabed 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 15 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.

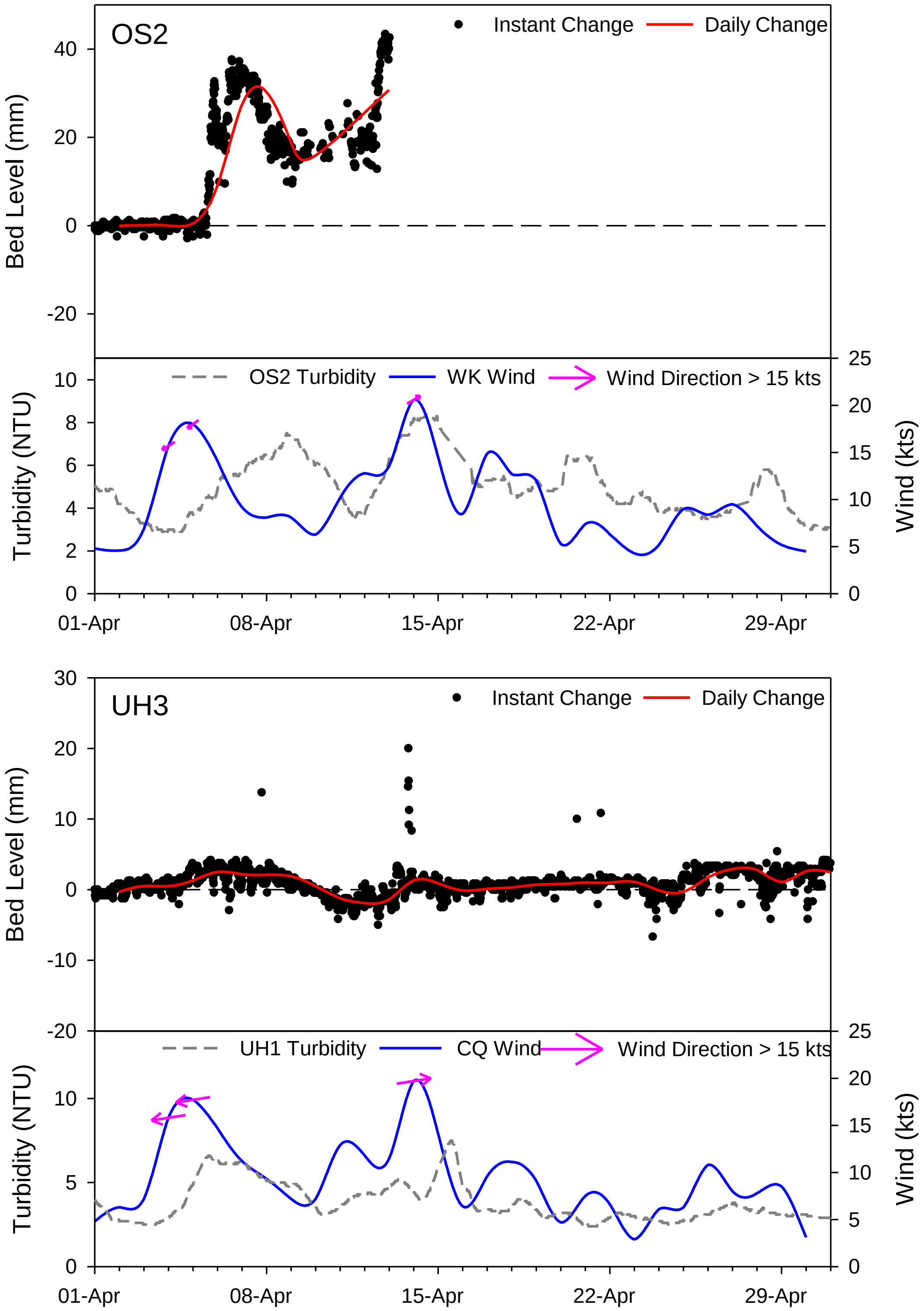


Figure 15 Mean instantaneous and daily averaged bed level change at OS2 and UH3 during April 2020 compared to ambient surface turbidity (24 hour rolling average), wind speed and direction.
Note: Arrows indicate the direction of travel for winds greater than 15 knots. Note OS2 data only available up until 12 April 2020.

Bed level at the offshore site OS2 appears relatively dynamic for the early part of April, while the first few days of the month appear stable, there was a sharp accretion (~ 30 mm) of sediment from the 6 to 8 April. This period closely followed conditions of increased wind speed and then increased turbidity. This was followed by a three-day period of erosion (~15 mm) followed by a gradual accretion of sediment, again coinciding with increased wind speed, until 12 April after which no further data is available. During the short period of available data OS2 recorded an overall accretion of ~ 31 mm of sediment (Table 14).

In line with previous months, bed level within the sheltered upper harbour at UH3 was more stable than that at OS2. A gradual and small accretion (~ 3 mm) of sediment was recorded from the 1 to the 10 April, during which wind strength was elevated. This was followed by a three-day period of erosion equating to around 2 mm before recovering. Again these episodes occurred during or following peaks in wind strength. A stable period in bed level then lasted until 23 April. The end of the month saw a slight accretion period of ~ 3 mm. UH3 recorded and overall accretion of 2.5 mm during April.

Table 14 Net Bed Level Change statistics from data collected from altimeters deployed at OS2 and UH3 during April 2020.
**Note OS2 data only available up until 12 April 2020.*

Site	April 2020 Net bed level change (mm)
OS2	+31*
UH3	+2.5

3.6 Water Samples

Discrete water sampling was conducted on 29 April 2020, in conjunction with vertical physicochemical profiling through the water column. Quality assurance/quality control (QA/QC) procedures included a duplicate water sample collected at one site, in addition to a laboratory and field blank for each parameter. Further details on the specific sampling methodology can be found within the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Laboratory results associated with VE QA/QC procedures are presented in Table 19 of the Appendix.

3.6.1 Nutrients

Total phosphorous concentrations exhibited no particular spatial pattern during April sampling, unlike previous months where higher concentrations have been recorded in the upper and central sites. Total phosphorous remained below the WQG of 30 µg/L at all sites. Dissolved reactive phosphorous concentrations were above the WQG of 5 µg/L at all sites in April, again exhibiting no particular spatial pattern. Both total nitrogen and total kjeldahl nitrogen (TKN) were < LOR and < WQG at all sites as reported in previous months.

Total ammonia ranged from 9 to 28 µg/L with all sites except for five sites exceeding the WQG (15 µg/L) with three located inshore and two offshore. Nitrogen oxide values ranged from 7.4 to 85 µg/L with nine sites recording values above the WQG (>15 µg/L). Concentrations of bioavailable nutrients were unusually high this may be an anomaly related to the Covid19 delay in sampling processing.

Chlorophyll *a*, an indicator of phytoplankton biomass, recorded concentrations above the WQG value (4 µg/L) at four sites in the spoil ground and outer harbour sites during April, indicating higher than normal algal populations potentially due to readily bioavailable nutrients (Table 15).

Table 15 Concentrations of nutrients and chlorophyll *a* at monitoring sites during April 2020.
Values outside recommended WQG are highlighted in blue.

Site	Parameter (µg/L)						
	Total Phosphorus	Dissolved Reactive Phosphorus	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)	Total Ammonia	Nitrogen Oxides (NOx)	Chlorophyll *a*
UH1	18	10.6	<300	<200	13	40	2.7
UH2	16	9.4	<300	<200	9	71	2.2
UH3	20	12.2	<300	<200	12	85	3
CH1	14	9.7	<300	<200	19	26	2.6
CH2	14	8.2	<300	<200	28	60	3.9
OS1	14	9.4	<300	<200	16	69	4.1
OS2	12	9	<300	<200	18	8.3	2.5
OS3	14	9.2	<300	<200	16	10.5	1.6
OS4	20	11.4	<300	<200	21	10.6	1.1
OS5	14	10.1	<300	<200	24	23	1.6
OS6	20	8	<300	<200	13	8.4	4.9
OS7	14	7.9	<300	<200	12	5.7	2.1
SG1	18	8.7	<300	<200	18	22	5
SG2	14	7.7	<300	<200	16	7.4	4.4
SG3	16	11.7	<300	<200	22	23	2.2
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

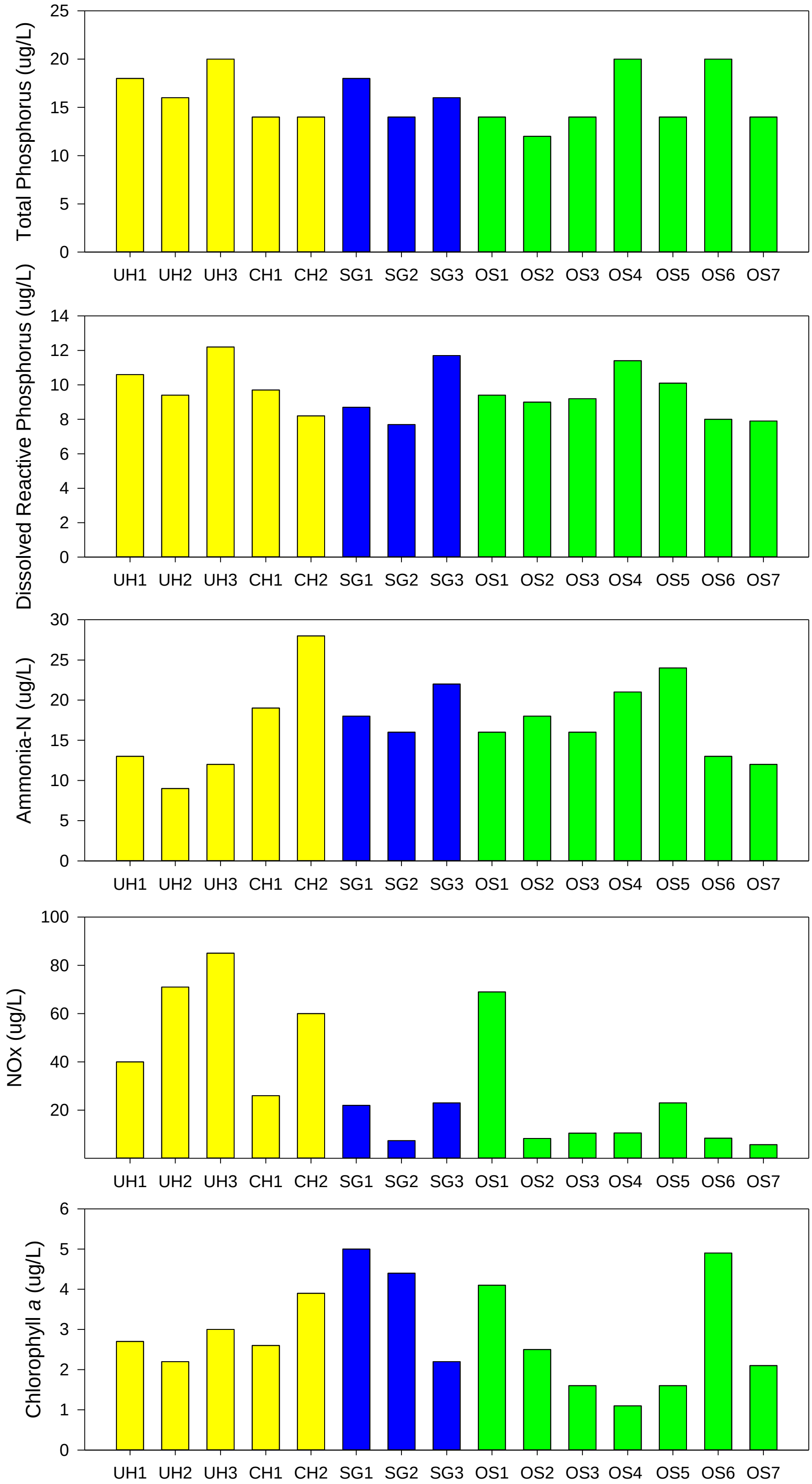


Figure 166 Nutrient and chlorophyll *a* concentrations at monitoring sites during April 2020. *Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.*

3.6.2 Total and Dissolved Metals

Concentrations of the majority of recorded metals were relatively low during the month of April. Concentrations of several metals (Tables 16 to 18, Figure 27 and 28) were reported as below the limit of reporting (LOR) at all sites, including dissolved and total arsenic (<4.2 µg/L), cadmium (<0.21 µg/L), cobalt (<0.63 µg/L), copper (<1.1 µg/L) lead (< 1.1 µg/L) mercury (<0.08 µg/L), nickel (<7 µg/L), selenium (<4.2 µg/L), silver (<0.43 µg/L), tin (<5.3 µg/L) and zinc (4.2 µg/L).

Dissolved concentrations of aluminium were <LOR at all sites. Concentrations of total aluminium exceeded the designated 95% species protection value of 24 µg/L at all sites except at UH1, CH1 and CH2. However, the WQG is applicable to the dissolved fraction only (ANZG, 2018), therefore no exceedances were recorded in April. Concentrations of dissolved iron were below the LOR of 4 µg/L for the majority of sites, except three inshore sites (UH1, UH2 and CH2), which recorded values of dissolved iron between 4 µg/L and 8 µg/L. Total aluminium and iron concentrations were highest amongst the inshore monitoring sites as often reported. There are no trigger values for dissolved or total iron concentrations.

Chromium, manganese, molybdenum and vanadium were recorded at majority of sites in both total and dissolved forms. Total and dissolved chromium concentrations were well below the 95% species protection trigger value of 4.4 µg/L from CrVI and 27.4 µg/L for CrIII at all sites. Vanadium concentrations ranged from 1.7 to 2.1 µg/L and were also well below the 95% species protection trigger value of 100 µg/L.

No trigger values are available for either manganese or molybdenum. Total and dissolved manganese concentrations showed little spatial variation and ranged from 3.2 to 9.3 µg/L and <1 to 5.2 µg/L respectively. As previously reported, total and dissolved molybdenum concentrations exhibited little spatial variation, ranging from 11.2 to 12 µg/L and 10.8 to 11.4 µg/L respectively.

Table 16 Total and dissolved metal concentrations at inshore monitoring sites during April 2020. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	<12	<12	<12	<12	24
	Total	<21	<21	108	78	107	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	1.3	<1	1.2	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.4	<1.1	<1.1	<1.1	1.7	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	8	4	<4	<4	5	-
	Total	<4	<4	141	80	124	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	4.2	<1	5.2	2.7	1.7	-
	Total	4.2	3.2	9.3	5.7	6.3	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	10.8	10.8	10.9	11.2	10.9	-
	Total	11.5	11.7	11.5	11.7	11.4	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	1.7	1.8	1.7	1.9	100
	Total	1.8	1.9	2.1	2	2	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 17 Total and dissolved metal concentrations at offshore monitoring sites during April 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites							WQG
		OS1	OS2	OS3	OS4	OS5	OS6	OS7	
Aluminium	Dissolved	<12	<12	<12	<12	<12	<12	<12	24
	Total	62	56	38	86	65	77	58	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	1	1.2	<1	1.1	<1	1.5	1.1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.2	1.2	<1.1	1.2	<1.1	1.5	1.3	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	<1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	<4	<4	<4	<4	<4	4	-
	Total	70	58	46	105	57	72	58	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.6	1.5	1.1	<1	2	1.6	1.4	-
	Total	4.3	4	4.1	3.8	4.6	4	4.2	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.4	11.1	11	11	10.7	11.4	11.1	-
	Total	11.7	11.2	12.1	11.7	11.3	11.9	12	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	2	1.9	1.9	1.9	1.9	1.9	1.7	100
	Total	2	2.1	2	2.1	2.1	2.1	2	
Zinc	Dissolved	<4	<4	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 18 Total and dissolved metal concentrations at spoil ground monitoring sites during April 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	37	45	56	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	1.3	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	<4	<4	-
	Total	36	53	66	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.1	<1	1.1	-
	Total	3.6	3.7	4.4	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.2	11.2	11.2	-
	Total	11.7	11.7	11.5	
Nickel	Dissolved	<7	<7	<7	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	1.8	1.9	100
	Total	2.1	2	2	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

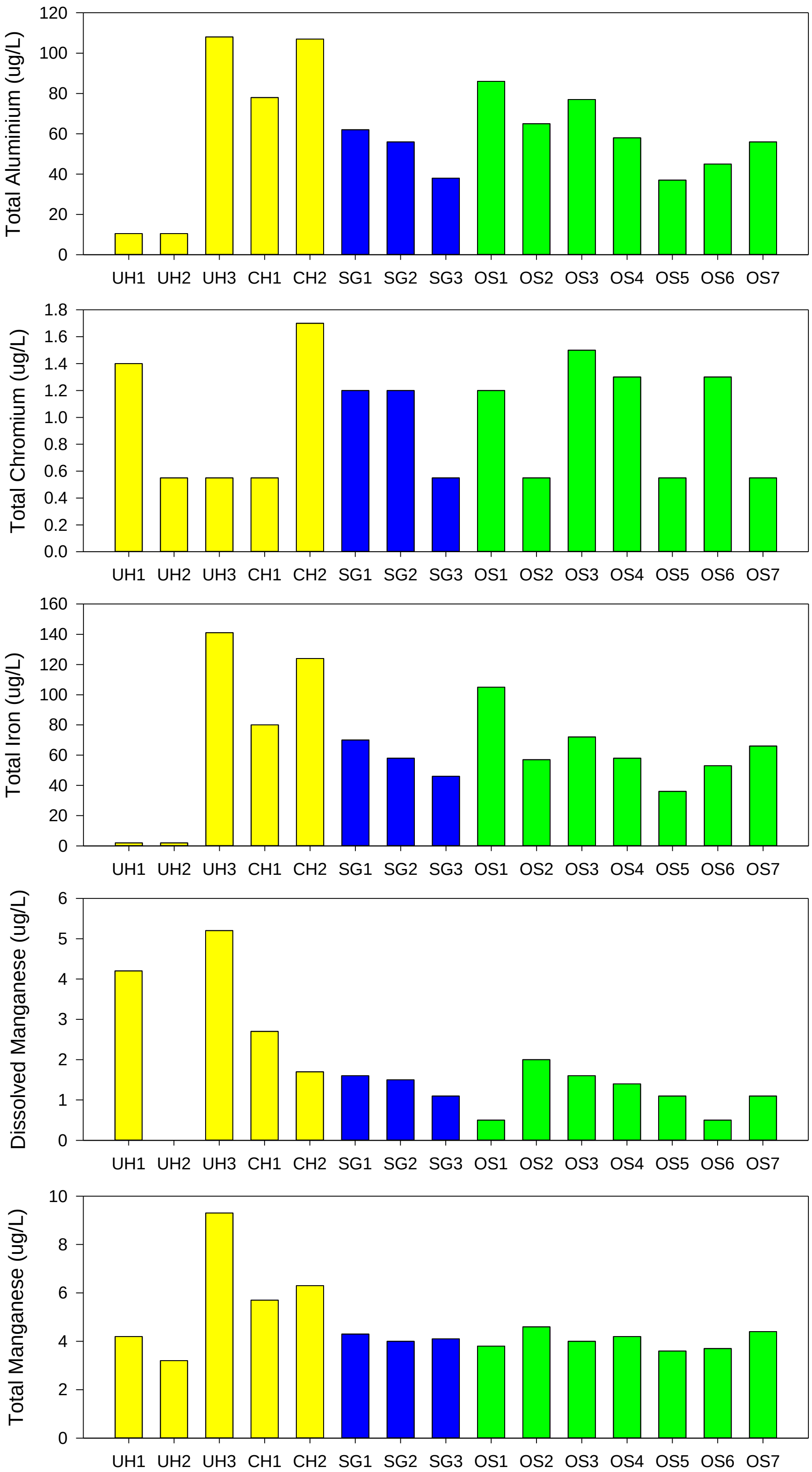


Figure 27 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during April 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

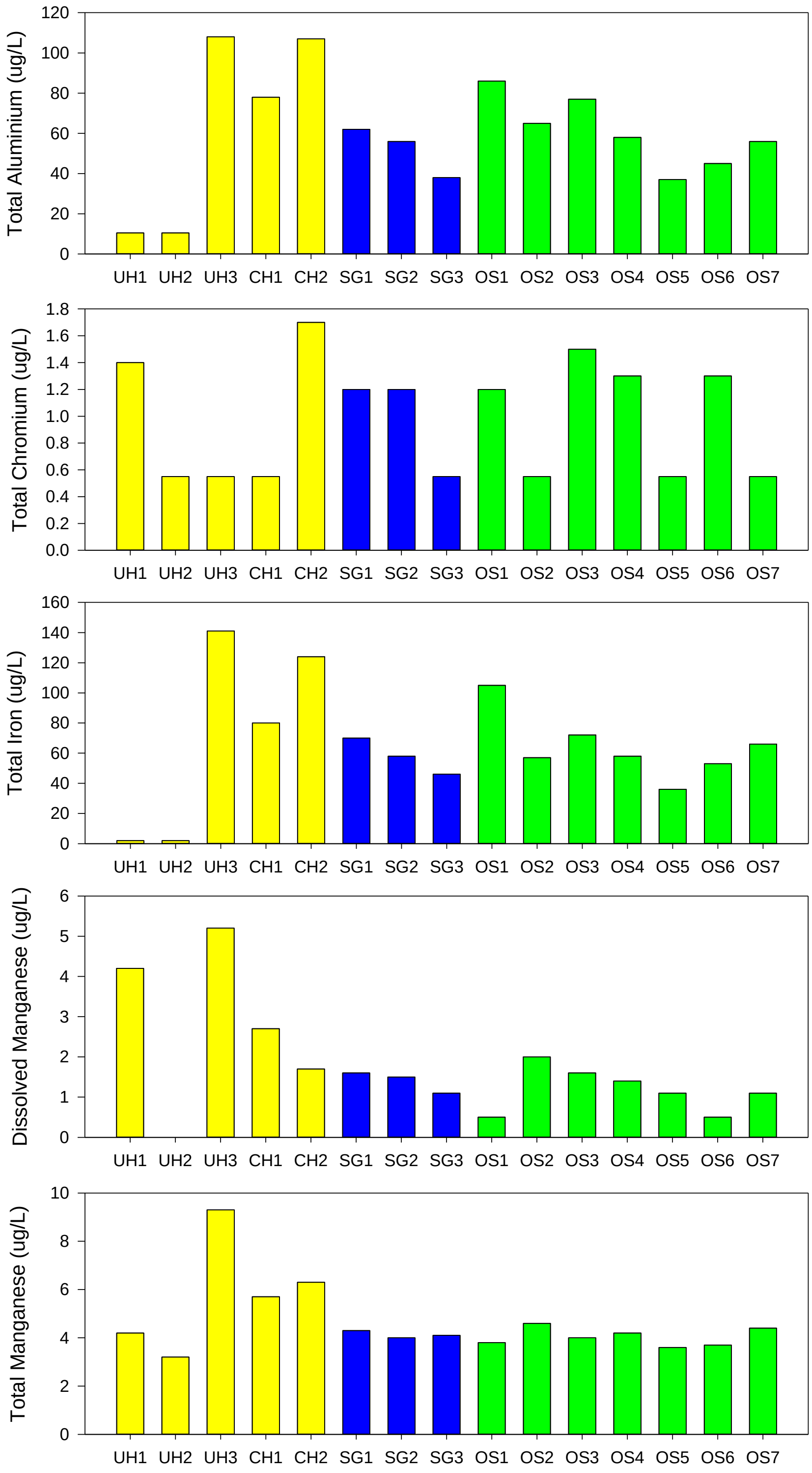


Figure 28 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during April 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

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5 APPENDIX

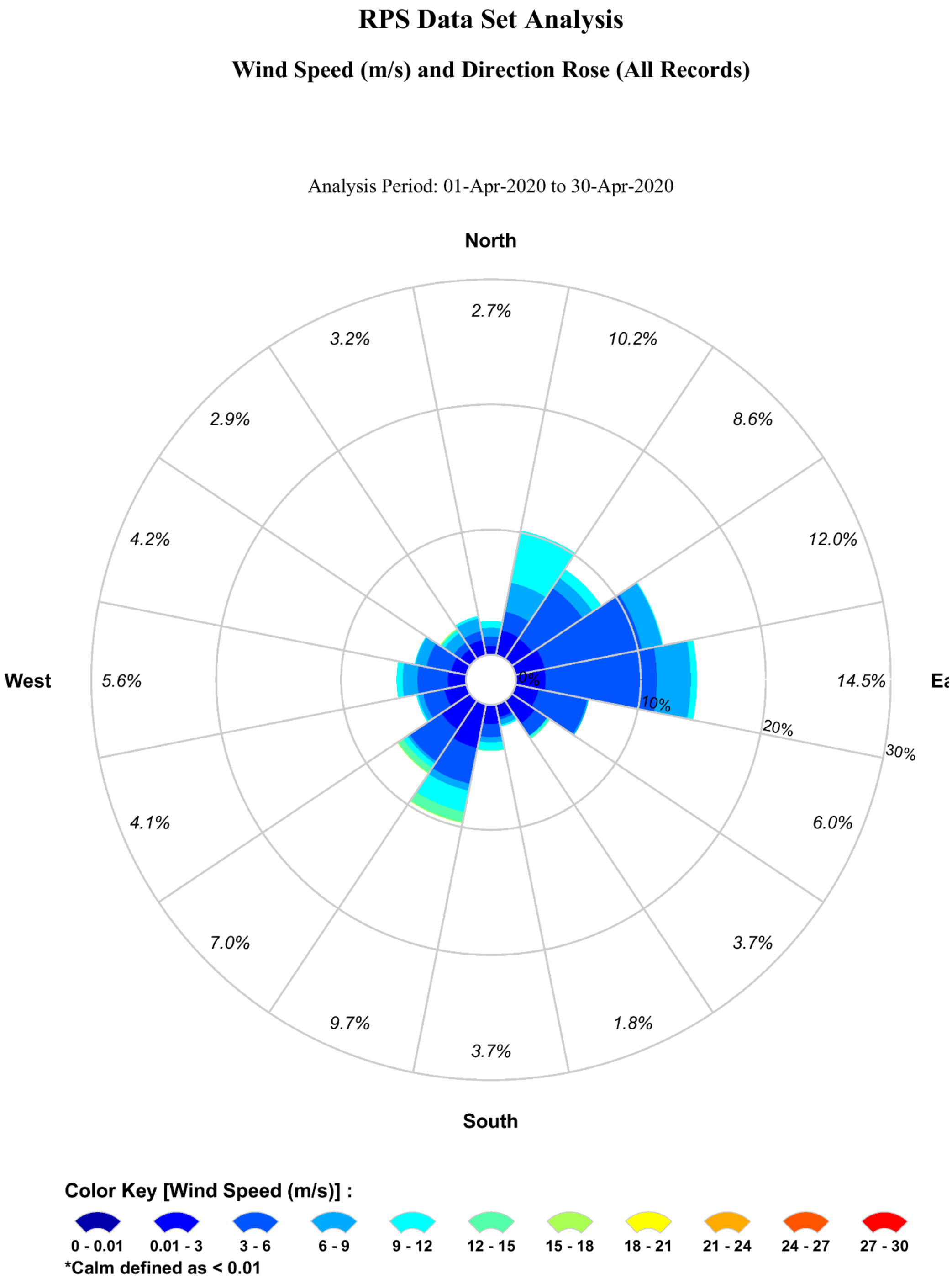
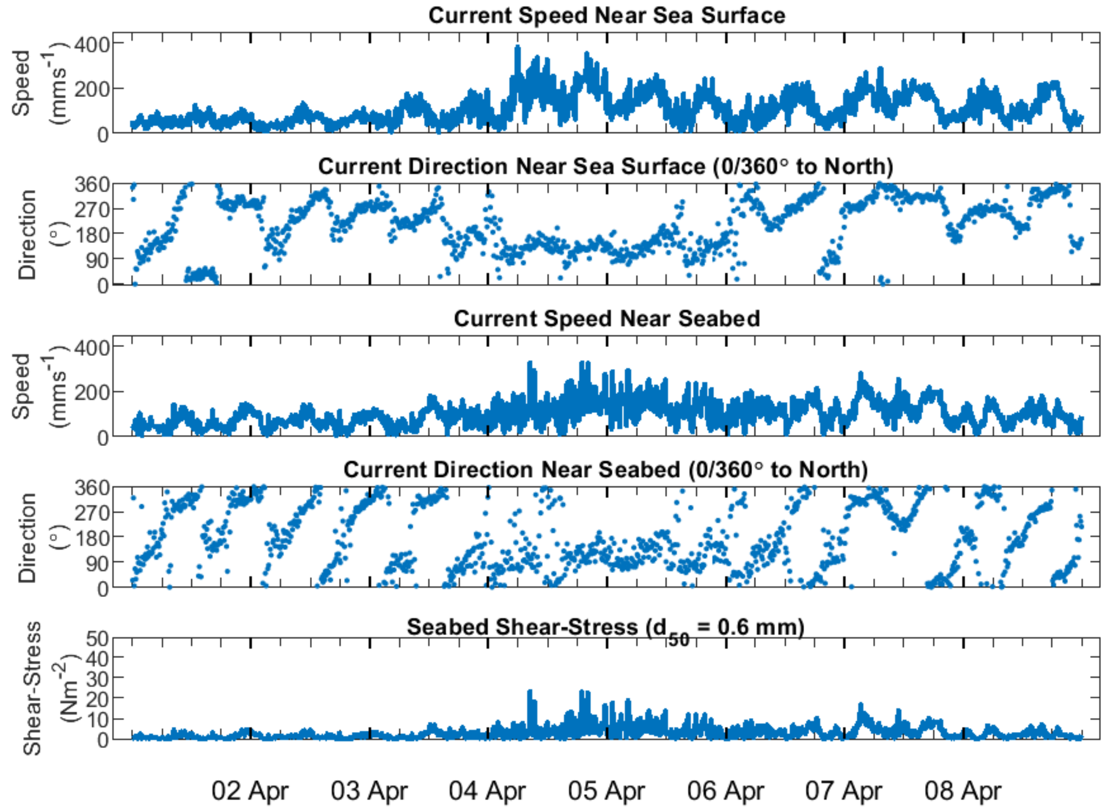


Figure 29 WatchKeeper wind speed (m/s) and direction rose (%) during April 2020.



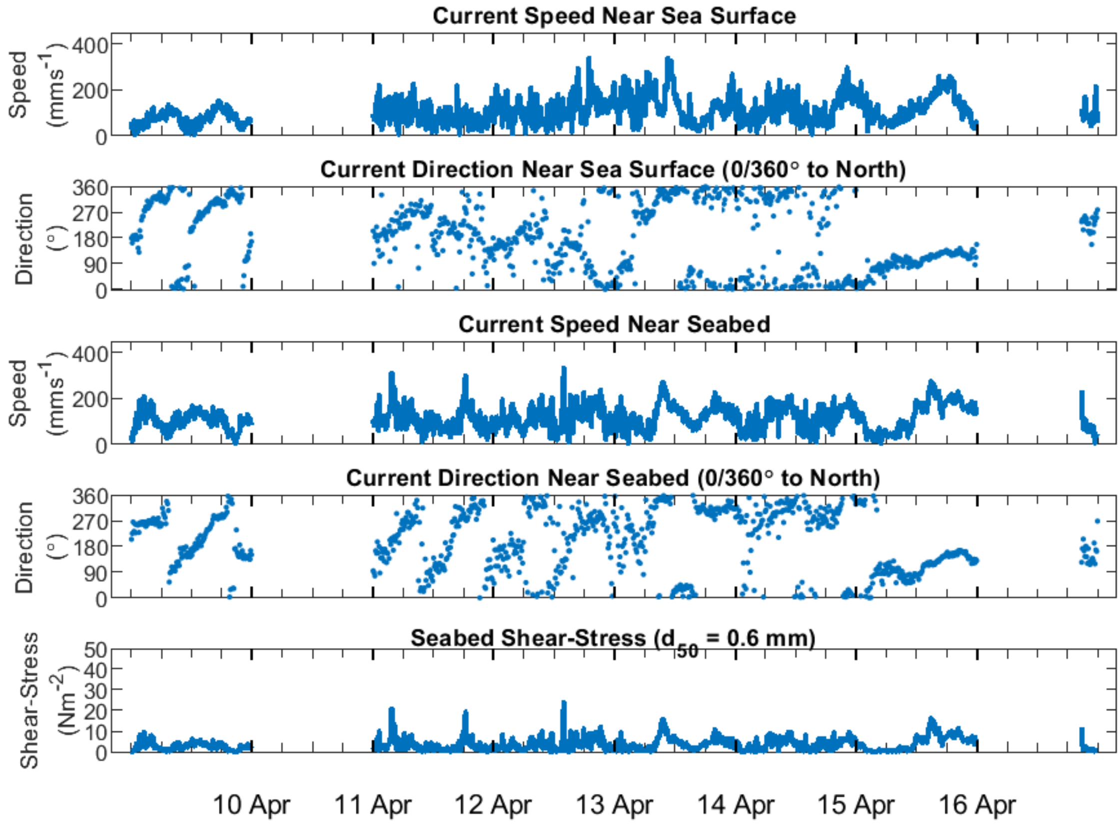


Figure 30 SG1 current speed, direction and shear bed stress 1 to 16 April 2020.

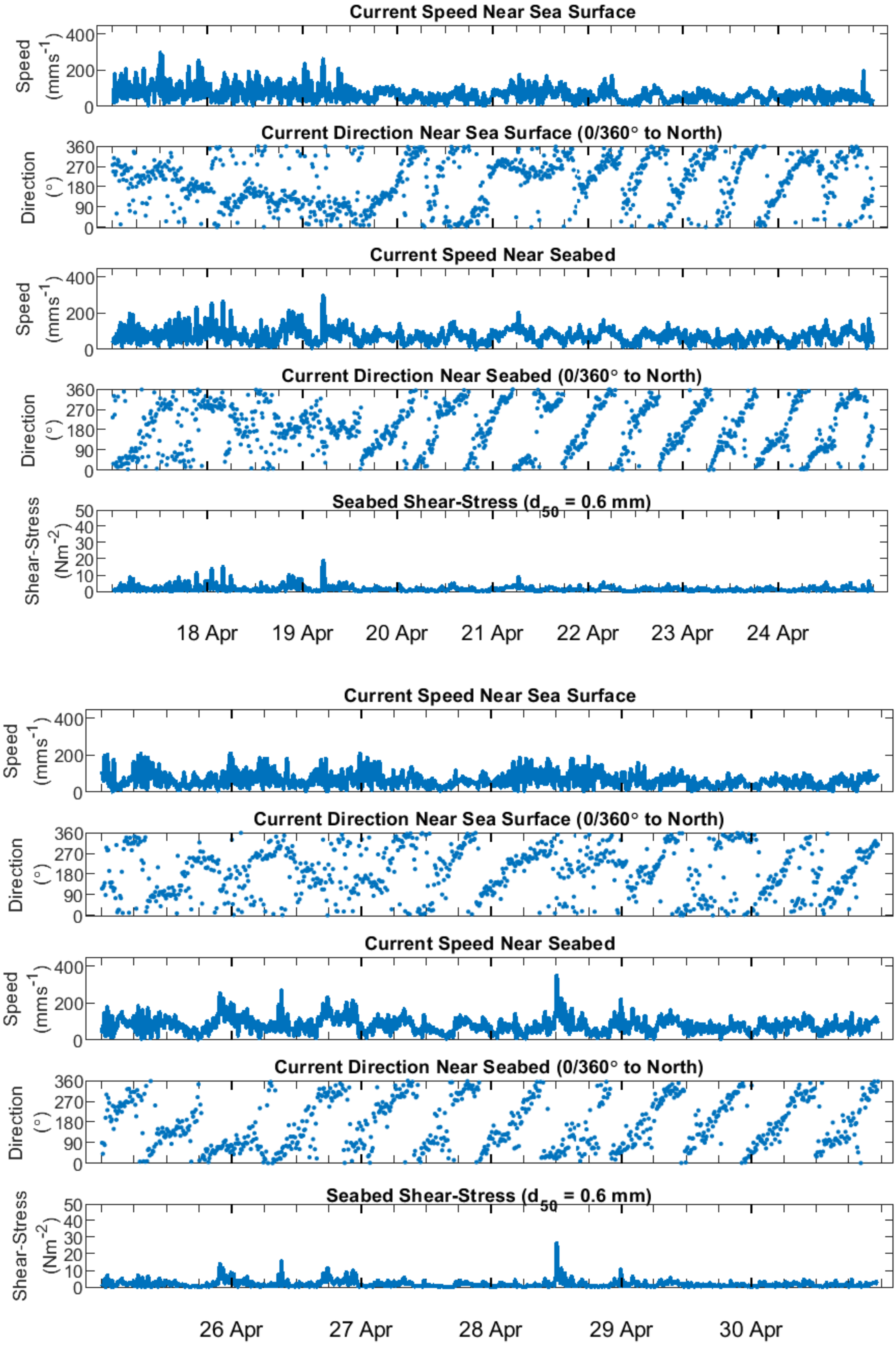
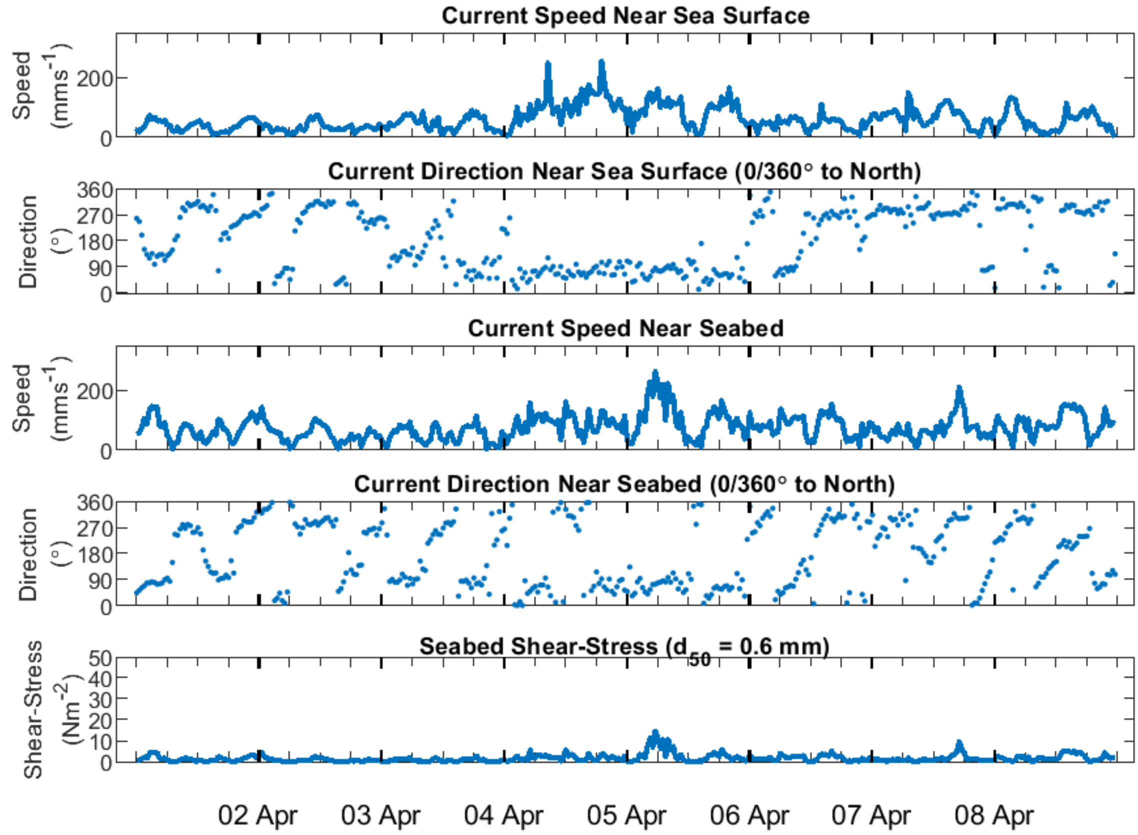


Figure 31 SG1 current speed, direction and shear bed stress 17 to 30 April 2020.


Current Speed Near Sea Surface
Speed (mms-1)
Current Direction Near Sea Surface (0/360° to North)
Direction (°)
Current Speed Near Seabed
Current Direction Near Seabed (0/360° to North)
Seabed Shear-Stress (d50 = 0.6 mm)
Shear-Stress (Nm-2)
02 Apr
03 Apr
04 Apr
05 Apr
06 Apr
07 Apr
08 Apr

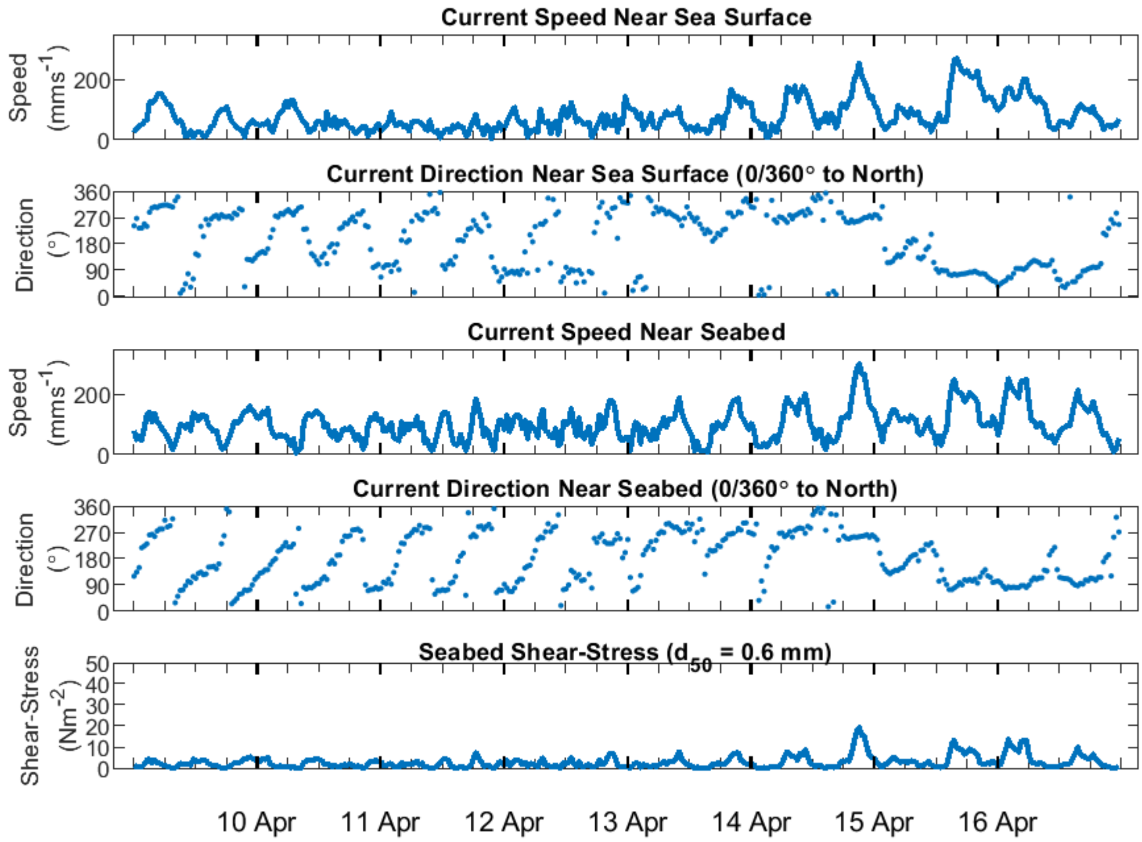
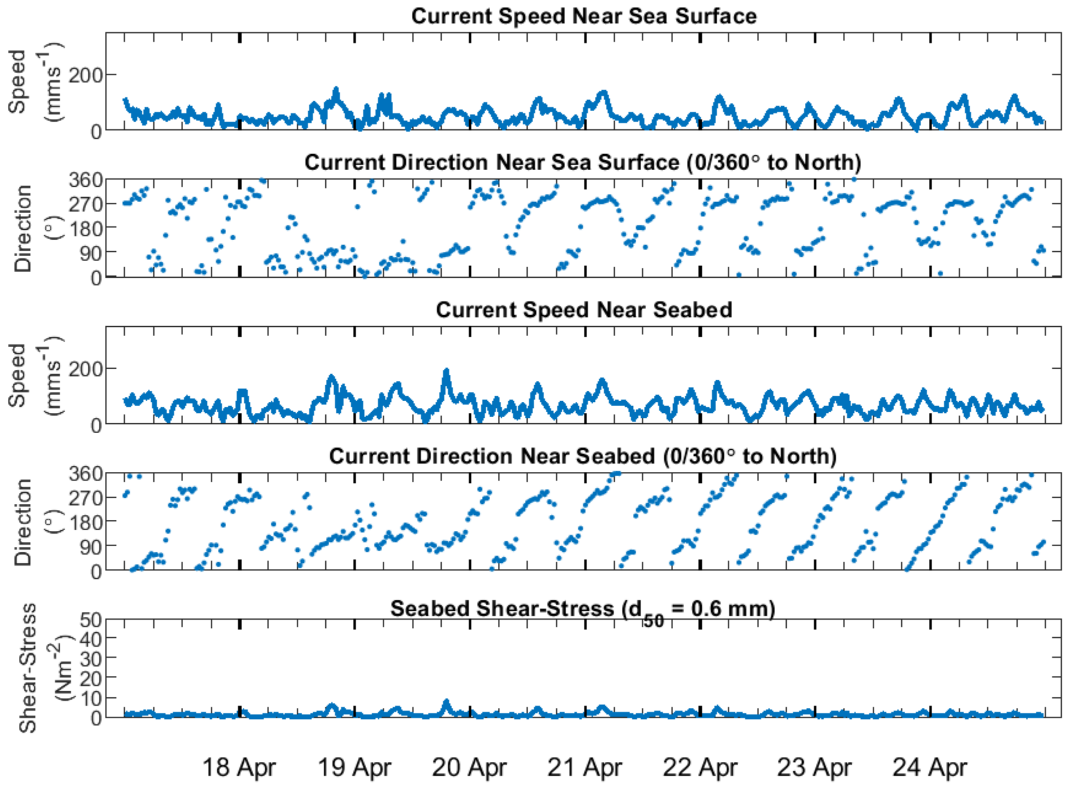

Current Speed Near Sea Surface
Speed (mms-1)
Current Direction Near Sea Surface (0/360° to North)
Direction (°)
Current Speed Near Seabed
Current Direction Near Seabed (0/360° to North)
Seabed Shear-Stress (d50 = 0.6 mm)
Shear-Stress (Nm-2)
10 Apr
11 Apr
12 Apr
13 Apr
14 Apr
15 Apr
16 Apr

Figure 32 SG2a (WatchKeeper) current speed, direction and shear bed stress 1 to 16 April 2020.



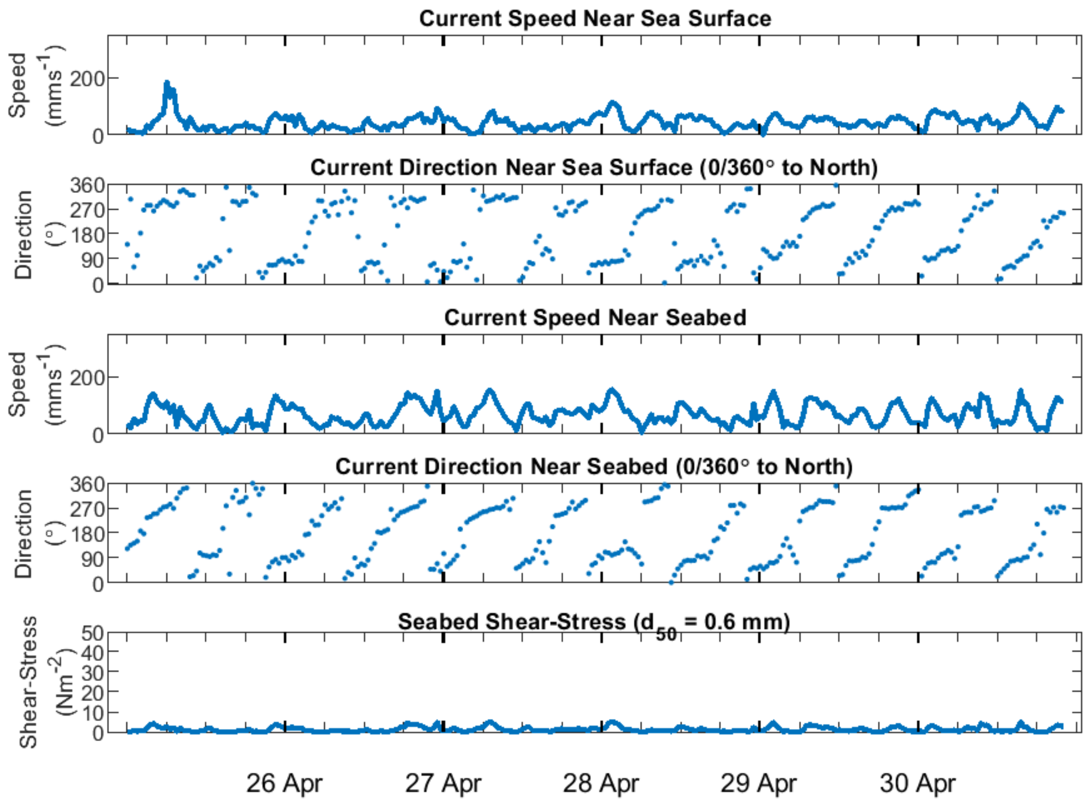


Figure 17 SG2a (WatchKeeper) current speed, direction and shear bed stress 17 to 30 April 2020.

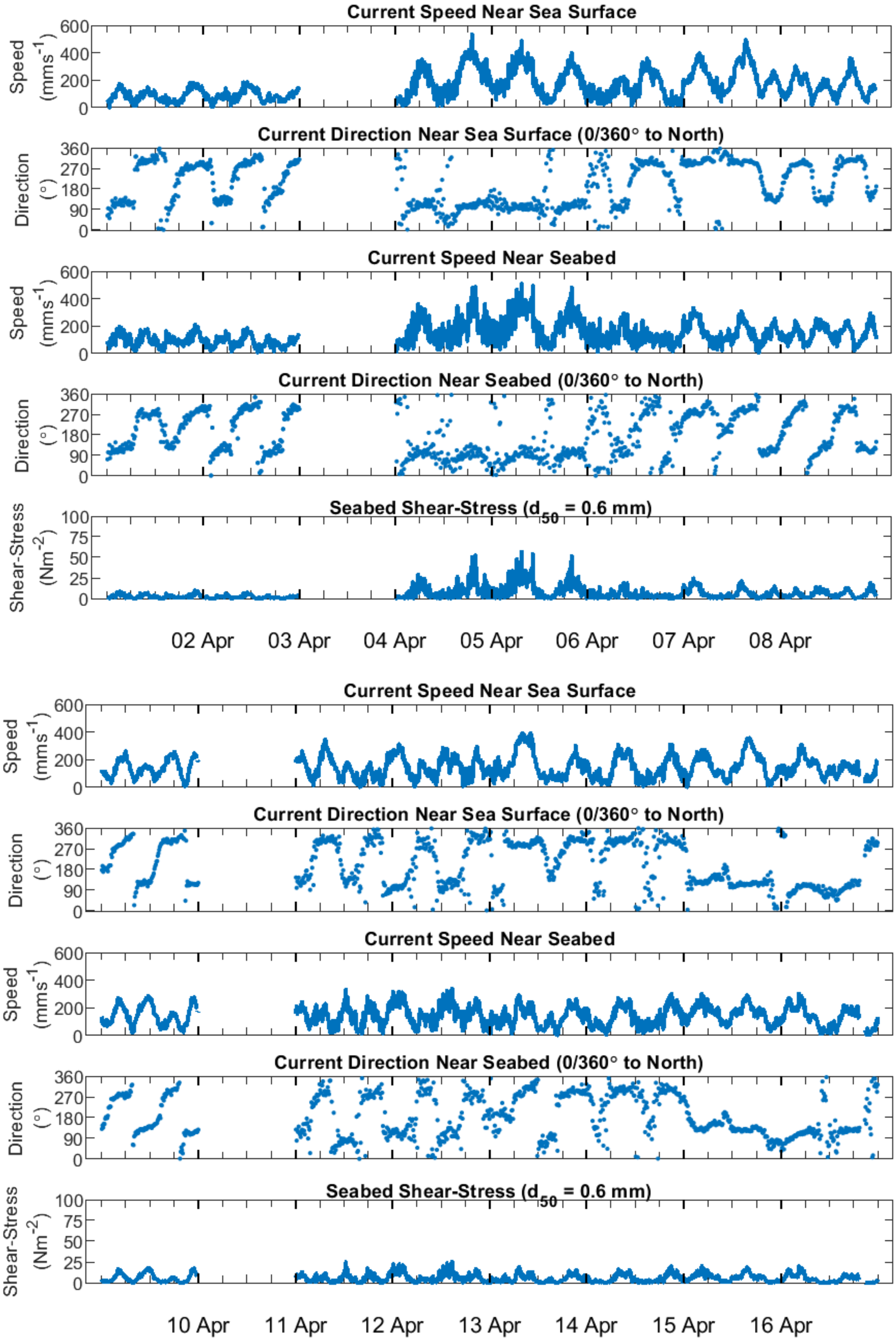


Figure 18 SG3 current speed, direction and shear bed stress 1 to 16 April 2020.

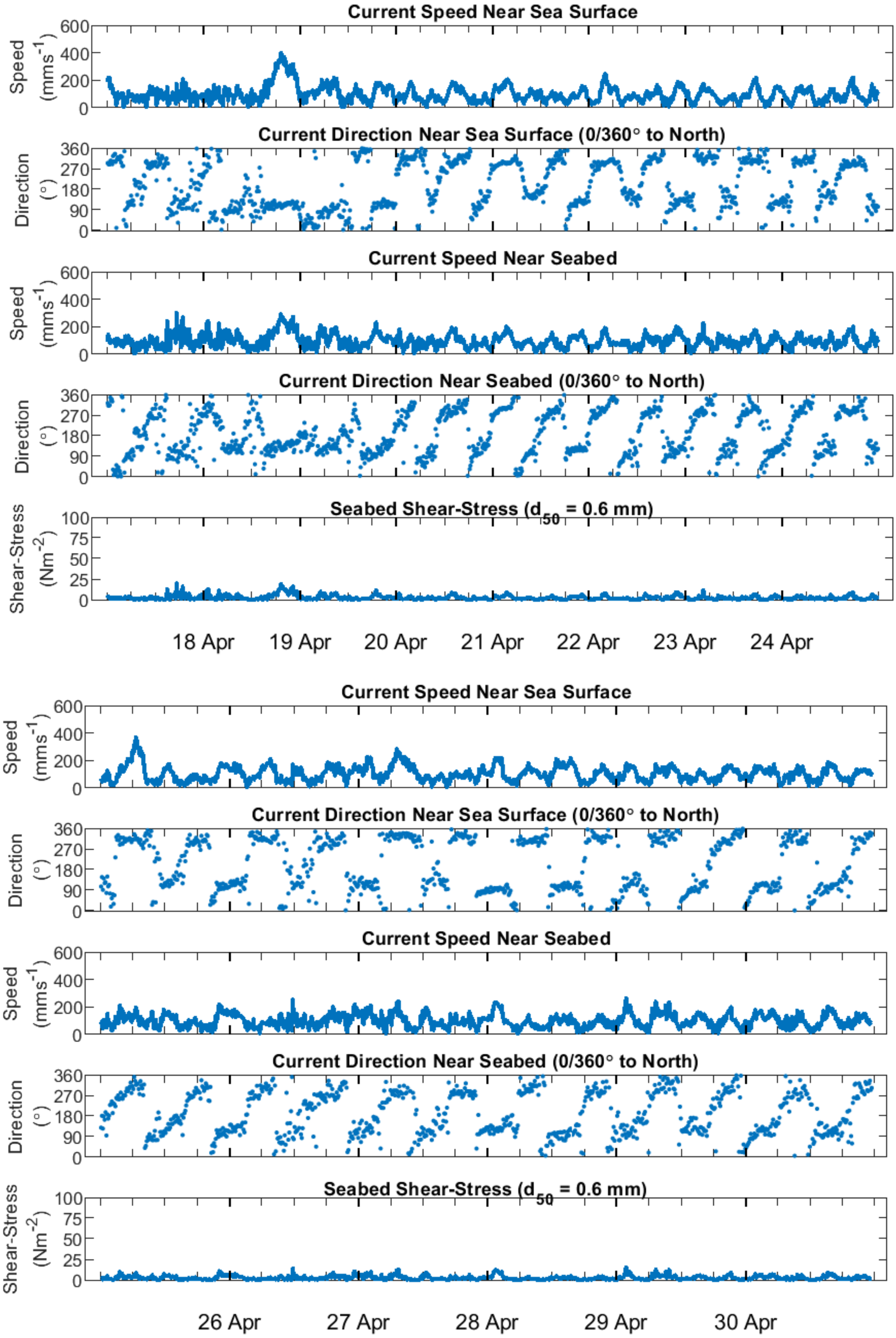


Figure 35 SG3 current speed, direction and shear bed stress 17 to 30 April 2020.

Table 19 Summary of Vision Environment quality control data for April 2020 water sampling.
ND = not determined as one or more samples was below LOR. Variation between duplicate field samples ≥ 50% has been highlighted in blue. High variation indicates heterogeneity within the water column.
** Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.*

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			UH1 (A) (µg/L)	UH1 (B) (µg/L)	Variation (%)
TSS mg/l	<3	<4	5	<3	ND
Dissolved Aluminium (µg/l)	<3	<3	<12	<12	ND
Total Aluminium (µg/l)*	<3.2	4.6	6.2	6.4	3
Dissolved Arsenic (µg/l)	<1.0	<1.0	<4	<4	ND
Total Arsenic (µg/l)	<1.1	<1.1	<4.2	<4.2	ND
Dissolved Cadmium (µg/l)	<0.05	<0.05	<0.2	<0.2	ND
Total Cadmium (µg/l)	<0.053	<0.053	<0.21	<0.21	ND
Dissolved Chromium (µg/l)	<0.5	<0.5	1	1.1	10
Total Chromium (µg/l)*	<0.53	<0.53	1.2	<1.1	ND
Dissolved Cobalt (µg/l)	<0.2	<0.2	<0.6	<0.6	ND
Total Cobalt (µg/l)	<0.21	<0.21	<0.63	<0.63	ND
Dissolved Copper (µg/l)	<0.5	<0.5	<1.0	<1.0	ND
Total Copper (µg/l)	<0.53	<0.53	<1.1	<1.1	ND
Dissolved Iron (µg/l)	<20	<20	<4	<4	ND
Total Iron (µg/l)	<21	<21	70	68	3
Dissolved Lead µg/l)*	<0.1	0.2	<1.0	<1.0	ND
Total Lead (µg/l)	<0.11	<0.11	<1.1	<1.1	ND
Dissolved Manganese (µg/l)	<0.5	<0.5	1.6	1.5	6
Total Manganese (µg/l)	<0.53	<0.53	4.3	4.3	0
Dissolved Mercury (µg/l)	<0.08	<0.08	<0.08	<0.08	ND
Total Mercury (µg/l)	<0.08	<0.08	<0.08	<0.08	ND
Dissolved Molybdenum (µg/l)	<0.2	<0.2	11.4	11	4
Total Molybdenum (µg/l)	<0.21	<0.21	11.7	11.7	0
Dissolved Nickel (µg/l)	<0.5	<0.5	<7	<7	ND
Total Nickel (µg/l)	<0.53	<0.53	<7	<7	ND
Dissolved Selenium (µg/l)	<1.0	<1.0	<0.4	<0.4	ND
Total Selenium (µg/l)	<1.1	<1.1	<0.42	<0.42	ND
Dissolved Silver (µg/l)	<0.10	<0.10	<0.4	<0.4	ND
Total Silver (µg/l)	<0.11	<0.11	<0.43	<0.43	ND
Dissolved Tin (µg/l)	<0.5	<0.5	<50	<50	ND
Total Tin (µg/l)	<0.53	<0.53	<53	<53	ND
Dissolved Vanadium (µg/l)	<1.0	<1.0	2	1.8	11
Total Vanadium (µg/l)	<1.1	<1.1	2	2.2	10
Dissolved Zinc (µg/l)	<1.0	<1.0	<4.0	<4.0	ND
Total Zinc (µg/l)	<1.1	<4.2	<4.2	<1.1	ND
Total Phosphorus (µg/l)	<4	<4	14	16	13
Dissolved Reactive Phosphorus (µg/l)	<4	<4	9.4	9.2	2
Total Nitrogen (µg/l)	<110	<110	<30	<30	ND
Total Kjeldahl Nitrogen (TKN) (µg/l)	<100	<100	<20	<20	ND
Total Ammonia (µg/l)*	10	10	16	15	6
Nitrate-N + Nitrite-N (µg/l)*	2	<2	69	39	56
Chlorophyll *a* (µg/L)	<0.2	<0.3	4.1	4.8	16

Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

May 2020

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Certified System Environment ISO 14001 SAI GLOBAL

FILE REFERENCE

05082020 FINAL LPC Water Quality Environmental Monitoring May 2020_VE

Summary

Since September 2016, Vision Environment (VE) has been undertaking water quality monitoring for the Environmental Monitoring and Management Plan (EMMP) associated with the Lyttelton Port Company (LPC) Channel Deepening Project (CDP) (Envisor, 2018). Baseline datasets were acquired from three spoil ground sites (SG1, SG2 and SG3), seven offshore sites (OS1 to OS7) and five inshore sites (UH1 to UH3, CH1 and CH2) to assess potential impacts of the dredging project.

Dredging operations for the CDP were undertaken from 29 August to 29 November 2018. Post-dredge monitoring was undertaken until 11 March 2019, when a smaller dredging operation began for the reclamation works at Cashin Quay and was completed on 23 March 2020. Channel maintenance dredging commenced at midday on 4 December 2019 and was completed 21 March 2020, thus commencing the post dredging monitoring phase, which will cease on project completion on 31 July 2020.

Post-dredge monitoring results collected during May 2020 are presented within this report. This monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018).

Climatic Conditions: During May higher rainfall was recorded at Cashin Quay (24.4 mm) than during April (16.8 mm), with highest daily rainfall recorded on 5 May (11.2 mm). Peak flows from the Waimakariri River were also recorded on 5 May at a maximum flow rate of 462 m^3/s, higher than the relatively low peak flow rate in April.

Monthly average air temperature (11.9°C) was lower than the mean air temperature of April (13.6°C) in line with seasonal cooling. Similar to previous months, inshore winds were generally from an easterly to north-easterly direction, with the highest mean daily wind speed of 19.5 kts recorded on 5 May. The highest offshore mean daily wind speed was also recorded on 5 May (13.6 kts) and the highest wave height was recorded two days prior on 3 May at 1.63 m. Note that the Watchkeeper was decommissioned for repairs on 17 May and therefore wind and wave data was only available for the first half of May.

Currents: Current data was recorded at SG1, SG2a (WatchKeeper) and SG3 for most of May however, data gaps and erroneous data were identified at SG1 (23 and 31 May), suggesting the ADCP may require antifouling maintenance. Note that the Watchkeeper was decommissioned for repairs on 17 May and therefore ADCP data was only available for the first half of May.

Maximum near-surface current speeds at, SG3 occurred on 3 May and at SG1 and SG2a on 5 May coinciding with recorded maximum wind speeds and wave heights. Maximum near-seabed current speeds were recorded on the 5, 14 and 28 May concurrent with dominant metocean forces of significant wave events (> 1m) and winds coming from a west south-westerly direction. Maximum near-seabed current speeds at SG2a and SG3 were recorded on 5 and 12 May, respectively. Maximum near-seabed current speeds at SG1 exceeded 800 mm/s on a number of occasions throughout the month. The elevated near-seabed layer speeds are significantly greater than those historically observed at this location and therefore should be interpreted with caution and indicate the unit may need servicing.

Near-surface predominant current movement at site SG3 moved in an east-southeast and northwest direction, while near-seabed currents tended towards an east-southeast and west-northwest direction. Both near-surface and near-seabed currents predominantly moved in an eastward and westward direction. During May the measured data for near-surface and near-seabed currents at SG1 did not report a dominant current direction, indicating the unit may need servicing.

Turbidity: Consistent with previous results, turbidity was higher overall at the inshore monitoring sites of the central and upper harbour than at the offshore and spoil ground monitoring locations. Mean turbidity values for May in addition to percentile statistics were lower than those recorded during the baseline monitoring period.

Short-lived elevated surface turbidity was recorded at all sites on multiple days in May coinciding with moderate to high inshore and offshore winds and significant wave heights >1 m, but in particular around 2 to 5 May in conjunction with the extreme weather event at this time.

Other Physicochemical Parameters: As expected mean monthly water temperatures were lower to those recorded in April with all sites displaying a seasonal decline. Consistent with previous winter sampling periods slightly lower temperatures were recorded in the upper and central harbour than the offshore sites.

Consistent with previous reports, surface pH during May was similar across all sites. As previously observed inner harbour sites recorded lower mean conductivity values than offshore and spoil ground sites most likely due to localised storm water run-off.

Dissolved oxygen (DO) concentrations showed strong diurnal fluctuations at all sites during May. All sites recorded slight declines in DO following periods of heavy rainfall. This was most pronounced at OS1 where declining DO (< 90% saturation) started after the 24 May and continued to the end of the month. These patterns are likely following a cycle of degrading and recovering algal bloom populations.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 29 May 2020, and once again a well-mixed water column was indicated. DO displayed a decreasing gradient through the water column at nearshore and offshore sites due to lower photosynthesis at depth.

Turbidity and total suspended solids (TSS) measurements for surface waters were again elevated at inshore sites compared to the offshore areas, resulting in the shallowest estimations of euphotic depth as typically recorded during the monitoring program. Euphotic depths at the offshore monitoring locations were relatively high; estimated to be at 20.2 m at SG3. No exceedances of WQGs were observed for sub-surface turbidity during the May sampling period.

Total phosphorous concentrations were found in higher concentrations in the upper harbour and central channel sites although no exceedances of WQG were recorded at any site. Dissolved reactive phosphorous concentrations were above the WQG of 5 µg/L at all sites in May, as occasionally found. Both total nitrogen and total kjeldahl nitrogen (TKN) were below the limit of reporting (LOR) and below WQG at all sites except one offshore site. Total Ammonia was recorded above WQG at all but nine sites, which included all of the of upper harbor and channel sites. Nitrogen oxide concentrations were above WQG at four of the monitoring sites during May, located both inshore and offshore. A combination of degrading algal populations, lack of utilization of available nutrients by algae in winter and introduction of nutrients from storm water run-off, may have contributed to elevated concentrations at certain sites.

Chlorophyll-*a* concentrations were low to moderate across all sites and exceeded the WQG value (4 µg/L) at two offshore sites, indicating higher than normal algal populations at these particular sites potentially due to the readily bioavailable nutrients.

As commonly observed, the majority of metals were reported as below the limit of reporting (LOR) and no dissolved metal fraction exceeded the designated WQG among the sites. Total aluminium concentrations did exceed the designated WQG at all sites except one offshore and one spoil ground site, but the dissolved and therefore readily bioavailable fraction, remained undetectable. Total aluminium, iron and manganese displayed a strong spatial difference with elevated concentrations found in the inshore locations (associated with increased suspended sediments). Total and dissolved chromium, vanadium and molybdenum were also detected during May but little spatial variability was noted.

Benthic physicochemical loggers, Benthic Photosynthetically Active Radiation (BPAR) and Sedimentation: All benthic equipment was removed at the beginning of May as data was deemed not necessary for the continuation of the Post Dredge monitoring period.

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Acronyms

ADCP	Acoustic Doppler Current Profiler
BPAR	Benthic Photosynthetically Active Radiation
BSL	Benthic self-logging sonde
CDP	Channel Deepening Project
DO	Dissolved oxygen
ECan	Environment Canterbury
EMMP	Environmental Monitoring and Management Plan
K_d	Light attenuation coefficient
KZ filter	Kolmogorov-Zurbenko filter
LOR	Limits of Reporting
LPC	Lyttelton Port Company
LYT	Lyttelton Port of Christchurch
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
QA/QC	Quality Assurance/Quality Control
SL	Self-Logger
ST	Subsurface telemetry
ST/ADCP	Subsurface telemetry/Acoustic Doppler Current Profiler
TAG	Technical Advisory Group
TDP	Total daily PAR
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VBCC	Vision Base Christchurch
VE	Vision Environment
WK	WatchKeeper telemetered weather station
WQG	Water Quality Guidelines

1 INTRODUCTION

Lyttelton Port Company (LPC) is undertaking a Channel Deepening Project (CDP) to extend the existing navigational channel to allow larger vessels access to the Lyttelton Port of Christchurch (LYT), the South Island's largest port. Utilising background information provided by LPC and advice from the Technical Advisory Group (TAG) in relation to ambient conditions, locations of sensitive habitats and dredge impact hydrodynamic modelling scenarios, a water quality monitoring program was designed.

Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August 2018 with completion of works on 29 November 2018. Monitoring continued into a post-dredge phase up until 11 March 2019 when smaller scale dredging operations for the reclamation works commenced and was completed on 23 March 2020. Note maintenance dredging of the channel was undertaken from 4 December 2019 to 21 March 2020, with spoil being relocated to the maintenance dredge spoil ground located off Godley Head. The interpreted environmental data provided by VE supports the process of the Environmental Monitoring and Management Plan (EMMP) for the LPC CDP (Envisor, 2018) and will assist to ascertain the potential impacts of the projects.

All dredge operations were completed on 23 March. Post Dredge monitoring will continue until 31 July 2020 when monitoring for the Project will be completed.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for the baseline and operations phases of water quality monitoring is provided in this section. A more detailed description of the importance of the measured parameters and the specific methodology for the CDP data collection and processing protocols can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

2.1.1 Monitoring Locations and Equipment

Guided by the results of preliminary hydrodynamic modelling (MetOcean, 2016a, b) in addition to advice from the TAG, baseline and dredge operations, monitoring sites were located outside the area of predicted direct impact (i.e. dredge footprint and offshore disposal ground), but within the zone of dredging and dredge material placement influence, in addition to being in the vicinity of sensitive receptors (e.g. mussels farms and important mahinga kai sites). For ease of identification the harbour was divided into four areas: spoil ground (SG); offshore (OS); central harbour (CH); and upper harbour (UH), in which 15 locations were selected for monitoring (Figure 1). In each area, one to three monitoring sites were selected for the deployment of the various individual types of equipment, which are identified in Table 1. A total of 22 monitoring units were deployed across the 15 locations.

The offshore monitoring area (encompassing monitoring sites SG1 to SG3 and OS1 to OS7) is a deep water (generally >15 m) oceanic environment, where turbidity appears to be mostly driven by wind speeds and wave heights, resulting in resuspension of material from the benthos. Benthic physicochemical loggers, BPAR and altimeters previously deployed at these sites were removed in May as the data was no longer relevant for post dredge monitoring.

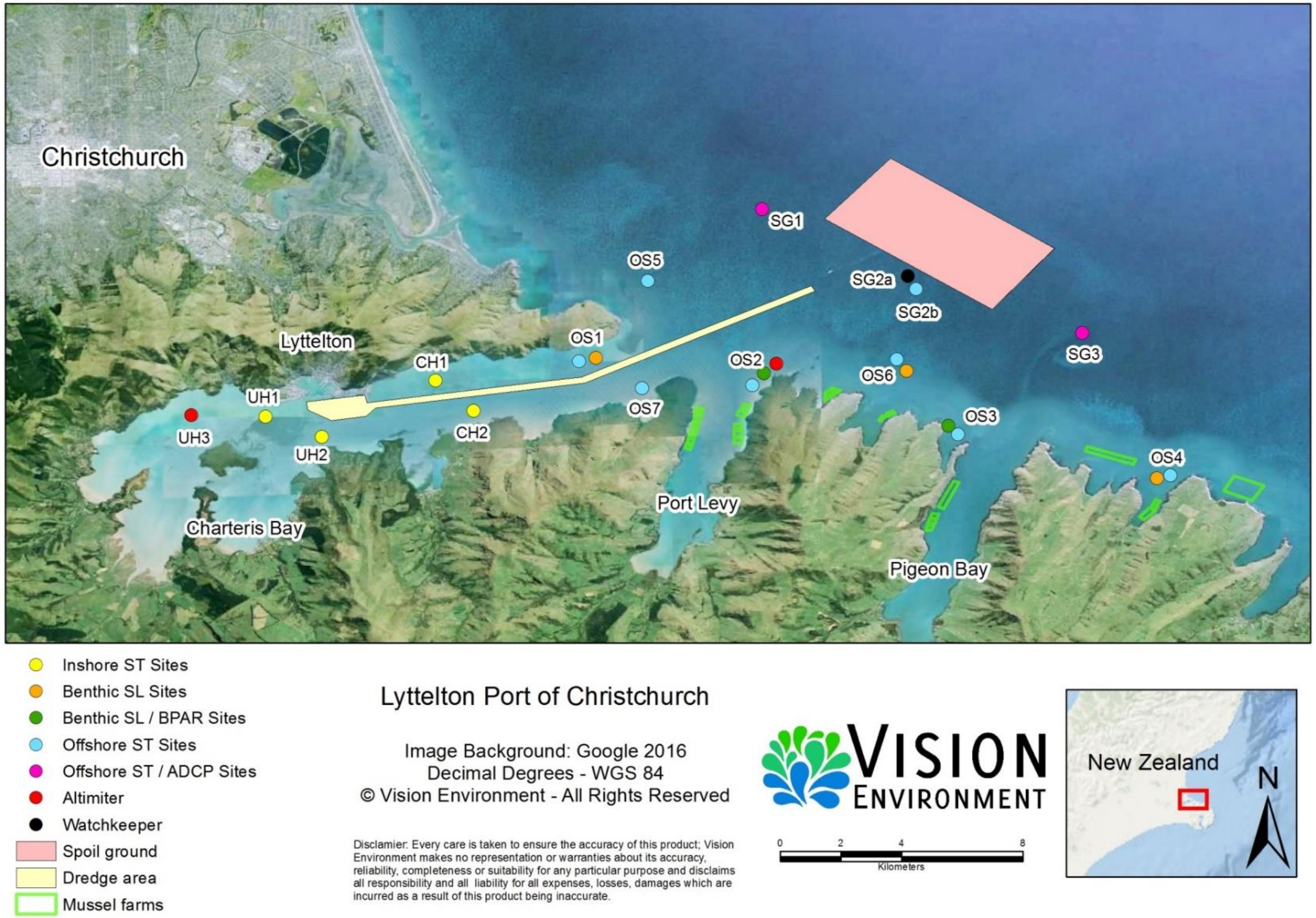


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

Table 1 Summary of monitoring sites and deployment equipment for the LPC Channel Deepening Project.
*ST = subsurface telemetry, SL = self-logger, *BSL = benthic self-logger, removed from all sites in May, *BPAR = benthic photosynthetically active radiation, removed from all sites in May and ADCP = Acoustic Doppler Current Profiler. *WK = WatchKeeper telemetered weather station removed from site on the 17 May for maintenance.*

Site	*WK	ST/ADCP	ST	*BSL sonde	*BSL sonde/BPAR	*Altimeter
	WatchKeeper telemetered weather station with currents and waves	Subsurface telemetered dual physico-chemistry and currents	Subsurface telemetered dual physico-chemistry	Benthic self-logging dual physico-chemistry	Benthic self-logging dual physico-chemistry and self-logging BPAR	Benthic self-logging dual altimeter
SG2a	√					
SG2b			√			
SG1		√				
SG3		√				
OS1			√	√		
OS2			√		√	√
OS3			√		√	
OS4			√	√		
OS5			√			
OS6			√	√		
OS7			√			
CH1			√			
CH2			√			
UH1			√			
UH2			√			
UH3						√
Total	1	2	12	3	2	2

The inshore monitoring area (including monitoring sites CH1 and CH2, and UH1 to UH3) is a shallow (<10 m depth) marine environment that, in addition to wind speeds and wave heights, is also influenced by tides (~ 0.2 m/s). The water column is well mixed at these sites, with little to no stratification. Therefore, surface loggers only have predominantly been utilised at these sites.

The comprehensive water quality component of the program involves the monitoring of:

- Physicochemistry, including turbidity; temperature; pH; conductivity and DO;
- Light attenuation (Photosynthetic Active Radiation or PAR);
- Benthic light (Benthic Photosynthetic Active Radiation or BPAR);
- Total Suspended Solids (TSS);
- Sedimentation rates;
- Nutrients and chlorophyll *a*;
- Metals (total and dissolved); and
- Organic compounds (biannually).

This monthly report presents data collected from the 22 monitoring locations for May 2020 during the post-dredge phase of operations. Monthly water sampling and depth profiling was conducted on 29 May 2020. A summary of climatic conditions during this period is provided, in addition to the results of continuous and discrete water sampling with comparisons to the baseline monitoring period.

2.1.2 Water Quality Guidelines

Water quality monitoring data from LYT were compared to the Australian and New Zealand Water Quality Guidelines (WQG) default trigger values (ANZG, 2018). In the absence of specific trigger values for New Zealand estuarine or marine ecosystems, the WQG suggest the use of trigger values for south-east Australian estuarine and marine ecosystems.

Total metals represent the concentration of metals determined in an unfiltered sample (those bound to sediments or colloidal particles in addition to dissolved metals), while dissolved metals are defined as those which pass through a 0.45 µm membrane filter (APHA, 2005). Specific trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived for several metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZG, 2018). The LYT coastal environment could be described as slightly-to-moderately disturbed, therefore the 95% WQG trigger value was considered appropriate for comparison.

3 RESULTS & DISCUSSION

3.1 Metocean Conditions

3.1.1 Wind and precipitation

A total of 24.4 mm of rainfall was recorded at Cashin Quay during May 2020, which was lower to the precipitation recorded in April (16.8 mm). The highest recorded rainfall was on 5 May at 11.2 mm (Metconnect, 2020) (Figure 2). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days' post flow. Flows for May were again low ranging between 42.6 m^3/s and 462.1 m^3/s with the maximum flow rate occurring on 5 May (ECAN, 2020), coinciding with maximum local rainfall. These low rates were not expected to greatly impact harbour parameters.

Inshore winds during May were generally from an easterly to north-easterly direction (Metconnect, 2020). Highest mean wind speed (19.5 kts) was recorded on 5 May from a west south-westerly direction, with maximum wind gusts of 42 kts also occurring on the 5 May from south-westerly direction, coinciding with the rainfall event. Daily mean wind speeds for the rest of May were below 15 kts.

Daily mean air temperatures at Cashin Quay ranged from 8°C to 18°C, resulting in a monthly mean temperature of 11.9°C, lower than the April mean temperature of 13.6°C (Metconnect, 2020) in line with seasonal cooling.

Offshore metocean data was not available from the 18 to 31 May as the WatchKeeper buoy was removed from site for maintenance during this time. Offshore significant wave height peaked on 2 May at 8:30 pm at a height of 2.0 m, leading to a mean daily significant wave height of 1.5 m (Figure 3). The highest mean daily significant wave event occurred on the 3 May with a height of 1.6 m. Significant wave heights >1m were recorded throughout the first half of May. Highest mean daily offshore wind speed 13.6 kts was recorded on the 5 May in line with the weather event recorded inshore. Offshore winds predominantly originated from a south south-westerly direction (Figure 26).

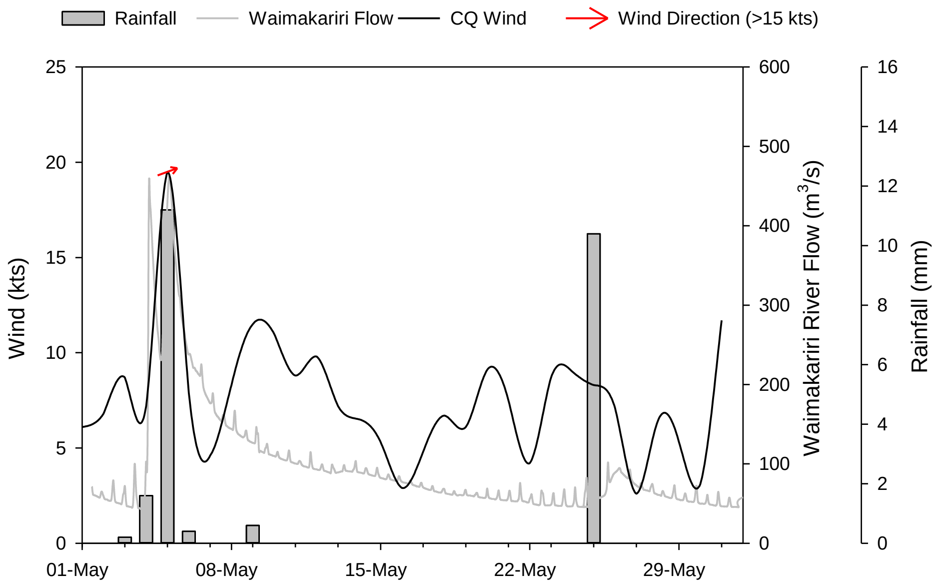


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during May 2020.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

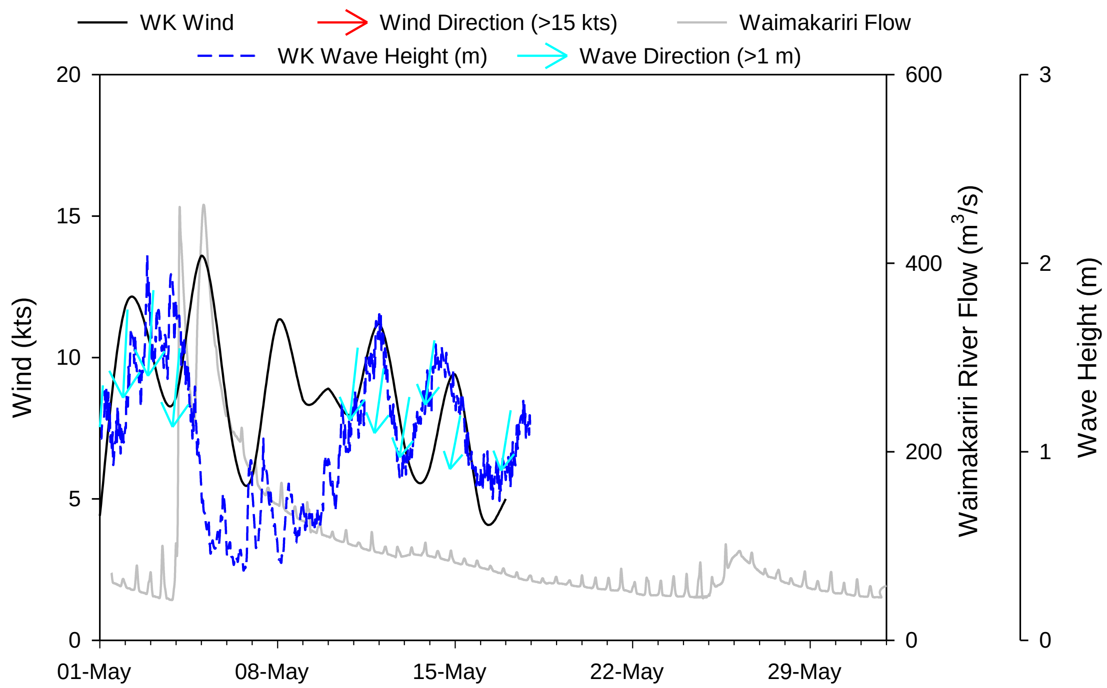


Figure 3 Offshore metocean conditions including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during May 2020.
Note: Arrows indicate the direction of travel for offshore winds greater than 15 knots and offshore waves above 1 m significant wave height. Directions from the WatchKeeper buoy have not been corrected for magnetic declination. The WatchKeeper buoy was removed from site SG2a for maintenance on the 17 May.

3.1.2 Currents

Acoustic Doppler Current Profilers (ADCPs) are deployed at the spoil ground monitoring sites SG1, SG2a (Watchkeeper) and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Summary ADCP statistics of available data are presented within Table 2, and Figures 4 to 6. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 26 to 32 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

During May data gaps were identified for two days at SG1 (23 and 31 May). In addition to some erroneous data this suggests the unit may need antifouling maintenance. The Watchkeeper ADCP deployed at SG2a was removed from site for maintenance on 17 May.

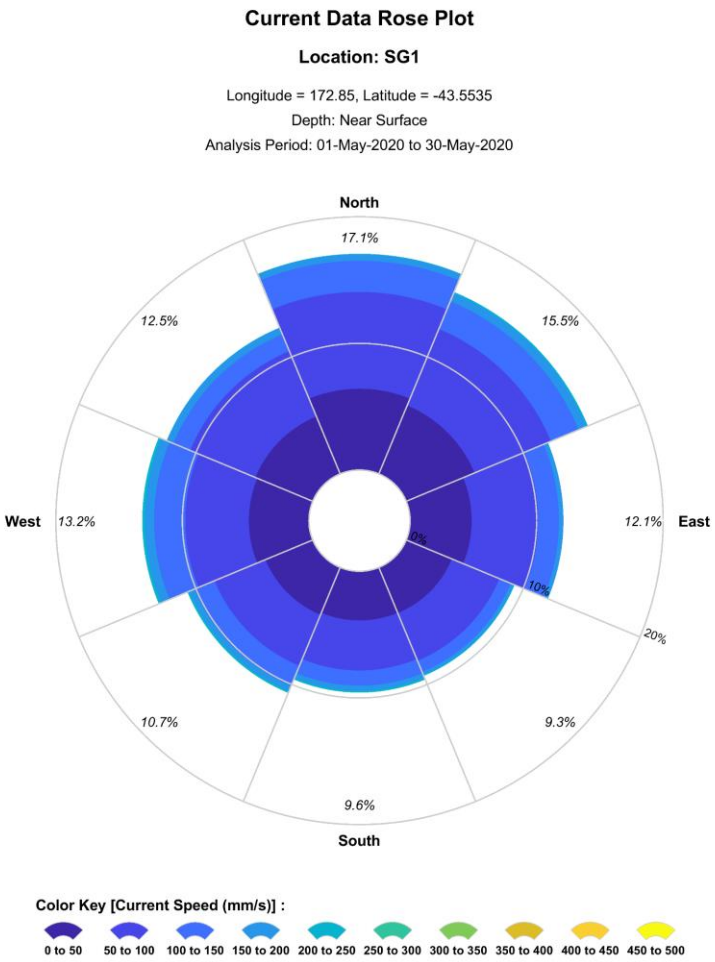
Table 2 Parameter statistics for spoil ground ADCPs during Mary 2020.
** SG1 increased near-seabed layer speeds are significantly greater than those historically observed at this location and suggest unit error. *SG2a was removed for maintenance on 17 May therefore limited data available.*

Parameter	Depth	Site		
		SG1	***SG2a**	**SG3**
Minimum current speed (mm/s)	*Near-surface*	1	1	2
	Near-seabed	2	5	1
Maximum current speed (mm/s)	*Near-surface*	296	184	438
	Near-seabed	>800*	211	358
Mean current speed (mm/s)	*Near-surface*	68	49	109
	Near-seabed	130*	77	105
Standard deviation of current speed (mm/s)	*Near-surface*	41	29	61
	Near-seabed	98*	38	54
Current speed, 95^{th} percentile (mm/s)	*Near-surface*	148	103	222
	Near-seabed	310*	143	205

Maximum near-surface current speeds at SG1 (296 m/s), SG2a (184 mm/s) and SG3 (438 mm/s), were recorded on 3 May at SG3 and 5 May at SG1 and SG2a. These peaks coincided with periods of moderate to high inshore and offshore winds coming from west south-westerly directions from the 4 to 5 May along with significant wave heights >1m.

Maximum near-seabed current speeds at SG2a (211 mm/s) and SG3 (358 mm/s), were recorded on 5 and 12 May, respectively. Maximum near-seabed current speeds at SG1 exceeded 800 mm/s on a number of occasions throughout the month however these increased near-seabed layer speeds were significantly greater than those historically observed at this location and as such these datasets should be interpreted with caution. The maximum near-seabed current speeds at SG2a and SG3 coincided with daily offshore and inshore wind speeds that were moderate to high from a south south-westerly direction and significant wave heights >1 m occurring.

The time-series plots (Figures 26 to 32 in Appendix) illustrate time-varying current direction, whilst the current rose diagrams (Figures 4 to 6) depict the distribution of current direction and velocity in the near-surface and near-seabed layers. When interpreting the current data, note that the convention for defining current direction is the direction in which the current flows *towards*, which is the reference used throughout the Figures presented.



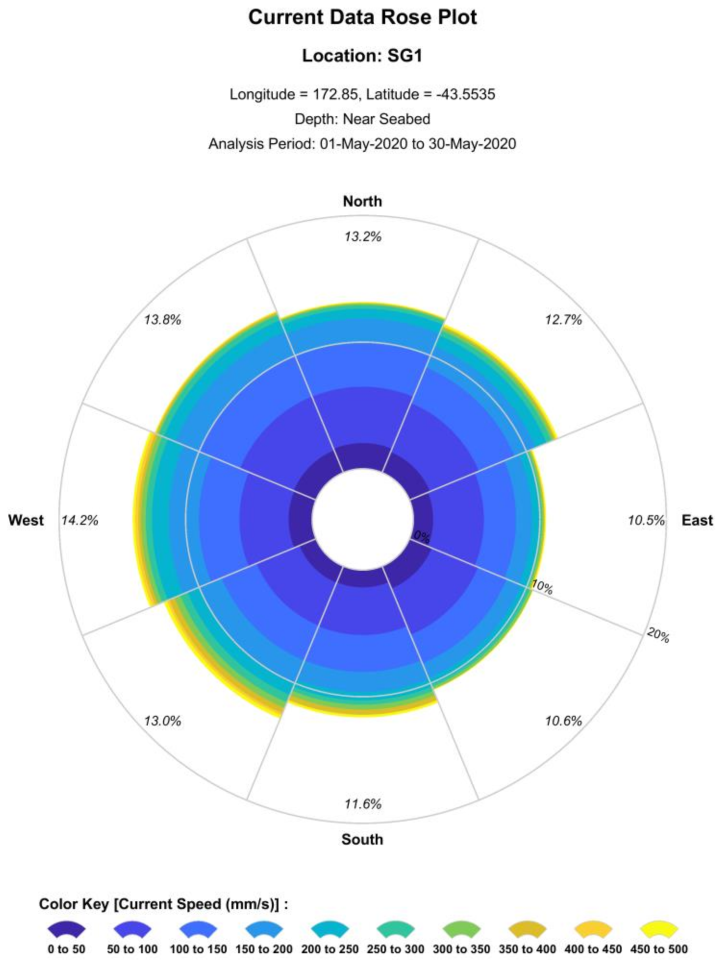
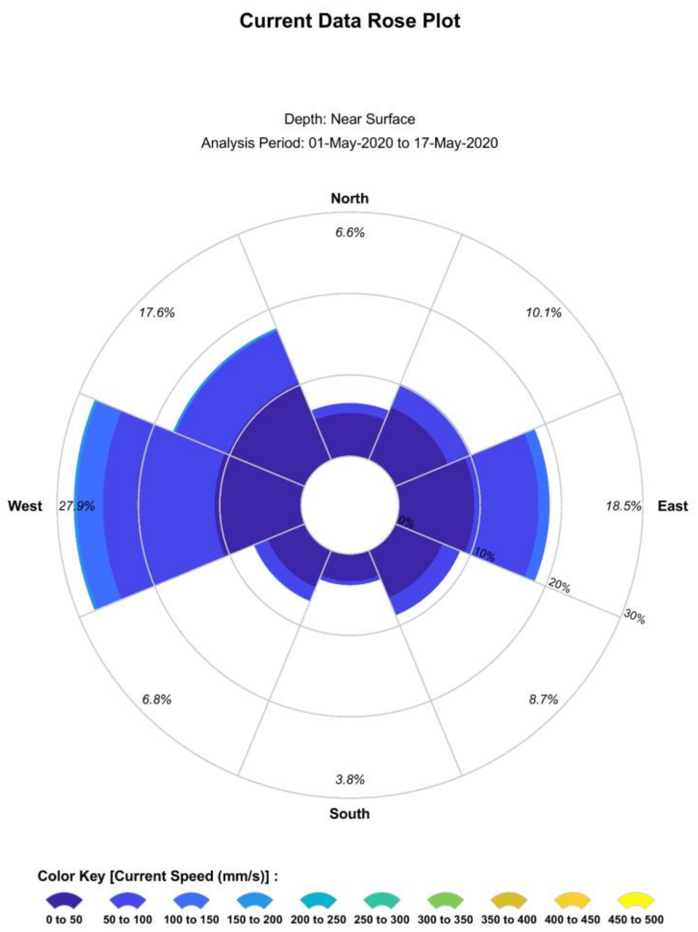


Figure 4 Near-surface and near-seabed current speed and direction at SG1 during May 2020.
Speed intervals of 50 mm/s are used.



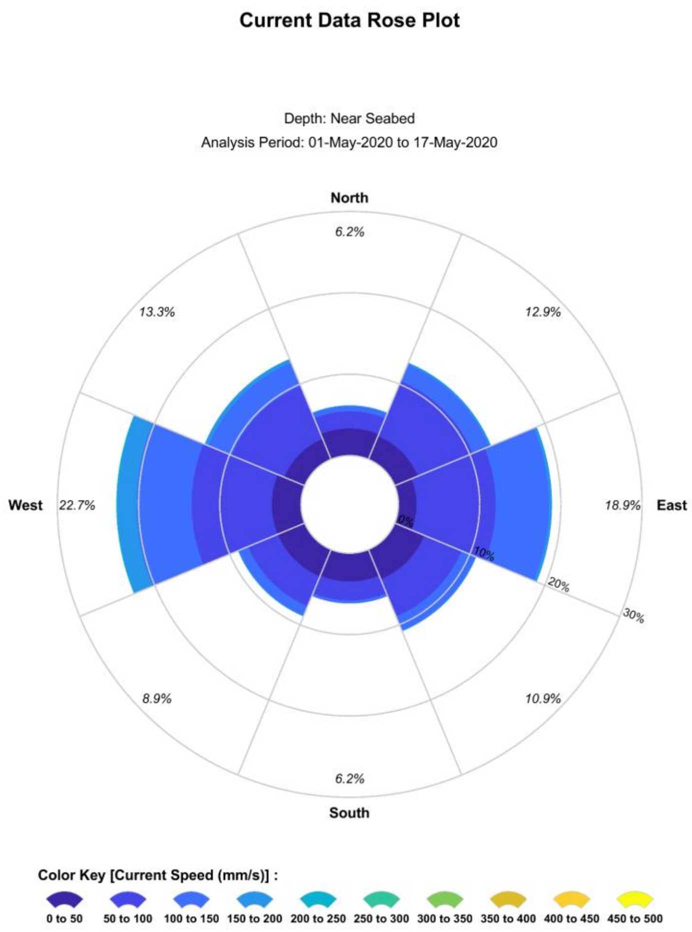
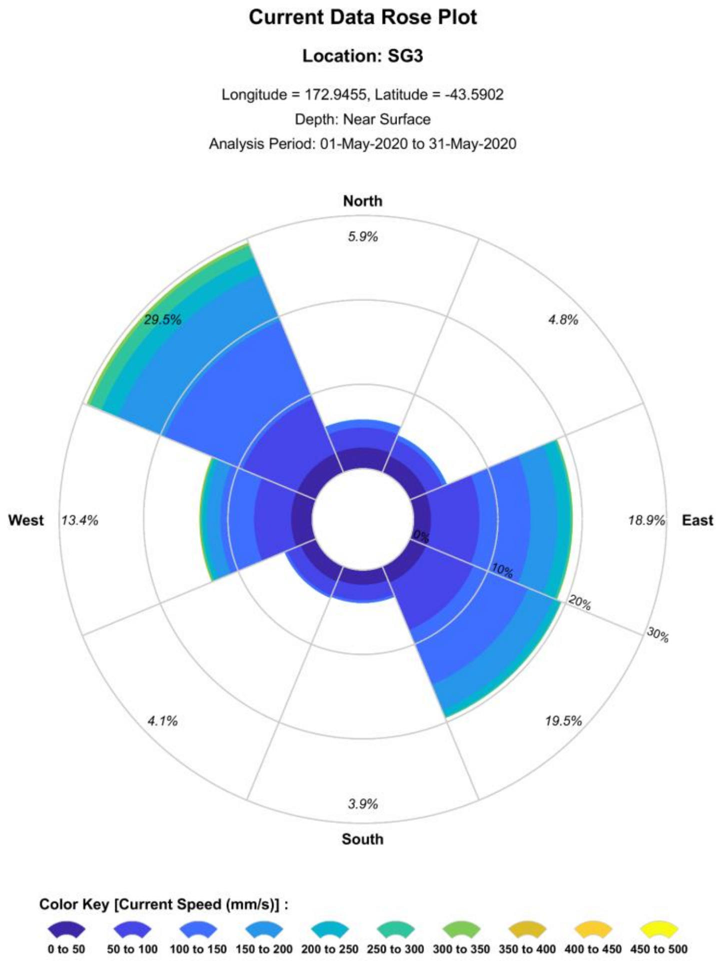


Figure 5 Near-surface and near-seabed current speed and direction at SG2a (Watchkeeper) during May 2020.
Speed intervals of 50 mm/s are used.



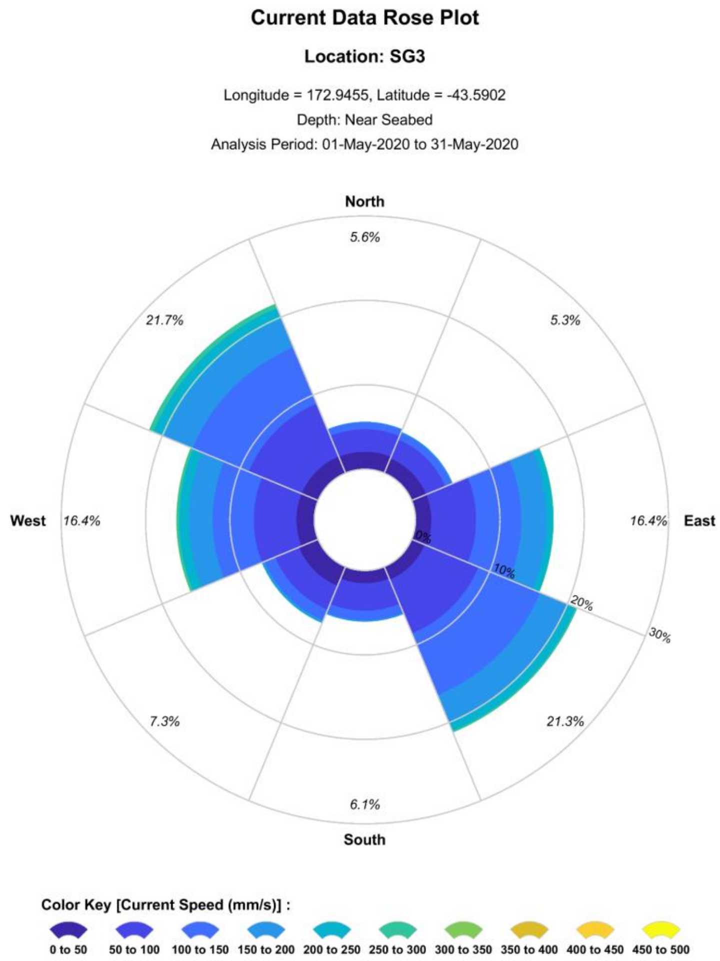


Figure 6 Near-surface and near-seabed current speed and direction at SG3 during May 2020.
Speed intervals of 50 mm/s are used.

During May the measured data for near-surface and near-seabed currents at SG1 did not report a dominant current direction and may indicate unit error. Near-surface currents at SG3 predominantly moved in an east-southeast (48.4%) and northwest (29.5%) direction. Near seabed currents at SG3 mainly moved in an east-southeast (37.7%) and west-northwest (38.1%) direction.

Near surface current movements at SG2a tended to move in an eastward and westward direction (18.5% and 27.9% respectively). As previously observed at this site, near-seabed currents also moved in an eastward (18.9%) and westward (22.7%) direction during May.

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties of the water column are measured at monitoring sites every 15 minutes by dual telemetered surface loggers. Benthic loggers that were deployed at five offshore sites (OS1 to OS4 and OS6) were removed in May as the data was no longer required for the post-dredge phase of the project. In conjunction with the continuous loggers, discrete depth profiles of all physicochemical parameters were also conducted at all 15 monitoring sites on 29 May 2020. Further details regarding the methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Summary statistics for each physicochemical parameter recorded during May are presented in Tables 3 to 12. Validated datasets for surface measurements are also presented in Figures 7 to 19. Due to the inherent high level of variability in the turbidity datasets, a 24-hour rolling average has been calculated every 15 minutes to act as a smoothing technique and aid in data interpretation.

Data was unavailable for surface sondes at OS5, OS6 and SG2b for certain periods during May due to monitoring buoys becoming adrift.

3.2.1 Turbidity

Of key importance within the real time parameters recorded are the surface turbidity measurements, due to their relevance to established trigger values for management of dredge operations. As such, summary turbidity statistics for the initial baseline period of monitoring from 1 November 2016 to 31 October 2017 (Fox, 2018) are also presented in Tables 3 to 5 to allow a comparison with the March 2020 dredge monitoring data.

May Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 3.3 to 5.9 NTU) at the inshore monitoring sites (Table 3 and Figure 6). Further offshore, the spoil ground sites (Table 4) exhibited lower surface turbidity values (1.0 to 1.5 NTU). This can be attributed to the deeper water column limiting expressions of seafloor sediment resuspension at the sub-surface. Mean turbidity values at offshore sites ranged from 1.2 to 5.2 NTU (Table 5) during May.

Turbidity across the inner harbour was relatively low (< 10 NTU) during the majority of May with only small elevations occurring at UH1 on the 5 May in conjunction with increased inshore winds (>15 kts). Slightly elevated short-lived turbidity peaks were noted at CH2 on the 20 and 24 May where inshore winds reached ~ 10 kts (Figure 8).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) were again relatively low during May (<10 NTU). Surface turbidity increased at all sites around the 2 to the 5 May in line with increased winds and significant wave heights (> 1m). This intense event was only short lived and therefore may not have resulted in such a notable impact on turbidity as would normally be expected. At the majority of nearshore sites, apart from OS1, short-lived turbidity peaks were noted from 12 to the 29 May (Figure 9).

Table 3 Mean turbidity and statistics at inshore water quality logger sites during May 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for May are means ± se, range and percentiles (n = 2922 to 2974) Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface May	Surface Baseline
UH1	Mean ± se	3.7 ± 0.0	12
	Range	1.3 – 17.3	-
	99th	8.8	39
	95th	6.1	22
	80th	4.5	15
UH2	Mean ± se	4.5 ± 0.0	10
	Range	<1 – 11.2	-
	99th	8.5	32
	95th	7.3	20
	80th	5.8	13
CH1	Mean ± se	4.9 ± 0.0	9
	Range	<1 – 12.5	-
	99th	8.3	29
	95th	7.2	18
	80th	5.9	12
CH2	Mean ± se	3.3 ± 0.0	8
	Range	0.5 – 10.0	-
	99th	7.3	24
	95th	5.3	16
	80th	4.4	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during May 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for May are means ± se, range and percentiles (n = 718 to 2865). Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface May	Surface Baseline
SG1	Mean ± se	1.0 ± 0.0	4.2
	Range	<1 – 9.9	-
	99th	5.7	14
	95th	3.7	10
	80th	1.7	6.2
SG2	Mean ± se	1.5 ± 0.0	4.6
	Range	0.7 – 4.5	-
	99th	3.4	20
	95th	2.6	11
	80th	1.8	7.0
SG3	Mean ± se	1.1 ± 0.0	3.6
	Range	<1 – 10.2	-
	99th	5.9	13
	95th	3.4	7.7
	80th	1.9	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during May 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for May are means ± se, range and percentiles (n = 1779 to 2974). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU)	
		Surface May	Surface Baseline
OS1	Mean ± se	3.1 ± 0.0	7.5
	Range	< 1 – 9.8	-
	99th	6.6	24
	95th	5.4	16
	80th	4.3	10
OS2	Mean ± se	3.5 ± 0.0	6.4
	Range	< 1 - 12.8	-
	99th	8.9	18
	95th	7.0	13
	80th	5.1	9.0
OS3	Mean ± se	5.2 ± 0.0	6.6
	Range	< 1 – 11.3	-
	99th	9.7	27
	95th	8.8	15
	80th	7.1	8.9
OS4	Mean ± se	3.5 ± 0.0	5.9
	Range	<1 -9.8	-
	99th	8.8	20
	95th	6.9	13
	80th	5.0	8.3
OS5	Mean ± se	1.6 ± 0.0	4.6
	Range	<1 – 7.4	-
	99th	6.1	19
	95th	4.2	11
	80th	2.6	6.4
OS6	Mean ± se	1.2 ± 0.0	4.7
	Range	0.0 – 9.1	-
	99th	5.3	19
	95th	4.0	12
	80th	2.4	7.2
OS7	Mean ± se	3.7 ± 0.0	6.4
	Range	< 1 – 9.9	-
	99th	8.7	23
	95th	7.2	14
	80th	5.1	9.2

Further offshore at OS5, OS6 and SG1 turbidity was below 10 NTU for the month of May with increases in turbidity occurring between the 2 to 5 May and 10 to 15 May in conjunction with increase wind and wave heights over 1 m (Figures 10 and 11). Site SG1 and SG3 both recorded short-lived but consistent peaks in turbidity from the 12 to 20 May associated with increased winds and significant wave heights. Available turbidity data for SG2 is consistent with previous months being typically low for the month.

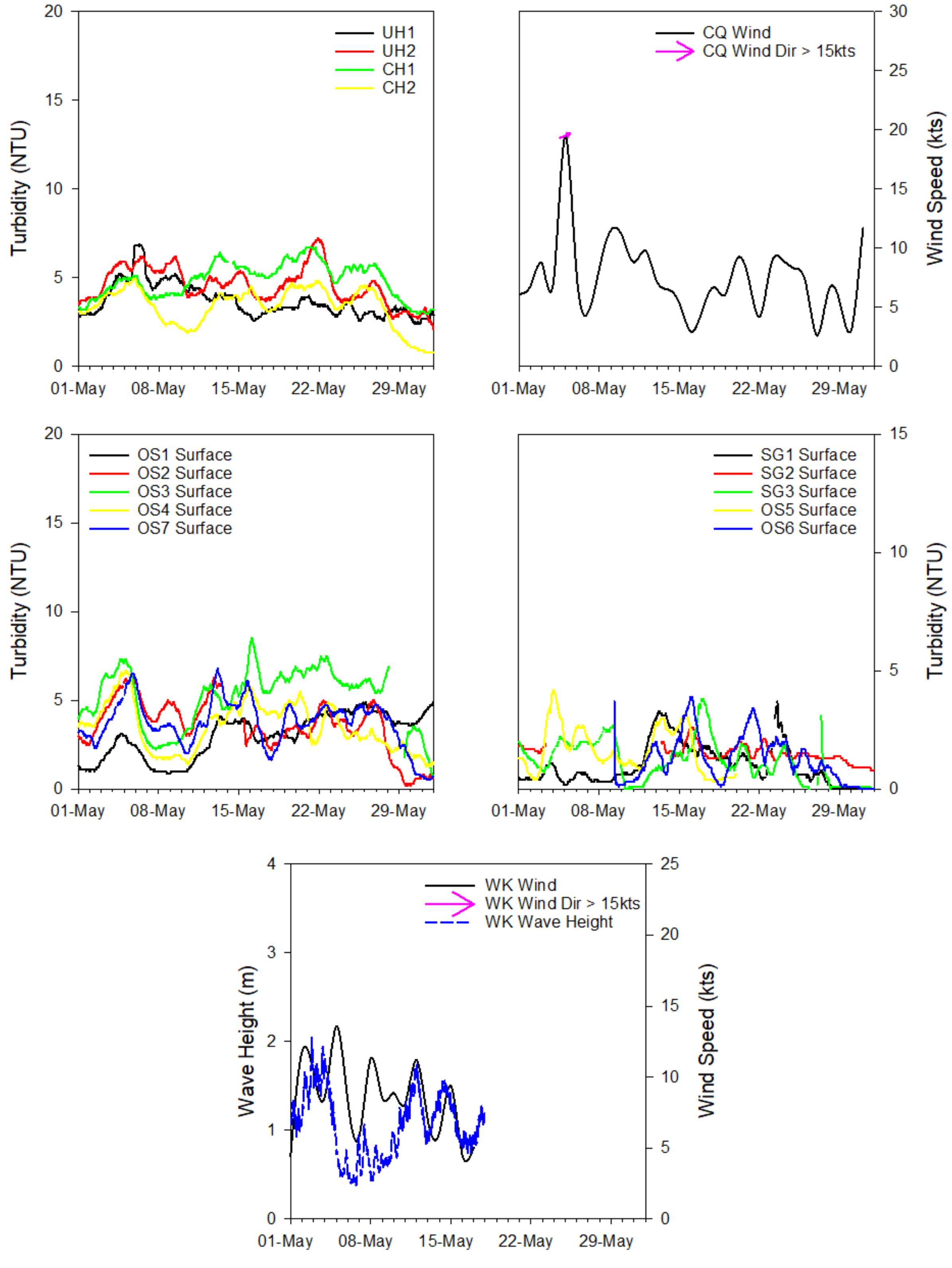


Figure 7 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations during May 2020.

Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 15 knots. The watchkeeper (WK) buoy was removed from site SG2 for maintenance on the 17 May.

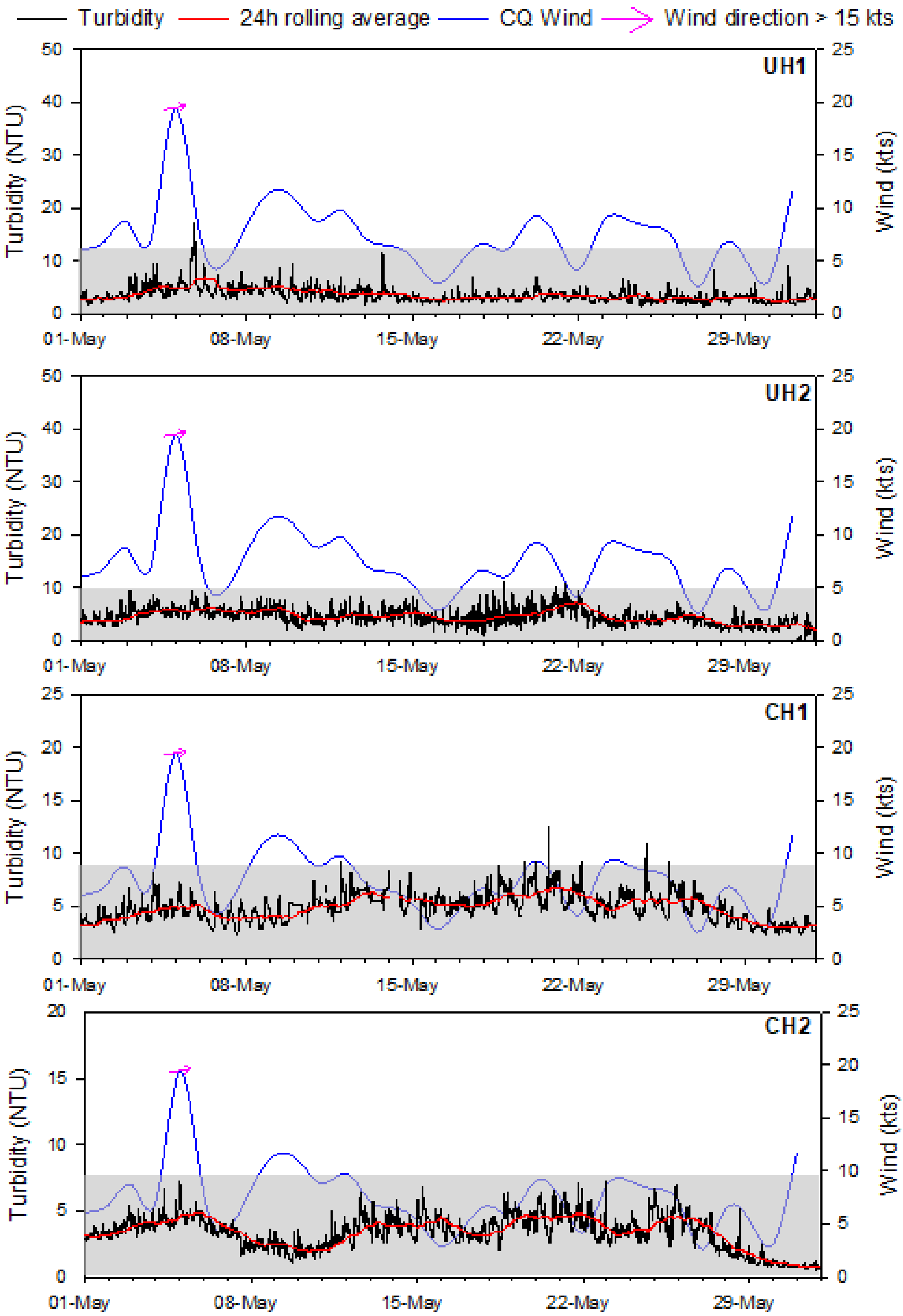


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during May 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

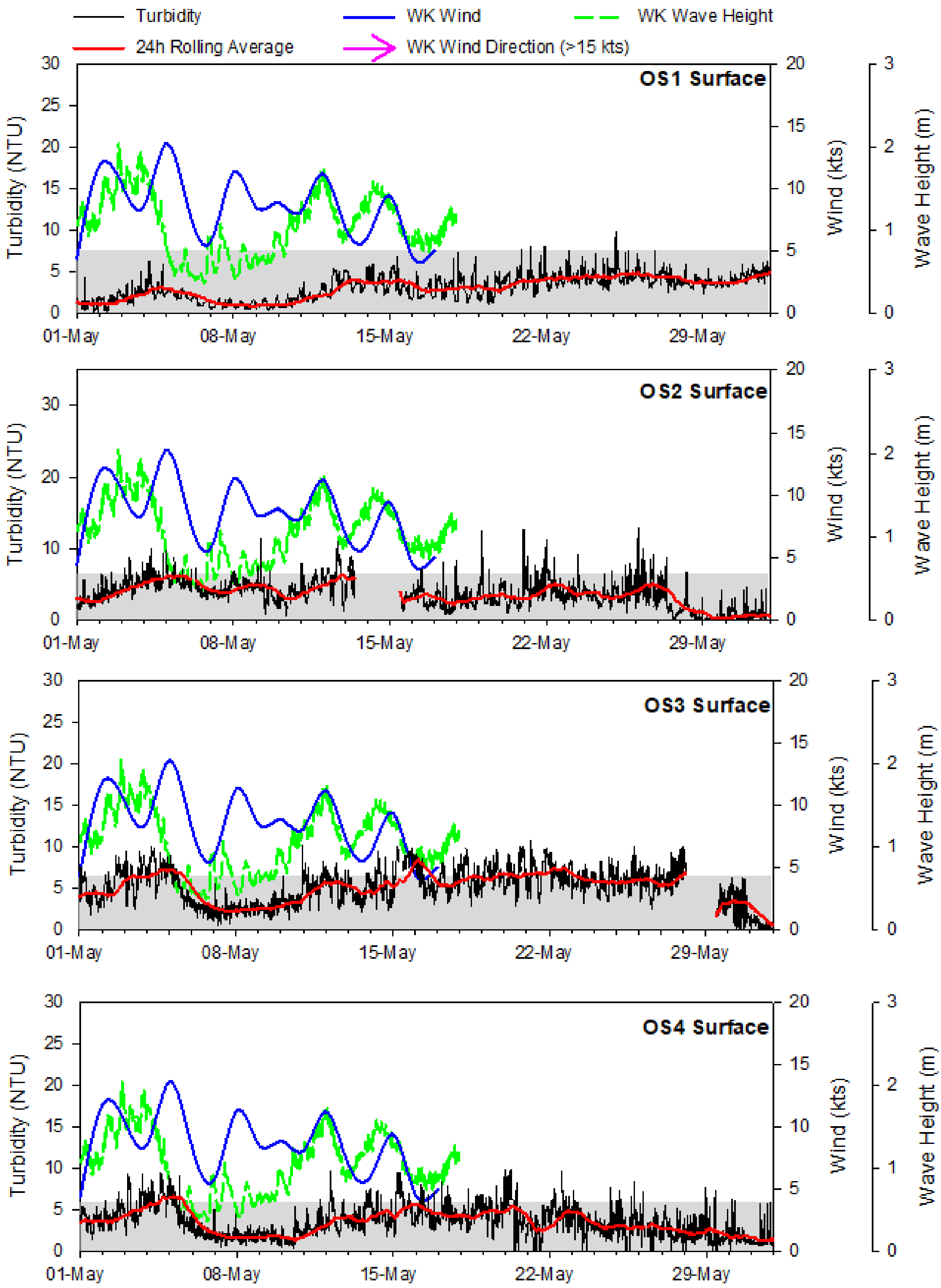


Figure 9 Surface turbidity and inshore daily averaged winds at inshore sites (OS1 to OS4) during May 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity

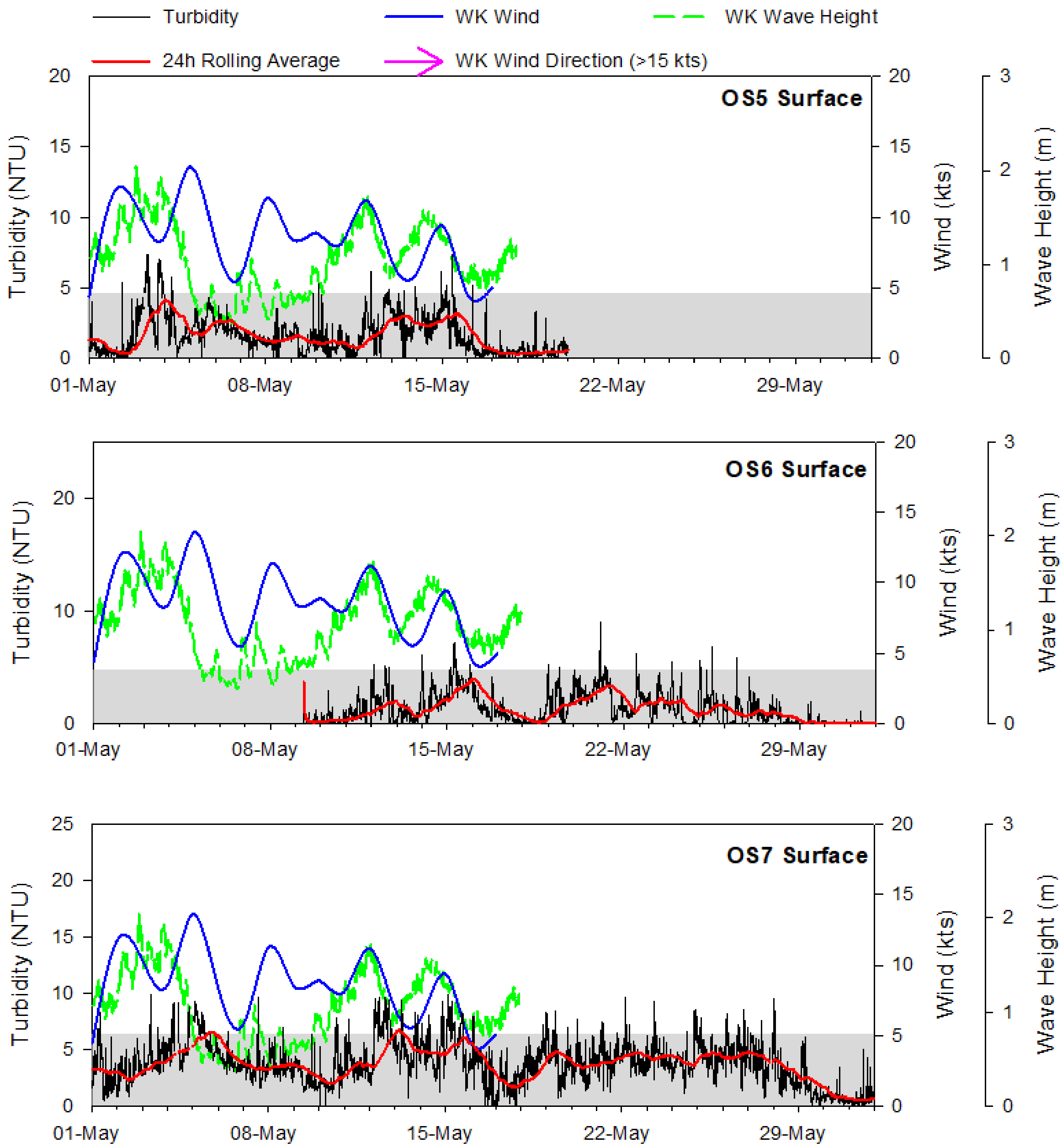


Figure 10 Surface turbidity and inshore daily averaged winds at inshore sites (OS5 to OS7) during May 2020.

Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

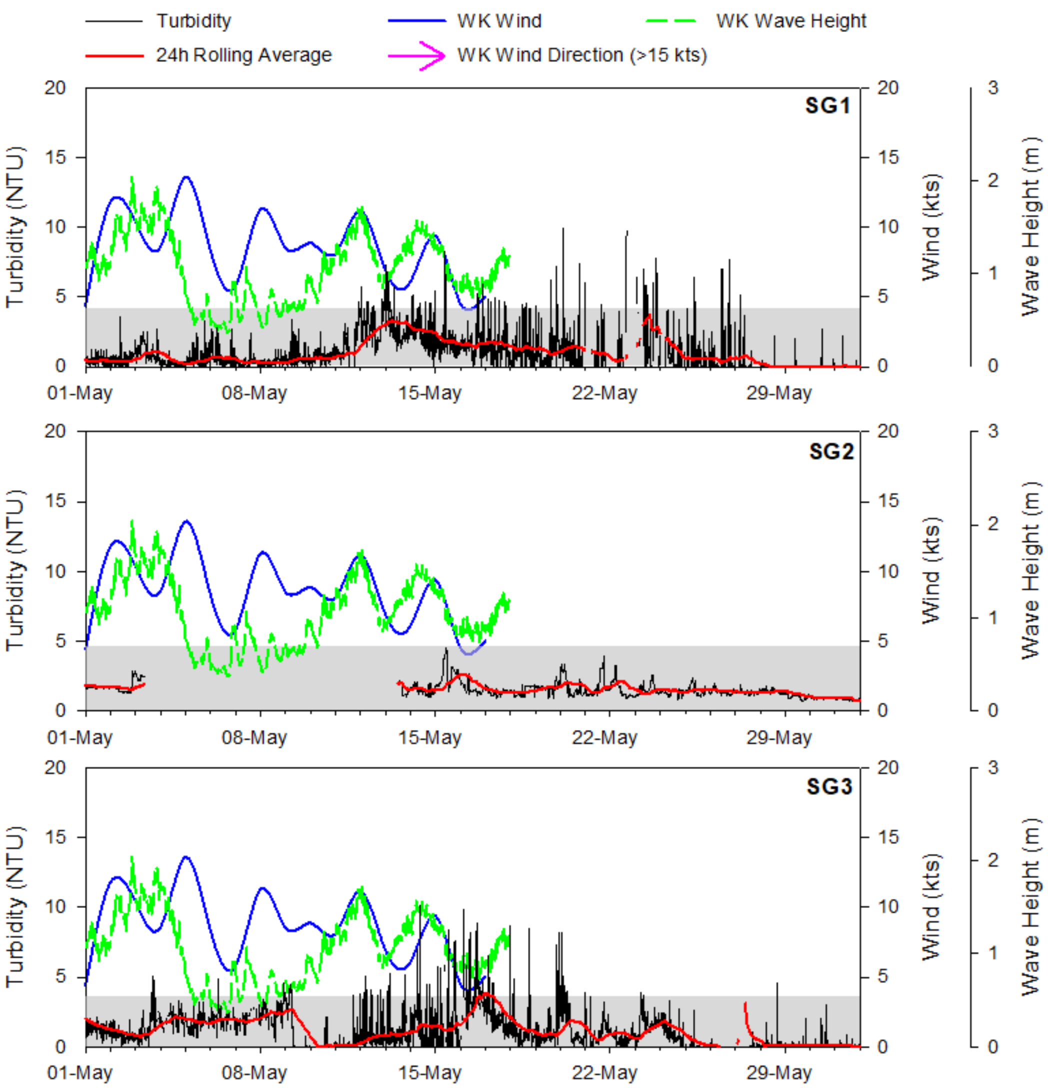


Figure 11 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during May 2020.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

Comparison to Baseline:

Mean surface turbidity values and statistics during May were lower than the values calculated from the baseline monitoring period (Tables 3 to 5, Figures 7 to 11).

3.2.2 Temperature

Mean monthly sea surface temperatures during May (12.0 to 13 °C) (Table 6) were significantly lower to those experienced during April (14.0 to 14.5 °C) as would be expected due to seasonal cooling. The overall declining temperature trend was consistent throughout May at all sites (Figures 12 and 13).

Table 6 Mean temperature at inshore, spoil ground and offshore water quality sites during May 2020. *Values are means ± se (n = 1784 to 2974).*

Site	Temperature (°C)
	Surface loggers
UH1	12.0 ± 0.0
UH2	12.2 ± 0.0
CH1	12.3 ± 0.0
CH2	12.7 ± 0.0
SG1	13.0 ± 0.0
SG2	12.9 ± 0.0
SG3	13.0 ± 0.0
OS1	12.8 ± 0.0
OS2	12.8 ± 0.0
OS3	12.9 ± 0.0
OS4	13.0 ± 0.0
OS5	13.2 ± 0.0
OS6	12.8 ± 0.0
OS7	12.8 ± 0.0

Similar to April and March but in contrast to previous summer months, slightly lower temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites during May. Semidiurnal variability (associated with tidal water movements and solar radiation) was again observed, particularly at the inner harbour and spoil ground sites.

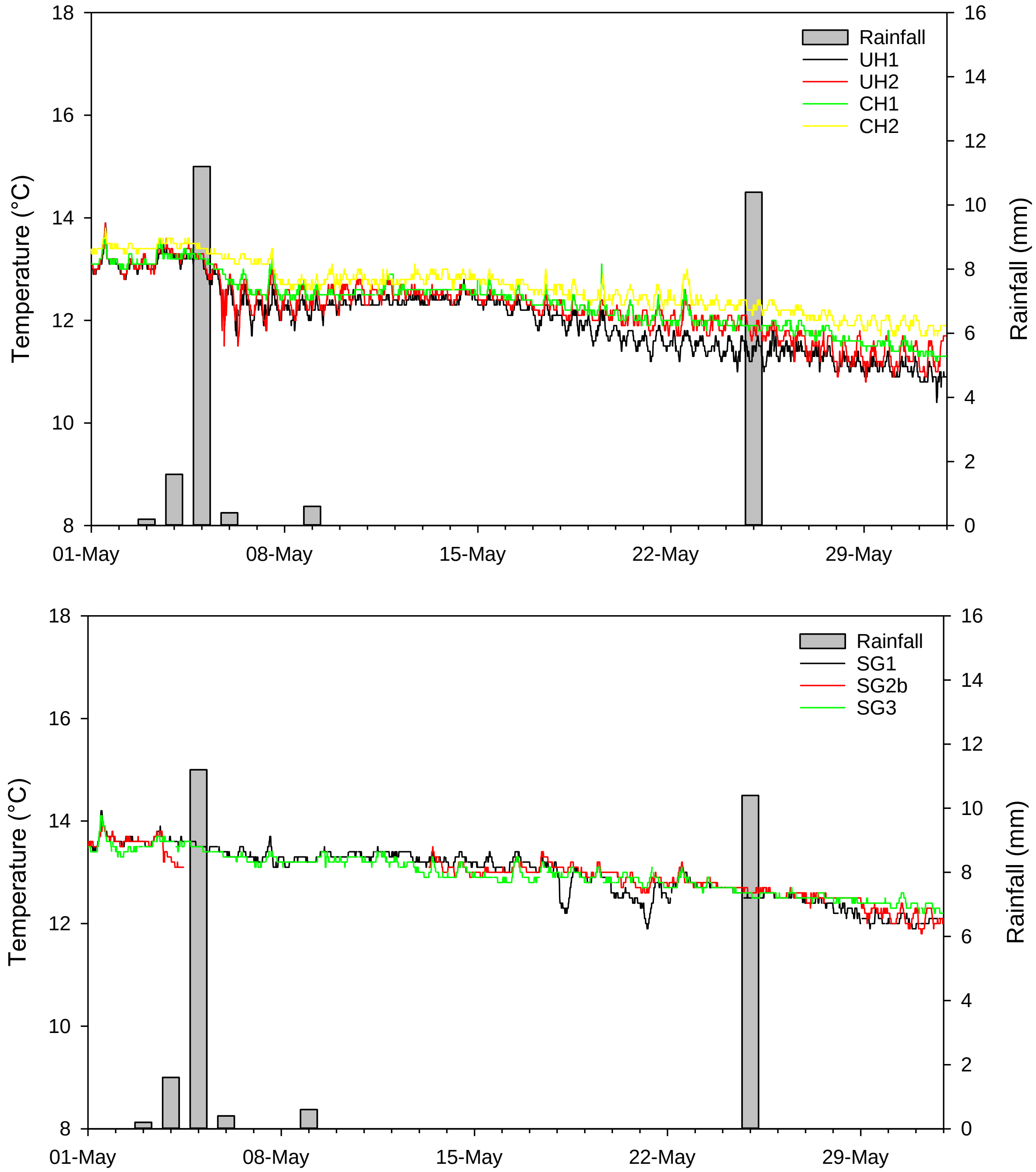


Figure 12 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during May 2020.

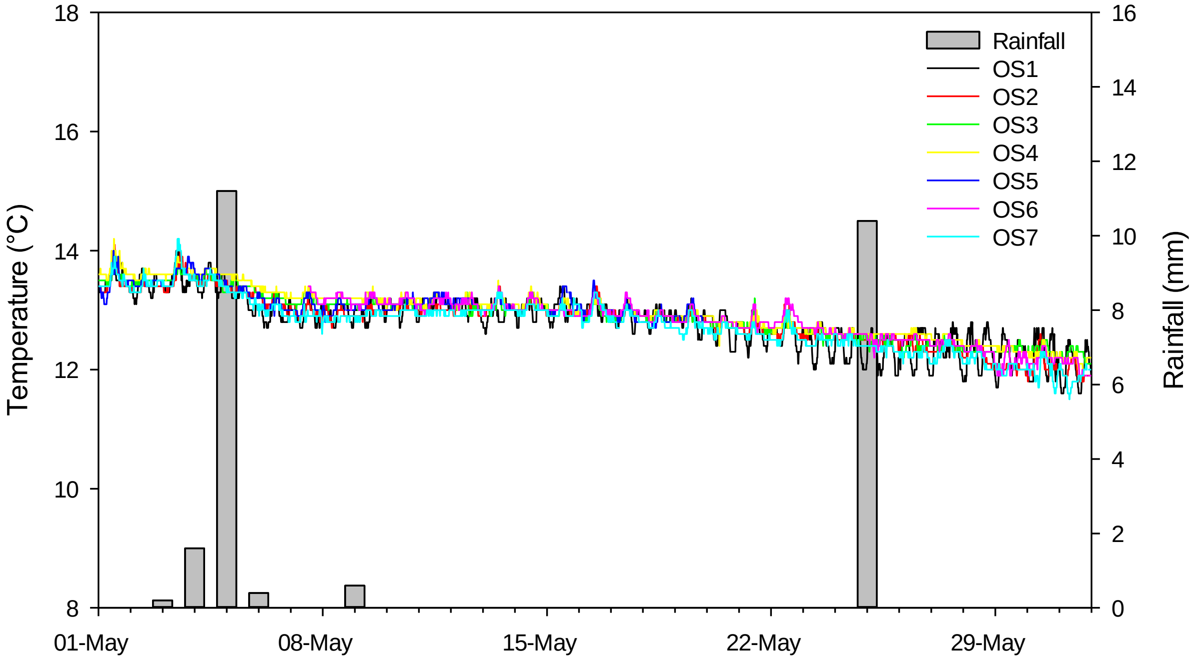


Figure 13 Surface temperature (OS1 to OS7) at nearshore and offshore water quality sites during May 2020.

3.2.3 pH

The pH remained consistent across surface and benthic sites, with monthly means ranging between 7.9 and 8.2 (Table 7, Figures 14 and 15).

Table 7 Mean pH at inshore, spoil ground and offshore water quality sites during May 2020. *Values are means ± se (n = 1567 to 2974).*

Site	pH
	Surface loggers
UH1	7.9 ± 0.0
UH2	8.0 ± 0.0
CH1	8.1 ± 0.0
CH2	8.1 ± 0.0
SG1	8.2 ± 0.0
SG2	8.1 ± 0.0
SG3	8.0 ± 0.0
OS1	8.1 ± 0.0
OS2	8.2 ± 0.0
OS3	8.2 ± 0.0
OS4	8.1 ± 0.0
OS5	8.2 ± 0.0
OS6	8.1 ± 0.0
OS7	8.0 ± 0.0

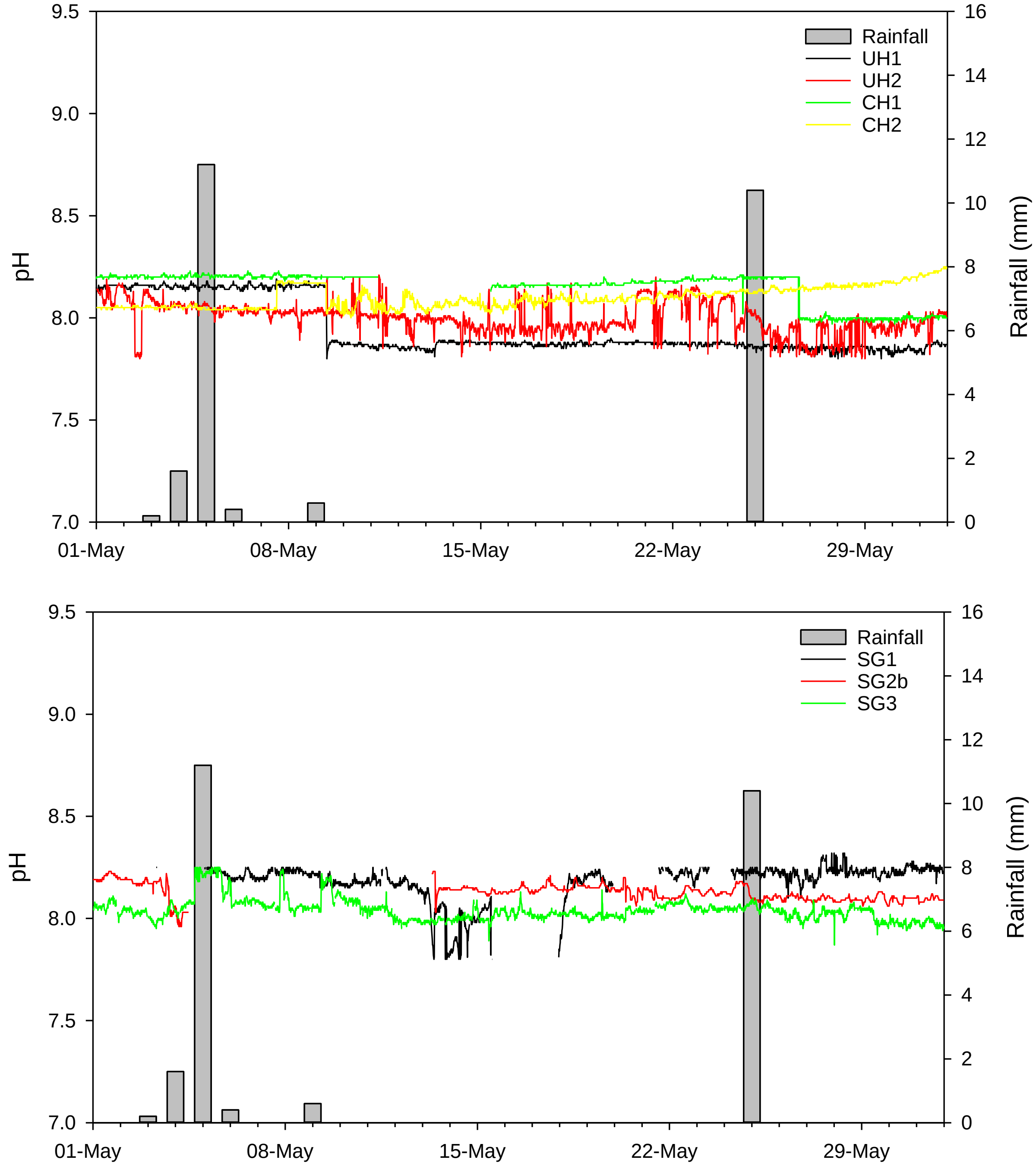


Figure 14 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during May 2020.

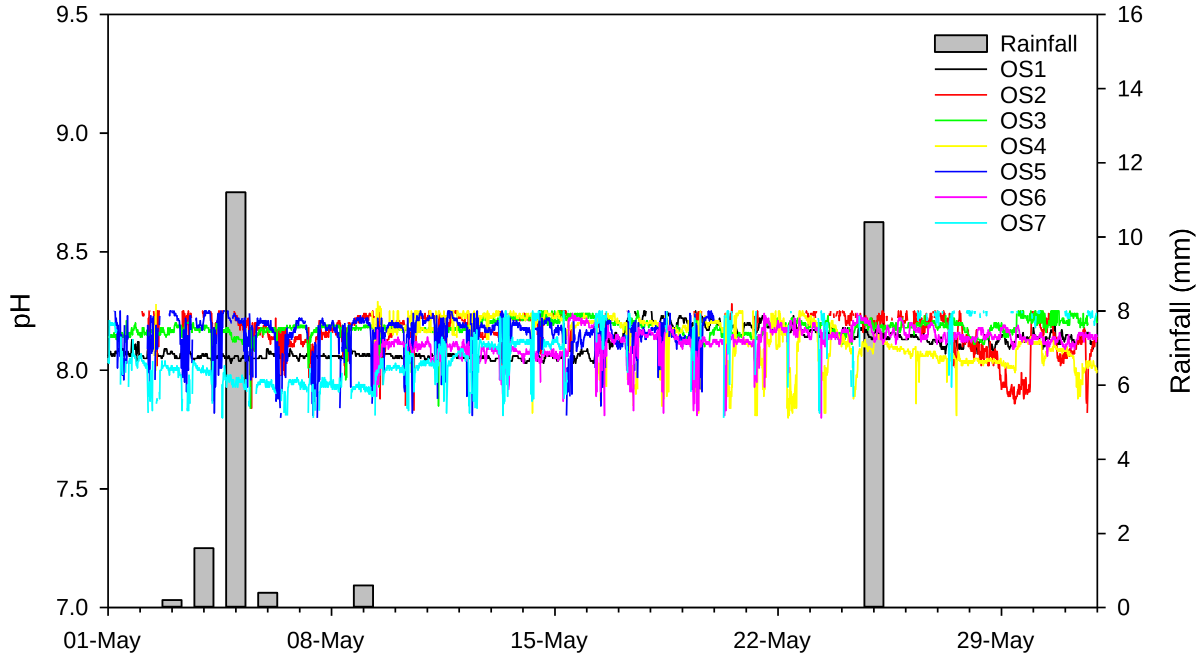


Figure 15 Surface pH (OS1 to OS7) at nearshore and offshore water quality sites during May 2020.

3.2.4 Conductivity

Surface conductivity in May ranged from 51.2 mS/cm to 53.8 mS/cm (Table 8, Figure 16 and 17). As observed in previous months, most inner harbour sites (apart from UH2) recorded slightly lower mean conductivity values than offshore and spoil ground sites due to previous localised freshwater influences compared to oceanic mixing. Surface conductivity was generally consistent within all sites during May. Flow rates from the Waimakariri River peaked on 5 May at 462 m^3/s and were below 300 m^3/s for the rest of the month explaining the stability in surface conductivity observed throughout most of May.

Table 8 Mean conductivity at inshore, spoil ground and offshore water quality sites during May 2020. *Values are means ± se (n = 1760 to 2975).*

Site	Conductivity (mS/cm)
	Surface loggers
UH1	51.2 ± 0.0
UH2	53.4 ± 0.0
CH1	51.6 ± 0.0
CH2	51.3 ± 0.0
SG1	51.3 ± 0.0
SG2	52.2 ± 0.0
SG3	52.1 ± 0.0
OS1	51.7 ± 0.0
OS2	53.6 ± 0.0
OS3	53.8 ± 0.0
OS4	53.4 ± 0.0
OS5	53.9 ± 0.0
OS6	52.8 ± 0.0
OS7	52.9 ± 0.0

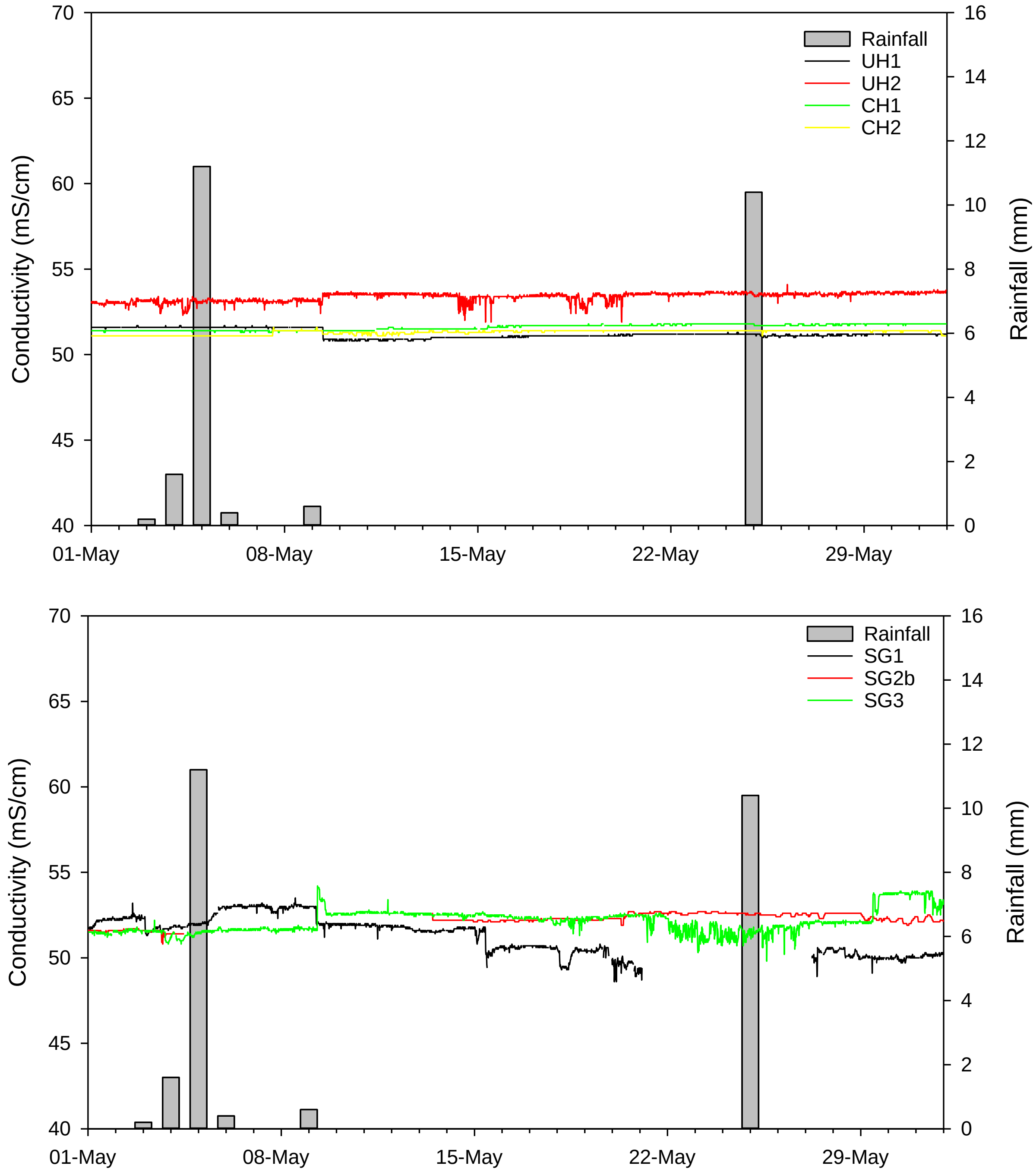


Figure 16 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during May 2020.

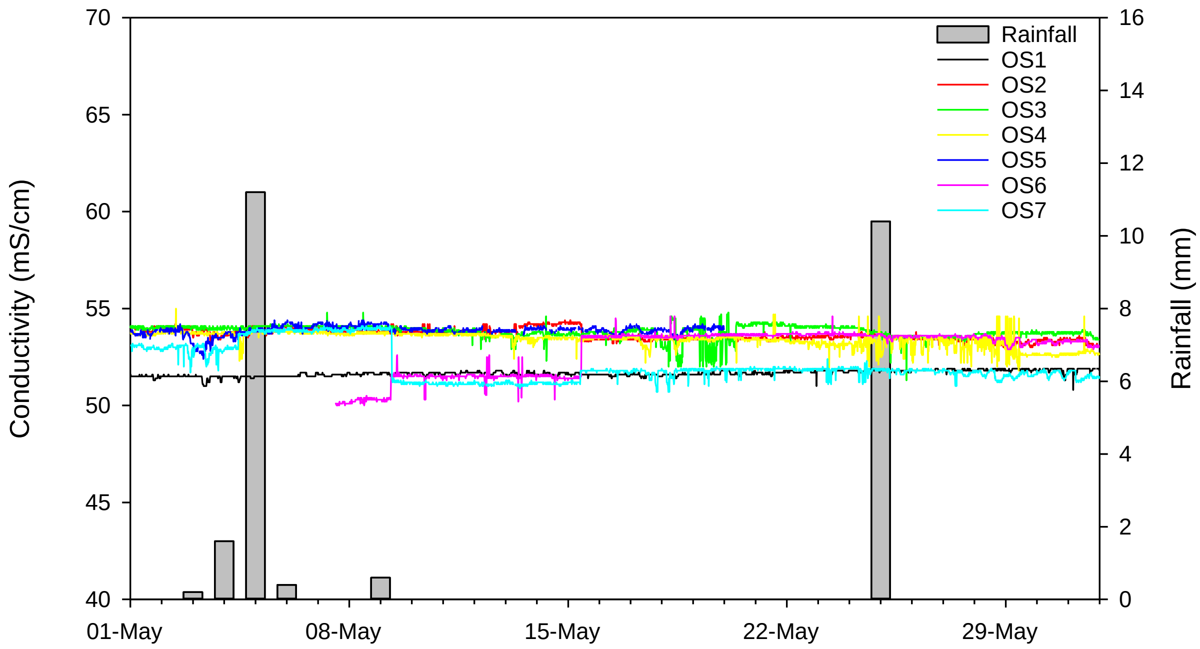


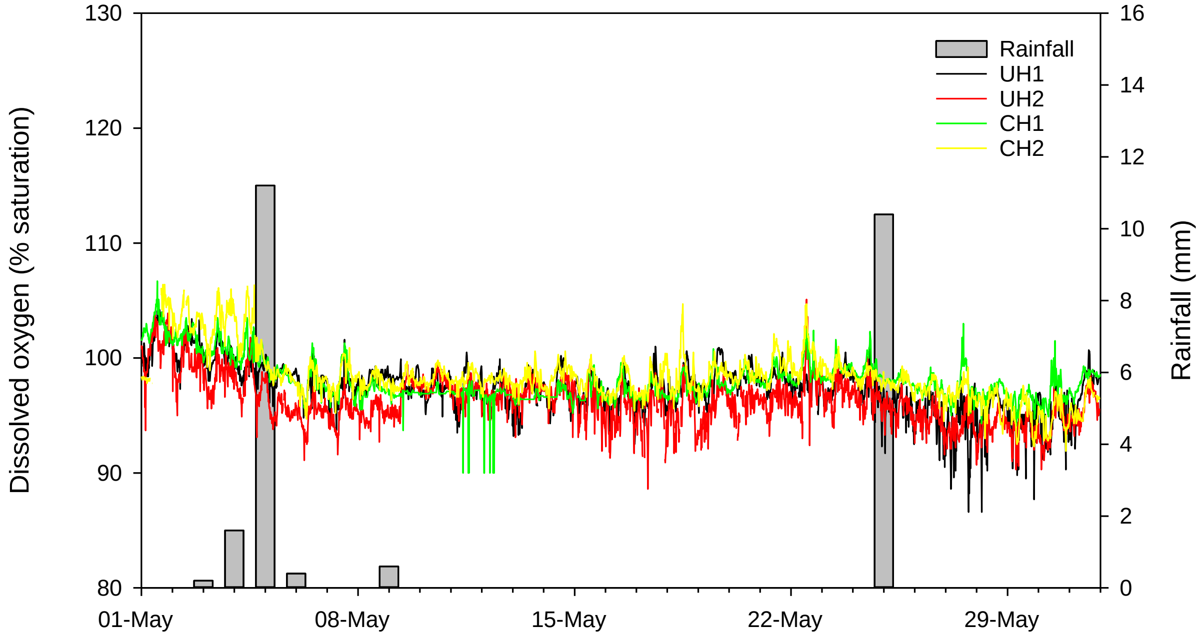
Figure 17 Surface conductivity (OS1 to OS7) at nearshore and offshore water quality sites during May 2020.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in May ranged from 96 to 103% saturation (Table 9) and demonstrated diurnal fluctuations at all sites, particularly those in the inshore area. DO concentrations at all sites appeared to be generally stable over the month (Figures 18 and 19). All sites displayed slight declines in DO following heavy rainfall on 4 May and 24 May. This was however more noticeable at the offshore site OS1 where declining DO (< 90% saturation) was recorded from 26 May to the end of the month. The declines in DO at the end of the month may have been associated with degrading algal blooms in which bacterial degradation results in respiration and oxygen consumption. In a cyclical pattern, warmer temperatures associated with increased sunlight following this period likely stimulated microalgal growth, leading to recovery of algal populations, increased photosynthesis, and therefore increased DO concentrations. Flows from the Waimakariri River may have also introduced nutrients contributing to algal growth.

Table 9 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during May 2020.
Values are means ± se (n = 1762 to 2974).

Site	Dissolved oxygen (% saturation)
	Surface loggers
UH1	97 ± 0
UH2	96 ± 0
CH1	98 ± 0
CH2	98 ± 0
SG1	102 ± 0
SG2	103 ± 0
SG3	100 ± 0
OS1	98 ± 0
OS2	97 ± 0
OS3	97 ± 0
OS4	96 ± 0
OS5	97 ± 0
OS6	100 ± 0
OS7	97 ± 0



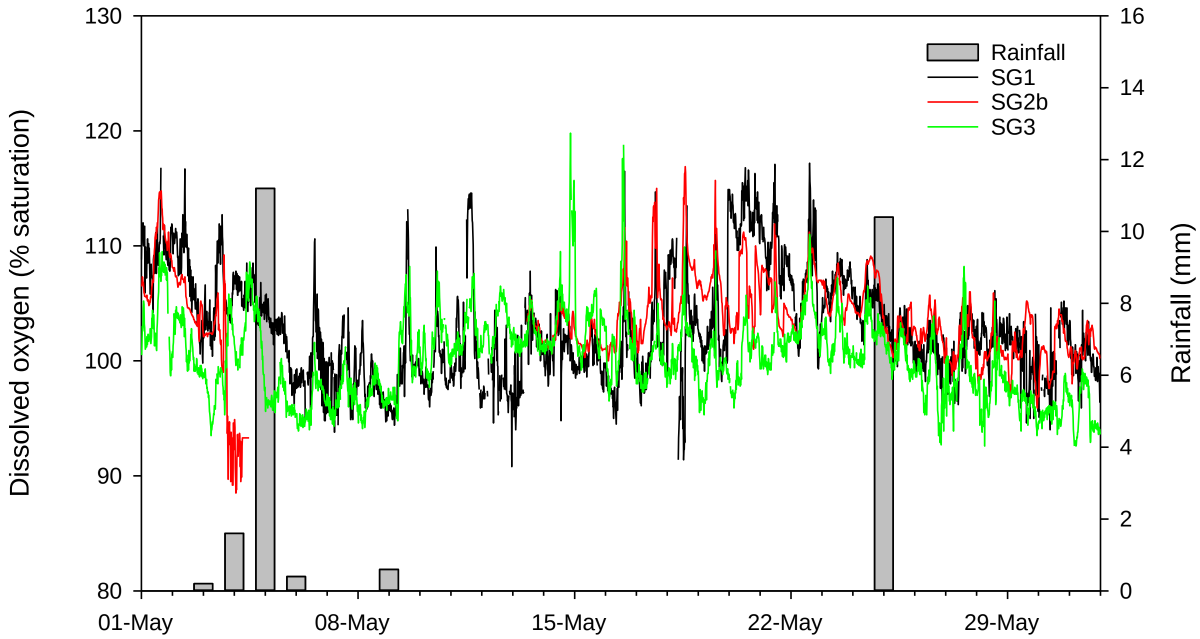


Figure 18 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during May 2020.

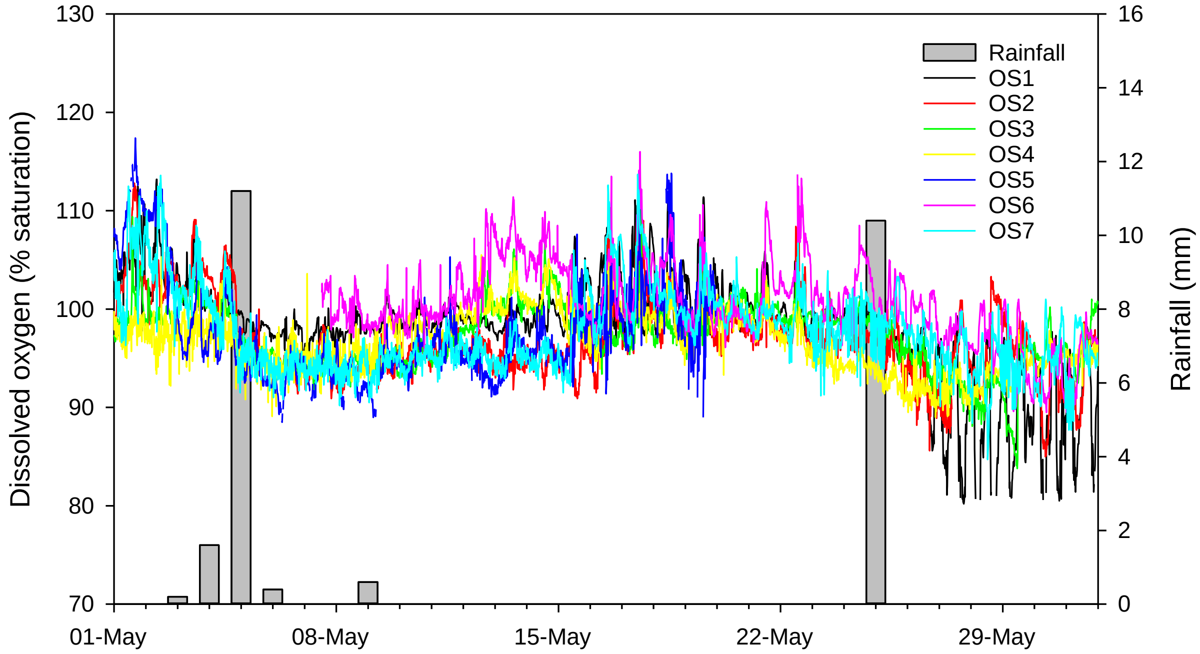


Figure 19 Surface DO (OS1 to OS7) at nearshore and offshore water quality sites during May 2020.

3.3 Physicochemistry Depth Profiling & TSS

Vertical depth profiling of the whole water column at each monitoring site was conducted in conjunction with monthly discrete water sampling on 29 May 2020. In addition to the previously discussed physicochemical parameters, the light attenuation rate (K_d, the rate at which light or PAR diminishes with depth through the water column) and resultant euphotic depth (the depth to which net photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were collected from three different depths (sub-surface, mid-column and approximately 1 m above the benthos) at the ten offshore and spoil ground sites. Due to the shallow water depths at the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, UH3, CH1 and CH2. Further information regarding the specific sampling methodology can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Statistical analyses of the resulting datasets are provided in Tables 10 to 12, with depth profile plots presented in Figures 20 to 22.

The relatively shallow sites of the upper and central harbour once again displayed well mixed conditions with little variability recorded in parameters through the water column (Figure 20). Turbidity was comparatively lower compared to previous months among all sites. As commonly reported turbidity was more elevated at the three inshore sights with highest turbidity readings recorded at UH1 and UH3. Temperature was marginally lower in the upper harbour and channel sites compared to those offshore during May. DO observed gradual declines with depth most likely due to decreased photosynthesis at depth.

Within the nearshore region, physicochemical profiles for temperature, conductivity and pH were relatively consistent throughout the water column at all sites, while DO showed a slight decrease with depth (Figure 21). Turbidity was variable through the water column at all sites showing increases with depth at sites OS4 and OS7 and a decrease with depth at OS1 after ~ 3 m. Turbidity at OS2 was very stable through the water column until ~ 12 m where a slight increase occurred, most probably due to the resuspension of benthic sediments.

Within the offshore region of the spoil ground, the water column displayed relative consistent temperature and conductivity profiles (Figure 22). Notably OS5 demonstrated a thermocline at ~ 7 m where temperatures increased with depth, which also lead to an increase in conductivity at the same depth. This was also recorded at OS6 with a shallower thermocline starting at ~ 2 m inducing an increase in conductivity at the same depth. pH was relatively consistent through the water column at most offshore sites apart from OS5 where a reduction in pH was seen at ~7m before a gradual increase from 10 to 13 m.

DO concentrations, again decreased among all spoil ground sites closer to the benthos, due to reduced photosynthetic activity at depth but was most pronounced at OS5 again at ~ 7 m. Turbidity remained stable at SG1, SG2 and SG3 throughout the water column, while a small increase occurred at OS6 at ~ 10 m probably due to the resuspension of sediments. OS5 experienced the most dynamic turbidity through the water column with a sharp increase between 7 and 12 m. The extreme changes in the profile at OS5 has been occasionally observed historically and has been previously attributed to potential upwelling of water currents or contributions from benthic fissures.

The shallowest euphotic depth of 7.4 m occurred within upper harbour monitoring site UH1 (Table 10), which reflects the typically higher levels of turbidity experienced in this area (Figure 21). The deepest euphotic depth was calculated to be 20.2 m at SG3 (Table 12) where turbidity throughout the column was typically low. During May no exceedances of WQG were recorded at the sub-surface during depth profiling.

Table 10 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the May 2020 sampling event. *Values are means ± se (n = 3 for sub-surface, n = 7 to 19 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/)	K_d	Euphotic Depth (m)
UH1	29/05/2020 14:22	Sub-surface	10.8 ± 0	8.1 ± 0	53.8 ± 0	100 ± 0	2.3 ± 0.3	7	0.6 ± 0	7.4
		Whole column	10.8 ± 0	8.1 ± 0	53.8 ± 0	99 ± 0	2.2 ± 0.2			
UH2	29/05/2020 14:06	Sub-surface	11 ± 0	8.2 ± 0	53.8 ± 0	98 ± 0	1.7 ± 0	<3	0.3 ± 0	13.6
		Whole column	11 ± 0	8.1 ± 0	53.8 ± 0	98 ± 0	1.8 ± 0			
UH3	29/05/2020 09:05	Sub-surface	10.2 ± 0.2	8.2 ± 0	53.6 ± 0	100 ± 0	2.8 ± 0.2	7	0.4 ± 0	10.4
		Whole column	10.3 ± 0	8.2 ± 0	53.6 ± 0	100 ± 0	2.9 ± 0.1			
CH1	29/05/2020 10:08	Sub-surface	11.3 ± 0	8.1 ± 0	53.9 ± 0	98 ± 0	0.9 ± 0.1	4	0.5 ± 0	9.1
		Whole column	11.3 ± 0	8.1 ± 0	53.9 ± 0	98 ± 0	0.9 ± 0			
CH2	29/05/2020 13:54	Sub-surface	11.5 ± 0	8.1 ± 0	53.9 ± 0	99 ± 0	0.4 ± 0.1	<3	0.4 ± 0	13.0
		Whole column	11.4 ± 0	8.1 ± 0	53.8 ± 0	98 ± 0	0.8 ± 0.1			
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 11 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the May 2020 sampling event. *Values are means ± se (n = 3 for sub-surface, mid and benthos, n = 16 to 17 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS1	29/05/2020 10:22	Sub-surface	12.2 ± 0	8.1 ± 0	54 ± 0	89 ± 0	1.2 ± 0.1	5	0.5 ± 0	9.6
		Mid	12.1 ± 0	8.1 ± 0	53.9 ± 0	88 ± 0	1.2 ± 0	3		
		Benthos	11.8 ± 0.1	8.1 ± 0	53.9 ± 0	90 ± 1	1.1 ± 0.1	6		
		Whole column	12.1 ± 0	8.1 ± 0	53.9 ± 0	88 ± 0	1.2 ± 0	-		
OS2	29/05/2020 13:19	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0.1 ± 0	3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0.1 ± 0	4		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.2 ± 0.1	3		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0.1 ± 0	-		
OS3	29/05/2020 13:19	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	4	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	< 3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	< 3		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
OS4	29/05/2020 12:13	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	< 3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	4		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	6		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
OS7	29/05/2020 13:35	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	6	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	< 3		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 12 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the May 2020 sampling event. *Values are means ± se (n = 3 for sub-surface, mid and benthos, n = 17 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS5	29/05/2020 10:43	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	5		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
OS6	29/05/2020 12:57	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	< 3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	7		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
SG1	29/05/2020 11:03	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	< 3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	< 3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	< 3		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
SG2	29/05/2020 11:27	Sub-surface	11.9 ± 0	8.2 ± 0	53.5 ± 0	101 ± 0	0 ± 0	< 3	0.3 ± 0	14.7
		Mid	11.9 ± 0	8.2 ± 0	53.6 ± 0.1	99 ± 3	0 ± 0	< 3		
		Benthos	12 ± 0	8.1 ± 0	53.8 ± 0	95 ± 0	0.1 ± 0.1	3		
		Whole column	11.9 ± 0	8.2 ± 0	53.6 ± 0	99 ± 0	0 ± 0	-		
SG3	29/05/2020 11:49	Sub-surface	12.2 ± 0	8.2 ± 0	54.1 ± 0	103 ± 0	0 ± 0	< 3	0.2 ± 0	20.2
		Mid	12.2 ± 0	8.2 ± 0	54.1 ± 0	102 ± 0	0 ± 0	< 3		
		Benthos	12.2 ± 0	8.2 ± 0	54.1 ± 0	101 ± 0	0 ± 0	4		
		Whole column	12.2 ± 0	8.2 ± 0	54.1 ± 0	102 ± 0	0 ± 0	-		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

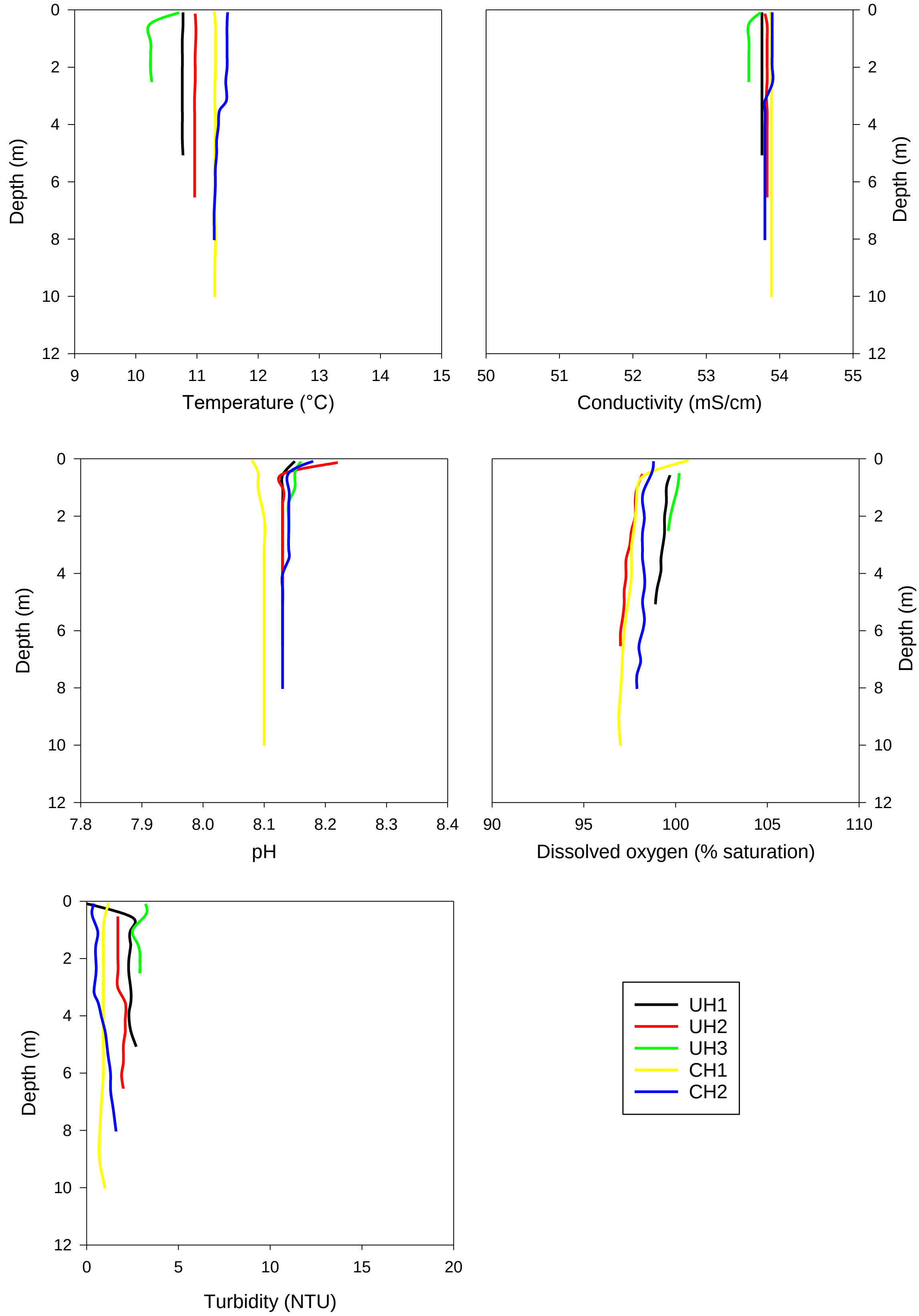


Figure 20 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 29 May 2020.

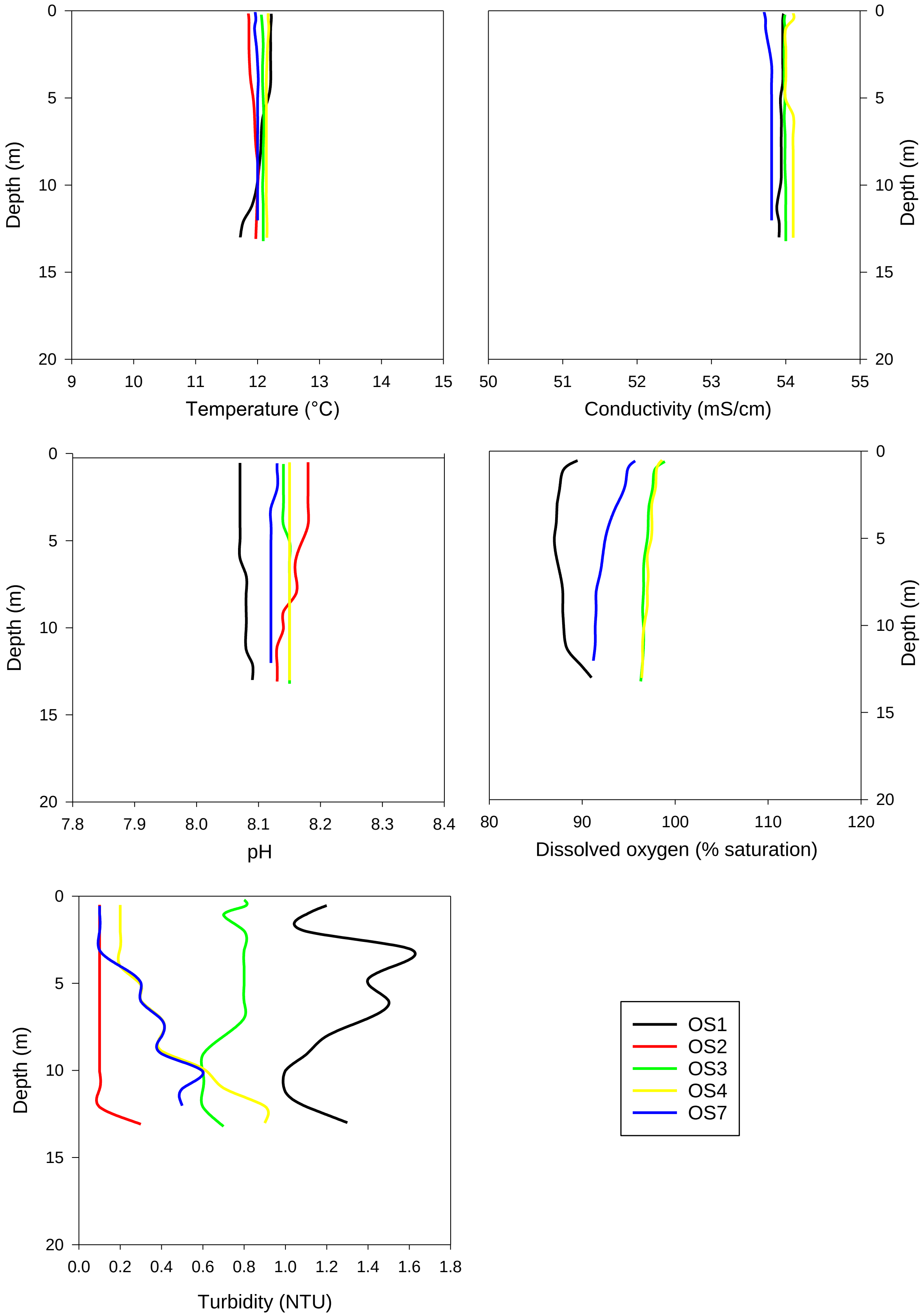


Figure 21 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 29 May 2020

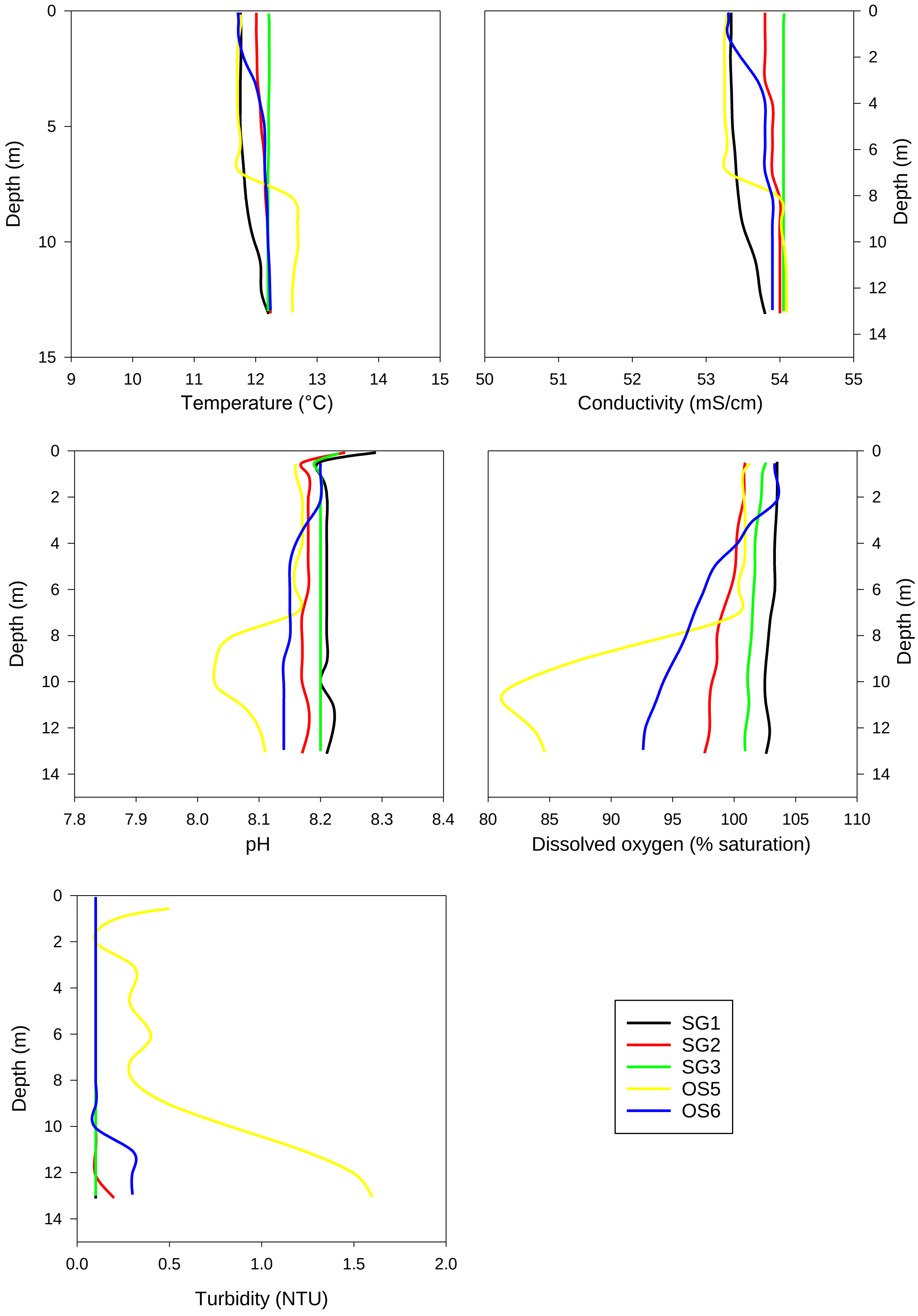


Figure 22 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 29 May 2020.

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3.4 Water Samples

Discrete water sampling was conducted on 29 May 2020, in conjunction with vertical physicochemical profiling through the water column. Quality assurance/quality control (QA/QC) procedures included a duplicate water sample collected at one site, in addition to a laboratory and field blank for each parameter. Further details on the specific sampling methodology can be found within the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Laboratory results associated with VE QA/QC procedures are presented in Table 17 of the Appendix.

3.4.1 Nutrients

Total phosphorous concentrations were found in higher concentrations in the upper and central sampling sites, which has been noted in previous months. Total phosphorous remained below the WQG of 30 µg/L at all sites. Dissolved reactive phosphorous concentrations were above the WQG of 5 µg/L at all sites in May and exhibiting no particular spatial pattern among the sampling sites. Both total nitrogen and total kjeldahl nitrogen (TKN) were < LOR and < WQG at all sites except OS7, which recoded anomalously high values (1700 µg/L) for both total nitrogen and TKN. These elevated concentrations could potentially be due to contamination from field or laboratory processes.

Total ammonia ranged from 11 to 24 µg/L with nine sites exceeding the WQG (15 µg/L), including all of those sites located in the upper harbour and channel areas. Nitrogen oxide values ranged from 1.2 to 21 µg/L with four sites recording values above the WQG (>15 µg/L).

Chlorophyll *a*, an indicator of phytoplankton biomass, recorded concentrations above the WQG value (4 µg/L) at two sites, SG1 (4.3 µg/L) and OS5 (5 µg/L) during May, indicating higher than normal algal populations potentially due to readily bioavailable nutrients (Table 13) on this sampling occasion. However these are likely to fluctuate through out the month.

Table 13 Concentrations of nutrients and chlorophyll *a* at monitoring sites during May 2020
Values outside recommended WQG are highlighted in blue.

Site	Parameter (µg/L)						
	Total Phosphorus	Dissolved Reactive Phosphorus	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)	Total Ammonia	Nitrogen Oxides (NOx)	Chlorophyll *a*
UH1	28	13.6	<300	<200	16	21	2.6
UH2	22	12.1	<300	<200	17	7.8	3.2
UH3	21	13.9	<300	<200	16	18	3.7
CH1	24	12.2	<300	<200	17	12	3.8
CH2	21	11.4	<300	<200	19	11	4
OS1	25	12.7	<300	<200	24	12	2.3
OS2	19	8.9	<300	<200	14	13	3.8
OS3	20	12.1	<300	<200	23	14	1.5
OS4	16	12	<300	<200	24	17	2.6
OS5	18	8.4	<300	<200	14	5.5	5
OS6	17	6.3	<300	<200	12	6.4	3.7
OS7	20	11	1700	1700	19	20	3.2
SG1	15	13.6	<300	<200	11	1.2	4.3
SG2	15	12.1	<300	<200	13	7.4	3.8
SG3	15	13.9	<300	<200	13	6.7	3.1
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

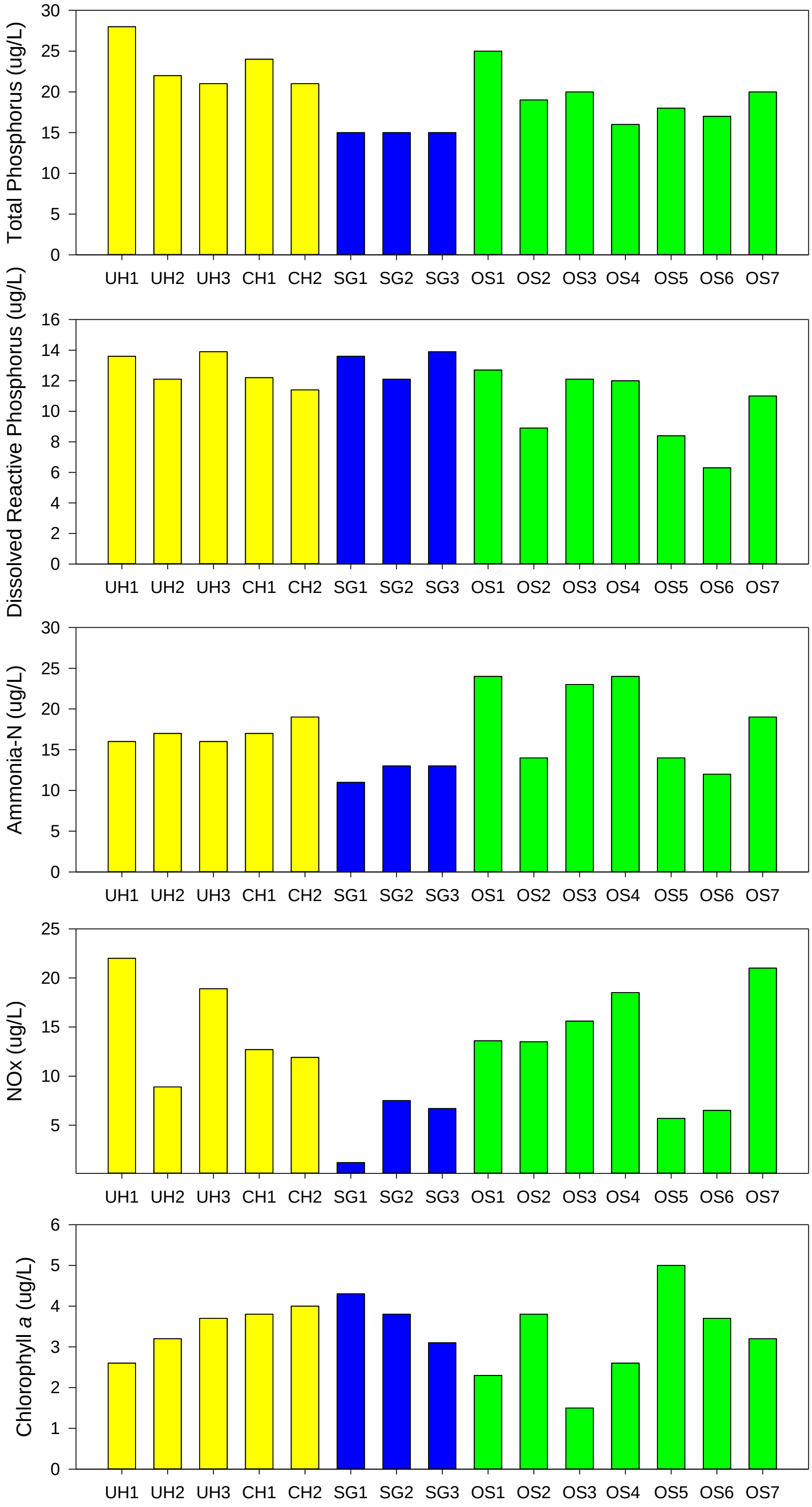

Figure 23 Nutrient and chlorophyll *a* concentrations at monitoring sites during May 2020.
Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.

3.4.2 Total and Dissolved Metals

Concentrations of the majority of recorded metals were relatively low during the month of May. Concentrations of several metals (Tables 14 to 16, Figure 24 and 25) were reported as below the limit of reporting (LOR) at all sites, including dissolved and total arsenic (<4.2 µg/L), cadmium (<0.21 µg/L), cobalt (<0.63 µg/L), copper (<1.1 µg/L) lead (< 1.1 µg/L) nickel (<7 µg/L), mercury (<0.08 µg/L) selenium (<4.2 µg/L), silver (<0.43 µg/L), and tin (<5.3 µg/L). Total zinc recorded a value (8.6 µg/L) at SG3 but was below recommended WQG (15 µg/L), all other sites and dissolved zinc was below LOR.

Dissolved concentrations of aluminium were <LOR at all sites. Concentrations of total aluminium exceeded the designated 95% species protection value of 24 µg/L at all sites except at OS6 and SG1. However, the WQG is applicable to the dissolved fraction only (ANZG, 2018), therefore no exceedances were recorded for May. Concentrations of dissolved iron were below the LOR of 4 µg/L for the majority of sites, except OS1, OS7, SG1 and SG3), which recorded values of dissolved iron between 5 µg/L and 18 µg/L. Total aluminium and iron concentrations were highest amongst the inshore monitoring sites as often reported. However concentrations were relatively low compared to previous months reflecting the lower concentrations of suspended sediment and colloidal particles in the water column over the winter months. There are no trigger values for dissolved or total iron concentrations.

Chromium, manganese, molybdenum and vanadium were recorded at majority of sites in both total and dissolved forms. Total and dissolved chromium concentrations were well below the 95% species protection trigger value of 4.4 µg/L from CrVI and 27.4 µg/L for CrIII at all sites. Vanadium concentrations ranged from 1.5 to 3.1 µg/L and were also well below the 95% species protection trigger value of 100 µg/L.

No trigger values are available for either manganese or molybdenum. Total and dissolved manganese concentrations ranged from 1.4 to 9.9 µg/L and <1 to 6.3 µg/L respectively, with higher concentrations recorded at sites in the upper harbour. Total and dissolved molybdenum concentrations exhibited little spatial variation, ranging from 10.6 to 11.8 µg/L and 10.6 to 11.8 µg/L respectively.

Table 14 Total and dissolved metal concentrations at inshore monitoring sites during May 2020. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	<12	<12	<12	<12	24
	Total	147	54	75	46	36	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.4	<1.1	1.4	<1.1	1.2	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	1.1	<1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	<4	<4	<4	<4	-
	Total	200	58	94	51	31	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	6.3	4.5	6.1	4.4	2.2	-
	Total	9.9	4.9	8.9	6.3	3	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	10.8	10.8	11	10.9	11.2	-
	Total	11.3	10.6	10.8	11.2	10.9	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.6	1.7	1.5	1.7	1.8	100
	Total	1.9	2	1.7	1.9	1.9	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 15 Total and dissolved metal concentrations at offshore monitoring sites during May 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites							WQG
		OS1	OS2	OS3	OS4	OS5	OS6	OS7	
Aluminium	Dissolved	<12	<12	<12	<12	<12	<12	<12	24
	Total	73	23	59	38	31	<21	28	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	1.3	1	<1	<1	<1	1.1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.1	<1.1	1.1	<1.1	<1.1	<1.1	1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	<1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	5	<4	<4	<4	<4	<4	11	-
	Total	91	17.9	74	60	36	20	32	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	2.5	1.4	1.4	1.3	<1	1	2.1	-
	Total	4.3	1.9	3.3	2.8	2	1.5	2.8	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.2	11.2	11.1	11.3	10.9	10.5	11.1	-
	Total	10.9	11.4	11.2	11.5	10.8	11.3	11.3	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	1.8	1.7	1.8	1.7	1.9	1.8	100
	Total	1.9	1.9	1.9	1.8	1.9	1.8	1.9	
Zinc	Dissolved	<4	<4	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 16 Total and dissolved metal concentrations at spoil ground monitoring sites during May 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	<21	30	29	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	1.1	1.3	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	
Iron	Dissolved	7	<4	18	-
	Total	18.2	24	30	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1	<1	1	-
	Total	1.4	1.8	1.7	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	10.6	11.7	11	-
	Total	10.6	11.4	11.8	
Nickel	Dissolved	<7	<7	<7	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.8	1.9	3.1	100
	Total	2.1	1.9	1.8	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	8.6	

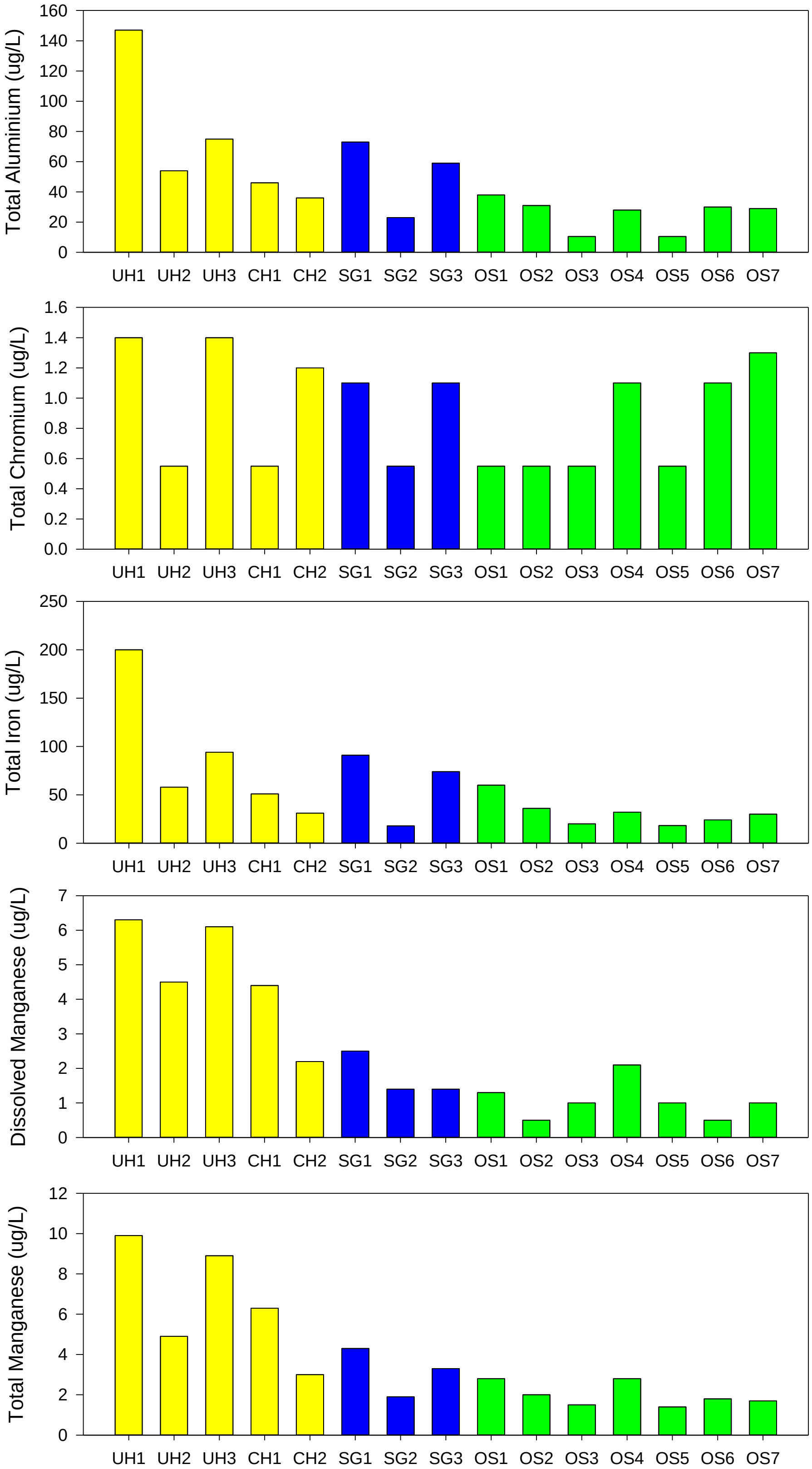

Figure 24 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during May 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

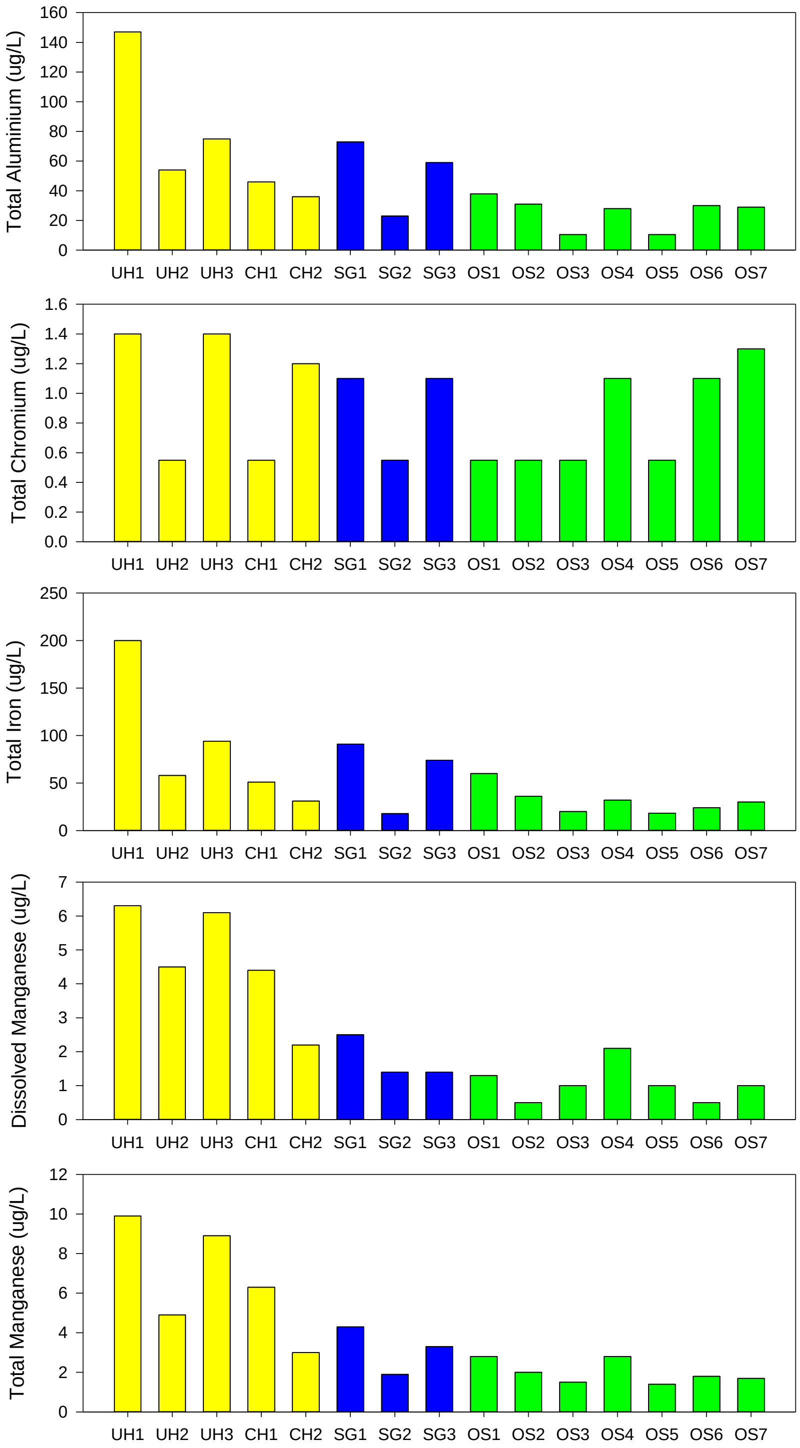

Figure 25 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during May 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

4 REFERENCES

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5 APPENDIX

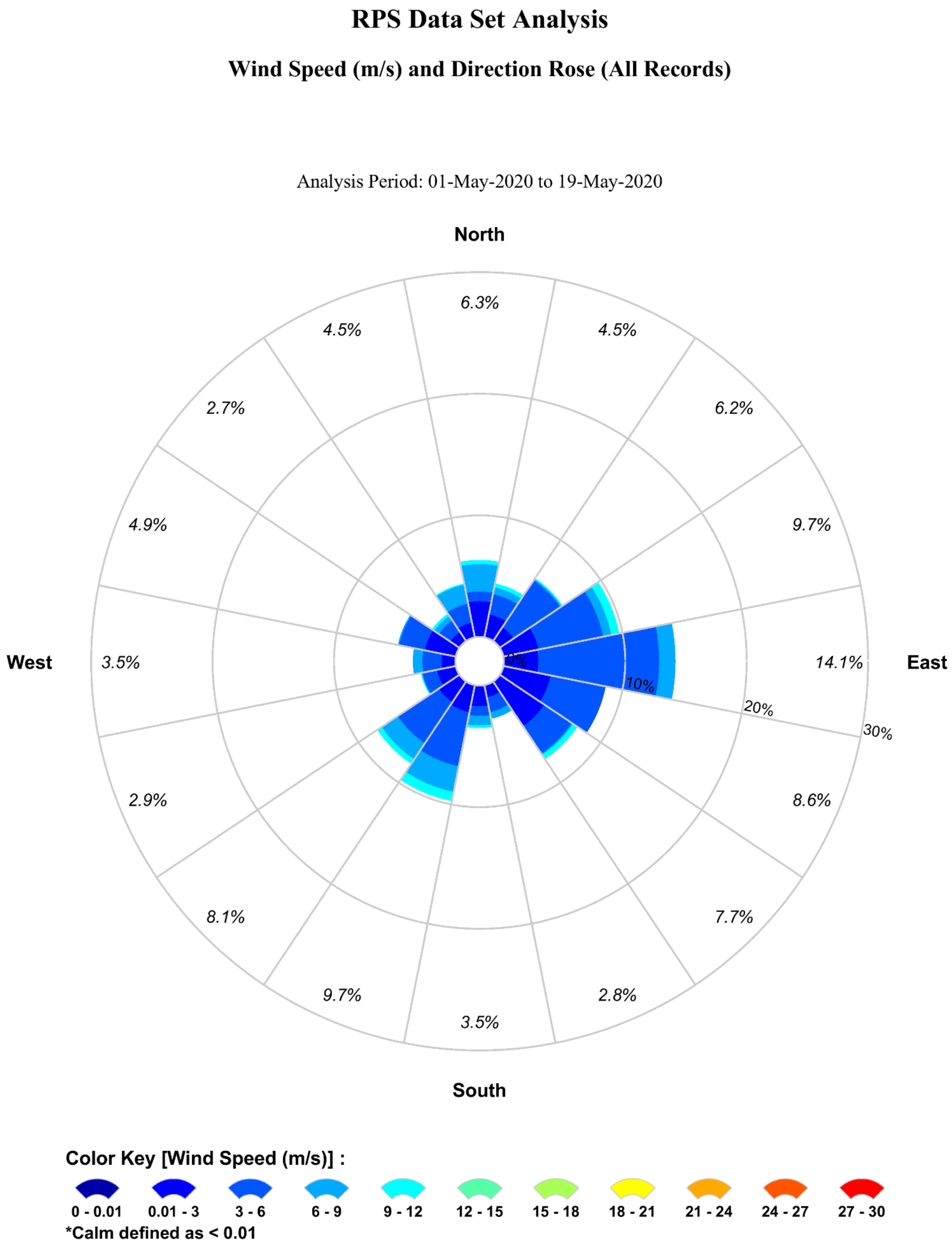

Figure 26 WatchKeeper wind speed (m/s) and direction rose (%) during May 2020.
Note data only available up to 17 May.

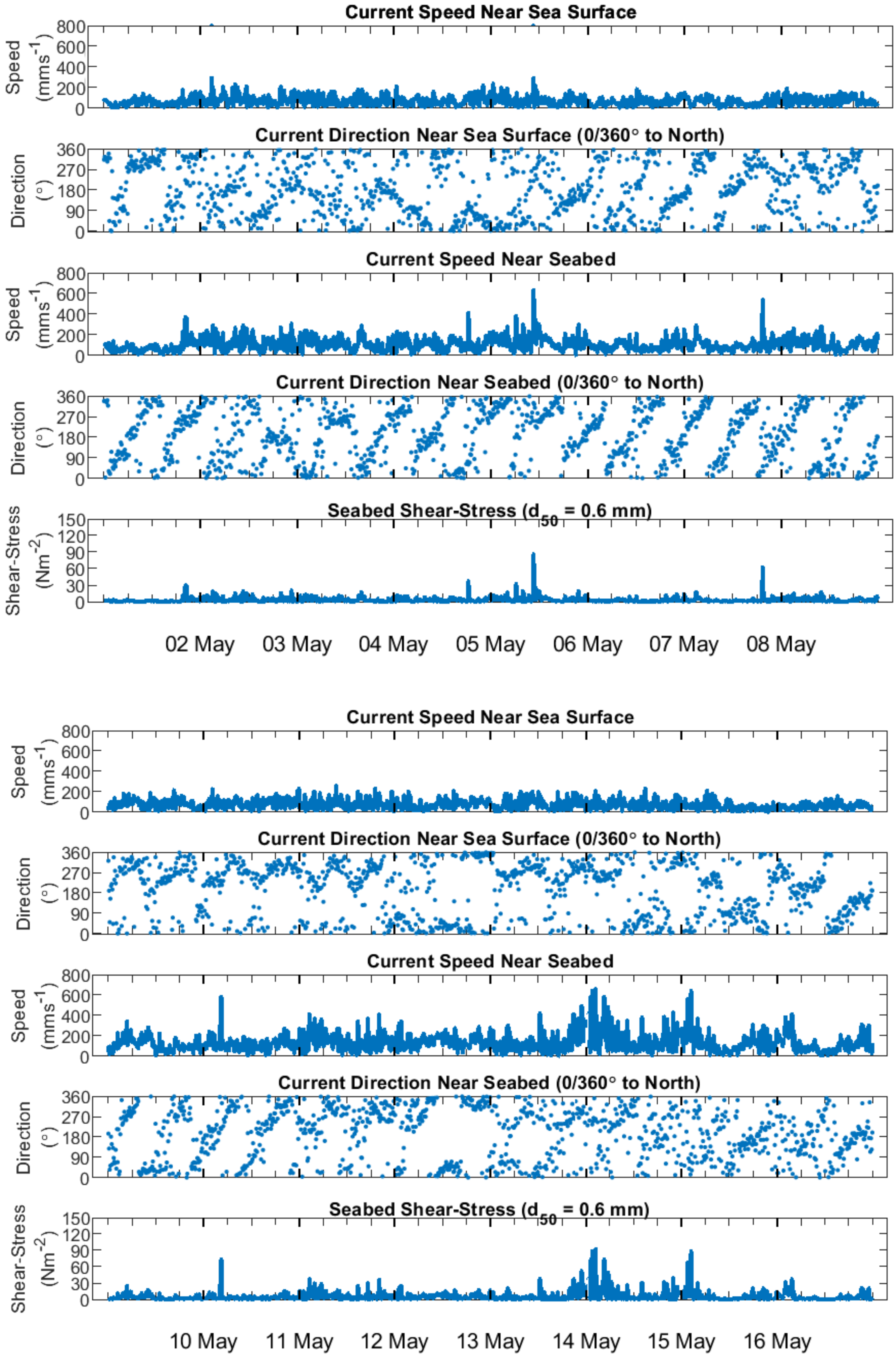

Figure 27 SG1 current speed, direction and shear bed stress 1 to 16 May 2020.

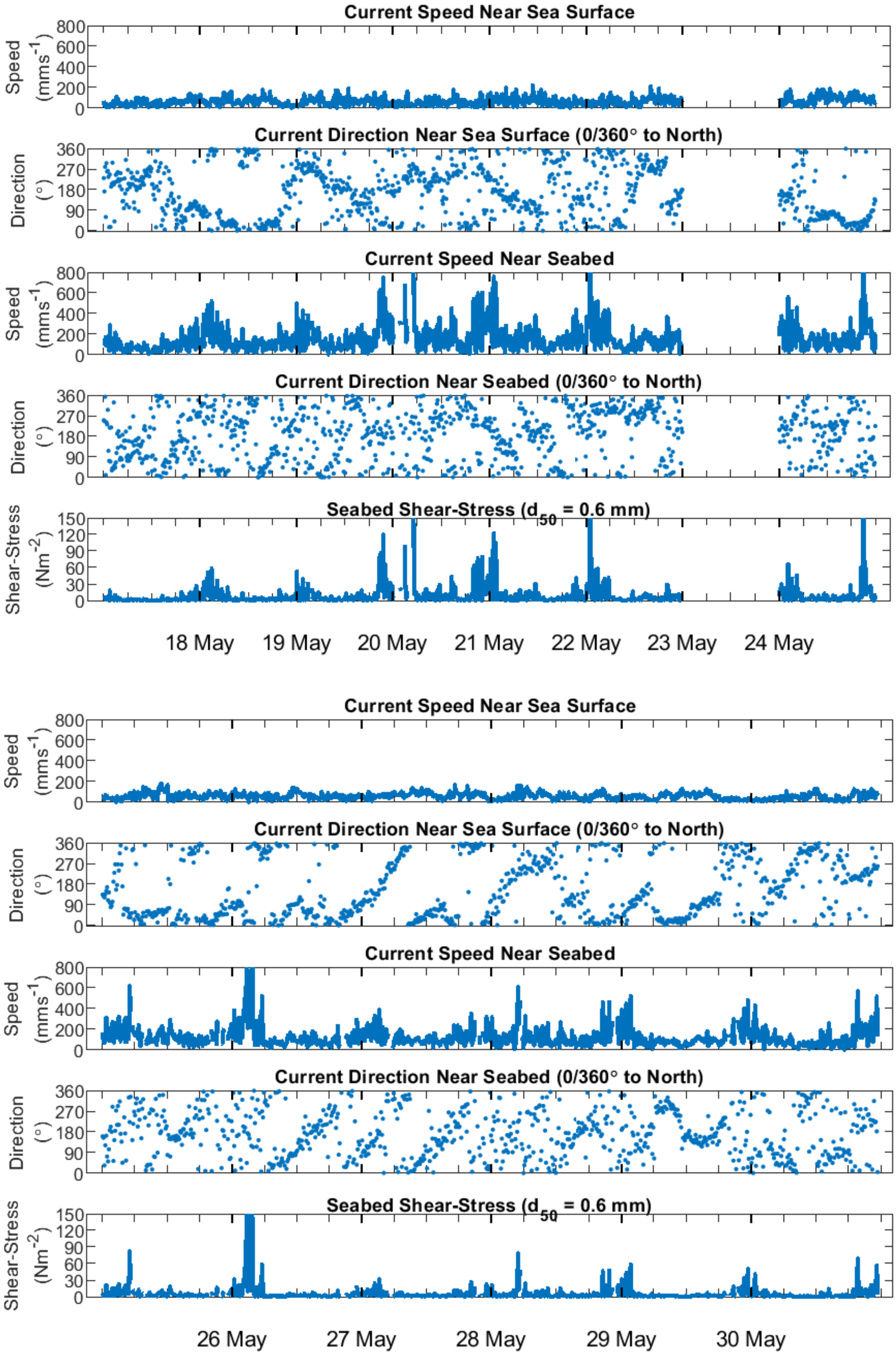

Figure 28 SG1 current speed, direction and shear bed stress 17 to 30 May 2020.
Note missing data due to unit malfunction.

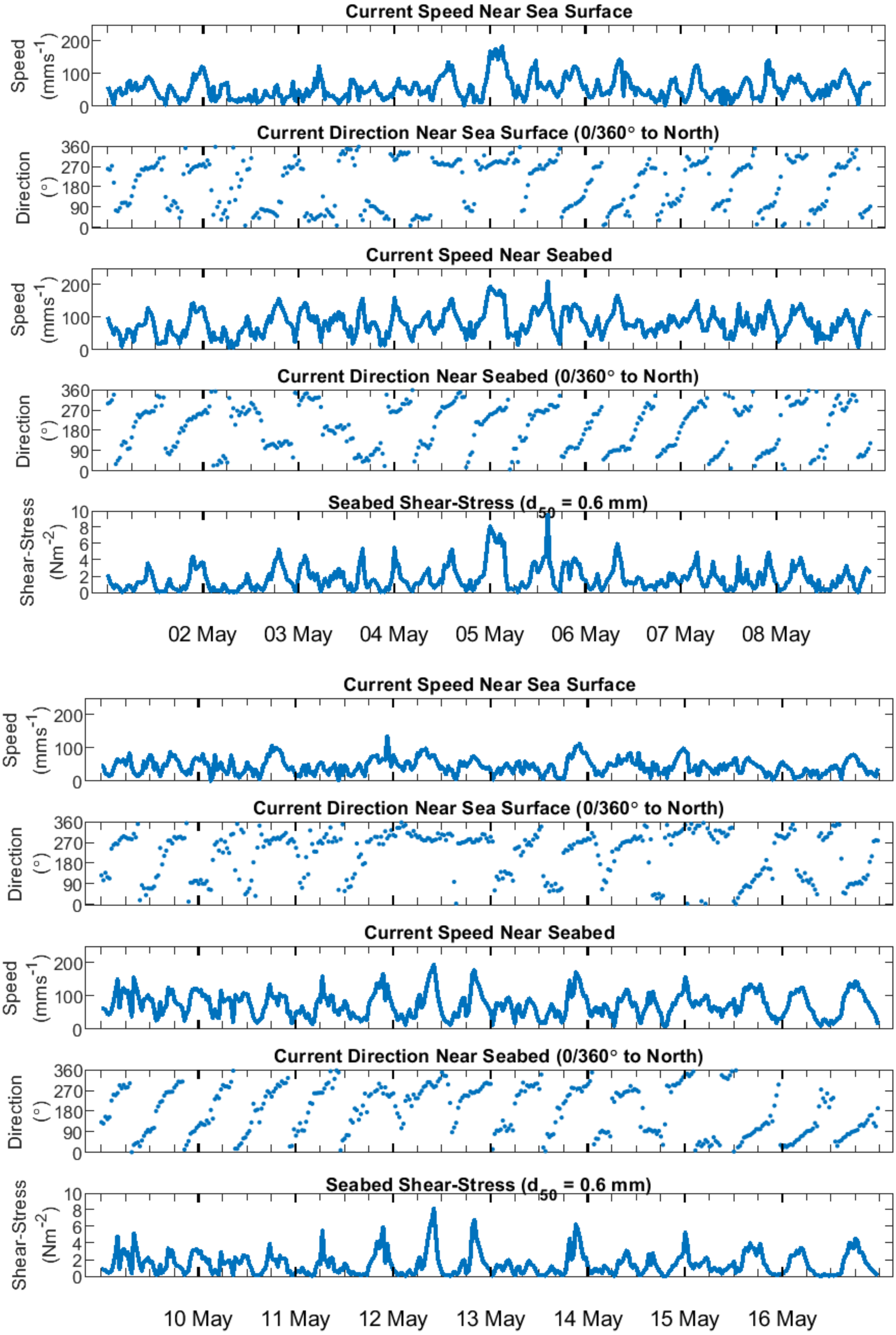

Figure 29 SG2a (WatchKeeper) current speed, direction and shear bed stress 1 to 16 May 2020.

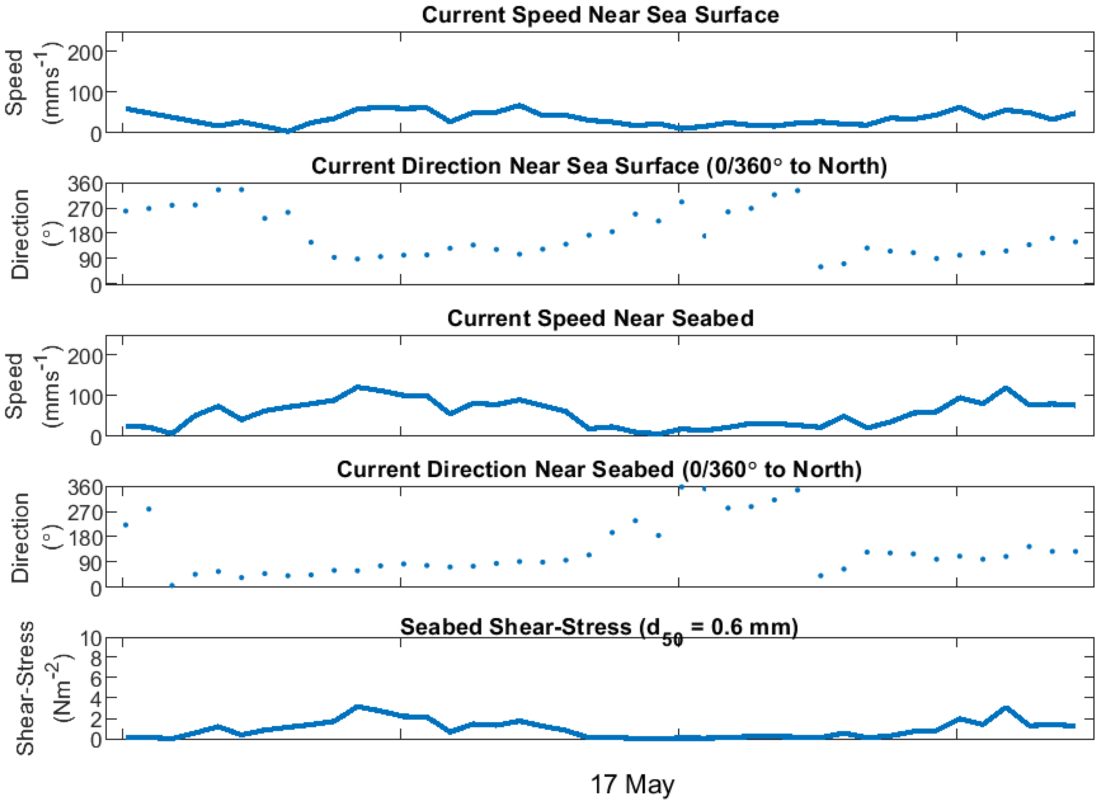

Figure 30 SG2a (WatchKeeper) current speed, direction and shear bed stress 17 May 2020.
SG2a (WatchKeeper) was removed from site for servicing on the 17 May.

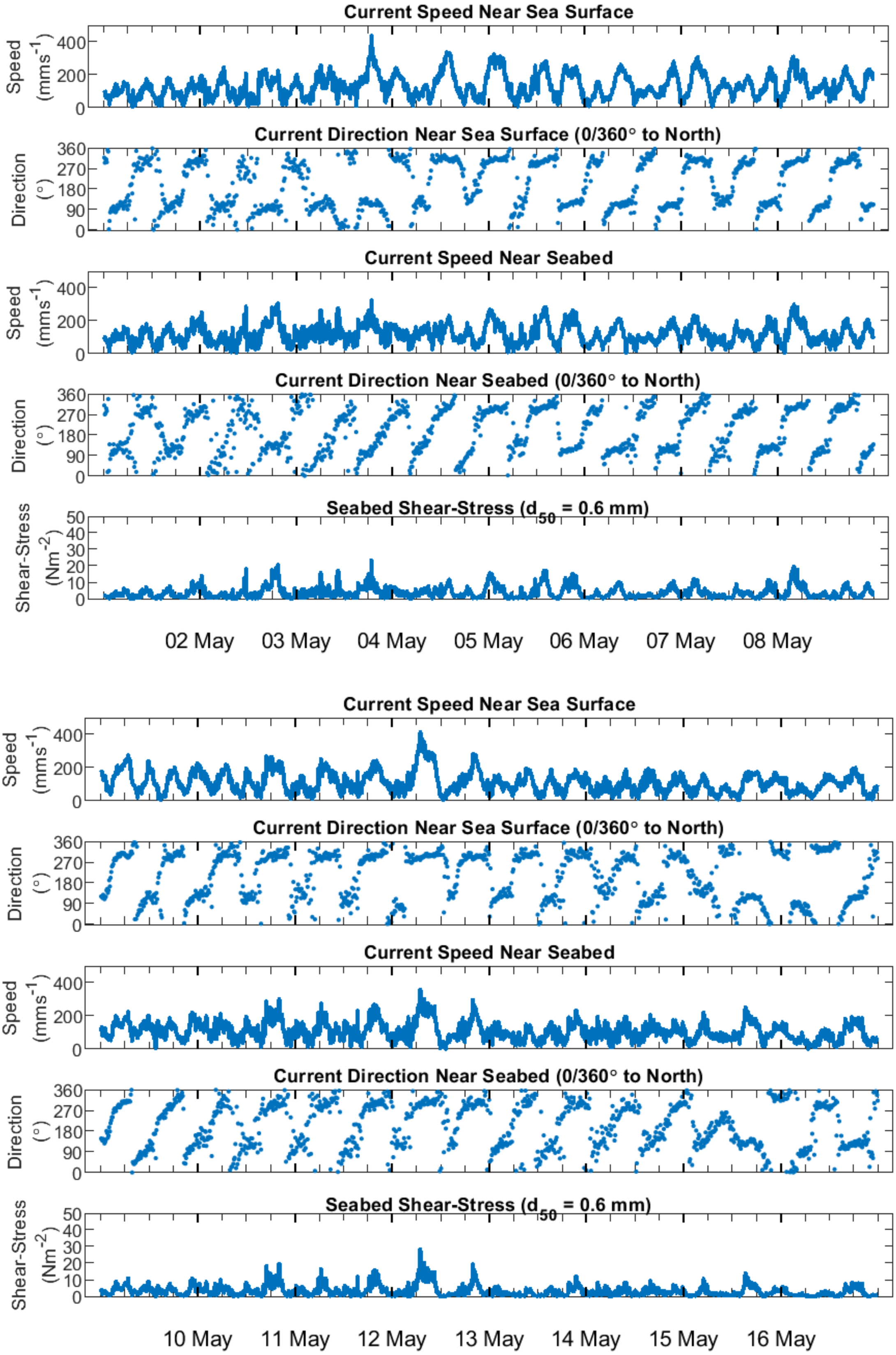

Figure 31 SG3 current speed, direction and shear bed stress 1 to 16 May 2020.

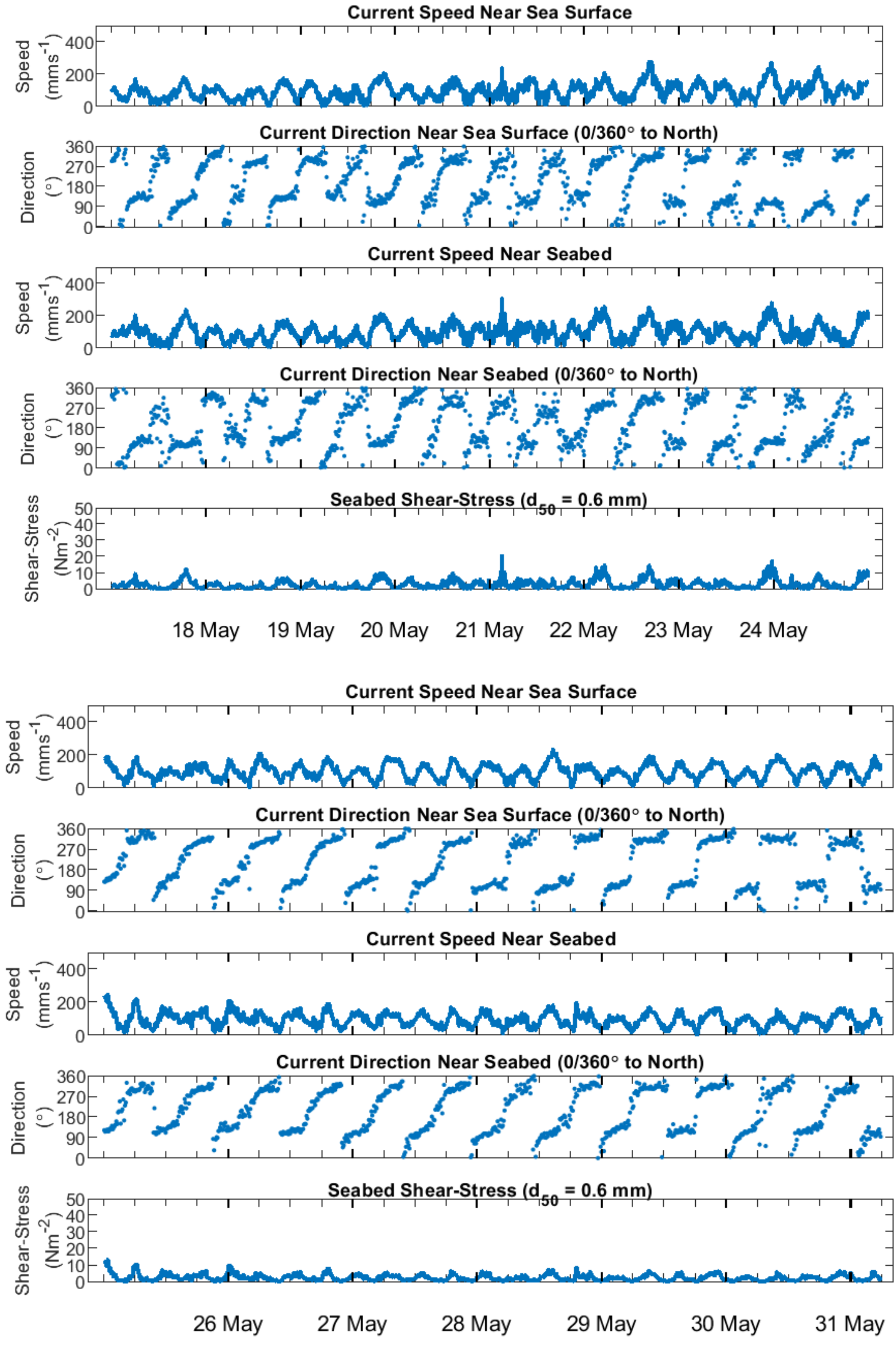

Figure 32 SG3 current speed, direction and shear bed stress 17 to 30 May 2020.

Table 17 Summary of Vision Environment quality control data for May 2020 water sampling.

ND = not determined as one or more samples was below LOR. Variation between duplicate field samples ≥ 50% has been highlighted in blue. High variation indicates heterogeneity within the water column.

* Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			UH1 (A) (µg/L)	UH1 (B) (µg/L)	Variation (%)
TSS mg/l	< 3	< 3	7	9	25
Dissolved Aluminium (µg/l)	< 3	< 3	< 12	< 12	ND
Total Aluminium (µg/l)*	< 3.2	< 3.2	147	128	14
Dissolved Arsenic (µg/l)	< 1	< 1	< 4	< 4	ND
Total Arsenic (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Dissolved Cadmium (µg/l)	< 0.05	< 0.05	< 0.2	< 0.2	ND
Total Cadmium (µg/l)	< 0.053	< 0.053	< 0.21	< 0.21	ND
Dissolved Chromium (µg/l)	< 0.5	< 0.5	< 1	< 1	ND
Total Chromium (µg/l)*	<5.3	<5.3	1.4	<1.1	ND
Dissolved Cobalt (µg/l)	< 0.2	< 0.2	< 0.6	< 0.6	ND
Total Cobalt (µg/l)	< 0.21	< 0.21	< 0.63	< 0.63	ND
Dissolved Copper (µg/l)	< 0.5	< 0.5	1.1	< 1	ND
Total Copper (µg/l)	< 0.21	< 0.21	< 0.63	< 0.63	ND
Dissolved Iron (µg/l)	< 20	< 20	< 4	< 4	ND
Total Iron (µg/l)	< 21	< 21	200	169	17
Dissolved Lead µg/l)*	< 0.1	< 0.1	< 1	< 1	ND
Total Lead (µg/l)	0.2	< 0.11	< 1.1	< 1.1	ND
Dissolved Manganese (µg/l)	< 0.5	< 0.5	6.3	6.1	3
Total Manganese (µg/l)	< 0.53	< 0.53	9.9	9.6	3
Dissolved Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	ND
Total Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	0
Dissolved Molybdenum (µg/l)	< 0.2	< 0.2	10.8	11.1	3
Total Molybdenum (µg/l)	< 0.21	< 0.21	11.3	10.6	6
Dissolved Nickel (µg/l)	< 0.5	< 0.5	< 7	< 7	ND
Total Nickel (µg/l)	< 0.53	< 0.53	< 7	< 7	ND
Dissolved Selenium (µg/l)	< 1	< 1	< 4	< 4	ND
Total Selenium (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Dissolved Silver (µg/l)	< 0.1	< 0.1	< 0.4	< 0.4	ND
Total Silver (µg/l)	< 0.11	< 0.11	< 0.43	< 0.43	ND
Dissolved Tin (µg/l)	< 0.5	< 0.5	< 5	< 5	ND
Total Tin (µg/l)	< 0.53	< 0.53	< 5.3	< 5.3	ND
Dissolved Vanadium (µg/l)	< 1	< 1	1.6	1.6	0
Total Vanadium (µg/l)	< 1.1	< 1.1	1.9	1.9	0
Dissolved Zinc (µg/l)	< 1.0	< 1.0	< 4.0	< 4.0	ND
Total Zinc (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Total Phosphorus (µg/l)	< 4.0	< 4.0	28	22	24
Dissolved Reactive Phosphorus (µg/l)	< 4.0	< 4.0	13.6	13.9	2
Total Nitrogen (µg/l)	<110	< 110	< 30	< 30	ND
Total Kjeldahl Nitrogen (TKN) (µg/l)	< 100	< 100	< 20	< 20	ND
Total Ammonia (µg/l)	< 10	< 10	16	19	17
Nitrate-N + Nitrite-N (µg/l)	< 2	<2	22	17.4	23
Chlorophyll *a* (µg/L)	< 0.2	< 0.2	2.6	3	14

June 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

VISION ENVIRONMENT

A Trinity Consultants Company

www.visionenvironment.com.au

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FILE REFERENCE

05082020 FINAL LPC Water Quality Environmental Monitoring June 2020_VE

Summary

Since September 2016, Vision Environment (VE) has been undertaking water quality monitoring for the Environmental Monitoring and Management Plan (EMMP) associated with the Lyttelton Port Company (LPC) Channel Deepening Project (CDP) (Envisor, 2018). Baseline datasets were acquired from three spoil ground sites (SG1, SG2 and SG3), seven offshore sites (OS1 to OS7) and five inshore sites (UH1 to UH3, CH1 and CH2) to assess potential impacts of the dredging project.

Dredging operations for the CDP were undertaken from 29 August to 29 November 2018. Post-dredge monitoring was undertaken until 11 March 2019, when a smaller dredging operation began for the reclamation works at Cashin Quay and was completed on 23 March 2020. Channel maintenance dredging commenced at midday on 4 December 2019 and was completed 21 March 2020, thus commencing the post dredging monitoring phase, which will cease on project completion on 31 July 2020.

Post-dredge monitoring results collected during June 2020 are presented within this report. This monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018).

Climatic Conditions: Higher precipitation was recorded at Cashin Quay during June (65 mm) compared to May (24.4 mm), with highest daily rainfall recorded on 29 June (20.8 mm). Flows from the Waimakariri River were low during June with peak flows recorded on 17 June at a maximum flow rate of 168.9 m^3/s, lower than the peak flow rate recorded in May (462 m^3/s).

Monthly average air temperature (9.6°C) was lower than the mean air temperature of May (11.6°C) in line with seasonal cooling. Similar to previous months, inshore winds were predominantly from an easterly to north-easterly direction, with the highest mean daily wind speed of 18.5 kts recorded on 29 June. Offshore wind and wave data is unavailable for June due to the Watchkeeper being decommissioned for repairs on 17 May and it is yet to be returned to site.

Currents: Current data was recorded at SG1 and SG3 for June, however ADCP data from the Watchkeeper is also not available. Erroneous data providing higher values then historically observed at near-seabed were identified at SG1 in May suggesting the ADCP required antifouling maintenance. This occurred in late June improving the received data.

Maximum near-surface current speeds at SG3 occurred on 4 June coinciding with medium to high wind speeds at inshore locations, which may provide a proxy for high winds offshore. Maximum near-seabed current speeds at SG3 were recorded on the 28 June. Maximum near-surface currents at SG1 occurred on the 28 June concurrent with significant wind speeds (15 kts) recorded inshore.

Near-surface predominant current movement at site SG3 tended towards east-southeast and northwest direction, while near-seabed currents tended towards an east-southeast and west-northwest direction, which is consistent with data from May. The measured data for near-surface and near-seabed currents at SG1 did not indicate a dominant current direction and included erroneous data, due to the unit requiring servicing. However, removal of erroneous data suggests near-surface currents moved in north-northeast direction and near-seabed currents favoured a west-northwest direction.

Turbidity: Consistent with previous results, turbidity was more elevated overall at the inshore monitoring locations of the central and upper harbour than at the offshore and spoil ground monitoring locations. Mean turbidity values for June in addition to percentile statistics were lower than those recorded during the baseline monitoring period. Peaks in turbidity at inshore sites followed moderate to high inshore wind speeds at the beginning and end of the month.

Turbidity remained below 10 NTU at all offshore and nearshore sites during June with peaks in turbidity recorded between 2 to 5 June at most sites. Turbidity peaks were also recorded at several offshore sites, including OS5 and OS7 towards the end of the month, occurring between the 25 and 29 June.

Other Physicochemical Parameters: Mean monthly water temperatures continued to display a seasonal decline during June compared to temperatures recorded in May. Consistent with previous winter sampling periods slightly lower temperatures were recorded in the upper and central harbour than the offshore sites.

During June surface pH was similar across all sites consistent with previous months reporting. Unlike previous months little spatial pattern in mean conductivity was observed in June, which is surprising considering the higher precipitation in June and likely resultant increased localised freshwater run-off into the inner harbour area.

Dissolved oxygen (DO) concentrations showed strong diurnal fluctuations at all sites during June especially at inshore monitoring sites. DO followed similar patterns at all sites with concentrations declining following periods of rainfall within the first weeks of the month and again at the end of the month in conjunction with heavy rainfall. These patterns are likely due to increased cloud cover reducing photosynthesis by algal populations.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 21 and 22 June and once again depth profiles indicated a well-mixed water column. Decreasing DO with depth was observed at the majority of sites within the offshore and spoil ground areas.

Turbidity and total suspended solids (TSS) measurements for surface waters were again elevated at inshore sites compared to the offshore areas, resulting in the shallowest estimations of euphotic depth as typically recorded during the monitoring program. Euphotic depths at the offshore monitoring locations were comparably high; estimated to be at 23.7 m at OS4. No exceedances of WQGs were observed for sub-surface turbidity during the June sampling period.

Total phosphorous concentrations were found in higher concentrations within the upper harbour and central channel sites although no exceedances of WQG were recorded at any location. Concentrations of dissolved reactive phosphorous were above the WQG of 5 µg/L at all sites in June, a result which was also recorded in the previous month. All sites reported concentrations of total nitrogen and total kjeldahl nitrogen (TKN) below the limit of reporting (LOR) and below WQG at all sites. Total Ammonia was recorded above WQG at four sites while nitrogen oxide concentrations were above WQG at three of the monitoring sites during June. Elevated concentrations at these sites may be attributed to a combination of factors including degrading algal populations, lack of utilization of available nutrients by algae in winter and introduction of nutrients from storm water run-off.

Chlorophyll-*a* concentrations exceeded the WQG value (4 µg/L) at nine offshore and spoil ground sites, indicating higher than normal algal populations at these particular sites, potentially due to the readily bioavailable nutrients.

The majority of metals were reported as below the limit of reporting (LOR) and no dissolved metal fraction exceeded the designated WQG among the sites. Concentrations of total aluminium exceeded the designated WQG at all sites except three, but the dissolved and therefore readily bioavailable fraction, remained undetectable. As often reported total aluminium, iron and manganese displayed a strong spatial variance with elevated concentrations found in the inshore locations (associated with increased suspended sediments). Dissolved iron concentrations (often associated with phytoplankton productivity cycles) were above LOR at eight locations spread across the sampling sites, however no WQG trigger levels are available for total or dissolved iron concentrations.

Total and dissolved chromium, vanadium and molybdenum were all detected during June but little spatial variability was noted and, while no trigger levels are available for molybdenum, levels of chromium and vanadium were both below their respective trigger levels at all sites.

Of the suite of 210 organic compounds analysed during June, all reported concentrations below the limit of reporting at all sites.

Benthic physicochemical loggers, Benthic Photosynthetically Active Radiation (BPAR) and Sedimentation: All benthic equipment was removed at the beginning of May as data was deemed not necessary for the continuation of the Post Dredge monitoring period.

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Acronyms

ADCP	Acoustic Doppler Current Profiler
BPAR	Benthic Photosynthetically Active Radiation
BSL	Benthic self-logging sonde
CDP	Channel Deepening Project
DO	Dissolved oxygen
ECan	Environment Canterbury
EMMP	Environmental Monitoring and Management Plan
K_d	Light attenuation coefficient
KZ filter	Kolmogorov-Zurbenko filter
LOR	Limits of Reporting
LPC	Lyttelton Port Company
LYT	Lyttelton Port of Christchurch
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
QA/QC	Quality Assurance/Quality Control
SL	Self-Logger
ST	Subsurface telemetry
ST/ADCP	Subsurface telemetry/Acoustic Doppler Current Profiler
TAG	Technical Advisory Group
TDP	Total daily PAR
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VBCC	Vision Base Christchurch
VE	Vision Environment
WK	WatchKeeper telemetered weather station
WQG	Water Quality Guidelines

1 INTRODUCTION

Lyttelton Port Company (LPC) is undertaking a Channel Deepening Project (CDP) to extend the existing navigational channel to allow larger vessels access to the Lyttelton Port of Christchurch (LYT), the South Island's largest port. Utilising background information provided by LPC and advice from the Technical Advisory Group (TAG) in relation to ambient conditions, locations of sensitive habitats and dredge impact hydrodynamic modelling scenarios, a water quality monitoring program was designed.

Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August 2018 with completion of works on 29 November 2018. Monitoring continued into a post-dredge phase up until 11 March 2019 when smaller scale dredging operations for the reclamation works commenced and was completed on 23 March 2020. Note maintenance dredging of the channel was undertaken from 4 December 2019 to 21 March 2020, with spoil being relocated to the maintenance dredge spoil ground located off Godley Head. The interpreted environmental data provided by VE supports the process of the Environmental Monitoring and Management Plan (EMMP) for the LPC CDP (Envisor, 2018) and will assist to ascertain the potential impacts of the projects.

All dredge operations were completed on 23 March. Post Dredge monitoring will continue until 31 July 2020 when monitoring for the Project will be completed.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for the baseline and operations phases of water quality monitoring is provided in this section. A more detailed description of the importance of the measured parameters and the specific methodology for the CDP data collection and processing protocols can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

2.1.1 Monitoring Locations and Equipment

Guided by the results of preliminary hydrodynamic modelling (MetOcean, 2016a, b) in addition to advice from the TAG, baseline and dredge operations, monitoring sites were located outside the area of predicted direct impact (i.e. dredge footprint and offshore disposal ground), but within the zone of dredging and dredge material placement influence, in addition to being in the vicinity of sensitive receptors (e.g. mussels farms and important mahinga kai sites). For ease of identification the harbour was divided into four areas: spoil ground (SG); offshore (OS); central harbour (CH); and upper harbour (UH), in which 15 locations were selected for monitoring (Figure 1). In each area, one to three monitoring sites were selected for the deployment of the various individual types of equipment, which are identified in Table 1. A total of 22 monitoring units were deployed across the 15 locations.

The offshore monitoring area (encompassing monitoring sites SG1 to SG3 and OS1 to OS7) is a deep water (generally >15 m) oceanic environment, where turbidity appears to be mostly driven by wind speeds and wave heights, resulting in resuspension of material from the benthos. Benthic physicochemical loggers, BPAR and altimeters previously deployed at these sites were removed in May as the data was no longer relevant for post dredge monitoring.

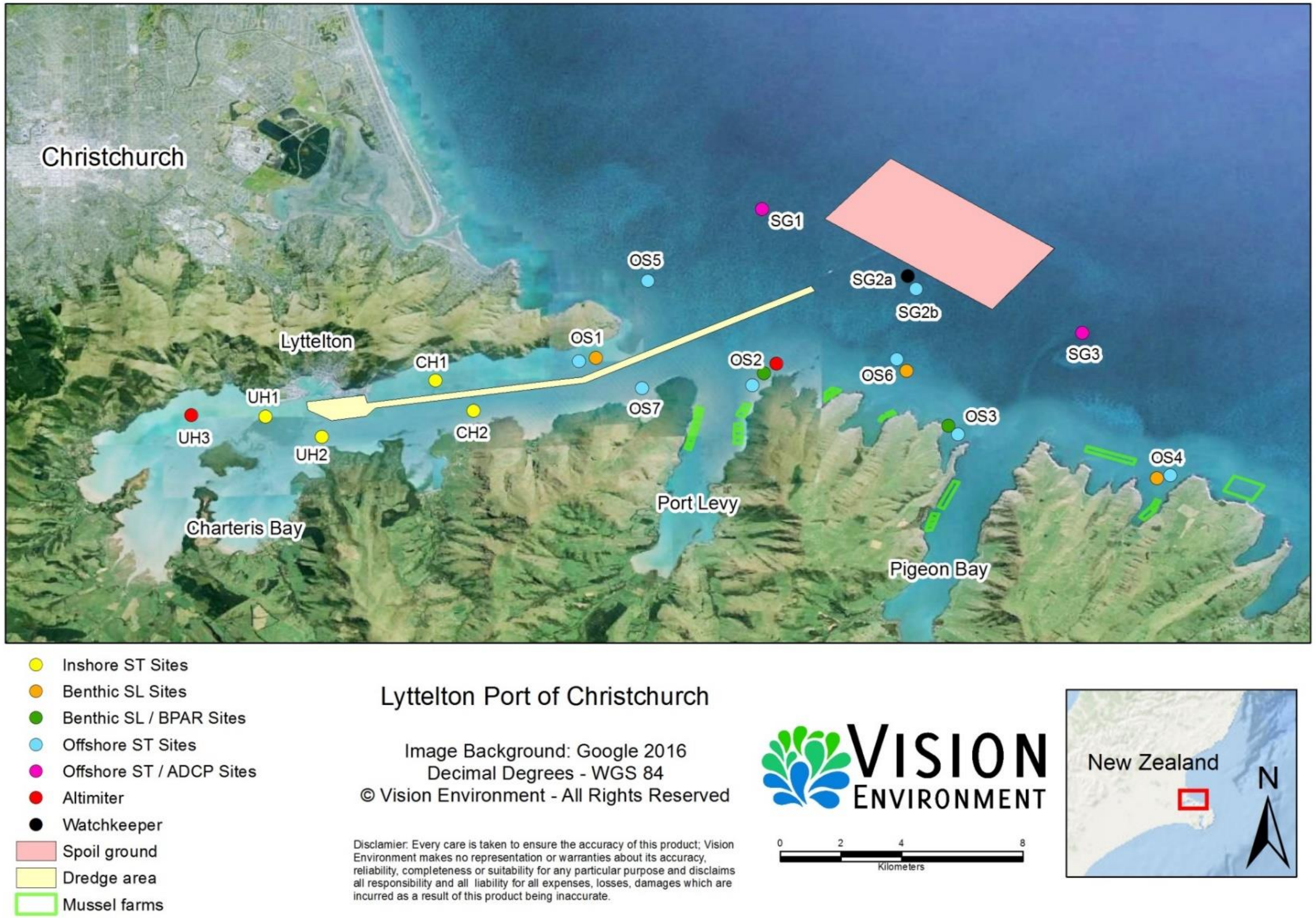


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

Table 1 Summary of monitoring sites and deployment equipment for the LPC Channel Deepening Project.
*ST = subsurface telemetry, SL = self-logger, *BSL = benthic self-logger, removed from all sites in May, *BPAR = benthic photosynthetically active radiation, removed from all sites in May and ADCP = Acoustic Doppler Current Profiler. *WK = WatchKeeper telemetered weather station removed from site on the 17 May for maintenance.*

Site	*WK	ST/ADCP	ST	*BSL sonde	*BSL sonde/BPAR	*Altimeter
	WatchKeeper telemetered weather station with currents and waves	Subsurface telemetered dual physico-chemistry and currents	Subsurface telemetered dual physico-chemistry	Benthic self-logging dual physico-chemistry	Benthic self-logging dual physico-chemistry and self-logging BPAR	Benthic self-logging dual altimeter
SG2a	√					
SG2b			√			
SG1		√				
SG3		√				
OS1			√	√		
OS2			√		√	√
OS3			√		√	
OS4			√	√		
OS5			√			
OS6			√	√		
OS7			√			
CH1			√			
CH2			√			
UH1			√			
UH2			√			
UH3						√
Total	1	2	12	3	2	2

The inshore monitoring area (including monitoring sites CH1 and CH2, and UH1 to UH3) is a shallow (<10 m depth) marine environment that, in addition to wind speeds and wave heights, is also influenced by tides (~ 0.2 m/s). The water column is well mixed at these sites, with little to no stratification. Therefore, surface loggers only have predominantly been utilised at these sites.

The comprehensive water quality component of the program involves the monitoring of:

- Physicochemistry, including turbidity; temperature; pH; conductivity and DO;
- Light attenuation (Photosynthetic Active Radiation or PAR);
- Benthic light (Benthic Photosynthetic Active Radiation or BPAR);
- Total Suspended Solids (TSS);
- Sedimentation rates;
- Nutrients and chlorophyll *a*;
- Metals (total and dissolved); and
- Organic compounds (biannually).

This monthly report presents data collected from the 22 monitoring locations for June 2020 during the post-dredge phase of operations. Monthly water sampling and depth profiling was conducted on 21 and 22 June 2020. A summary of climatic conditions during this period is provided, in addition to the results of continuous and discrete water sampling with comparisons to the baseline monitoring period.

2.1.2 Water Quality Guidelines

Water quality monitoring data from LYT were compared to the Australian and New Zealand Water Quality Guidelines (WQG) default trigger values (ANZG, 2018). In the absence of specific trigger values for New Zealand estuarine or marine ecosystems, the WQG suggest the use of trigger values for south-east Australian estuarine and marine ecosystems.

Total metals represent the concentration of metals determined in an unfiltered sample (those bound to sediments or colloidal particles in addition to dissolved metals), while dissolved metals are defined as those which pass through a 0.45 µm membrane filter (APHA, 2005). Specific trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived for several metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZG, 2018). The LYT coastal environment could be described as slightly-to-moderately disturbed, therefore the 95% WQG trigger value was considered appropriate for comparison.

3 RESULTS & DISCUSSION

3.1 Metocean Conditions

3.1.1 Wind and precipitation

A total of 65 mm of rainfall was recorded at Cashin Quay during June 2020, which was significantly higher than the precipitation recorded in May (24.4 mm). The highest recorded rainfall of 20.8 mm was recorded on 29 June (Metconnect, 2020) (Figure 2). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days' post flow. Flows during June were extremely low ranging from 41.4 m^3/s and 168.9 m^3/s with the maximum flow rate occurring on 17 June (ECAN, 2020). The low flow rates recorded were not expected to impact harbour parameters.

Inshore winds during June predominantly occurred from easterly to north-easterly direction (Metconnect, 2020). Highest mean wind speed (18.6 kts) was recorded on 29 June from a west south-westerly direction, with maximum wind gusts of 48 kts also occurring on the 29 June from south-westerly direction. Observations for 28 and 29 June include higher rainfall and windspeeds plus the highest wind gusts for the month.

Daily mean air temperatures at Cashin Quay ranged from 6°C to 15°C, resulting in a monthly mean temperature of 9.6°C. As expected this was lower than the mean air temperature recorded in May of 11.6°C (Metconnect, 2020) and is in line with seasonal cooling.

The Watchkeeper weather buoy was decommissioned for maintenance during May and has not yet been redeployed at site. Therefore, site specific offshore metocean data is unavailable for June.

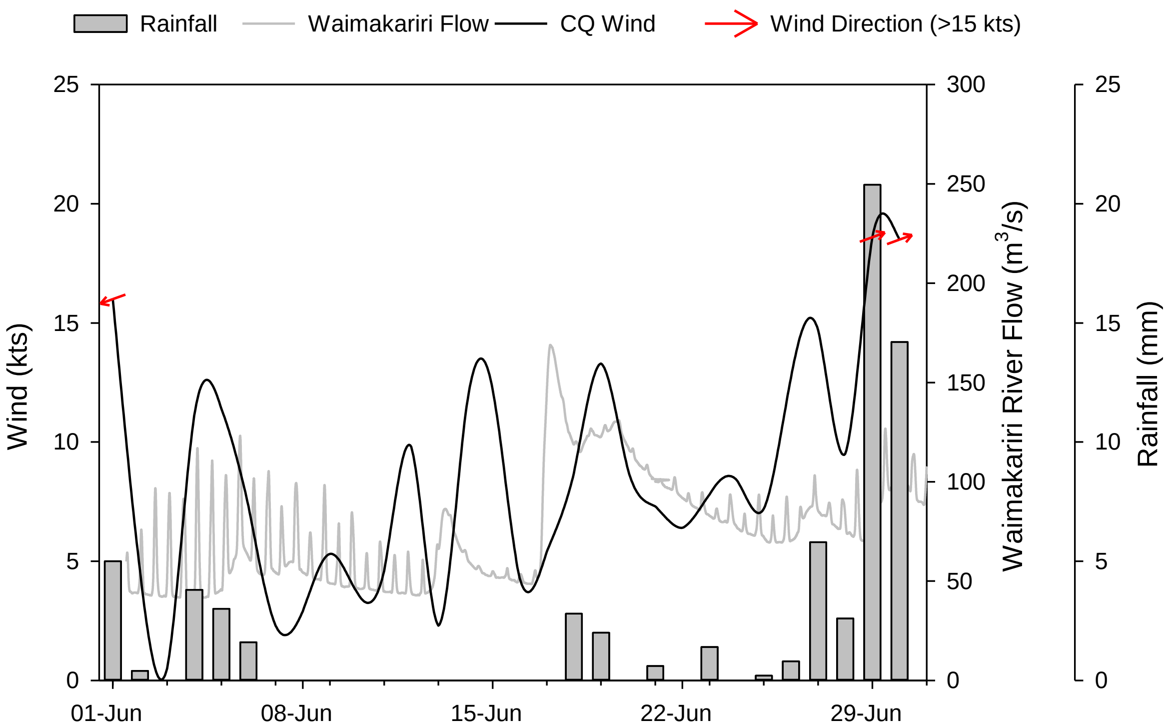


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during June 2020.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

3.1.2 Currents

Acoustic Doppler Current Profilers (ADCPs) are deployed at the spoil ground monitoring sites SG1, SG2a (Watchkeeper) and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Note that Watchkeeper was removed from site for maintenance in May and therefore the following analyses does not include data from that site. In addition, some erroneous data at unit SG1 suggests the unit required antifouling maintenance, which was not undertaken until late June.

Summary ADCP statistics of available data are presented within Table 2, and Figures 3 and 4. Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 24 to 27 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

Table 2 Parameter statistics for spoil ground ADCPs during June 2020.
**SG1 increased near-seabed layer speeds are greater than those historically observed at this location and suggest unit error. *SG2a was removed for maintenance on 17 May and therefore no data is available.*

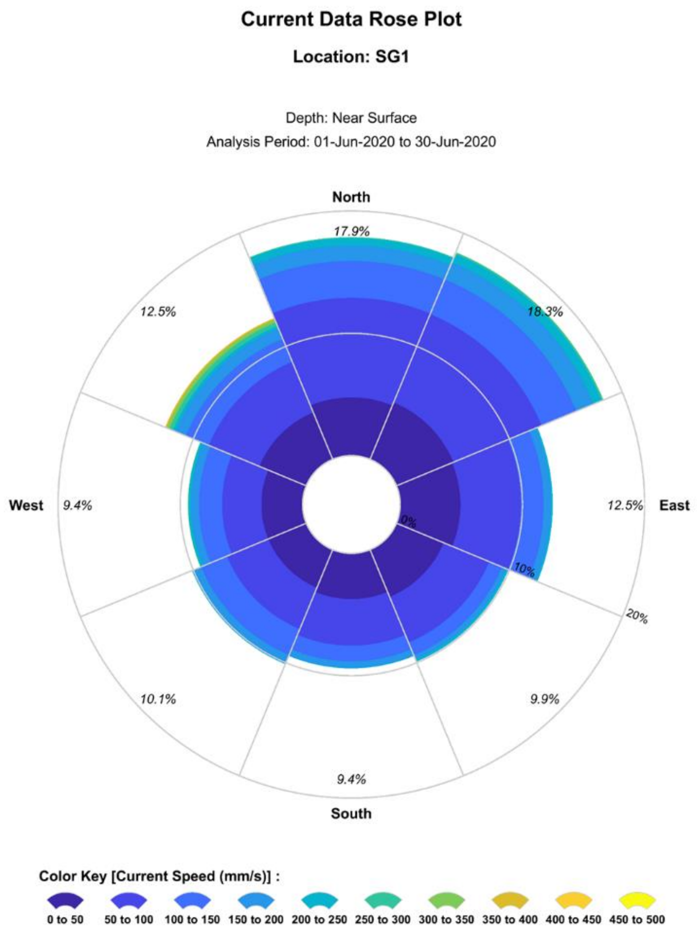
Parameter	**Depth**	**Site**		
		***SG1**	****SG2a**	**SG3**
Minimum current speed (mm/s)	*Near-surface*	1	ND	2
	Near-seabed	1	ND	1
Maximum current speed (mm/s)	*Near-surface*	391	ND	473
	Near-seabed	537	ND	396
Mean current speed (mm/s)	*Near-surface*	79	ND	115
	Near-seabed	132	ND	109
Standard deviation of current speed (mm/s)	*Near-surface*	52	ND	70
	Near-seabed	94	ND	60
Current speed, 95th percentile (mm/s)	*Near-surface*	178	ND	239
	Near-seabed	320	ND	220

Maximum near-surface current speeds at SG1 (391 mm/s) and SG3 (473 mm/s), were recorded on 4 June and 28 June respectively. Inshore winds around 4 June were moderate coming from a west south-westerly direction, while inshore winds at the 28 June peaked at over 15 kts and came from a westerly direction.

The maximum near-seabed current speed at SG3 (396 mm/s) was recorded on 28 June while the maximum near-seabed current speed at SG1 was 537 mm/s. However, due to the high erroneous readings (> 600 mm/s) recorded during June at SG1, values > 600 mm/s were filtered and the mean filtered near-seabed current speed of 132 mm/s provides a more accurate analysis of the current speeds at this site.

The time-series plots (Figures 24 to 27 in Appendix) illustrate time-varying current direction, whilst the current rose diagrams (Figures 3 and 4) depict the distribution of current direction and velocity in the near-surface and near-seabed layers. When interpreting the current data, note that the convention for defining current direction is the direction in which the current flows *towards*, which is the reference used throughout the Figures presented.

After removing erroneous readings at SG1, dominant flows of near-surface currents tended towards north-northeast (36.2%), while near-seabed currents at SG1 inclined towards west-northwest direction (34.7%). Near-surface currents at SG3 predominantly moved in an east-southeast (37.7%) and northwest (31.5%) direction while near-seabed currents at SG3 mainly moved in an east-southeast (33.6%) and west-northwest (43.8%) direction.



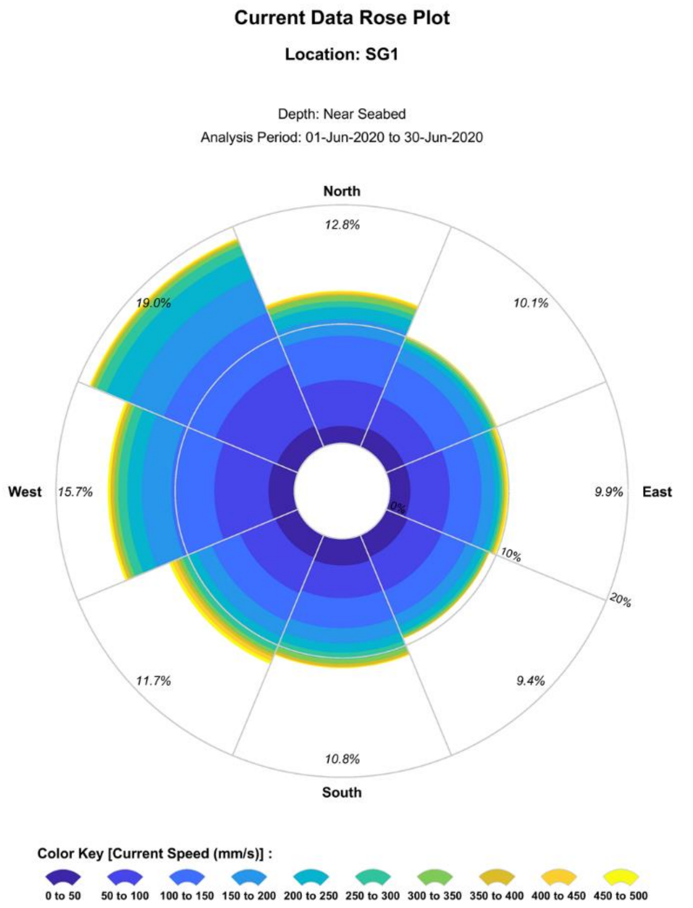


Figure 3 Near-surface and near-seabed current speed and direction at SG1 during June 2020.
Speed intervals of 50 mm/s are used.

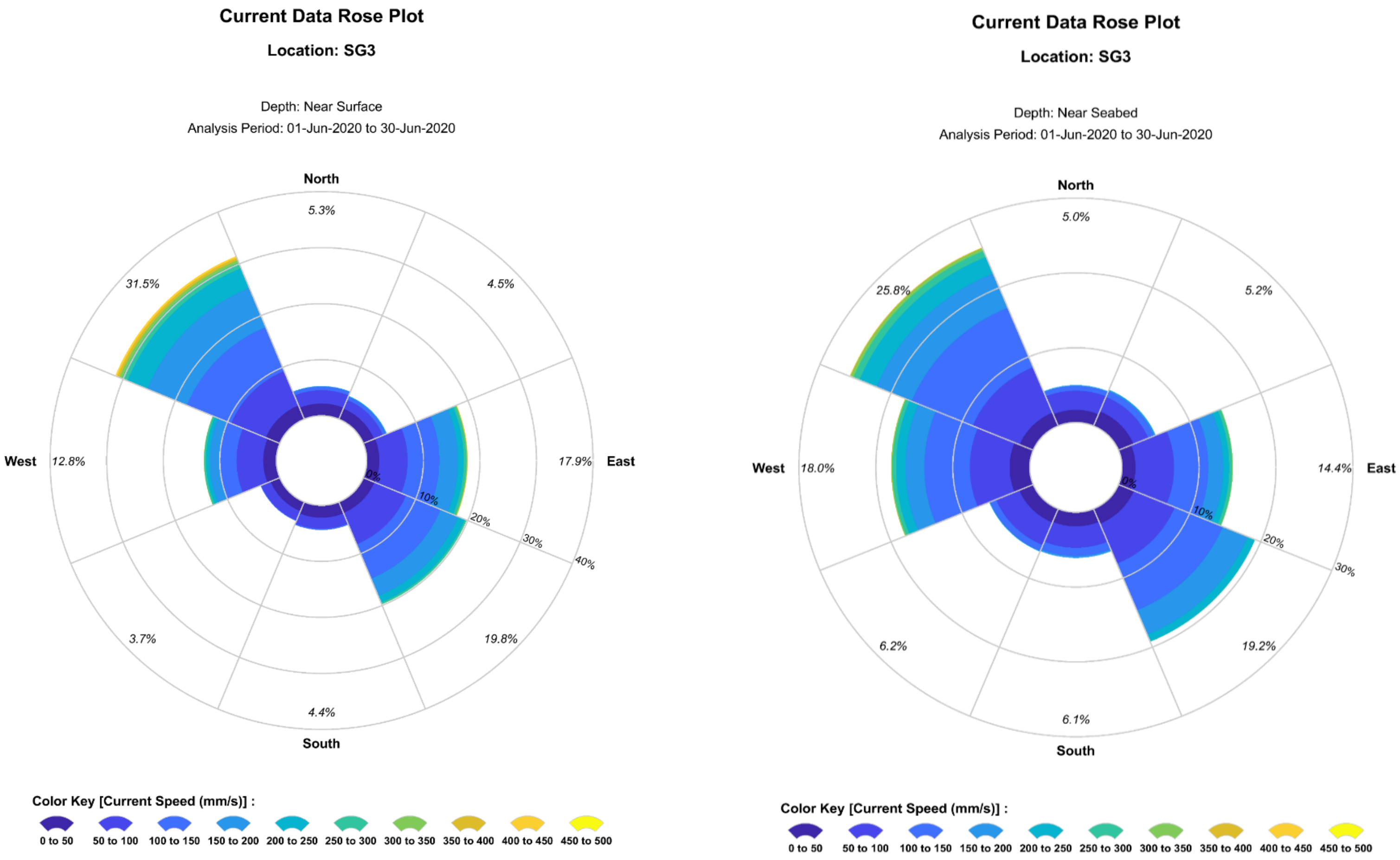


Figure 4 Near-surface and near-seabed current speed and direction at SG3 during June 2020.
Speed intervals of 50 mm/s are used.

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties of the water column are measured at monitoring sites every 15 minutes by dual telemetered surface loggers. Benthic loggers that were deployed at five offshore sites (OS1 to OS4 and OS6) were removed in May as the data was no longer required for the post-dredge phase of the project. In conjunction with the continuous loggers, discrete depth profiles of all physicochemical parameters were also conducted at all 15 monitoring sites on 21 and 22 June 2020. Further details regarding the methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Summary statistics for each physicochemical parameter recorded during June are presented in Tables 3 to 12. Validated datasets for surface measurements are also presented in Figures 5 to 16. Due to the inherent high level of variability in the turbidity datasets, a 24-hour rolling average has been calculated every 15 minutes to act as a smoothing technique and aid in data interpretation.

3.2.1 Turbidity

Of key importance within the real time parameters recorded are the surface turbidity measurements, due to their relevance to established trigger values for management of dredge operations. As such, summary turbidity statistics for the initial baseline period of monitoring from 1 November 2016 to 31 October 2017 (Fox, 2018) are also presented in Tables 3 to 5 to allow a comparison with the June 2020 dredge monitoring data. Data at OS5 was not available from 1 to 9 June due to the buoy going adrift in late May.

June Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 1.8 to 4.0 NTU) at the inshore monitoring sites (Table 3 and Figure 6). Lower surface turbidity values (<1 – 1.2 NTU) were recorded at the spoil ground sites (Table 4), which can be attributed to the deeper water column limiting expressions of seafloor sediment resuspension at the sub-surface. Similarly, the mean surface turbidity values at offshore sites were relatively low and ranged from 1.0 to 2.4 NTU (Table 5) during June.

During June turbidity across the inner harbour was relatively low (< 10 NTU) with small elevations occurring at CH2 at the beginning of the month in conjunction with increased inshore winds. Slightly elevated short-lived turbidity peaks were noted at CH1 and CH2 on 29 June, associated with increased wind speeds > 15 kts (Figure 7).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) was again relatively low during June (<10 NTU). Surface turbidity increased at all sites from 4 to 5 June. Although offshore metocean data is not available for this period, inshore wind speed data may be used as a proxy to indicate that wind speeds were also higher at nearshore and offshore sites during these discrete time periods. Lessor turbidity peaks were also recorded between 26 and 30 June during elevated wind speeds (Figure 8).

Table 3 Mean turbidity and statistics at inshore water quality logger sites during June 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for June are means ± se, range and percentiles (n = 2809 to 2874) Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU) Surface June	Surface Baseline
UH1	Mean ± se	2.7 ± 0.0	12
	Range	0.6 – 9.9	-
	99th	7.0	39
	95th	5.1	22
	80th	3.2	15
UH2	Mean ± se	2.3 ± 0.0	10
	Range	< 1 – 10.0	-
	99th	8.3	32
	95th	5.7	20
	80th	3.5	13
CH1	Mean ± se	4.0 ± 0.0	9
	Range	2.0 – 9.9	-
	99th	7.4	29
	95th	5.8	18
	80th	4.8	12
CH2	Mean ± se	1.8 ± 0.0	8
	Range	0.4 – 9.2	-
	99th	7.6	24
	95th	4.6	16
	80th	2.5	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during June 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for June are means ± se, range and percentiles (n = 2825 to 2853). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU) Surface June	Surface Baseline
SG1	Mean ± se	< 1 ± 0.0	4.2
	Range	< 1 – 5.5	-
	99th	3.4	14
	95th	1.4	10
	80th	0.6	6.2
SG2	Mean ± se	1.2 ± 0.0	4.6
	Range	0.5 – 4.8	-
	99th	2.7	20
	95th	2.1	11
	80th	1.6	7.0
SG3	Mean ± se	< 1 ± 0.0	3.6
	Range	< 1 – 7.0	-
	99th	3.1	13
	95th	2.1	7.7
	80th	1.0	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during June 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for June are means ± se, range and percentiles (n = 2063 to 2864). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU)	
		Surface June	Surface Baseline
OS1	Mean ± se	2.2 ± 0.0	7.5
	Range	< 1 – 9.3	-
	99th	7.4	24
	95th	5.5	16
	80th	3.0	10
OS2	Mean ± se	1.5 ± 0.0	6.4
	Range	< 1 - 12.3	-
	99th	7.0	18
	95th	4.8	13
	80th	2.3	9.0
OS3	Mean ± se	1.8 ± 0.0	6.6
	Range	< 1 – 10.0	-
	99th	8.6	27
	95th	5.4	15
	80th	3.1	8.9
OS4	Mean ± se	1.2 ± 0.0	5.9
	Range	< 1 -10.0	-
	99th	8.5	20
	95th	5.4	13
	80th	1.7	8.3
OS5	Mean ± se	1.0 ± 0.0	4.6
	Range	< 1 – 8.5	-
	99th	4.4	19
	95th	2.8	11
	80th	1.6	6.4
OS6	Mean ± se	1.6 ± 0.0	4.7
	Range	0.0 – 9.4	-
	99th	6.0	19
	95th	4.5	12
	80th	3.1	7.2
OS7	Mean ± se	2.4 ± 0.0	6.4
	Range	< 1 – 9.9	-
	99th	7.7	23
	95th	5.4	14
	80th	3.5	9.2

Further offshore at OS5, OS6 and the spoil ground sites turbidity remained below 10 NTU for the month of June. Increases in turbidity occurred at SG2 and OS6 between 4 to 16 June. Sites SG1 and SG2 exhibited consistently low turbidity throughout the month.

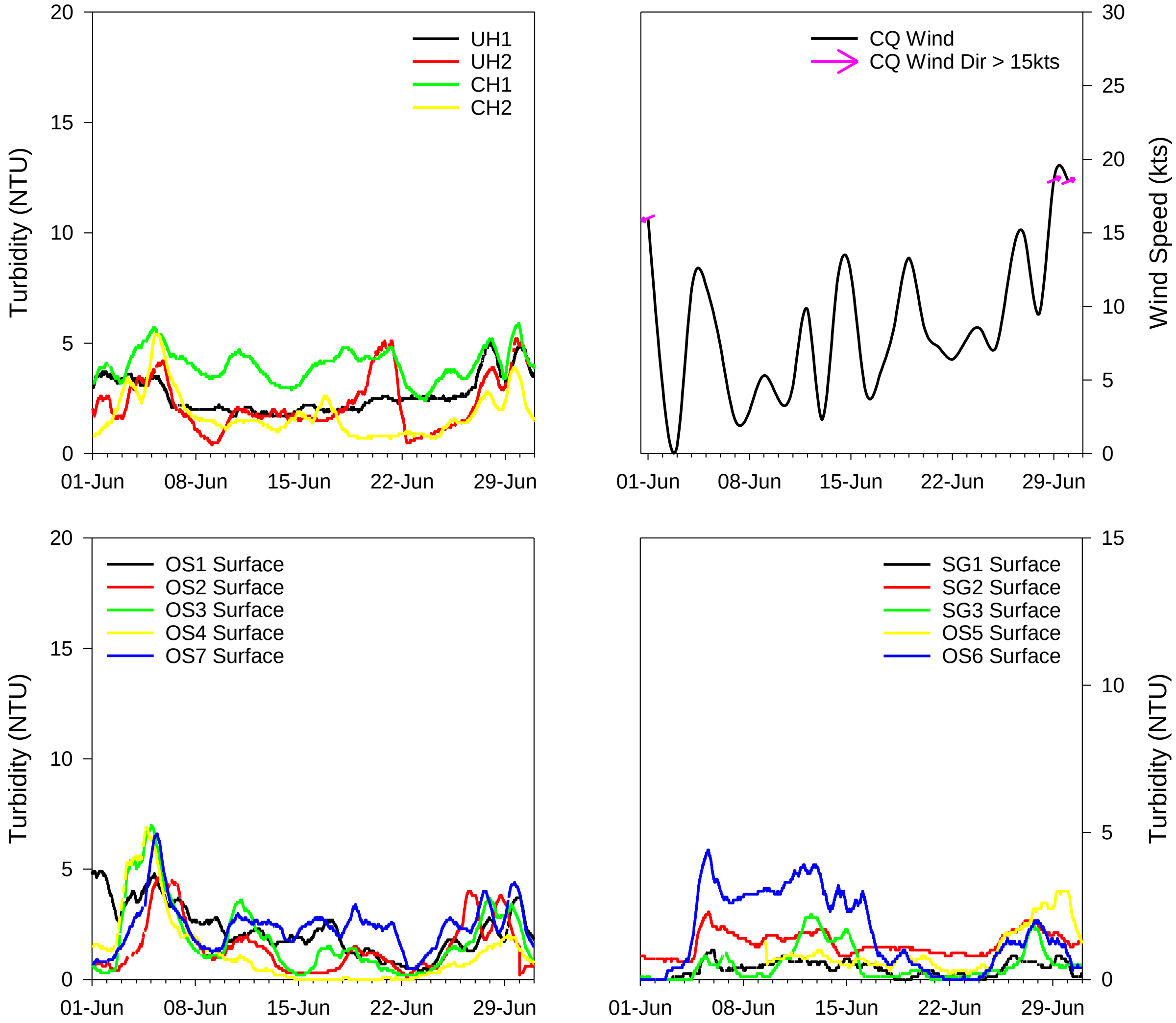


Figure 5 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore during June 2020.

Note differing scales between plots. Arrows indicate the direction of travel for inshore winds greater than 15 knots. The watchkeeper (WK) buoy was removed from site (SG2) for maintenance on the 17 May and has not been re-instated, therefore offshore metocean data is not presented.

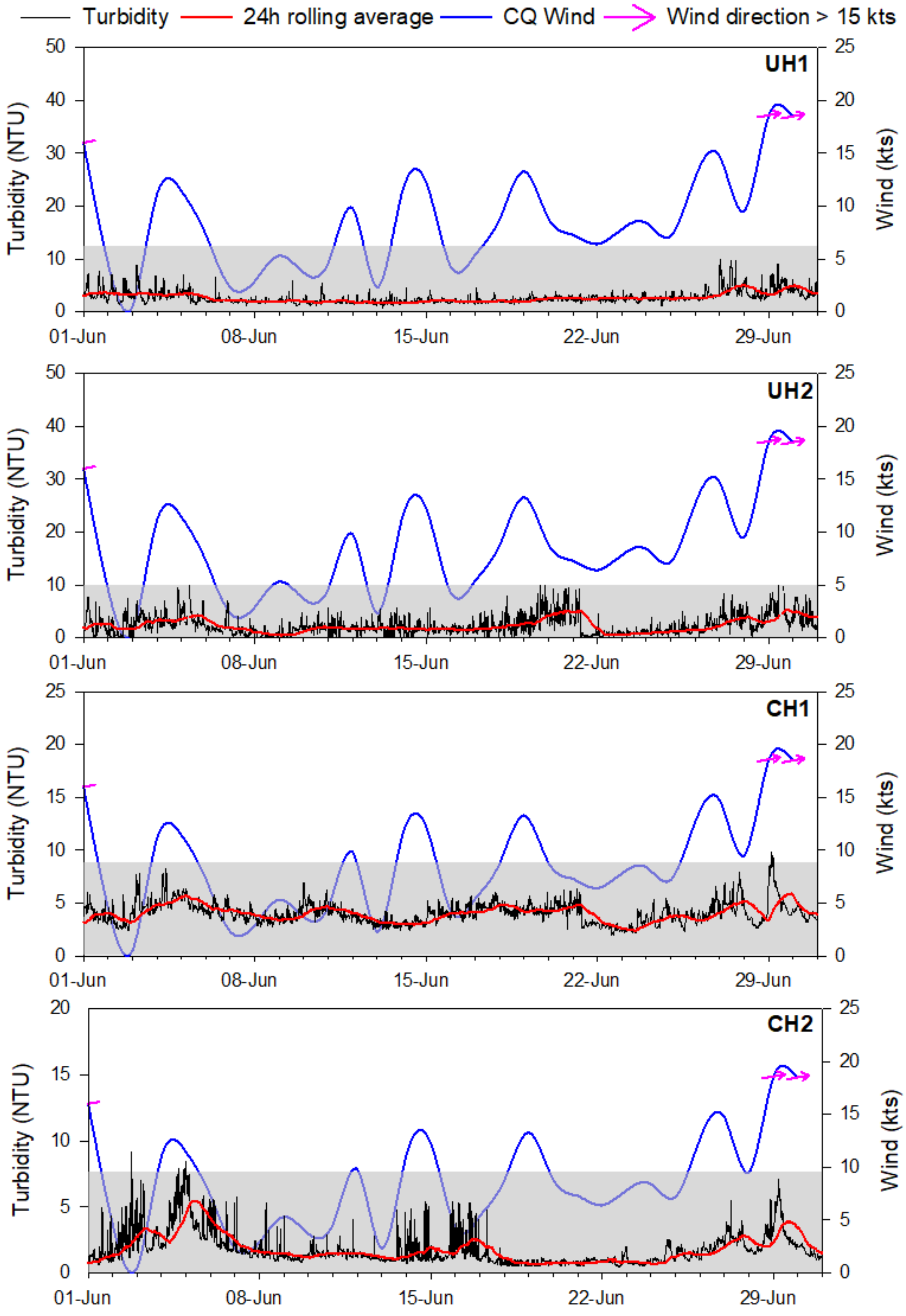


Figure 6 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during June 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

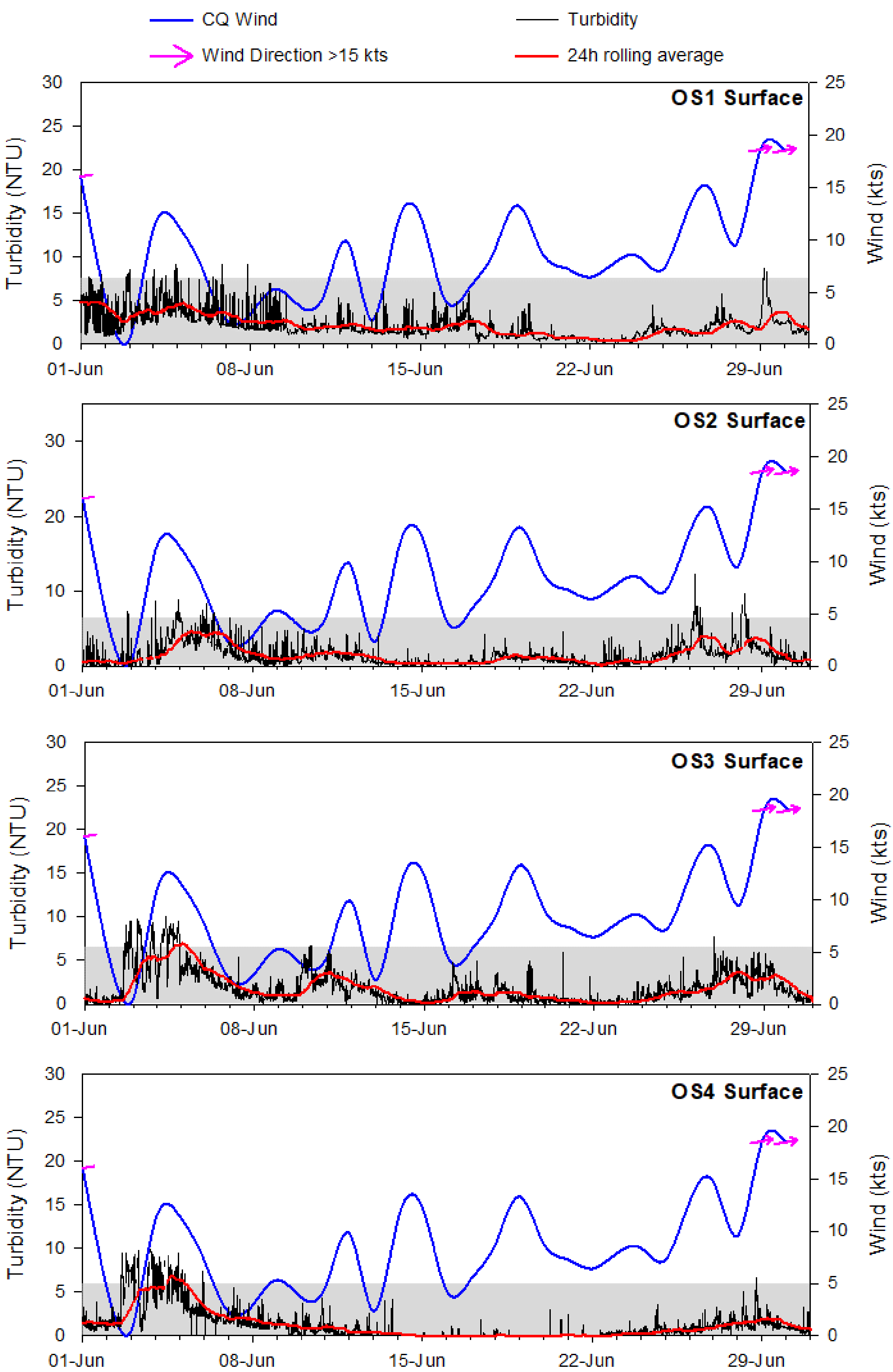


Figure 7 Surface turbidity at offshore sites (OS1 to OS4) during June 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity

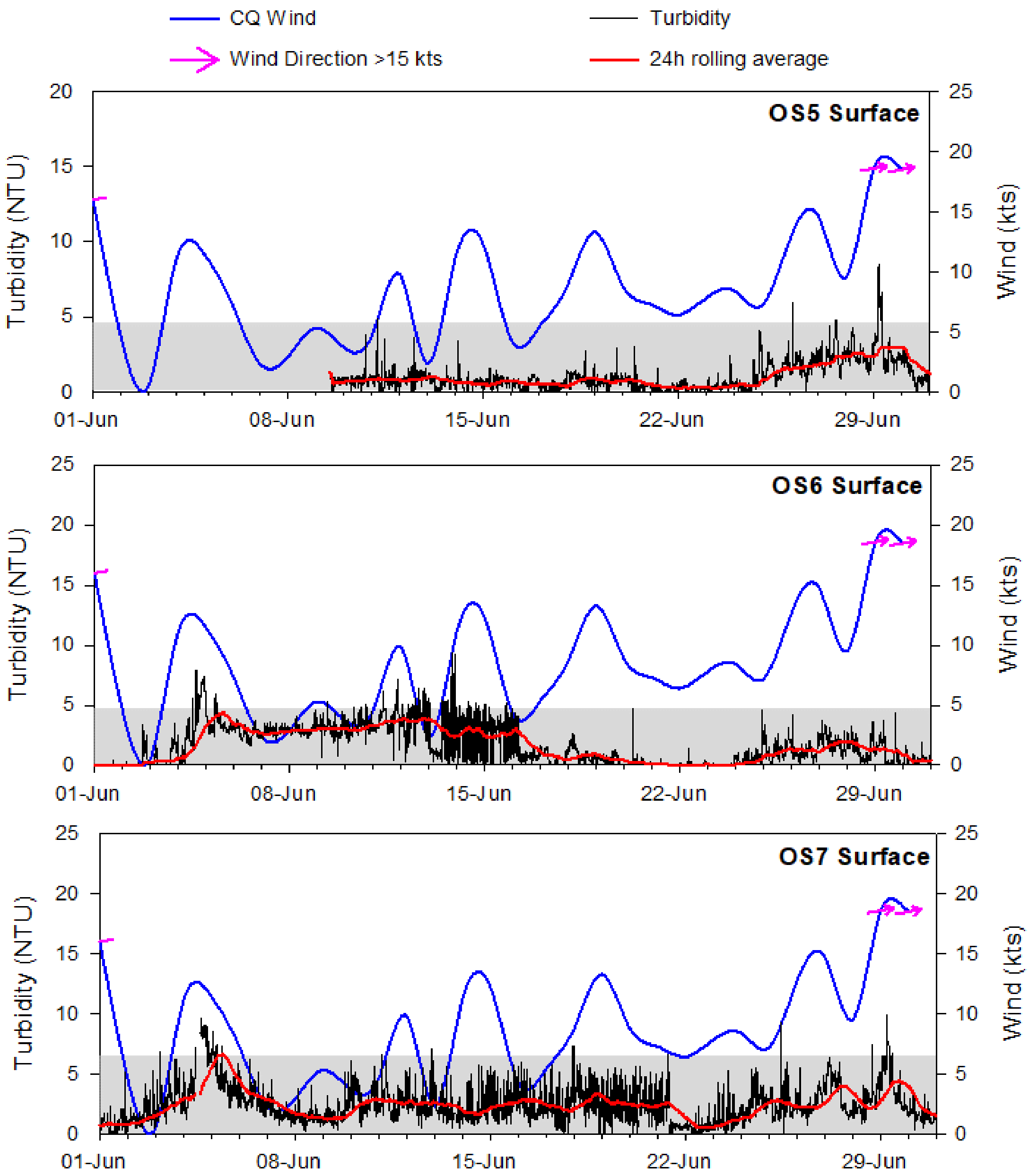


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (OS5 to OS7) during June 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

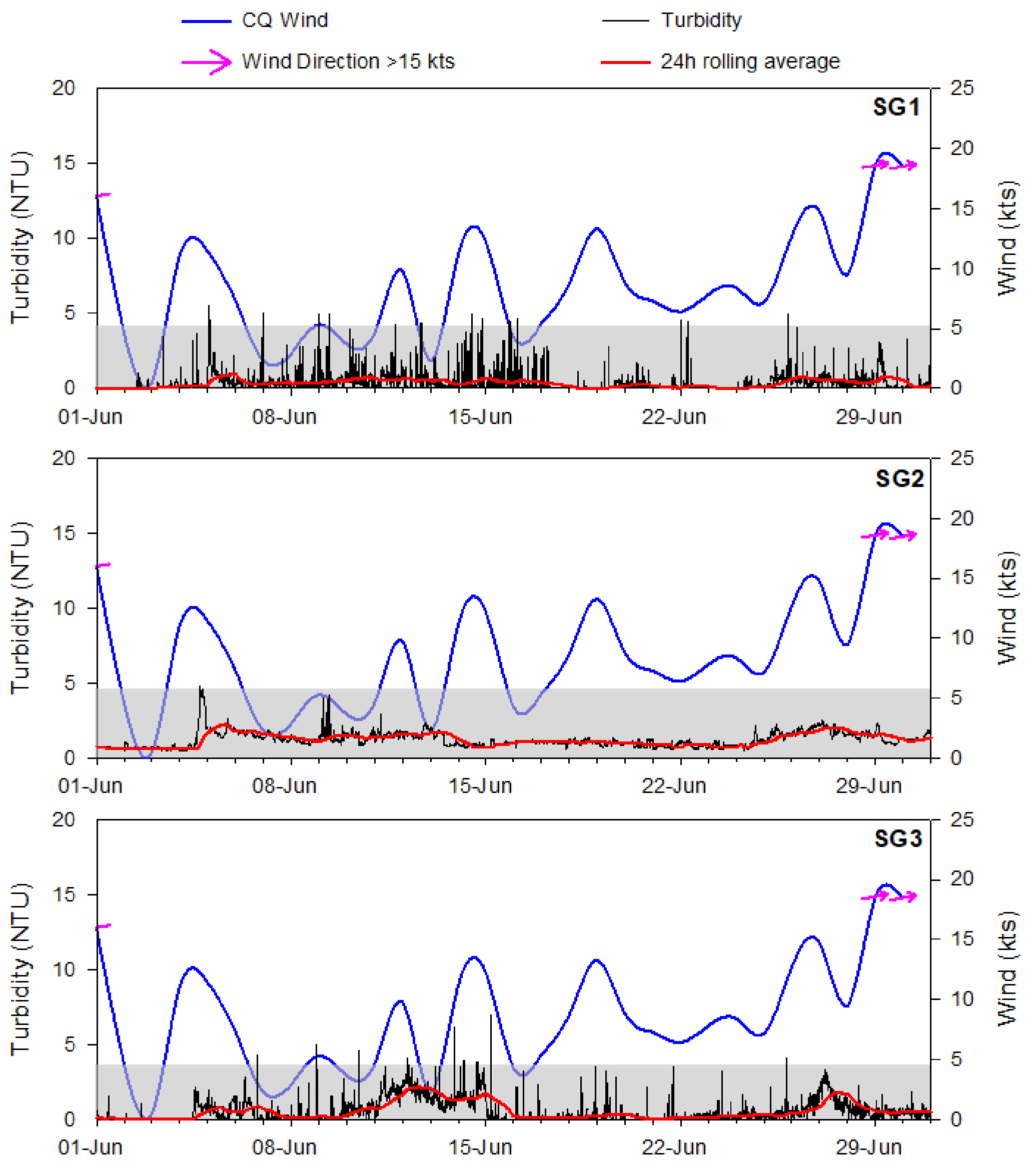


Figure 9 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during June 2020. *Grey shading indicates the baseline mean turbidity. Arrows indicate the direction of travel for inshore winds greater than 15 knots.*

Comparison to Baseline:

Mean surface turbidity values and statistics during June were lower than the values calculated from the baseline monitoring period (Tables 3 to 5, Figures 5 to 9).

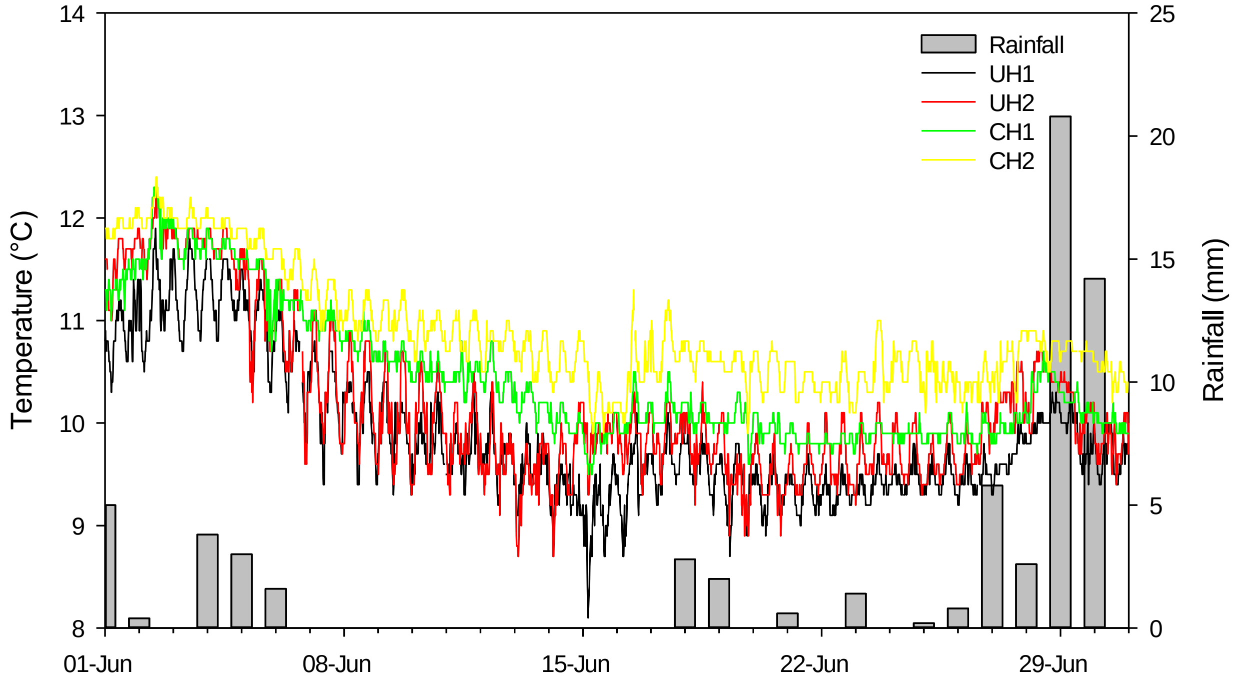
3.2.2 Temperature

In line with seasonal cooling mean monthly sea surface temperatures during June (9.9 to 11.4°C) (Table 6) were significantly lower than those recorded during May (12.0 to 13.0 °C). The overall declining temperature trend was consistent throughout June across the monitoring sites, though temperatures in the upper harbour did increase slightly at the end of the month coinciding with heavy rainfall and likely stormwater run-off. (Figures 10 and 11).

Table 6 Mean temperature at inshore, spoil ground and offshore water quality sites during June 2020. *Values are means ± se (n = 2066 to 2879).*

Site	Temperature (°C)
	Surface loggers
UH1	9.9 ± 0.0
UH2	10.2 ± 0.0
CH1	10.4 ± 0.0
CH2	10.9 ± 0.0
SG1	11.0 ± 0.0
SG2	11.4 ± 0.0
SG3	11.4 ± 0.0
OS1	11.0 ± 0.0
OS2	11.2 ± 0.0
OS3	11.2 ± 0.0
OS4	11.2 ± 0.0
OS5	11.0 ± 0.0
OS6	11.3 ± 0.0
OS7	11.1 ± 0.0

As recorded in recent winter months, slightly lower temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites during June. Semidiurnal variability, associated with tidal water movements and solar radiation, was again observed, particularly at the inner harbour and nearshore sites.



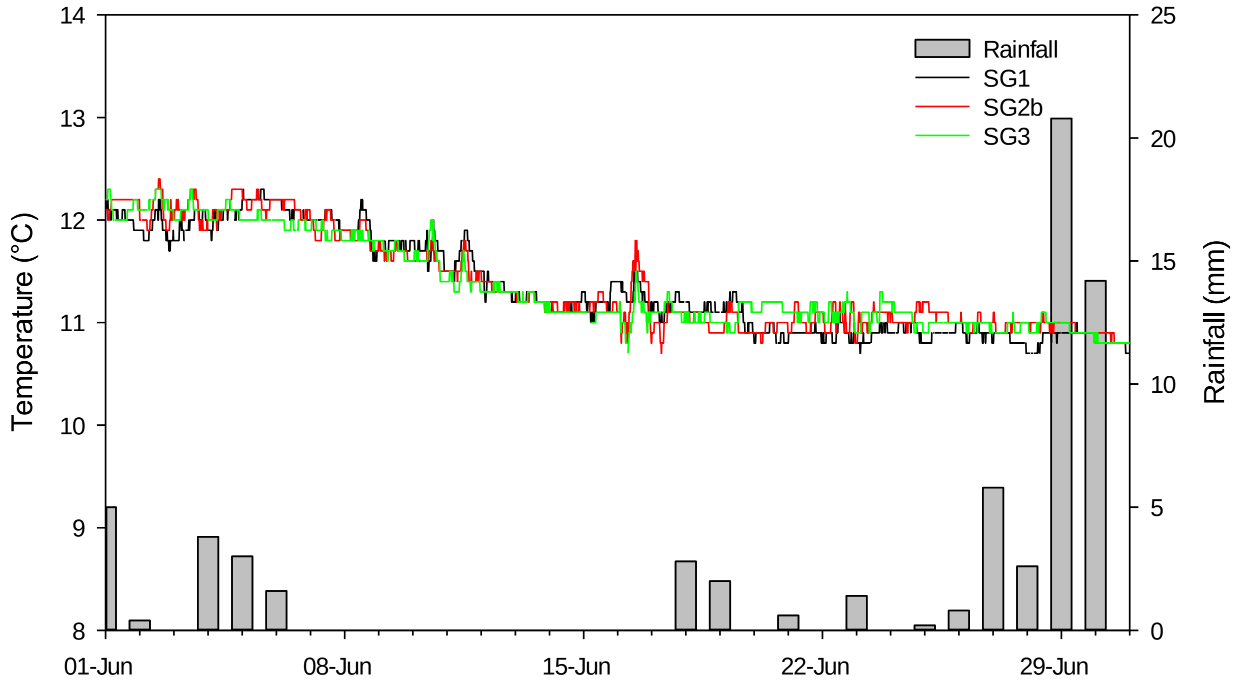


Figure 10 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during June 2020.

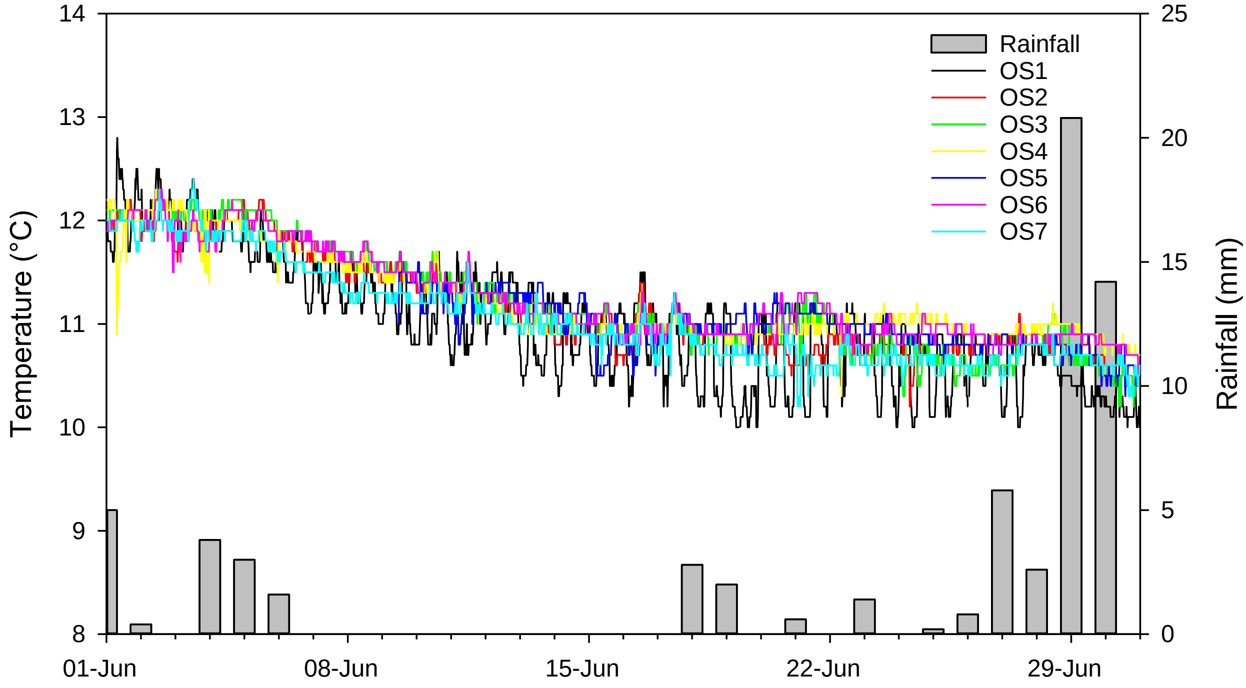


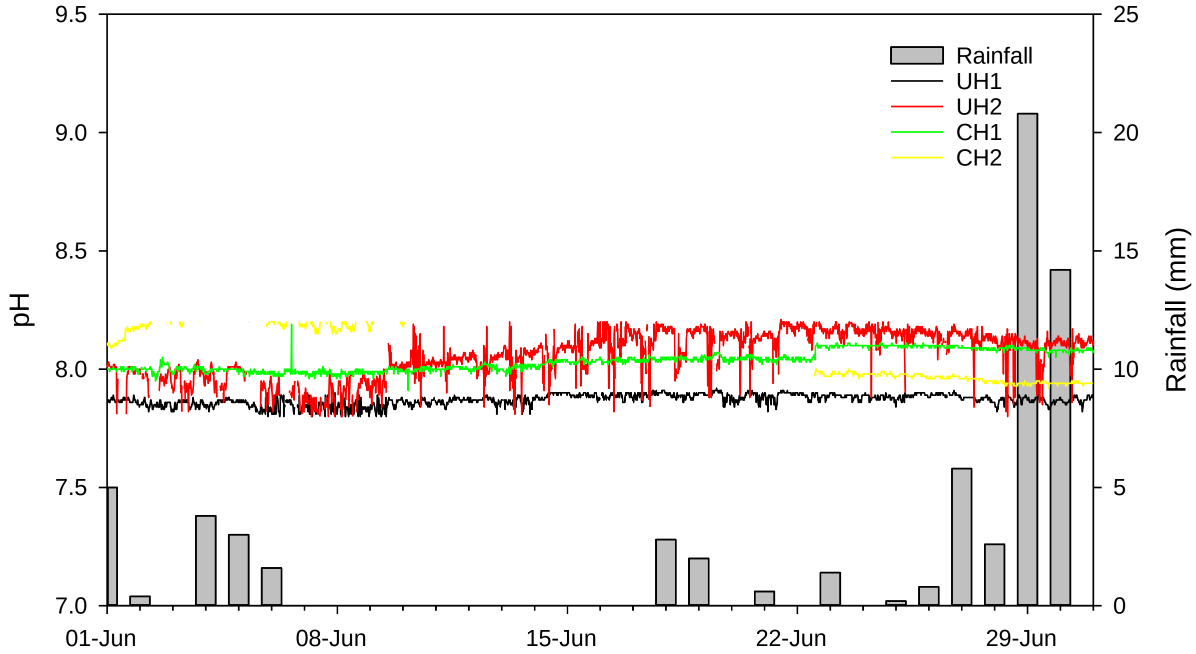
Figure 11 Surface temperature (OS1 to OS7) at nearshore and offshore water quality sites during June 2020.

3.2.3 pH

The pH remained consistent across the monitoring sites, with monthly means ranging between 7.9 and 8.2 (Table 7, Figures 12 and 13).

Table 7 Mean pH at inshore, spoil ground and offshore water quality sites during June 2020. *Values are means ± se (n = 51 to 2879).*

Site	pH
	Surface loggers
UH1	7.9 ± 0.0
UH2	8.1 ± 0.0
CH1	8.0 ± 0.0
CH2	8.0 ± 0.0
SG1	8.1 ± 0.0
SG2	8.1 ± 0.0
SG3	8.0 ± 0.0
OS1	8.2 ± 0.0
OS2	8.1 ± 0.0
OS3	8.2 ± 0.0
OS4	8.1 ± 0.0
OS5	8.1 ± 0.0
OS6	8.1 ± 0.0
OS7	8.0 ± 0.0



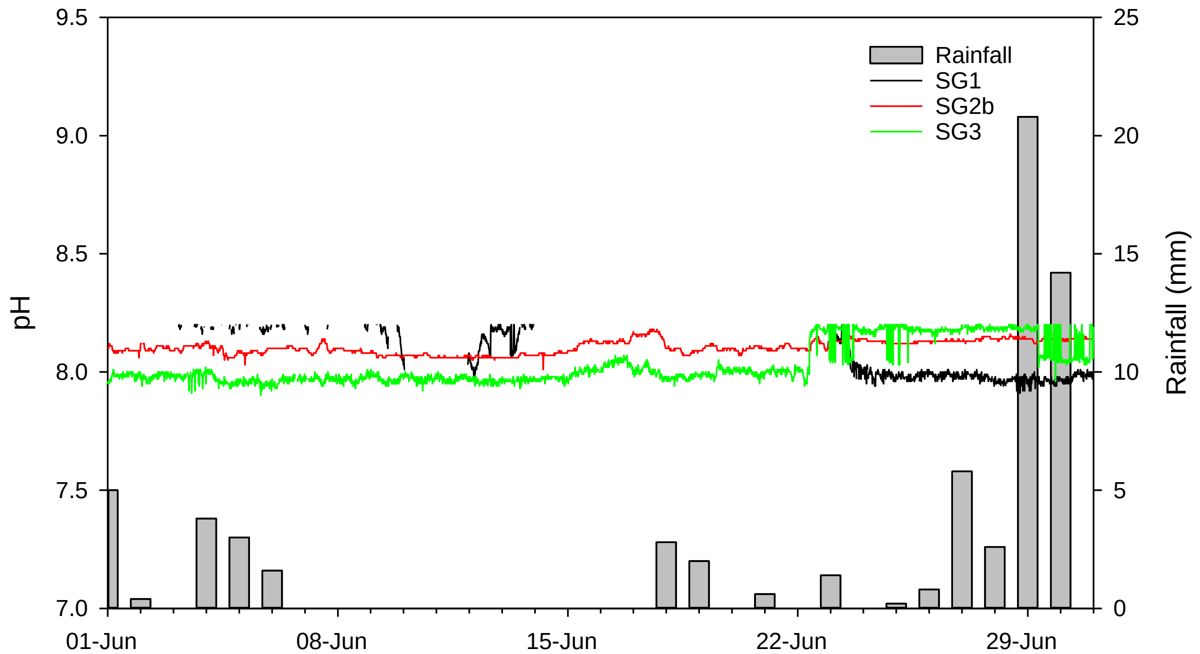


Figure 12 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2020.

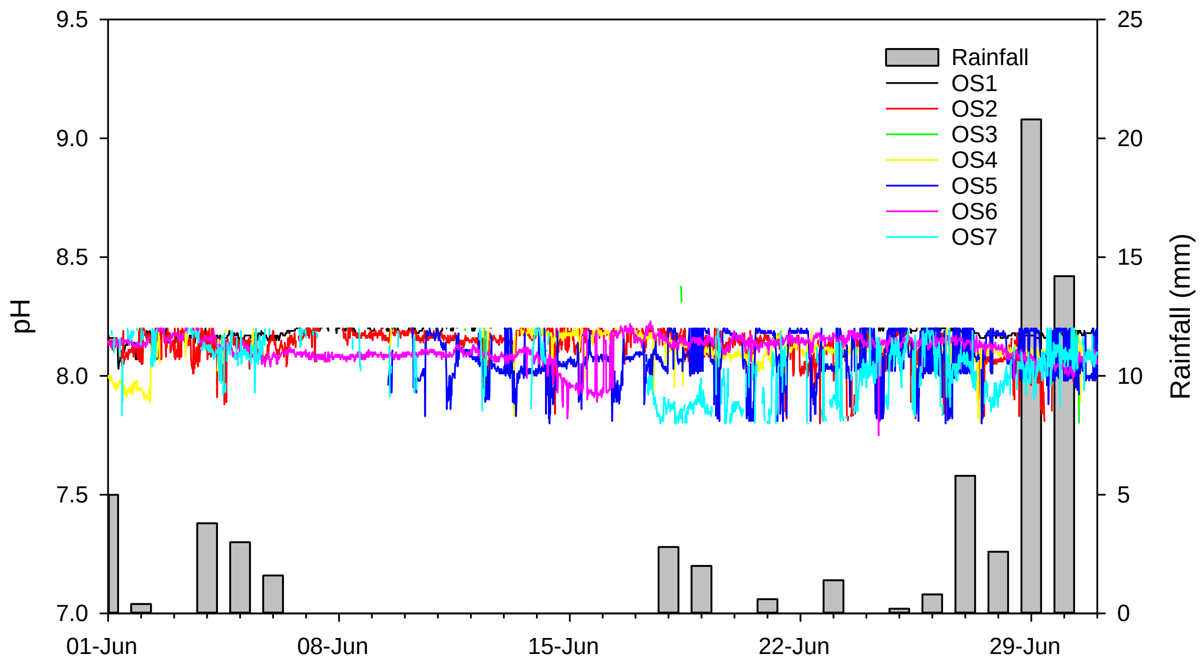


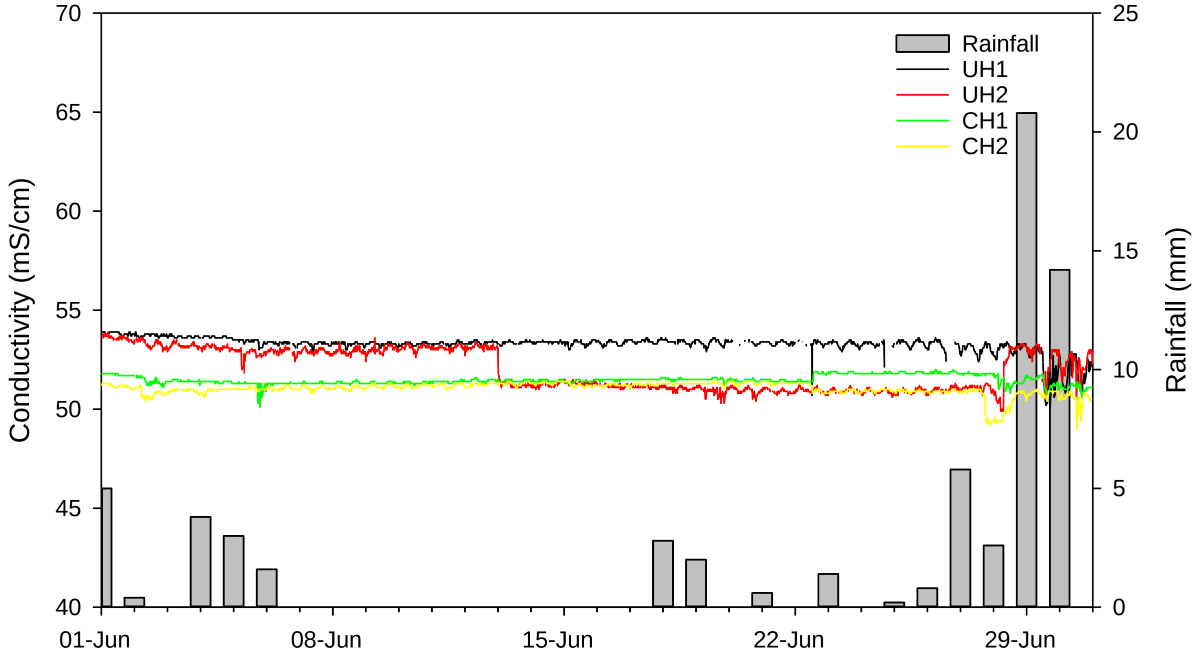
Figure 13 Surface pH (OS1 to OS7) at nearshore and offshore water quality sites during June 2020.

3.2.4 Conductivity

Surface conductivity in June ranged from 51 mS/cm to 53.6 mS/cm (Table 8, Figure 14 and 15). Unlike previous months little spatial pattern in conductivity was observed amongst the upper harbour and offshore sites. This may be attributed to the low flow rates recorded from the Waimakariri River reducing localised freshwater influences, with peak flows only reaching 168 m^3/s compared to a peak flow of 462 m^3/s in May. Heavy rainfall from 27 June to the end of the month appeared to reduce conductivity at several of the inshore (UH1 and UH2) and offshore sites, most notably OS3 and OS5.

Table 8 Mean conductivity at inshore, spoil ground and offshore water quality sites during June 2020. *Values are means ± se (n = 2020 to 2979).*

Site	Conductivity (mS/cm)
	Surface loggers
UH1	53.3 ± 0.0
UH2	52.0 ± 0.0
CH1	51.5 ± 0.0
CH2	51.0 ± 0.0
SG1	53.6 ± 0.0
SG2	52.5 ± 0.0
SG3	53.5 ± 0.0
OS1	51.7 ± 0.0
OS2	53.3 ± 0.0
OS3	53.6 ± 0.0
OS4	53.0 ± 0.0
OS5	52.0 ± 0.0
OS6	53.6 ± 0.0
OS7	52.1 ± 0.0



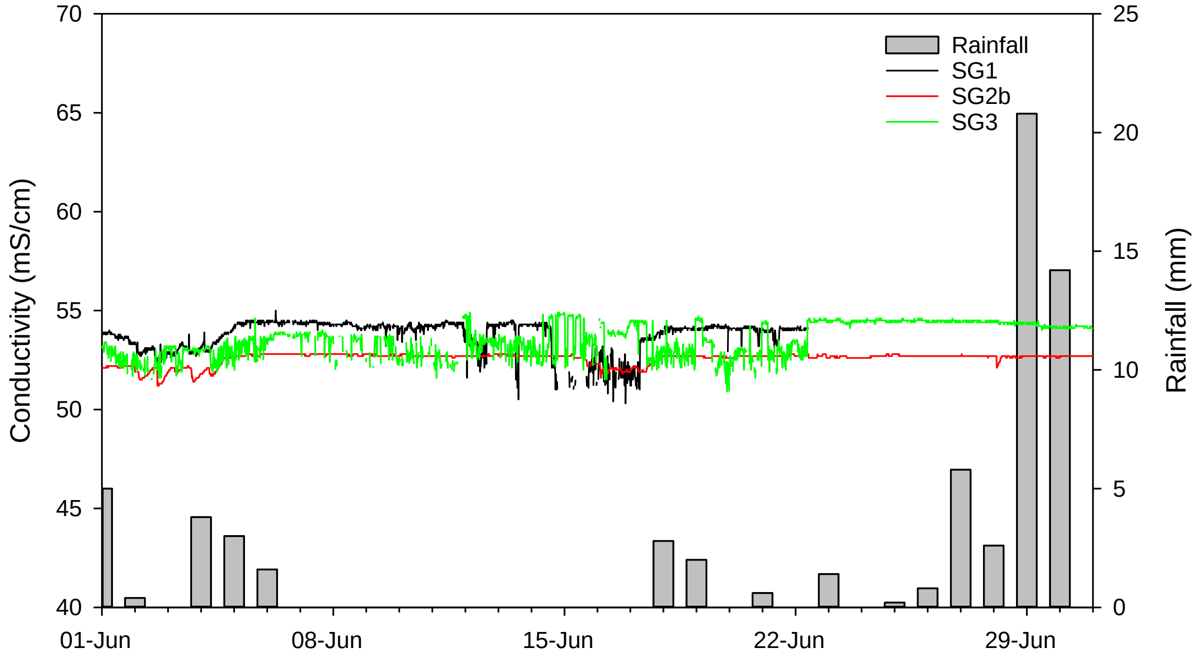


Figure 14 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2020.

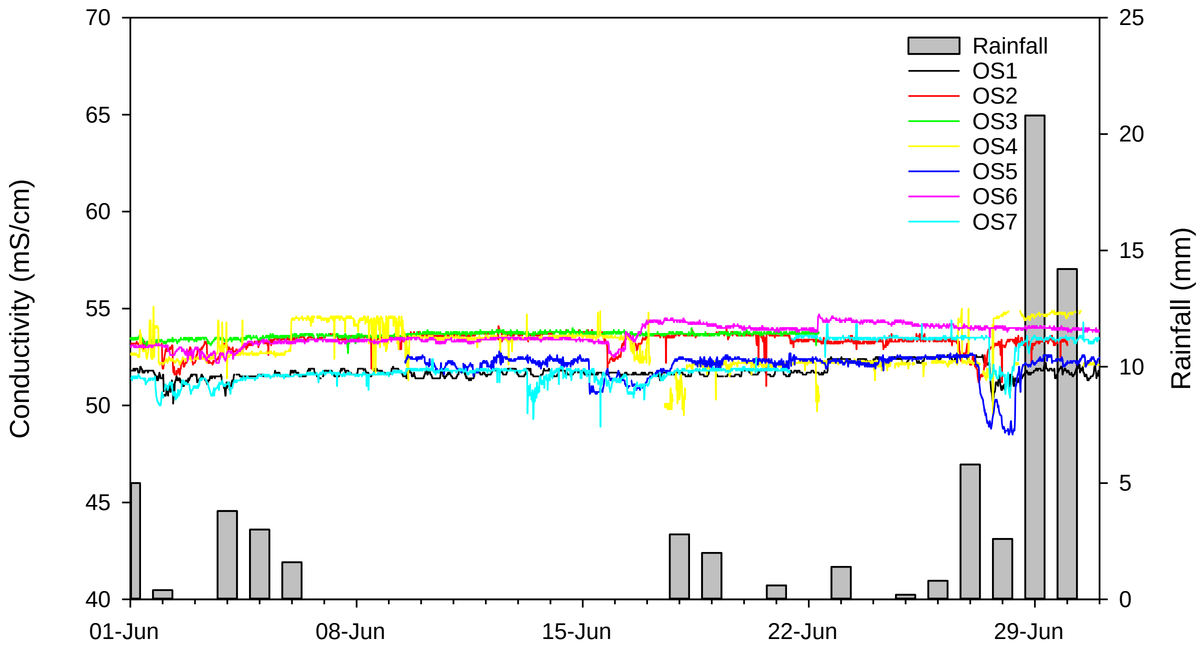


Figure 15 Surface conductivity (OS1 to OS7) at nearshore and offshore water quality sites during June 2020.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations during June ranged from 96 to 105% saturation (Table 9) and demonstrated diurnal fluctuations at all sites, particularly those in the inshore area (Figures 16 and 17). All monitoring sites followed similar patterns in DO concentrations throughout the month, decreasing from the beginning of the month to around 9 June. During this period significant declining DO (< 90% saturation) was recorded at UH2, OS1, OS2, OS6 and OS7 and coincided with increased precipitation and therefore cloud cover. DO then recovered till around 17 June and then stabilised for the majority of sites until the end of the month. Declines were again recorded coinciding with heavy rainfall and associated cloud cover from 27 to 30 June.

The declines in DO seen at the beginning and the end of the month may have been associated with degrading algal blooms in which bacterial degradation results in respiration and oxygen consumption. In a cyclical pattern, warmer temperatures associated with increased sunlight following this period likely stimulated microalgal growth, leading to recovery of algal populations, increased photosynthesis, and therefore increased DO concentrations. However, extended periods of cloud cover in the absence of degrading algal blooms will also result in lower DO due to a generalised reduction in photosynthesis of existing algal populations.

Table 9 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during June 2020.
Values are means ± se (n = 2064 to 2979).

Site	Dissolved oxygen (% saturation)
	Surface loggers
UH1	97 ± 0
UH2	96 ± 0
CH1	100 ± 0
CH2	99 ± 0
SG1	98 ± 0
SG2	102 ± 0
SG3	97 ± 0
OS1	99 ± 0
OS2	96 ± 0
OS3	100 ± 0
OS4	99 ± 0
OS5	105 ± 0
OS6	97 ± 0
OS7	97 ± 0

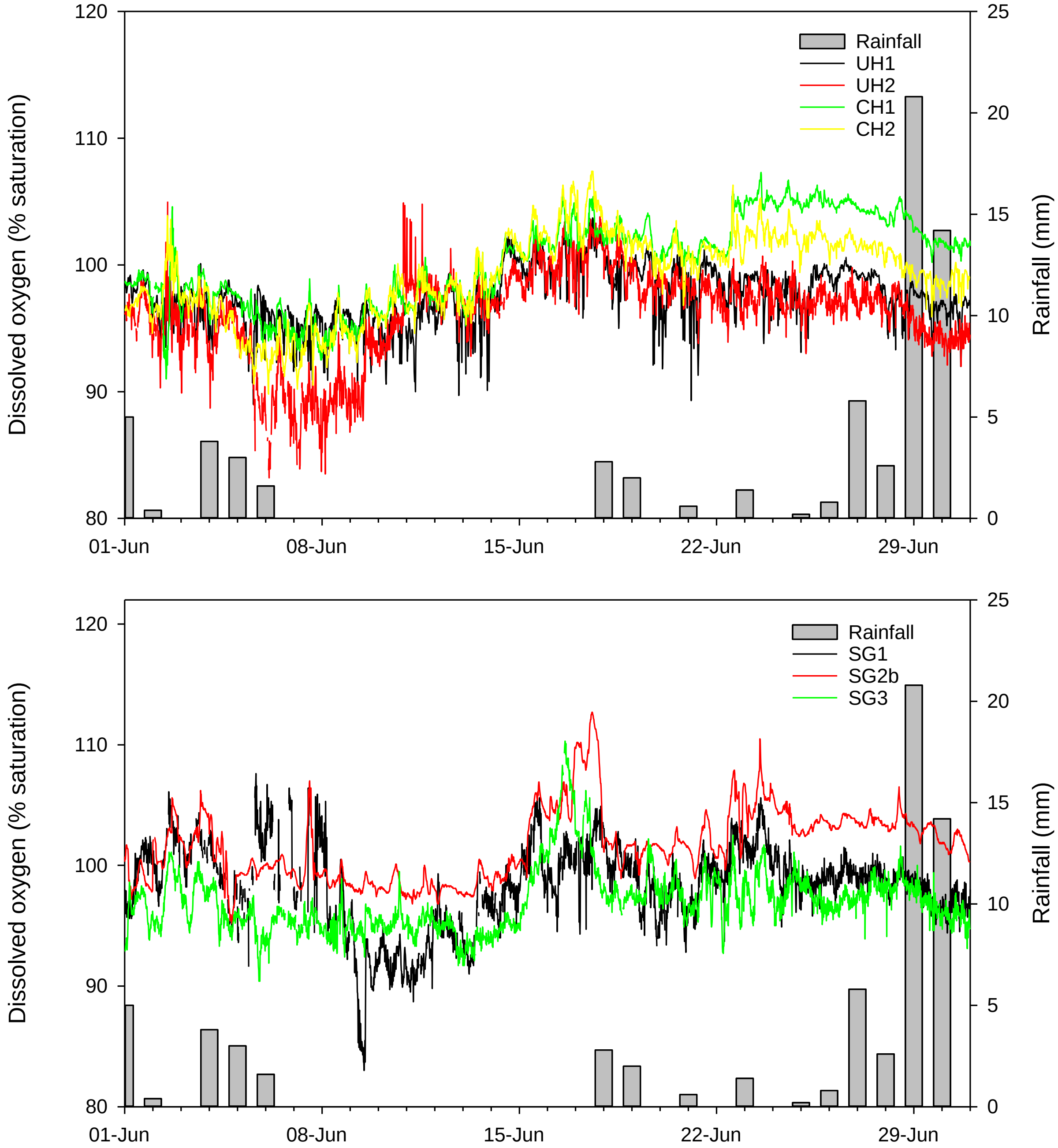


Figure 16 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during June 2020.

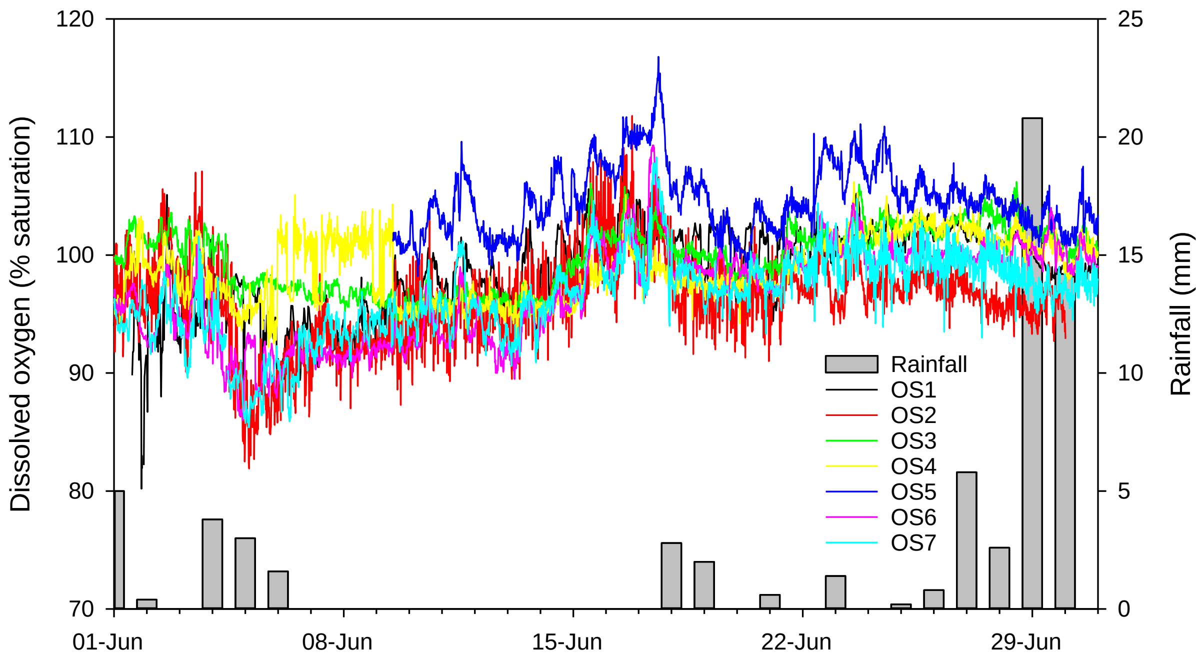


Figure 17 Surface DO (OS1 to OS7) at nearshore and offshore water quality sites during June 2020.

3.3 Physicochemistry Depth Profiling & TSS

Vertical depth profiling of the whole water column at each monitoring site was conducted in conjunction with monthly discrete water sampling on 21 and 22 June. In addition to the previously discussed physicochemical parameters, the light attenuation rate (K_d, the rate at which light or PAR diminishes with depth through the water column) and resultant euphotic depth (the depth to which net photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were collected from three different depths (sub-surface, mid-column and approximately 1 m above the benthos) at the ten offshore and spoil ground sites. Due to the shallow water depths at the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, UH3, CH1 and CH2. Further information regarding the specific sampling methodology can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Statistical analyses of the resulting datasets are provided in Tables 10 to 12, with depth profile plots presented in Figures 18 to 20.

The relatively shallow sites of the upper and central harbour displayed well mixed conditions with little variability recorded in parameters through the water column as typically observed. Spatially amongst the sites temperature appeared to be lower within the upper harbour compared to that of the central harbour consistent with telemetered surface loggers. Turbidity remained relatively stable through the water column at UH1 and UH3, while turbidity at UH2 was stable until >6 m depth where it increased most likely due to benthic resuspension of sediments. Within the top 2 m at site CH2 turbidity increased slightly between the surface and 0.5 m depth before decreasing from 10 NTU to 1.1 NTU at 1 m. However, this was not recorded in the second depth profile and therefore could be attributed to a passing turbidity plume.

Within the nearshore region, physicochemical profiles for OS1, OS3 and OS4 remained relatively consistent through the water column for temperature, conductivity and pH (Figure 19). Temperature at OS2 and OS7 both displayed a slight thermocline at ~5 m with an increase in temperature below this depth. DO concentrations decreased slightly from ~ 5m at most nearshore sites apart from OS3 and OS4, which exhibited uniform concentrations through the water column. Declining DO with depth from the surface to the benthos is associated with decreasing photosynthesis with depth. Most sites exhibited relatively consistent turbidity through the water column however, OS7 recorded a gradual decline in turbidity from the near-surface to ~5m. This site also displayed a sharp increase in turbidity from ~11 m depth most likely due to the resuspension of sediments.

Within the offshore region of the spoil ground, OS5 and OS6, the water column displayed well mixed conditions with little variability recorded in parameters through the water column (Figure 20). DO concentrations at all sites did record a shallow decrease with depth while OS5 recorded a sharper decrease of DO at ~12 m to the benthos. Turbidity remained stable until between 12 and 16 m where it increased with depth due to benthic resuspension at all sites. This was most pronounced at SG1.

The shallowest euphotic depth occurred within the upper harbour monitoring site UH1 at a depth of 8.4 m (Table 10), which reflects the typically higher levels of turbidity experienced in this area. The deepest euphotic depth was calculated to be 23.7 m at OS4 (Table 12), where turbidity is characteristically low throughout the water column indicating clear water. During June no exceedances of WQG were recorded at any of the monitoring sites.

Table 10 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the June 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, n = 14 to 42 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
UH1	21/06/2020 06:49	Sub-surface	9.1 ± 0	8.1 ± 0	50.8 ± 0	101 ± 0	2.5 ± 0	< 3	0.5 ± 0.1	8.4
		Whole column	9.1 ± 0	8.1 ± 0	50.8 ± 0	100 ± 0	2.5 ± 0	–		
UH2	21/06/2020 07:30	Sub-surface	9.3 ± 0	8.1 ± 0	50.8 ± 0	100 ± 0	2.3 ± 0	< 3	0.3 ± 0	16.3
		Whole column	9.3 ± 0.1	8.1 ± 0	50.8 ± 0	100 ± 00	2.2 ± 0.2	–		
UH3	21/06/2020 07:07	Sub-surface	8.6 ± 0	8.1 ± 0	50.3 ± 0	100 ± 0	2.8 ± 0.2	3	0.5 ± 0	8.9
		Whole column	8.6 ± 0	8.1 ± 0	50.4 ± 0	100 ± 0	3.3 ± 0.3	–		
CH1	21/06/2020 08:18	Sub-surface	9.7 ± 0	8.2 ± 0	51.1 ± 0	102 ± 0	3.2 ± 0.5	3	0.4 ± 0	11.9
		Whole column	9.8 ± 0	8.2 ± 0	51.2 ± 0	102 ± 0	3 ± 0.2	–		
CH2	21/06/2020 07:56	Sub-surface	10.2 ± 0	8.2 ± 0	51.3 ± 0	102 ± 0	5.5 ± 2	3	0.3 ± 0	17.9
		Whole column	10.3 ± 0	8.2 ± 0	51.3 ± 0	102 ± 0	2.5 ± 0.4	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 11 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the June 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 30 to 38 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS1	21/06/2020 08:54	Sub-surface	10.1 ± 0	8.2 ± 0	51.3 ± 0	104 ± 0	1.7 ± 0	4	0.3 ± 0	15.4
		Mid	10.1 ± 0	8.2 ± 0	51.3 ± 0	104 ± 0	1.8 ± 0	3		
		Benthos	10.1 ± 0	8.2 ± 0	51.3 ± 0	103 ± 0	1.8 ± 0	9		
		Whole column	10.1 ± 0	8.2 ± 0	51.3 ± 0	103 ± 0	1.8 ± 0	–		
OS2	21/06/2020 09:51	Sub-surface	10.5 ± 0	8.2 ± 0	51.4 ± 0	103 ± 0	1.7 ± 0.2	< 3	0.3 ± 0	15.4
		Mid	10.7 ± 0	8.1 ± 0	51.5 ± 0	102 ± 0	1.3 ± 0	< 3		
		Benthos	10.9 ± 0	8.1 ± 0	51.7 ± 0	100 ± 0	2.9 ± 0.3	9		
		Whole column	10.7 ± 0	8.1 ± 0	51.5 ± 0	102 ± 0	1.8 ± 0.1	–		
OS3	22/06/2020 07:18	Sub-surface	10.9 ± 0	8.1 ± 0	51.7 ± 0	102 ± 0	1.4 ± 0	3	0.2 ± 0	19.2
		Mid	10.9 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	1.4 ± 0.1	4		
		Benthos	10.9 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	1.6 ± 0.2	4		
		Whole column	10.9 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	1.4 ± 0	–		
OS4	22/06/2020 07:49	Sub-surface	11 ± 0	8.2 ± 0	51.7 ± 0	102 ± 0	1.2 ± 0	< 3	0.2 ± 0	23.7
		Mid	11 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	1.2 ± 0	< 3		
		Benthos	11 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	2.3 ± 0.2	7		
		Whole column	11 ± 0.2	8.1 ± 0	51.7 ± 0	101 ± 0	1.4 ± 0.1	–		
OS7	21/06/2020 10:16	Sub-surface	10.5 ± 0	8.2 ± 0	51.4 ± 0	104 ± 0	2.3 ± 0.4	< 3	0.3 ± 0	14.2
		Mid	10.7 ± 0	8.2 ± 0	51.5 ± 0	103 ± 0	1.5 ± 0	3		
		Benthos	10.7 ± 0	8.2 ± 0	51.5 ± 0	101 ± 0	3.5 ± 0.8	9		
		Whole column	10.6 ± 0	8.2 ± 0	51.5 ± 0	103 ± 0	2.2 ± 0.2	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 12 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the June 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 38 to 46 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (°C)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS5	21/06/2020 09:23	Sub-surface	11.1 ± 0	8.2 ± 0	51.5 ± 0	102 ± 0	< 1 ± 0	< 3	0.2 ± 0	20.4
		Mid	11.1 ± 0	8.2 ± 0	51.5 ± 0	101 ± 0	1 ± 0	4		
		Benthos	11.2 ± 0	8.1 ± 0	51.7 ± 0	96 ± 1	2.8 ± 0.4	6		
		Whole column	11.1 ± 0	8.2 ± 0	51.5 ± 0	100 ± 0	1.3 ± 0.1			
OS6	22/06/2020 06:43	Sub-surface	10.9 ± 0	8.1 ± 0	51.7 ± 0	102 ± 0	1.2 ± 0	< 3	0.2 ± 0	18.8
		Mid	11 ± 0	8.1 ± 0	51.7 ± 0	102 ± 0	1.2 ± 0	3		
		Benthos	11 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	3.7 ± 0.8	9		
		Whole column	11 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	1.6 ± 0.2			
SG1	22/06/2020 09:23	Sub-surface	10.8 ± 0	8.2 ± 0	51.6 ± 0	105 ± 0	1.1 ± 0	< 3	0.3 ± 0	18.4
		Mid	10.8 ± 0	8.2 ± 0	51.6 ± 0	103 ± 0	1.1 ± 0	< 3		
		Benthos	10.9 ± 0	8.2 ± 0	51.6 ± 0	102 ± 0	6.2 ± 2.5	10		
		Whole column	10.8 ± 0	8.2 ± 0	51.6 ± 0	103 ± 0	1.8 ± 0.4			
SG2	22/06/2020 08:59	Sub-surface	11.1 ± 0	8.2 ± 0	51.7 ± 0	101 ± 0	1.5 ± 0	5	0.3 ± 0	14.2
		Mid	11.1 ± 0	8.1 ± 0	51.8 ± 0	100 ± 0	1.5 ± 0	4		
		Benthos	11.1 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	2.7 ± 0.6	18		
		Whole column	11.1 ± 0	8.1 ± 0	51.7 ± 0	100 ± 0	1.8 ± 0.1			
SG3	22/06/2020 08:22	Sub-surface	11 ± 0	8.2 ± 0	51.7 ± 0	103 ± 0	1.2 ± 0	< 3	0.3 ± 0	18.1
		Mid	11 ± 0	8.2 ± 0	51.7 ± 0	101 ± 0	1.3 ± 0	< 3		
		Benthos	11 ± 0	8.2 ± 0	51.7 ± 0	100 ± 0	2.1 ± 0.3	5		
		Whole column	11 ± 0	8.2 ± 0	51.7 ± 0	101 ± 0	1.4 ± 0.1			
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

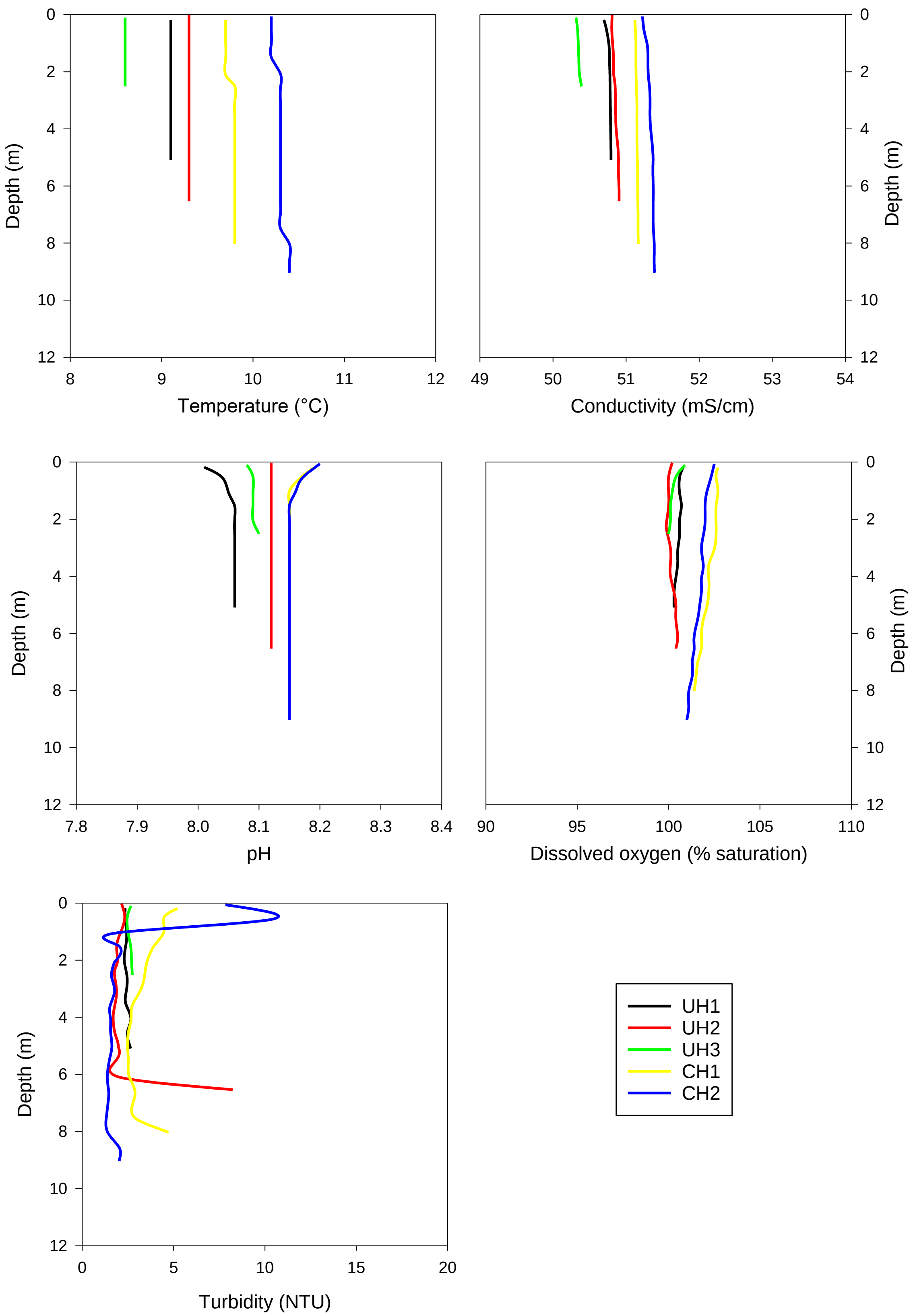


Figure 18 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 21 and 22 June 2020.

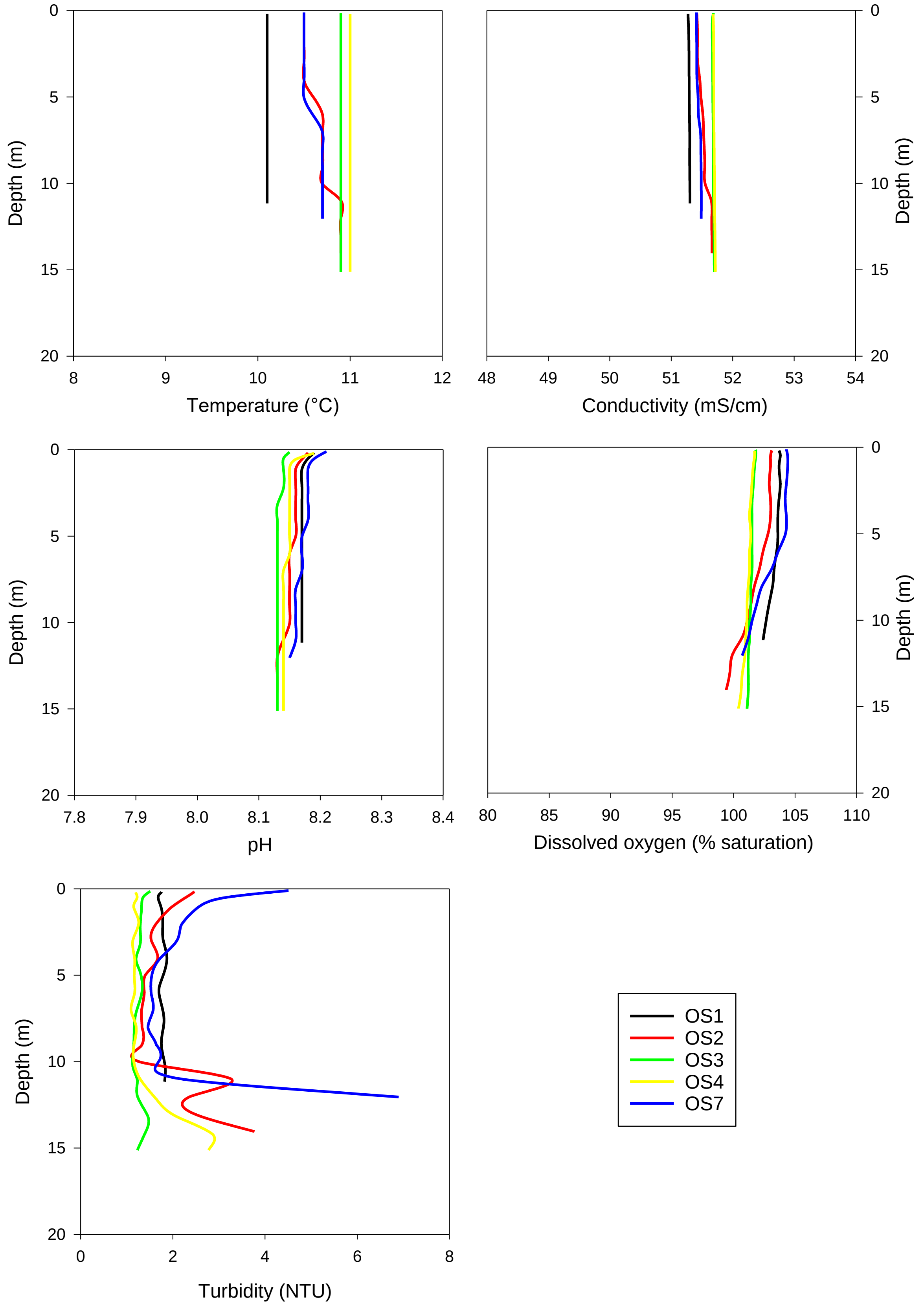


Figure 19 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 21 and 22 June 2020.

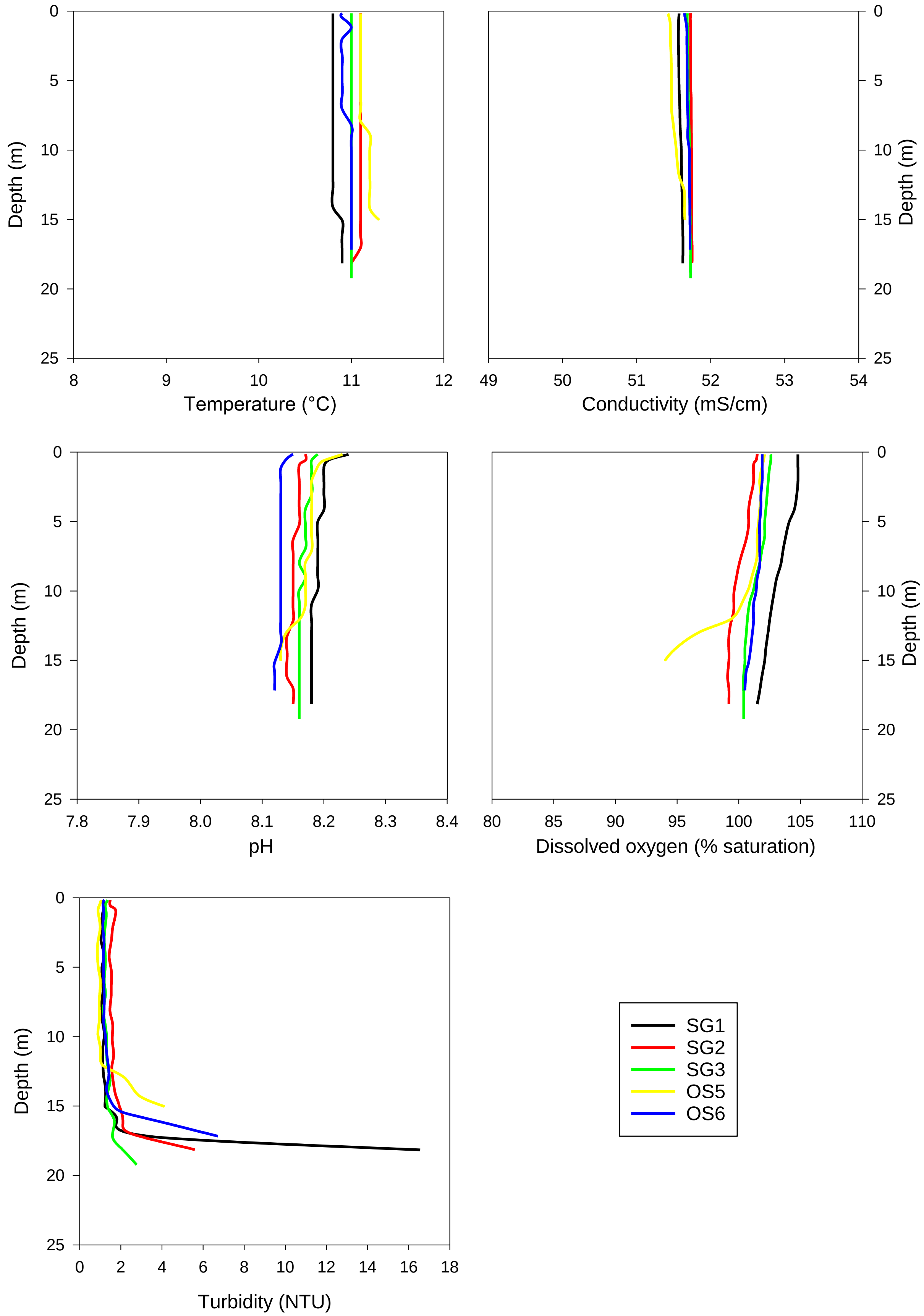


Figure 20 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 21 and 22 June 2020.

3.4 Water Samples

Discrete water sampling was conducted on 21 and 22 June 2020, in conjunction with vertical physicochemical profiling through the water column. Quality assurance/quality control (QA/QC) procedures included a duplicate water sample collected at one site, in addition to a laboratory and field blank for each parameter. Further details on the specific sampling methodology can be found within the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Laboratory results associated with VE QA/QC procedures are presented in Table 18 and 19 of the Appendix.

3.4.1 Nutrients

Total phosphorous concentrations were found in higher concentrations in the upper and central sampling sites, though higher concentrations were also found offshore at OS5 and SG2 (Figure 21). However, total phosphorous remained below the WQG of 30 µg/L at all sites. Dissolved reactive phosphorous concentrations exceeded the WQG of 5 µg/L at all sites in June with higher concentrations being recorded in the upper harbor sites. Both total nitrogen and total kjeldahl nitrogen (TKN) recorded values ≤ LOR value and were below WQG at all sites for this sampling period.

Total ammonia concentrations ranged from 9 to 21 µg/L with four sites exceeding the WQG (15 µg/L). Nitrogen oxide values ranged from 2.4 to 22 µg/L with three of the monitoring sites recording values above the WQG (>15 µg/L).

During June nine sites at the offshore and spoil ground area recorded Chlorophyll *a* concentrations that exceeded the WQG value (4 µg/L) (Table 13). Chlorophyll *a* is an indicator of phytoplankton biomass, and may indicate higher than normal algal populations, potentially due to readily bioavailable nutrients on this sampling occasion. However, these are likely to fluctuate throughout the month.

Table 13 Concentrations of nutrients and chlorophyll *a* at monitoring sites during June 2020
Values outside recommended WQG are highlighted in blue.

Site	Parameter (µg/L)						
	Total Phosphorus	Dissolved Reactive Phosphorus	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)	Total Ammonia	Nitrogen Oxides (NOx)	Chlorophyll *a*
UH1	22	11.2	<300	<200	11	2.4	3.2
UH2	21	11.4	<300	<200	12	2.5	1.4
UH3	24	13	300	200	10	2.6	0.6
CH1	20	9.3	<300	<200	17	8.4	1.5
CH2	19	8.6	<300	<200	11	2.2	1.2
OS1	19	8	<300	<200	9	10.1	4.4
OS2	19	9.5	<300	<200	21	4	6.3
OS3	17	9.8	<300	<200	14	20	3.6
OS4	18	9.4	<300	<200	17	22	4.3
OS5	25	8.1	<300	<200	16	4.9	6.7
OS6	16	8.4	<300	<200	11	14.9	5.2
OS7	17	8.1	<300	<200	15	2.9	5.5
SG1	18	8.1	<300	<200	10	3.6	8
SG2	22	9.2	<300	<200	11	16.3	7.4
SG3	15	7.7	<300	<200	11	7.6	7
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

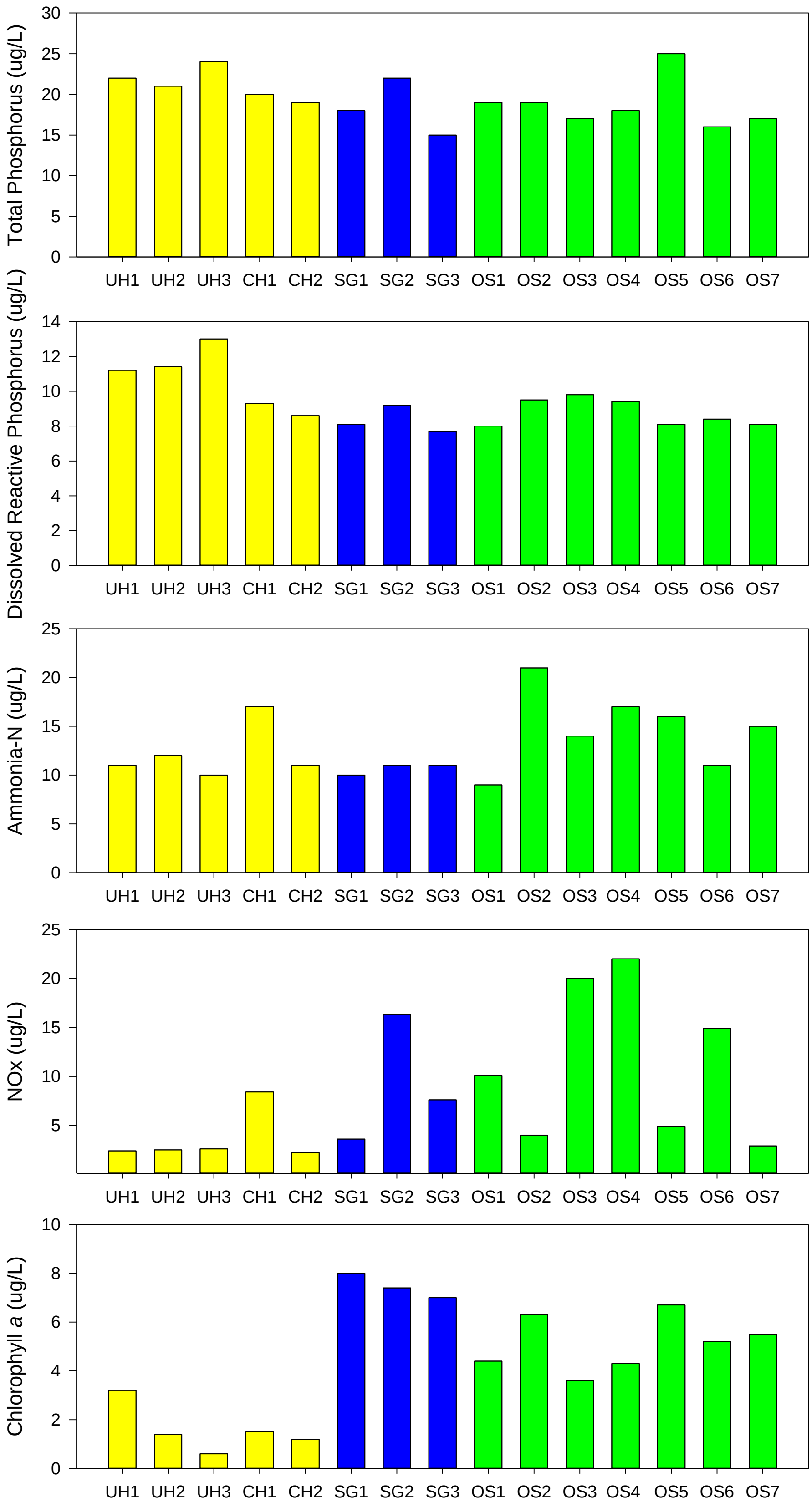


Figure 21 Nutrient and chlorophyll *a* concentrations at monitoring sites during June 2020. *Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.*

3.4.2 Total and Dissolved Metals

Concentrations of the majority of recorded metals were relatively low during the month of June. Concentrations of several metals (Tables 14 to 16, Figure 22 and 23) were reported as below the limit of reporting (LOR) at all sites, including dissolved and total arsenic (<4.2 µg/L), cadmium (<0.21 µg/L), cobalt (<0.63 µg/L), lead (< 1.1 µg/L), nickel (<7 µg/L), mercury (<0.08 µg/L) selenium (<4.2 µg/L), silver (<0.43 µg/L), tin (<5.3 µg/L) and zinc (< 4.2 µg/L). Dissolved copper at OS4 recorded a concentration of 1.1 µg/L however this was still below the recommended WQG (1.3 µg/L). Total copper concentrations above WQG were recorded at UH1 (1.4 µg/L), UH2 (1.4 µg/L) and CH2 (1.6 µg/L), though as the WQG is only applicable to dissolved fractions of the metal no exceedances were noted.

Dissolved concentrations of aluminium were <LOR at all sites in June. Concentrations of total aluminium exceeded the designated 95% species protection value of 24 µg/L at all sites except at OS5, SG1 and SG3, with the highest concentrations occurring at the inshore monitoring sites. However, the WQG is applicable to the dissolved fraction only (ANZG, 2018), therefore no exceedances were recorded for June. Concentrations of dissolved iron were above the LOR (4 µg/L) for most sites, except UH1, UH2, UH3, OS2, OS3, OS7 and SG1, and similar to total aluminium, total iron concentrations were highest amongst the inshore monitoring sites. Concentrations of dissolved iron are comparable to previous winter months reflecting the lower concentrations of suspended sediment and colloidal particles in the water column during the cooler season. There are no trigger values for dissolved or total iron concentrations.

Chromium, manganese, molybdenum and vanadium were recorded at majority of sites in both total and dissolved forms. Dissolved chromium was detected at seven sites but both total and dissolved chromium concentrations were well below the 95% species protection trigger value of 4.4 µg/L for CrVI and 27.4 µg/L for CrIII at all sites. Vanadium concentrations ranged from 1.5 to 2.1 µg/L and were also well below the 95% species protection trigger value of 100 µg/L.

Total and dissolved manganese concentrations ranged from 1.8 to 7.9 µg/L and 1.5 to 6.1 µg/L respectively, with higher concentrations recorded at sites in the upper harbour. Total and dissolved molybdenum concentrations exhibited little spatial variation, ranging from 10.9 to 11.9 µg/L and 10.9 to 11.7 µg/L respectively. No trigger values are available for either manganese or molybdenum.

Table 14 Total and dissolved metal concentrations at inshore monitoring sites during June 2020. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	13	<12	<12	12	24
	Total	75	59	76	48	29	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	1.1	<1	<1	<1	1.3	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	<1	<1	1.3
	Total	1.4	1.4	1.2	<1.1	1.6	
Iron	Dissolved	<4	<4	<4	4	10	-
	Total	102	73	99	61	32	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	6.1	4.7	4.6	5.6	3.7	-
	Total	7.9	5.9	6.3	7	4.8	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.1	10.9	10.9	11.7	11.4	-
	Total	10.8	10.9	10.7	11.2	10.9	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.5	1.5	1.6	1.7	1.7	100
	Total	1.7	1.6	1.7	1.8	1.8	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 15 Total and dissolved metal concentrations at offshore monitoring sites during June 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites							WQG
		OS1	OS2	OS3	OS4	OS5	OS6	OS7	
Aluminium	Dissolved	<12	<12	<12	<12	<12	<12	<12	24
	Total	41	25	32	23	<21	24	38	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	1.1	1.1	1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.1	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	1.2	
Iron	Dissolved	8	<4	<4	6	5	12	<4	-
	Total	39	23	22	14.4	17.5	24	39	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	3.8	2.4	1.7	1.5	1.6	1.8	2.8	-
	Total	5.2	3.4	2.6	1.8	2.5	2.2	4.4	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.1	11.7	11.1	11.6	11.4	11.9	11.8	-
	Total	11.4	11.1	11.5	11.6	11.4	11.2	11.3	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.6	1.7	1.9	1.8	1.9	1.8	1.6	100
	Total	1.8	1.8	1.9	2	2	2.1	1.7	
Zinc	Dissolved	<4	<4	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 16 Total and dissolved metal concentrations at spoil ground monitoring sites during June 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	<21	30	<21	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	1	1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	<1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	6	9	-
	Total	13.1	33	12	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.7	1.8	1.6	-
	Total	3.1	2.5	1.9	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.4	11.5	11.6	-
	Total	11.7	11.7	11.4	
Nickel	Dissolved	<7	<7	<7	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.9	1.8	2	100
	Total	1.8	1.8	1.9	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

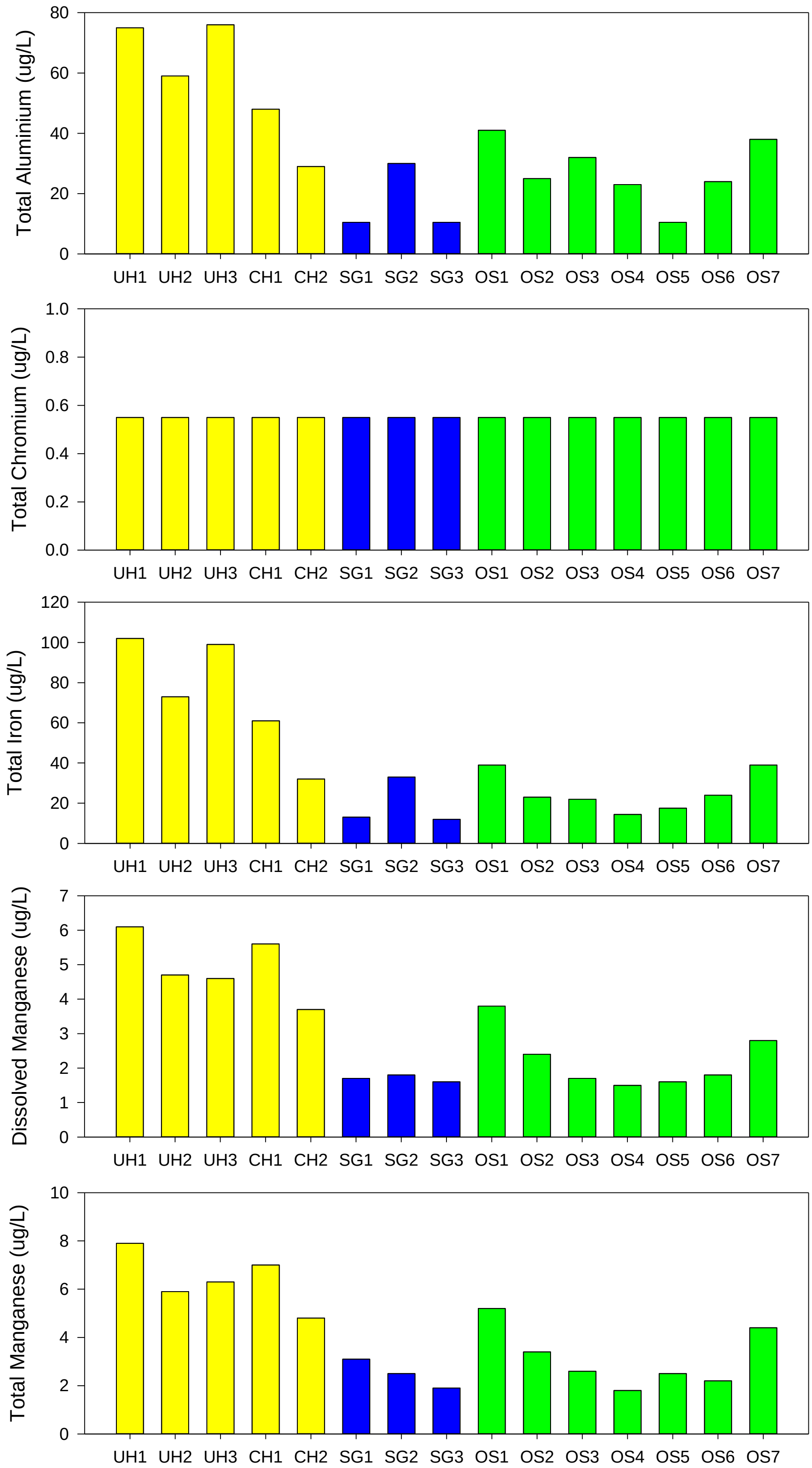


Figure 22 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during June 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

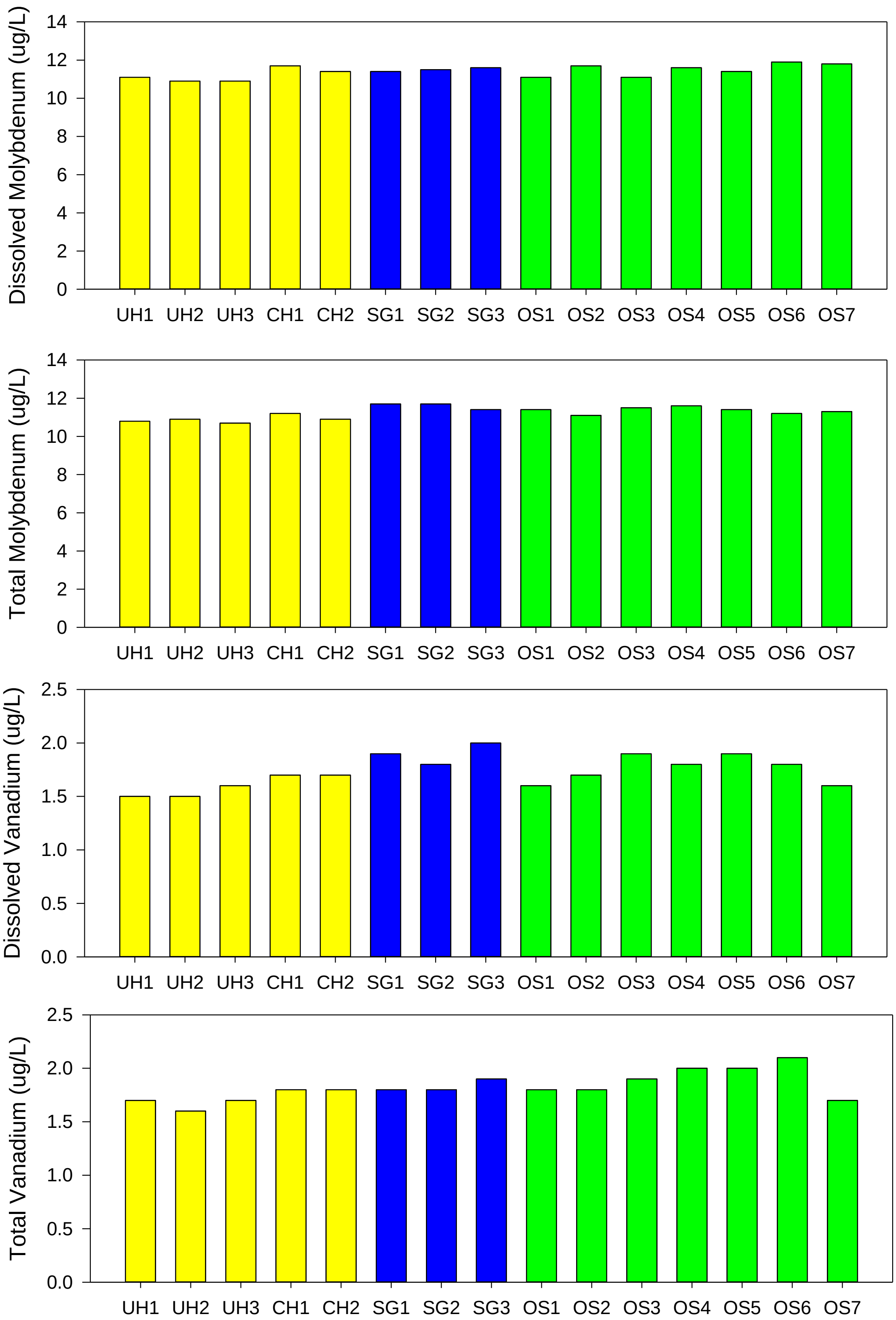


Figure 23 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during June 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

3.4.3 Organics

Organic compounds (herbicides, pesticides and hydrocarbons) are measured and reported biannually at all sites as part of the monitoring project. For the June monitoring period 210 compounds were analysed including; total petroleum hydrocarbons (C6 – C36), PAH and multiresidue pesticides (179 individual), plus acid herbicides (22 individual herbicides). All compounds measured were below LOR at all sites (Table 17), which has been a consistent finding throughout the monitoring project.

Table 17 Organic compound concentrations at monitoring sites during June 2020.

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
C7 - C9	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100
C10 - C14	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200
C15 - C36	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400
Total hydrocarbons (C7 - C36)	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700
Benzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Toluene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Ethylbenzene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
2,3,4,6-Tetrachlorophenol (TCP)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
2,4,5-Trichlorophenoxyacetic acid (245T)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
2,4'-DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4'-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4'-DDT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2,4-Dichlorophenoxyacetic acid (24D)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
2,4-Dichlorophenoxybutyric acid (24DB)	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
2-methyl-4-chlorophenoxyacetic acid (MCPA)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
2-methyl-4-chlorophenoxybutanoic acid (MCPB)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
4,4'-DDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4,4'-DDE	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
4,4'-DDT	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Acetochlor	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Acifluorfen	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Alachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Aldrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
alpha-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Atrazine	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Atrazine-desethyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Atrazine-desisopropyl	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Azaconazole	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Azinphos-methyl	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Benalaxyl	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bendiocarb	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Benodanil	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Bentazone	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
beta-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Bifenthrin	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bitertanol	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Bromacil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromophos-ethyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromopropylate	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Bromoxynil	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Bupirimate	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Buprofezin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Butachlor	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Captafol	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Captan	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Carbaryl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carbofenothion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carbofuran	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carboxin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorfenvinphos	<0.04	<0.04	<0.04	<0.08	<0.04	<0.08	<0.04	<0.04	<0.08	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorfluazuron	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorothalonil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorpropham	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chlorpyrifos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlorpyrifos-methyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Chlortoluron	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Chlozolinate	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
cis-Chlordane	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Clopyralid	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Coumaphos	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Cyanazine	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyfluthrin	<0.04	<0.04	<0.04	<0.07	<0.04	<0.07	<0.04	<0.04	<0.07	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyhalothrin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cypermethrin	<0.08	<0.08	<0.08	<0.13	<0.08	<0.13	<0.08	<0.08	<0.13	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Cyproconazole	<0.04	<0.04	<0.04	<0.1	<0.04	<0.1	<0.04	<0.04	<0.1	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cyprodinil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
delta-BHC	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deltamethrin (including Tralomethrin)	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Demeton-S-methyl	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Diazinon	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Dicamba	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Dichlobenil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichlofenthion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichlofluanid	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichloran	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dichlorprop	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Dichlorvos	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dicofol	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dicrotophos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dieldrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Difenoconazole	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dimethoate	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dinocap	<0.3	<0.3	<0.3	<0.6	<0.3	<0.6	<0.3	<0.3	<0.6	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Diphenylamine	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Disulfoton	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Diuron	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Endosulfan I	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan II	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endosulfan sulfate	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Endrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Endrin aldehyde	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Endrin ketone	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
EPN	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Esfenvalerate	<0.04	<0.04	<0.04	<0.08	<0.04	<0.08	<0.04	<0.04	<0.08	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Ethion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Etrimfos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Famphur	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenamiphos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenarimol	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenitrothion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenpropathrin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenpropimorph	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fensulfothion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenthion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fenvalerate	<0.04	<0.04	<0.04	<0.08	<0.04	<0.08	<0.04	<0.04	<0.08	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluazifop	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Fluazifop-butyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluometuron	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluroxypyr	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Flusilazole	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Fluvalinate	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Folpet	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Furalaxyl	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
gamma-BHC (Lindane)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Haloxyfop	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Haloxyfop-methyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Heptachlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Heptachlor epoxide	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Hexachlorobenzene	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Hexaconazole	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Hexazinone	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Hexythiazox	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Imazalil	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Indoxacarb	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Iodofenphos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Isazophos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Isofenphos	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Kresoxim-methyl	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Leptophos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Linuron	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
m&p-Xylene	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Malathion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mecoprop	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Metalaxyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methacrifos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methidathion	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methiocarb	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methoxychlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Metolachlor	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Metribuzin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mevinphos	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Molinate	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Myclobutanil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Naled	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrofen	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Nitrothal-Isopropyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Norflurazon	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Oryzalin	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6
Oxadiazon	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Oxychlordane	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Oxyfluorfen	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
o-Xylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Paclobutrazol	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Parathion-ethyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Parathion-methyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Penconazole	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pendimethalin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pentachlorophenol (PCP)	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Permethrin	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Phorate	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Phosmet	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Phosphamidon	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Picloram	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Pirimicarb	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pirimiphos-methyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Prochloraz	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Procymidone	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Prometryn	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Propachlor	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Propanil	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Propazine	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Propetamphos	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
Propham	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Propiconazole	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Prothiofos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrazophos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrifenox	<0.04	<0.04	<0.04	<0.08	<0.04	<0.08	<0.04	<0.04	<0.08	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrimethanil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyriproxyfen	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Quintozene	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Quizalofop	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Quizalofop-ethyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Simazine	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Simetryn	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Sulfentrazone	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Sulfotep	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Tebuconazole	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tebufenpyrad	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Terbacil	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbufos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbumeton	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbuthylazine	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Terbuthylazine-desethyl	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Terbutryn	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Tetrachlorvinphos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Thiabendazole	<0.2	<0.2	<0.2	<0.3	<0.2	<0.3	<0.2	<0.2	<0.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Thiobencarb	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Thiometon	<0.08	<0.08	<0.08	<0.1	<0.08	<0.1	<0.08	<0.08	<0.1	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08

Parameter (µg/L)	Site														
	UH1	UH2	UH3	CH1	CH2	OS1	OS2	OS3	OS4	OS5	OS6	OS7	SG1	SG2	SG3
Tolylfluanid	<0.02	<0.02	<0.02	<0.03	<0.02	<0.03	<0.02	<0.02	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total Chlordane [(cis+trans)*100/42]	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Total DDT Isomers	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06	<0.06
trans-Chlordane	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Triadimefon	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Triazophos	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Triclopyr	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Trifluralin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Vinclozolin	<0.04	<0.04	<0.04	<0.05	<0.04	<0.05	<0.04	<0.04	<0.05	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04

4 REFERENCES

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5 APPENDIX

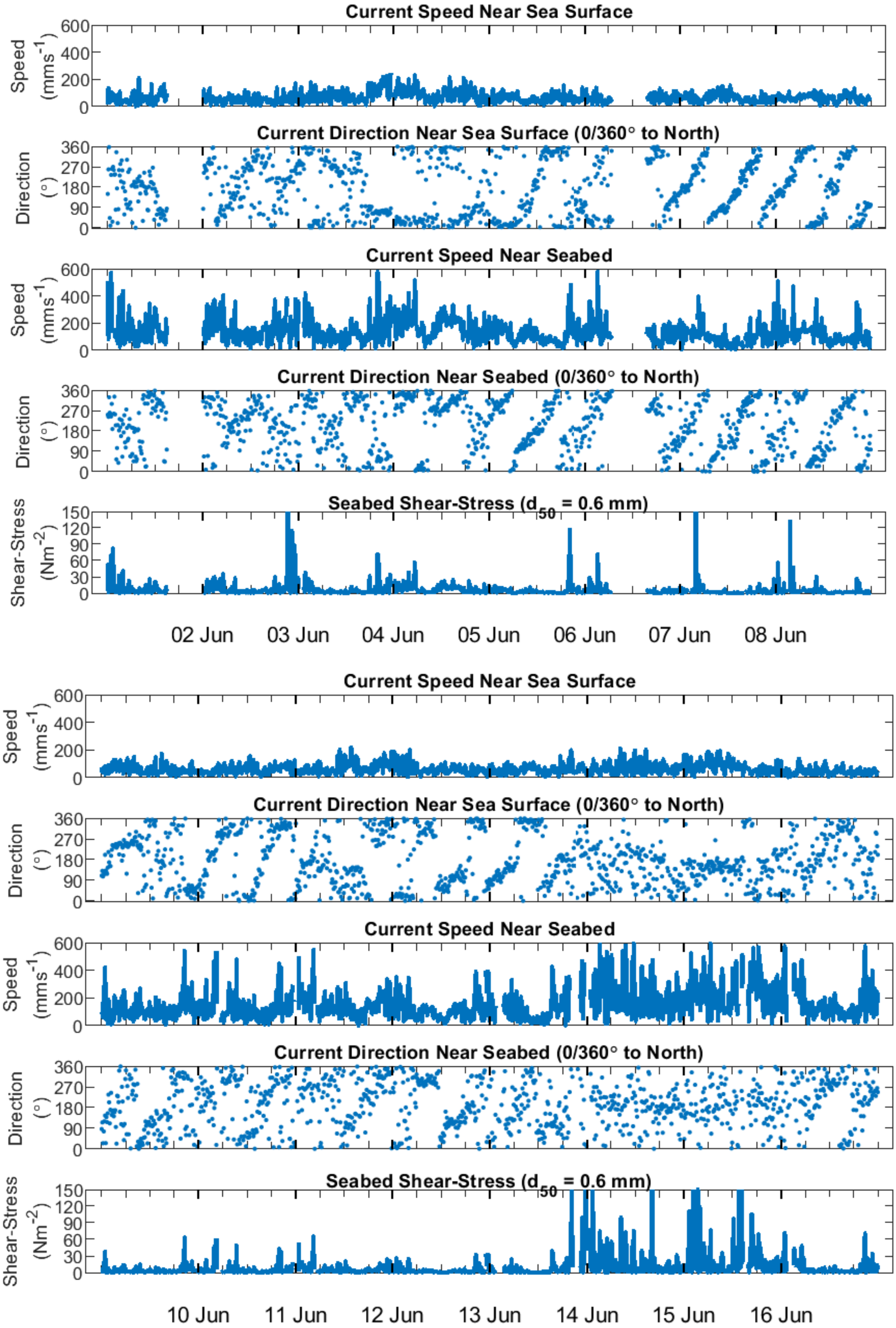
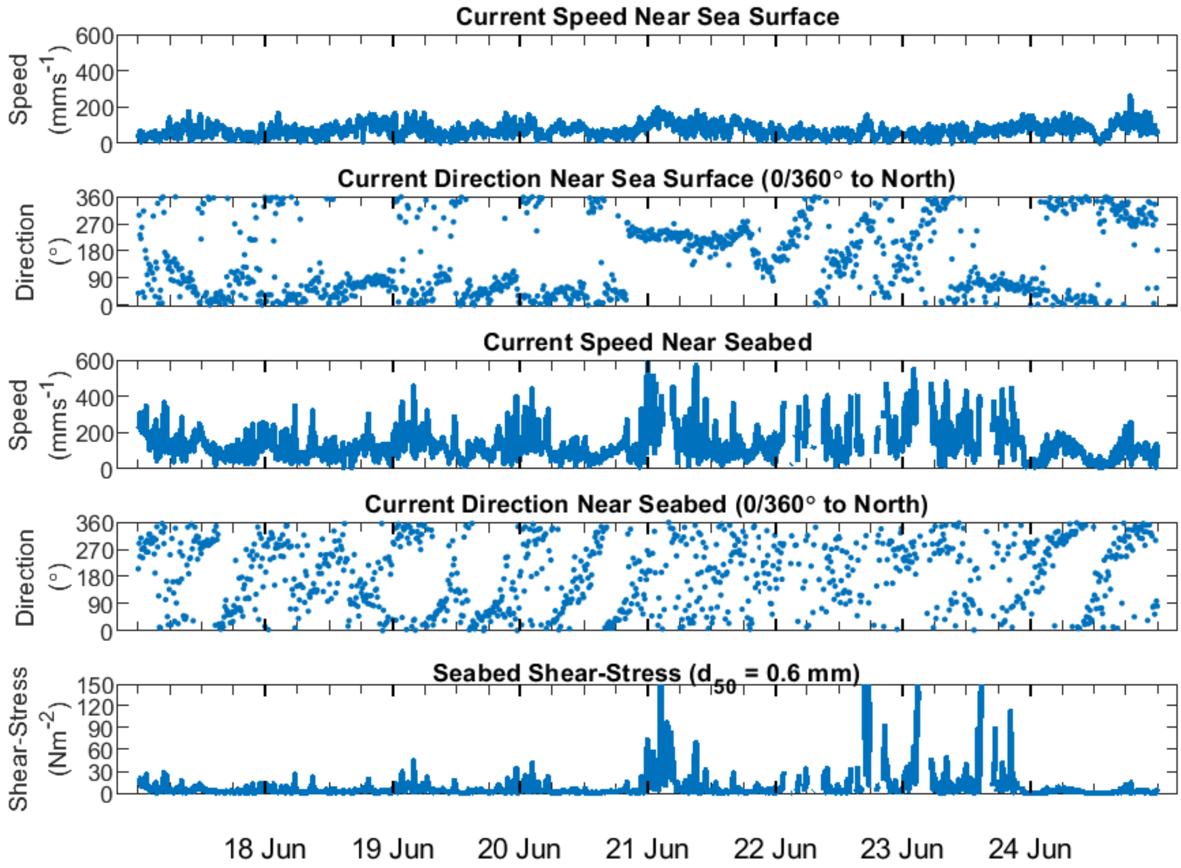


Figure 24 SG1 current speed, direction and shear bed stress 1 to 16 June 2020.



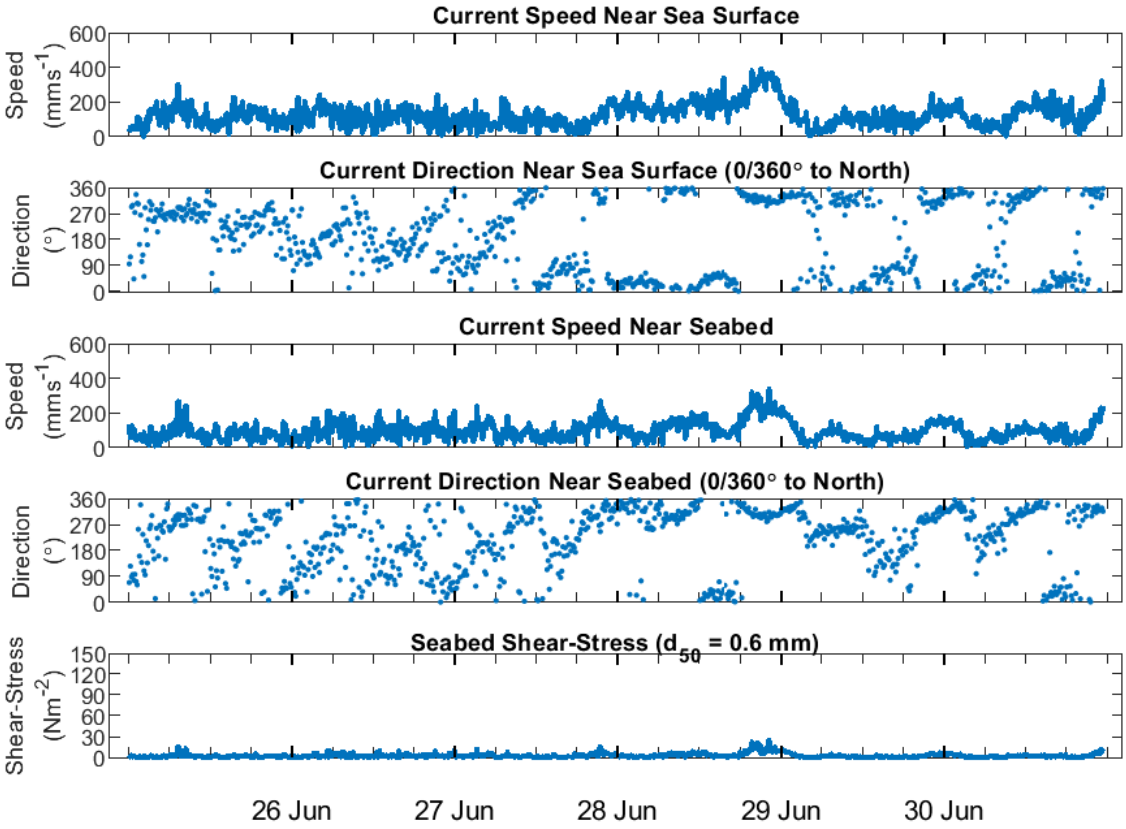


Figure 25 SG1 current speed, direction and shear bed stress 17 to 30 June 2020.
Note missing data due to unit malfunction.

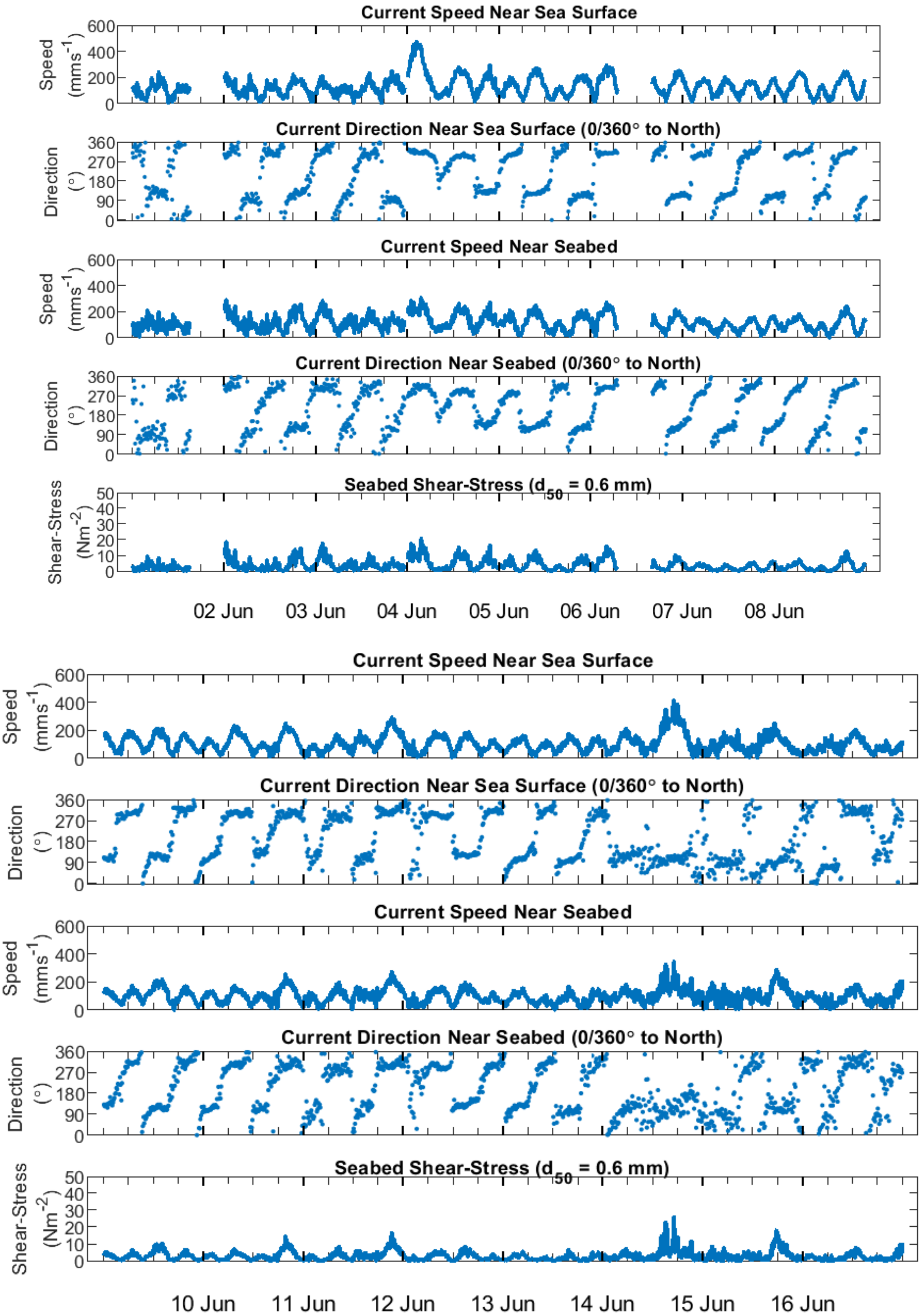


Figure 26 SG3 current speed, direction and shear bed stress 1 to 16 June 2020.

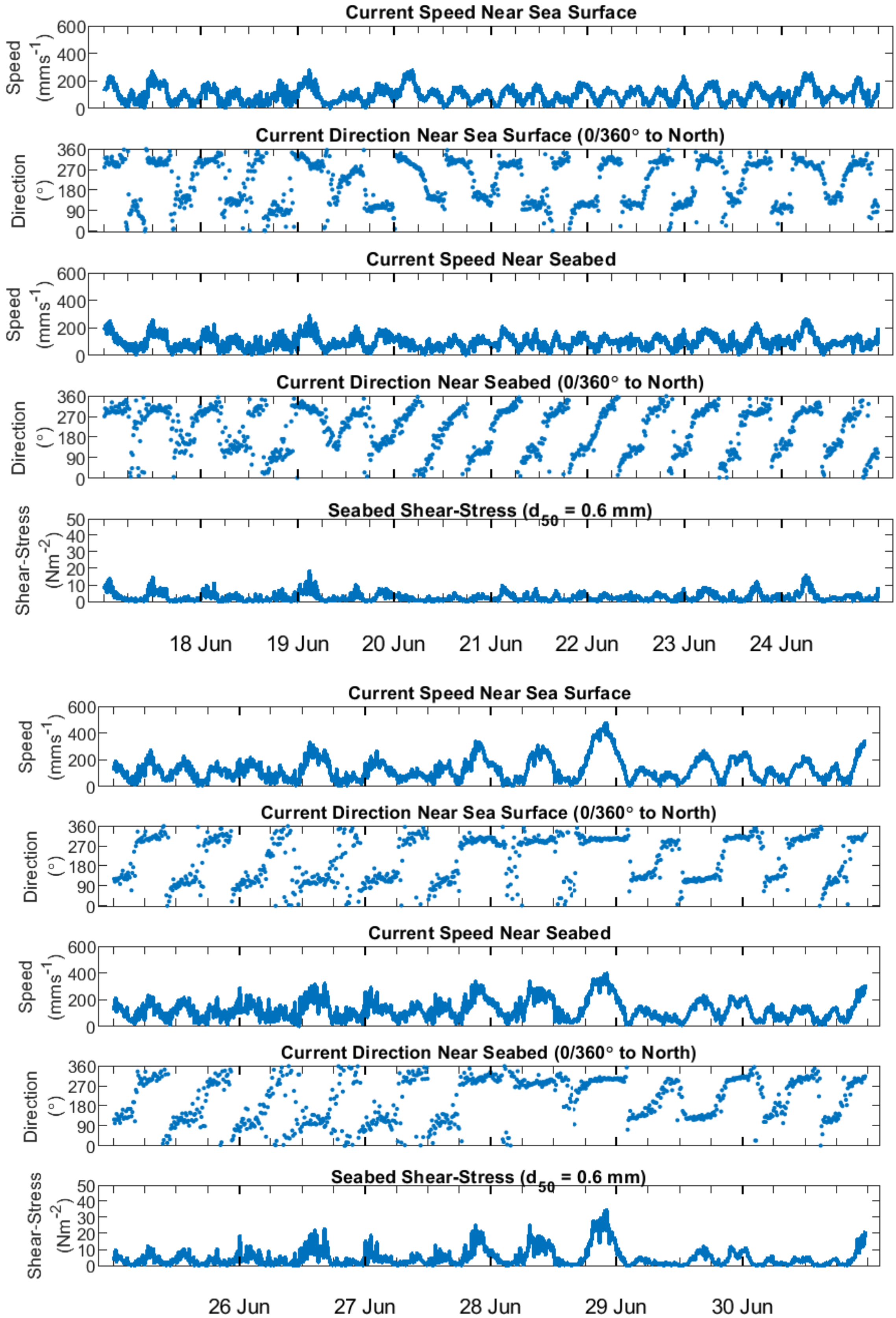


Figure 27 SG3 current speed, direction and shear bed stress 17 to 30 June 2020.

Table 18 Summary of Vision Environment quality control data for June 2020 water sampling.
ND = not determined as one or more samples was below LOR. Variation between duplicate field samples ≥ 50% has been highlighted in blue. High variation indicates heterogeneity within the water column.

* Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			UH3 (A) (µg/L)	UH3 (B) (µg/L)	Variation (%)
TSS mg/l	<3	<3	3	4	29
Dissolved Aluminium (µg/l)	<3	<3	< 12	14	ND
Total Aluminium (µg/l)	<3.2	<3.2	76	78	3
Dissolved Arsenic (µg/l)	<1	<1	<4	<4	ND
Total Arsenic (µg/l)	< 1.1	< 1.1	<4.2	<4.2	ND
Dissolved Cadmium (µg/l)	< 0.05	< 0.05	< 0.2	< 0.2	ND
Total Cadmium (µg/l)	< 0.053	< 0.053	< 0.21	< 0.21	ND
Dissolved Chromium (µg/l)	< 0.5	< 0.5	< 1	< 1	ND
Total Chromium (µg/l)	< 0.53	< 0.53	< 1.1	< 1.1	ND
Dissolved Cobalt (µg/l)	< 0.2	< 0.2	< 0.6	< 0.6	ND
Total Cobalt (µg/l)	< 0.21	< 0.21	< 0.63	< 0.63	ND
Dissolved Copper (µg/l)	< 0.5	< 0.5	< 1	< 1	ND
Total Copper (µg/l)	< 0.53	< 0.53	1.2	1.7	34
Dissolved Iron (µg/l)	< 20	< 20	<4	<4	ND
Total Iron (µg/l)	< 21	< 21	99	100	1
Dissolved Lead µg/l)	< 0.10	< 0.10	< 1	< 1	ND
Total Lead (µg/l)	< 0.11	< 0.11	< 1.1	< 1.1	ND
Dissolved Manganese (µg/l)	< 0.5	< 0.5	4.6	5.2	12
Total Manganese (µg/l)	< 0.53	< 0.53	6.3	6.4	2
Dissolved Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	ND
Total Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	ND
Dissolved Molybdenum (µg/l)	< 0.2	< 0.2	10.9	10.8	1
Total Molybdenum (µg/l)	< 0.21	< 0.21	10.7	10.9	2
Dissolved Nickel (µg/l)	< 0.5	< 0.5	< 7	< 7	ND
Total Nickel (µg/l)	< 0.53	< 0.53	< 7	< 7	ND
Dissolved Selenium (µg/l)	< 1	< 1	< 4	< 4	ND
Total Selenium (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Dissolved Silver (µg/l)	< 0.10	< 0.10	< 0.4	< 0.4	ND
Total Silver (µg/l)	< 0.11	< 0.11	< 0.43	< 0.43	ND
Dissolved Tin (µg/l)	< 0.5	< 0.5	< 5	< 5	ND
Total Tin (µg/l)	< 0.53	< 0.53	< 5.3	< 5.3	ND
Dissolved Vanadium (µg/l)	< 1	< 1	1.6	1.4	13
Total Vanadium (µg/l)	< 1.1	< 1.1	1.7	1.5	13
Dissolved Zinc (µg/l)	< 1	< 1	< 4	< 4	ND
Total Zinc (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Total Phosphorus (µg/l)	< 4	< 4	24	22	9
Dissolved Reactive Phosphorus (µg/l)	< 4	< 4	13	12.6	3
Total Nitrogen (µg/l)	< 110	< 110	300	< 300	ND
Total Kjeldahl Nitrogen (TKN) (µg/l)	< 100	< 100	200	< 200	ND
Total Ammonia (µg/l)	< 10	< 10	10	11	10
Nitrate-N + Nitrite-N (µg/l)	< 2	< 2	2.6	3.3	24
Chlorophyll *a* (µg/L)	< 0.2	< 0.2	0.6	0.5	18

Table 19 Summary of Vision Environment quality control data for June 2020 water organic sampling. *ND = not determined as one or more samples was below LOR. * Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.*

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 3 (A) (µg/l)	UH 3 (B) (µg/l)	Variation (%)
C7 - C9	<100	<100	<100	<100	ND
C10 - C14	<200	<200	<200	<200	ND
C15 - C36	<400	<400	<400	<400	ND
Total hydrocarbons (C7 - C36)	<700	<700	<700	<700	ND
Benzene	<1	<1	<1	<1	ND
Toluene*	<1	<1	<1	<1	ND
Ethylbenzene	<1	<1	<1	<1	ND
2,3,4,6-Tetrachlorophenol (TCP)	<0.4	<0.4	<0.4	<0.4	ND
2,4,5-Trichlorophenoxyacetic acid (245T)	<0.4	<0.4	<0.4	<0.4	ND
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<0.4	<0.4	<0.4	<0.4	ND
2,4'-DDD	<0.01	<0.01	<0.01	<0.01	ND
2,4'-DDE	<0.01	<0.01	<0.01	<0.01	ND
2,4'-DDT	<0.01	<0.01	<0.01	<0.01	ND
2,4-Dichlorophenoxyacetic acid (24D)	<0.4	<0.4	<0.4	<0.4	ND
2,4-Dichlorophenoxybutyric acid (24DB)	<0.6	<0.6	<0.6	<0.6	ND
2-methyl-4-chlorophenoxyacetic acid (MCPA)	<0.4	<0.4	<0.4	<0.4	ND
2-methyl-4-chlorophenoxybutanoic acid (MCPB)	<0.4	<0.4	<0.4	<0.4	ND
4,4'-DDD	<0.01	<0.01	<0.01	<0.01	ND
4,4'-DDE	<0.01	<0.01	<0.01	<0.01	ND
4,4'-DDT	<0.01	<0.01	<0.01	<0.01	ND
Acetochlor	<0.04	<0.04	<0.04	<0.04	ND
Acifluorfen	<0.4	<0.4	<0.4	<0.4	ND
Alachlor	<0.04	<0.04	<0.04	<0.04	ND
Aldrin	<0.005	<0.005	<0.005	<0.005	ND
alpha-BHC	<0.01	<0.01	<0.01	<0.01	ND
Atrazine	<0.04	<0.04	<0.04	<0.04	ND
Atrazine-desethyl	<0.04	<0.04	<0.04	<0.04	ND
Atrazine-desisopropyl	<0.08	<0.08	<0.08	<0.08	ND
Azaconazole	<0.02	<0.02	<0.02	<0.02	ND
Azinphos-methyl	<0.08	<0.08	<0.08	<0.08	ND
Benalaxyl	<0.02	<0.02	<0.02	<0.02	ND
Bendiocarb	<0.04	<0.04	<0.04	<0.04	ND
Benodanil	<0.08	<0.08	<0.08	<0.08	ND
Bentazone	<0.4	<0.4	<0.4	<0.4	ND
beta-BHC	<0.01	<0.01	<0.01	<0.01	ND
Bifenthrin	<0.02	<0.02	<0.02	<0.02	ND
Bitertanol	<0.08	<0.08	<0.08	<0.08	
Bromacil	<0.04	<0.04	<0.04	<0.04	ND
Bromophos-ethyl	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 3 (A) (µg/l)	UH 3 (B) (µg/l)	Variation (%)
Bromopropylate	<0.04	<0.04	<0.04	<0.04	ND
Bromoxynil	<0.4	<0.4	<0.4	<0.4	ND
Bupirimate	<0.04	<0.04	<0.04	<0.04	ND
Buprofezin	<0.04	<0.04	<0.04	<0.04	ND
Butachlor	<0.04	<0.04	<0.04	<0.04	ND
Captafol	<0.2	<0.2	<0.2	<0.2	ND
Captan	<0.08	<0.08	<0.08	<0.08	ND
Carbaryl	<0.04	<0.04	<0.04	<0.04	ND
Carbofenothion	<0.04	<0.04	<0.04	<0.04	ND
Carbofuran	<0.04	<0.04	<0.04	<0.04	ND
Carboxin	<0.04	<0.04	<0.04	<0.04	ND
Chlorfenvinphos	<0.04	<0.04	<0.04	<0.04	ND
Chlorfluazuron	<0.04	<0.04	<0.04	<0.04	ND
Chlorothalonil	<0.04	<0.04	<0.04	<0.04	ND
Chlorpropham	<0.08	<0.08	<0.08	<0.08	ND
Chlorpyrifos	<0.04	<0.04	<0.04	<0.04	ND
Chlorpyrifos-methyl	<0.04	<0.04	<0.04	<0.04	ND
Chlortoluron	<0.08	<0.08	<0.08	<0.08	ND
Chlozolinate	<0.04	<0.04	<0.04	<0.04	ND
cis-Chlordane	<0.005	<0.005	<0.005	<0.005	ND
Clopyralid	<0.4	<0.4	<0.6	<0.6	ND
Coumaphos	<0.08	<0.08	<0.08	<0.08	ND
Cyanazine	<0.04	<0.04	<0.04	<0.04	ND
Cyfluthrin	<0.04	<0.04	<0.04	<0.04	ND
Cyhalothrin	<0.04	<0.04	<0.04	<0.04	ND
Cypermethrin	<0.08	<0.08	<0.08	<0.08	ND
Cyproconazole	<0.04	<0.04	<0.04	<0.04	ND
Cyprodinil	<0.04	<0.04	<0.04	<0.04	ND
delta-BHC	<0.01	<0.01	<0.01	<0.01	ND
Deltamethrin (including Tralomethrin)	<0.06	<0.06	<0.06	<0.06	ND
Demeton-S-methyl	<0.08	<0.08	<0.08	<0.08	ND
Diazinon	<0.02	<0.02	<0.02	<0.02	ND
Dicamba	<0.4	<0.4	<0.4	<0.4	ND
Dichlobenil	<0.04	<0.04	<0.04	<0.04	ND
Dichlofenthion	<0.04	<0.04	<0.04	<0.04	ND
Dichlofluanid	<0.04	<0.04	<0.04	<0.04	ND
Dichloran	<0.2	<0.2	<0.2	<0.2	ND
Dichlorprop	<0.4	<0.4	<0.4	<0.4	ND
Dichlorvos	<0.08	<0.08	<0.08	<0.08	ND
Dicofol	<0.2	<0.2	<0.2	<0.2	ND
Dicrotophos	<0.04	<0.04	<0.04	<0.04	ND
Dieldrin	<0.005	<0.005	<0.005	<0.005	ND
Difenoconazole	<0.08	<0.08	<0.08	<0.08	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 3 (A) (µg/l)	UH 3 (B) (µg/l)	Variation (%)
Dimethoate	<0.08	<0.08	<0.08	<0.08	ND
Dinocap	<0.3	<0.3	<0.3	<0.3	ND
Diphenylamine	<0.08	<0.08	<0.08	<0.08	ND
Disulfoton	<0.04	<0.04	<0.04	<0.04	ND
Diuron	<0.04	<0.04	<0.04	<0.04	ND
Endosulfan I	<0.01	<0.01	<0.01	<0.01	ND
Endosulfan II	<0.01	<0.01	<0.01	<0.01	ND
Endosulfan sulfate	<0.01	<0.01	<0.01	<0.01	ND
Endrin	<0.005	<0.005	<0.005	<0.005	ND
Endrin aldehyde	<0.005	<0.005	<0.005	<0.005	ND
Endrin ketone	<0.01	<0.01	<0.01	<0.01	ND
EPN	<0.04	<0.04	<0.04	<0.04	ND
Esfenvalerate	<0.04	<0.04	<0.04	<0.04	ND
Ethion	<0.04	<0.04	<0.04	<0.04	ND
Etrimfos	<0.04	<0.04	<0.04	<0.04	ND
Famphur	<0.04	<0.04	<0.04	<0.04	ND
Fenamiphos	<0.04	<0.04	<0.04	<0.04	ND
Fenarimol	<0.04	<0.04	<0.04	<0.04	ND
Fenitrothion	<0.04	<0.04	<0.04	<0.04	ND
Fenpropathrin	<0.04	<0.04	<0.04	<0.04	ND
Fenpropimorph	<0.04	<0.04	<0.04	<0.04	ND
Fensulfothion	<0.04	<0.04	<0.04	<0.04	ND
Fenthion	<0.04	<0.04	<0.04	<0.04	ND
Fenvalerate	<0.04	<0.04	<0.04	<0.04	ND
Fluazifop	<0.4	<0.4	<0.4	<0.4	ND
Fluazifop-butyl	<0.04	<0.04	<0.04	<0.04	ND
Fluometuron	<0.04	<0.04	<0.04	<0.04	ND
Fluroxypyr	<0.4	<0.4	<0.4	<0.4	ND
Flusilazole	<0.04	<0.04	<0.04	<0.04	ND
Fluvalinate	<0.04	<0.04	<0.04	<0.04	ND
Folpet	<0.08	<0.08	<0.08	<0.08	ND
Furalaxyl	<0.02	<0.02	<0.02	<0.02	ND
gamma-BHC (Lindane)	<0.01	<0.01	<0.01	<0.01	ND
Haloxyfop	<0.4	<0.4	<0.4	<0.4	ND
Haloxyfop-methyl	<0.04	<0.04	<0.04	<0.04	ND
Heptachlor	<0.005	<0.005	<0.005	<0.005	ND
Heptachlor epoxide	<0.005	<0.005	<0.005	<0.005	ND
Hexachlorobenzene	<0.04	<0.04	<0.04	<0.04	ND
Hexaconazole	<0.04	<0.04	<0.04	<0.04	ND
Hexazinone	<0.02	<0.02	<0.02	<0.02	ND
Hexythiazox	<0.2	<0.2	<0.2	<0.2	ND
Imazalil	<0.2	<0.2	<0.2	<0.2	ND
Indoxacarb	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 3 (A) (µg/l)	UH 3 (B) (µg/l)	Variation (%)
Iodofenphos	<0.04	<0.04	<0.04	<0.04	ND
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)	<0.2	<0.2	<0.2	<0.2	ND
Isazophos	<0.04	<0.04	<0.04	<0.04	ND
Isofenphos	<0.02	<0.02	<0.02	<0.02	ND
Kresoxim-methyl	<0.02	<0.02	<0.02	<0.02	ND
Leptophos	<0.04	<0.04	<0.04	<0.04	ND
Linuron	<0.05	<0.05	<0.05	<0.05	ND
m&p-Xylene	<2	<2	<2	<2	ND
Malathion	<0.04	<0.04	<0.04	<0.04	ND
Mecoprop	<0.4	<0.4	<0.4	<0.4	ND
Metalaxyl	<0.04	<0.04	<0.04	<0.04	ND
Methacrifos	<0.04	<0.04	<0.04	<0.04	ND
Methidathion	<0.04	<0.04	<0.04	<0.04	ND
Methiocarb	<0.04	<0.04	<0.04	<0.04	ND
Methoxychlor	<0.005	<0.005	<0.005	<0.005	ND
Metolachlor	<0.04	<0.04	<0.04	<0.04	ND
Metribuzin	<0.04	<0.04	<0.04	<0.04	ND
Mevinphos	<0.08	<0.08	<0.08	<0.08	ND
Molinate	<0.08	<0.08	<0.08	<0.08	ND
Myclobutanil	<0.04	<0.04	<0.04	<0.04	ND
Naled	<0.2	<0.2	<0.2	<0.2	ND
Nitrofen	<0.08	<0.08	<0.08	<0.08	ND
Nitrothal-Isopropyl	<0.04	<0.04	<0.04	<0.04	ND
Norflurazon	<0.08	<0.08	<0.08	<0.08	ND
Oryzalin	<0.6	<0.6	<0.6	<0.6	ND
Oxadiazon	<0.04	<0.04	<0.04	<0.04	ND
Oxychlordane	<0.02	<0.02	<0.02	<0.02	ND
Oxyfluorfen	<0.02	<0.02	<0.02	<0.02	ND
o-Xylene	<1	<1	<1	<1	ND
Paclobutrazol	<0.04	<0.04	<0.04	<0.04	ND
Parathion-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Parathion-methyl	<0.04	<0.04	<0.04	<0.04	ND
Penconazole	<0.04	<0.04	<0.04	<0.04	ND
Pendimethalin	<0.04	<0.04	<0.04	<0.04	ND
Pentachlorophenol (PCP)	<0.4	<0.4	<0.4	<0.4	ND
Permethrin	<0.02	<0.02	<0.02	<0.02	ND
Phorate	<0.08	<0.08	<0.08	<0.08	ND
Phosmet	<0.04	<0.04	<0.04	<0.04	ND
Phosphamidon	<0.04	<0.04	<0.04	<0.04	ND
Picloram	<0.4	<0.4	<0.4	<0.4	ND
Pirimicarb	<0.04	<0.04	<0.04	<0.04	ND
Pirimiphos-methyl	<0.04	<0.04	<0.04	<0.04	ND
Prochloraz	<0.2	<0.2	<0.2	<0.2	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			UH 3 (A) (µg/l)	UH 3 (B) (µg/l)	Variation (%)
Procymidone	<0.04	<0.04	<0.04	<0.04	ND
Prometryn	<0.02	<0.02	<0.02	<0.02	ND
Propachlor	<0.04	<0.04	<0.04	<0.04	ND
Propanil	<0.2	<0.2	<0.2	<0.2	ND
Propazine	<0.02	<0.02	<0.02	<0.02	ND
Propetamphos	<0.06	<0.06	<0.06	<0.06	ND
Propham	<0.04	<0.04	<0.04	<0.04	ND
Propiconazole	<0.04	<0.04	<0.04	<0.04	ND
Prothiofos	<0.04	<0.04	<0.04	<0.04	ND
Pyrazophos	<0.04	<0.04	<0.04	<0.04	ND
Pyrifenox	<0.04	<0.04	<0.04	<0.04	ND
Pyrimethanil	<0.04	<0.04	<0.04	<0.04	ND
Pyriproxyfen	<0.04	<0.04	<0.04	<0.04	ND
Quintozene	<0.08	<0.08	<0.08	<0.08	ND
Quizalofop	<0.4	<0.4	<0.4	<0.4	ND
Quizalofop-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Simazine	<0.04	<0.04	<0.04	<0.04	ND
Simetryn	<0.04	<0.04	<0.04	<0.04	ND
Sulfentrazone	<0.2	<0.2	<0.2	<0.2	ND
Sulfotep	<0.04	<0.04	<0.04	<0.04	ND
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]	<0.08	<0.08	<0.08	<0.08	ND
Tebuconazole	<0.04	<0.04	<0.04	<0.04	ND
Tebufenpyrad	<0.02	<0.02	<0.02	<0.02	ND
Terbacil	<0.04	<0.04	<0.04	<0.04	ND
Terbufos	<0.04	<0.04	<0.04	<0.04	ND
Terbumeton	<0.04	<0.04	<0.04	<0.04	ND
Terbuthylazine	<0.02	<0.02	<0.02	<0.02	ND
Terbuthylazine-desethyl	<0.04	<0.04	<0.04	<0.04	ND
Terbutryn	<0.04	<0.04	<0.04	<0.04	ND
Tetrachlorvinphos	<0.04	<0.04	<0.04	<0.04	ND
Thiabendazole	<0.2	<0.2	<0.2	<0.2	ND
Thiobencarb	<0.04	<0.04	<0.04	<0.04	ND
Thiometon	<0.08	<0.08	<0.08	<0.08	ND
Tolylfluanid	<0.02	<0.02	<0.02	<0.02	ND
Total Chlordane [(cis+trans)*100/42]	<0.02	<0.02	<0.02	<0.02	ND
Total DDT Isomers	<0.06	<0.06	<0.06	<0.06	ND
trans-Chlordane	<0.005	<0.005	<0.005	<0.005	ND
Triadimefon	<0.04	<0.04	<0.04	<0.04	ND
Triazophos	<0.04	<0.04	<0.04	<0.04	ND
Triclopyr	<0.4	<0.4	<0.4	<0.4	ND
Trifluralin	<0.04	<0.04	<0.04	<0.04	ND
Vinclozolin	<0.04	<0.04	<0.04	<0.04	ND

July 2020

Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Final Project Report

Water Quality Environmental Monitoring Services – Monthly Report

VISION ENVIRONMENT

A Trinity Consultants Company

www.visionenvironment.com.au

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Certified System Quality ISO 9001 SAI GLOBAL
Certified System ISO 45001 Occupational Health and Safety SAI GLOBAL
Certified System Environment ISO 14001 SAI GLOBAL

FILE REFERENCE

21082020 FINAL LPC Water Quality Environmental Monitoring July 2020 Final Project Report_VE

Summary

Since September 2016, Vision Environment (VE) has been undertaking water quality monitoring for the Environmental Monitoring and Management Plan (EMMP) associated with the Lyttelton Port Company (LPC) Channel Deepening Project (CDP) (Envisor, 2018). Baseline datasets were acquired from three spoil ground sites (SG1, SG2 and SG3), seven offshore sites (OS1 to OS7) and five inshore sites (UH1 to UH3, CH1 and CH2) to assess potential impacts of the dredging project.

Dredging operations for the CDP were undertaken from 29 August to 29 November 2018. Post-dredge monitoring was undertaken until 11 March 2019, when a smaller dredging operation began for the reclamation works at Cashin Quay and was completed on 23 March 2020. Channel maintenance dredging commenced at midday on 4 December 2019 and was completed 21 March 2020, thus commencing the post dredging monitoring phase, which ceased on project completion on 31 July 2020. Therefore, this is the final report for the CDP, completing monitoring for this project.

Post-dredge monitoring results collected during July 2020 are presented within this report. This monthly report includes comparisons of turbidity data collected during the initial baseline monitoring period from 1 November 2016 to 31 October 2017 (Fox, 2018).

Climatic Conditions: Lower precipitation was recorded at Cashin Quay during July (45 mm) compared to June (65 mm), with highest daily rainfall recorded on 1 July (16 mm). Flows from the Waimakariri River were comparatively low during July with peak flows recorded on 22 July at a maximum flow rate of 151 m^3/s, which was slightly lower than the peak flow rate recorded in June (168.9 m^3/s).

Monthly average air temperature (8.3°C) was lower than the mean air temperature of June (9.6°C) in line with seasonal cooling. Similar to recent months, inshore winds were predominantly from an easterly to north-easterly direction, with the highest mean daily wind speed recorded on 1 July (25.7 kts). Offshore wind and wave data is unavailable for July as the Watchkeeper was decommissioned on 17 May.

Currents: Current data was recorded at SG1 for July only. Data from SG3 and the Watchkeeper were not available due to both units requiring maintenance.

Maximum near-surface current speed at SG1 was recorded on 8 July coinciding with significant inshore wind speeds (>15 kts), while maximum near-seabed currents occurred on 18 July again in conjunction with medium to high inshore wind speeds. Near-surface currents at SG1 predominantly moved in a north-northeast direction and near-seabed currents tended to move in a westerly direction during July.

Turbidity: Consistent with previous results, mean turbidity in July was lowest among the spoil ground sites due to the deeper water column characteristic of these sites. Mean turbidity at the inshore monitoring locations of the central and upper harbour were amongst the higher turbidity sites as often reported, however mean turbidity at several of the offshore sites were higher than most commonly reported, particularly at site OS3 where turbidity peaked at ~60 NTU. This was driven by a prolonged period of elevated winds, from 16 to 22 July, increasing wave-energy along the coastline, which affected all sites to differing degrees.

Despite this, mean turbidity values for July remained lower than those recorded during the baseline monitoring period, though percentile statistics at OS3 were slightly higher than those recorded during the baseline monitoring period.

Turbidity peaks were also recorded at several sites including UH1, UH2, OS5 and the spoil ground sites at the beginning of the month when inshore wind speeds exceeded 15 kts on 1 July and 8 July.

Other Physicochemical Parameters: Mean monthly water temperatures were lower than those recorded in June continuing to display a seasonal decline. Consistent with previous winter sampling periods slightly lower temperatures were recorded in the upper and central harbour compared to offshore sites and also showed more variability throughout the month.

Surface pH during July was similar across all sites consistent with previous months reporting. Similar to the findings of June there was little spatial pattern in mean conductivity across the sites. Low rainfall and subsequent reduced localised freshwater input into the upper harbour are likely to explain the consistent results.

Dissolved oxygen (DO) concentrations showed typical diurnal fluctuations at all sites during July especially those situated inshore. DO at inshore sites was relatively consistent throughout July, although UH1 exhibited declining DO following heavy rainfall at the beginning of the month. DO concentrations at offshore and spoil ground sites were more variable at the beginning and end of the month. The spoil ground at OS5 in particular displayed cycles of decreasing and increasing DO from 22 July to the end of the month, which may be associated with increased vertical mixing during the high energy wave event.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 16 and 17 July. Depth profiles indicated a well-mixed water column at the majority of sites though a strong thermocline was evident at two offshore site (OS5 and SG1). These sites are situated to the northeast of the sampling array and therefore the cooler fresher surface waters at these sites may have originated from localised rainfall and stormwater run-off not recorded at Lytellton. As seen throughout the monitoring survey, DO declined with depth at the majority of sites within the offshore and spoil ground areas, which can be attributed to a reduction in photosynthesis with reduced light attenuation.

Turbidity measurements and total suspended solids (TSS) for surface waters were comparatively low to previous months among all sites, but were still elevated at inshore sites compared to the offshore areas, resulting in the shallowest estimations of euphotic depth as typically recorded during the monitoring program. Highest euphotic depths at the offshore monitoring sites were calculated to be 27.1 m at OS3 and no exceedances of WQGs were observed for sub-surface turbidity during the July sampling period.

Total phosphorous concentrations were below WQG at all sites with no particular spatial pattern observed between site locations. Concentrations of dissolved reactive phosphorous were above the WQG of 5 µg/L at all sites in July and is a continuation from results recorded in both May and June. Total nitrogen and total kjeldahl nitrogen (TKN) concentrations were below the limit of reporting (LOR) and below WQG at all sites except SG3, while total ammonia and nitrogen oxides were recorded above WQG at all of the sampling sites. The total ammonia and nitrogen oxides results were atypical and should be treated with caution. Elevated concentrations at these sites may be attributed to a combination of factors including introduction of nutrients from storm water run-off, degrading algal populations, or lack of utilization of available nutrients by algae in winter as demonstrated by low Chlorophyll-*a* concentrations, which were below the WQG value (4 µg/L) at all sites during July.

The majority of metals were reported as below the limit of reporting (LOR) and no dissolved metal fraction exceeded the designated WQG among the sites. Concentrations of total aluminum exceeded the 95 % species protection value at six sites however the dissolved and therefore bioavailable fraction remained < LOR at all sites. Total iron concentrations were detected at all sites though dissolved iron concentrations were only recorded at detectable levels at OS5, however no trigger values are available for this metal.

As typically observed total aluminium, iron and manganese displayed a strong spatial pattern with elevated concentrations found in the inshore locations (associated with increased suspended sediments). Total and dissolved chromium, vanadium and molybdenum were all detected during July but little spatial variability was noted and, while no trigger levels are available for molybdenum, levels of chromium and vanadium were both below their respective trigger levels at all sites.

Benthic physicochemical loggers, Benthic Photosynthetically Active Radiation (BPAR) and Sedimentation: All benthic equipment was removed at the beginning of May as data was deemed not necessary for the continuation of the Post Dredge monitoring period.

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Acronyms

ADCP	Acoustic Doppler Current Profiler
BPAR	Benthic Photosynthetically Active Radiation
BSL	Benthic self-logging sonde
CDP	Channel Deepening Project
DO	Dissolved oxygen
ECan	Environment Canterbury
EMMP	Environmental Monitoring and Management Plan
K_d	Light attenuation coefficient
KZ filter	Kolmogorov-Zurbenko filter
LOR	Limits of Reporting
LPC	Lyttelton Port Company
LYT	Lyttelton Port of Christchurch
NTU	Nephelometric Turbidity Units
PAR	Photosynthetically Active Radiation
QA/QC	Quality Assurance/Quality Control
SL	Self-Logger
ST	Subsurface telemetry
ST/ADCP	Subsurface telemetry/Acoustic Doppler Current Profiler
TAG	Technical Advisory Group
TDP	Total daily PAR
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VBCC	Vision Base Christchurch
VE	Vision Environment
WK	WatchKeeper telemetered weather station
WQG	Water Quality Guidelines

1 INTRODUCTION

Lyttelton Port Company (LPC) completed a Channel Deepening Project (CDP) to extend the existing navigational channel to allow larger vessels access to the Lyttelton Port of Christchurch (LYT), the South Island's largest port. Utilising background information provided by LPC and advice from the Technical Advisory Group (TAG) in relation to ambient conditions, locations of sensitive habitats and dredge impact hydrodynamic modelling scenarios, a water quality monitoring program was designed.

Baseline water quality monitoring and data collection undertaken by Vision Environment (VE) commenced in September 2016, progressing into dredge operations monitoring from 29 August 2018 with completion of works on 29 November 2018. Monitoring continued into a post-dredge phase up until 11 March 2019 when smaller scale dredging operations for the reclamation works commenced and this was completed on 23 March 2020. Note maintenance dredging of the channel was most recently undertaken from 4 December 2019 to 21 March 2020, with spoil being relocated to the maintenance dredge spoil ground located off Godley Head. The interpreted environmental data provided by VE has supported the process of the Environmental Monitoring and Management Plan (EMMP) for the LPC CDP (Envisor, 2018) and assisted to ascertain the potential impacts of the projects.

All dredge operations were completed on 23 March and post dredge monitoring continued until project completion on 31 July. Thus, the July monthly report represents the final reporting for the CDP.

2 METHODOLOGY

2.1 Approach

An overview of the methodology for the baseline and operations phases of water quality monitoring is provided in this section. A more detailed description of the importance of the measured parameters and the specific methodology for the CDP data collection and processing protocols can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology (Vision Environment, 2017).

2.1.1 Monitoring Locations and Equipment

Guided by the results of preliminary hydrodynamic modelling (MetOcean, 2016a, b) in addition to advice from the TAG, baseline and dredge operations, monitoring sites were located outside the area of predicted direct impact (i.e. dredge footprint and offshore disposal ground), but within the zone of dredging and dredge material placement influence, in addition to being in the vicinity of sensitive receptors (e.g. mussels farms and important mahinga kai sites). For ease of identification the harbour was divided into four areas: spoil ground (SG); offshore (OS); central harbour (CH); and upper harbour (UH), in which 15 locations were selected for monitoring (Figure 1). In each area, one to three monitoring sites were selected for the deployment of the various individual types of equipment, which are identified in Table 1. A total of 22 monitoring units were deployed across the 15 locations.

The offshore monitoring area (encompassing monitoring sites SG1 to SG3 and OS1 to OS7) is a deep water (generally >15 m) oceanic environment, where turbidity appears to be mostly driven by wind speeds and wave heights, resulting in resuspension of material from the benthos. Benthic physicochemical loggers, BPAR and altimeters previously deployed at these sites were removed in May as the data was no longer relevant for post dredge monitoring.

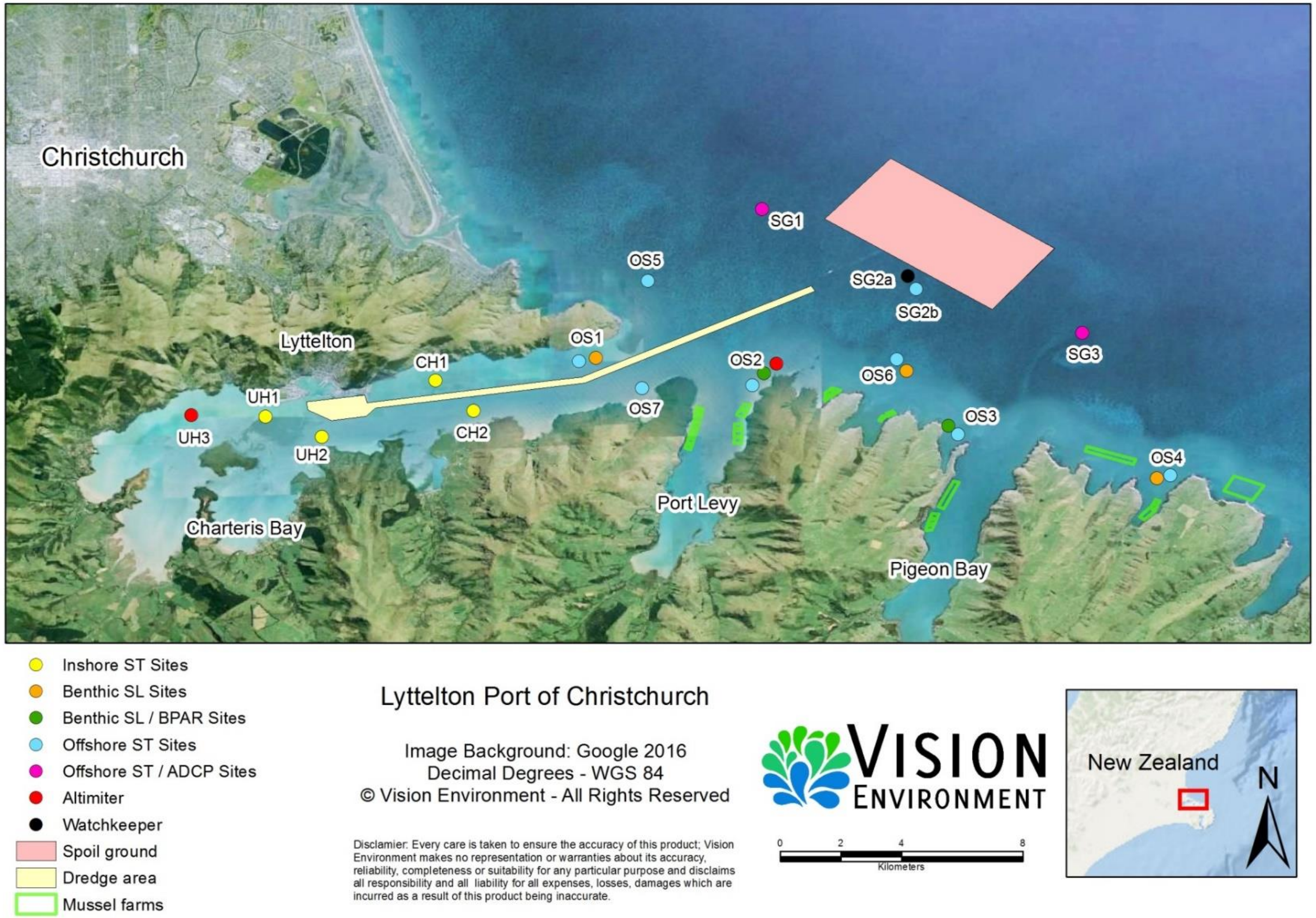


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

Table 1 Summary of monitoring sites and deployment equipment for the LPC Channel Deepening Project.
*ST = subsurface telemetry, SL = self-logger, *BSL = benthic self-logger, removed from all sites in May, *BPAR = benthic photosynthetically active radiation, removed from all sites in May and ADCP = Acoustic Doppler Current Profiler. *WK = WatchKeeper telemetered weather station removed from site on the 17 May for maintenance.*

Site	*WK	ST/ADCP	ST	*BSL sonde	*BSL sonde/BPAR	*Altimeter
	WatchKeeper telemetered weather station with currents and waves	Subsurface telemetered dual physico-chemistry and currents	Subsurface telemetered dual physico-chemistry	Benthic self-logging dual physico-chemistry	Benthic self-logging dual physico-chemistry and self-logging BPAR	Benthic self-logging dual altimeter
SG2a	√					
SG2b			√			
SG1		√				
SG3		√				
OS1			√	√		
OS2			√		√	√
OS3			√		√	
OS4			√	√		
OS5			√			
OS6			√	√		
OS7			√			
CH1			√			
CH2			√			
UH1			√			
UH2			√			
UH3						√
Total	1	2	12	3	2	2

The inshore monitoring area (including monitoring sites CH1 and CH2, and UH1 to UH3) is a shallow (<10 m depth) marine environment that, in addition to wind speeds and wave heights, is also influenced by tides (~ 0.2 m/s). The water column is well mixed at these sites, with little to no stratification. Therefore, surface loggers only have predominantly been utilised at these sites.

The comprehensive water quality component of the program involves the monitoring of:

- Physicochemistry, including turbidity; temperature; pH; conductivity and DO;
- Light attenuation (Photosynthetic Active Radiation or PAR);
- Benthic light (Benthic Photosynthetic Active Radiation or BPAR);
- Total Suspended Solids (TSS);
- Sedimentation rates;
- Nutrients and chlorophyll *a*;
- Metals (total and dissolved); and
- Organic compounds (biannually).

This monthly report presents data collected from the 22 monitoring locations for July 2020 during the post-dredge phase of operations. Monthly water sampling and depth profiling was conducted on 16 and 17 July 2020. A summary of climatic conditions during this period is provided, in addition to the results of continuous and discrete water sampling with comparisons to the baseline monitoring period.

2.1.2 Water Quality Guidelines

Water quality monitoring data from LYT were compared to the Australian and New Zealand Water Quality Guidelines (WQG) default trigger values (ANZG, 2018). In the absence of specific trigger values for New Zealand estuarine or marine ecosystems, the WQG suggest the use of trigger values for south-east Australian estuarine and marine ecosystems.

Total metals represent the concentration of metals determined in an unfiltered sample (those bound to sediments or colloidal particles in addition to dissolved metals), while dissolved metals are defined as those which pass through a 0.45 µm membrane filter (APHA, 2005). Specific trigger levels for varying levels of ecosystem protection (99%, 95%, 90% and 80% of species) have been derived for several metals. These guidelines refer to the dissolved fraction, as they are considered to be the potentially bioavailable fraction (ANZG, 2018). The LYT coastal environment could be described as slightly-to-moderately disturbed, therefore the 95% WQG trigger value was considered appropriate for comparison.

3 RESULTS & DISCUSSION

3.1 Metocean Conditions

3.1.1 Wind and precipitation

During July a total of 45 mm of rainfall was recorded at Cashin Quay, which was significantly lower than the total precipitation recorded in June (65 mm). Maximum rainfall was recorded on 1 July at 16 mm (Metconnect, 2020) (Figure 2). Freshwater flows from the Waimakariri River, can be transported south along the coastline and enter Lyttelton Harbour several days' post flow. Flow rates during July were similar to June and were low compared to the warmer months, ranging from 45.4 m^3/s and 151.3 m^3/s. Maximum flow rate occurred on 22 July (ECAN, 2020).

Inshore winds during July predominantly occurred from an east to north-easterly direction (Metconnect, 2020). Highest mean wind speed (25.7 kts) was recorded on 1 July from a west south-westerly direction. Maximum wind gusts (49 kts) also occurred on 1 July from a south-westerly direction.

Daily mean air temperatures at Cashin Quay ranged from 5°C to 13°C, resulting in a monthly mean air temperature of 8.3°C, slightly lower than the mean air temperature recorded in June of 9.6°C (Metconnect, 2020) and in line with seasonal cooling.

The Watchkeeper weather buoy was decommissioned for maintenance during May and has not been redeployed at site. Therefore, site specific offshore metocean data is unavailable for July.

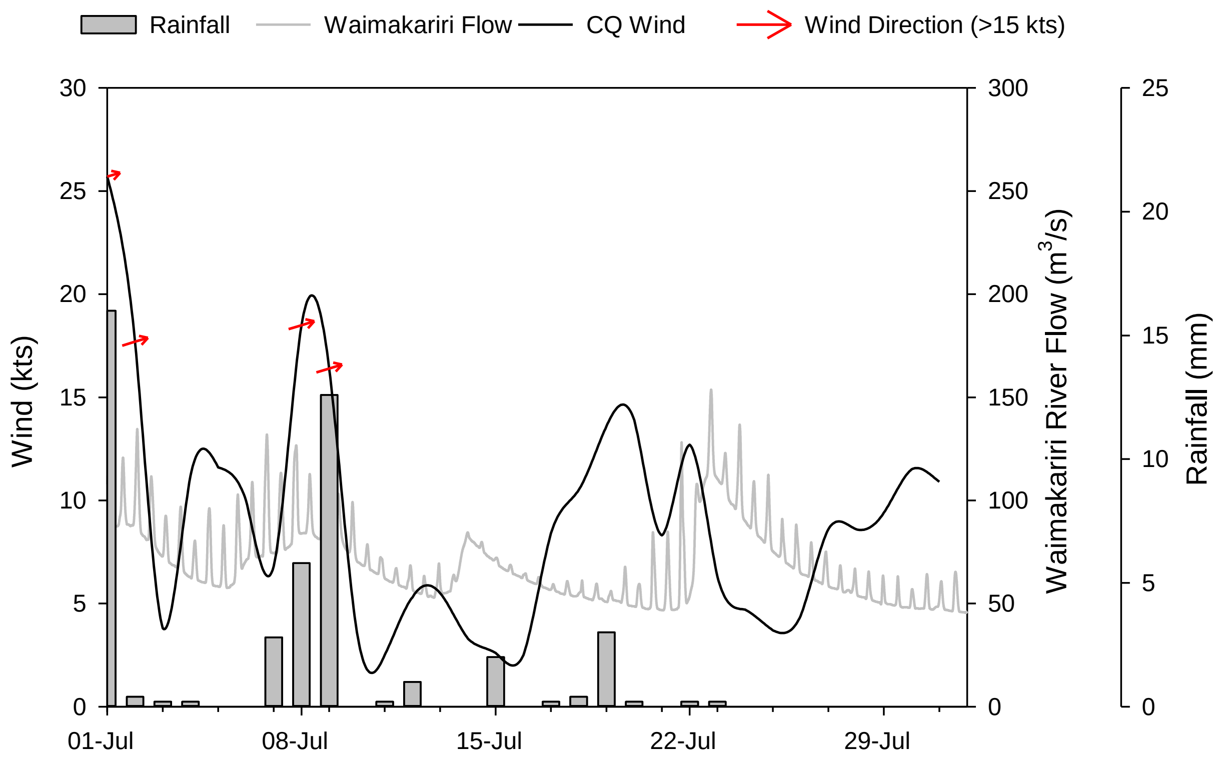


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during July 2020.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

3.1.2 Currents

Acoustic Doppler Current Profilers (ADCPs) are deployed at the spoil ground monitoring sites SG1, SG2a (Watchkeeper) and SG3, reporting the speed and direction of currents in a profile from the sea surface to seabed. Note that Watchkeeper was removed from site for maintenance in May and therefore the following analyses does not include data from that site. In addition, unit SG3 went offline in early July and therefore data from that site is also not available.

Summary ADCP statistics of available data are presented within Table 2 and Figure 3 Additional current information in the form of weekly current speed, direction and associated shear stress plots are provided in Figures 23 and 24 in the Appendix. Note that the ADCP data are presented in this report using the UTC time format.

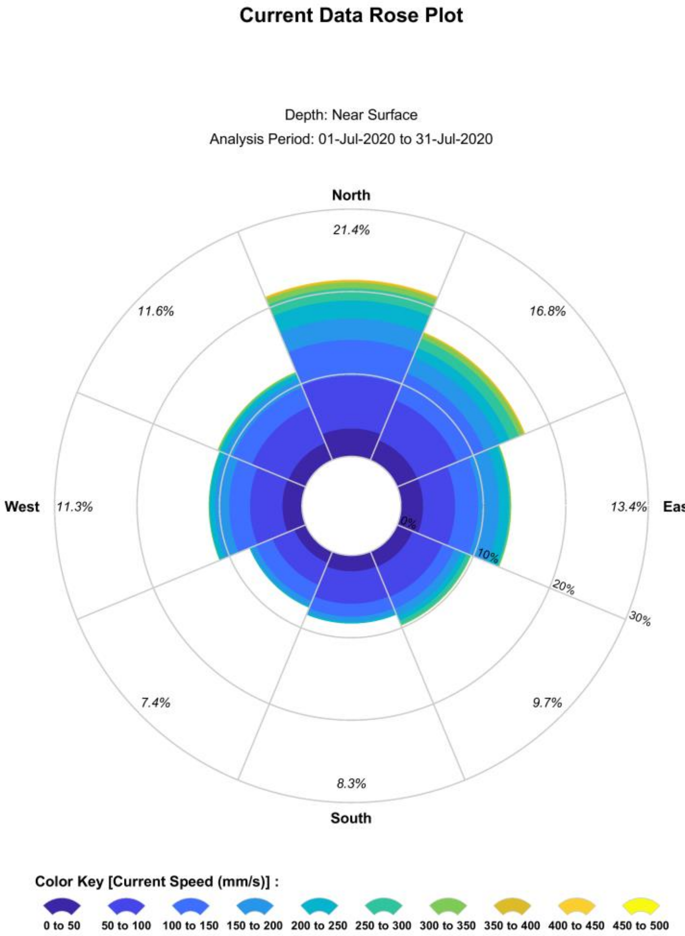
Table 2 Parameter statistics for spoil ground ADCPs during July 2020.
**SG2a was removed for maintenance on 17 May and therefore no data is available. **The instrument at SG3 was removed from site for servicing at the beginning of July and therefore no data is available.*

Parameter	Depth	Site		
		SG1	*SG2a	**SG3
Minimum current speed (mm/s)	*Near-surface*	1	ND	ND
	Near-seabed	1	ND	ND
Maximum current speed (mm/s)	*Near-surface*	436	ND	ND
	Near-seabed	589	ND	ND
Mean current speed (mm/s)	*Near-surface*	112	ND	ND
	Near-seabed	91	ND	ND
Standard deviation of current speed (mm/s)	*Near-surface*	73	ND	ND
	Near-seabed	66	ND	ND
Current speed, 95^{th} percentile (mm/s)	*Near-surface*	261	ND	ND
	Near-seabed	226	ND	ND

Maximum near-surface current speed at SG1 was recorded on 8 July (436 mm/s) and the maximum near-seabed current speed was recorded on 18 July (589 mm/s). Mean inshore winds on 8 July were high (>15 kts) and predominantly coming from a west south-westerly direction, this day also produced the second highest recorded wind gust of the month at 48 kts. Winds on 18 July were not as severe, averaging 10.5 kts, and originating from an east north-easterly direction.

The time-series plots (Figures 23 and 24 in Appendix) illustrate time-varying current direction, whilst the current rose diagram (Figures 3) depict the distribution of current direction and velocity in the near-surface and near-seabed layers at SG1. When interpreting the current data, note that the convention for defining current direction is the direction in which the current flows *towards*, which is the reference used throughout the Figures presented.

Dominant flows of near-surface currents at SG1 tended to move towards north-northeast (38.2%), while near-seabed currents at this site predominantly moved towards a westerly direction (44.1 %).



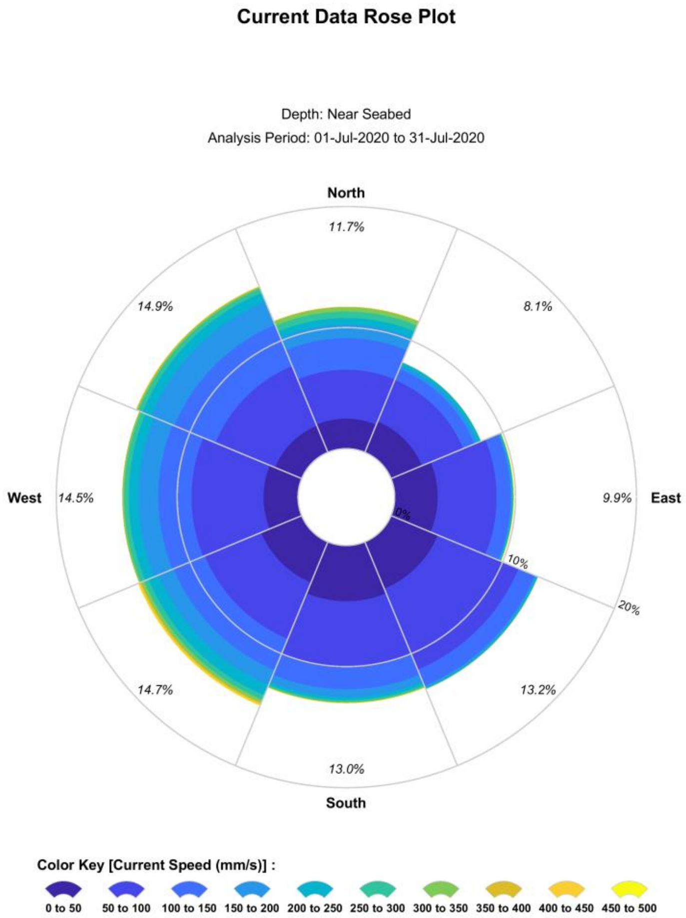


Figure 3 Near-surface and near-seabed current speed and direction at SG1 during July 2020.
Speed intervals of 50 mm/s are used.

3.2 Continuous Physicochemistry Loggers

Physical and chemical properties of the water column are measured at monitoring sites every 15 minutes by dual telemetered surface loggers. Benthic loggers that were deployed at five offshore sites (OS1 to OS4 and OS6) were removed in May as the data was no longer required for the post-dredge phase of the project. In conjunction with the continuous loggers, discrete depth profiles of all physicochemical parameters were also conducted at all 15 monitoring sites on 16 and 17 July 2020. Further details regarding the methodology used can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017).

Summary statistics for each physicochemical parameter recorded during July are presented in Tables 3 to 12. Validated datasets for surface measurements are also presented in Figures 5 to 16. Due to the inherent high level of variability in the turbidity datasets, a 24-hour rolling average has been calculated every 15 minutes to act as a smoothing technique and aid in data interpretation.

3.2.1 Turbidity

Of key importance within the real time parameters recorded are the surface turbidity measurements, due to their relevance to established trigger values for management of dredge operations. As such, summary turbidity statistics for the initial baseline period of monitoring from 1 November 2016 to 31 October 2017 (Fox, 2018) are also presented in Tables 3 to 5 to allow a comparison with the July 2020 post dredge monitoring data. Data from SG3 is only available until 8 July due to unit malfunction.

July Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 2.7 to 4.1 NTU) at the inshore monitoring sites (Table 3 and Figure 4). Mean surface turbidity at the offshore sites also exhibited some comparatively high values ranging from 1.2 – 4.3 NTU with the highest mean recorded at OS3. Surface turbidity levels were typically lower at the spoil ground sites (1.1 to 2.1 NTU), which can be attributed to the deeper water column limiting incursion of seafloor sediment resuspension at the sub-surface.

During July turbidity across the inner harbour was relatively low for most of the month. However, peaks (> 20 NTU) occurred at site UH2 on 1 July in association with strong inshore winds (>15 kts) and wind gusts of 49 kts. Further peaks in turbidity were recorded at UH2, CH1 and CH2 on 21 and 22 July. Although inshore winds were not as strong at this time (<15 kts), increased wind speeds were recorded and elevated for a prolonged period (from 16 to 22 July) (Figure 5).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) exhibited a comparable pattern to the inshore sites with peaks in surface turbidity from 21 to 23 July, these were most pronounced at OS3, OS4 and OS7 (Figure 6 and Figure 7). Site OS3 in particular recorded a large spike in turbidity (>50 NTU) on 21 July and a 24-hour rolling average of ~20 NTU compared to other offshore sites that peaked at ~10 NTU (Figure 4). This peak was responsible for the higher than usual monthly mean typically observed at this site. Interestingly, a similar event occurred in July 2019 (Vision Environment, 2019) when elevated wave heights from a north-easterly direction initiated a strong swell and back wash against the coastline creating elevated turbidity (>100 NTU) at OS3. In the absence of offshore metocean data, it is more than likely the same wave conditions observed in July 2019 prevailed in July 2020, creating wave-energies that increased turbidity particularly among the nearshore sites.

Table 3 Mean turbidity and statistics at inshore water quality logger sites during July 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for July are means ± se, range and percentiles (n = 2934 to 2964) Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU) Surface July	Surface Baseline
UH1	Mean ± se	3.3 ± 0.0	12
	Range	< 1 – 14.2	-
	99th	9.0	39
	95th	6.3	22
	80th	4.4	15
UH2	Mean ± se	3.4 ± 0.1	10
	Range	< 1 – 30.4	-
	99th	13.8	32
	95th	8.6	20
	80th	4.9	13
CH1	Mean ± se	4.1 ± 0.0	9
	Range	1.7 – 15.1	-
	99th	11.0	29
	95th	7.5	18
	80th	5.3	12
CH2	Mean ± se	2.7 ± 0.0	8
	Range	< 1 – 17.8	-
	99th	10.2	24
	95th	6.2	16
	80th	3.6	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during July 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for July are means ± se, range and percentiles (n = 656 to 2962). Baseline values modified from Fox 2018. Note data from SG3 is only available until 8 July and therefore statistics are derived from this period only.

Site	Statistic	Turbidity (NTU) Surface July	Surface Baseline
SG1	Mean ± se	1.2 ± 0.0	4.2
	Range	< 1 – 9.0	-
	99th	7.2	14
	95th	5.1	10
	80th	1.7	6.2
SG2	Mean ± se	2.1 ± 0.0	4.6
	Range	< 1 – 7.0	-
	99th	5.7	20
	95th	4.6	11
	80th	2.5	7.0
SG3	Mean ± se	1.1 ± 0.0	3.6
	Range	< 1 – 6.4	-
	99th	4.8	13
	95th	3.5	7.7
	80th	1.8	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during July 2020 and Baseline period (1 November 2016 to 31 October 2017).
Values for July are means ± se, range and percentiles (n = 2917 to 2963). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU)	
		Surface July	Surface Baseline
OS1	Mean ± se	2.3 ± 0.0	7.5
	Range	< 1– 13.9	-
	99th	8.0	24
	95th	5.5	16
	80th	3.2	10
OS2	Mean ± se	3.5 ± 0.0	6.4
	Range	< 1 – 13.4	-
	99th	10.9	18
	95th	8.1	13
	80th	4.7	9.0
OS3	Mean ± se	4.3 ± 0.1	6.6
	Range	< 1 – 62.3	-
	99th	23.1	27
	95th	15.4	15
	80th	6.7	8.9
OS4	Mean ± se	1.9 ± 0.1	5.9
	Range	< 1 -22.5	-
	99th	13.3	20
	95th	8.2	13
	80th	2.9	8.3
OS5	Mean ± se	1.2 ± 0.0	4.6
	Range	< 1 – 9.0	-
	99th	6.4	19
	95th	4.3	11
	80th	1.9	6.4
OS6	Mean ± se	2.6 ± 0.1	4.7
	Range	< 1 – 14.9	-
	99th	12.1	19
	95th	8.5	12
	80th	4.7	7.2
OS7	Mean ± se	3.1 ± 0.1	6.4
	Range	< 1 – 18.7	-
	99th	13.1	23
	95th	9.1	14
	80th	5.0	9.2

Further offshore at OS5 surface turbidity remained below 10 NTU for the whole month, although a peak in turbidity still occurred on 21 and 22 July (Figure 8). OS6 recorded a short-lived turbidity peak on 7 July then remained below 5 NTU until 21 July, when turbidity reached ~15 NTU on 22 July. The spoil ground sites, which are typically characterised by low turbidity remained below 10 NTU throughout the month but again peaks in turbidity were observed in association with high wind speeds on 7 July at SG2 and at both SG1 and SG2 during the weather episode of 21 July. Unfortunately, data from site SG3 is not available after 8 July as the instruments were removed from site for maintenance.

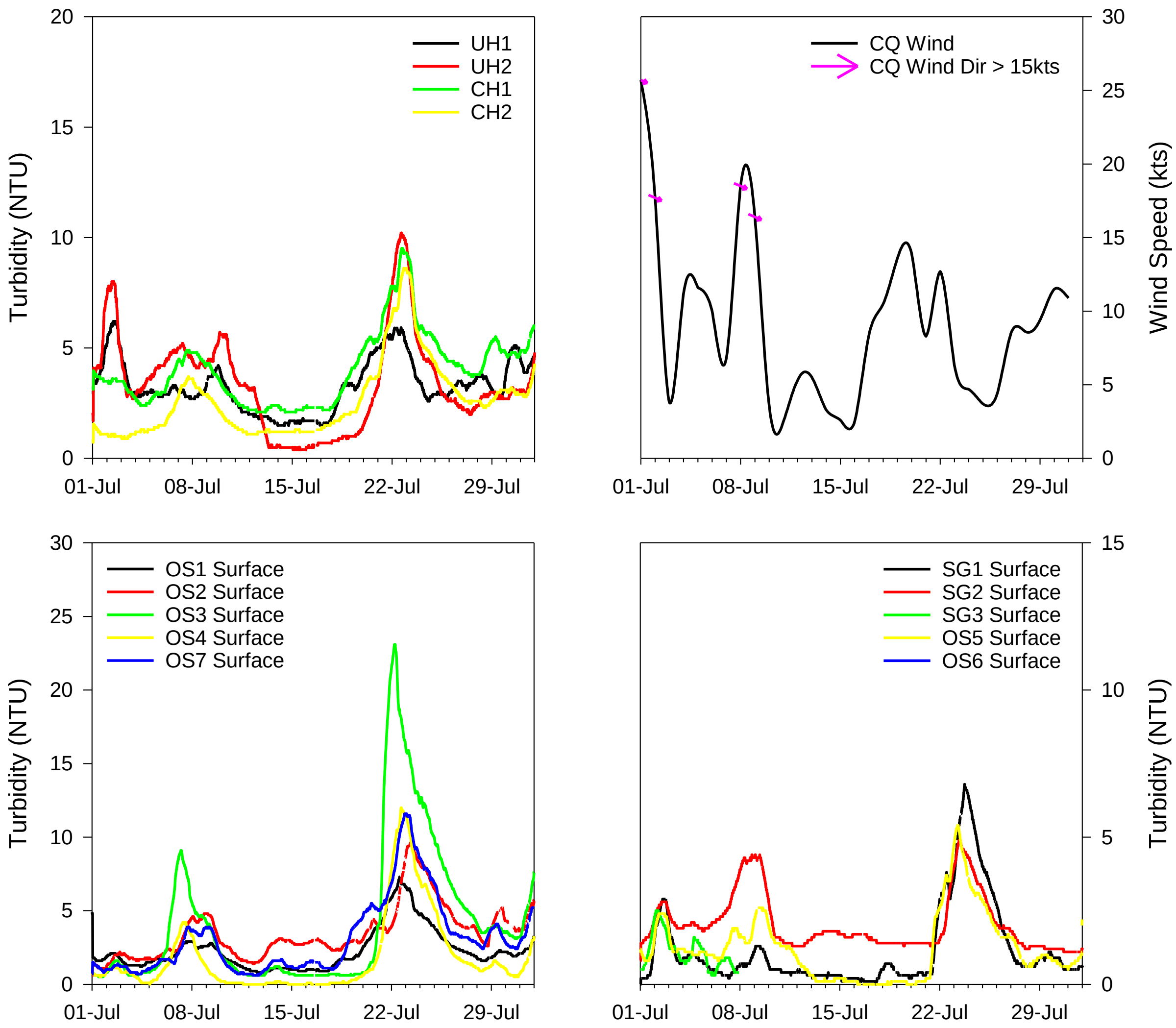


Figure 4 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore during July 2020.
Note differing scales between plots. Arrows indicate the direction of travel for inshore winds greater than 15 knots. The watchkeeper (WK) buoy was removed from site (SG2) for maintenance on the 17 May and has not been re-instated, therefore offshore metocean data is not presented. Additionally, the instruments at SG3 were also removed for maintenance on 8 July.

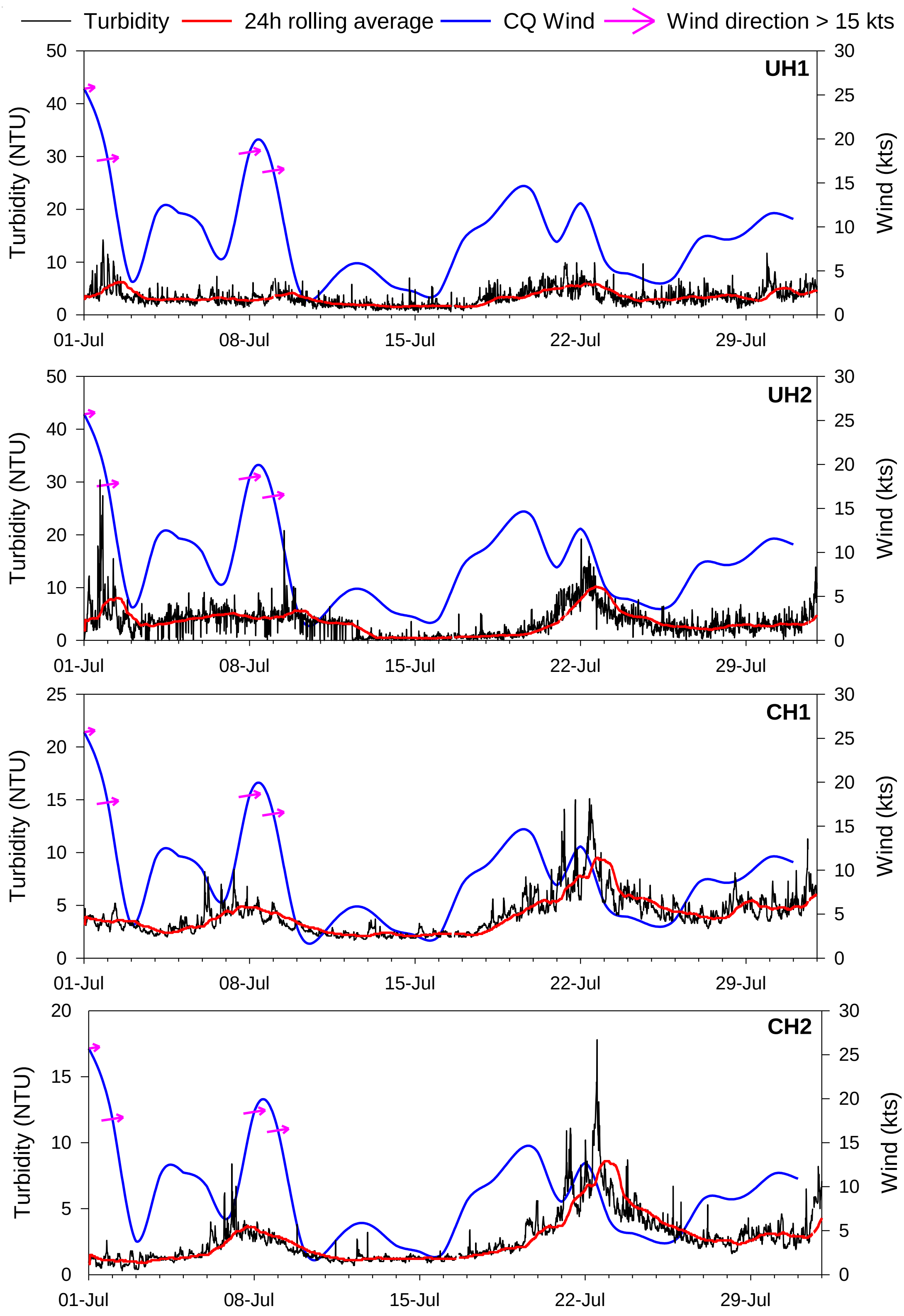


Figure 5 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during July 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

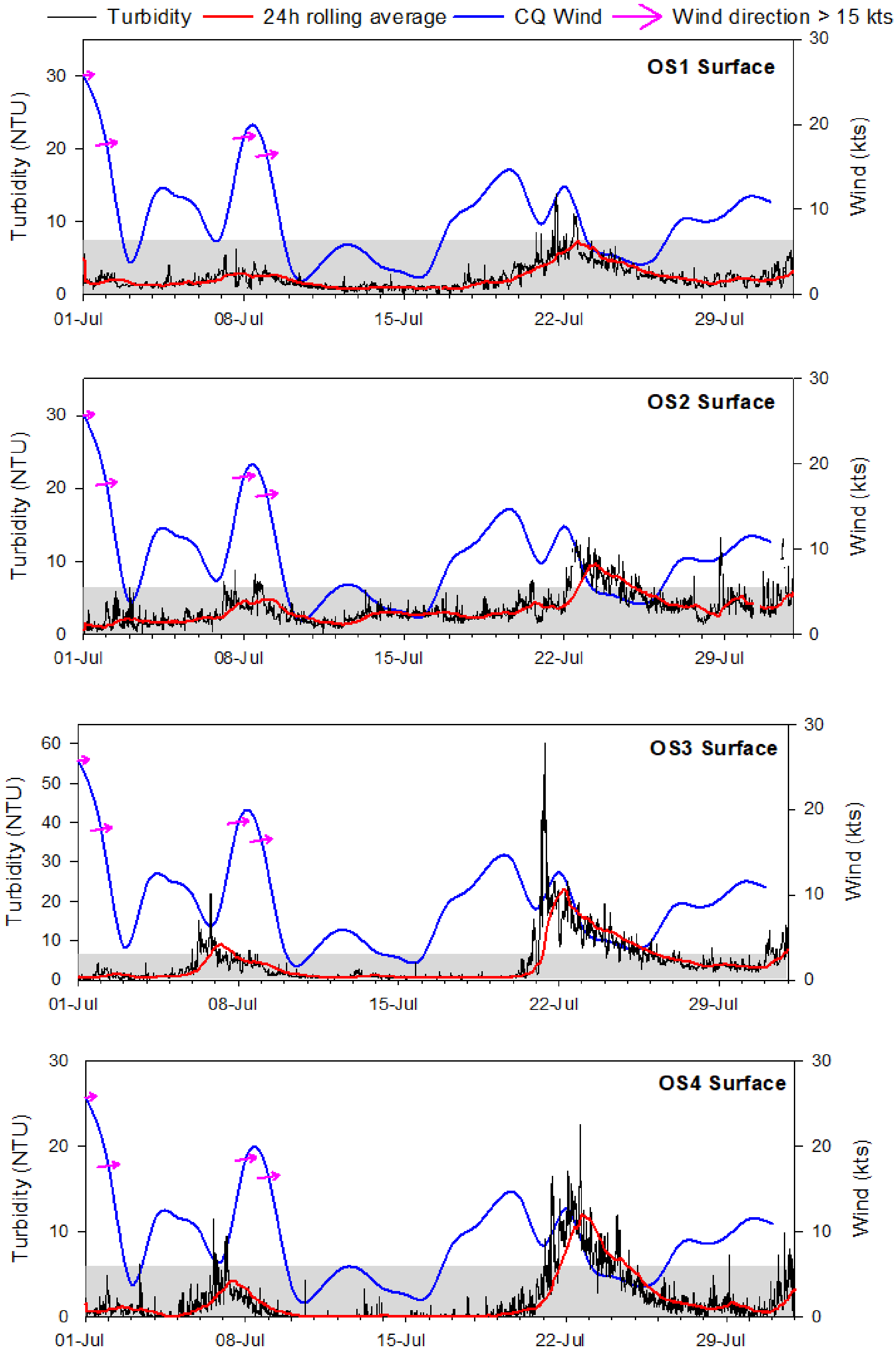


Figure 6 Surface turbidity at offshore sites (OS1 to OS4) during July 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity, note differing turbidity scales.

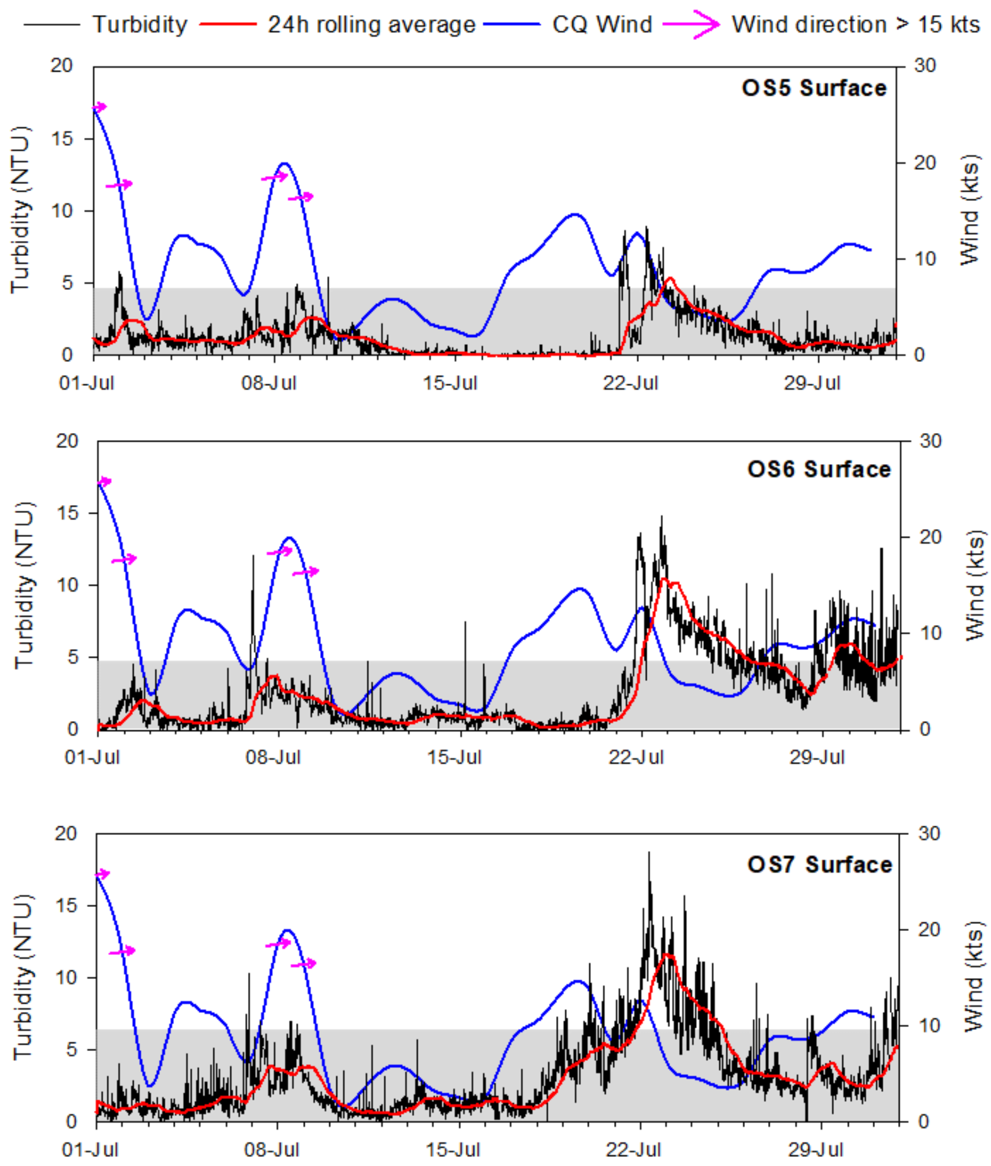


Figure 7 Surface turbidity and inshore daily averaged winds at inshore sites (OS5 to OS7) during July 2020.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

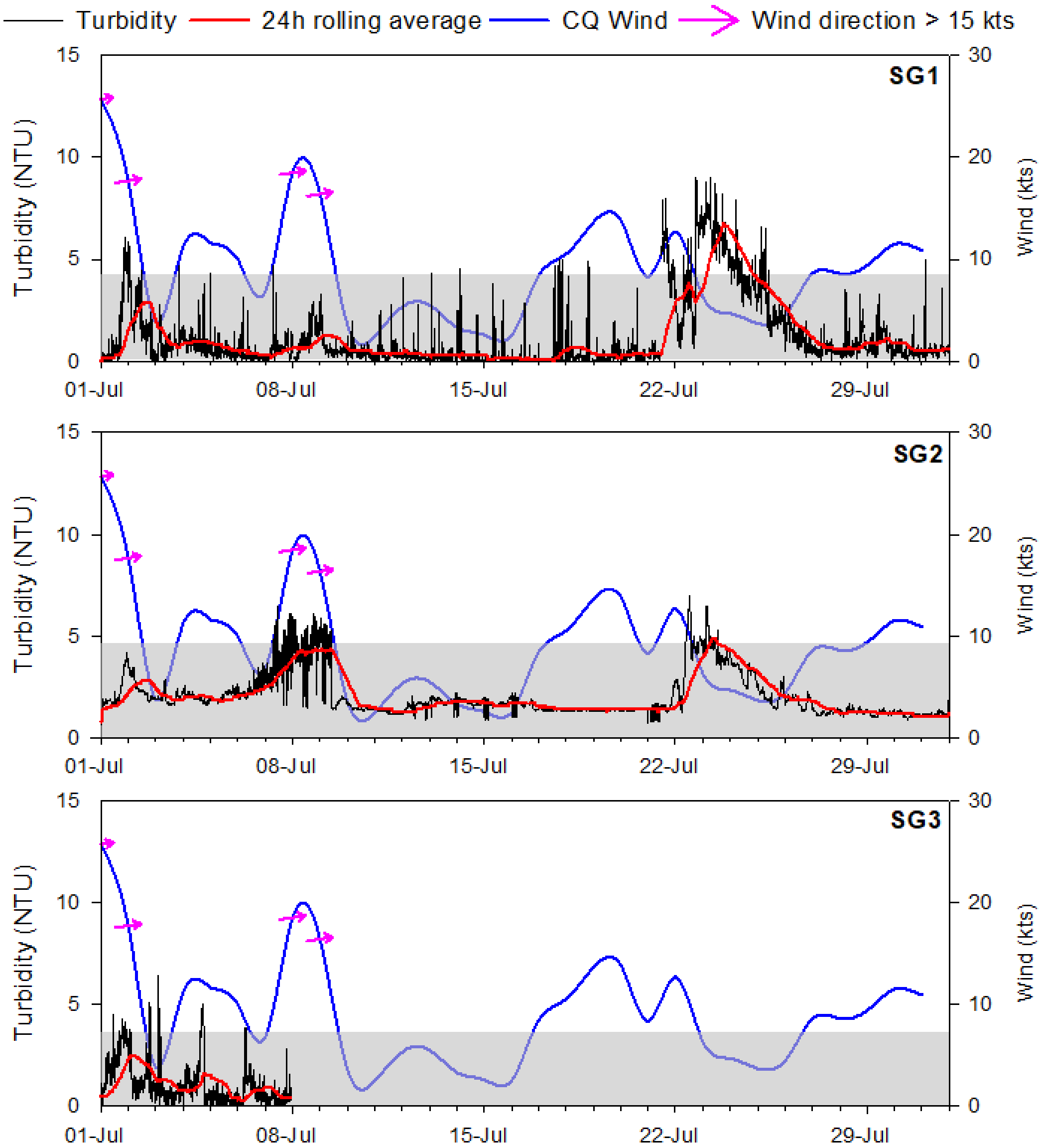


Figure 8 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during July 2020.
Grey shading indicates the baseline mean turbidity. Arrows indicate the direction of travel for inshore winds greater than 15 knots. Note data only available for SG3 until 8 July.

Comparison to Baseline:

Mean surface turbidity values remained lower than the values calculated from the baseline monitoring period at all sites However the 95th percentile statistics at OS3 was just above the baseline value (15 NTU) at 15.4 NTU during July (Tables 3 to 5, Figures 5 to 9). This was driven by a prolonged weather event, increased wind and wave energy which affected all sites but particularly those nearshore and to the south-west.

3.2.2 Temperature

Mean monthly sea surface temperatures during July ranged from 8.7 to 10.3°C (Table 6), which was lower than those recorded in June (9.9 to 11.4°C), in line with continued seasonal cooling. While an overall declining temperature trend was recorded at the offshore and spoil ground monitoring sites throughout July, the sites of the upper harbour and channel reported a more variable temperature profile over time indicating the influence of freshwater and storm water incursions (Figures 9 and 10).

Table 6 Mean temperature at inshore, spoil ground and offshore water quality sites during July 2020. *Values are means ± se (n = 656 to 2963).*

Site	Temperature (°C)
	Surface loggers
UH1	8.7 ± 0.0
UH2	8.8 ± 0.0
CH1	9.1 ± 0.0
CH2	9.3 ± 0.0
SG1	9.6 ± 0.0
SG2	9.7 ± 0.0
SG3	10.3 ± 0.0
OS1	9.3 ± 0.0
OS2	9.6 ± 0.0
OS3	9.7 ± 0.0
OS4	9.7 ± 0.0
OS5	9.6 ± 0.0
OS6	9.7 ± 0.0
OS7	9.5 ± 0.0

During July lower temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore, a pattern that has been characteristic of the area during the winter months. Semidiurnal variability, associated with tidal water movements and solar radiation, was again observed, particularly at the inner harbour and nearshore sites.

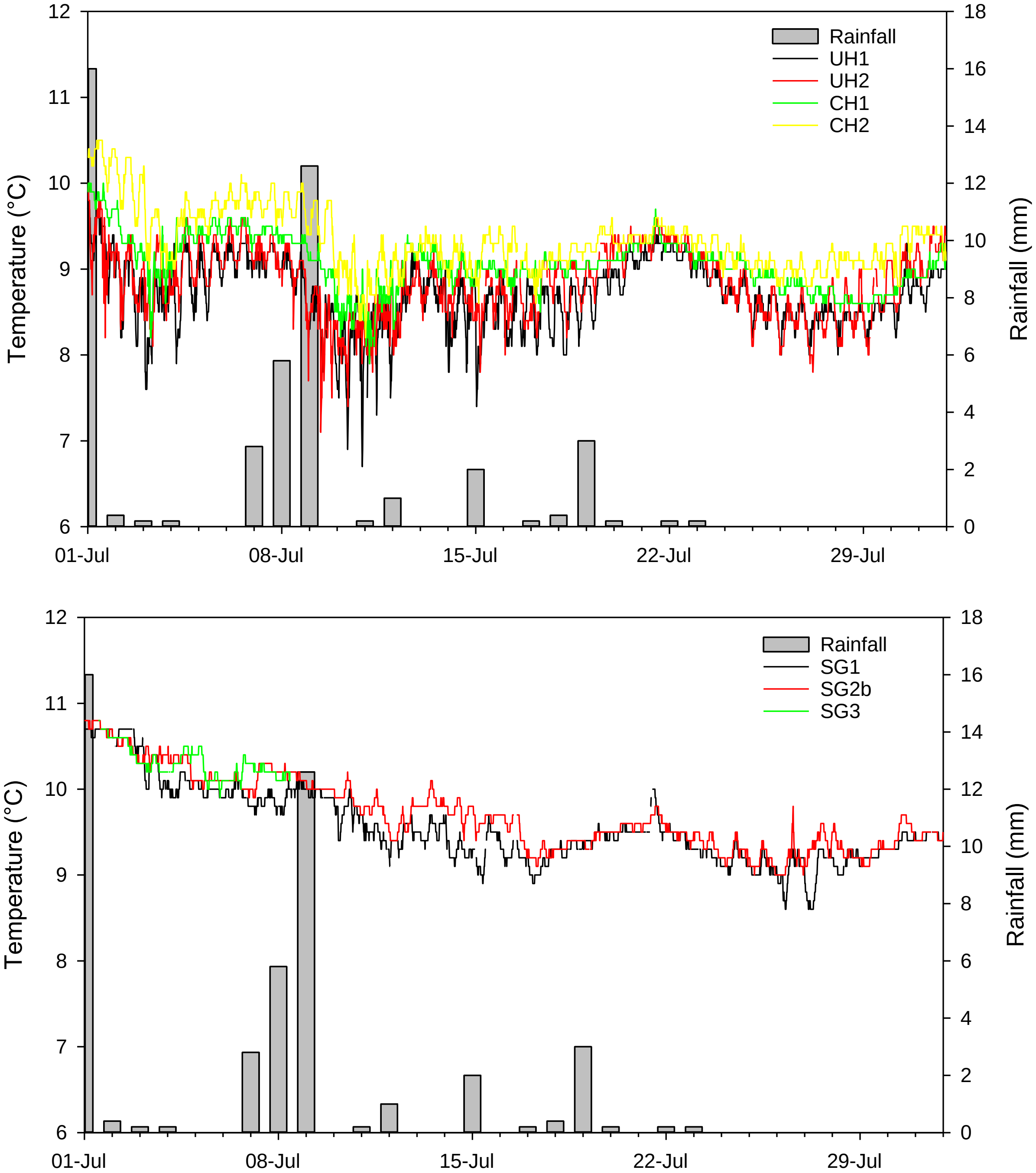


Figure 9 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during July 2020.
Note data for SG3 only available until 8 July.

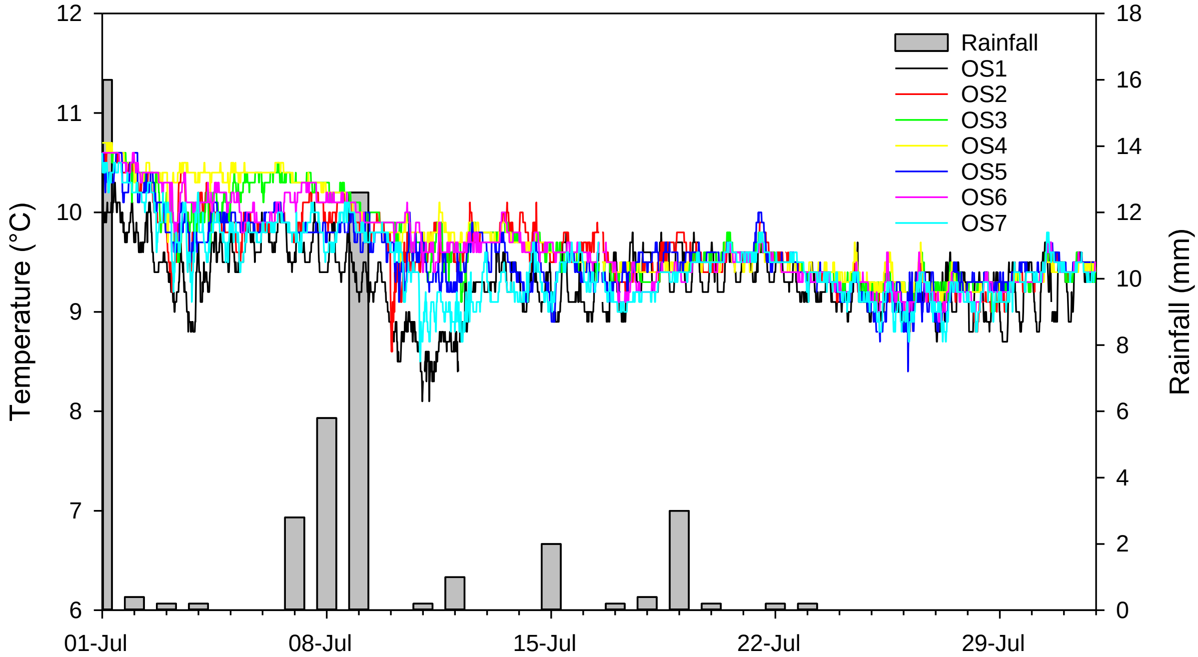


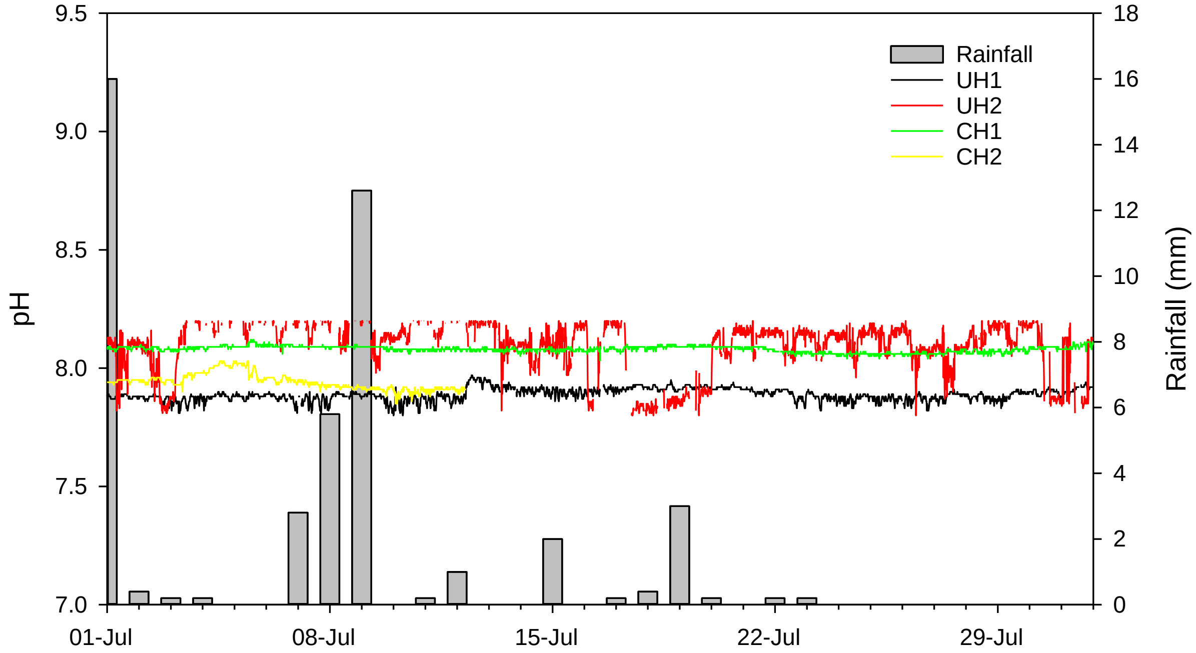
Figure 10 Surface temperature (OS1 to OS7) at nearshore and offshore water quality sites during July 2020.

3.2.3 pH

The pH remained consistent across the monitoring sites, with monthly means ranging between 7.9 and 8.2 (Table 7, Figures 11 and 12).

Table 7 Mean pH at inshore, spoil ground and offshore water quality sites during July 2020. *Values are means ± se (n = 656 to 2962).*

Site	pH
	Surface loggers
UH1	7.9 ± 0.0
UH2	8.1 ± 0.0
CH1	8.1 ± 0.0
CH2	7.9 ± 0.0
SG1	8.0 ± 0.0
SG2	8.2 ± 0.0
SG3	8.0 ± 0.0
OS1	8.2 ± 0.0
OS2	8.0 ± 0.0
OS3	8.1 ± 0.0
OS4	8.1 ± 0.0
OS5	8.1 ± 0.0
OS6	8.1 ± 0.0
OS7	8.1 ± 0.0



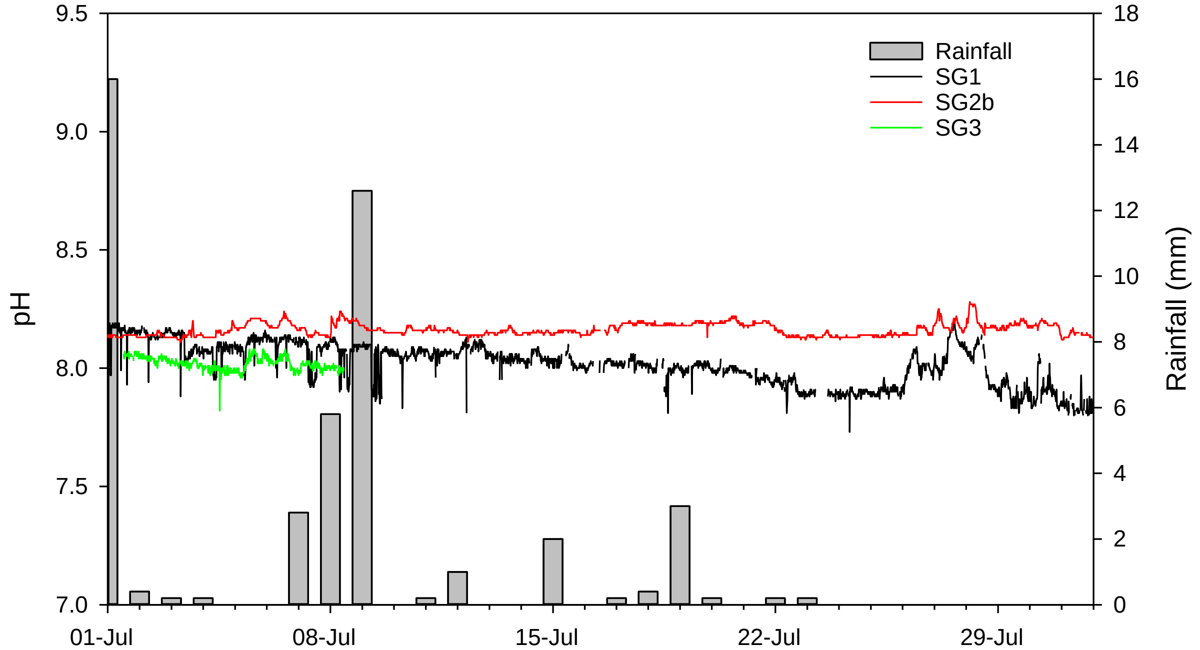


Figure 11 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during July 2020.
Note data for SG3 only available until 8 July.

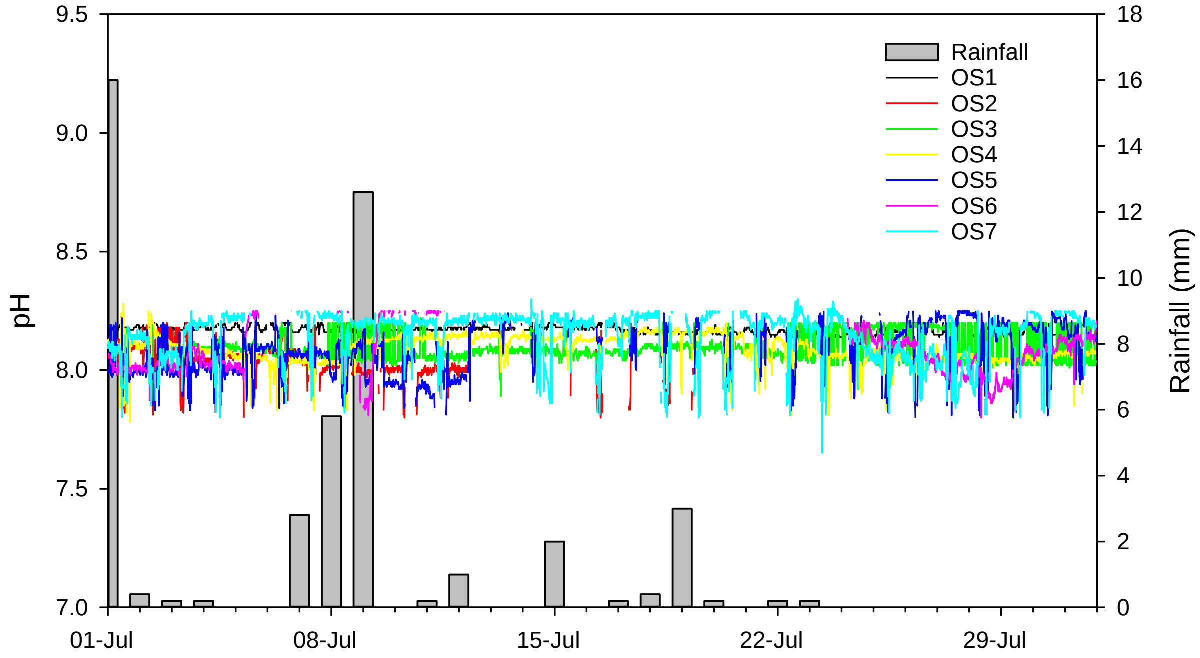


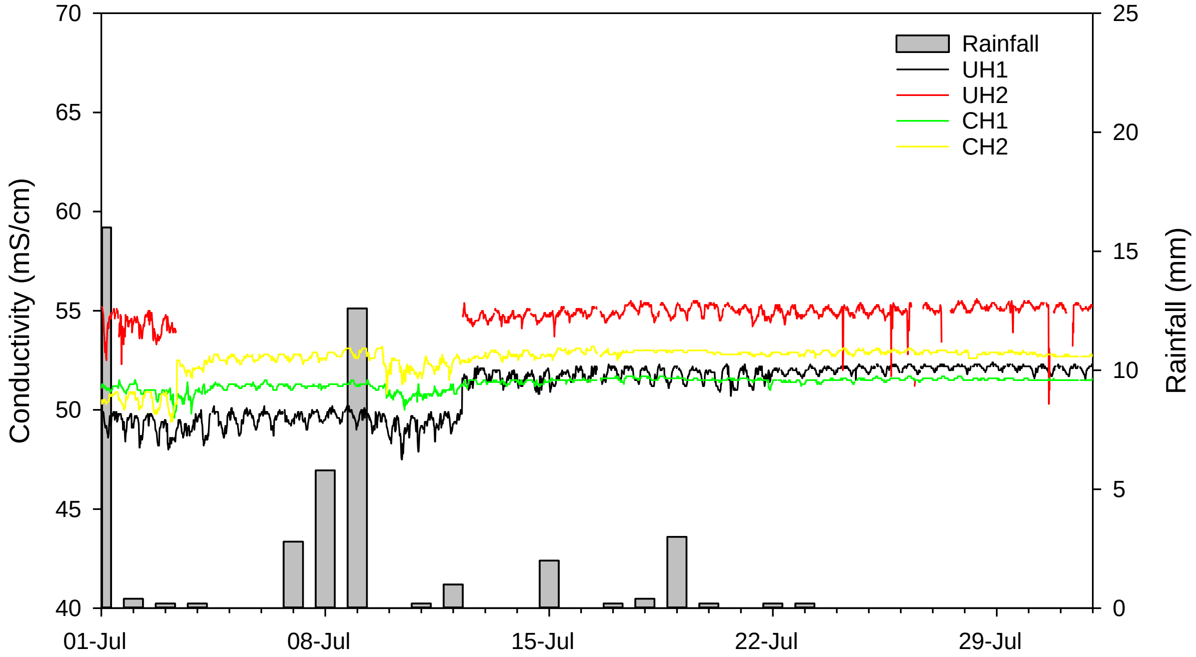
Figure 12 Surface pH (OS1 to OS7) at nearshore and offshore water quality sites during July 2020.

3.2.4 Conductivity

Mean surface conductivity in July ranged from 51 mS/cm to 56 mS/cm (Table 8, Figure 13 and 14). Consistent with the previous month's data there appeared to be little spatial pattern in conductivity across the sites. Similar to June, this may be attributed to the low rainfall for most of the month and low flow rates recorded from the Waimakariri River reducing localised freshwater influences.

Table 8 Mean conductivity at inshore, spoil ground and offshore water quality sites during July 2020. *Values are means ± se (n = 656 to 2963).*

Site	Conductivity (mS/cm)
	Surface loggers
UH1	51.0 ± 0.0
UH2	54.9 ± 0.0
CH1	51.3 ± 0.0
CH2	52.6 ± 0.0
SG1	56.0 ± 0.0
SG2	52.4 ± 0.0
SG3	54.0 ± 0.0
OS1	51.8 ± 0.0
OS2	51.8 ± 0.0
OS3	53.6 ± 0.0
OS4	53.3 ± 0.0
OS5	52.3 ± 0.0
OS6	53.6 ± 0.0
OS7	53.5 ± 0.0



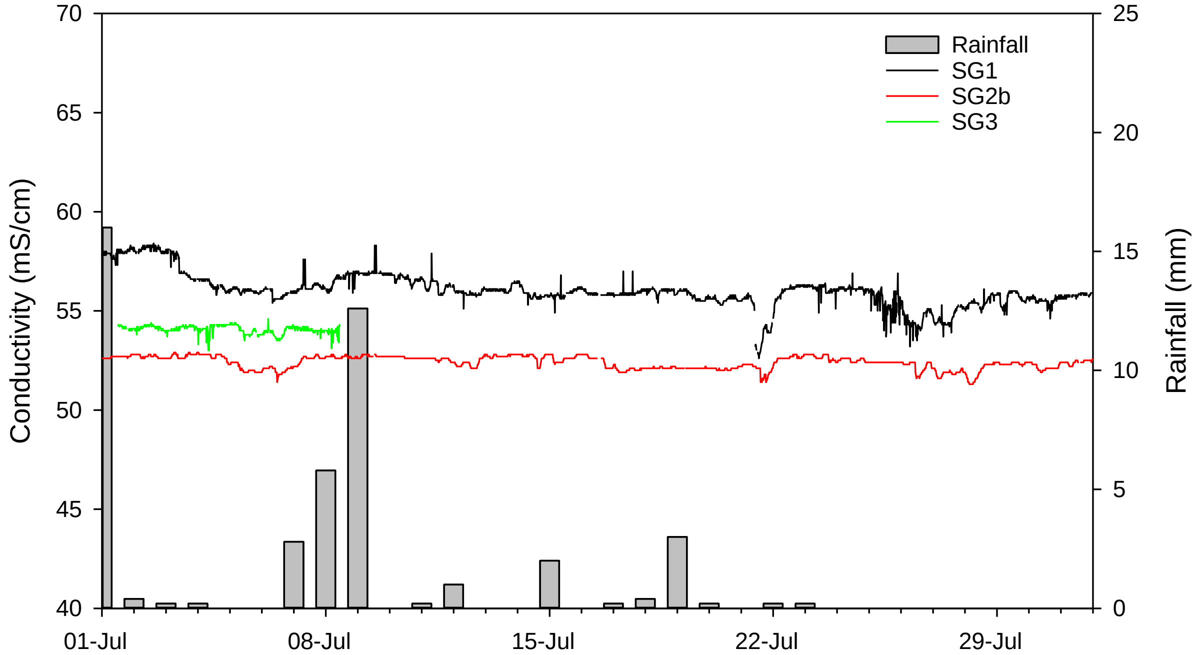


Figure 13 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during July 2020.
Note data for SG3 only available until 8 July.

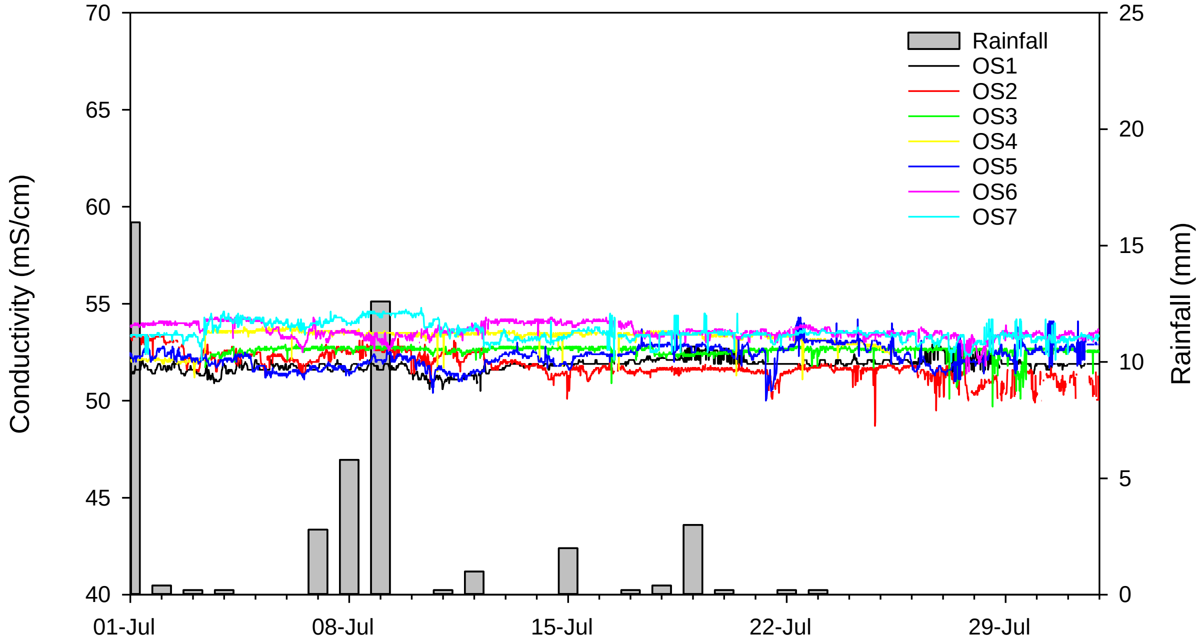


Figure 14 Surface conductivity (OS1 to OS7) at nearshore and offshore water quality sites during July 2020.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations during July ranged from 95 to 103% saturation (Table 9) and exhibited diurnal fluctuations at all sites, particularly those in the inshore area (Figures 15 and 16). DO concentrations were relatively stable for most of July especially within the upper harbour monitoring sites, though declining DO at UH1 was noted following heavy rainfall on 9 July. A decline in DO concentrations was also noted at several sites from 21 July until 24 July, which was most pronounced at the spoil ground sites and OS5. This was followed by a period of increasing DO until 28 July (again most pronounced at the spoil ground sites). Further fluctuations were observed before the end of the month at the three spoil ground sites. These cycles at the end of July may be linked to increased vertical mixing of the water column during prolonged intense high winds as previously mentioned, coupled with extended periods of cloud cover. In a cyclical pattern, extended periods of cloud cover in the absence of degrading algal blooms will also result in lower DO due to a generalised reduction in photosynthesis of existing algal populations.

Table 9 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during July 2020.
Values are means ± se (n 656 to 2963).

Site	Dissolved oxygen (% saturation)
	Surface loggers
UH1	95 ± 0
UH2	104 ± 0
CH1	100 ± 0
CH2	97 ± 0
SG1	100 ± 0
SG2	101 ± 0
SG3	97 ± 0
OS1	97 ± 0
OS2	94 ± 0
OS3	98 ± 0
OS4	98 ± 0
OS5	103 ± 0
OS6	96 ± 0
OS7	96 ± 0

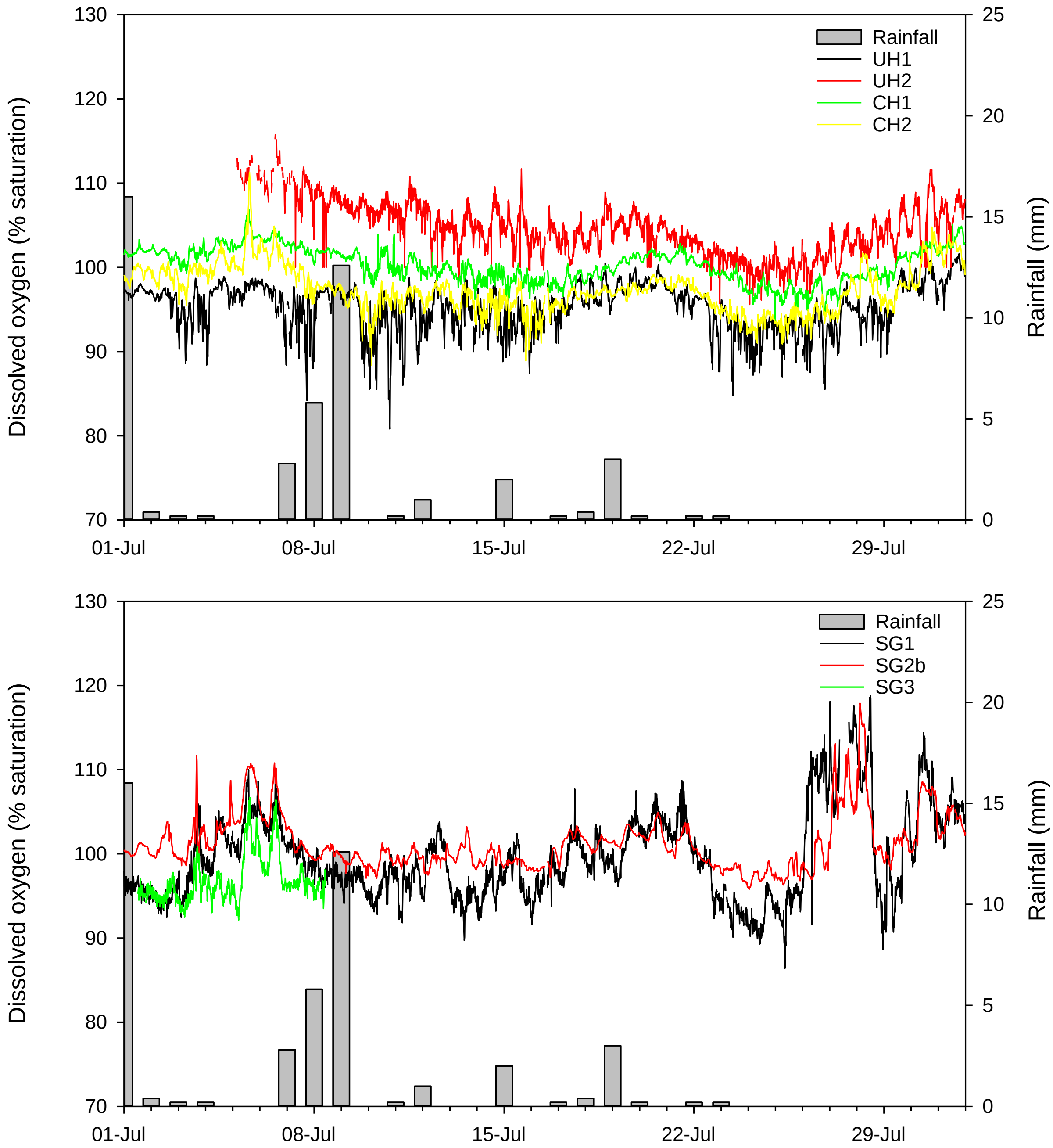


Figure 15 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during July 2020.
Note data for SG3 only available until 8 July.

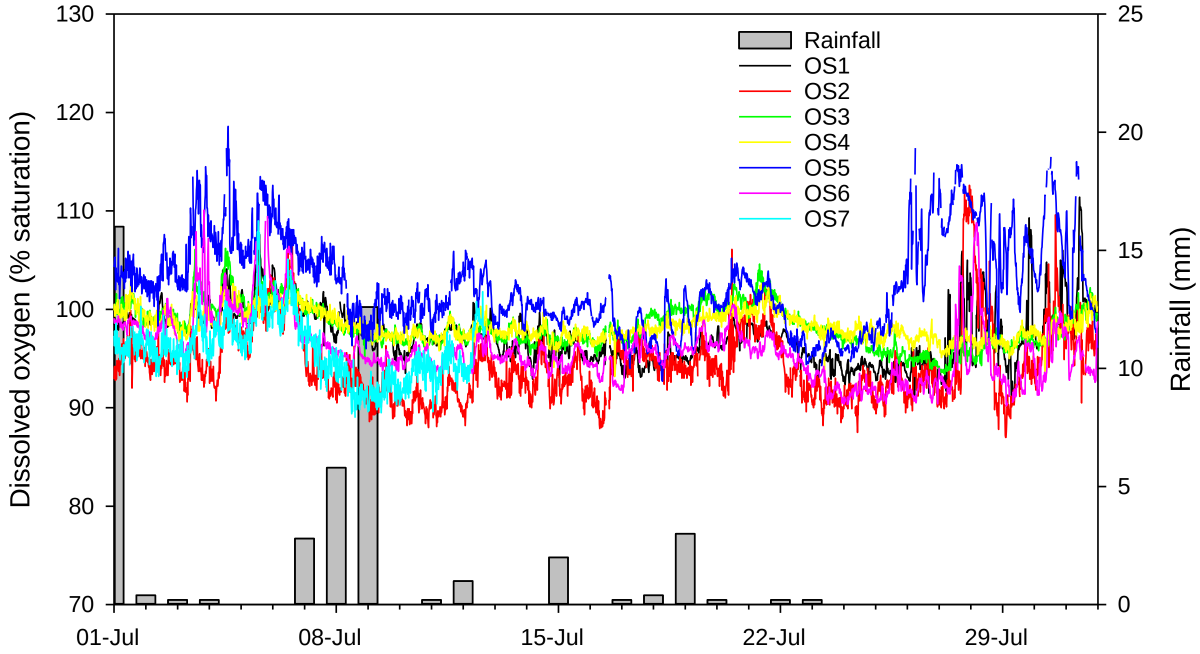


Figure 16 Surface DO (OS1 to OS7) at nearshore and offshore water quality sites during July 2020.

3.3 Physicochemistry Depth Profiling & TSS

Vertical depth profiling of the whole water column at each monitoring site was conducted in conjunction with monthly discrete water sampling on 16 and 17 July. In addition to the previously discussed physicochemical parameters, the light attenuation rate (K_d, the rate at which light or PAR diminishes with depth through the water column) and resultant euphotic depth (the depth to which net photosynthesis can occur/where light levels are ~1% of those at the surface) were also calculated.

Water samples for the determination of TSS were collected from three different depths (sub-surface, mid-column and approximately 1 m above the benthos) at the ten offshore and spoil ground sites. Due to the shallow water depths at the inshore monitoring sites, only surface TSS samples were collected from sites UH1, UH2, UH3, CH1 and CH2. Further information regarding the specific sampling methodology can be found in the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Statistical analyses of the resulting datasets are provided in Tables 10 to 12, with depth profile plots presented in Figures 17 to 19.

The relatively shallow sites of the upper and central harbour predominantly displayed well mixed conditions with little variability recorded in parameters through the water column. Temperature at CH2 exhibited a weak thermocline at ~ 5 m depth, and as expected conductivity followed the same pattern. The pH at all sites recorded a slight decline in surface waters but showed little variability from ~1 to the benthos. As typically observed DO recorded a gradual decline at all sites with depth, which is associated with a reduction in photosynthetic activity due to reduced light.

Sites within the nearshore region exhibited relatively consistent physicochemical profiles through the water column for conductivity and pH (Figure 18). Temperature at OS2, OS3 and OS4 were relatively consistent with depth, while temperature at OS7 cooled with depth to ~10 m before a slight temperature increase near the benthos. OS1 also exhibited a slight incremental decline in temperature with depth. Dissolved oxygen at nearshore sites followed a pattern of gradual decline with depth (as often reported) as the result of decreasing photosynthesis with increasing light attenuation. Turbidity profiles were variable among nearshore sites with OS3 exhibiting consistent and low turbidity (< 2 NTU) through the water column. Turbidity at OS4 and OS7 appeared slightly higher at sub-surface waters before declining at ~0.5 to 1 m. Turbidity at OS7 also increased at the benthos (~16 m) most likely due to the resuspension of sediments, while turbidity at sites OS1 and OS2 was consistent through the water column until ~ 7 to 8 m, where a gradual increase was measured to the benthos.

Further offshore SG2, SG3 and OS6 delivered relatively uniform temperature, conductivity and pH profiles (Figure 19). A temperature gradient was evident at OS5, where temperature increased sharply from 7 to 10 m before finding a new equilibrium. As expected conductivity followed a similar trajectory, while pH and DO at this site mirrored temperature and conductivity profiles and declined with depth. These cooler and fresher surface waters are likely the result of freshwater input potentially from localised coastal rainfall not captured at Lyttelton Port. The freshwater input also appears to have impacted site SG1, though to a lesser extent. Temperature and conductivity at SG1 recorded a gradual increase from the sub-surface to ~ 15 m, while pH showed a slight and gradual decline from surface to benthos. DO was relatively consistent through the water column from the surface to ~ 12m at which point DO declined from 100% saturation to 95% saturation at ~15m. Turbidity at the offshore sites was consistent through the water column only increasing at depths of ~ 13 to 15 m, most likely due to benthic resuspension of sediments.

The shallowest euphotic depth occurred within the upper harbour monitoring site UH3 at a depth of 7.4 m (Table 10), which reflects the typically higher levels of turbidity characteristic of this area. The deepest euphotic depth was recorded at OS3 and calculated to be 27.1 m (Table 11). This site typically demonstrates clear waters. During July no exceedances of WQG were recorded at any of the monitoring sites.

Table 10 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the July 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, n = 14 to 42 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
UH1	17/07/2020 09:36	Sub-surface	8.7 ± 0	8.1 ± 0	50.7 ± 0	97 ± 0	3.2 ± 0.1	5	0.4 ± 0	11.7
		Whole column	8.8 ± 0	8.1 ± 0	50.8 ± 0	96 ± 0	3.3 ± 0	-		
UH2	17/07/2020 09:23	Sub-surface	8.9 ± 0	8.1 ± 0	51 ± 0	97 ± 0	2.3 ± 0.1	4	0.4 ± 0	11.2
		Whole column	9 ± 0.1	8.1 ± 0	51 ± 0	97 ± 0	2.9 ± 0.4	-		
UH3	17/07/2020 09:49	Sub-surface	8.3 ± 0	8.1 ± 0	50.3 ± 0	98 ± 0	3.2 ± 0.1	5	0.6 ± 0	7.4
		Whole column	8.3 ± 0	8.1 ± 0	50.3 ± 0	98 ± 0	3.2 ± 0.1	-		
CH1	17/07/2020 08:44	Sub-surface	8.9 ± 0	8.1 ± 0	51 ± 0	97 ± 0	2.0 ± 0	< 3	0.4 ± 0	12.8
		Whole column	9.1 ± 0	8.1 ± 0	51.1 ± 0	95 ± 0	3.1 ± 0.8	-		
CH2	17/07/2020 09:01	Sub-surface	8.9 ± 0	8.1 ± 0	51.1 ± 0	97 ± 0	1.8 ± 0.1	< 3	0.3 ± 0	15.6
		Whole column	9.1 ± 0.1	8.1 ± 0	51.2 ± 0	96 ± 0	2.1 ± 0.1	-		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 11 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the July 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 30 to 38 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (ºC)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS1	16/07/2020 07:37	Sub-surface	9.0 ± 0	8.1 ± 0	51.1 ± 0	97 ± 0	1.5 ± 0	< 3	0.3 ± 0	15.5
		Mid	9.3 ± 0	8.1 ± 0	51.1 ± 0	96 ± 0	1.5 ± 0	1.8		
		Benthos	9.5 ± 0	8.1 ± 0	51.3 ± 0	94 ± 0	2.6 ± 0.1	5.7		
		Whole column	9.2 ± 0	8.1 ± 0	51.1 ± 0	96 ± 0	1.8 ± 0.1	-		
OS2	16/07/2020 10:51	Sub-surface	9.6 ± 0	8.1 ± 0	51.4 ± 0	96 ± 0	2.1 ± 0.3	< 3	0.3 ± 0	15.9
		Mid	9.5 ± 0	8.1 ± 0	51.5 ± 0	95 ± 0	2.6 ± 0.6	1.7		
		Benthos	9.5 ± 0	8.1 ± 0	51.6 ± 0	95 ± 0	2.7 ± 0.2	46		
		Whole column	9.6 ± 0	8.1 ± 0	51.5 ± 0	95 ± 0	2.9 ± 0.4	-		
OS3	16/07/2020 10:09	Sub-surface	9.3 ± 0	8.1 ± 0	51.6 ± 0	99 ± 0	1.2 ± 0	< 3	0.2 ± 0	27.1
		Mid	9.4 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	1.2 ± 0	1.8		
		Benthos	9.4 ± 0	8.1 ± 0	51.7 ± 0	97 ± 0	2.0 ± 0.7	1.4		
		Whole column	9.4 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	1.3 ± 0.1	-		
OS4	16/07/2020 09:27	Sub-surface	9.4 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	2.0 ± 0.3	< 3	0.2 ± 0	24.9
		Mid	9.4 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	1.5 ± 0	1.2		
		Benthos	9.4 ± 0	8.1 ± 0	51.8 ± 0	97 ± 0	2.1 ± 0.5	2.6		
		Whole column	9.4 ± 0.1	8.1 ± 0	51.7 ± 0	98 ± 0	1.7 ± 0.1	-		
OS7	16/07/2020 11:09	Sub-surface	9.5 ± 0	8.1 ± 0	51.2 ± 0	100 ± 0	1.1 ± 0	< 3	0.3 ± 0	17.4
		Mid	9.3 ± 0	8.1 ± 0	51.3 ± 0	97 ± 0	1.5 ± 0	1.6		
		Benthos	9.6 ± 0.1	8.1 ± 0	51.5 ± 0	94 ± 1	2.2 ± 0.1	4.5		
		Whole column	9.4 ± 0	8.1 ± 0	51.3 ± 0	97 ± 0	1.5 ± 0.1	-		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 12 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the July 2020 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 38 to 46 for whole column). Sub-surface values outside recommended WQG are highlighted in blue.*

Site	Sample date/time	Depth	Temperature (°C)	pH	Conductivity (mS/cm)	Dissolved oxygen (% saturation)	Turbidity (NTU)	TSS (mg/L)	K_d	Euphotic Depth (m)
OS5	16/07/2020 07:52	Sub-surface	9.2 ± 0	8.1 ± 0	50.9 ± 0	101 ± 0	1.0 ± 0	< 3	0.2 ± 0	20.9
		Mid	9.7 ± 0.2	8.1 ± 0	51.2 ± 0.1	99 ± 1	1.0 ± 0	1.2		
		Benthos	10.0 ± 0	8.0 ± 0	51.7 ± 0	90 ± 0	3.0± 0.2	2.6		
		Whole column	9.6 ± 0.1	8.1 ± 0	51.2 ± 0.1	97 ± 1	1.4 ± 0.1	-		
OS6	16/07/2020 10:28	Sub-surface	9.6 ± 0	8.1 ± 0	51.7 ± 0	99 ± 0	1.3 ± 0	3	0.2 ± 0	21.3
		Mid	9.6 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	1.8 ± 0.3	11.6		
		Benthos	9.6 ± 0	8.1 ± 0	51.8 ± 0	98 ± 0	2.4 ± 0.3	< 1		
		Whole column	9.6 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	1.7 ± 0.1	-		
SG1	16/07/2020 08:13	Sub-surface	9.2 ± 0	8.1 ± 0	51 ± 0	102 ± 0	1.0 ± 0.1	< 3	0.2 ± 0	22.4
		Mid	9.5 ± 0	8.1 ± 0	51.3 ± 0	101 ± 0	0.9 ± 0	< 1		
		Benthos	9.8 ± 0	8.1 ± 0	51.7 ± 0	95 ± 0	2.2 ± 0.3	< 1		
		Whole column	9.5 ± 0	8.1 ± 0	51.3 ± 0	100 ± 0	1.2 ± 0.1	-		
SG2	16/07/2020 08:36	Sub-surface	9.5 ± 0	8.1 ± 0	51.6 ± 0	99 ± 0	1.3 ± 0.1	< 3	0.2 ± 0	21.1
		Mid	9.5 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	1.2 ± 0	1.8		
		Benthos	9.6 ± 0	8.1 ± 0	51.7 ± 0	97 ± 0	2.2 ± 0.1	20		
		Whole column	9.5 ± 0	8.1 ± 0	51.7 ± 0	98 ± 0	1.4 ± 0.1	-		
SG3	16/07/2020 09:00	Sub-surface	9.6 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	1.3 ± 0	< 3	0.2 ± 0	24.3
		Mid	9.6 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	1.3 ± 0	< 1.0		
		Benthos	9.6 ± 0	8.1 ± 0	51.8 ± 0	98 ± 0	1.3 ± 0.1	1		
		Whole column	9.6 ± 0	8.1 ± 0	51.8 ± 0	99 ± 0	1.4 ± 0.1	-		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

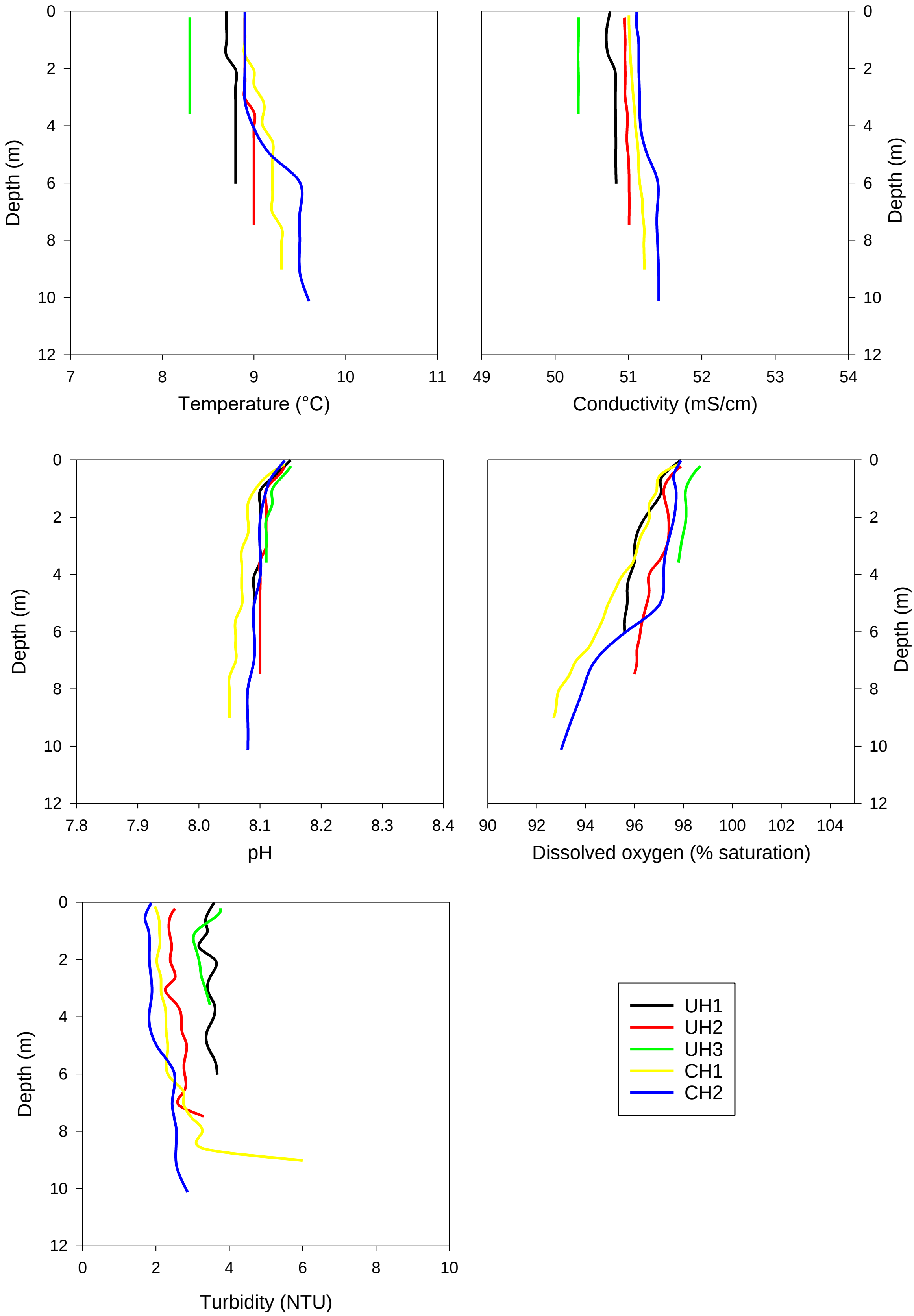


Figure 17 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 17 July 2020.

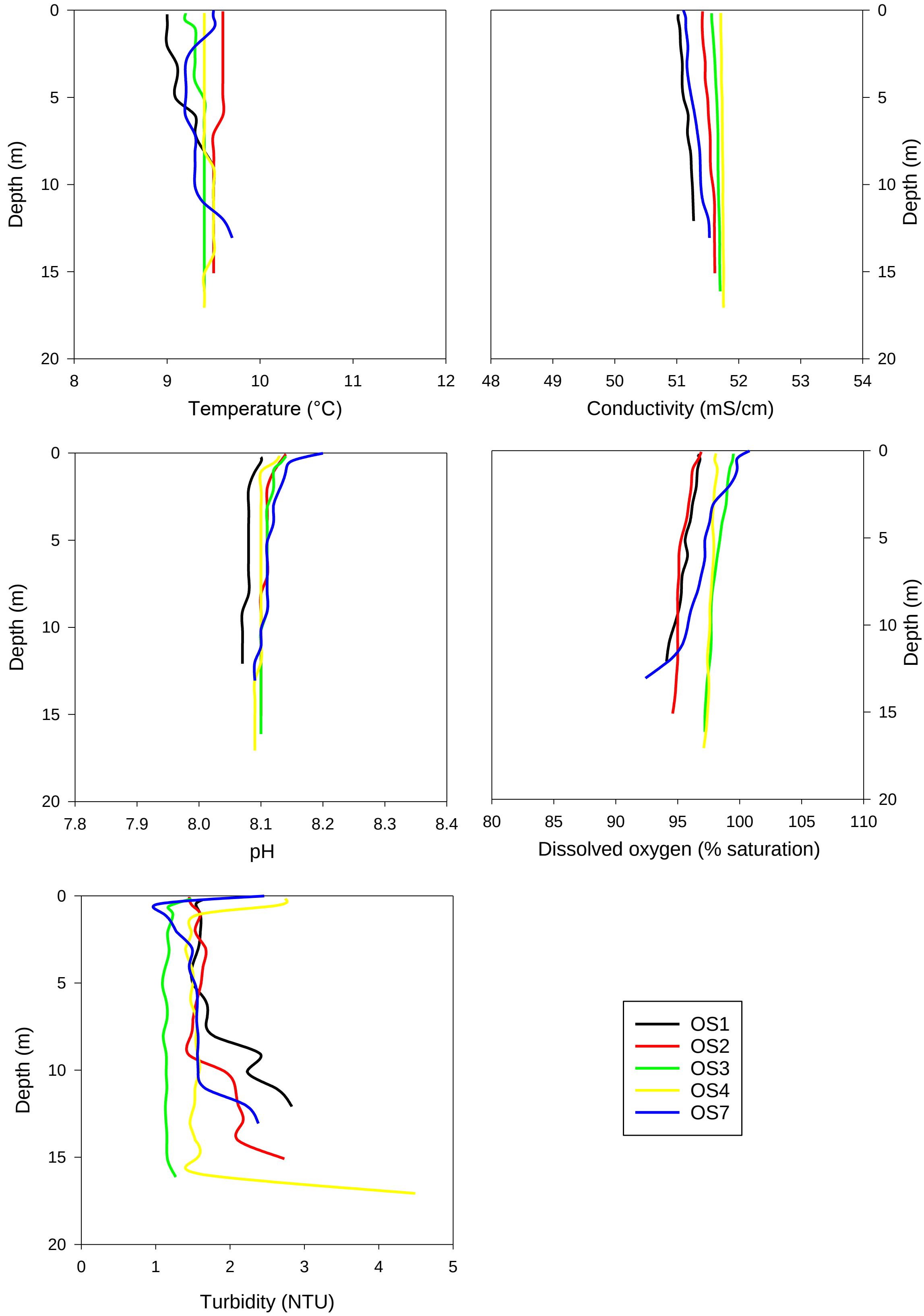


Figure 18 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 16 July 2020.

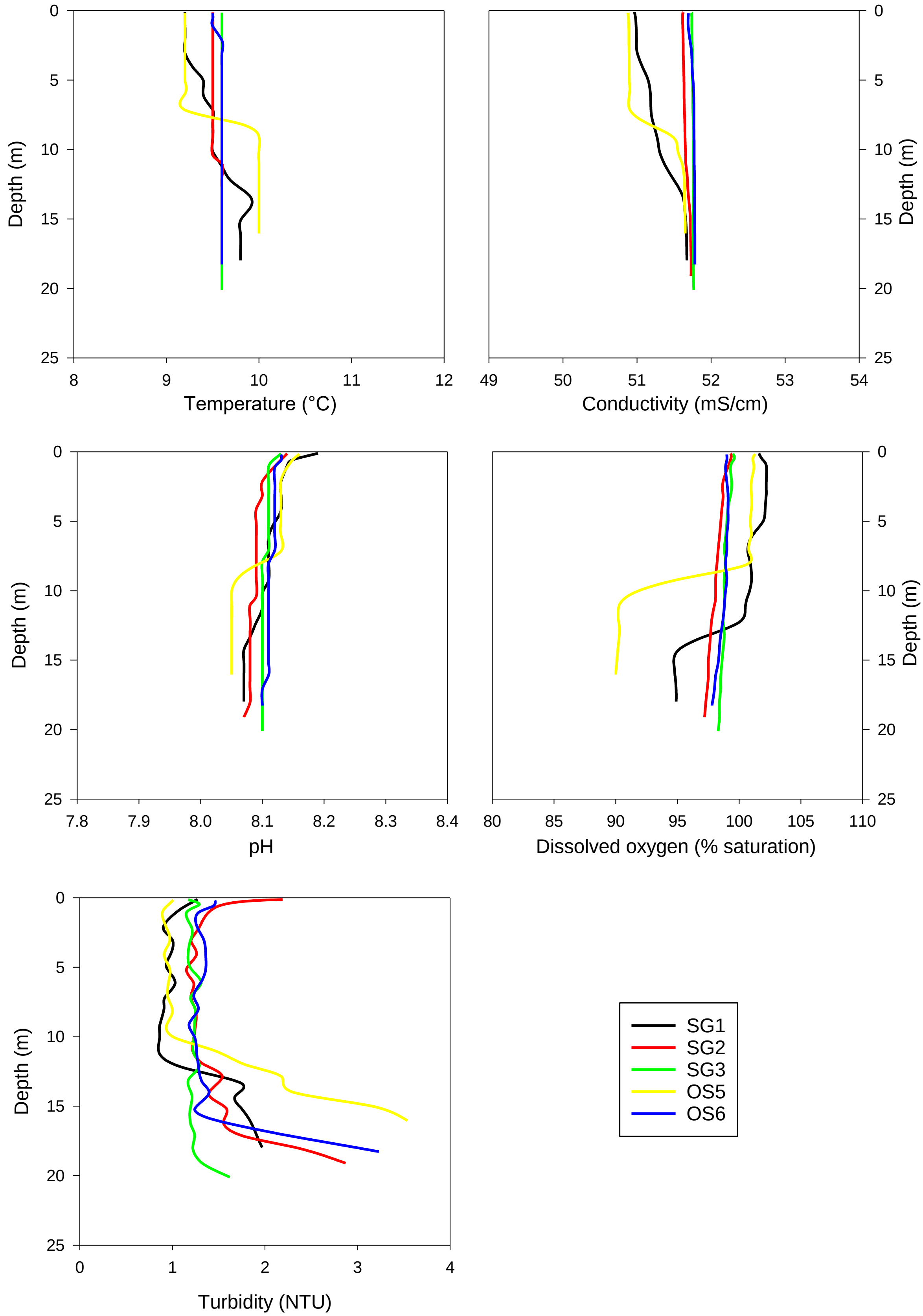


Figure 19 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 16 July 2020.

3.4 Water Samples

Discrete water sampling was conducted on 16 and 17 July 2020, in conjunction with vertical physicochemical profiling through the water column. Quality assurance/quality control (QA/QC) procedures included a duplicate water sample collected at one site, in addition to a laboratory and field blank for each parameter. Further details on the specific sampling methodology can be found within the Channel Deepening Project Water Quality Environmental Monitoring Methodology report (Vision Environment, 2017). Laboratory results associated with VE QA/QC procedures are presented in Table 17 of the Appendix.

3.4.1 Nutrients

Total phosphorous concentrations showed no spatial pattern across the monitoring locations and remained below the WQG of 30 µg/L at all sites (Figure 20). Similar to June dissolved reactive phosphorous concentrations exceeded the WQG of 5 µg/L at all sites in July, though no particular spatial pattern was noted. Total nitrogen and total kjeldahl nitrogen (TKN) were ≤ LOR value at all sites except SG3, which recorded concentrations of 300 µg/L and 500 µg/L respectively. Contamination was evident at site OS6 with total nitrogen and nitrogen oxide values exceeding 1000 µg/L, the total nitrogen value for OS6 has therefore been omitted from Figure 13.

During July total ammonia concentrations exceeded the WQG (15 µg/L) at all sites and ranged from 19 to 59 µg/L. Similarly, nitrogen oxide values were above WQG at all sites during July's sampling period and ranged from 24 to 46 µg/L across the sites. These results are out of character and should be treated with caution as potentially contamination during sampling or laboratory analysis occurred.

Unlike most previous months Chlorophyll *a* concentrations were below WQG (4 µg/L) at all sites in July (Table 13). Chlorophyll *a* is an indicator of phytoplankton biomass, and tends to fluctuate throughout the month depending on a variety of variables including the level of bioavailable nutrients, temperature and light availability.

Table 13 Concentrations of nutrients and chlorophyll *a* at monitoring sites during July 2020
Values outside recommended WQG are highlighted in blue.

Site	Parameter (µg/L)						
	Total Phosphorus	Dissolved Reactive Phosphorus	Total Nitrogen	Total Kjeldahl Nitrogen (TKN)	Total Ammonia	Nitrogen Oxides (NOx)	Chlorophyll *a*
UH1	19	11.1	200	<200	22	45	1.5
UH2	23	9.7	<300	<200	22	38	2.9
UH3	19	8.9	<300	<200	25	46	1.7
CH1	15	11.2	<300	<200	22	39	1.6
CH2	16	10.9	<300	<200	21	37	1.3
OS1	18	10.9	<300	<200	29	39	1.6
OS2	16	11.7	<300	<200	29	36	0.7
OS3	18	10.7	<300	<200	19	35	1.2
OS4	18	10.9	<300	<200	24	43	1.2
OS5	22	13	200	<200	59	25	1.8
OS6	16	10.2	*1500*	<200	21	*1410*	1.7
OS7	15	10.6	<300	<200	34	33	0.7
SG1	16	11.1	<300	<200	42	24	1.8
SG2	17	9.7	<300	<200	21	31	1.5
SG3	16	8.9	600	500	22	35	1.8
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

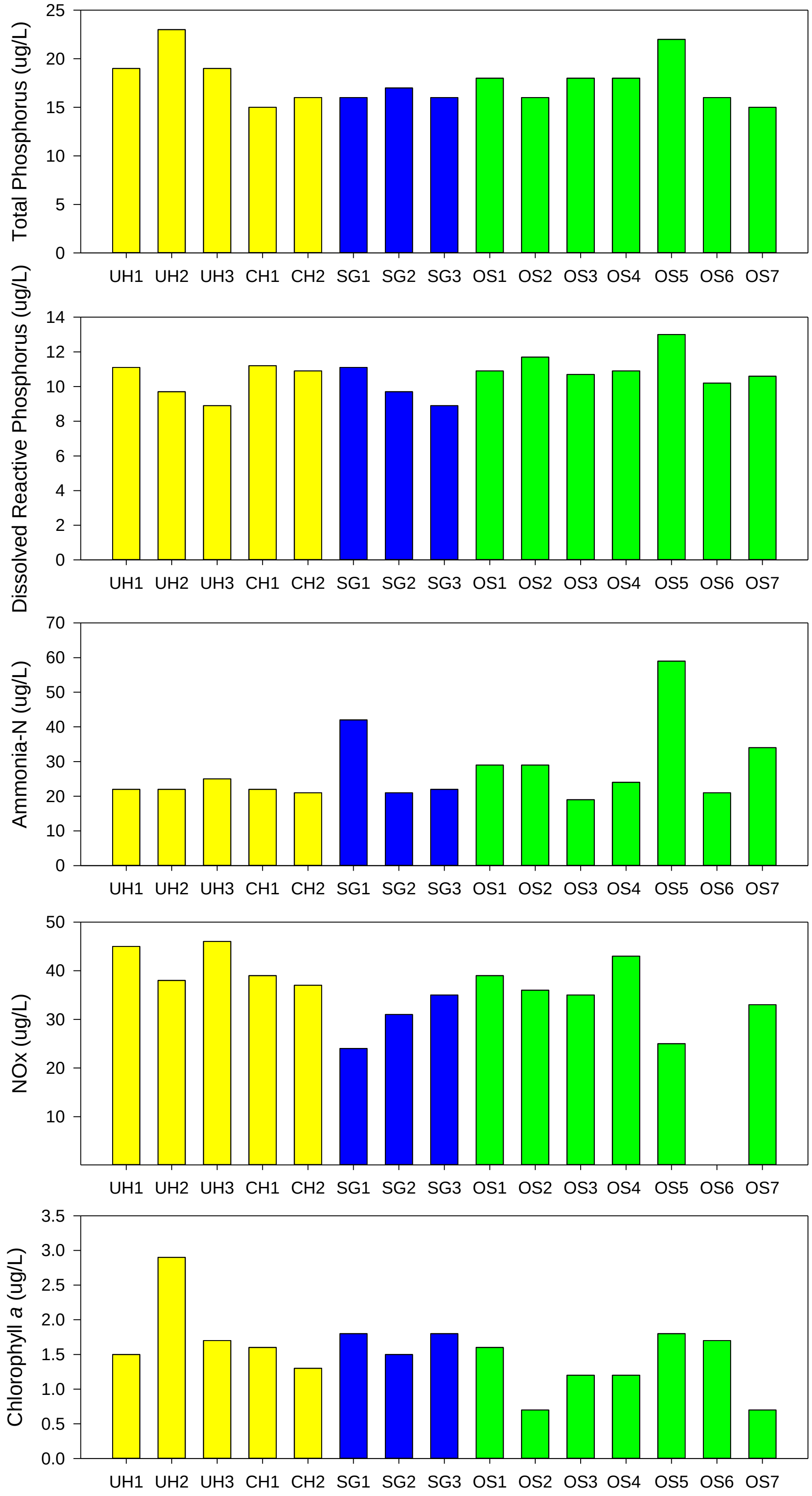


Figure 20 Nutrient and chlorophyll *a* concentrations at monitoring sites during July 2020.
Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.

3.4.2 Total and Dissolved Metals

During July the majority of metal concentrations were relatively low throughout the sampling sites. Concentrations of several metals (Tables 14 to 16, Figure 21 and 22) were reported as below the limit of reporting (LOR) at all sites, including dissolved and total arsenic (<4.2 µg/L), cadmium (<0.21 µg/L), cobalt (<0.63 µg/L), lead (< 1.1 µg/L), mercury (<0.08 µg/L), nickel (<7 µg/L), selenium (<4.2 µg/L), silver (<0.43 µg/L), tin (<5.3 µg/L) and zinc (<4.2 µg/L). Total copper was detected at seven sites but above WQG (1.3 µg/L) at only three sites (UH1, UH3 and SG3), however the bioavailable dissolved copper fraction was detected at just one site (UH2) and this concentration was below WQG.

Concentrations of total aluminium were detected at nine sites, six of which exceeded the designated 95% species protection value of 24 µg/L WGQ including all those of the upper harbour. However, the WQG is applicable to the dissolved fraction only (ANZG, 2018) and dissolved aluminium was < LOR at all sites. Total iron concentrations were detected at all sites with the highest values recorded within the upper and central harbour. Dissolved iron concentrations were < LOR at all sites except OS5 that recorded a concentration of 7 µg/L, however there are no trigger values for dissolved or total iron concentrations.

Dissolved and total chromium concentrations were < LOR at the majority of sites, though the total fraction was detected at UH1 and UH3, however the concentrations at both these sites were below well below the 95% species protection trigger value of 4.4 µg/L for CrVI and 27.4 µg/L for CrIII. Vanadium concentrations ranged from 1.6 to 2.1 µg/L in both total and dissolved form, though these concentrations were well below the 95% species protection trigger value of 100 µg/L.

Total manganese concentrations ranged from 2.1 to 9.3 µg/L with the higher concentrations recorded within the upper harbor sites. Dissolved manganese concentrations exhibited the same spatial pattern with concentrations ranging from 1.3 to 5.6 µg/L.

Total and dissolved molybdenum was detected at all sites but exhibited little spatial variation, ranging from 10.7 to 12.4 µg/L and 10.3 to 11.4 µg/L respectively. No trigger values are available for either manganese or molybdenum.

Table 14 Total and dissolved metal concentrations at inshore monitoring sites during July 2020. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	<12	<12	<12	<12	24
	Total	61	59	121	42	42	
Arsenic	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	1.3	<1.1	1.6	1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	1.1	<1	<1	<1	1.3
	Total	1.5	1.2	1.6	<1.1	1.1	
Iron	Dissolved	<4	<4	<4	<4	<4	-
	Total	93	88	171	54	51	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	5.6	5.4	5.6	5	4.6	-
	Total	8.1	7.8	9.3	6.8	6.7	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	10.5	10.6	10.4	11.4	10.8	-
	Total	11	11	10.7	11	11.2	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.6	1.8	1.6	1.7	1.7	100
	Total	1.8	1.9	1.9	1.7	1.8	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 15 Total and dissolved metal concentrations at offshore monitoring sites during July 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites							WQG
		OS1	OS2	OS3	OS4	OS5	OS6	OS7	
Aluminium	Dissolved	<12	<12	<12	<12	<12	<12	<12	24
	Total	31	24	<21	22	<21	24	<21	
Arsenic	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	<1	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	<1	<1	<1	<1	1.3
	Total	<1.1	<1.1	1.2	<1.1	1.2	<1.1	1.3	
Iron	Dissolved	<4	<4	<4	<4	7	<4	<4	-
	Total	55	32	18	27	14.4	25	14.1	
Lead	Dissolved	<1	<1	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	4.1	3.6	2.5	1.6	1.7	3.1	2.1	-
	Total	5.5	5	3.1	2.5	2.3	4.6	3	
Mercury	Dissolved	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11	10.8	10.5	10.7	10.3	10.9	10.2	-
	Total	11.2	11.4	11.3	11.9	11	12.4	11.3	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	<5	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	1.7	1.6	1.8	1.7	1.9	1.7	100
	Total	1.7	2	1.9	2	2	2.1	1.8	
Zinc	Dissolved	<4	<4	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 16 Total and dissolved metal concentrations at spoil ground monitoring sites during July 2020. *Values outside recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites			WQG
		SG1	SG2b	SG3	
Aluminium	Dissolved	<12	<12	<12	24
	Total	<21	<21	<21	
Arsenic	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Cadmium	Dissolved	<0.2	<0.2	<0.2	5.5
	Total	<0.21	<0.21	<0.21	
Chromium	Dissolved	<1	<1	<1	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	<1.1	<1.1	
Cobalt	Dissolved	<0.6	<0.6	<0.6	1.0
	Total	<0.63	<0.63	<0.63	
Copper	Dissolved	<1	<1	<1	1.3
	Total	<1.1	<1.1	1.7	
Iron	Dissolved	<4	<4	<4	-
	Total	13.3	22	27	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.7	2.4	1.3	-
	Total	2.2	3.8	2.1	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11	10.8	10.5	-
	Total	11.2	11.4	11.3	
Nickel	Dissolved	<7	<7	<7	70
	Total	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	-
	Total	<4.2	<4.2	<4.2	
Silver	Dissolved	<0.4	<0.4	<0.4	1.4
	Total	<0.43	<0.43	<0.43	
Tin	Dissolved	<5	<5	<5	-
	Total	<5.3	<5.3	<5.3	
Vanadium	Dissolved	1.7	1.6	1.7	100
	Total	1.9	1.9	2.1	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

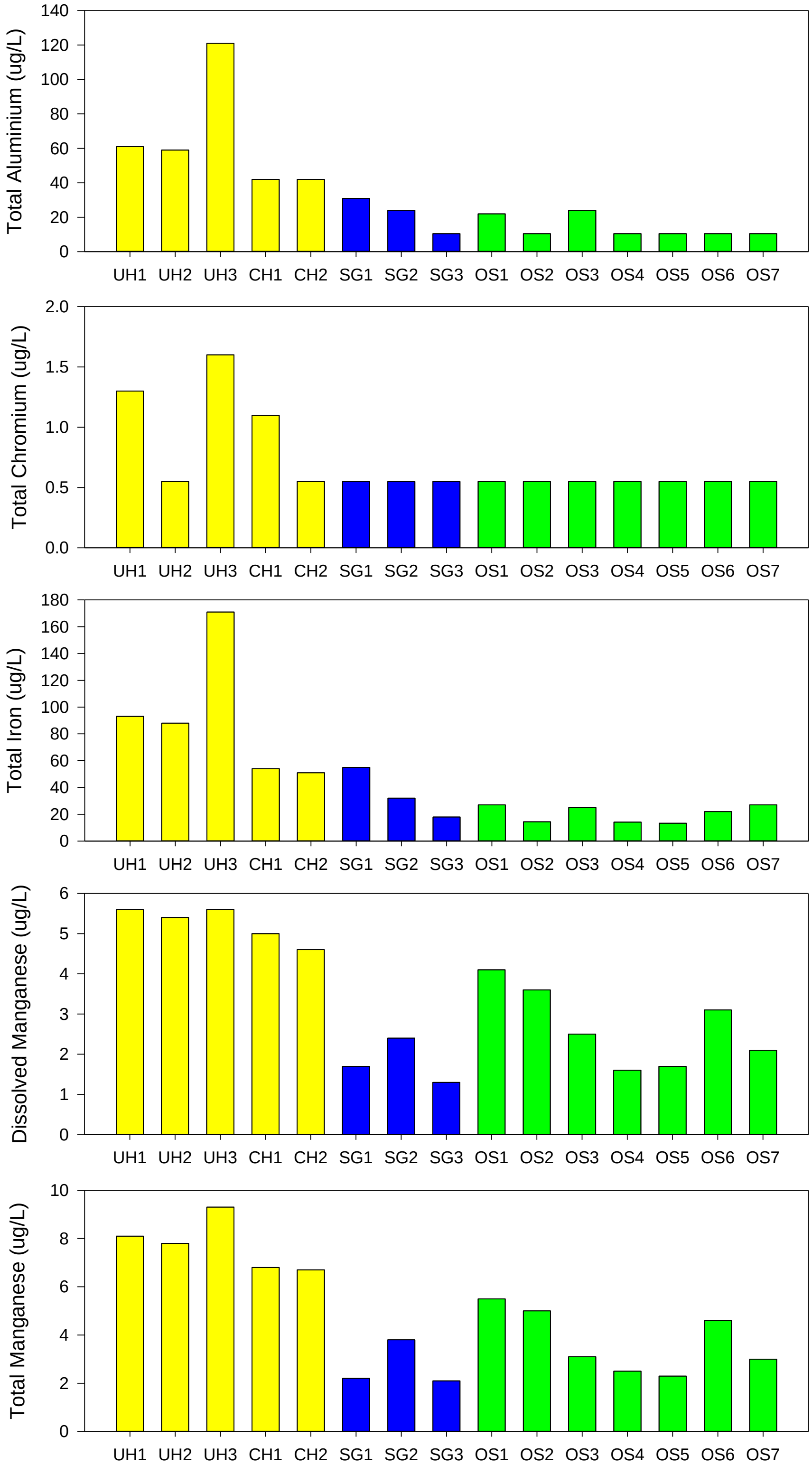


Figure 21 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during July 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

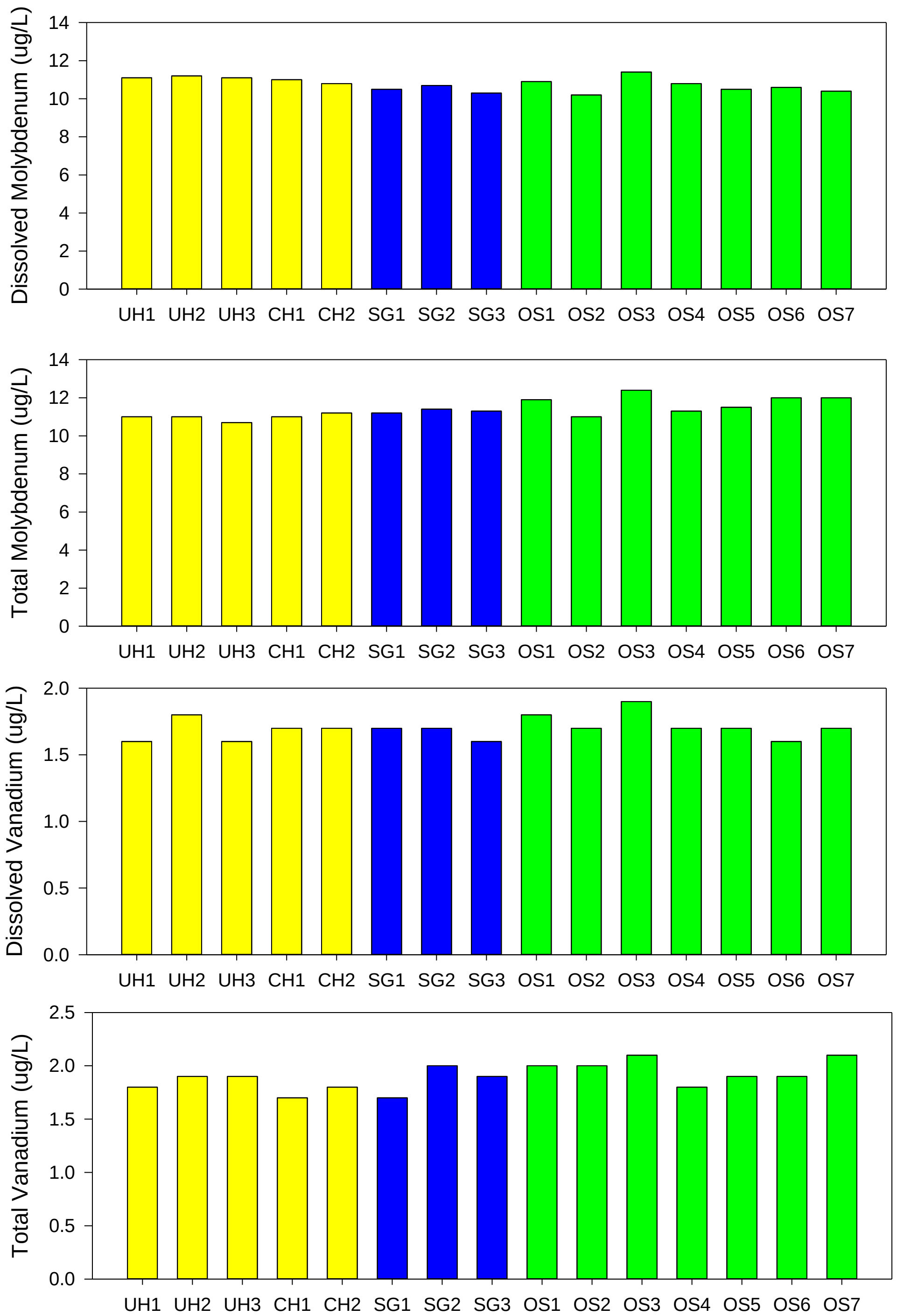


Figure 22 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during July 2020.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

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5 APPENDIX

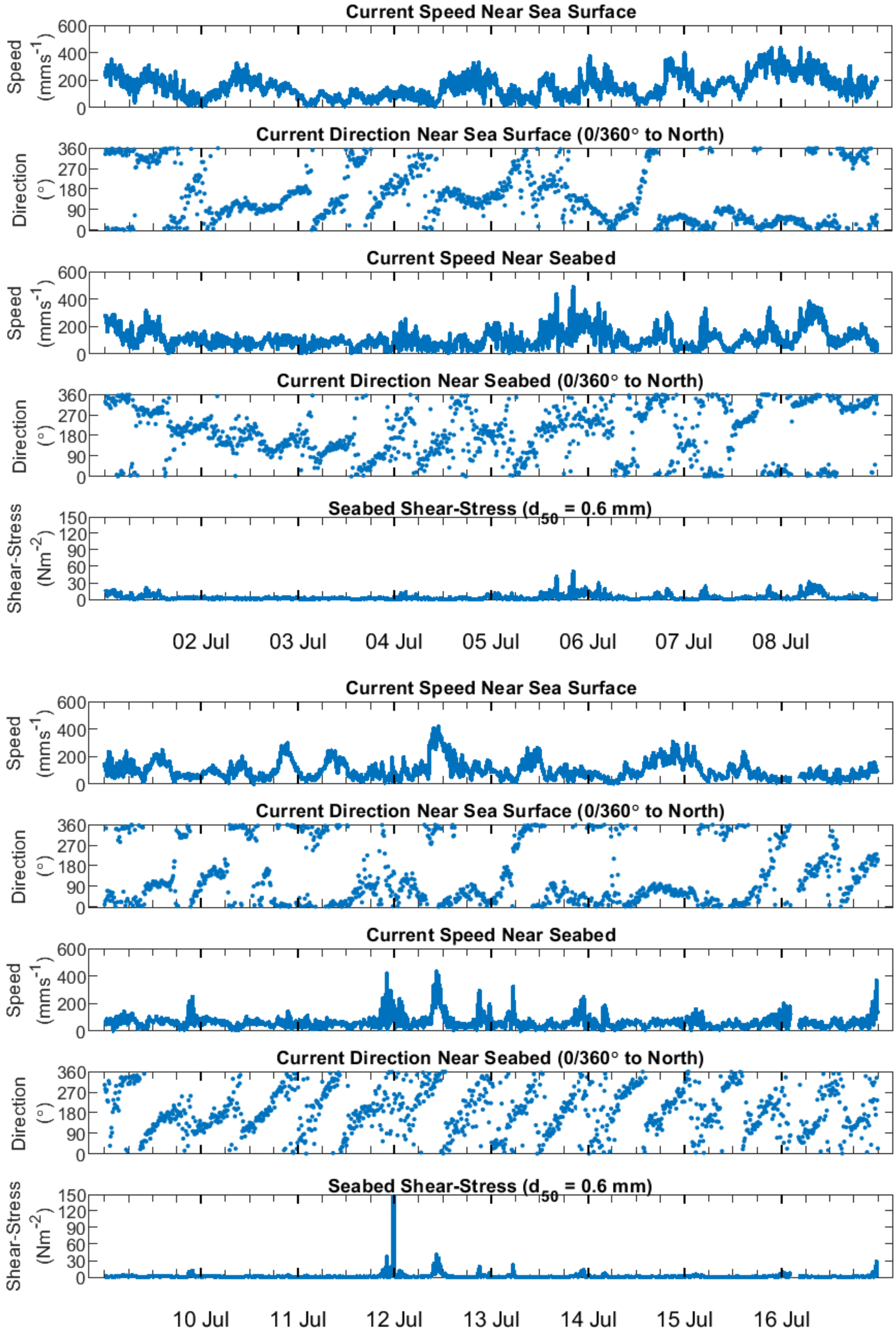

Figure 23 SG1 current speed, direction and shear bed stress 1 to 16 July 2020.

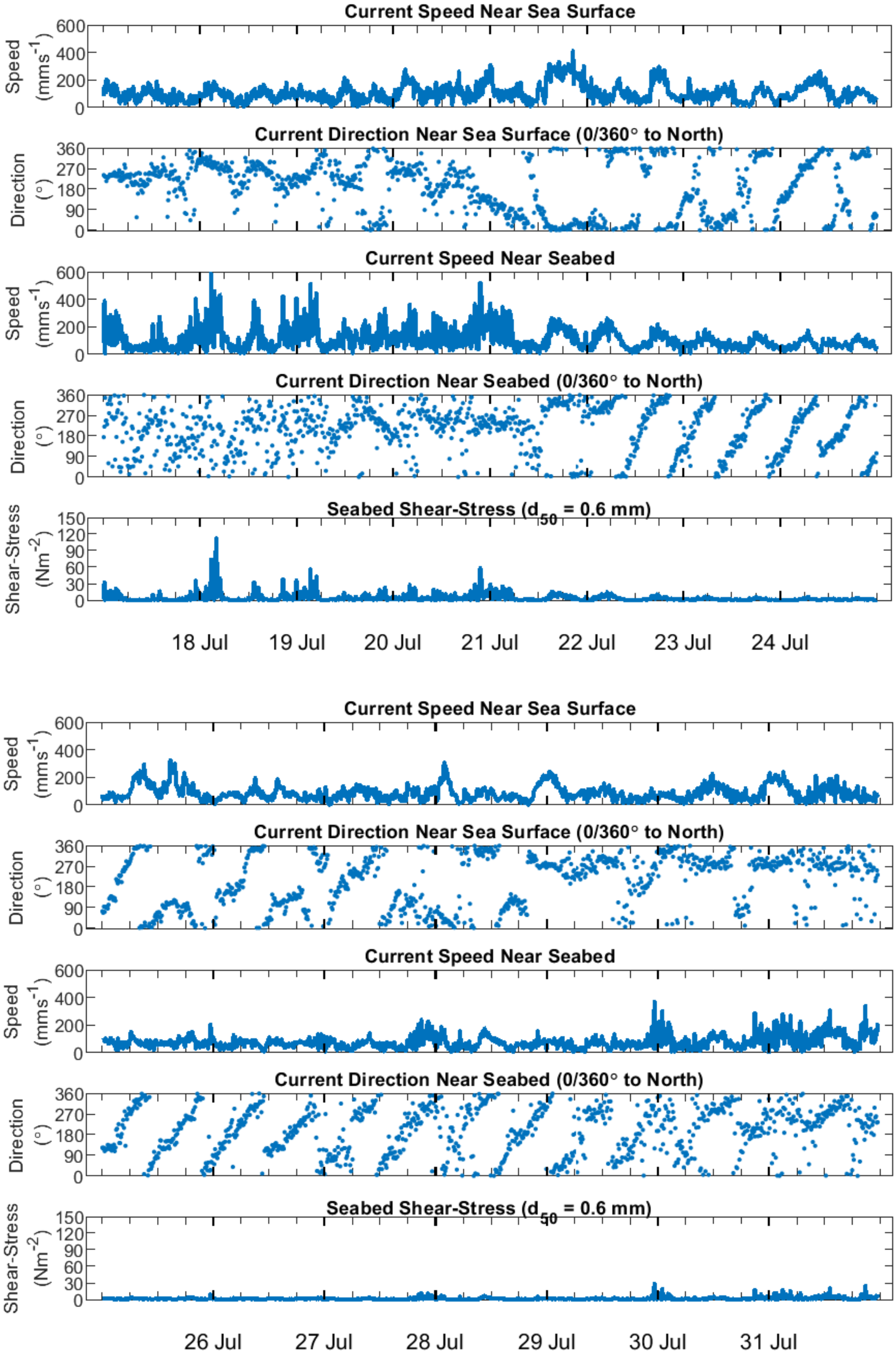

Figure 24 SG1 current speed, direction and shear bed stress 17 to 31 July 2020.

Table 17 Summary of Vision Environment quality control data for July 2020 water sampling.
ND = not determined as one or more samples was below LOR. Variation between duplicate field samples ≥ 50% has been highlighted in blue. High variation indicates heterogeneity within the water column.

* Slightly higher concentrations in the field and lab blank, indicating potential sample contamination.

Parameter	VE Field Blank (µg/L)	VE Lab Blank (µg/L)	Duplicate		
			OS4 (A) (µg/L)	OS4 (B) (µg/L)	Variation (%)
TSS mg/l	< 3	< 3	< 3	< 3	ND
Dissolved Aluminium (µg/l)	< 3	< 3	< 12	< 12	ND
Total Aluminium (µg/l)	< 3.2	< 3.2	24	23	4
Dissolved Arsenic (µg/l)	< 1	< 1	< 4	< 4	ND
Total Arsenic (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Dissolved Cadmium (µg/l)	< 0.05	< 0.05	< 0.2	< 0.2	ND
Total Cadmium (µg/l)	< 0.053	< 0.053	< 0.21	< 0.21	ND
Dissolved Chromium (µg/l)	< 0.5	< 0.5	< 1	< 1	ND
Total Chromium (µg/l)	< 0.53	< 0.53	< 1.1	< 1.2	ND
Dissolved Cobalt (µg/l)	< 0.2	< 0.2	< 0.6	< 0.6	ND
Total Cobalt (µg/l)	< 0.21	< 0.21	< 0.63	< 0.63	ND
Dissolved Copper (µg/l)	< 0.5	< 0.5	< 1	< 1	ND
Total Copper (µg/l)	< 0.53	< 0.53	< 1.1	< 1.1	ND
Dissolved Iron (µg/l)	< 20	< 20	< 4	< 4	ND
Total Iron (µg/l)	< 21	< 21	27	22	20
Dissolved Lead µg/l)	< 0.1	< 0.1	< 1	< 1	ND
Total Lead (µg/l)	< 0.11	< 0.11	< 1.1	< 1.1	ND
Dissolved Manganese (µg/l)	< 0.5	< 0.5	1.6	2	22
Total Manganese (µg/l)	< 0.53	< 0.53	2.5	2.5	0
Dissolved Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	ND
Total Mercury (µg/l)	< 0.08	< 0.08	< 0.08	< 0.08	ND
Dissolved Molybdenum (µg/l)	< 0.2	< 0.2	10.7	10.7	0
Total Molybdenum (µg/l)	< 0.21	< 0.21	11.9	11.3	5
Dissolved Nickel (µg/l)	< 0.5	< 0.5	< 7	< 7	ND
Total Nickel (µg/l)	< 0.53	< 0.53	< 7	< 7	ND
Dissolved Selenium (µg/l)	< 1	< 1	< 4	< 4	ND
Total Selenium (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Dissolved Silver (µg/l)	< 0.1	< 0.1	< 0.4	< 0.4	ND
Total Silver (µg/l)	< 0.11	< 0.11	< 0.43	< 0.43	ND
Dissolved Tin (µg/l)	< 0.5	< 0.5	< 5.0	< 5.0	ND
Total Tin (µg/l)	< 0.53	< 0.53	< 5.3	< 5.3	ND
Dissolved Vanadium (µg/l)	< 1	< 1	1.8	1.8	0
Total Vanadium (µg/l)	< 1.1	< 1.1	2	2	0
Dissolved Zinc (µg/l)	< 1	< 1	< 4	< 4	ND
Total Zinc (µg/l)	< 1.1	< 1.1	< 4.2	< 4.2	ND
Total Phosphorus (µg/l)	< 4	< 4	18	19	5
Dissolved Reactive Phosphorus (µg/l)	< 4	< 4	10.9	11.2	3
Total Nitrogen (µg/l)	110	110	< 300	< 300	ND
Total Kjeldahl Nitrogen (TKN) (µg/l)	100	100	< 200	< 200	ND
Total Ammonia (µg/l)	< 10	< 10	21	16	27
Nitrate-N + Nitrite-N (µg/l)	< 2	< 2	43	44	2
Chlorophyll *a* (µg/L)	< 0.2	< 0.2	1.2	1.1	9

Appendix B: Physical Shoreline Monitoring

ican REPORT

Tonkin+Taylor

LPC Channel Deepening Project

Physical Monitoring: Capital Dredging Update Q2 2020

Prepared for
Lyttelton Port Company

Prepared by
Tonkin & Taylor Ltd

Date
July 2020

Job Number
31791.5000

Exceptional thinking together

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Document Control

Title: LPC Channel Deepening Project					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
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Executive summary

Introduction

Lyttelton Port of Christchurch (LPC) has deepened and extended its navigation channel to accommodate all tide access with vessels of a 14.5 m draught as well as deepening the swing basin, associated berths and entrance to the Inner Harbour. Up to 18M m^3 of capital dredged material has been dredged and deposited at an offshore disposal site located some 6 km off Godley Head in 20 m water depth. Ongoing maintenance dredging of some 0.9M m^3 per annum will be disposed of at the existing consented maintenance spoil disposal grounds within the harbour and/or to an offshore spoil deposition ground 3 km off Godley Head in 17-18 m water depth.

In granting consents CRC172455, CRC172522, CRC172456 and CRC172523 (12 July 2017), a coastal monitoring programme is required to be undertaken to inform an Environmental Monitoring and Management Plan (EMMP). This includes data collected over a baseline year, during and following capital dredging and during maintenance dredging. Tonkin & Taylor Ltd. (T+T) have been engaged to evaluate whether and how both the capital and maintenance dredging will alter coastal processes, specifically with reference to potential changes in shorelines position and composition. A shoreline monitoring programme has been designed to detect such changes. This programme includes:

1 Photo-point monitoring
2 Sediment size analysis
3 Beach profile surveys
4 Seabed surveys
5 Shoreline analysis

Monitoring executed

Baseline shoreline monitoring has been undertaken on the dates shown in the Table below (as defined by Consent Condition 7.12.4, Appendix 1: Table of Monitoring and Frequency of Monitoring of CRC172455/CRC172522 and the draft Environmental Monitoring and Management Plan submitted with the resource consent applications). In general, monitoring has been undertaken in accordance with the proposed. It should be noted that a marine exclusion zone at Gollans Bay, implemented by the Christchurch City Council and McConnell Dowell, prevented access to location 7 after February 2017, therefore no monitoring was undertaken at this site for the duration of the monitoring period.

Name	2017 Baseline monitoring periods			
	Round 1	**Round 2**	**Round 3**	**Round 4**
Photo-point monitoring	30 January – 14 February 2017.	12 May - 9 June 2017.	15 August – 11 September 2017. Alternative round: 17 October 2017. Locations 14 and 15 not photographed at this round due to weather.	17 October – 3 November 2017.
Sediment size analysis	30 January – 1 February 2017		15 August – 17 October 2017	
Beach profile survey	ECan cycle: 22 February – 2 March 2017. Eliot Sinclair cycle: 3 February 2017.		ECan cycle: 18 August – 5 September 2017. Eliot Sinclair cycle: 6 November 2017.	

Seabed survey	15 February 2017, 18 February 2018[1] and 4 April 2018[1]
Shoreline analysis	5 December 2017 (with reference to 2015-16 aerial data).

[1]Addtional transects were collected following resolution of the dredging consent appeal (LPC email Comm. April 2018).

Following the commencement of capital dredging activities in September 2018, the 'during capital dredging' phase of monitoring has been undertaken.

Name	**2018 During capital dredge monitoring periods**
Photo-point monitoring	11 – 12 November 2018.
Sediment size analysis	7 and 12 November 2018.
Beach profile survey	7 November – 7 December 2018 (Eliot Sinclair) *Previous surveys also undertaken 15 February 2018 (ES) and 20 – 31 July 2018 (ECan)
Seabed survey	N/A
Shoreline analysis	N/A

Following the completion of the capital dredging activities, the 'following capital dredging' phase of monitoring has been undertaken.

Name	**2019 Post-capital dredge monitoring periods**
Photo-point monitoring	6 – 16 May 2019, 18-22 July 2019, 17-29 October 2019.
Sediment size analysis	6 – 18 May 2019, 18-22 July 2019.
Beach profile survey	8-10 May 2019, 15-22 July 2019
Seabed survey	December 2018 – January 2019
Shoreline analysis	N/A

Name	**2020 Post-capital dredge monitoring periods**
Photo-point monitoring	27 January – 2 February 2020, 8 – 9 June 2020
Sediment size analysis	27- January – 2 February 2020
Beach profile survey	23-30 January 2020, 11 May 2020
Seabed survey	N/A
Shoreline analysis	N/A

This report updates the previous monitoring report covering Q3 and 4 2019 (T+T, January 2020) and includes additional analysis of photo-point monitoring in January 2020 and June 2020, sediment size analysis from January 2020 and beach profile survey from January and May 2020

Results

Photo point monitoring

Photo point monitoring is intended to highlight any changes occurring in the morphology of the beach as seen from the ground. Over the course of the baseline year, no significant changes in morphology were observed at any of the monitored sites. Changes in beach appearance were mainly in relation to the movement of driftwood, shells and seaweed.

The 'during capital' round of monitoring continued to yield no significant changes in morphology at the observed sites. As in 2017, the changes observed in November 2018 were primarily centred on amounts of seashells, driftwood, and seaweed. There were some cases of water channels down the beach having disappeared.

The 'following capital' round of monitoring continued to yield no notable changes in morphology at the observed sites. As in previous years, the majority of changes observed in 2019 were centred on quantities of seashells, driftwood and seaweed. There were some cases of water channels re-appearing on the beach in locations that they had previously existed. As seashells, driftwood and seaweed are inconsequential in monitoring the effects of the dredging programme, the photo point monitoring results in 2020 only highlights any changes in the sediment composition and the beach levels. No notable changes in the morphology were observed.

Sediment size analysis

Sediment size analysis showed changes in the composition of each bay over the course of the baseline year. The sampled sites consistently presented with sediment size distributions that were very finely poorly sorted (i.e. a high proportion of very fine grains).

During the baseline monitoring period New Brighton and Sumner showed poorly graded, fine to medium sand across the profiles with very little change through the year. This is consistent with exposed open coast beaches. Taylors Mistake showed coarse sand in the lower profile increasing to very coarse through the year. This material may be derived from local cliff erosion. The Harbour beaches showed more widely graded, fine to coarse sands with size grading changing throughout the year, though no clear trend was discernible. This likely indicates that sands are layered according to grain size and results dependent on exactly where the sample is taken. Therefore it is likely that the baseline grain size for these beaches is widely graded with the mean size varying depending on sample location. The low tide sample at Purau Bay was very fine to fine sand and may be more representative of an intertidal platform than a beach.

During the capital dredging monitoring period New Brighton and Sumner remained poorly graded in all three regions and showed relatively stable distributions of sediment sizes. However, the low shore region for both New Brighton and Sumner showed a small increase in sediment size. All regions still consisted of only fine to medium sands. Taylors Mistake continued to present dynamic behaviour with its proportion of very coarse sands in the lower profile reduced between samples. The harbour beaches continued to show more widely graded sediments. All these harbour sites showed fluctuations (to some degree) in the proportion of fine to coarse sands however there were still no discernible overarching trends with respect to either beach region (upper-, mid- or lower-shore) or position within the harbour.

Some changes in the sediment distributions are apparent in the 2019 samples following the capital dredging. The Southshore, Sumner, Camp Bay and Port Levy sites generally exhibit similar grading profiles to those exhibited prior to capital dredging. The grading at Taylors Mistake is slightly coarser in May 2019 and slightly finer in July 2019, while the grading at Gollans and Corsair Bay's is slightly finer in May 2019 and notably coarser in July 2019.

Sediment size analysis in 2020 were, in general, consistent with what was observed in the previously rounds. Notable changes observed during the sediment size analysis and changes outside our previous envelope of change are outlined in the report.

Beach profile surveys

Beach profile surveys were carried out at six month intervals over the course of the baseline year of monitoring. The New Brighton Profiles were very stable over the monitoring period with the upper beach fluctuating in level by 0.1 to 0.4 m. Previous studies (T+T, 2017) have shown vertical fluctuations of up to 1.5 m associated with significant storm events indicating that this monitoring period was particularly benign. It is recommended that future profiles are compared to the historic profile record here as well as just these baseline records. The lower parts of the Sumner profile adjacent to the Avon-Heathcote estuary mouth has moved landward by up to 50 m. This is not surprising in this dynamic environment. Furthermore, previous studies (T+T, 2015) have indicated that the coastline adjacent to the estuary may respond to changes in the estuary tidal prism caused by seabed uplift during the Canterbury earthquake sequence. The Sumner and Taylors profiles have dropped by up to 0.5 m with the Taylors profile retreating by almost 10 m. The harbour profiles have been more stable showing profile level changes of less than 0.2-0.3 m, although the outer portions of Camp Bay appear to have accreted by up to 0.5 m.

Beach profile surveys were also carried out biannually during the 2018 capital dredging works. The New Brighton profiles were again very stable, with observed fluctuations in beach level reaching only 0.15 m. Compared to both the baseline monitoring period and the historical record mentioned above, this suggests another benign year for area. The Southshore profile appeared similarly stable except for the lower foreshore where beach levels appear to have lifted by around 0.3 m since the baseline period. The lower beach at the Sumner profiles has again moved seaward, with accretion across the foreshore shifting the shoreline up to 75 m further offshore. The Taylors Mistake profile appears relative stable since 2017, the only notable change comes with the lower foreshore dropping in level by up to 0.3 m between August 2017 and December 2018 corresponding to the lower profile shifting up to 8 m landward. Apart from Corsair Bay and Camp Bay, the harbour profiles continued to present a more stable picture with beach level changes of less than 0.2 m. Corsair Bay and Camp Bay both showed vertical fluctuations in parts of the foreshore of up to 0.3 m where, generally speaking, the February 2018 profiles had lost sediment since 2017 but the November 2018 profiles had accreted.

In general, the beaches outside the harbour show accretion of the foreshore following the capital dredging works in May 2019 and fluctuating levels in accretion and loss of sediment in July 2019. The beaches within the harbour present a more mixed picture. Rapaki Beach and Purau Bay appear relatively stable throughout the years (including the ‘during capital’ and ‘following capital’ years). The profile at Corsair Bay steepened between November 2018 and May 2019 (with accretion at the upper shore and erosion at the lower shore) but then during the July round the profile has smoothed (with erosion at the upper shore and accretion at the lower shore). The profile at Camp Bay has lowered between November 2018 and July 2019.

Beach profiles in 2020 where in general were consistent to what was observed in the previously rounds of beach profiling. The notable changes observed from the previous round in the beach profile surveys were at New Brighton and Taylors Mistake where accretion was observed at the mid to low shores. Loss of sediment was evident at both the Sumner locations. Sumner (Main Rd) experienced a loss of sediment at the seaward face dunes and at the mid shore where Sumner (Hardwicke St) showed an average decrease of 0.3 m of sediment from the beach toe to the end of the foreshore.

Seabed survey

A seabed survey was carried out once over the course of the baseline monitoring study (February 2017 – April 2018). A total of ten transects of bathymetry were surveyed to capture the navigation channel, the spoil ground and the surroundings. Following an initial survey of eight transects in February 2017, additional transects were surveyed following the resolution of a consent appeal (LPC communications, 19 April 2018). From the combined survey a defined channel is clearly evident within the harbour and relatively flat seabed offshore.

The eight original transects and the additional transects have been surveyed again in December 2018 and January 2019, respectively, as part of the post-dredging monitoring phase. Transect 1 and 1a show a slight decrease in level (~0.1 to 0.2 m) between January 2017 and December 2018. The uniformity of the drop in both transects is somewhat unusual however no error in the surveys is apparent. Particular attention should be paid to upcoming surveys to see if any trend continues. Transects 2, 3, 4 and 5 show the dredged channel at between -13.8 and -15 m. These profiles also show slight (0.1 to 0.5 m) increase in seabed level adjacent to the dredged channels with transect 5 also showing a lightly shallower (~0.5 m) seabed towards Godley Head, although this may be a function of exact dredging line and whether specific seabed are captured. Profile 5a shows minimal (<0.1 m change).The offshore surveys (transects 6 through 8) capture the spoil disposal activity with the seabed inside the spoil area up to 1.5 m (typically <1 m) higher than in 2017 and no changes seen elsewhere.

Shoreline analysis

Shoreline analysis was carried out using historic aerial imagery to assess how the shoreline extents have changed over time. The shoreline was digitised for all fifteen sites, based on LINZ's 2015-16 Urban and Rural aerial sets for Christchurch. As a general rule, the shoreline was defined by the vegetation line. No conclusions have been drawn from this single assessments.

1 Introduction

Lyttelton Port of Christchurch (LPC) has deepened and extended its existing navigation channel to accommodate all tide access with vessels of a 14.5 m draught as well as deepening the swing basin, associated berths and entrance to the Inner Harbour. Up to 18M m^3 of capital dredged material has been be deposited at an offshore disposal site located some 6 km off Godley Head in 20 m water depth. Ongoing maintenance dredging of some 0.9M m^3 per annum will be disposed of at the existing consented maintenance spoil disposal grounds within the harbour and/or to an offshore spoil deposition ground 3 km off Godley Head in 17-18 m water depth.

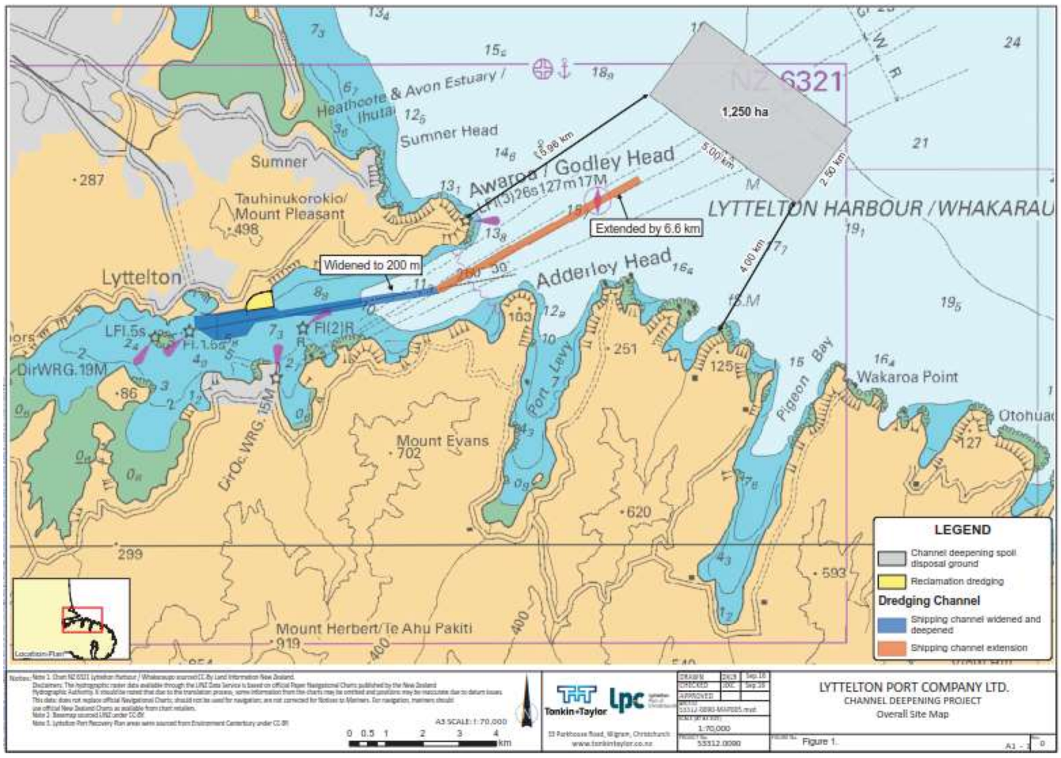

Figure 1.1: Location of Capital and Maintenance dredging and disposal locations

In granting consents CRC172455, CRC172522, CRC172456 and CRC172523 (12 July 2017), a coastal monitoring programme is required to be undertaken to inform an Environmental Monitoring and Management Plan (EMMP). This includes data collected over a baseline year, during and following capital dredging and during maintenance dredging.

Tonkin & Taylor Ltd. (T+T) have been engaged to evaluate whether and how both the capital and maintenance dredging will alter coastal process, specifically with reference to potential changes in shorelines position and composition. A shoreline monitoring programme has been designed to detect such changes. This programme includes:

1 Photo-point monitoring
2 Sediment size analysis
3 Beach profile surveys
4 Seabed surveys
5 Shoreline analysis.

Further details on the methods, outputs and frequency are presented in the section below. Results of our coastal monitoring for the baseline year are presented and discussed in Section 3.

2 Monitoring programme

The following programme has been undertaken to monitor potential changes in shoreline position and characteristics:

Table 2.1: Shoreline monitoring programme

Name	Description	Monitoring requirement	Frequency[1]			
			Baseline	**During capital**	**Following capital**	**During maintenance**
Photo-point monitoring	Photographs taken from fixed locations and aspects.	Visually assess beach level change or fine sediment deposition.	3 monthly	3 monthly	3 monthly for 2 years 6 monthly to 5 years	Annually
Sediment size analysis	Particle size analysis of sediment samples from the intertidal beach face (3 locations on surface)	Quantifies sediment size on beach to determine changes in texture and composition	6 monthly	6 monthly	6 monthly for 2 years Annually to 5 years	N/A – effects not likely if not observed during capital works
Beach profile survey	Beach profile survey from established benchmark[2].	Quantifies changes in profile geometry and/or location	6 monthly	6 monthly	6 monthly to 5 years	Annually[3]
Seabed survey	Profile survey across seabed or seabed depth at specific locations	Quantified change in seabed level over time	Annually	Annually	Annually to 5 years	5 yearly
Shoreline analysis	Digitise and compare shoreline positions from aerial photographs/satellite imagery	Determines change in shoreline position.	Baseline assessment of historic shoreline (Lyttelton harbour only)	Annually (or as aerial photographs/ satellite imagery become available) to 5 years following dredging project.		5 yearly

[1]Monitoring frequency is broken into three stages,

- ***Baseline*** before capital dredging begins; ***During*** capital dredging project; ***Following*** capital dredging project
- ***Maintenance*** during maintenance dredging (if disposed offshore)

[2]Survey requirements,

- *Survey using staff and level, total station or RTK GPS*
- *Survey during spring low tide, pick up all changes in grade*
- *Required horizontal accuracy +/- 0.1 m, vertical accuracy +/- 0.05 m*

[3]Assume profiles at Brighton and Sumner will continue to be monitored at 6 month intervals by ECan.

2.1 Locations

Monitoring has been undertaken at the locations shown in Figure 2 1 for the types of monitoring shown in Table 2.2 below:

Table 2.2: Proposed coastal monitoring locations and specifications

Location		Capital dredging project			Maintenance dredging (if disposed offshore)		
		Photo-point monitoring	Sediment size analysis	Beach profile survey	Photo-point monitoring	Sediment size analysis	Beach profile survey
1.	New Brighton ECAN C0815 (Rodney Street)	✓		✓[1]	✓		✓[1]
2.	South New Brighton ECAN C0513 (Halsey Street)	✓		✓[1]	✓		✓[1]
3.	Southshore ECAN C0362 (Tern Street)	✓	✓	✓[1]	✓		✓[1]
4.	Sumner ECAN CCC0190 (Main Rd)	✓		✓[1]	✓		✓[1]
5.	Sumner ECAN CCC0112 (Hardwicke St)	✓	✓	✓[1]	✓		✓[1]
6.	Taylors Mistake	✓	✓	✓	✓		✓
7.	Gollans Bay	✓	✓				
8.	Corsair Bay	✓	✓	✓			
9.	Cass Bay	✓					
10.	Rapaki Bay	✓		✓	✓		✓
11.	Purau Bay	✓	✓	✓			
12.	Pile Bay	✓					
13.	Camp Bay	✓	✓	✓	✓		✓
14.	Little Port Cooper	✓					
15.	Port Levy	✓	✓		✓		

[1]ECAN currently collect profile data here and are likely to continue (Cope pers. Comm. Sept 2016)

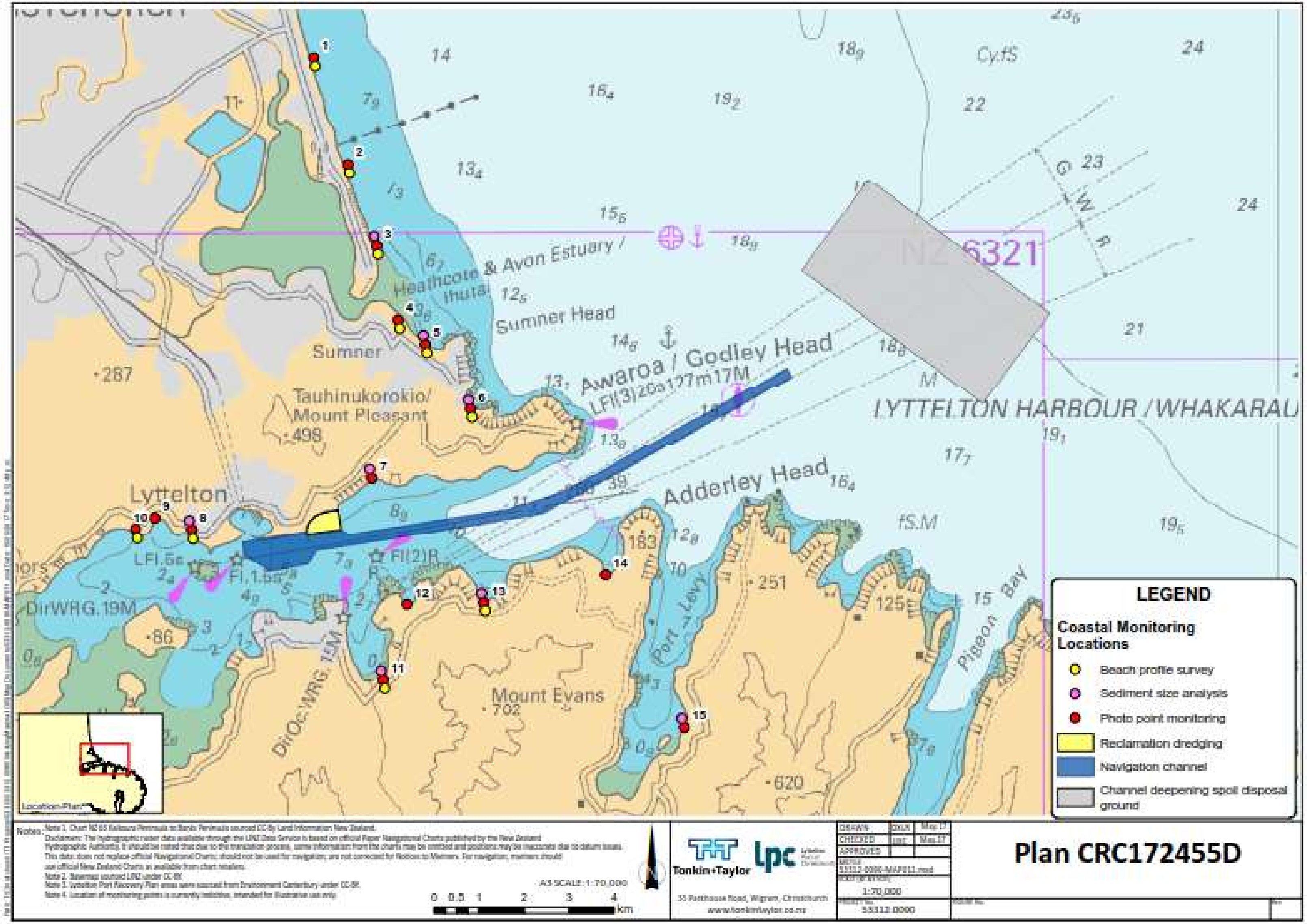

Figure 2.1: Map of coastal monitoring locations

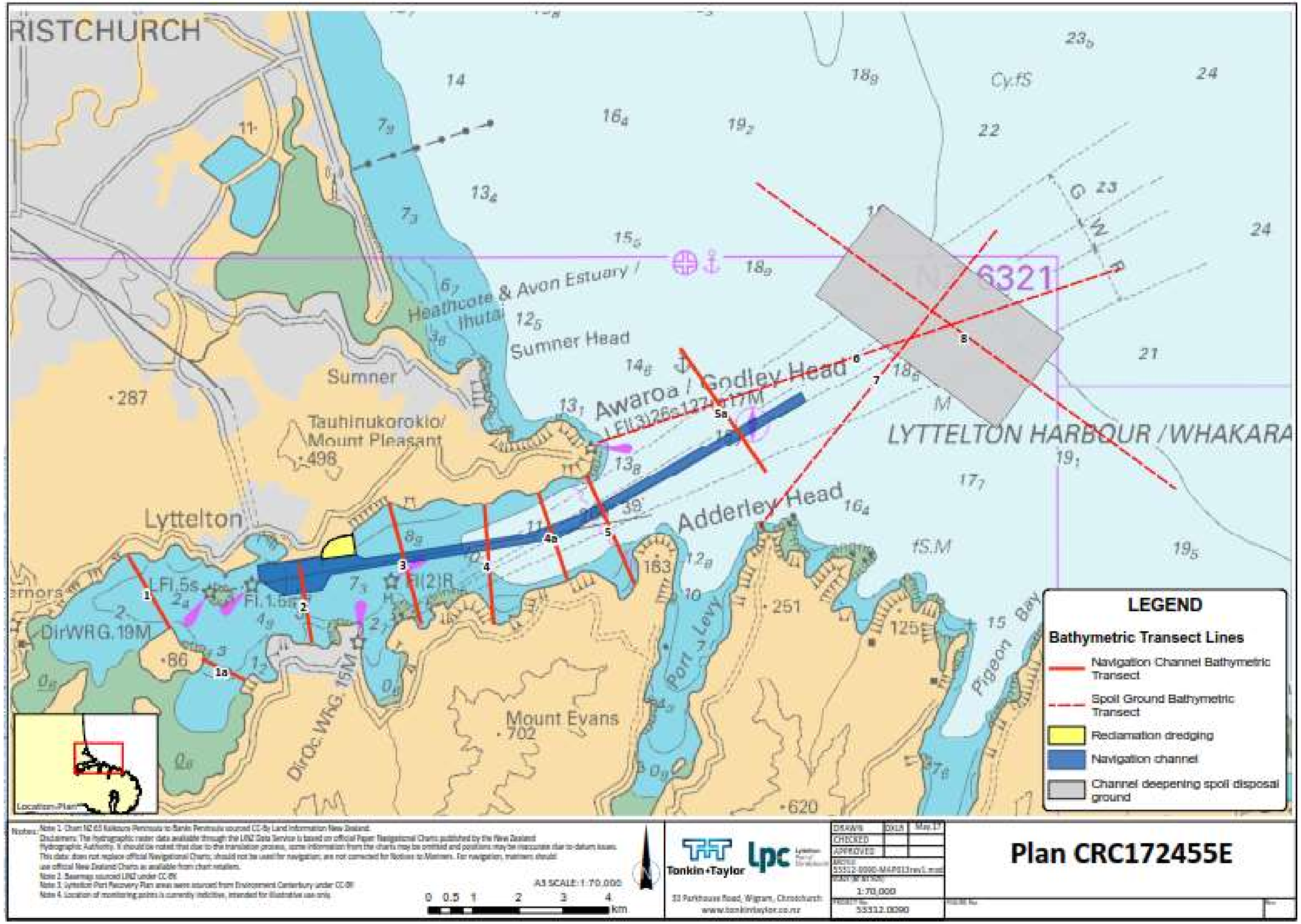

Figure 2.2: Map of proposed bathymetric survey transect locations

2.2 Monitoring undertaken

Baseline shoreline monitoring has been undertaken on the dates shown in Table 2.3 below. In general, monitoring has been undertaken in accordance with the plan proposed above.

It should be noted that a marine exclusion zone at Gollans Bay, implemented by the Christchurch City Council and McConnell Dowell, prevented access to location 7 after February 2017, therefore no monitoring was undertaken at this site for the duration of the monitoring period.

Table 2.3: 2017 Baseline year shoreline monitoring timeline as executed

Name	2017 Baseline monitoring periods			
	Round 1	Round 2	Round 3	Round 4
Photo-point monitoring	30 January – 14 February 2017.	12 May - 9 June 2017.	15 August – 11 September 2017. Alternative round: 17 October 2017. Locations 14 and 15 not photographed at this round due to weather.	17 October – 3 November 2017.
Sediment size analysis	30 January – 1 February 2017		15 August – 17 October 2017	
Beach profile survey	ECan cycle: 22 February – 2 March 2017. Eliot Sinclair cycle: 3 February 2017.		ECan cycle: 18 August – 5 September 2017. Eliot Sinclair cycle: 6 November 2017.	
Seabed survey	15 February 2017, 18 February 2018[1] and 4 April 2018[1]			
Shoreline analysis	5 December 2017 (with reference to 2015-16 aerial data).			

[1]Addtional transects were collected following resolution of the dredging consent appeal (LPC email Comm. April 2018).

Following the commencement of capital dredging activities in September 2018, the 'during capital dredging' phase of monitoring has been undertaken.

Table 2.4: 2018 During capital shoreline monitoring/sampling timeline as executed

Name	2018 During capital monitoring periods
Photo-point monitoring	11 – 12 November 2018.
Sediment size analysis	7 and 12 November 2018.
Beach profile survey	7 November – 7 December 2018 (Eliot Sinclair) *Previous surveys also undertaken 15 February 2018 (ES) and 20 – 31 July 2018 (ECan)
Seabed survey	N/A
Shoreline analysis	N/A

Following the completion of the capital dredging activities, the 'following capital dredging' phase of monitoring has been undertaken.

Table 2.5: 2019 Following capital shoreline monitoring/sampling timeline as executed

Name	**2019 Following capital monitoring periods**
Photo-point monitoring	6 – 16 May 2019, 18-22 July 2019, 17-29 October 2019.
Sediment size analysis	6 – 18 May 2019, 18-22 July 2019.
Beach profile survey	8 – 10 May 2019 (Eliot Sinclair).15-22 July 2019.
Seabed survey	December 2018 – January 2019
Shoreline analysis	N/A

Table 2.6: 2020 Following capital shoreline monitoring/sampling timeline as executed

Name	**2020 Post-capital dredge monitoring periods**
Photo-point monitoring	27 January – 2 February 2020, 8 – 9 June 2020
Sediment size analysis	27- January – 2 February 2020
Beach profile survey	23-30 January 2020, 11 May 2020
Seabed survey	N/A
Shoreline analysis	N/A

This report updates the previous monitoring report (T+T, January 2020 covering Q3 and 4 2019) and includes additional analysis of photo-point monitoring in January 2020 and June 2020, sediment size analysis from January 2020 and beach profile survey from January and May 2020. The Q2 photopoint monitoring was slightly delayed from April until June due to the Covid-19 lock down.

3 Results and discussion

Raw data for each type of monitoring is included within Appendices A – E. Results are described and discussed below.

3.1 Photo point monitoring

This section describes the shoreline as seen in each set of photos attached in Appendix A. Any changes to the shoreline that have occurred are noted below.

As part of the baseline monitoring all fifteen monitoring locations were photographically monitored in 2017. Where possible, these were undertaken at 3-month intervals as per the monitoring plan (see Table 2.2). For the monitoring phases during and following capital dredging in November 2018 and May 2019 respectively, the fifteen locations were all photographed again (see Table 2.4 and 2.5).

Photo point monitoring is intended to highlight any changes occurring in the morphology of the beach as seen from the ground. Over the course of the baseline year, no significant changes in morphology were observed at any of the monitored sites. Changes in beach appearance were mainly in relation to the movement of driftwood, shells and seaweed. The only other changes came with some isolated cases of changing sand colour (from grey to brown) at the Brighton sites.

The 'during capital' round of monitoring continued to yield no significant changes in morphology at the observed sites. As in 2017, the changes observed in November 2018 were primarily centred on amounts of seashells, driftwood, and seaweed. There were some cases of water channels down the beach having disappeared, and sediment surfaces roughening.

The 'following capital' round of monitoring continued to yield no notable changes in morphology at the observed sites. As in previous years, the majority of changes observed in 2019 were centred on quantities of seashells, driftwood and seaweed.

As seashells, driftwood and seaweed are inconsequential in monitoring the effects of the dredging programme, the photo point monitoring results in 2020 only highlights any changes in the sediment composition and the beach levels. As previous years, no notable changes in the morphology were observed.

3.1.1 Location 1, New Brighton

Between January and May 2017, the amount of seaweed and shells around the point decreased. The colour of the shoreline shifted from grey to brown. By August 2017, the visible seaweed and driftwood had washed away from the point. Then by November 2017, seaweed and driftwood have gathered around the point. By November 2018, some of the seaweed had washed away from the point, and the mark showing the high tide line appeared straighter. By May 2019, no further changes had been observed. Then by 2019, the amount of seaweed around the point has decreased. Longshore ripples have formed and the surface of the beach has smoothed. By January and June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.2 Location 2, South Brighton

Between January and May 2017, the amount of driftwood and shells at the point reduced while longshore ripples developed in the sand and the colour of the shoreline shifted from grey to brown. By August 2017, the visible driftwood and seaweed had disappeared from the point. Then by November 2017, the longshore ripples were gone, seaweed and driftwood had gathered on the beach. By November 2018, the seaweed and driftwood had washed away from the point and the surface of the sediment had roughened. By May 2019, the surface of the sediment had smoothed slightly and some driftwood had gathered around the photo point. By July 2019, the surface of the sediment has smoothed while longshore ripples developed in the sand, and the colour of the shoreline shifted from grey to grey brown. By October 2019 and January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.3 Location 3, Southshore

Between January and May 2017, driftwood and seaweed had disappeared from the shore while faint longshore ripples in the sand had formed and the colour gradient of the sediment is more gradual. By August 2017, the number of shells around the point had decreased and there was a more prominent change in colour partway down the beach. Then by November 2017, a small amount of driftwood and seaweed had gathered on the beach. By November 2018, the longshore ripples in the sand had washed away, and the surface of the sediment had roughened to the south. By May 2019, a large piece of driftwood had appeared on the beach. By July 2019, the amount of shells on the beach has decreased and the shells have converged more in line to the centre of the shoreline. By October 2019 and January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.4 Location 4, Sumner (at the Surf Life Saving Club)

Between January and May 2017, the amount of driftwood and seaweed visible around the point had increased and the beach surface had roughened. Between January and August 2017 there we no noticeable changes. By November 2017, however, the sand appeared rougher to the south east and more driftwood and seaweed had gathered around the point. By November 2018, some of the seaweed and driftwood had washed away from the point. By May 2019, the surface of the sediment had smoothed slightly and the seaweed and driftwood had washed away from the point. By July 2019, the colour of the shoreline has shifted from grey to grey brown and the colour is uniform throughout the area. By October 2019, no further changes were observed. By January 2020, the sandbar present at the high tide mark was more evident. In June 2020, the beach surface is undulating. Water is present in the troughs.

3.1.5 Location 5, Sumner

By May 2017, the sand has lost a green tinge observed in January (assumed to be from washed up seaweed or other plant life) and longshore ripples had formed on the beach. By August 2017, the ripples were more noticeable. Then, between August and November 2017, there we no observed changes. By November 2018, the channel of water to the south of the point had dissipated. By May 2019, the surface of the sediment had become slightly rougher to the north of the photo point. By July 2019, the surface of the sediment has smoothed and the ripples are more noticeable. By October 2019, rocks were visible at the high tide mark signifying minor sediment loss. By January 2020, there was minor accretion as the top surface of the rocks at the high tide mark were less visible. By June 2020, minor sediment loss were evident as the rocks at the high tide mark were more exposed.

3.1.6 Location 6, Taylors Mistake

Between January and May 2017, a small amount of seaweed had gathered near the point and the bands of colour change (observed in January) had increased in number. Between May and November 2017, there we no observed changes. By November 2018, the driftwood had washed away from the point. By May 2019, the surface of the sediment had smoothed and the changes in colour had become more pronounced. By July 2019, the sediment had smoothed across the area and the colour change has become more evident. By October 2019, the longshore ripples where not visible on the shoreline. By January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.7 Location 7, Gollans Bay

No changes to the shoreline could be observed due to a marine exclusion zone imposed after the first photo point survey. A second observation was undertaken in November 2018 and no noticeable changes were observed. A third observation was undertaken in May 2019, and there was an increased amount of black sediment in the bay. By July 2019, there were less black sediment visible and the bay had a moderate gradient. By October 2019, no further changes had been observed. By January 2020, rocks previously not visible were now visible signifying minor sediment loss. By June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.8 Location 8, Corsair Bay

Between January and May 2017, a small amount of seaweed had gathered at the point. By September 2017, different sections of colour (observed in January and May 2017) were more distinct. Then, between September 2017 and November 2018, there we no observed changes. No changes were observed in May 2019. By July 2019, small amounts of driftwood had gathered around the photo point. By October 2019, the sediments at the shoreline appears to be more golden in colour. By January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.9 Location 9, Cass Bay

Between January and May 2017, there we no observed changes. By September 2017, however, the gravel (previously observed at the upper and western parts of the beach) was more uniform over the bay. Then, by November 2017, the gravel had less uniform coverage. By November 2018, the channel previously observed had disappeared and the gravel layer had become more uniform. In May 2019, the gravel layer appeared less uniform and the water channel had reappeared in its previous location. By July 2019, the water channel has disappeared and the gravel layer appeared more uniform. By October 2019, no further changes had been observed. By January 2020, the gravel had less coverage across the surface of the bay, exposing more areas of fine sediment (sand and silt). In June 2020, more gravel were visible across the bay.

3.1.10 Location 10, Rapaki Bay

Between January and May 2017, a small amount of moss had grown on the bay’s rocks. By September 2017, the extent of the moss had greatly increased. By November 2017, less moss was present. By November 2018, less moss was present and some water was retained on the surface of the sediment. By May 2019, there was less moss over the gravel and the gravel layer was less uniform. By July 2019, there was no moss visible and some water has been retained on the surface of the bay. By October 2019 and January 2020, no noticeable changes in the sediment composition or beach level were observed. By June 2020, more cobbles were covering the bay. This was especially more evident at the high tide mark.

3.1.11 Location 11, Purau Bay

Between January 2017 and November 2018, there we no noticeable changes to the shoreline. In May 2019, the central sediment band appeared cleaner, with a more uniform colour. By July 2019, the central band has expanded to the lower band to the east of the bay. By October 2019 and January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.12 Location 12, Pile Bay

Between January and May 2017, the amount of seaweed in the bay had reduced while bands of discolouration had formed in the sand. Between May 2017 and May 2019 there were no observed changes. By July 2019, the amount of seaweed in the high water mark has increased. By October 2019 and January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.13 Location 13, Camp Bay

Between January and May 2017, there was a slight increase in the amount of seaweed and driftwood in the bay. By September 2017, the amount of visible seaweed and driftwood had lessened and a patch of dark sediment had collected in the middle of the bay. By November 2017, the black sediment observed previously was gone and a demarcation in the colour of the sand had shifted further down the beach. By November 2018, the colour change had washed away, as had the seaweed and driftwood. By May 2019, the sediment displayed a more uniform colour and more driftwood has gathered around the photo point. By July 2019, dark sediment has re-appeared in the middle on the bay. By October 2019 and January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.1.14 Location 14, Little Port Cooper

By June 2017, the sand appeared a more golden colour than in the February 2017 observation. The seaweed and driftwood previously observed was all gone and bands of changing colour were more prominent. By October 2017, the surface of the bay was smoother and seaweed had gathered around the photo point. The colour bands had formed two distinct bands. The third round of 2017 photographs was missed due to weather. By November 2018, the seaweed had washed away, but larger pieces of driftwood had collected around the point. By May 2019, the larger pieces of driftwood had given way to smaller driftwood which sat along the high tide line. By July 2019, the colour of the colour of the shoreline had shades of light and dark brown. By October 2019, rocks were visible from the high tide mark. By January and June 2020, there were minor accretion as the rocks previously visible across the bay were now not visible.

3.1.15 Location 15, Port Levy/Koukourarata

Between February and June 2017, the amount of seaweed present below the water line had increased. By October 2017, a channel had formed in the bay indicating water had been running down the beach. The third round of photographs was missed due to weather. By November 2018, the channel had disappeared and many of the shells had washed away. By May 2019, the sand and silt band was once again covered in gravels and shells. Two water channels has formed west of the photo point indicating water has been running down. By October 2019, the water channels had disappeared. By January/June 2020, no noticeable changes in the sediment composition or beach level were observed.

3.2 Sediment size analysis

This section summarises the results of the sediment size analyses undertaken over the course of the year. Any changes that occurred as time passed are noted. Note that proportional diameters reflect the proportion of the sediment that has a diameter equal or less than the value by volume.

For the baseline monitoring phase, eight beaches were sampled in 2017; where possible, sediment samples were taken twice for each site at intervals of at least 6 months as per the monitoring plan (see Table 1). For the monitoring phase during capital dredging, the each beaches were sampled again in the same manner in November 2018. Following capital dredging, the eight beaches were sampled in May 2019. Site-by-site results can be seen in Appendix B.

During the baseline monitoring period New Brighton and Sumner showed poorly graded, fine to medium sand across the profiles with very little change through the year. This is consistent with exposed open coast beaches. Taylors Mistake showed coarse sand in the lower profile increasing to very coarse through the year. This material may be derived from local cliff erosion. The Harbour beaches showed more widely graded, fine to coarse sands with size grading changing throughout the year, though no clear trend was discernible. This likely indicates that sands are layered according to grain size and results dependent on exactly where the sample is taken. Therefore it is likely that the baseline grain size for these beaches is widely graded with the mean size varying depending on sample location. The low tide sample at Purau Bay was very fine to fine sand and may be more representative of an intertidal platform than a beach.

During the capital dredging monitoring period New Brighton and Sumner remained poorly graded in all three regions and showed relatively stable distributions of sediment sizes. However, the low shore region for both New Brighton and Sumner showed a small increase in sediment size. All regions still consisted of only fine to medium sands. Taylors Mistake continued to present dynamic behaviour with its proportion of very coarse sands in the lower profile reduced between samples. The harbour beaches continued to show more widely graded sediments. All these harbour sites showed fluctuations (to some degree) in the proportion of fine to coarse sands however there were still no discernible overarching trends with respect to either beach region (upper-, mid- or lower-shore) or position within the harbour.

Some changes in the sediment distributions are apparent in the 2019 samples following the capital dredging. The Southshore, Sumner, Camp Bay and Port Levy sites generally exhibit similar grading profiles to those exhibited prior to capital dredging. The grading at Taylors Mistake is slightly coarser in May 2019 and slightly finer in July 2019, while the grading at Gollans and Corsair Bay's is slightly finer in May 2019 and notably coarser in July 2019.

Sediment size analysis in 2020 where in general were consistent to what was observed in the previously rounds. Notable changes observed during the sediment size analysis are shown in the description below and changes outside our previous envelope of change is outlined in the conclusion section.

3.2.1 Location 3, Southshore

3.2.1.1 Baseline monitoring

The distribution of sediments size has remained relatively stable across the Southshore site, most notably the upper (High) region of the beach profile presents with near-identical sediment size breakdown results in both the January 2017 and August 2017 samples. The mid shore sediments have slightly increased is size while the lower shore sediments have very slightly decreased in size.

All three regions of the beach remain poorly graded and consist of only fine to medium sand.

3.2.1.2 During capital monitoring

The upper (High) region of the beach profile again presents a similar sediment size breakdown, although a very slight trend of increasing sediment size is apparent. The mid shore presents a more varied picture – after sediment sizes slightly increased in 2017, they are very slightly reduced (finer sediments observed) in November 2018 compared to August 2017. The lower shore sediment distribution also shows more fines in November 2018 to indicate a trend of decreasing sediment size.

All three regions of the beach remain poorly graded and consist of only fine to medium sand

3.2.1.3 Following capital monitoring

The upper (High) beach sample shows slightly decreased sediment size compared to 2018 and presents a similar sediment size to 2017 during the Baseline monitoring. The mid shore shows negligible change in sediment size since 2018. The lower shore sediment showed a negligible change in sediment size distribution at May 2019 however, the sample taken on July 2019 shows an increase in sediment size. Sample taken in January 2020 shows a slight increase in sediment size at the low shore and negligible change in the high and mid shores.

All three regions of the beach remain poorly graded and consist of only fine to medium sand.

3.2.2 Location 5, Sumner

3.2.2.1 Baseline monitoring

The distribution of sediments size has remained very stable across the Sumner site, with all three sampling regions showing minimal change in the 10%, 50% and 90% diameters.

All three regions of the beach remain poorly graded and consist of only fine to medium sand.

3.2.2.2 During capital monitoring

All three regions of the beach are still very stable in their distribution of sediment size. All three regions of the beach remain poorly graded and consist of only fine to medium sand.

3.2.2.3 Following capital monitoring

The high shore shows negligible change in sediment size since 2017. The mid beach sample shows slightly increased sediment size compared to 2017 and 2018. The lower shore sediment distribution shows an increase in sediment size with all 10%, 50% and 90% diameters increasing. Sample taken in January 2020 shows negligible change in sediment size for all three shores.

All three regions of the beach remain poorly graded and consist of only fine to medium Sand.

3.2.3 Location 6, Taylors Mistake

3.2.3.1 Baseline monitoring

The Taylors Mistake sediment sampling presents more dynamic behaviour. The upper- (High) shore only shows a minor change between January and August (with sediment sizes slightly increasing), but the mid shore sediment distribution has shifted to show an increase in sediments greater than 200 µm and the lower shore region shows a dramatic change in its distribution of sediments.

More specifically, the lower shore has gone from being poorly graded to very well graded with an increase in the proportion of both finer and coarser sediments (as opposed to sediments being moderately uniform in size).

3.2.3.2 During capital monitoring

Sampling continues to present dynamic behaviour at Taylors Mistake. The upper (High) shore still only presents minor changes in sediment size. The distribution of sediment sizes at the mid shore appears to be somewhat finer, with the 10%, 50% and 90% diameters all decreased to below those sampled in January 2017. The lower shore has bounced back after its very well graded sample in August 2017. The sediment distribution is now poorly graded with a finer sediments than what was seen in January 2017.

All three regions of the beach remain poorly graded. The upper and mid shore regions consists of only fine to medium sand while the low shore while consists of fine to coarse sand.

3.2.3.3 Following capital monitoring

The two sediment size analysis undertaken following capital monitoring showed very differing results. For the sediments sampled in May 2019 the high, mid and low shore sediment distributions shows a coarser sediment size, with their 10%, 50% and 90% diameters all increasing compared to 2018. However, for the sediments sampled in July 2019, for all three regions the sediments had become finer compared to 2018. The sediment size analysis taken during capital monitoring in 2018 lies in the middle of the two curves. Sample taken in January 2020 shows an increase in sediment size at the low shore with their 10%, 50% and 90% diameters all increasing compared to its previous round and negligible change in the high and mid shores.

All three regions of the beach remain poorly graded. The lower shore region now consists of fine to coarse sand.

3.2.4 Location 7, Gollans Bay

3.2.4.1 Baseline monitoring

Gollans Bay was inaccessible during the second period of sampling (due to a marine exclusion zone imposed), therefore changes in sediments cannot be assessed.

3.2.4.2 During capital monitoring

With a mismatched labelling system between the 2017 and 2018 samples, region-specific comparisons were not possible. However, the distribution of sediment sizes appear relatively consistent across the bay. The three 2018 samples are poorly graded and the samples consisted of coarse sand.

3.2.4.3 Following capital monitoring

The two sediment sampled following capital monitoring shows differing results. For the sediments sampled in May 2019, the high and low shore sediment distributions show a slightly finer sediment size compared to 2018 with the mid shore sediment showing negligible change. However, for the sediments sampled in July 2019, the sediments overall showed a significantly coarser sediment size, except for the mid region of the beach profile which presented slightly finer sediment size breakdowns, with their 10%, 50% and 90% diameters all decreasing to those sampled in 2018. However, for the sample taken in January 2020, the mid shore distribution follows the trend in 2018 very closely. The high shore distribution, shows significant increase in sediment size with the curve on the left of the envelope of previous changes. The low shore sediment size distribution shows a decrease in sediment size since the previous data but now follows the data taken in 2018 and May 2019 very closely.

All three regions of the beach are now moderately well graded and consists of fine to coarse sand. The lower shore region now consists of fine to coarse sand.

3.2.5 Location 8, Corsair Bay

3.2.5.1 Baseline monitoring

Corsair Bay shows substantial change, with the upper (High) shore increasing its proportion of sediments greater than 200 µm, the mid shore becoming significantly finer by September and the lower shore becoming finer still. Interestingly, the pattern of sediment sizes moving offshore has reversed between January and September – in January, average sediment sizes went from finer to coarser moving from the upper to lower shore, whereas in September, the opposite was true.

The upper region of the beach remains moderately well graded and consists of fine to coarse sand. The mid and lower shore remains poorly graded and also consists of fine to coarse sand.

3.2.5.2 During capital monitoring

Sediments at the lower shore have increased in size since 2017, suggesting a general trend of increasing sediment size. The mid shore sample also shows an increase in average sediment size, specifically the 10% and 50% diameter measures have increased. The upper (High) shore shows a significant decrease in sediment size since 2017. All three regions are now poorly graded and mainly consist of fine to medium sand size particles.

3.2.5.3 Following capital monitoring

The two sediment sampled following capital monitoring shows differing results. For the sediments sampled in May 2019, the upper sediment distribution shows a slightly finer sediment size compared to 2018, while for the upper sediment sampled in July 2019 showed a significant increase in sediment size for all 10%, 50% and 90% diameters. Most notably, the 50% diameter has increased approximately 550 µm from 2018.

The middle shore has also become significantly finer in May 2019 but the sample taken in July 2019 shows negligible change in comparison to 2018.

The lower shore displays a much more erratic response with the 10% diameter reduced dramatically, the 50% diameter increased and the 90% diameter remaining stable from the analysis on May 2019. For the sediments sampled in July 2019 for the lower shore, shows a similar sediment size to the sample taken during capital monitoring (2018). Sample taken in January 2020 in the low and mid shore shows an increase in average sediment size, specifically the 10% and 50% diameter measures have increased since 2019. The high shore shows a notable decrease in sediment size for all 10%, 50% and 90% diameters. However, all the changes are within the previous change of envelope.

As a result, the high and mid region is still poorly graded and now consists of medium to coarse sand particle sizes and the low region is now classified as well graded with particle sizes ranging from fine silts to coarse sand.

3.2.6 Location 11, Purau Bay

3.2.6.1 Baseline monitoring

Purau Bay appears relatively stable at its lower shore but shows changes in sediment size at the upper and mid regions. The upper (High) and mid shore present with higher proportions of finer sediments in September compared to January's samples.

All three regions of the beach remain moderately to poorly graded and mainly consists of fine to coarse sand particle sizes.

3.2.6.2 During capital monitoring

Purau Bay is still relatively stable at the lower beach but shows a very slight trend of decreasing sediment size – i.e. increasing proportion of finer sediments. The mid shore shows a somewhat stable distribution with no major changes observed between September 2017 and November 2018. The upper (High) shore presents a more dramatic shift in its distribution with a higher proportion of fine sediments observed in this latest sample. The mid and lower shore remains moderately well graded and poorly graded respectively, while the upper beach has now shifted from moderately well graded to poorly graded. All regions still mainly consists of fine to coarse sand particle sizes.

3.2.6.3 Following capital monitoring

Looking at the first upper beach sample (High), the sediment size distributions have narrowed slightly since the capital dredging. Their 10% and 50% diameters have increased while their 90% diameters have decreased. During the second round of sediment sampling the upper sediment size distribution curve shows a significant increase in sediment size for all 10%, 50% and 90% diameters. Most notably, the 90% diameter has increased approximately 700 µm from 2018. The mid shore shows minor change in sediment size since 2018. The lower shore sediment distribution shows a slightly increased sediment size with all 10%, 50% and 90% diameters slightly increasing. Sample taken in January 2020 for the high shore shows a decrease in sediment size from the previous round but follows the 2018 data very closely. The mid shore shows a decrease in average sediment size, specifically the 90% diameter measure has decreased since the previous round. The low shore sediment size, which has been relatively consistent and contained only fine to medium sands, in 2020, shows a significant increase in sediment size.

Now all three regions of the beach are moderately well graded. All regions mainly consists of fine to coarse sand particle sizes.

3.2.7 Location 13, Camp Bay

3.2.7.1 Baseline monitoring

All three Camp Bay sampling locations appear to be finer in sediment composition at the September sampling date compared to January. All three regions of the beach are very poorly graded and consists of mainly fine to medium coarse sand particle sizes.

3.2.7.2 During capital monitoring

The upper and lower beach regions are finer in their grading since January 2017. The mid shore appears slightly coarser in its distribution of sediments size when compared to the September 2017 samples but, as with the other regions, presents a finer grading than the January 2017 sample. All three regions remain very poorly graded.

3.2.7.3 Following capital monitoring

Sediment sizes sampled at Camp Bay have generally increased since the capital dredging. The upper (High) beach grading is slightly coarser across the board. The mid shore sediment grading analysed on May 2019 is significantly coarser since the capital dredging however the sediment sample taken on July 2019 shows a significant decrease in sediment size with all 10%, 50% and 90% diameters significantly decreasing. The lower beach shows moderate changes with only the 90% diameter increasing in May 2019 and only the 90% decreasing in sediment size in July 2019. Sample taken in January 2020 shows a slight decrease in sediment size for the low shore. The mid shore shows a slight increase in sediment size across all diameters in 2020. The high shore shows negligible change since 2018.

Now all three regions of the beach are poorly graded sorted with the vast majority of particle size dominated by medium sand.

3.2.8 Location 15, Port Levy/Koukourarata

3.2.8.1 Baseline monitoring

Port Levy shows little change at its mid shore but an increase in sediments coarser than 200 µm at its upper (High) shore and a substantial decrease in sediments coarser than 100 µm at its lower shore.

The mid shore remains very poorly sorted and consists of fine to medium sand particle sizes. The upper and lower regions of the beach, consisting of fine to coarse sand particle sizes, have shifted from moderately well graded (in February) to poorly graded (in October).

3.2.8.2 During capital monitoring

The upper (High) and mid regions of the beach show a decrease in sediment size since October 2017 – i.e. higher proportions of fine sediments. The lower beach distribution has expanded to include a wider range of sediment sizes. The upper beach has remained poorly graded from October 2017. The mid shore remains very poorly graded. The lower shore has shifted from poorly graded (in October 2017) to moderately well graded with particle sizes now ranging from silt to medium sand.

3.2.8.3 Following capital monitoring

Sediment sizes sampled at Port Levy in 2019 have generally increased since the capital dredging in 2018. The upper (High) and mid shore distributions are both moderately coarser with their 10%, 50% and 90% diameters all increasing. In January 2020, the sediment size particle results for both the high and mid shore follows the data taken during capital dredging in 2018 very closely. On May 2019, the lower beach showed moderate changes with the 10% and 50% diameters both increasing but in July 2019, the sediment size distribution showed a significant decrease in sediment size with all 10%, 50% and 90% diameters decreasing. In January 2020, the sediment size distribution shows an increase in sediment size and overlaps with the data taken in 2018.

The upper shore grading has widened to now be classified as moderately well graded and consists of fine to coarse sand size particles. The mid shore sorting is relatively unchanged, remaining very poorly sorted. More notable the lower shore is now much wider, the moderately well graded region in 2018 is now well graded and consists of silt to medium sand particle sizes.

3.3 Beach profile survey

This section describes the results of the beach profile surveys undertaken over the course of the year. Any changes that occur as time passes are noted.

For baseline monitoring, ten beaches were surveyed in 2017; as per the monitoring plan (see Table 2.2), profiles were surveyed twice for each site at intervals of at least 6 months. Six beach profiles, from New Brighton through to Taylors Mistake, were surveyed by ECan, while four beach profiles within the Lyttleton Harbour where surveyed by Eliot Sinclair and Partners Ltd.

For the 'during capital' monitoring phase, the same ten beaches were surveyed in 2018. A per the monitoring plan (see Table 2.2) profiles were surveyed twice for each site. The six beach profiles from New Brighton through to Taylors Mistake were surveyed first by ECan in July and then by Eliot Sinclair and Partners Ltd. in December. It should be noted the minimum interval of 6 months was not quite achieved for these six beaches, with surveys being carried out in late July and early December. The four beach profiles within the Lyttleton Harbour were surveyed entirely by Eliot Sinclair and Partners Ltd.

For the 'following capital' monitoring phase, the beach profile surveys were conducted twice in 2019. All ten beaches were surveyed in May 2019 by Eliot Sinclair and Partners Ltd. In July 2019, the six beach profiles, from New Brighton through to Taylors Mistake, were surveyed by ECan, while four beach profiles within the Lyttleton Harbour where surveyed by Eliot Sinclair and Partners Ltd.

In general, the beaches outside the harbour show accretion of the foreshore following the capital dredging works in May 2019 and fluctuating levels in accretion and loss of sediment in July 2019. The beaches within the harbour present a more mixed picture. Rapaki Beach and Purau Bay appear relatively stable throughout the years (including the 'during capital' and 'following capital' years). The profile at Corsair Bay steepened between November 2018 and May 2019 (with accretion at the upper shore and erosion at the lower shore) but then during the July round the profile has smoothed (with erosion at the upper shore and accretion at the lower shore). The profile at Camp Bay has lowered between November 2018 and July 2019.

Beach profiles in 2020 where in general were consistent to what was observed in the previously rounds of beach profiling. The notable changes observed from the previous round in the beach profile surveys were at New Brighton and Taylors Mistake where accretion was observed at the mid to low shores. Loss of sediment was evident at both the Sumner locations. Sumner (Main Rd) experienced a loss of sediment at the seaward face dunes and at the mid shore where Sumner (Hardwicke St) showed an average decrease of 0.3 m of sediment from the beach toe to the end of the foreshore.

Site-by-site overlays of these beach profiles can be seen in Appendix C and each beach is discussed in more detail below.

3.3.1 Location 1, New Brighton

New Brighton Beach is a long, straight, sandy beach consisting of a gently sloping foreshore backed by high vegetated dunes approximately 50 m wide.

The March 2017 beach profile shows the dune crest sitting just above 10 m RL, with a (relatively) small dune berm sitting around 4.5 m RL and the foreshore hitting the 0 m RL contour at approximately CH 140 offshore. The September 2017 profile shows accretion of the foreshore from CH 115 onwards, resulting in a flattening of the profile. With this accretion, the foreshore hits the 0 m RL contour at CH 150, effectively shifting the shoreline approximately 10 m seaward. The dune berm has also accreted somewhat, with the berm crest sitting approximately 0.2 m higher. Landward of the dune berm, the beach profile is relatively unchanged.

The July 2018 profile shows minor sediment loss at the dune berm and along the foreshore between CH 90 and CH 125. Despite this loss, the foreshore level beyond CH 125 remains the same and so still hits the 0 m RL contour around CH 150 offshore. The December 2018 profiles follows the July 2018 profile very closely, with the only discernible changes coming with slight accretion around CH 85.

The May 2019 profile shows further minor sediment loss (up to 0.1 m drop in beach level) at the upper beach from the dune to CH 65. The remainder of the profile displays accretion since 2018, most notably in front of the dune toe (CH 70) where the beach level has lifted by up to 0.34 m. The profile slope characteristics remain similar to those observed in 2017, except for a slight steepening around the CH 115 mark.

The July 2019 profile shows a relatively stable dune levels since May 2019 with small changes to the dune tone and foreshore. In front of the dune tone (CH70) the beach level has dropped back down 0.34 m to the level it was at in 2018. From this point on, the profile follows the May 2019 profile very closely, with the only changes coming with a loss of sediment between CH 85 and CH 120 and with slight accretion from CH 130. The profile now crosses the 0.0 m RL contour around CH 160 – i.e. 10 m further seaward than in 2018.

The January 2020 profile follows the previous July 2019 profile very closely, with the only changes coming with slight accretion between CH 85 and CH130.

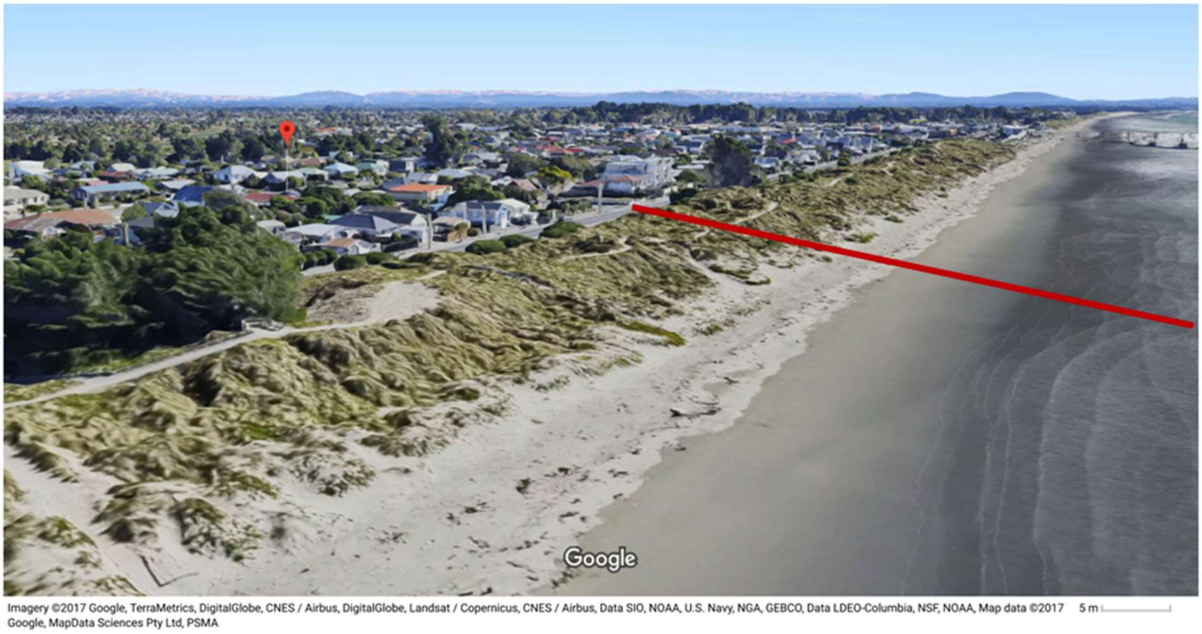

Figure 3.1: Oblique 3D view (looking northwest) of New Brighton Beach near Rodney St with indicative profile location in red (Source: Google Maps, 2017)

3.3.2 Location 2, South New Brighton

Similar to New Brighton further north, the South New Brighton beach profile is characterised by a gently sloping foreshore backed by substantial vegetated dunes. The dunes here a more undulating and are around 100 m wide.

With the crest sitting at approximately 6.9 m RL in February 2017, the dunes do not present with an obvious seaward berm. In February 2017, the foreshore crossed the 0.0 m RL contour at approximately CH 220. By August 2017, the crests and troughs of the undulating dunes are slightly dampened and the profile has flattened out, losing sediment between CH 145 and CH 205 and accreting sediment from CH 205. The August 2017 profile crosses the 0.0 m RL contour at approximately CH 227.

The July 2018 profile shows loss of sediment at the most seaward dune crest and then accretion along much of the foreshore. Between CH 140 and CH 230, the foreshore has lifted by up to 0.15 m. The December 2018 profile mostly follows the July 2018 profile, except for some loss of sediment between CH 200 and CH 240 where beach levels match those seen in August 2017.

The May 2019 profile shows further minor sediment loss (up to 0.1 m drop in beach level) at the upper beach from the dune to CH 125. The remainder of the profile displays accretion since 2018 with the beach level lifted by up to 0.52 m at CH 175. Around this point a berm appears to have formed meaning the profile has flattened out between CH 145 and CH 175 and steepened between CH 175 and CH 210. The profile now crosses the 0.0 m RL contour around CH 230 – i.e. 10 m further seaward than in 2018.

The July 2019 profile shows a relatively stable levels since May 2019. The profile displays a minor accretion at the top of the dune at CH 115 and then continues to show minor sediment loss at from the dune (CH 120) to CH 125. From this point on, the profile follows the May 2019 profile very closely, with the only changes coming with a loss of sediment between CH 155 and CH 215 where beach levels match those seen in February 2017. The profile still crosses the 0.0 m RL contour around CH 230 – i.e. 10 m further seaward than in 2018.

The January 2020 profile follows the previous July 2019 profile very closely, with the only changes coming with slight accretion between CH 160 and CH 180.

Figure 3.2: Oblique 3D view (looking northwest) of South New Brighton Beach near Hasley St with indicative profile location in red (Source: Google Maps, 2017)

3.3.3 Location 3, Southshore

Southshore presents a sandy beach backed by vegetated dunes, however the dunes are lower and narrower and the foreshore is steeper than the New Brighton Beach profiles to the north.

The dunes here are around 25 m wide, with a crest sitting at approximately 5.7 m RL in February 2017. The profile slopes down from the dune toe, at 3.9 m RL, for 75 m before crossing the 0.0 m RL contour. Looking at the August profile 2017, the dunes and upper beach are relatively unchanged, but the foreshore (between CH 230 and CH 300) has lost sediment, dropping the bed level in this area by up to 0.15 m.

The July 2018 profile shows the development of a dune berm around CH 230 which has brought the dune face slightly seaward. Most notably however, there is substantial accretion at the seaward edge of the foreshore (from CH 285). Specifically, around CH 300 the foreshore sits around 0.3 m higher. The December 2018 then looks largely unchanged in relation to the July 2018 profile.

The May 2019 profile presents a similar pattern of change to that seen at New Brighton with minor sediment loss at the upper beach (between CH 0 and CH 220). These drops reach a maximum of 0.15 m at CH 205. The mid shore (between CH 220 and CH 290) shows accretion with beach levels lifting up to 0.37 m since 2018. Offshore of CH 290 the profile appears relatively stable. While the profile's crossing of the 0.0 m RL contour remains unchanged since 2018 at CH 320, the profile at the mid shore has pushed seaward by up to 10 m.

The July 2019 profile presents a substantial accretion on top of the dune at CH 125 from May 2019 where profile levels match those seen in February 2017. The mid shore (between CH220 and CH 245) shows similar beach levels to May 2019 but with two areas of minor accretion at CH230 and CH 245. From CH 245, there is substantial sediment loss all the way down crossing the 0.0 m RL contour at CH 305– i.e. eroding landward by approximately 15 m.

The January 2020 profile follows the previous July 2019 profile very closely, with the only changes coming with minor sediment loss between CH 240 and CH 290.

Figure 3.3: Oblique 3D view (looking northwest) of Southshore near Tern St with indicative profile location in red (Source: Google Maps, 2017)

3.3.4 Location 4, Sumner (near Main Rd)

The section of Sumner's open coast fronting Main Rd consists of a sandy beach partially backed by dunes, but predominantly backed by the alignment of Main Rd.

The February 2017 beach profile indicates the dunes are around 50 m wide and have a crest elevation of 3.8 m RL. These dunes then lead in to a near-flat 50 m section (at an elevation of around 2.2 m RL), followed by foreshore extending down for approximately 60 m to the 0.0 m RL contour. The August 2017 profile presents a similar dune topography, although the seaward faces of the dune crests appear to have eroded – pushing parts of the dune faces landward by up to 3.5 m. The 50 m flat section, on the other hand, has accreted very slightly – raising in elevation by up to 0.1 m. The sloping foreshore has accreted dramatically, reducing the slope from around 1(V):30(H) to around 1(V):55(H). As a result, the foreshore profile crosses the 0.0 m RL contour at CH 260 – a seaward shift of 60 m.

The July 2018 profile shows a reshaping of the most seaward dune face. The face has steepened with the crest sitting higher and more seaward than in previous profiles. The profile is slightly lifted between CH 85 and CH 135. Most notably, the foreshore offshore of CH 170 appears lifted by approximately 0.3 m. Substantial accretion at the very seaward edge of the survey then shows the foreshore crossing the 0.0 m RL contour at CH 335 – a seaward shift of 75 m. The December 2018 profile then shows a similar pattern of accretion, with the foreshore again lifted by up to 0.3 m. However sediment loss at the survey's seaward edge leaves the foreshore crossing the 0.0 m RL contour at CH 335 again.

The May 2019 profile shows relatively stable dune levels since 2018 but a fluctuating mid and lower shore. Between CH 190 and CH 260, sediment has accreted with beach levels rising by up to 0.43 m and the profile sitting up to 15 m further seaward. Looking further offshore, the levels have dropped by up to 0.16 m and the profile now crosses the 0.0 m RL contour at CH 330 (i.e. eroding landward by approximately 15 m since 2018).

The July 2019 again shows relatively stable dune levels since 2018 but a fluctuating mid and lower shore. There is erosion at CH 110 compared to May 2019. The accretion of sediment between CH 190 and CH 260 shown in May 2019 has dropped and now the beach profile shows a loss of sediment from December 2018. The profile now crosses the 0.0 m RL contour at CH 310 (i.e. eroding landward by approximately 20 m since May 2019).

The January 2020 profile follows the crests and troughs of the undulating dunes. However, there is some sediment loss at the bottom of the dune between CH 75 and CH 125. The berm has moved back to CH 175 where it was at CH 200 in the previous profile due to the loss of sediment. The profile now crosses the 0.0 m RL contour around CH 275 – i.e. 30 m further inward than in 2019.

Figure 3.4: Oblique 3D view (looking west) of Sumner near Main Rd with indicative profile location in red (Source: Google Maps, 2017)

3.3.5 Location 5, Sumner (near Hardwick St)

This south-eastern stretch of Sumner's open coast is characterised by a flat sandy beach backed by rock armour and a wide pedestrian promenade. The surveyed profiles have the rock armour covering a width of around 9.5 m with a crest height of just under 4.2 m RL.

In February 2017, the beach toe at the seaward edge of the rock armour was sitting at approximately 0.9 m RL, by August 2017 this had dropped by 0.5 m to approximately 0.4 m RL. In February 2017, the overall foreshore slope was measured at around 1(V):40(H), while August 2017 shows a loss of sediment at the upper foreshore and accretion at the lower foreshore resulting in a more gradual slope of around 1(V):60(H).

The July 2018 profile shows accretion of the foreshore from CH 60 mark onwards. Importantly, the beach toe at the edge of the rock armour is lifted back up to approximately 0.9 m RL. The December 2018 profile presents little detail around the rock armour, but shows the foreshore sitting at similar levels to July 2018. The foreshore crosses the 0.0 m RL contour at around CH 105 – i.e. shifting this measure of the shoreline around 15 m seaward.

The May 2019 profile shows no loss of sediment since 2018. The beach elevation immediately in front of the revetment structure (at CH 55) has risen by approximately 0.4 m and further offshore the beach levels have risen by at least 0.1 m. These changes have steepened the profile in front of the revetment from 1:35 in 2018 to 1:25.

The July 2019 profile shows a loss of sediment since May 2019. The beach toe at the edge of the rock armour has drop back down 0.4 m to approximately 0.9 m RL. From CH 75 onwards the profile shows a similar levels to the profile shown in May 2019.

The January 2020 profile shows a loss of sediment since July 2019. The beach profile gradient is consistent with the profile on 2019 but starting from the beach toe at the edge of the rock armour to the end of the foreshore, the profile shows an average decrease of 0.3 m of sediment.

Figure 3.5: Oblique 3D view (looking northwest) of Sumner near Hardwicke St with indicative profile location in red (Source: Google Maps, 2017)

3.3.6 Location 6, Taylors Mistake

Taylors Mistake presents as a sandy bay, partially backed by a combination of vegetated dunes, buildings, rocky outcrops and cliffs. The profile surveyed covers the widest section of the dunes.

In February 2017, the surveyed elevation of the dunes ranged from 2.4 m RL to 2.7 m RL, with this region being approximately 50 m wide. The beach then slopes down to the 0.0 m RL contour between CH 145and CH 176. By August 2017, the dune face appears to have been eroded back by up to 15 m, while the lower foreshore has accreted. As a result, the beach sits at a gentler gradient, with the foreshore hitting the 0.0 m RL contour at CH 187 – i.e. shifting this measure of the shoreline 11 m seaward.

The July 2018 profile shows accretion of the dune face and a repositioning of the dune crest. Specifically, the dune face is approximately 5 m further seaward, while the crest is lifted by up to 0.3 m but has been pushed approximately 10 m landward. The foreshore then appears to have lost sediment, dropping up to 0.15 m in elevation. The December 2018 profile shows further reshaping of the dune with the dune face and toe lowered by up to 0.15 m. The foreshore has also lost more sediment to sit approximately 0.1 m below the July 2018 profile. This leaves the foreshore to cross the 0.0 m RL contour at CH 180 – a 7 m landward shift since August 2017.

The May 2019 profile shows no loss of sediment since 2018. Instead accretion is apparent around the mid shore (between CH 120 and CH 160) with the beach level 0.5 m higher at CH 150. This has pushed the profile seaward by up to 5 m, getting it closer to the profile observed in February 2017. The beach levels elsewhere (along the upper and lower shore) have remained relatively stable showing either no change or minor accretion.

The July 2019 profile shows relatively stable dune levels since 2018 but a fluctuating mid and lower shore. Accretion is apparent between CH 130 and CH 140 with the beach level 0.3m higher at CH 135. However, from CH 140 there is sediment loss and again from CH 160 there is accretion apparent. The profile crosses the 0.0 m RL contour around CH 180 – i.e. similar levels to what is was in 2018.

The January 2020 profile initially follows the July 2019 profile closely. Accretion is apparent in the mid shore between CH 140 to CH 165 with the beach level 1.0m higher at CH 145. This is compensated at the low shore where minor sediment loss is apparent from CH 165 onwards.

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Figure 3.6: Oblique 3D view (looking northwest) of Taylors Mistake with indicative profile location in red (Source: Google Maps, 2017)

3.3.7 Location 8, Corsair Bay

Corsair Bay is a small sandy beach backed by a low lying seawall, with rock armour protection to the northwest and rocky cliffs to the southeast. The profiles surveyed bisect the middle of the beach, beginning at the crest of the seawall.

The seawall crest elevation remains unchanged at 3.2 m RL. Adjacent to the seawall, the beach toe elevation has accreted slightly, between February and November 2017, from 1.57 m RL to 1.60 m RL. The upper beach has dropped in elevation, by up to 0.12 m, while the lower beach has accreted by up to 0.31 m. This has flattened the beach slope slightly, but the profile's intersection of the 0.0 m RL contour remains unchanged at approximately CH 26 offshore.

By February 2018, the beach toe in front of the seawall has accreted further to sit at 1.7 m RL. The foreshore appears to have steepened with the upper beach lifted by up to 0.2 m and the lower beach lowered slightly. The November 2018 profile reverses the foreshore changes yet again with the beach toe in front of the seawall lowered to February 2017 levels, the upper beach lowered by up to 0.3 m and the lower beach raised slightly. Despite all the foreshore fluctuations, its crossing of the 0.0 m RL contour remains stable at approximately CH 26.

By May 2019, the beach toe in front of the seawall has accreted slightly from 1.55 m RL to 1.60 m RL. This is the same level measured in November 2017. The foreshore up to CH 10 m has accreted, with the upper level raised by 0.05 m as previously mentioned, and the level at CH 10 m accreting by 0.15 m. The shore between CH 12 and CH 22 has become steeper, CH 24 to CH 36 has shallowed and CH 36 to CH 42 has steepened. The overall slope on average has steepened slightly, with the top end rising by 0.05 m and the bottom end dropping by 0.03 m.

By July 2019, the upper beach as a whole (between CH 3 m and CH 12 m) has eroded with beach levels dropping by up to 0.5 m. This is compensated at the mid and lower shore were the profile now sits at or above the previous surveys.

The January 2020 profile follows the July 2019 profile very closely with the only changes coming with accretion at the upper beach (between CH 3 m and CH 12 m). The profile now sits around where it previous was before July 2019.

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Figure 3.7: Oblique 3D view (looking northwest) of Corsair Bay with indicative profile location in red (Source: Google Maps, 2017)

3.3.8 Location 10, Rapaki Beach

Rapaki Beach is sandy bay fronting a small grass reserve and forested land.

Looking 2 metres offshore of the edge of the grass reserve (with a constant elevation of 3.1 m RL), the beach toe elevation has risen slightly, between February 2017 and November 2017, from 1.8 m RL to 1.9 m RL. Apart from some points of no change around the 10 m mark, the survey shows slight accretion along the entire November 2017 profile with the foreshore bed level increasing in elevation by up to 0.1 m.

The February 2018 profile shows minimal change apart from approximately 0.1 m of lift around CH 10. The November 2018 profile then shows, for the most part, a return to November 2017 levels.

The 2019 profiles shows minimal change.

The January 2020 profile shows minimal change in the beach profiles.

Imagery ©2017 Google, Map data ©2017 Google, MapData Sciences Pty Ltd, PSMA 20 m

Figure 3.8: Oblique aerial view of Rapaki Beach with indicative profile location in red (Source: Google Maps, 2017)

3.3.9 Location 11, Purau Bay

Purau Bay presents as a straight stretch of beach nestled in a deep bay (see Figure 3 9), with the shoreline dominated by a river mouth in the northwest and a road's alignment along the southeast. The beach is backed by varying patches of grass, gravel and small vegetated dunes.

Following the static elevation of 2.2 m RL measured at a masonry nail (0 m offshore), a comparison of the 2017 beach profiles indicates minor accretion across the entire foreshore. Similar to the accretion observed at Rapaki Beach, the beach level has risen by up to 0.1 m.

The February 2018 profile presents even less change, with only isolated points of accretion – for example, the profile is approximately 0.05 m higher in elevation at 38 m offshore. The November 2018 profile shows minimal change again with it following the February 2018 levels closely.

The May and July 2019 profile again shows minimal change.

The January 2020 profile shows minimal change in the beach profiles.

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Figure 3.9: Oblique aerial view (looking southwest) of Purau Bay with indicative profile location in red (Source: Google Maps, 2017)

3.3.10 Location 13, Camp Bay

The surveyed profiles of Camp Bay (a sandy and rocky beach backed by grassed land, see Figure 3 10) show significant changes in the beach level between February 2017 and November 2017. At the upper beach, between CH 0 and CH 20 offshore, said change is less pronounced, but beyond 20 m the foreshore has accreted and risen in elevation by up to 0.6 m. In February 2017, the beach profile crossed the 0.0 m RL contour at approximately CH 30, while in November 2017 it was at around CH 42. This foreshore accretion has thus shifted the 0.0 m RL shoreline approximately 12 m seaward.

The February 2018 profile presents a mixed pattern of beach level change with accretion apparent between CH 12 and CH 22 but sediments loss offshore of CH 22. Specifically, the beach each levels are up to 0.3 m higher between CH 12 and CH 22 and up to 0.3 m lower moving seaward. The November 2018 profile shows further dynamic behaviour. Accretion since February 2018 is present between CH 8 and CH 60 offshore beach levels up to 0.4 m higher in elevation. The November 2018 profile crossed the 0.0 m RL contour at approximately CH 44, i.e. the 0.0 m RL shoreline has shifted 14 m seaward since February 2017.

The May 2019 profile shows a mixture of minor sediment loss and accretion since 2017. The upper beach (from CH 0 to CH 45) has dropped by up to 0.13 m. Conversely, the lower beach (CH 45 onwards) has lifted by up to 0.13 m.

The July 2019 profile shows further erosion at the upper beach. Especially between CH 5 m and CH 45 m, where the profile now sits between those surveyed in November 2017 and February 2018.

The January 2020 profile shows minimal change. There are very minor fluctuations above and below the July 2019 profile.

Figure 3.10: Oblique aerial view (looking southwest) of Camp Bay with indicative profile location in red (Source: Google Maps, 2017)

3.4 Seabed survey

This section summarises the changes in seabed levels collected to date. Figure 3.11 shows the location of seabed profile surveys collected.

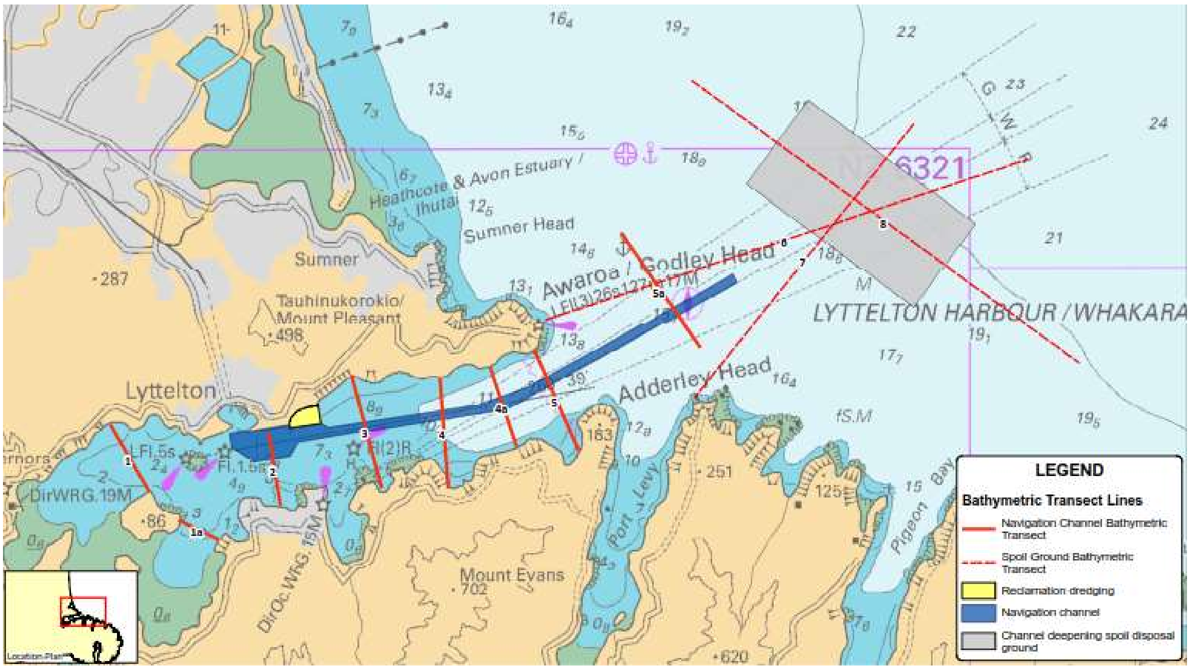

Figure 3.11: Map of bathymetric survey transect locations

Eight transects of bathymetry (labelled 1 through 8) have been surveyed in February 2017 – five of which are within the Lyttelton Harbour and three out on the open coast – and three additional transects (labelled 1a, 4a and 5a) have been surveyed between February and April 2018. The additional transects (1a, 4a and 5a) were surveyed following the resolution of a consent appeal (LPC communications, 19 April 2018).

The eight original transects and the additional transects have been surveyed again in December 2018 and January 2019, respectively, as part of the post-dredging monitoring phase.

Transect 1 is further up the harbour from the dredging works. Transects 2 through 5 (including 5a) capture the navigation channel while transects 6, 7 and 8 cover the spoil ground and its surroundings. More specifically, transects 1 to 5 (including 1a and 4a) represent the harbour itself, transect 5a is located some 3 km offshore of the harbour entrance and cuts across the proposed navigation channel and maintenance dredge disposal site, transections 6 and 7 extend offshore from Godley and Adderley Head through the capital dredge disposal site and transect 8 runs along the proposed capital dredge disposal site.

Transect 1 and 1a show a slight decrease in level (~0.1 to 0.2 m) between January 2017 and December 2018. The uniformity of the drop in both transects is somewhat unusual however no error in the surveys is apparent. Particular attention should be paid to upcoming surveys to see if any trend continues.

Transects 2, 3, 4 and 5 show the dredged channel at between -13.8 and -15 m. These profiles also show slight (0.1 to 0.5 m) increase in seabed level adjacent to the dredged channels with transect 5 also showing a lightly shallower (~0.5 m) seabed towards Godley Head, although this may be a function of exact dredging line and whether specific seabed are captured. Profile 5a shows minimal (<0.1 m change)

The offshore surveys (transects 6 through 8) capture the spoil disposal activity with the seabed inside the spoil area up to 1.5 m (typically <1 m) higher than in 2017 and no changes seen elsewhere.

The full set of bathymetry sections can be found in Appendix D.

3.5 Shoreline analysis

The shoreline has been digitised for all fifteen monitoring sites, based on the most recent aerial photography available for the area. The aerial photographs employed in this have been sourced from LINZ's 2015-16 Urban and Rural aerial sets for Christchurch. As a general rule, the shoreline has been defined by the vegetation line.

The resulting shorelines are intended to serve as baseline conditions in future shoreline analysis. No new shoreline analysis has been carried out and thus there are no changes to report.

4 Conclusions

This monitoring report summarises the results of photo-point monitoring round in January/June 2020, sediment size analysis from January 2020 and beach profile survey from January/May 2020.

Based on comparison of monitoring data from previous rounds, the notable changes observed during photo point monitoring were at

- Sumner (at the Surf Life Saving Club): The sandbar present at the high tide mark becoming more evident in January. In June, the sandbar had disappeared but the surface of the beach was undulated.
- Gollans Bay: In January, rocks previously not visible were now visible, signifying minor sediment loss. No changes in June 2020.
- Rapaki Bay: In June, the cobbles having more coverage across the bay.
- Little Port Cooper: In January and June 2020, there were minor accretion as the rocks previously visible across the bay were now not visible.

However, all these changes observed were within the previous envelope of changes.

Notable changes observed during the sediment size analysis were at:

- Southshore: Increase in sediment size in the low shore. This was outside the envelope of change.
- Gollans Bay: Increase in sediment size in the high shore which is outside the previous envelope of change and increases and decreases in the mid and low shore sediment size which were within the envelope of change.
- Corsair Bay: Notable decrease in sediment size in the high shore. However, this was within our previous envelope of change.
- Purau Bay: Notable increase in sediment size in the low shore and decrease in sediment size in the mid shore. Both changes had not previously been encountered.
- Camp Bay: Decrease in sediment size in the low shore. This was outside the envelope of change.

These changes observed during the sediment size analysis should be monitored on the next round especially the changes that were outside of the envelope for changes in Southshore, Gollans Bay, Purau Bay and Camp Bay.

The notable changes observed from the previous round in the beach profile surveys were at

- New Brighton: Accretion at the mid to low shore between CH 85 and CH130.
- Sumner (Main Rd): Loss of sediment at the seaward face dunes between CH 75 and CH 125 and the loss of sediment at the mid shore, the berm now sits at CH 200, 25m inwards.
- Sumner (Hardwicke St): An average decrease of 0.3 m of sediment from the beach toe to the end of the foreshore.
- Taylors Mistake: Accretion at the mid shore between CH 140 to CH 165.

Accretion at the mid to low shore at New Brighton had not previously been observed. But sediment accretion being on average 0.3 m higher is very minimal. There has been large fluctuations in elevation at Sumner (Main Rd). Where the loss of sediment in the mid shore is within our previous envelope of changes, the loss of sediment at the seaward face dune is something new. The next round should be monitored in this area. The loss of sediment at Sumner (Hardwicke) is within our previous envelope of changes. The accretion at the mid shore at Taylors Mistake is not within our envelope of change and should be monitored in the next round.

5 Applicability

This report has been prepared for the exclusive use of our client Lyttelton Port Company, with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

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Appendix A: Photo point monitoring results

Location 1: New Brighton	North	To sea	South
31-01-2017			
12-05-2017			

15-08-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 1: New Brighton	Description of photos	Changes from previous photos
31-01-2017	A large amount of seaweed and driftwood has collected around the photo point. The shore composition appears to be largely sands and silts, with a slight darkening in colour as the sand gets closer to the watermark. The shape of the shoreline is linear with very few noticeable undulations. The gradient of the shore is near-flat.	N/A
12-05-2017	Small amounts of driftwood and shells have gathered around the photo point. The shoreline composition appears to be primarily silts and sands and its shape is linear. The shore gradient is near flat. The colour of the beach is brown, darkening gradually towards the water.	The amount of seaweed and shells around the point has decreased. The colour of the shoreline has shifted from grey to brown.
15-08-2017	No seaweed or driftwood has gathered around the point. The sediment appears to be composed of sands and silts, which are brown in colour. This colour darkens gradually towards the water. The shoreline is linear and has a near flat gradient.	The seaweed and driftwood has washed away from the point.
03-11-2017	A large amount of driftwood and seaweed of various sizes has gathered around the photo point. The beach appears to have a shallow gradient, and the sediment is grey in colour. The sediment appears to be composed of silts and sands. The shoreline is linear in shape.	Seaweed and driftwood have gathered around the point.
07-11-2018	A small amount of flotsam and jetsam has collected near the photo point, in a line parallel to the water. The shore appears to be composed of silts and sands, and the sediment is grey in colour. The beach has a shallow gradient and is linear in shape.	The amount of seaweed around the point has decreased. The waterline is straighter.
06-05-2019	A small amount of driftwood and seaweed has collected near the photo point. The shore appears to be composed of silts and sands which are grey in colour. The colour darkens slightly towards the water. The beach has a shallow gradient and is linear in shape.	NIL
18-07-2019	A small amount of driftwood (no seaweed) has collected near the photo point. The shore appears to be composed of silts and sands, which are grey brown in colour. The colour is uniform throughout the area. The ripple shaped bands have formed parallel to the water. The beach has a shallow gradient and is linear in shape. The surface of the beach appears to be smooth.	The amount of seaweed has decreased. The colour of the shoreline has shifted from grey to grey brown. Ripple shaped bands have formed parallel to the water. The surface of the beach have smoothed.

17-10-2019	No noticeable changes in the sediment composition or beach level.	The amount of driftwood around the photo point has increased.
27-01-2020	No noticeable changes in the sediment composition or beach level.	The amount of driftwood around the photo point has increased.
09-06-2020	No noticeable changes in the sediment composition or beach level.	The amount of driftwood around the photo point has decreased.

Location 2: South New Brighton	**North**	**To sea**	**South**
31-01-2017			
12-05-2017			

15-08-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 2: South New Brighton	Description of photos	Changes from previous photos
31-01-2017	A large amount of seaweed and driftwood has collected around the photo point. The sediment on the shore appears to be composed of sands and silts. The sediment colour darkens noticeably at the high water mark, but does not change significantly as it gets closer to the water. The shoreline forms a straight line along the length of this section. The gradient of the shore is near-flat.	N/A
12-05-2017	A small amount of driftwood has gathered around the point. The shoreline appears to be composed of sands and silts. The colour of the beach is a grey-brown, darkening closer to the shoreline. There are ripple-shaped bands in the sand. The shoreline is linear in this section. The gradient is near-flat.	The amount of driftwood and shells at the point has reduced. Ripple-like bands have developed in the sand.
15-08-2017	A small number of shells have collected around the photo point. The shoreline appears to be composed of sands and silts of a grey-brown colour. The colour of the sediment darkens gradually closer to the water. The shoreline appears linear in shape along this section. Ripple shaped bands of discolouration are visible in the sand, running parallel to the shoreline. The gradient towards the water is near flat.	The driftwood and seaweed has disappeared from the point.
03-11-2017	Driftwood and shells have gathered around the photo point. The shoreline appears to be composed of sands and silts that are grey in colour. The beach has a shallow grade. The shoreline appears linear in shape.	The ripple shaped bands are gone, seaweed and driftwood have gathered.
07-11-2018	A small number of shells have gathered around the photo point. The surface of the beach is very rough. The sediment appears to be composed of silts and sands. The beach has a shallow gradient and appears linear in shape. The sediment appears to be brown in colour.	Seaweed and driftwood have disappeared, surface has roughened significantly.
06-05-2019	A small amount of driftwood and shells has gathered around the photo point. The surface of the beach is rough. The sediment appears to be composed of silts and sands and is grey in colour. The colour darkens in a band parallel to the waterline between two lighter coloured bands. The shore has a shallow gradient and is linear in shape.	A small amount of driftwood has gathered around the point.
18-07-2019	A small amount of driftwood and shells (no seaweed) has collected near the photo point. The shore appears to be composed of silts and sands,	The amount of shells has decreased. The colour of the shoreline has shifted from grey to grey brown. Ripple

	which are grey brown in colour. The colour is uniform throughout the area. The ripple shaped bands have formed parallel to the water. The beach has a shallow gradient and is linear in shape. The surface of the beach appears to be smooth.	shaped bands have formed parallel to the water. The surface of the beach have smoothed.
17-10-2019	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
27-01-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 3: Southshore	North	To sea	South
31-01-2017			
12-05-2017			

15-08-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 3: Southshore	Description of photos	Changes from previous photos
31-01-2017	A large amount of seaweed and driftwood has collected near the water mark in discrete groups. The sediment on the shoreline appears to be composed of silts and sands. The colour of sediment changes sharply at the water mark, then darkens as it approaches the low tide. The shoreline is linear. The gradient of the shoreline is near-flat.	N/A
12-05-2017	Many shells have gathered around the point. Some faint ripple-shaped bands have formed in the sand. The shore appears to be composed of sands and silts and is a grey-brown colour. The colour gradually darkens towards the water. The gradient is near flat. The shoreline is linear towards the sea and to the north, but curves in towards the land to the south.	Driftwood and seaweed have disappeared from the shore. Faint ripple-shaped bands in the sand have formed. The colour gradient is more gradual.
15-08-2017	Few shells have gathered around the photo point. Ripple shaped bands are present in the sediment, running parallel to the water. The sediment appears to be composed of sands and silts which are grey in colour. The colour changes significantly from light to dark partway down the beach. The shoreline is linear in shape to the north, but curves inland to the south. The gradient is near flat.	The number of shells around the point has decreased. There is a more prominent change in colour partway down the beach.
03-11-2017	A small amount of driftwood and shells has collected around the photo point. The sediment is brown-grey in colour with ripple-shaped bands of discolouration. The shoreline has a shallow gradient and curves inland, particularly to the south.	A small amount of driftwood and seaweed has gathered.
07-11-2018	A small amount of shells has gathered around the photo point. The sediment appears to be composed of silts and sands and is grey in colour. Near the photo point, the surface of the beach is rough. The beach appears to have a shallow gradient and a linear shape to the north, and curves inland to the south.	The ripple-shaped bands have disappeared and the surface of the beach has roughened near the point.
06-05-2019	Shells and driftwood have gathered around the photo point. The sediment appears to be composed of silts and sands and is grey in colour. Near the photo point, the surface of the shore is rough. There is a large piece of driftwood to the south of the photo point. The beach appears to have a shallow gradient. The shape is linear to the north and curves inland to the south.	A large piece of driftwood has appeared on the beach.

18-07-2019	Minimal shells and driftwood have gathered around the photo point. The sediment appears to be composed of silts and sands and is grey brown in colour. The colour is uniform throughout the area. The ripple shaped bands have formed parallel to the water. Near the photo point, the surface of the shore is very smooth. There is a large piece of driftwood to the south of the photo point. It appears to be the same driftwood seen from the previous round. The gradient is near flat. The shoreline is linear towards the sea and to the north, but curves in towards the land to the south.	The colour of the shoreline has shifted from grey to grey brown. The surface of the shore has smoothed and ripple shaped bands have formed parallel to the water. The amount of shells have decreased and the shells have converged more in line to the centre of the shore.
17-10-2019		The ripple shaped bands are less visible and a tyre track runs across the shoreline.
27-01-2020	No noticeable changes in the sediment composition or beach level.	The amount of seaweed around the photo point has increased.
09-06-2020	No noticeable changes in the sediment composition or beach level.	N/A

Location 4: Sumner Surf Life Saving Club	North-West	To sea	South-East
31-01-2017			
12-05-2017			

15-08-2017			
03-11-2017			

<table>
<tr><td>07-11-2018</td><td></td><td></td><td></td></tr>
<tr><td>06-05-2019</td><td></td><td></td><td></td></tr>
</table>

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 4: Sumner Surf Life Saving Club	Description of photos	Changes from previous photos
31-01-2017	Minimal seaweed and driftwood has collected around the high water mark. The sediment on the shoreline appears to be composed of sands and silts. There is a sandbar past the low tide mark. The colour of sediment changes in bands down the beach. The shoreline curves around the sandbar, particularly towards the South. The far side of the sandbar is somewhat convex. The gradient of the shoreline is shallow, but undulates as it approaches low tide, this is what has caused the sandbar.	N/A
12-05-2017	The surface of the beach is rough, and some driftwood and seaweed have gathered around the photo point. A sandbar is present beyond the waterline. The shore is mainly composed of silts and sands, but some larger rock formations are present to the south. The shoreline curves in a convex manner, particularly to the north. The sediment is a grey-brown colour.	Increased amount of driftwood and seaweed around the point. The surface has roughened.
15-08-2017	The surface of the beach is rough, and a moderate amount of driftwood has collected near the photo point. A sandbar is present beyond the water's edge. The sediment appears to be composed of sands and silts that are grey in colour. There are some large rock formations south of the photo point. The shoreline curves in a convex manner and has a near-flat gradient.	No noticeable differences.
03-11-2017	The surface of the beach is rough, and a large amount of seaweed and driftwood has collected around the point. A sand bar is present beyond the edge of the water. The sediment appears to be composed of sands and silts that are grey in colour. There are some large rocks and formations to the south of the point. The shoreline has a shallow gradient and curves inland in both directions.	Sand is rougher to the south east, more driftwood and seaweed has gathered around the point.
07-11-2018	The surface of the beach is rough, and there is a small amount of seaweed around the photo point. A sandbar is present beyond the water line. The sediment of the beach appears to be composed of silts and sands and is grey in colour. There are some large rock formations to the south of the photo point. The shoreline has a shallow gradient and curves inland in both directions.	Amount of seaweed and driftwood has decreased.

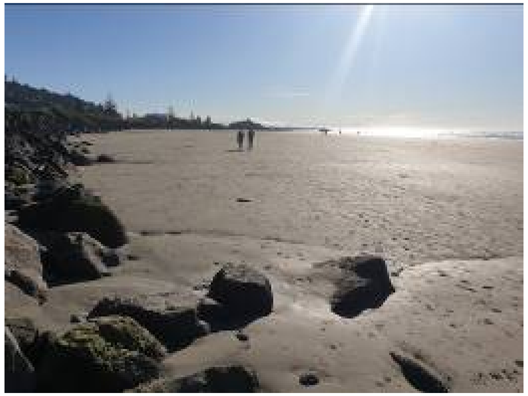
06-05-2019	The surface of the beach is rough. The sediment appears to be composed of silts and sands that are grey in colour. There is a band of darker sediment parallel to the waterline between two lighter bands. The shoreline has a shallow gradient, curves inland to the north, and is linear to the south. There are some large rock formations to the south of the photo point.	The seaweed and driftwood has disappeared from the point. The surface of the sand has smoothed slightly.
18-07-2019	The surface of the beach is rough. The sediment appears to be composed of silts and sands that are grey brown in colour. The colour is uniform throughout the area. The shoreline has a shallow gradient, curves inland to the north, and is linear to the south. There are some large rock formations to the south of the photo point.	The colour of the shoreline has shifted from grey to grey brown. The distinctive bands has disappeared and the colour is uniform throughout the area.
17-10-2019		Increased amount of driftwood and seaweed around the point.
27-01-2020	The difference in the beach level at the high tide mark is more is more noticeable. No noticeable changes in the sediment composition.	The difference in the beach level at the high tide mark is more is more noticeable.
09-06-2020	The surface of the beach is uneven causing water to be trapped on the shore.	The surface of the beach is uneven. Water puddles left on the shoreline.

Location 5: Sumner	**North-west**	**North-east**	**South-east**
31-01-2017 (NW photo taken 14-02-2017)			
12-05-2017			

15-08-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 5: Sumner	Description of photos	Changes from previous photos
31-01-2017	No significant seaweed or driftwood has collected near the photo point, though the sand is tinged green. This indicates that some seaweed or other plant life has washed up on the beach. The sediment appears to be composed of silts and sands. The colour of the shore changes in ripple-like bands towards the sea. The shape of the shoreline is linear to the northwest, but curves around with the shape of the land to the southeast. The gradient of the beach is shallow above the high tide mark, then slightly steeper in the centre, and levels out near low tide.	N/A
12-05-2017	No driftwood or seaweed has gathered around the point. The shoreline curves in a concave manner to the south and is linear to the north. The shoreline is primarily composed of silts and sands, with some rock formations to the north. The gradient of the shore is near-flat. The sediment is grey, and ripple-shaped bands have formed.	The sand is no longer tinged green. Instead it is now grey and ripple-shaped bands have formed.
15-08-2017	No driftwood or seaweed has gathered around the photo point. The shoreline curves concave to the south of the photo point, and appears linear to the north. The shoreline appears to be primarily composed of sands and silts which are grey in colour. The shoreline's gradient is near flat. Ripple-shaped bands of discolouration have formed parallel to the water.	The ripple shaped bands are more noticeable.
03-11-2017	No driftwood or seaweed has gathered around the point. The shoreline curves inland to the north and to the south, before extending out to the southern point. The shore has a very shallow gradient. The sediment appears to be composed of silts and sands, which are grey-brown in colour. Ripple-shaped bands of discolouration have formed parallel to the tide line. A channel of water has formed to the south of the photo point.	No noticeable changes.
07-11-2018	No driftwood or seaweed has gathered around the point. The shoreline curves inland to the north and south of the point before extending out to the point near Taylors Mistake to the south. The shore has a very shallow grade. The sediment appears to be composed of silts and sands which are grey in colour. Ripple shaped bands are barely visible in the beach.	The channel of water to the south is no longer present.
06-05-2019	No driftwood or seaweed is currently around the point. The shoreline curves inland to the north and south of the point before extending out to the point towards Taylors Mistake. The shore has a very shallow	Sediment is slightly rougher to the north

	gradient. There are ripple-shaped bands of discolouration, though they are not very pronounced. The beach appears to be composed of silts and sands which are grey in colour.	
18-07-2019	No driftwood or seaweed is currently around the point. The shoreline curves inland to the north and south of the point before extending out to the point towards Taylors Mistake. The shore has a very shallow gradient. The ripple shaped bands have formed parallel to the water. The beach appears to be composed of silts and sands that are grey brown in colour. The surface of the beach appears to be smooth.	The surface of the beach appears to be smooth. The ripple shaped bands are more noticeable. The colour of the shoreline has shifted from grey to grey brown. The level of sand and silt has decreased, as the end of the handrail is now visible.
17-10-2019		There are less sand on the shoreline, the rocks are more visible from the surface.
27-01-2020	There is more sand on the shoreline. Where half of the rocks were visible previously, only the now the top surface is. No noticeable changes in the sediment composition.	More sand on the shoreline. The rocks at the high tide mark are less visible.
09-06-2020	There is less sand on the shoreline. Where only the top surface of the rocks were visible previously now half of the rocks are visible. No noticeable changes in the sediment composition.	Less sand on the shoreline. The rocks at the high tide mark are more visible.

Location 6: Taylors Mistake	North	East	South
14-02-2017			
12-05-2017			

15-08-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 6: Taylors Mistake	Description of photos	Changes from previous photos
14-02-2017	No seaweed or driftwood has collected near the photo point. The sediment seems to be composed of sands and silts. The colour of the sand is a dark-grey/brown colour, with a lighter band parallel to the low tide water line approximately halfway down the beach. The shoreline curves in a concave manner, lining up with the heads to the north and south. The beach has a very shallow gradient near the water line, which grows steeper as it approaches the surf club.	N/A
12-05-2017	The sediment is a brown-grey colour, alternating between light and dark in broad bands parallel to the tide. The gradient of the shore grows flatter towards the water. A small amount of seaweed has gathered near the point. The shore is primarily composed of silts and sands, with some rock formations at both ends of the beach.	A small amount of seaweed has gathered near the point. The bands of colour change have increased in number.
15-08-2017	The sediment is brown-grey in colour, with alternating bands of light and dark colour running parallel to the waterline. The gradient of the shore becomes shallower closer to the water. The shoreline is curved in a concave manner and there are large rock formations to the north and south. There is no seaweed or driftwood around the point, but some shells close to the water.	No noticeable changes.
03-11-2017	A small amount of driftwood/seaweed has gathered around the photo point. The gradient of the shoreline gradually becomes shallower as it approaches the water. The sediment appears to be composed of sands and silts that are brown in colour. This brown colour is patchy, appearing darker in some places and lighter in others. The shoreline curves in a concave manner. There are large rock formations at both ends of the bay.	No noticeable changes.
07-11-2018	The gradient of the shoreline gets gradually shallower as it approaches the water. The sediment appears to be composed of sands and silts that are brown in colour. This brown colour is not uniform, with patches of the sediment being significantly darker. The shoreline is concave in shape, and there are large rock formations at either end of the beach.	The driftwood has disappeared.
06-05-2019	The gradient of the shoreline gets gradually shallower as it approaches the water. The sediment appears to be composed of silts and sands that are brown in colour. The colour is not uniform, with patches of the sediment showing darker shades of brown. The shoreline is slightly	Surface smoother, colour changes more prominent

	concave in shape. There are large natural rock formations to the north and south of the photo point.	
18-07-2019	The gradient of the shoreline gets gradually shallower as it approaches the water. The sediment appears to be composed of silts and sands that are light brown in colour. The colour is not uniform with patches of the sediment showing darker shades of brown/grey brown. The surface of the beach appears to be smooth. The shoreline is slightly concave in shape. There are large natural rock formations to the north and south of the photo point.	Surface smoother, colour changes more prominent.
17-10-2019		The surface is slightly rougher to the west.
27-01-2020	No noticeable changes in the sediment composition or beach level.	The amount of dirftwood around the photo point has increased.
09-06-2020	No noticeable changes in the sediment composition or beach level.	The amount of dirftwood around the photo point has decreased.

Location 7: Gollans Bay	**West**	**North (from boat)**	**East**
01-02-2017			
13-11-2018			

17-05-2019			
22-07-2019			

29-10-2019			
11-02-2020			

08-06-2020			

Location 7: Gollans Bay	Description of photos	Changes from previous photos
01-02-2017	There is no seaweed or driftwood in the bay. There is a significant amount of shellfish and moss/algae in the bay, which indicates that it may be submerged regularly at high tide. The majority of the bay is composed of boulders and large rocky formations, however there are two smaller silt-sand areas within the bay. The sand is coloured a light grey/brown colour, and this is consistent in the western portion of the bay. The eastern sandy portion of the bay contains this same colour marbled with a darker grey colour. There are several trees present at the edge of the bay, particularly toward the eastern end of it. The gradient of the sandy bays is near-flat.	N/A
Round 2	Not surveyed due to marine exclusion zone.	N/A
Round 3	Not surveyed due to marine exclusion zone.	N/A
Round 4	Not surveyed due to marine exclusion zone.	N/A
13-11-2018	There is no seaweed or driftwood in the bay. The majority of the bay is composed of large rock formations, however there is one smaller area that appears to be composed of silts and sands. This sediment is coloured brown with a small amount of black. The bay has a shallow gradient and is concave in shape.	No noticeable changes
17-05-2019	There is no seaweed or driftwood in the bay. The majority of the bay is composed of large rock formations, however there is one small area that appears to be composed of silts and sands. The sediment is mostly coloured brown, though this is not uniform with some areas of black. The bay has a shallow gradient and is concave in shape.	More black sediment is visible
22-07-2019	There is no seaweed or driftwood in the bay. The majority of the bay is composed of large rock formations, however there is one small area that appears to be composed of silts and sands. The sediment is mostly coloured brown, though this is not uniform with some areas of black. The bay has a moderate gradient and is concave in shape.	Less black sediment is visible and the bay has a steeper gradient.
29-10-2019		No noticeable changes
11-02-2020	The amount of sand has decreased, as rocks previously not visible are visible. No noticeable changes in the sediment composition.	The amount of sand has decreased around the photo point.
08-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes

Location 8: Corsair Bay	West	South	East
30-01-2017			
12-05-2017			

11-09-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 8: Corsair Bay	Description of photos	Changes from previous photos
30-01-2017	There is no seaweed or driftwood in the bay. The bay itself is composed of sands and fine gravels and is a golden colour. There is a small amount of darker sediment that has settled on top of the beach, mimicking the shape of the wave fronts at the western side of the beach. The eastern and western sides of the bay each have an apparently man-made wall. These each have a minimal amount of fine sediment on them, but are primarily composed of boulders and concrete. The shape of the shoreline itself is concave. The gradient of the beach is steeper than the others, but still shallow.	N/A
12-05-2017	The sediment at the shoreline appears to be composed of sands and fine gravels that are brown in colour. The shoreline curves concave slightly. A small amount of dark sediment is present next to the water. The beach has an apparently manmade rock and concrete wall at its eastern and western ends. The beach gradient is steep relative to the others surveyed. There is a small amount of seaweed and driftwood at and above the point.	A small amount of seaweed has gathered at the point.
11-09-2017	The sediment making up Corsair Bay appears to be composed of sands and fine gravels that are grey in colour, transitioning to brown near the waterline. There is a small amount of water running down the beach toward the sea. The shoreline is slightly concave in shape and appears to have a steeper gradient than other bays surveyed. Large rocks are at each end of the bay as in previous surveys. There is no driftwood or seaweed gathered around the photo point.	The different sections of colour are more distinct.
03-11-2017	The sediment making up Corsair Bay appears to be composed of fine gravels and sands. These are brown and grey in colour in different patches. The gradient of the bay is steeper than most others observed. The shoreline is slightly concave in shape. There are large rock formations at each end of the beach that appear to be manmade. No driftwood or seaweed has collected around the photo point.	No noticeable changes.
07-11-2018	The sediment in Corsair Bay appears to be composed of fine gravels and sands. These appear to be primarily brown in colour, with some patches of grey shades. The beach has a moderate gradient, steeper than most	No noticeable changes

	others surveyed. The shoreline is slightly concave in shape. There are large, manmade rock formations at either end of the shore. No driftwood or seaweed has gathered around the photo point.	
06-05-2019	The sediment appears to be composed of sands and fine gravels that are brown in colour. There are some small patches of sediment that appear grey. The beach has a moderate gradient, steeper than most other beaches monitored. There are large, manmade rock formations to both the west and east of the photo point. No driftwood or seaweed has gathered around the point.	No noticeable changes
18-07-2019	The sediment appears to be composed of sands, fine gravels and shells that are brown in colour. There are some small patches of sediment that appear grey. The beach has a moderate gradient, steeper than most other beaches monitored. There are large, manmade rock formations to both the west and east of the photo point. Minimal amounts of driftwood has gathered around the point.	Small amounts of driftwood has gathered around the photo point.
17-10-2019		The sediments at the shoreline appears to be golden in colour.
27-01-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 9: Cass Bay	West	South	East
30-01-2017			
12-05-2017			

11-09-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 9: Cass Bay	Description of photos	Changes from previous photos
30-01-2017	No seaweed or driftwood has collected in the bay. There are two distinct compositions in the bay. The section closest to the water appears to be composed of sands and silts, while the upper section is composed of gravels. The colour of these bands is generally a dark grey/brown, though at the top of the bay, the gravels are a lighter grey. The western end of the bay has a greater proportion of the silty, sandy band than the eastern end. The shoreline is concave in shape. The gradient of the bay is shallow near the tide, steepening gradually as it gets further away. The gradient levels out again at the top of the beach.	N/A
12-05-2017	No seaweed or driftwood has gathered around the point. There are two definite compositions in the bay. Silts and sands make up the composition near the water, particularly to the east and gravels and cobbles make up the section of the beach furthest from the water and the western part of the beach. There is a wall composed of boulders to the east. The shoreline is concave in shape. The sediment in the bay is typically grey-brown. The gradient is near flat, but steepens slightly as it gets further from the shore.	No noticeable changes.
11-09-2017	Cass Bay appears to be composed primarily of silts and sands, though there are gravels and cobbles covering much of the foreshore. The sediment is grey in colour. The shoreline is concave in shape and has a steep gradient which decreases as it approaches the shoreline. There is a large rock form to the west. No seaweed or driftwood has gathered around the photo point.	The gravel is more uniform over the bay.
03-11-2017	The sediment making up Cass Bay appears to be primarily composed of sands and silts, which are dark brown in colour. A significant amount of the beach is covered with gravels and cobbles, which are light grey in colour. The shoreline is concave in shape, and has a moderate gradient which grows shallower as it approaches the water. No seaweed or driftwood has gathered around the photo point, however a channel of water has formed down the beach.	The gravel has less uniform coverage, exposing more areas of fine sediment (sand and silt).
07-11-2018	The sediment in Cass Bay appears to be primarily composed of sands and silts which are dark brown in colour. The beach is covered in a layer of light grey gravels and cobbles. The shoreline is concave in shape and has	The channel of water has disappeared. The gravel layer is more uniform.

	a moderate gradient which becomes shallower as it approaches the shoreline. No seaweed or driftwood has gathered around the photo point.	
06-05-2019	The sediment in Cass Bay appears to be composed of sands and silts, which are dark brown in colour. The beach is mostly covered in a layer of gravels and cobbles which are grey in colour. The shoreline is concave in shape and has a moderate gradient which becomes shallower as it approaches the water. No seaweed or driftwood has gathered around the point. A channel of water has formed to the west of the photo point.	The gravel layer has become less uniform. A channel of water has formed in front of the photo point.
18-07-2019	The sediment in Cass Bay appears to be composed of sands and silts, which are dark brown in colour. The beach is mostly covered in a layer of gravels and cobbles which are grey in colour. The shoreline is concave in shape and has a moderate gradient which becomes shallower as it approaches the water. No seaweed or driftwood has gathered around the point. A channel of water has formed to the west of the photo point.	The channel of water has disappeared. The gravel layer is more uniform.
17-10-2019	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
27-01-2020	No noticeable changes in the beach level.	The gravel has less coverage across the shoreline, exposing more areas of fine sediment (sand and silt).
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 10: Rapaki Bay	**West**	**To sea**	**East**
30-01-2017	 		 

12-05-2017			
11-09-2017			

03-11-2017			
07-11-2018			

06-05-2019			
18-07-2019			

17-10-2019			
27-01-2020			

09-06-2020			

Location 10: Rapaki Bay	**Description of photos**	**Changes from previous photos**
30-01-2017	Rapaki Bay at the place of observation is composed of two smaller bays. The eastern one of these has a large number of shells scattered throughout as well as many cobbles. Beneath these stones and shells is a silt and sand beach which is gold in colour. Large rock formations line the eastern and western sides. The shoreline is concave in shape. The western of the two bays is smaller. Shells have also collected in this bay. The western section of the bay is covered in cobbles and boulders, while the eastern section is composed of golden silts and sands. This bay is also concave in shape, but the curve is sharper. Both of the bays have a shallow gradient.	N/A
12-05-2017	The eastern bay mostly consists of sands and silts underneath a layer of dark gravel/cobbles. The sands and silts are brown in colour. There is a small amount of moss on the gravel. Some shells are scattered on the beach, but there is no driftwood or seaweed. The gradient of the shore is shallow, and the shape is slightly concave. Larger rock formations just out into the water at either end of the bay.	Small amount of moss has grown on the rocks.
11-09-2017	The bay is mostly covered by a layer of grey gravel and cobbles, which are coated in moss. This layer sits on top of sands and silts which appear to be brown in colour. The shoreline has a shallow gradient, and is concave in shape. No seaweed or driftwood has gathered around the photo point.	The extent of the moss has greatly increased.
03-11-2017	Much of Rapaki Bay is covered in a layer of cobbles, and those directly between the photo point and the water are covered in a layer of moss. Under the cobbles, the sediment appears to be composed of sands and silts that are light brown in colour. There are large rock formations at each end of the bay. The shoreline has a shallow gradient and is slightly concave in shape. No seaweed or driftwood has collected around the photo point.	Less moss is present.
07-11-2018	Much of Rapaki Bay is covered in a layer of grey cobbles, and small areas of these are coated in a green moss. The sediment beneath these cobbles appears to be composed of brown silts and sands. There are large natural rock formations at either end of the bay. The shoreline has a shallow gradient and is slightly concave in shape. No seaweed or driftwood is present around the photo point.	Less moss is present, some water has been retained on the surface of the bay.

06-05-2019	Much of the bay is covered in a layer of grey cobbles. There is a small amount of green moss present on top of some of the cobbles. The sediment beneath these cobbles appears to be composed of silts and sands, and is brown in colour. There are large natural rock formations to the east and west of the photo point. The shore has a shallow gradient and is slightly concave in shape. No seaweed or driftwood is present around the photo point.	Less moss is present, the cobble layer is less uniform.
18-07-2019	Much of the bay is covered in a layer of grey cobbles. The sediment beneath these cobbles appears to be composed of silts and sands, and is brown in colour. There are large natural rock formations to the east and west of the photo point. The shore has a shallow gradient and is slightly concave in shape. No seaweed or driftwood is present around the photo point.	Less to no moss is present. Some water has been retained on the surface of the bay. There are less shells scattered on the beach.
17-10-2019	No noticeable changes in the sediment composition or beach level.	Small amount of moss has grown on the rocks.
27-01-2020	No noticeable changes in the sediment composition or beach level.	Less to no moss is present.
09-06-2020	More cobbles visible at the high tide mark	More gravel visible at the high tide mark

Location 11: Purau Bay	West	North	East
30-01-2017			
12-05-2017			

11-09-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

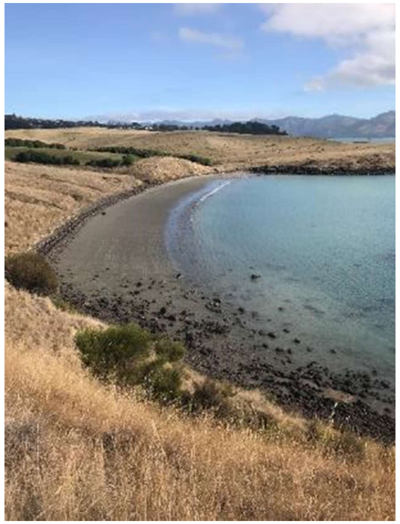
27-01-2020			
09-06-2020			

Location 11: Purau Bay	Description of photos	Changes from previous photos
30-01-2017	Shells and driftwood have collected around the high water mark of the bay. The bay itself appears to be composed of fine gravels and sands with some cobbles. Closer to the low tide mark, the bay transitions to more of a gravel and cobble composition. The colour of the bay is a light grey, with the section closer to the water being a darker grey colour. A western section of the bay has an additional bar of this beyond the low tide mark. The shoreline's shape is irregular, curving towards and away from the road. The gradient is very shallow near the low tide mark, but grows steeper further from this mark.	N/A
12-05-2017	The bay is composed of gravels at the water level. These gravels are grey-black in colour. Above this, the bay consists of silts and sands that are brown-grey in colour. There is a layer of shells and fine gravels that sits on top of this, consisting of black and white particles. The gradient is near-flat at the water level, but gradually steepens away.	No noticeable changes.
11-09-2017	The bay is composed of three bands parallel to the shoreline of varying sediment sizes. The central band is composed of sands and silts, with the two outer bands appearing to be made up more of gravels and cobbles. The colour of the sediment tends to be grey, transitioning to a brown colour to the east. No driftwood or seaweed has gathered around the photo point, however some shells are present in the top band of gravel. The shoreline is slightly concave to the east and undulates to the west. The shore has a shallow gradient throughout.	No noticeable changes.
03-11-2017	The bay is composed of three bands parallel to the water, one composed of sands and silts in the centre and two with gravels and cobbles. The sands and silts are brown in colour and the gravels and cobbles are generally grey. The gradient of the shoreline is steep at the top and shallows as it approaches the water. No seaweed or driftwood has collected around the photo point.	No noticeable changes.
07-11-2018	The bay is composed of three bands of sediment parallel to the water. The upper and lower bands are composed of gravels and cobbles, which are grey in colour. The central band is composed primarily of sands and silts, and these are grey-brown in colour. The lower gravel band is partly submerged. The gradient of the bay is moderate, shallowing as it	No noticeable changes

	approaches the water. No driftwood or seaweed is present around the photo point.	
06-05-2019	The bay is composed of three distinct bands of sediment running parallel to the waterline. The upper and lower bands appear to be composed primarily of gravels and cobbles, which are grey in colour. The central band appears to be composed of silts and sands, which appear brown in colour. The gradient of the bay is moderate, shallowing as it approaches the water line. No driftwood or seaweed is present around the point.	The middle band appears cleaner than it has previously.
18-07-2019	The bay is composed of three distinct bands of sediment running parallel to the waterline. The upper and lower bands appear to be composed primarily of gravels and cobbles, which are grey in colour. The central band appears to be composed of silts and sands, which appear brown in colour. The gradient of the bay is moderate, shallowing as it approaches the water line. No driftwood or seaweed is present around the point	To the east of the photo point the middle band composed of sands and silts appears to have expanded down to the lower band to the waterline.
17-10-2019	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
27-01-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 12: Pile Bay	**West**		
30-01-2017			
12-05-2017			

11-09-2017			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 12: Pile Bay	Description of photos	Changes from previous photos
30-01-2017	The bay appears to be primarily composed of silts and sands and coloured a dark grey/brown. Towards the eastern end of the bay, some larger cobbles and boulders can be found. There appears to be minimal seaweed and driftwood in the bay. The shoreline is concave in shape. The gradient appears to be shallow.	N/A
12-05-2017	The bay appears to be composed of sands and silts that are grey-brown in colour. Some ripple-shaped bands have formed in the sand, alternating between light and dark coloured sediment. The shoreline is concave in shape and appears to have a shallow gradient. There appears to be no seaweed or driftwood in the bay.	The amount of seaweed in the bay has reduced. Bands of discolouration have formed in the sand.
11-09-2017	The bay appears to be composed of sands and silts that are grey-brown in colour. Some light brown bands of discolouration have formed parallel to the shoreline, which is concave in shape. The bay appears to have a shallow gradient. No seaweed or driftwood has appeared to collect in the bay.	No noticeable changes.
03-11-2017	The bay appears to be composed of silts and sands that are grey-brown in colour. There are larger boulders at either end of the bay. The bay is concave in shape and appears to have a shallow gradient. No seaweed or driftwood has gathered in the bay. Some lighter bands of colour have formed parallel to the water.	No noticeable changes.
07-11-2018	The bay appears to be primarily composed of sands and silts that are grey-brown in colour. Larger boulders are present at either end of the bay. The bay is concave in shape and appears to have a shallow gradient. There are ripple-shaped bands of discolouration running parallel to the waterline.	No noticeable changes.
06-05-2019	The bay appears to be primarily composed of silts and sands that are grey-brown in colour. Large boulders are present at the near end of the bay. The bay is concave in shape and appears to have a shallow gradient. There are ripple-shaped bands of discolouration parallel to the waterline.	No noticeable changes
18-07-2019	The bay appears to be primarily composed of silts and sands that are grey-brown in colour. Large boulders and seaweed are present at the near end of the bay. The bay is concave in shape and appears to have a	The amount of seaweed at the high water mark has increased.

	shallow gradient. There are ripple-shaped bands of discolouration parallel to the waterline.	
17-10-2019	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
27-01-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 13: Camp Bay	West	North	East
30-01-2017			
12-05-2017			

11-09-17			
03-11-2017			

07-11-2018			
06-05-2019			

18-07-2019			
17-10-2019			

27-01-2020			
09-06-2020			

Location 13: Camp Bay	Description of photos	Changes from previous photos
30-01-2017	There has been no collection of driftwood or seaweed around the photo point. The composition of the bay is sand and silt in the centre, with large rock formations at the eastern and western sides. The sands and silts are a light brown colour at the top of the bay, but gradually darkens as it approaches the low tide mark. The shoreline is concave, though the waterline is slightly lower at the western end. The gradient of the bay is very shallow from the low tide mark downwards and steeper above this.	N/A
12-05-2017	A very small amount of seaweed has gathered around the photo point. The shoreline appears to be composed of brown sands and silts primarily, with boulders and large rock formations at the east and west ends of the bay. The colour of the sediment darkens gradually as it gets closer to the water. The shoreline is concave in shape. The gradient is near-flat.	Slight increase in the amount of seaweed and driftwood in the bay.
11-09-2017	Brown silts and sands appear to make up the majority of the bay, with a significant deposit of black sand. Large dark rock formations are present at each end of the beach. The shoreline is slightly concave in shape and has a shallow gradient towards the water. No seaweed or driftwood has collected around the point.	The seaweed and driftwood has lessened from the previous round. A patch of dark sediment has collected in the middle of the bay.
03-11-2017	The bay appears to be composed of silts and sands that are brown in colour. The colouration changes from a lighter shade to a darker one approximately halfway between the water and the photo point. There is a small amount of seaweed around the photo point. There are large rock formations at either end of the bay. The shoreline is slightly concave and has a shallow gradient.	The black sediment is gone, and the colour change occurs further down the beach.
07-11-2018	The bay appears to be composed of sands and silts which are brown in colour. The colour is not uniform, with patches of lighter colour scattered across the bay. There is no seaweed or driftwood around the photo point. There are large natural rock formations at either end of the bay. The shoreline is slightly concave in shape and has a shallow gradient.	The colour change is gone, the seaweed and driftwood have disappeared.
06-05-2019	The bay appears to be composed of sands and silts which are brown in colour. There are a few large pieces of driftwood near the photo point. There are large natural rock formations at the western and eastern ends. The shoreline is slightly concave in shape and has a shallow gradient.	The colour of the sediment is more uniform, a few driftwood pieces have gathered around the point.

18-07-2019	The bay appears to be composed of sands and silts which are brown in colour. The colour is not uniform with some areas of black in the central water mark. There are no driftwood or seaweed near the photo point. There are large natural rock formations at the western and eastern ends. The shoreline is slightly concave in shape and has a shallow gradient.	Black sediments are present in the middle of the bay.
17-10-2019	No noticeable changes in the sediment composition or beach level.	Slight increase in the amount of seaweed and driftwood in the bay.
27-01-2020	No noticeable changes in the sediment composition or beach level.	Significant increase in the amount of driftwood in the bay.
09-06-2020	No noticeable changes in the sediment composition or beach level.	No noticeable changes.

Location 14: Little Port Cooper	West	North	East
01-02-2017			
09-06-2017			

17-10-2017			
13-11-2018			

17-05-2019			
22-07-2019			

17-10-2019			
11-02-2020			

08-06-2020			

Location 14: Little Port Cooper	**Description of photos**	**Changes from previous photos**
01-02-2017	A large amount of driftwood and seaweed has collected in the bay. The bay's composition appears to be sands and silts. The colour is a reasonably consistent dark brown throughout. The shape of the shoreline is slightly concave, becoming more noticeably concave towards the eastern and western ends. The gradient of the shoreline is shallow.	N/A
09-06-2017	The bay appears to be composed of golden brown silts and sands. No seaweed or driftwood has collected in the bay. The colour changes between a light and dark shade of brown in tide-shaped bands. The shape of the shoreline is slightly concave, with more noticeable curvature at the eastern and western ends of the bay. The gradient is shallow.	The sand is a more golden colour than the previous observation. The seaweed and driftwood is all gone. Bands of changing colour are more prominent.
Round 3	Not photographed due to weather.	N/A
17-10-2017	The bay appears to be composed of light brown sands and silts. The sand has a darker coloured section closer to the water. The shoreline is shallow in gradient and slightly concave in shape. Some seaweed has gathered around the point. Large rock formations are present at either end of the bay.	The surface of the bay is smoother and seaweed has gathered around the photo point. The colour bands have formed two distinct bands.
13-11-2018	The bay appears to be composed of light brown sands and silts. The sediment changes colour to be slightly darker closer to the water line. There are large pieces of driftwood that have gathered around the photo point. The bay has a shallow gradient and is slightly concave in shape.	The seaweed has been replaced with larger pieces of driftwood.
17-05-2019	The bay appears to be composed of light brown sands and silts. There is some driftwood around the photo point. The bay has a shallow gradient and is concave in shape. The colour is consistent throughout. Large rock formations are present at each end of the bay. There are cattle footprints across the beach.	The larger pieces of driftwood have gone and been replaced by smaller pieces.
22-07-2019	The bay appears to be composed of brown sands and silts. There is some driftwood around the photo point. The colour is not uniform with shades of light brown. The bay has a shallow to moderate gradient and is concave in shape. The ripple shaped bands have formed parallel to the water. Large rock formations are present at each end of the bay. Two channels of water have formed west of the photo point.	The colour of the bay is not uniform with shades of light and dark brown across the area. Two channel has formed west side of the bay indicating water has been running down.

29-10-2019	No noticeable changes in the sediment composition.	The top of the rocks are now visible from the shoreline.
11-02-2020	No noticeable changes in the sediment composition.	There is small increase in the amount of sand on the shoreline as there are less rocks visible.
08-06-2020	No noticeable changes in the sediment composition.	There is small increase in the amount of sand on the shoreline as there are less rocks visible.

Location 15: Port Levy/Koukourarata	West	North	East
01-02-2017			
09-06-2017			

17-10-2017			
13-11-2018			

17-05-2019			
22-07-2019			

29-10-2019			
11-02-2020			

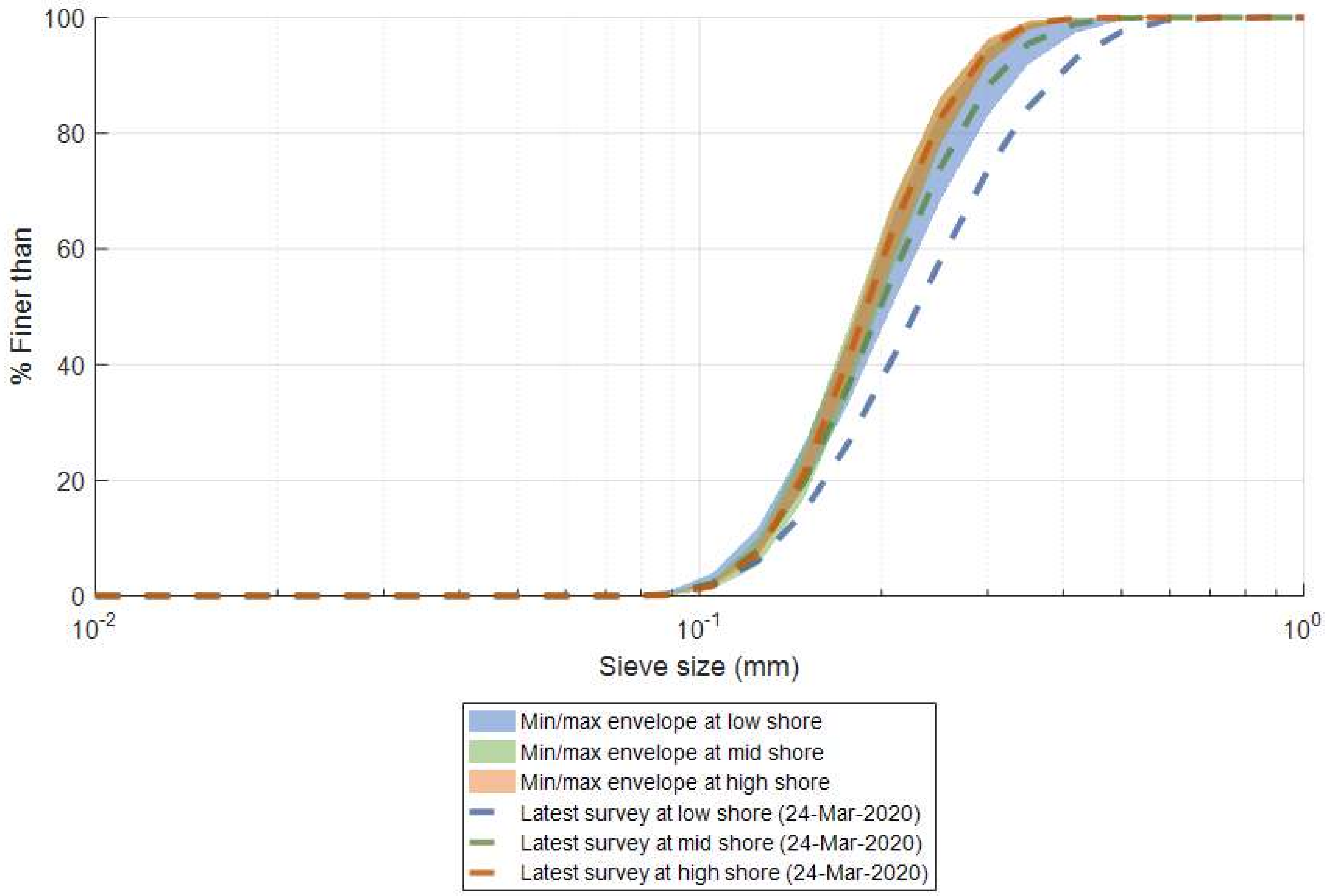
08-06-2020			

Location 15: Port Levy/Koukourarata	Description of photos	Changes from previous photos
01-02-2017	Driftwood and shells have collected above the high water mark. The bay is composed of gravel and cobbles at the top, then a section of sands and silts in the middle, and another gravel and cobble section nearest to low tide. The upper section is a light grey colour, the middle section is a dark grey/brown and the lowest section is a dark grey. The shoreline is an irregular shape, curving back and forth along the length of the shoreline. The top of the bay has a steep slope and the central and lower sections have a shallow gradient.	N/A
09-06-2017	The bay is primarily composed of dark grey cobbles and gravels. Just below the high tide mark there is a section of beach made up of silts and sands, which are also dark grey in colour. The slope of the shoreline is shallow near the water, but grows steeper further away. There is some seaweed on the gravels and cobbles below the water line. The shoreline is primarily concave in shape, though there are many irregularities as it curves along its length.	A greater amount of seaweed is present below the water line.
Round 3	Not photographed due to weather.	N/A
17-10-2017	The bay is comprised of dark grey cobbles and gravels, with a section of silty and sandy beach just below the high tide mark. Shells have accumulated near the high tide mark, as well has across the foreshore looking north-west. The shoreline appears irregular, curving back and forth along its length with a shallow channel transecting the foreshore near the centre of the bay.	Channel has formed in the bay indicating water has been running down.
13-11-2018	The bay is composed of two separate bands of sediment running parallel to the water line. The upper band is composed of sands and silts that are brown in colour. The lower band appears to be composed of grey gravels and cobbles. The shoreline appears to be irregular, curving in and out along its length.	Channel is gone, shells are mostly gone.
17-05-2019	The bay is composed of two distinct bands of sediment. The one closer to the high tide mark is made up of brown silts and sands with a scattered layer of grey gravels atop it. The further band is composed of gravels and cobbles, also grey. The shoreline undulates along its length and has a shallow gradient.	Sand and silt band is covered with gravel and shells

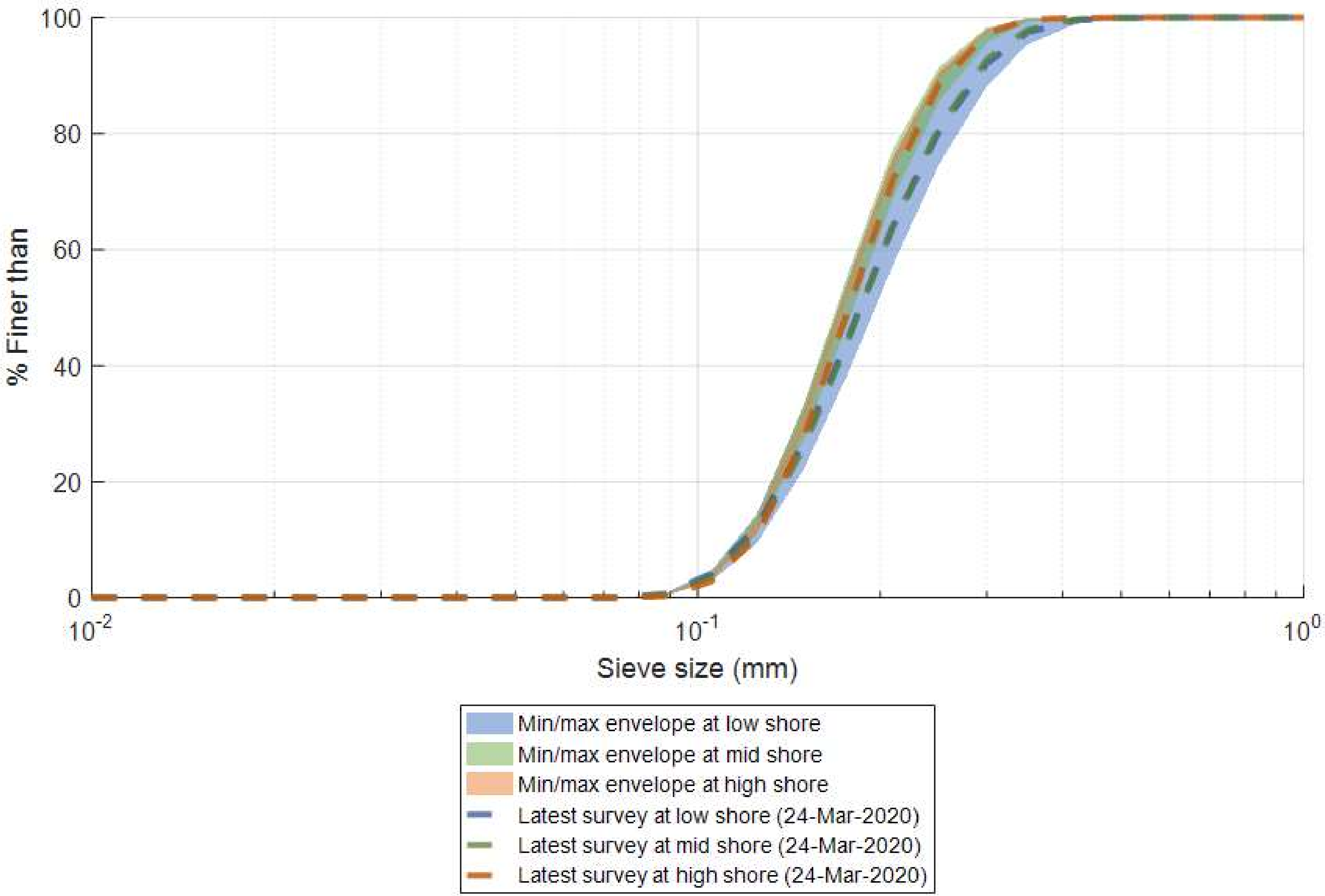
22-07-2019	The bay is composed of two bands of sediment. The one closer to the high tide mark is made up of brown silts and sands with a scattered layer of grey gravels atop it. The lower band is composed of gravels and cobbles and shells which are also grey. The shoreline undulates along its length and has a shallow gradient. There is a number of narrow channels running down perpendicular to the water.	There is a lesser degree of gravels and cobbles on the lower band. There is a number of narrow channels running down perpendicular to the water.
29-10-2019		Channel is gone.
11-02-2020	No noticeable changes in the sediment composition or beach level.	There is more seaweed around the photo point.
08-06-2020	No noticeable changes in the sediment composition or beach level.	N/A

Appendix B: Sediment size analysis results

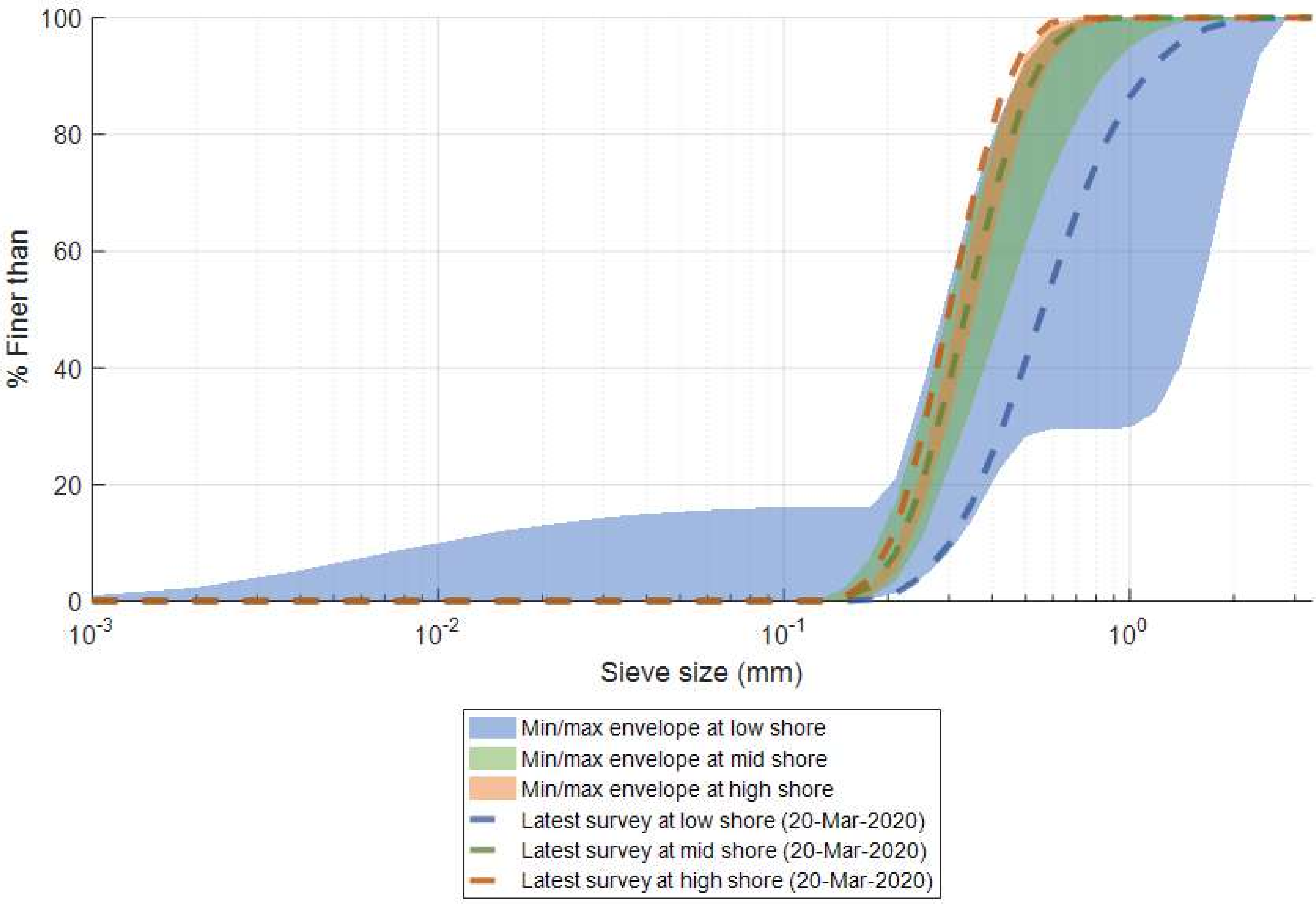
Sediment Analysis - Southshore

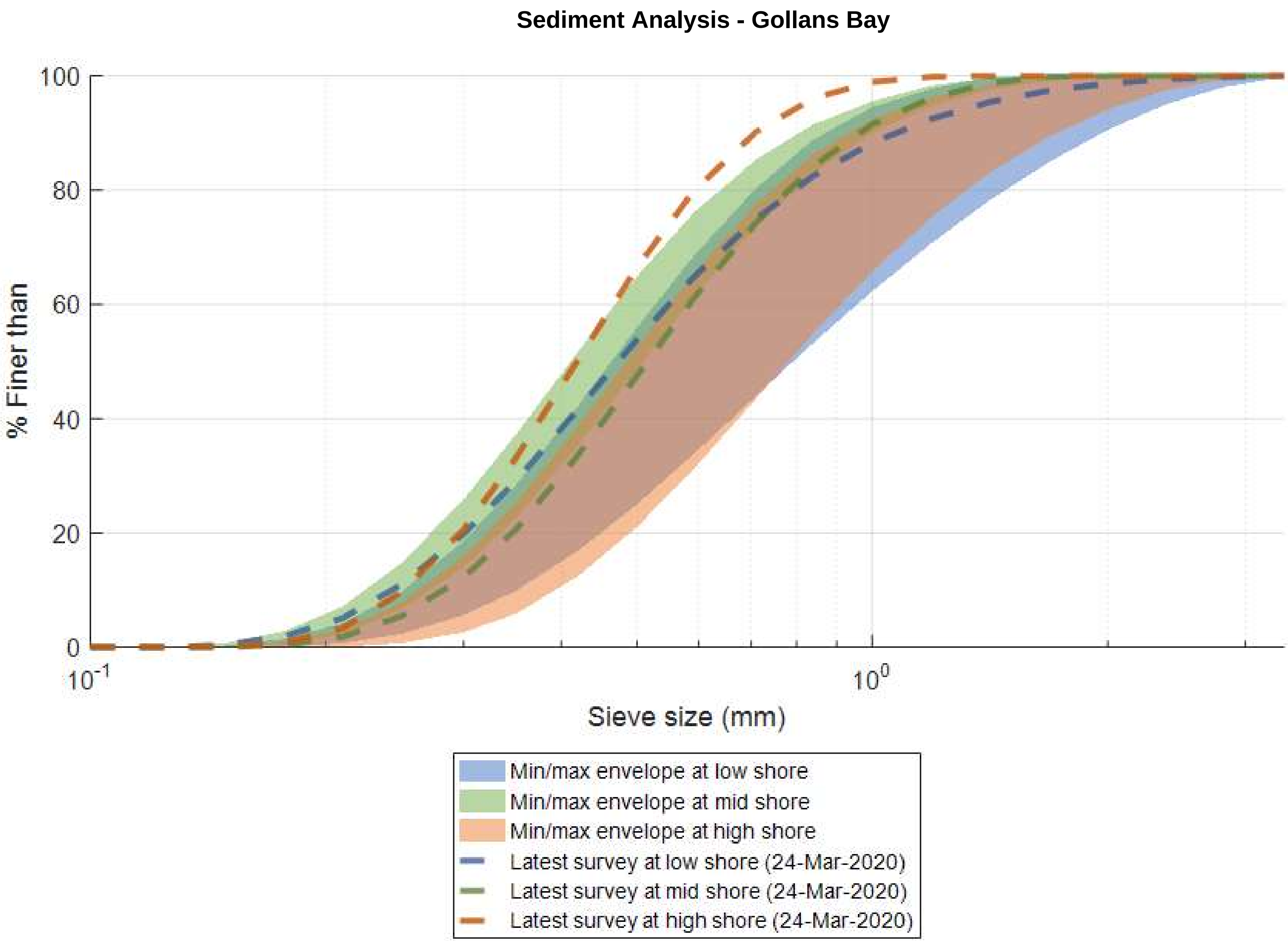


Sediment Analysis - Sumner

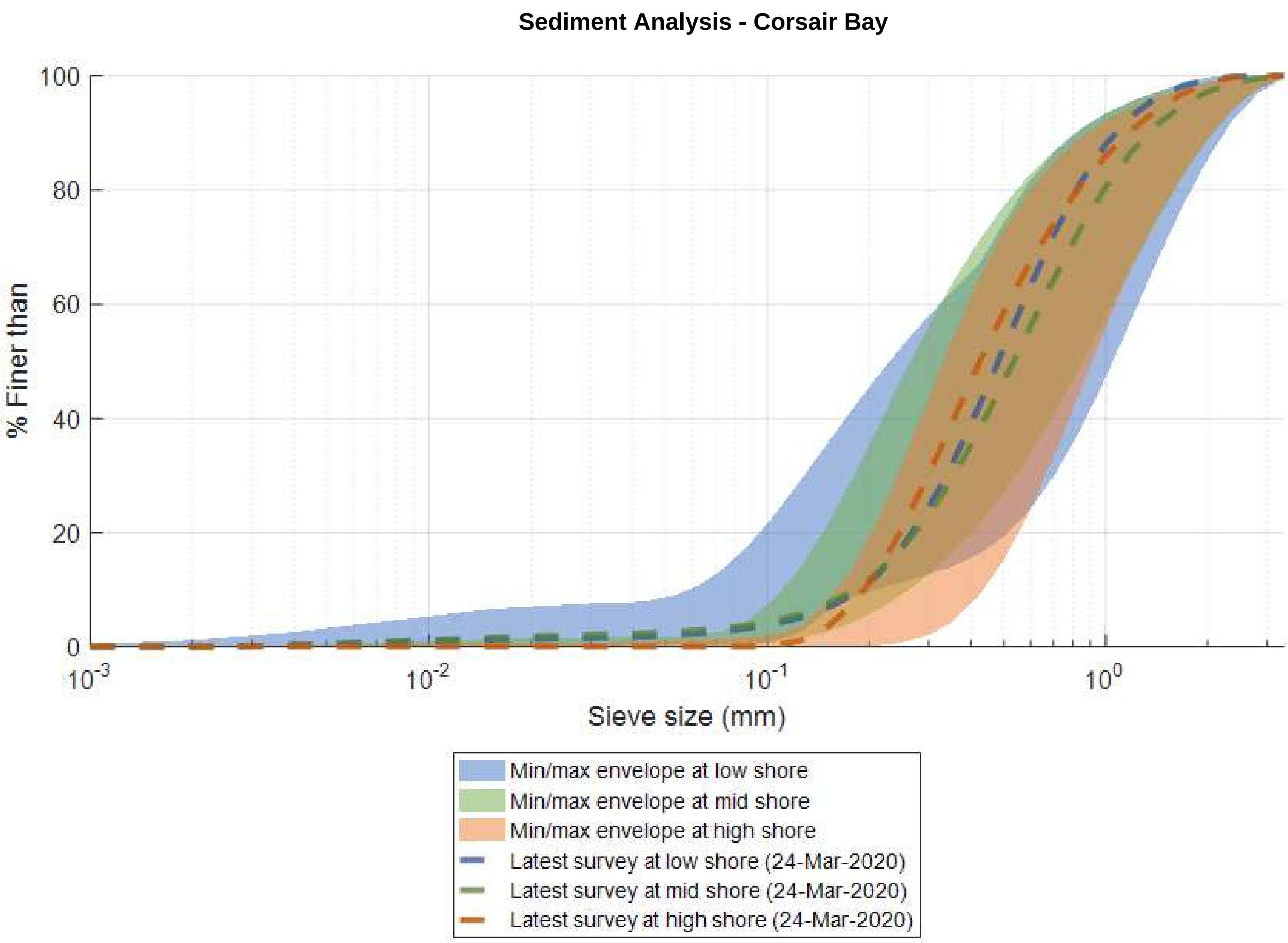


Sediment Analysis - Taylor's Mistake

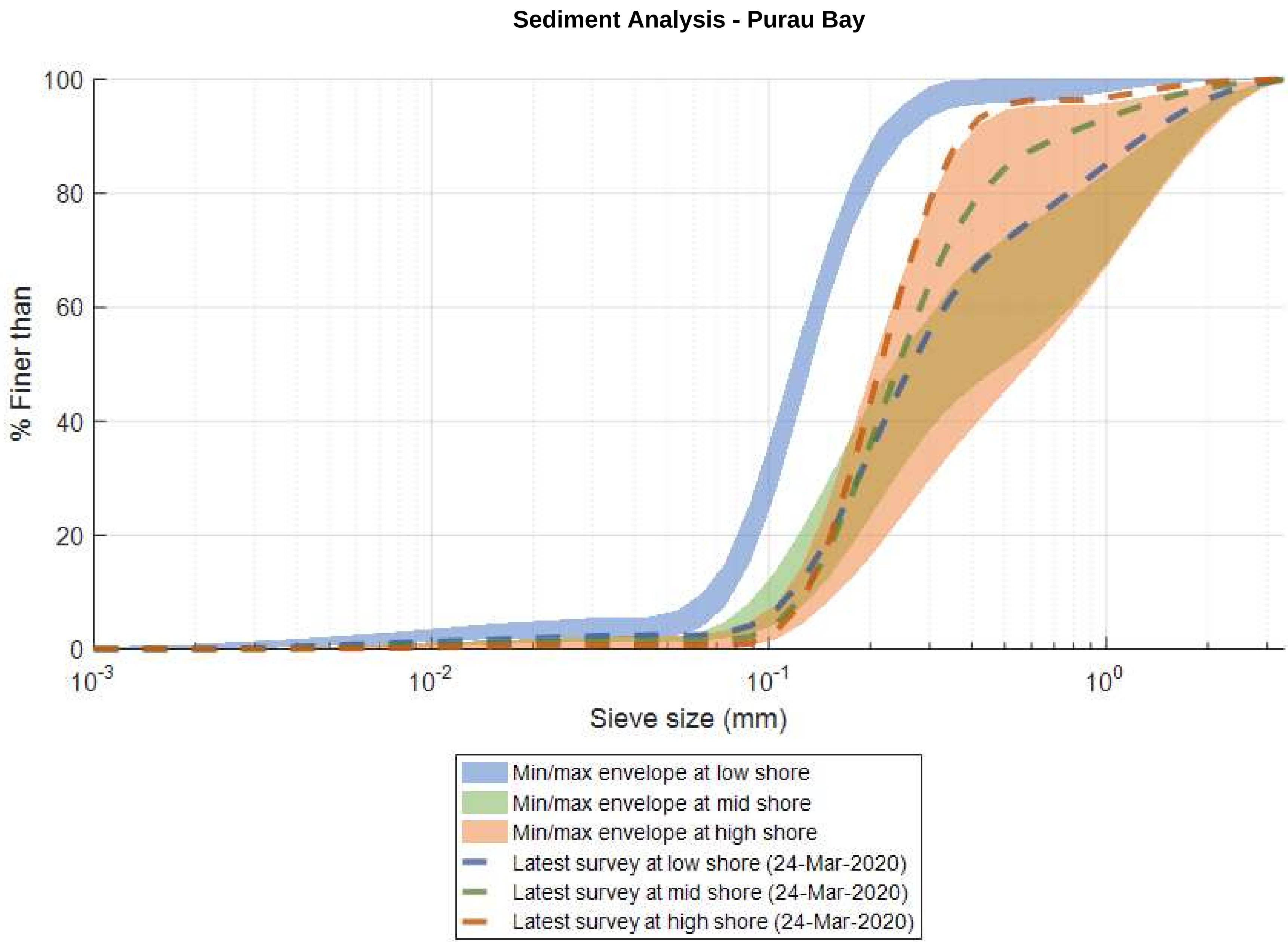




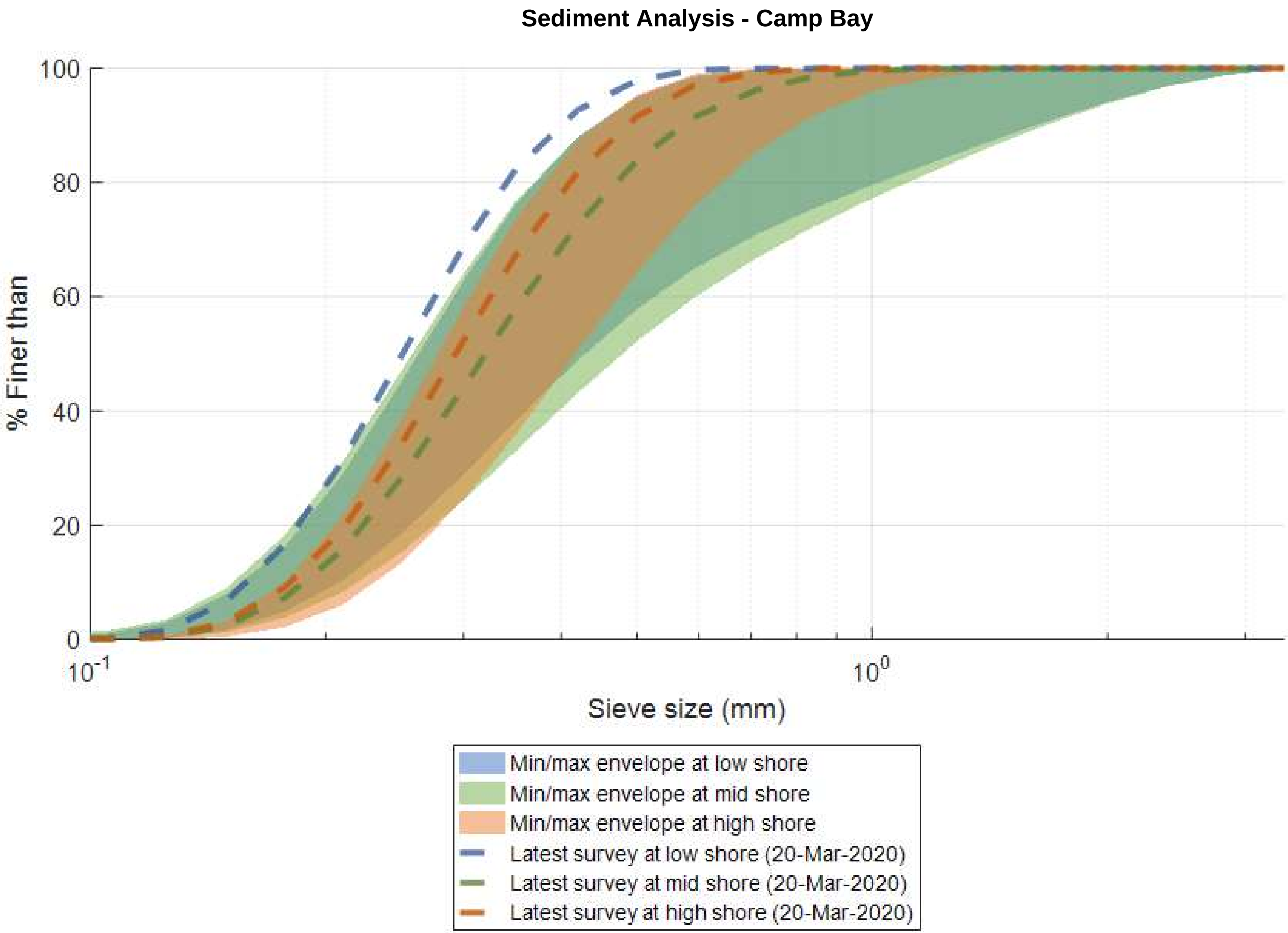
Sediment Analysis - Gollans Bay
100
80
60
40
20
0
% Finer than
10^{-1}
10^{0}
Sieve size (mm)
Min/max envelope at low shore
Min/max envelope at mid shore
Min/max envelope at high shore
Latest survey at low shore (24-Mar-2020)
Latest survey at mid shore (24-Mar-2020)
Latest survey at high shore (24-Mar-2020)



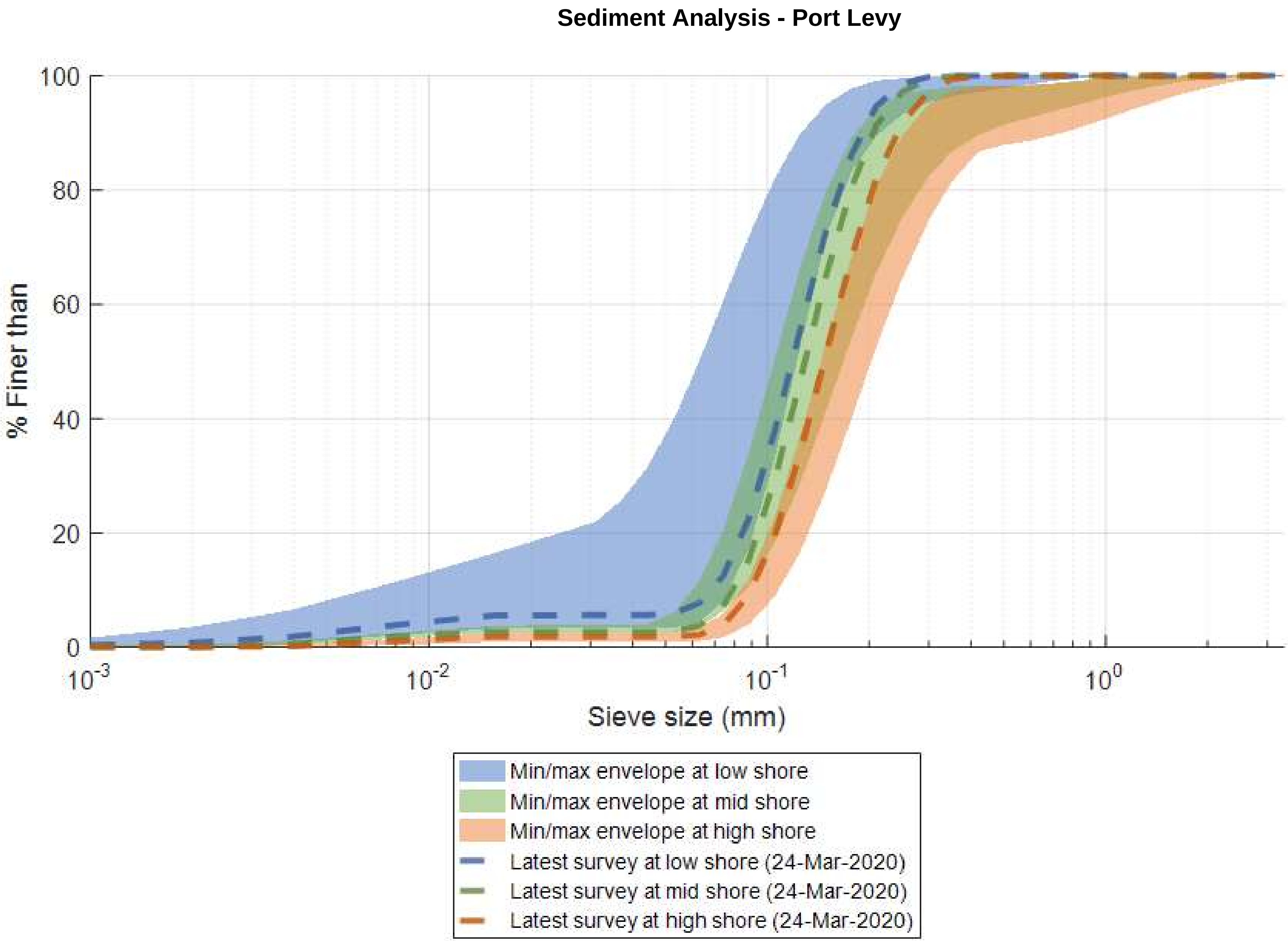
Sediment Analysis - Corsair Bay
% Finer than
100
80
60
40
20
0
10-3
10-2
10-1
10^0
Sieve size (mm)
Min/max envelope at low shore
Min/max envelope at mid shore
Min/max envelope at high shore
Latest survey at low shore (24-Mar-2020)
Latest survey at mid shore (24-Mar-2020)
Latest survey at high shore (24-Mar-2020)



Sediment Analysis - Purau Bay
% Finer than
100
80
60
40
20
0
10^{-3}
10^{-2}
10^{-1}
10^{0}
Sieve size (mm)
Min/max envelope at low shore
Min/max envelope at mid shore
Min/max envelope at high shore
Latest survey at low shore (24-Mar-2020)
Latest survey at mid shore (24-Mar-2020)
Latest survey at high shore (24-Mar-2020)

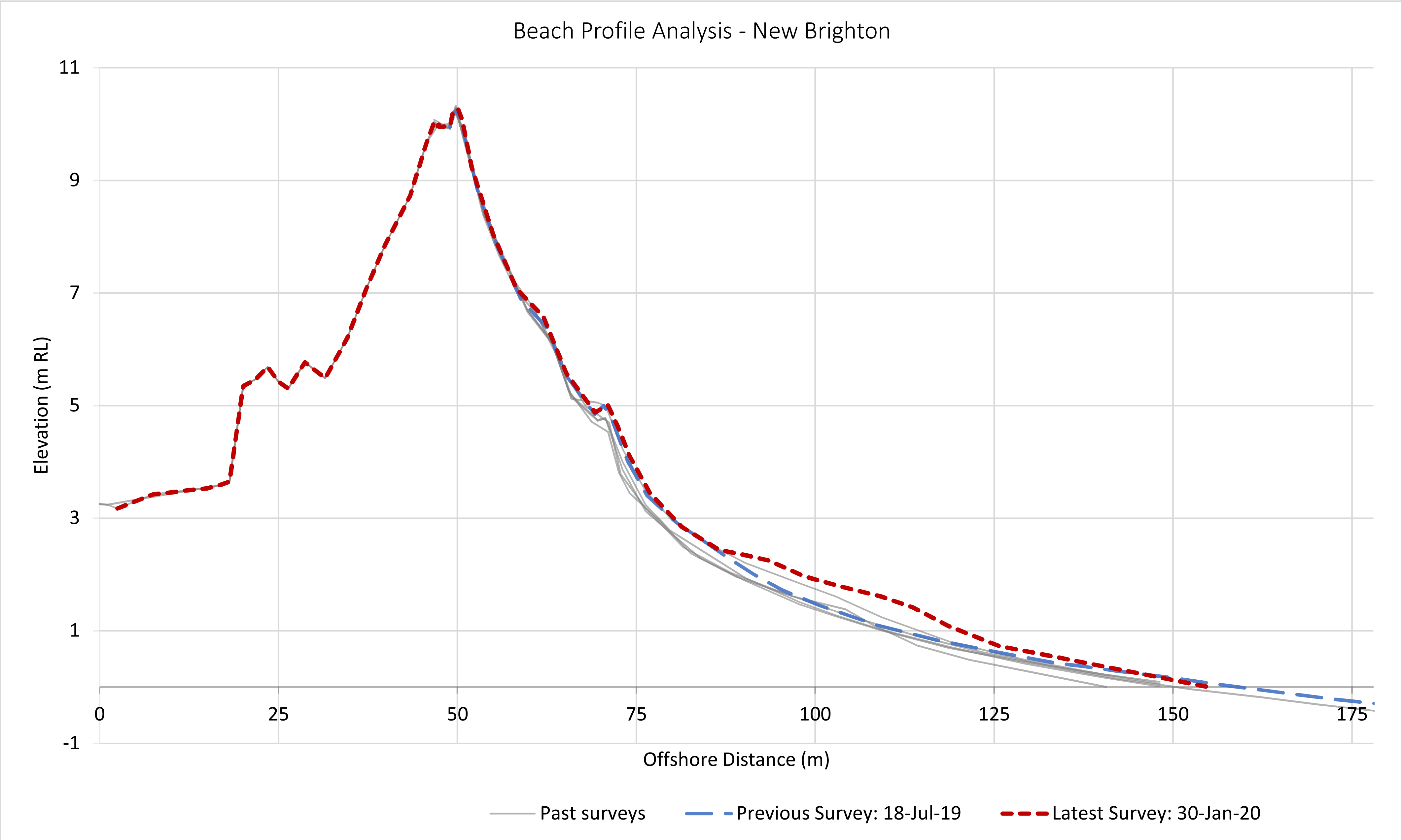


Sediment Analysis - Camp Bay
100
80
60
40
20
0
% Finer than
10^{-1}
10^{0}
Sieve size (mm)
Min/max envelope at low shore
Min/max envelope at mid shore
Min/max envelope at high shore
Latest survey at low shore (20-Mar-2020)
Latest survey at mid shore (20-Mar-2020)
Latest survey at high shore (20-Mar-2020)

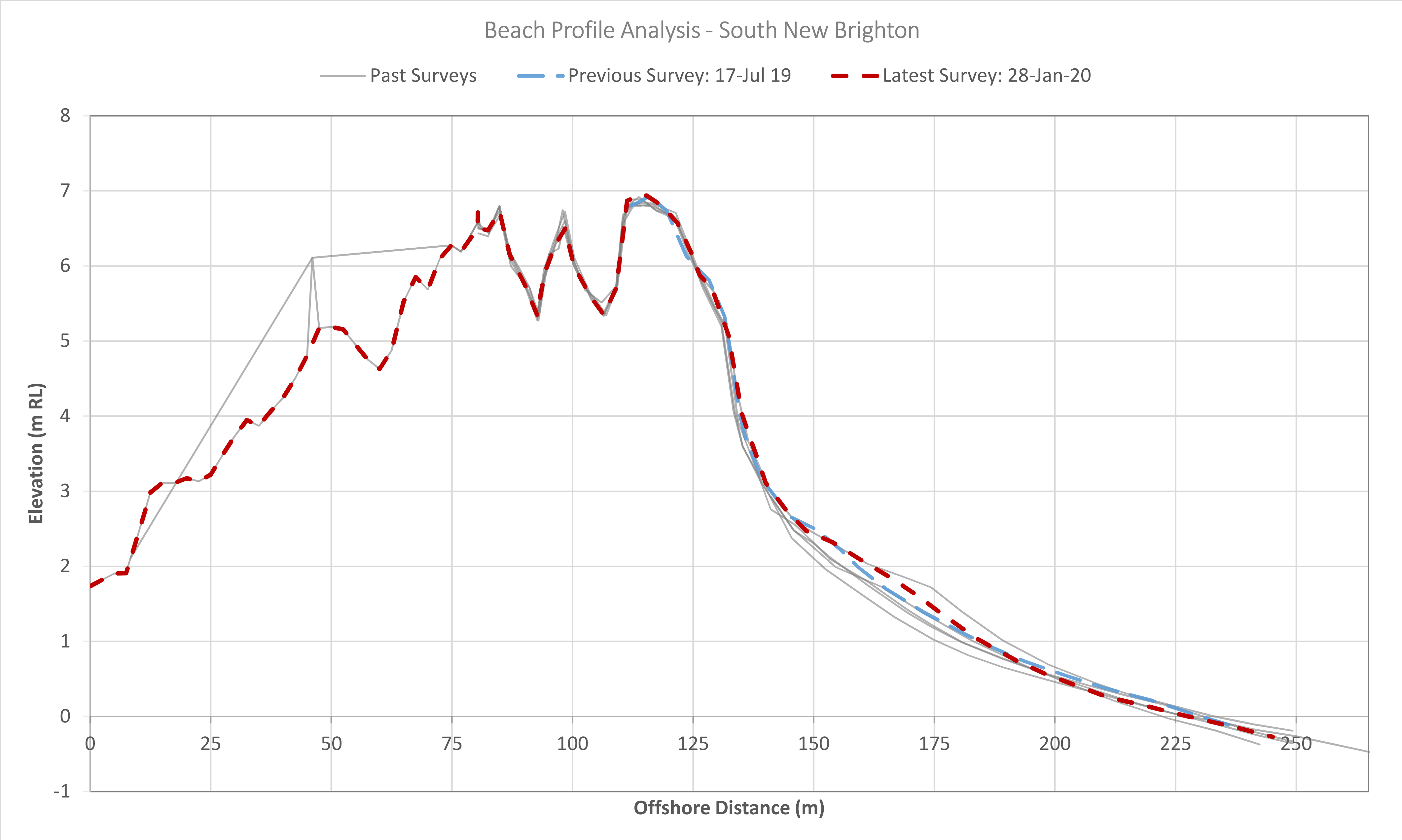


Sediment Analysis - Port Levy
100
80
60
40
20
0
% Finer than
10^{-3}
10^{-2}
10^{-1}
10^{0}
Sieve size (mm)
Min/max envelope at low shore
Min/max envelope at mid shore
Min/max envelope at high shore
Latest survey at low shore (24-Mar-2020)
Latest survey at mid shore (24-Mar-2020)
Latest survey at high shore (24-Mar-2020)

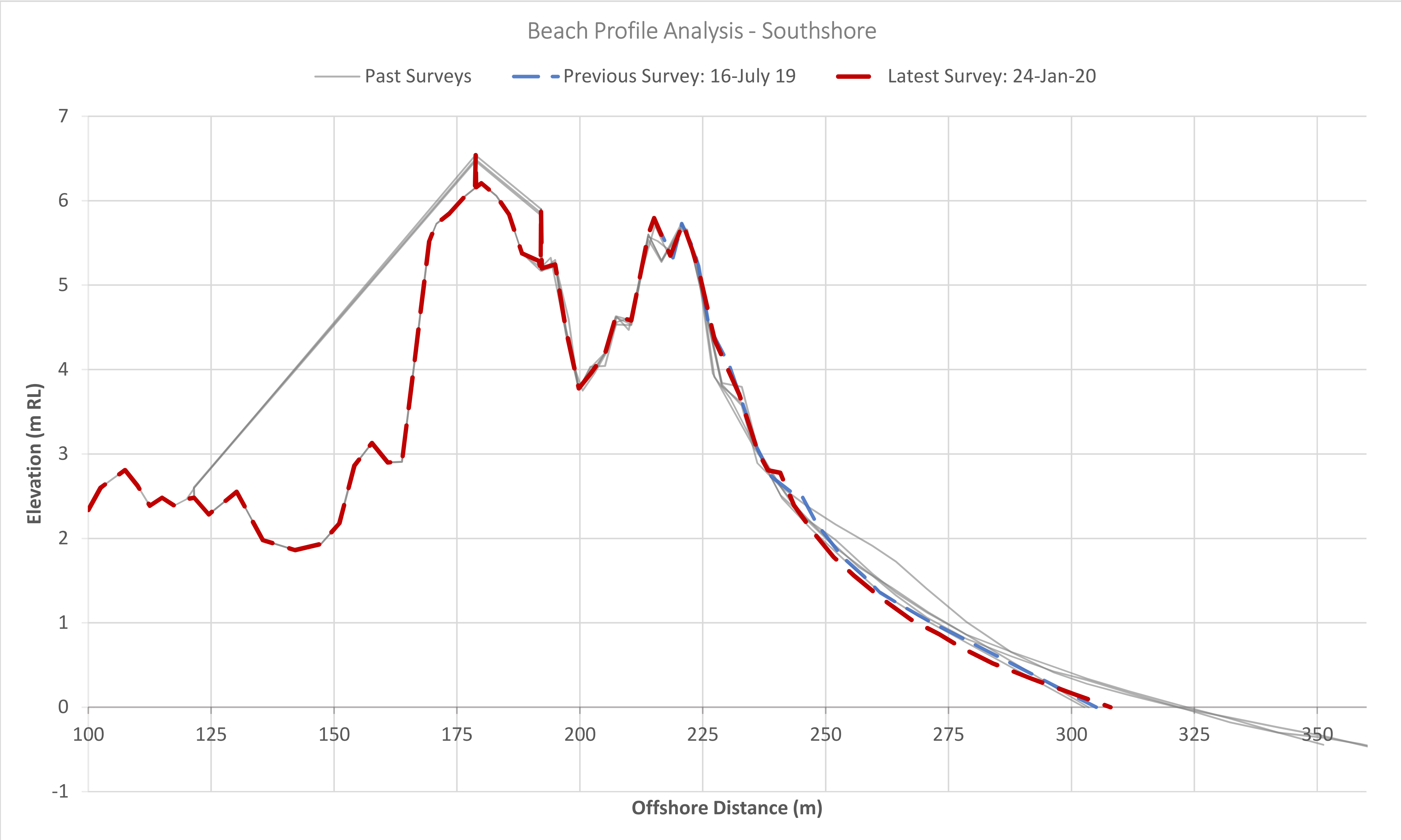
Appendix C: Beach profile surveys



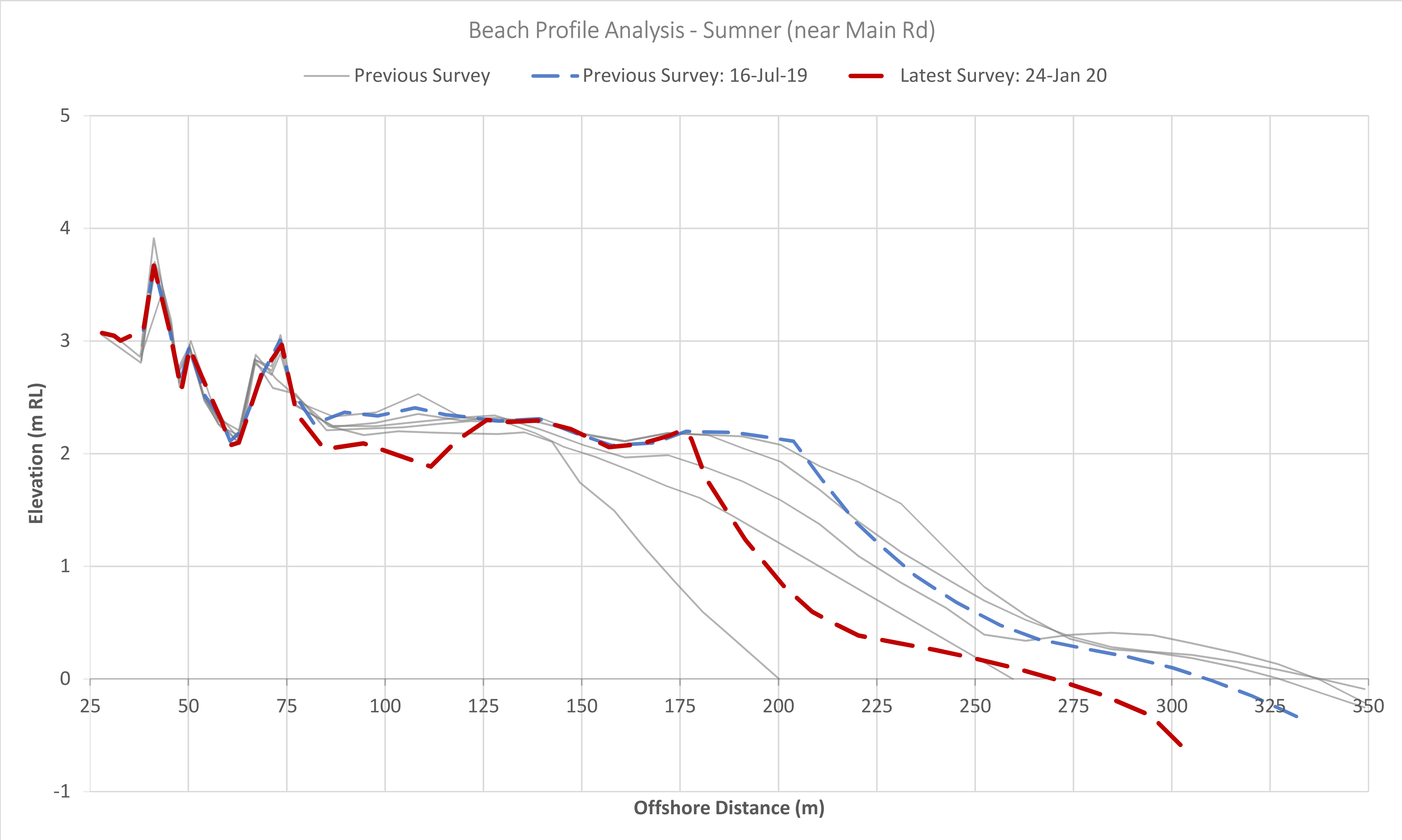
Beach Profile Analysis - New Brighton
11
9
7
5
3
1
-1
Elevation (m RL)
0
25
50
75
100
125
150
175
Offshore Distance (m)
Past surveys
Previous Survey: 18-Jul-19
Latest Survey: 30-Jan-20



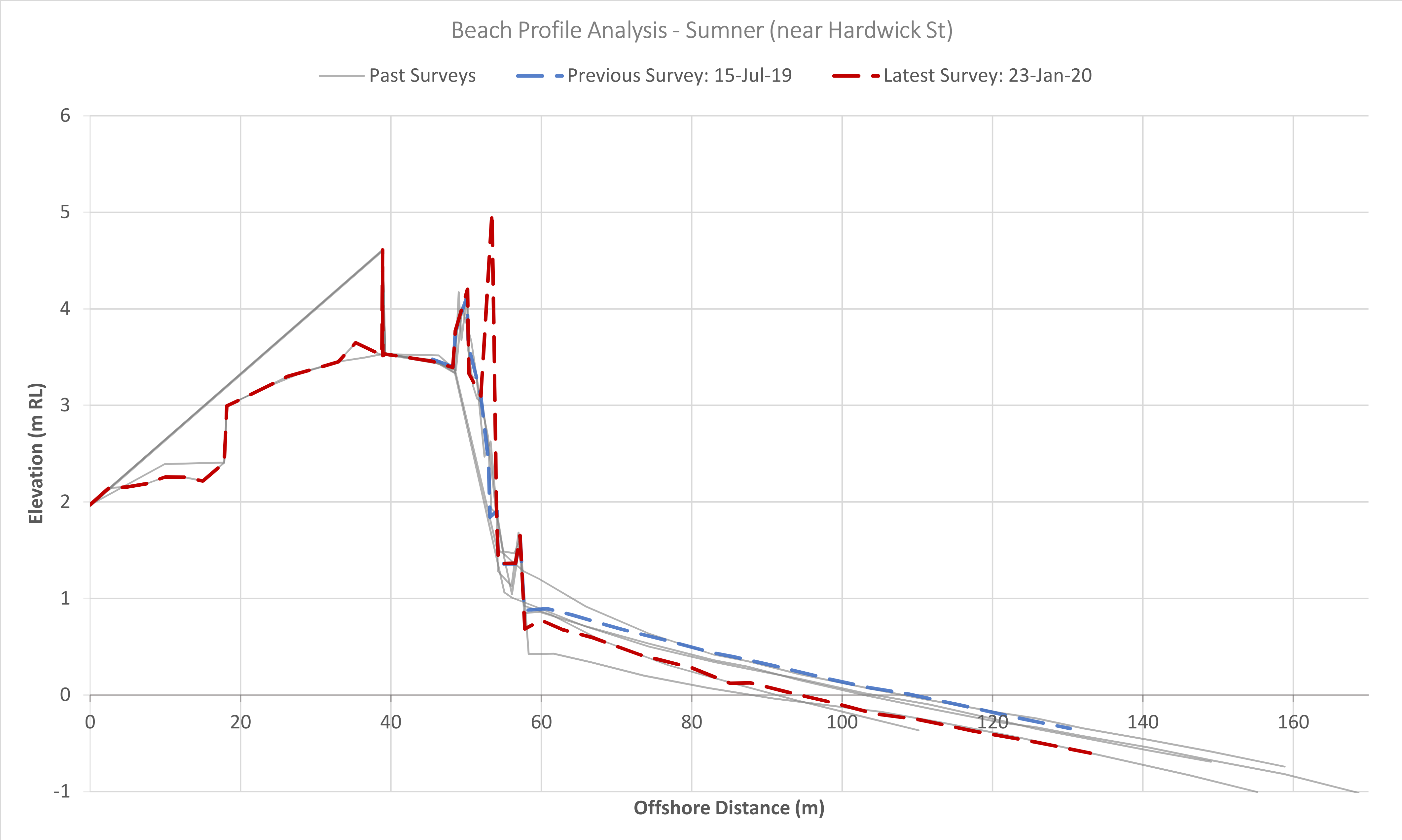
Beach Profile Analysis - South New Brighton
Past Surveys
Previous Survey: 17-Jul 19
Latest Survey: 28-Jan-20
Elevation (m RL)
8
7
6
5
4
3
2
1
0
-1
0
25
50
75
100
125
150
175
200
225
250
Offshore Distance (m)



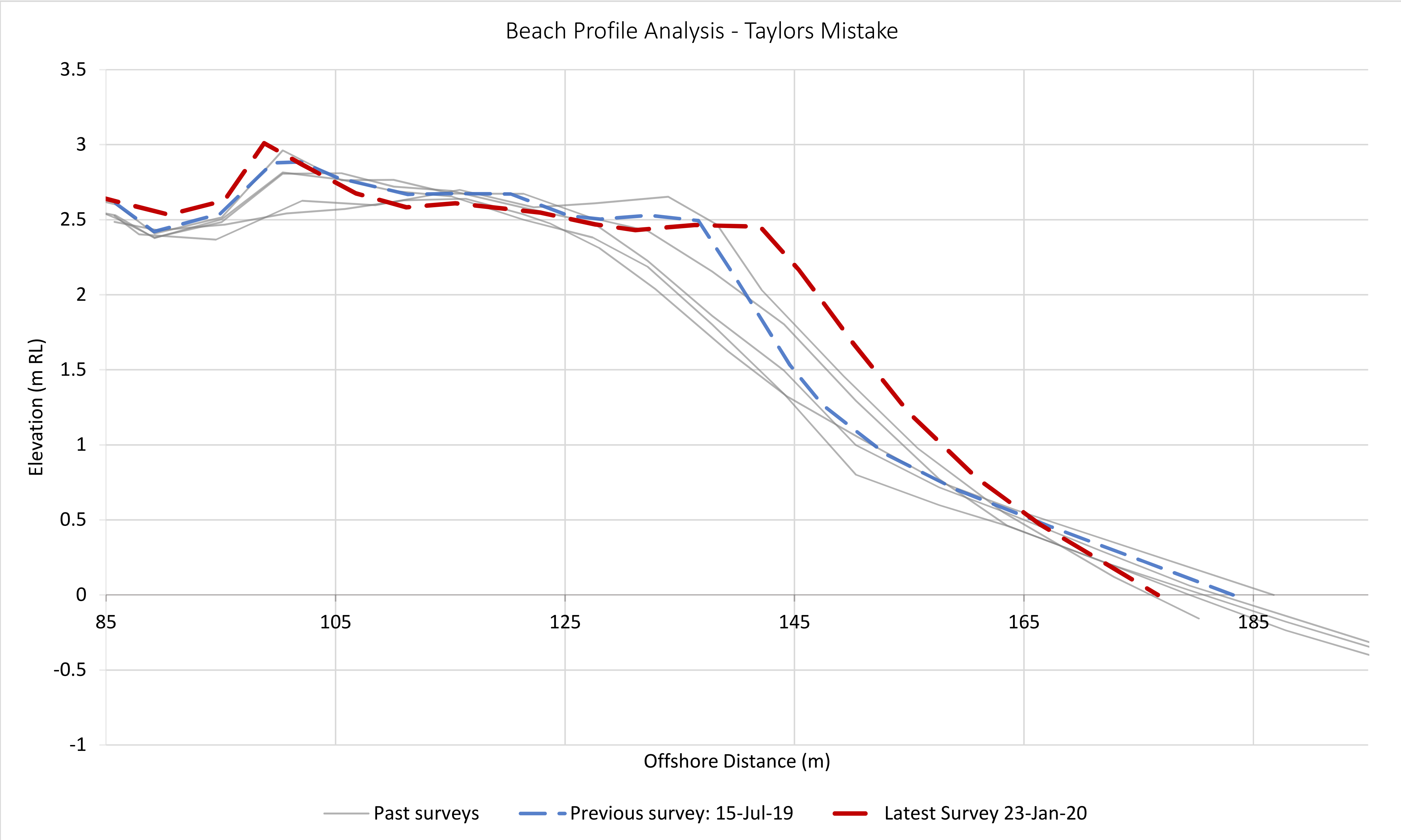
Beach Profile Analysis - Southshore
Past Surveys
Previous Survey: 16-July 19
Latest Survey: 24-Jan-20
Elevation (m RL)
7
6
5
4
3
2
1
0
-1
100
125
150
175
200
225
250
275
300
325
350
Offshore Distance (m)



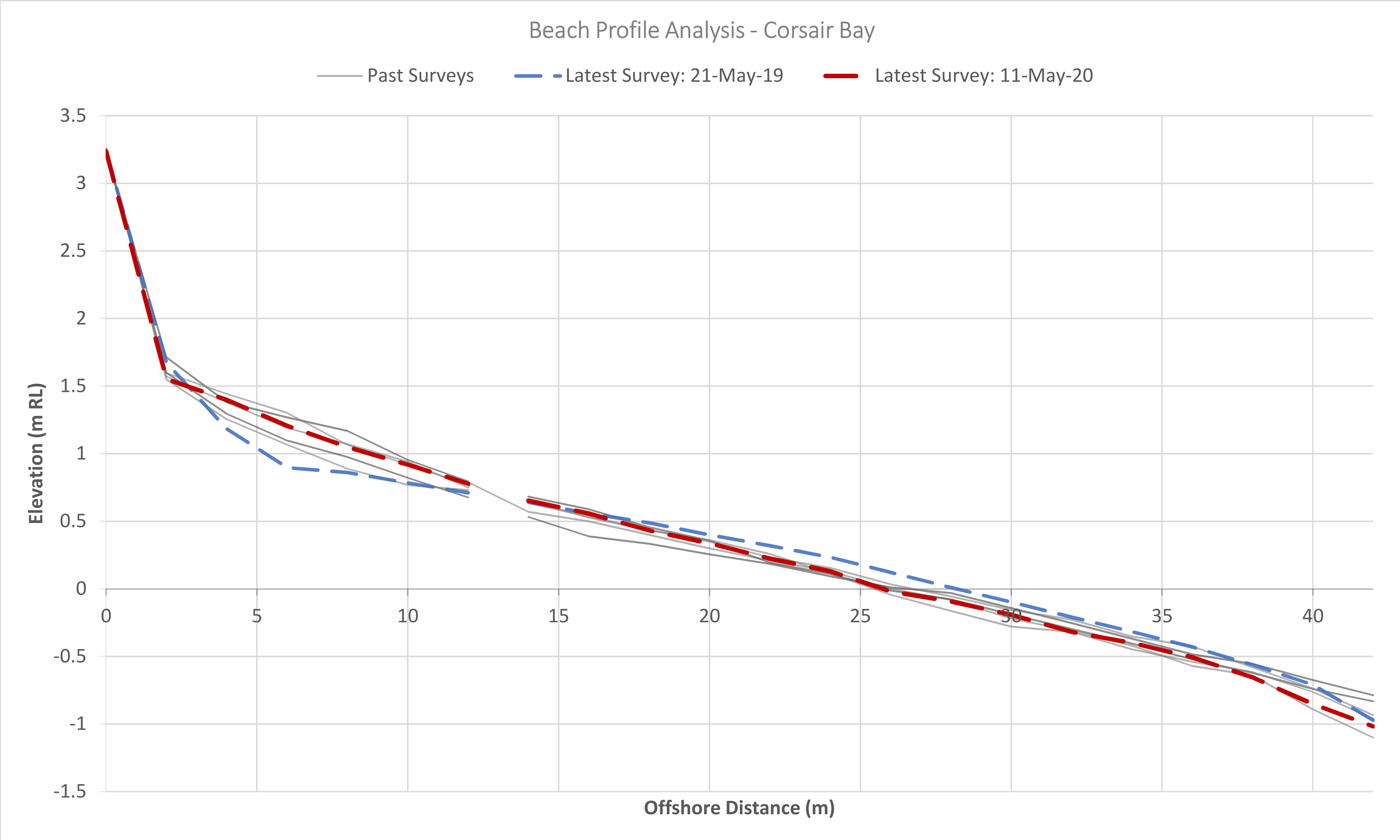
Beach Profile Analysis - Sumner (near Main Rd)
Previous Survey
Previous Survey: 16-Jul-19
Latest Survey: 24-Jan 20
Elevation (m RL)
Offshore Distance (m)
5
4
3
2
1
0
-1
25
50
75
100
125
150
175
200
225
250
275
300
325
350

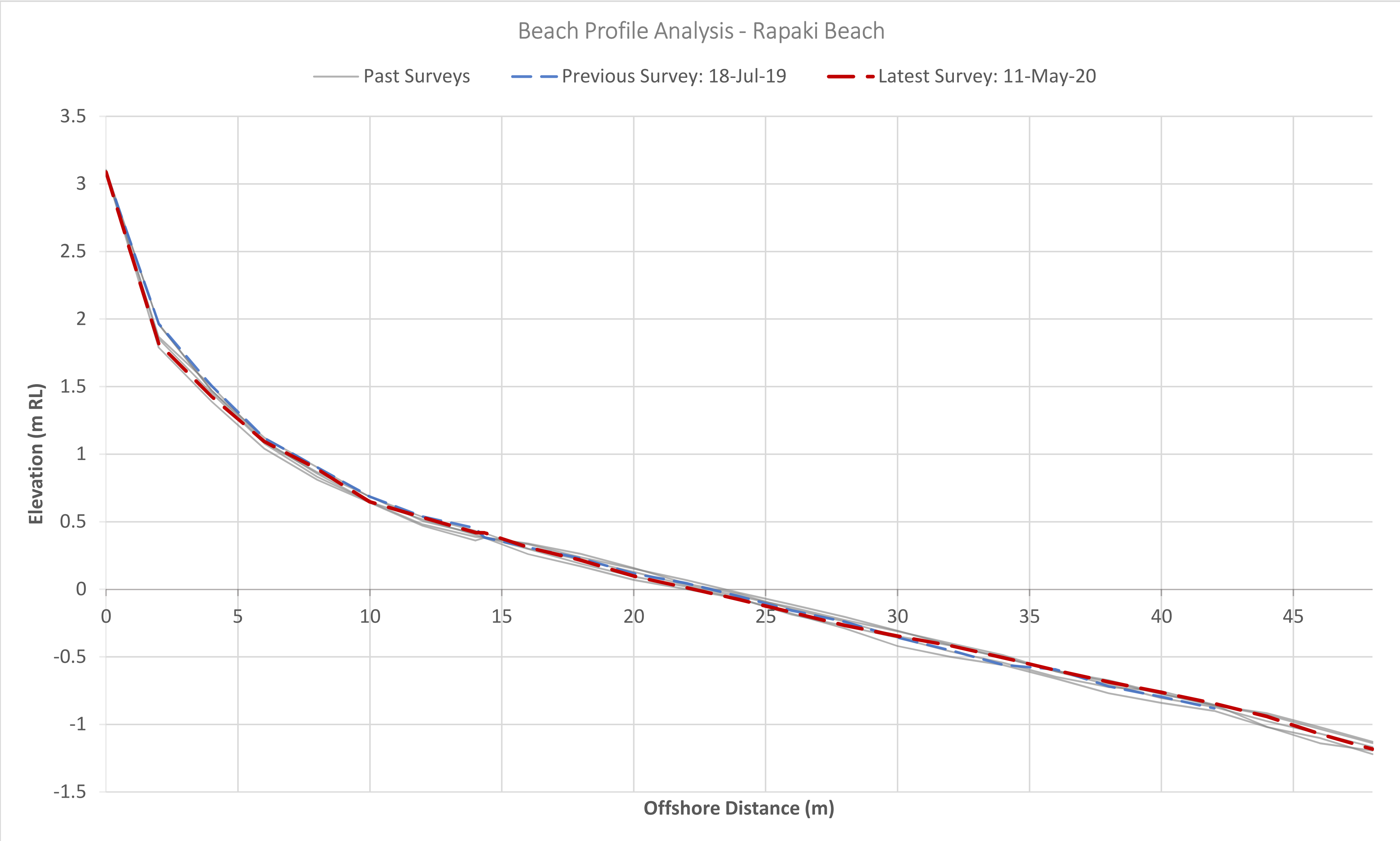


Beach Profile Analysis - Sumner (near Hardwick St)
Past Surveys
Previous Survey: 15-Jul-19
Latest Survey: 23-Jan-20
Elevation (m RL)
6
5
4
3
2
1
0
-1
0
20
40
60
80
100
120
140
160
Offshore Distance (m)

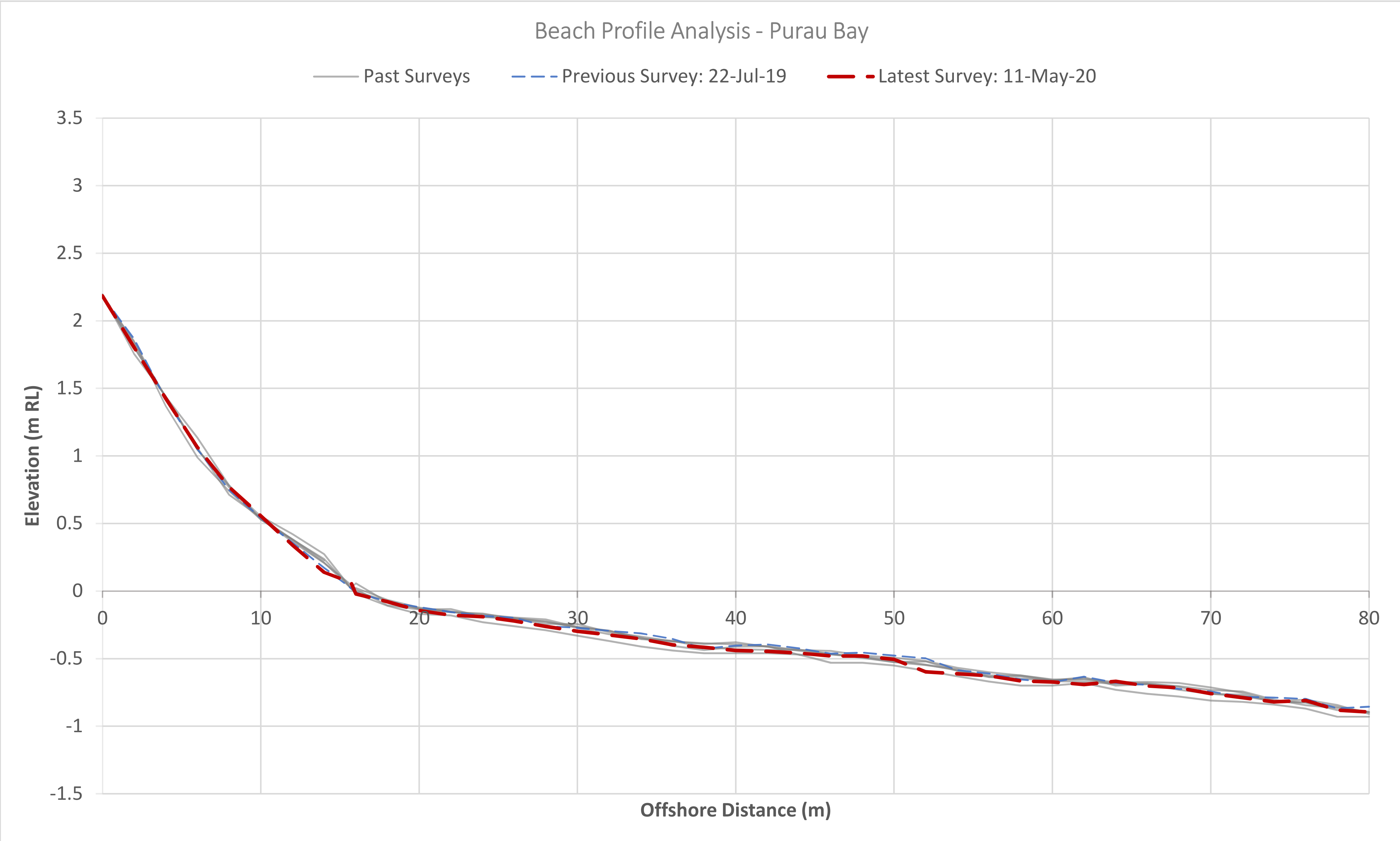


Beach Profile Analysis - Taylors Mistake
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
Elevation (m RL)
85
105
125
145
165
185
Offshore Distance (m)
Past surveys
Previous survey: 15-Jul-19
Latest Survey 23-Jan-20

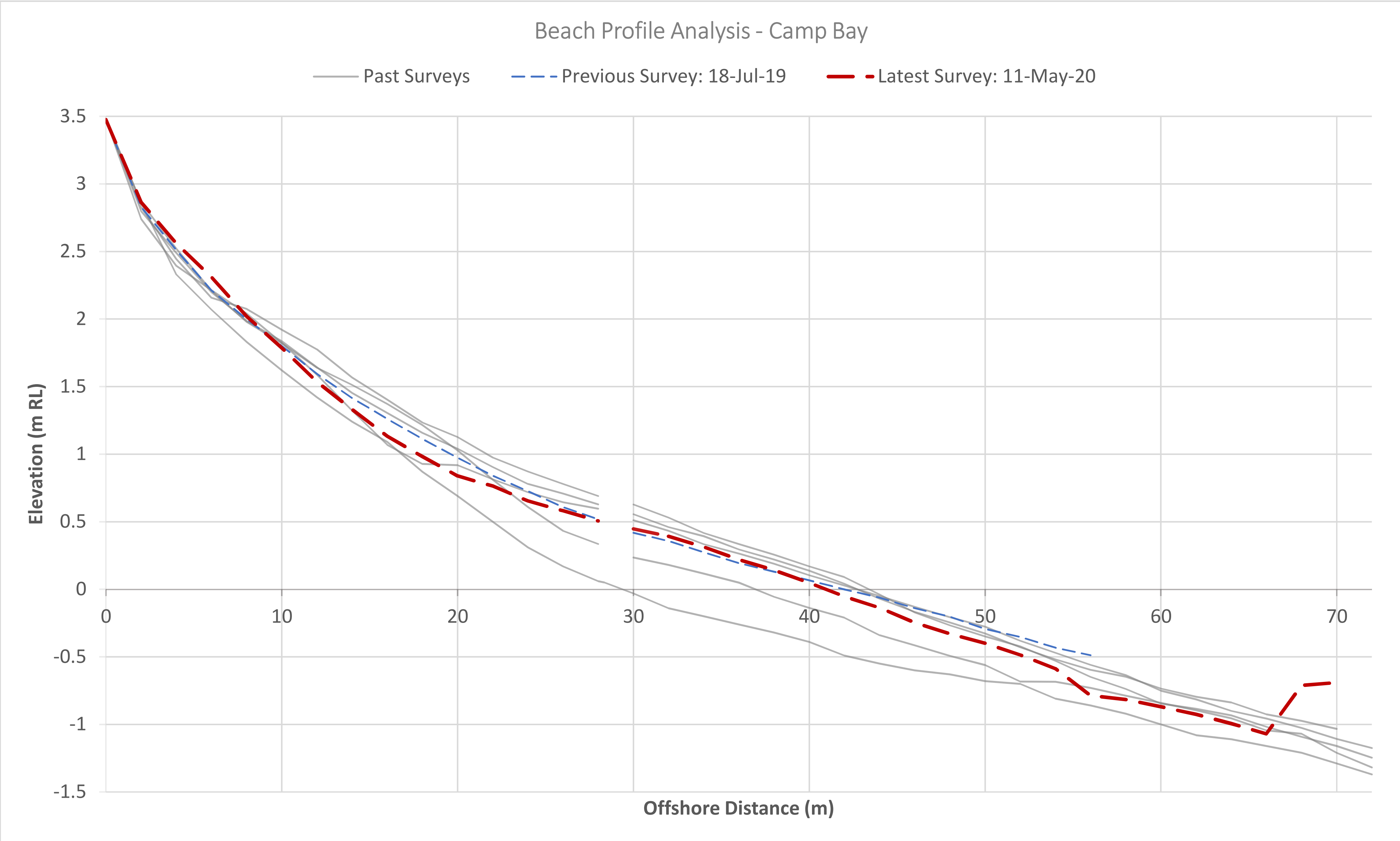

Beach Profile Analysis - Corsair Bay
Past Surveys
Latest Survey: 21-May-19
Latest Survey: 11-May-20
Elevation (m RL)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20
25
30
35
40
Offshore Distance (m)



Beach Profile Analysis - Rapaki Beach
Past Surveys
Previous Survey: 18-Jul-19
Latest Survey: 11-May-20
Elevation (m RL)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
5
10
15
20
25
30
35
40
45
Offshore Distance (m)



Beach Profile Analysis - Purau Bay
Past Surveys
Previous Survey: 22-Jul-19
Latest Survey: 11-May-20
Elevation (m RL)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
10
20
30
40
50
60
70
80
Offshore Distance (m)



Beach Profile Analysis - Camp Bay
Past Surveys
Previous Survey: 18-Jul-19
Latest Survey: 11-May-20
Elevation (m RL)
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
0
10
20
30
40
50
60
70
Offshore Distance (m)