Lyttelton Port Company Channel Deepening Project Environmental Monitoring

Water Quality Environmental Monitoring Services – Monthly Report

December 2019

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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 is continuing. Channel maintenance dredging commenced at midday on 4 December 2019 and is likely to be completed in March 2020.

Monitoring results collected during December 2019 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). KZ filtered data are also included within the Appendix and are compared to compliance trigger values.

Climatic Conditions: During December similar rainfall was recorded at Cashin Quay (25.8 mm) than during November 2019 (24.6 mm), with highest daily rainfall recorded on 18 December (13.6 mm). Flows from the Waimakariri River were elevated during the month with multiple peak flows (> 600 m^3/s) occurring between 3 to 9 and 20 December with peaks ranging from 633 m^3/s to 1218 m^3/s. The moderate to high volume of these freshwater flows is likely to have impacted Lyttelton harbour.

Monthly average air temperature (16.7°C) was similar than that recorded in November (16.1°C). Inshore winds were generally from an easterly to north-easterly direction, with mean daily wind speeds > 15 kts recorded between 17 and 22 December. The highest offshore mean daily wind speeds (> 15 kts) were recorded on 3, 4, 17 and 20 December, with greatest mean daily significant wave height recorded on 3 December (1.97 m).

Currents: Data availability for SG1, SG2a (WatchKeeper) and SG3 was good for December. Maximum near-surface and near-seabed currents at SG1, SG2a and SG3 occurred on different days to each other throughout December. Dominant metocean forces to explain maximum currents were due to corresponding significant wave events (> 1m) from a north-easterly direction in addition to moderate to high inshore and offshore winds from a southerly to westerly direction.

Near-surface predominant current movement for SG1 and SG3 tended to move in an east-southeast and northerly direction, while near-seabed currents moved in a westerly to north-easterly direction. In contrast, near-surface and near-seabed currents at SG2a moved in an east and west direction.

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 December in addition to percentile statistics were lower than those recorded during the baseline monitoring period, except for OS6 which recorded a similar value to baseline turbidity.

Elevated turbidity was recorded at all sites on multiple days in December (10 to 44 NTU), due to moderate to high inshore and offshore winds, significant wave >1m and rainfall. Inshore sites recorded elevated turbidity in the latter half of December when elevated wind speeds occurred. At offshore sites elevated turbidity reflected the high offshore winds and significant wave event on 3 to 4 December, that was not observed at the inshore sites.

Benthic turbidity responded to both wind speed and wave height events in December, with mean benthic turbidity being more elevated than their surface counterparts, as typically observed.

Dredge Compliance Turbidity Trigger Values: During December, there were no exceedances of the Tier 3 intensity values at any site within the monitoring network.

Other Physicochemical Parameters: Mean monthly temperatures were warmer in December than November with all sites displaying a seasonal variation. Consistent with November, warmer temperatures were recorded in the upper and central harbour than the offshore sites. Benthic temperatures were consistent with those at the surface indicating a well-mixed water column.

Consistent with previous reports, surface and benthic pH during December was similar across all sites. Higher flows from the Waimakariri River and localised rainfall appear to have reduced conductivity at most sites from 12 to 14 December. A second reduced conductivity event occurred on 27 December at all sites. These offshore sites may have been affected by delayed impacts from a large acute peak flow of over 1200 m^3/s from the Waimakariri, which had occurred on 3 to 9 December and the second flow of 689 m^3/s on the 20 December.

Dissolved oxygen (DO) concentrations fluctuated at all sites during December, with lower concentrations on the 8 to 9 and 18 to 19 December. These fluctuations were most likely due to increased rainfall and water temperatures stimulating microalgal populations thus increasing photosynthesis and therefore oxygen production. Diurnal fluctuations in DO were observed at most sites for the month of December as typically observed. Benthic DO trended similarly to surface DO throughout December.

Water Sample Analysis and Depth Profiling: Discrete water sampling was conducted in conjunction with vertical profiling of the water column on 12 December 2019, and once again a well-mixed water column was indicated. Increasing conductivity gradients were observed at the nearshore sites contrasting with decreasing DO down through the water column.

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 23 m at OS6. One exceedance was observed within the sub-surface for turbidity (35 NTU) at UH2, possibly due to a passing sediment plume that was recorded on the second depth profile and not on the first suggesting a heterogenous water column. No further exceedances of WQGs were observed for sub-surface during the December sampling.

As commonly observed, total and dissolved reactive phosphorous concentrations were highest at the inshore sites and decreased further offshore. Exceedances of the WQG for dissolved reactive phosphorous was recorded at the inner harbour sites, which is similar to results in November.

Concentrations of total nitrogen and total kjeldahl nitrogen remained below detection limits at all sampling sites, except for UH2 recording a total nitrogen LOR and WQG value of 300 µg/L. In contrast to previous months, ammonia and nitrogen oxide concentrations were < WQG and at a number of sites nitrogen oxides concentrations were <LOR. Chlorophyll *a* concentrations were moderate across all sites with OS1 recording a value (4 µg/L) the same as the WQG. This suggests bioavailable forms of nutrients were being utilised by algal populations.

Several metals were reported as below the limit of reporting (LOR) at all sites as commonly found. No dissolved metal fraction exceeded their designated WQG. Total aluminium concentrations exceeded designated WQG at the majority of the monitoring sites, but the dissolved and therefore readily bioavailable fraction, remained relatively undetectable. Total aluminium, iron and manganese displayed a strong spatial difference with elevated concentrations found in the inshore locations (associated with increased suspended sediments), whereas offshore and spoil ground sites reported the lowest concentrations. Total and dissolved chromium, vanadium and molybdenum were also detected during December, with little spatial variability and a large component contained within the dissolved phase.

All organic compounds measured biannually in and around Lyttelton harbour were once again below laboratory limits of reporting. Except for total hydrocarbons (C10- C36) which recorded low values at OS6 suggesting potential contamination of the sample or the presence of fuel at the site. There is no ANZG water quality guideline for TPH.

Benthic Photosynthetically Active Radiation (BPAR): Levels of ambient sunlight were higher in December than November associated with the increased day lengths. However, mean BPAR at both OS2 and OS3 were lower than November due to low BPAR at the start of December as a result of elevated turbidity. Both sites did record high BPAR peaks > 4000 mmol/m^2/day in the middle and late December, when ambient PAR was reasonably high and water turbidity was low.

Sedimentation: Overall accumulation of sediments at both OS2 and UH3 was evident in December. Periods of high sediment flux was evident at OS2 during periods of strong winds, elevated wave heights and therefore high turbidity, leading to an overall accumulation of 29 mm of sediment over the month. Sediment flux at UH3 was more stable as typically observed with a period of accretion at the start of December and a brief period of minor erosion and higher sediment flux occurring mid-December. This resulted in an overall accumulation of 16 mm of sediments at this location.

Table of Contents

List of Tables

List of Figures

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. Maintenance dredging of the channel commenced on 4 December 2019 and is expected to be completed in 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.

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.

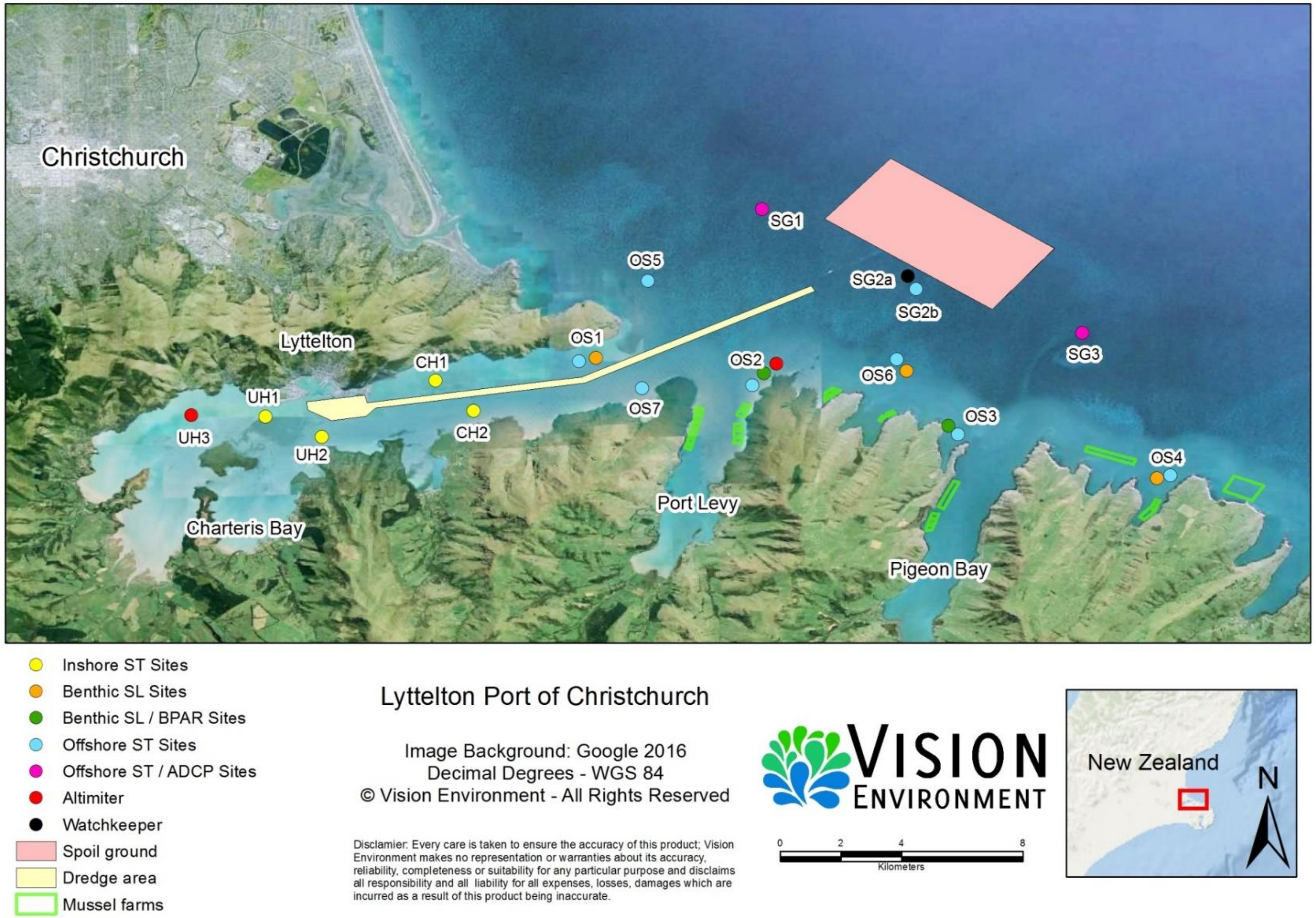


Figure 1 Monitoring locations for the LPC Channel Deepening Project, displaying sites within each location.
ST = subsurface telemetry, SL = self-logger, BPAR = benthic photosynthetically active radiation, ADCP = Acoustic Doppler Current Profiler

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 December 2019 during dredge operations. Monthly water sampling and depth profiling was conducted on 12 December 2019. 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 25.8 mm of rainfall was recorded at Cashin Quay during December 2019, which was similar to the precipitation recorded in November (24.6 mm). Highest rainfall (13.6 mm) was recorded on 18 December, preceded by 8.8 mm on 17 December (Metconnect, 2019) (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 December ranged between 81 m^3/s and 1218 m^3/s with peaks >600 m^3/s recorded on the 3 December (1218 m^3/s), 5 December (934 m^3/s), 8 December (700 m^3/s), 9 December (633 m^3/s) and the 20 December (689 m^3/s) (ECAN, 2019). These higher flows recorded in addition to localised rainfall appeared to have reduced specific conductivity in mid and late December.

Inshore winds during December were generally from an easterly to north-easterly direction (Metconnect, 2019). Highest mean winds speeds (22.7 kts) were recorded on 18 December from a west-south-westerly direction, with maximum wind gusts of 44 kts also occurring from the west-south-westerly direction. Daily mean wind speeds > 15 kts were also recorded on the 17 and 20 December from west-south-westerly direction (16.8 and 17.9 kts respectively) and 16.7 kts recorded on the 22 December from the east-north-easterly direction.

Daily mean air temperatures at Cashin Quay ranged from 13°C to 22°C, resulting in a monthly mean temperature of 16.7°C, somewhat similar to the November mean temperature of 16.1°C (Metconnect, 2019).

Offshore significant wave height peaked at 2.79 m at 1:00 pm on 3 December, leading to a mean daily significant wave height of 1.97 m (Figure 3). Highest mean daily offshore wind speeds 16.7 kts were also recorded on the 3 December and the daily mean offshore wind direction was from a southerly direction, although offshore winds during December were were recorded at 29% from a north-easterly direction (Figure 32). Other significant mean daily offshore wind speeds > 15 kts were recorded on 4, 17 and 20 December from a southerly to south-westerly direction (Figure 3).

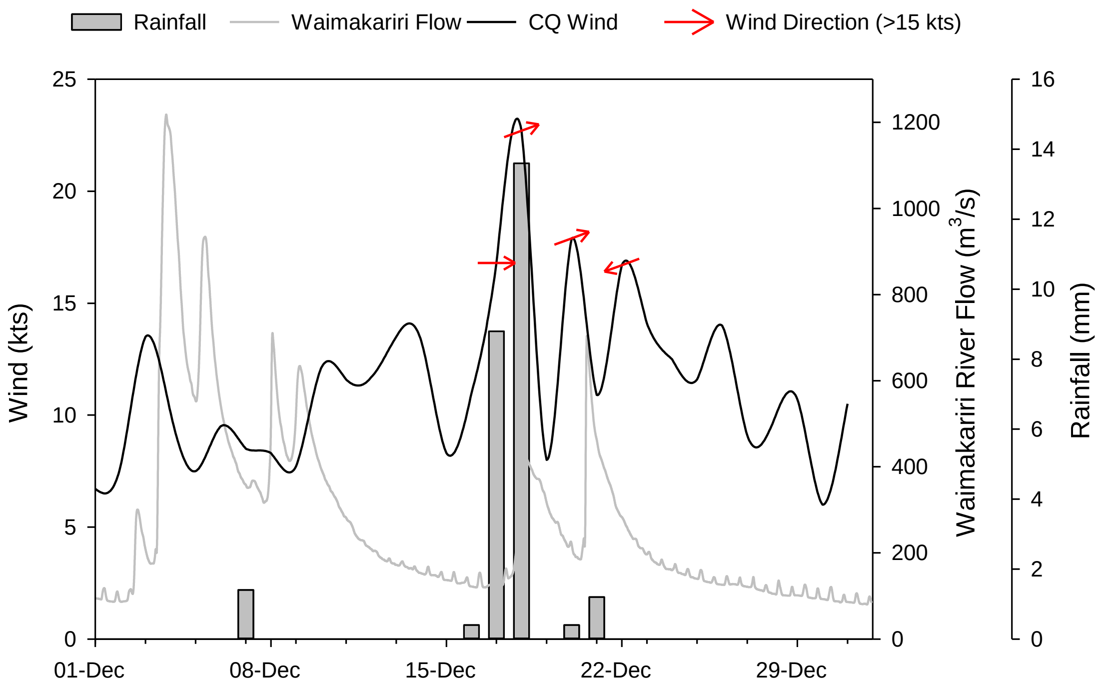


Figure 2 Inshore metocean conditions including wind speed and direction, rainfall measured at Cashin Quay, and Waimakariri River flow at the Old Harbour Bridge station, during December 2019.
Note: Arrows indicate the direction of travel for inshore winds greater than 15 knots.

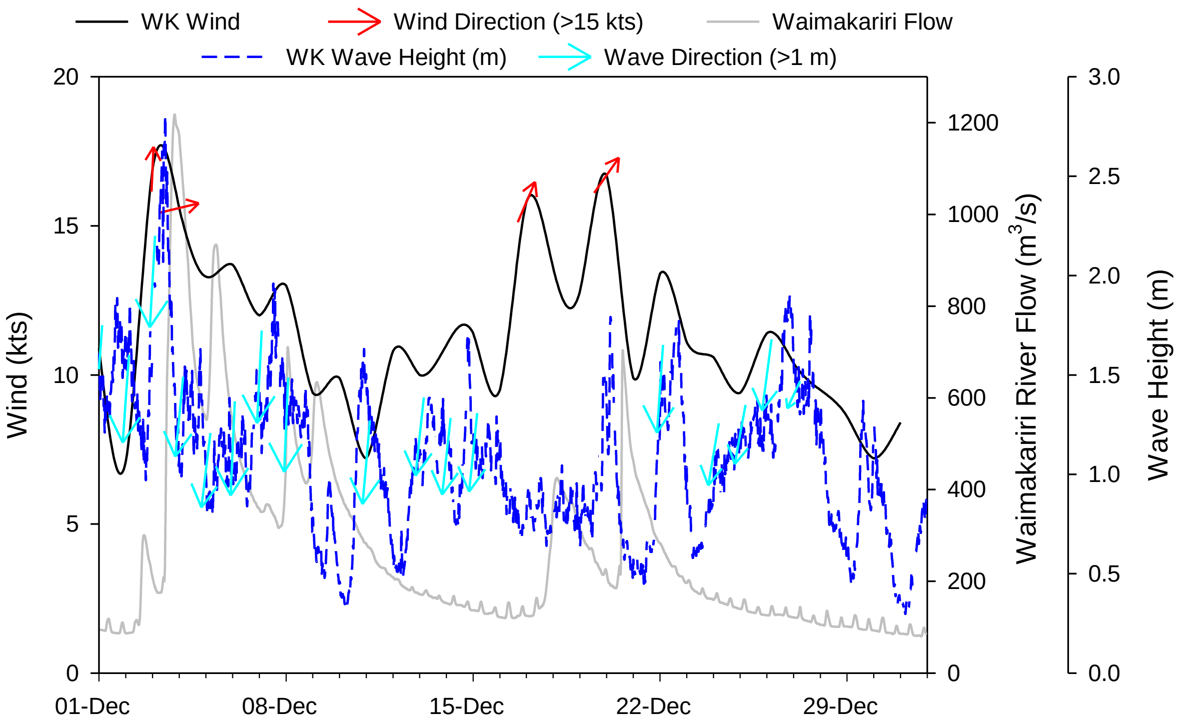


Figure 3 Offshore metocean conditions including wind speed and direction, significant wave height and daily averaged wave direction as measured by the WatchKeeper Buoy at site SG2a, and Waimakariri River flow at the Old Harbour Bridge station, during December 2019.
Note: Arrows indicate the direction 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 33 to 38 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 December 2019.

Parameter	Depth	Site		
		SG1	**SG2a**	**SG3**
Minimum current speed (mm/s)	*Near-surface*	2	1	2
	Near-seabed	4	2	3
Maximum current speed (mm/s)	*Near-surface*	502	303	601
	Near-seabed	356	360	528
Mean current speed (mm/s)	*Near-surface*	127	68	153
	Near-seabed	112	104	136
Standard deviation of current speed (mm/s)	*Near-surface*	75	51	97
	Near-seabed	57	56	73
Current speed, 95th percentile (mm/s)	*Near-surface*	268	173	339
	Near-seabed	217	207	273

Maximum near-surface current speeds at SG1 (502 mm/s), SG2a (303 mm/s) and SG3 (601 mm/s) were recorded on the respective days 17, 19 and 4 December during periods of high offshore winds from a southerly to westerly direction and significant wave heights >1 m on 4 and 19 December from easterly direction.

Maximum near-seabed current speeds at SG1 (356 mm/s), SG2a (360 mm/s) and SG3 (528 mm/s) were recorded on the different days to near-surface current speeds with maximums recorded on 27, 15, and 26 December respectively. Daily offshore wind speeds were moderate 11.4 kts from a north-easterly or south-south-westerly direction with maximum significant wave heights >1 m possibly explaining the increased near-seabed currents on these dates.

The time-series plots (Figures 33 to 38 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.

In contrast to previous months, currents at SG1 near-surface during December tended to move in an east-southeast (40.4%) and northerly (32.8%) direction, while the near sea-bed currents moved in a west-northwesterly (36.1%) and south-southeasterly (31.0%) direction. SG3 was similar to previous months with near-surface current moving in an east-southeast (20.1%) and west-northwest (23.4%) direction, and near-seabed currents moving in a west-northwest (35.5%) and east-southeast (34.5%) direction.

Current movements at SG2a were found to be in a more east/west direction, similar to previous months. Near-surface currents moved in an east-northeast (44.7%) and west-northwest (23.5%) direction, while near-seabed currents moved in a west-northwest (33.0%) and east-southeast (31.7%) direction.

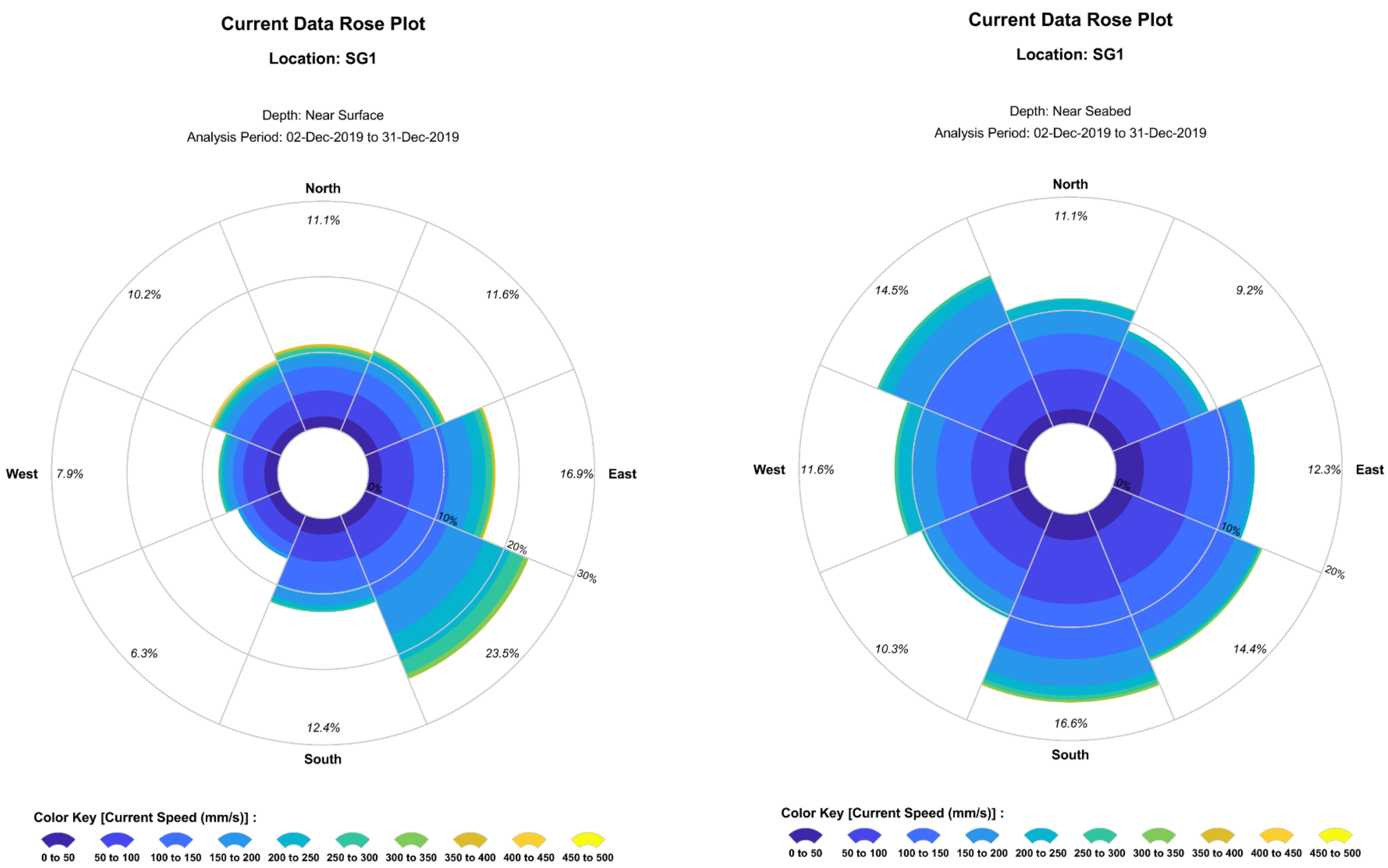
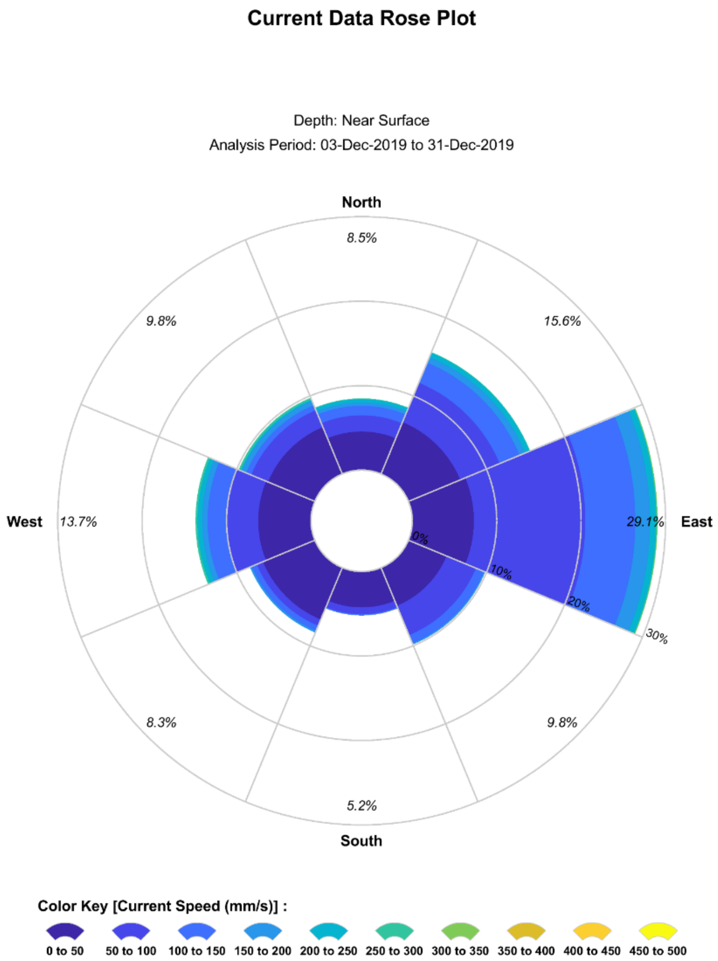


Figure 4 Near-surface and near-seabed current speed and direction at SG1 during December 2019.
Speed intervals of 50 mm/s are used.



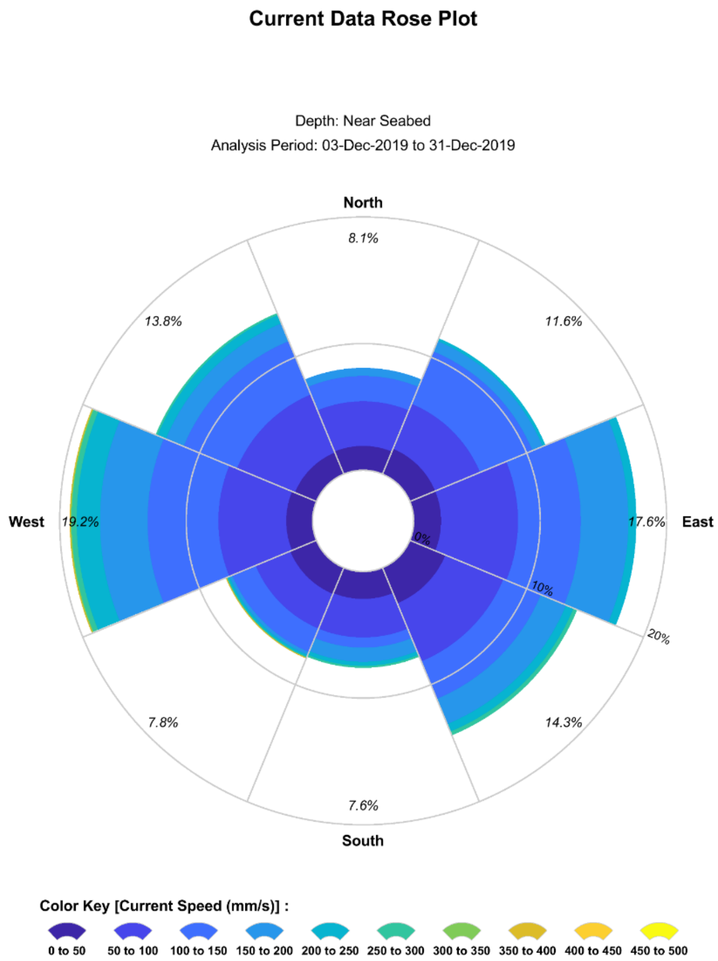


Figure 5 Near-surface and near-seabed current speed and direction at SG2a (Watchkeeper) during December 2019. *Speed intervals of 50 mm/s are used.*

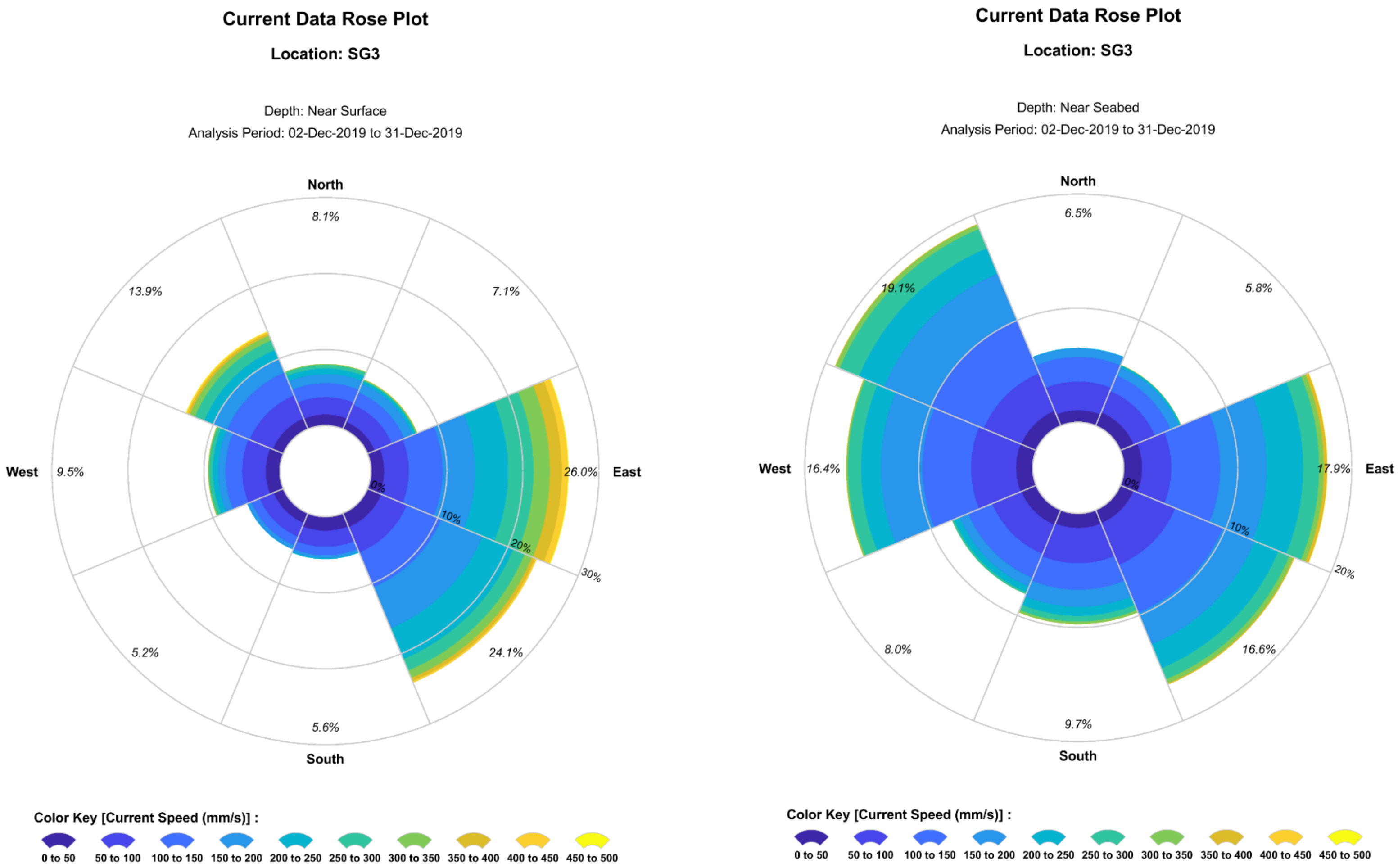


Figure 6 Near-surface and near-seabed current speed and direction at SG3 during December 2019. *Speed intervals of 50 mm/s are used.*

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 12 December 2019. 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 December 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

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 December 2019 dredge monitoring data. Summary statistics for KZ filtered turbidity data, used for real time compliance monitoring during dredge operations, are also presented in Tables 23 to 25 in the Appendix. Similarly, plots of KZ filtered turbidity data with site specific trigger values are also presented within Figures 39 to 42 in the Appendix.

December Turbidity:

Consistent with previous monitoring months, mean surface turbidity values were typically highest (monthly means of 4.2 to 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 (1.6 to 2.1 NTU), which are likely due to the deeper water column limiting expressions of seafloor sediment resuspension at the sub-surface. As typically observed, nearshore sites experienced intermediate mean turbidity values (2.8 to 4.8 NTU) during December (Table 5).

During December turbidity across the inner harbour was relatively low (< 10 NTU) with exception of short lived turbidity peaks of 34.8 NTU on 11 December at UH1 and 44.4 NTU on 18 December at UH2 in response to moderate to high inshore winds (10 to 23 kts) and higher rainfall (Figure 8).

Surface turbidity at the nearshore sites (OS1 to 4 and OS7) produced peaks ~15NTU on 3 to 4 December in correlation to high offshore winds from the westerly direction and significant waves > 1m at OS3, OS4 and OS7. All sites produced other short-lived peaks <15 NTU throughout December in relation to offshore winds and significant waves.

Further offshore at OS5, OS6 and the spoil ground sites, turbidity peaks were evident on 3 to 4 and 20 December at OS5 and OS6 due to high offshore winds and significant waves. Turbidity at the spoil ground sites was less pronounced than at the inshore sites (Figures 11 and 12). This is likely due to greater depths at these sites, with less movement of benthic sediments during periods of higher wind speeds and wave heights.

Benthic:

Data return was gained for all benthic sites during December. Benthic turbidity data corresponded with surface measurements, with increased turbidity evident during early and mid to late December, during periods of high winds and waves (Figure 6).

Table 3 Mean turbidity and statistics at inshore water quality logger sites during December 2019 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 2885 to 2975) Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
UH1	Mean ± se	8.4 ± 0.1	12
	Range	3.5 – 35	-
	99th	20.7	39
	95th	14.7	22
	80th	10.5	15
UH2	Mean ± se	9.0 ± 0.1	10
	Range	<1 – 44.4	-
	99th	21.9	32
	95th	16.2	20
	80th	11.4	13
CH1	Mean ± se	5.6 ± 0.0	9
	Range	2 – 15.1	-
	99th	11.6	29
	95th	9.3	18
	80th	7.4	12
CH2	Mean ± se	4.2 ± 0.0	8
	Range	1.5 – 12.8	-
	99th	10.0	24
	95th	7.3	16
	80th	5.5	10

Table 4 Mean turbidity and statistics at spoil ground water quality logger sites during December 2019 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 2868 to 2947). Baseline values modified from Fox 2018.

Site	Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
SG1	Mean ± se	1.6 ± 0.0	4.2
	Range	<1 – 7.8	-
	99th	5.7	14
	95th	4.6	10
	80th	2.6	6.2
SG2	Mean ± se	2.1 ± 0.0	4.6
	Range	<1 – 7.4	-
	99th	4.9	20
	95th	3.5	11
	80th	2.6	7.0
SG3	Mean ± se	1.8 ± 0.0	3.6
	Range	<1 – 15.5	-
	99th	5.4	13
	95th	3.8	7.7
	80th	2.6	4.8

Table 5 Mean turbidity and statistics at offshore water quality logger sites during December 2019 and Baseline period (1 November 2016 to 31 October 2017).
Values for December are means ± se, range and percentiles (n = 1910 to 2976). Baseline values modified from Fox 2018.

Site	Statistic	Turbidity (NTU)		
		Surface December	Surface Baseline	Benthic December
OS1	Mean ± se	3.5 ± 0.0	7.5	46.5 ± 0.6
	Range	<1 – 15.6	-	7.6 – 172
	99th	9.2	24	128.8
	95th	7.0	16	104.4
	80th	4.8	10	67.5
OS2	Mean ± se	3.7 ± 0.0	6.4	41.8 ± 0.7
	Range	<1 – 15.9	-	6.1 – 968
	99th	11.3	18	135.1
	95th	7.4	13	96.4
	80th	5.0	9.0	62
OS3	Mean ± se	4.1 ± 0.1	6.6	26 ± 0.3
	Range	<1 – 27.9	-	<1 – 175.5
	99th	16.8	27	90.5
	95th	10.0	15	63.2
	80th	5.9	8.9	37.3
OS4	Mean ± se	3.9 ± 0.0	5.9	32.8 ± 0.5
	Range	<1 – 15.7	-	1.4 – 167.9
	99th	11.9	20	113.5
	95th	8.9	13	86.1
	80th	5.5	8.3	50.7
OS5	Mean ± se	2.8 ± 0.0	4.6	–
	Range	<1 – 16.5	-	–
	99th	11.3	19	–
	95th	7.2	11	–
	80th	4.1	6.4	–
OS6	Mean ± se	4.8 ± 0.0	4.7	42.8 ± 0.5
	Range	<1 – 14.2	-	3 – 155.4
	99th	11.6	19	120.1
	95th	9.6	12	89.9
	80th	7.1	7.2	59
OS7	Mean ± se	4.7 ± 0.1	6.4	–
	Range	<1 – 17.6	-	–
	99th	13.4	23	–
	95th	9.7	14	–
	80th	6.7	9.2	–

Comparison to Baseline:

Mean surface turbidity values during December were lower than the values calculated from the baseline monitoring period (Tables 3 to 5, Figures 7 to 12). The exception was OS6 with a December mean of 4.8 NTU which was slightly above the baseline value. However, December percentiles were lower than baseline percentiles. Fouling at OS6 may have contributed to higher values due to validation of data being problematic due to both sondes being fouled and inclement weather preventing cleaning.

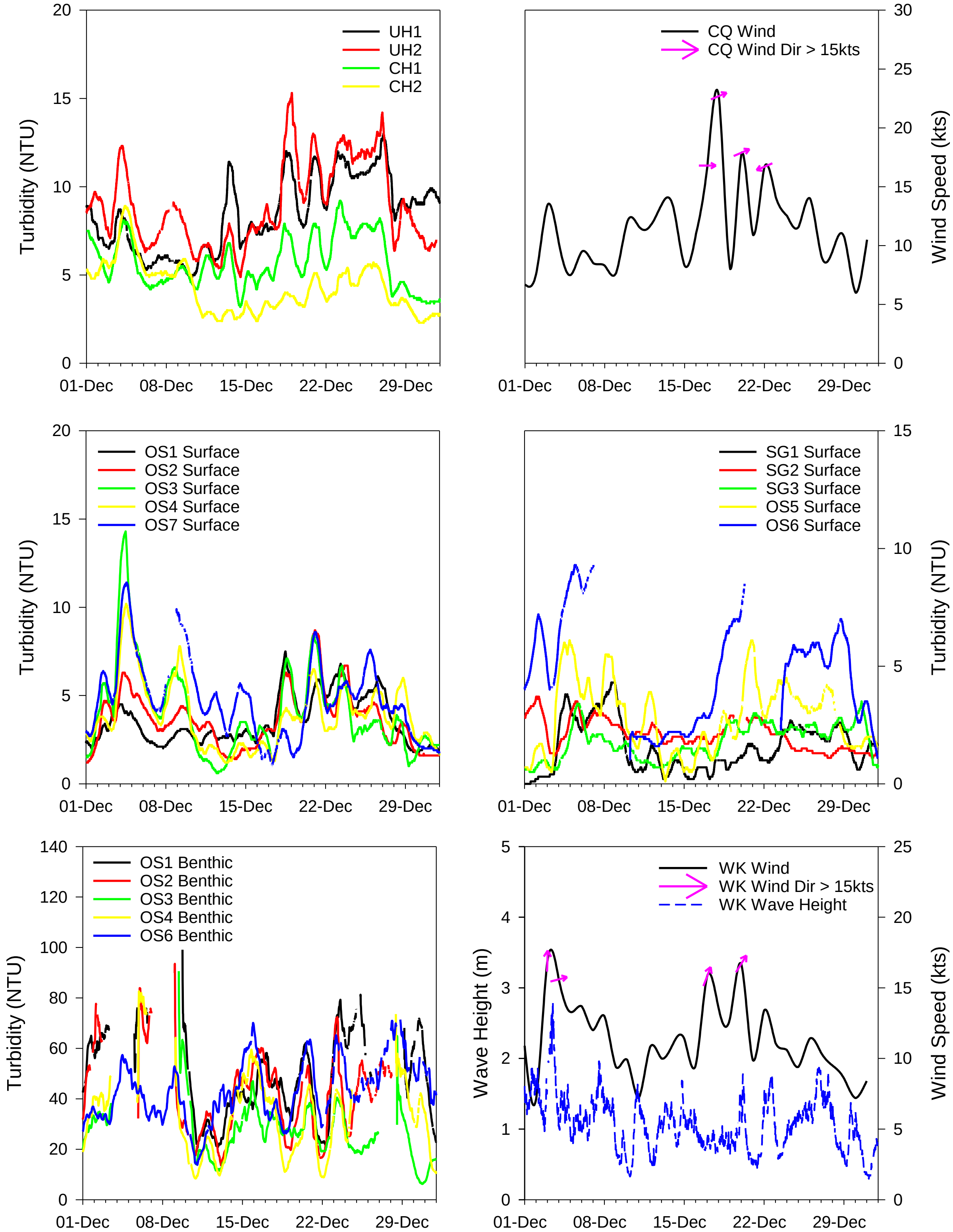


Figure 7 24 hour rolling average turbidity and metocean data for inshore, nearshore, offshore and benthic monitoring stations during December 2019.
Note differing scales between plots. Arrows indicate the direction of travel for inshore/offshore winds greater than 15 knots.

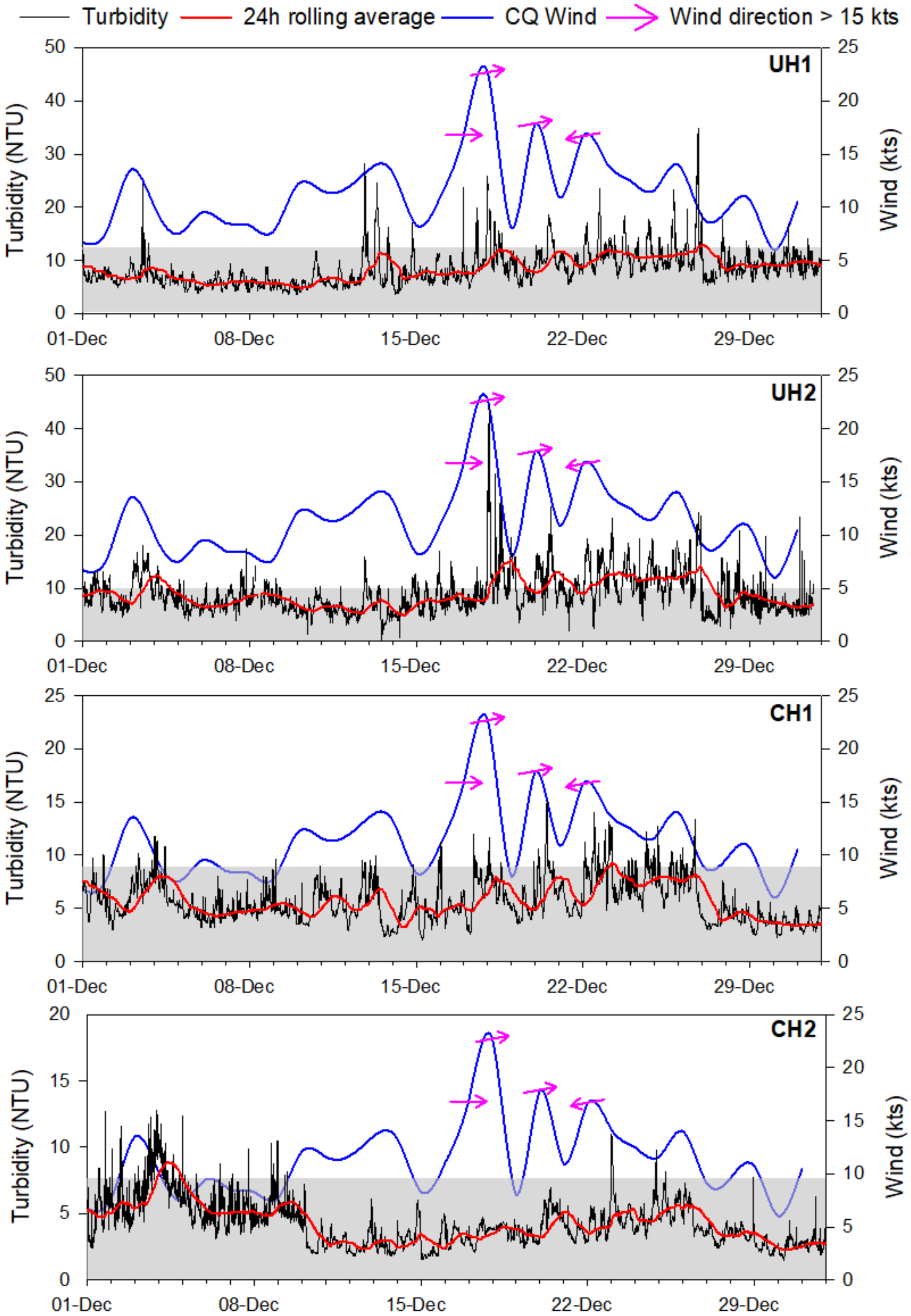


Figure 8 Surface turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during December 2019.
Arrows indicate the direction of travel for inshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

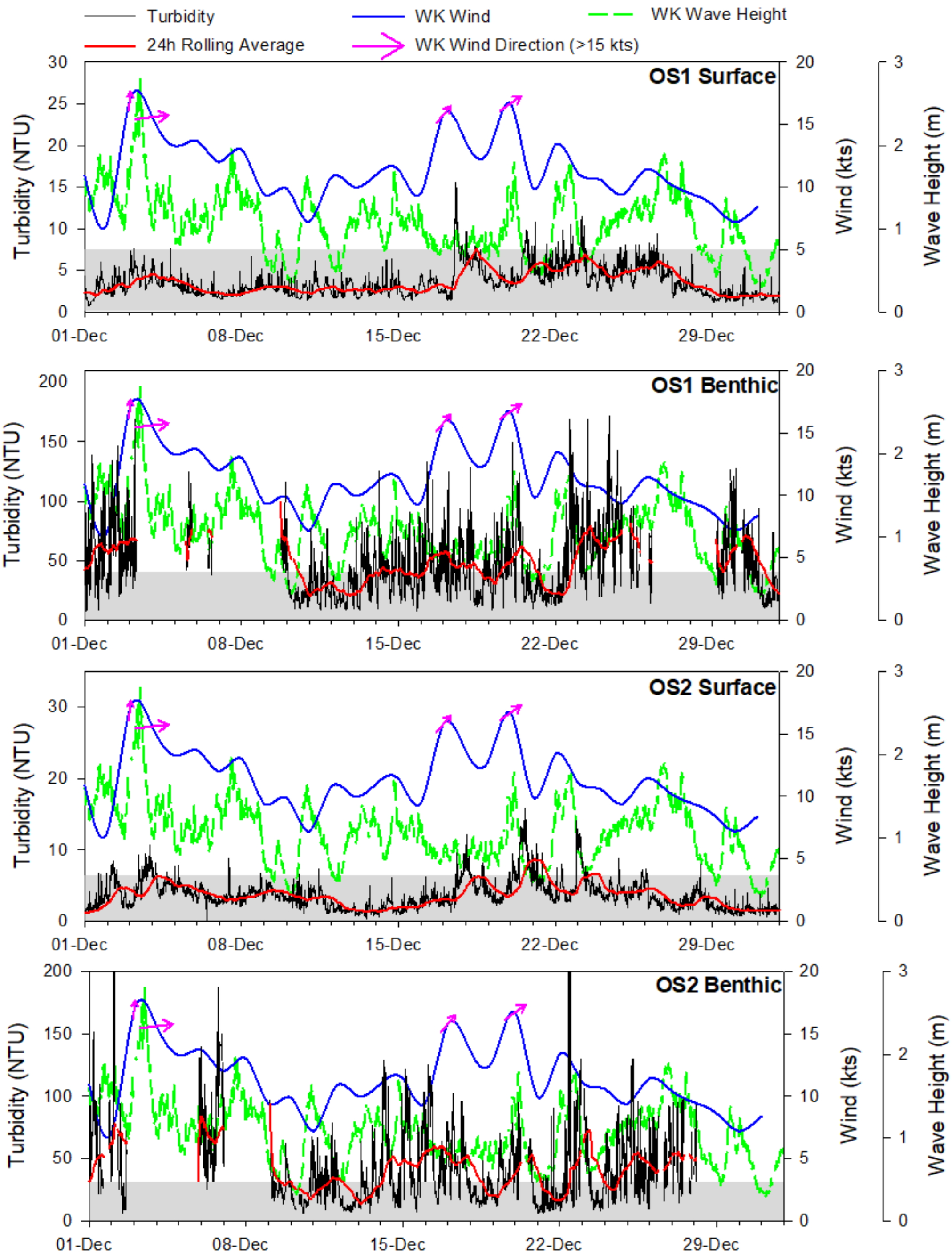


Figure 9 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS1 and OS2) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity

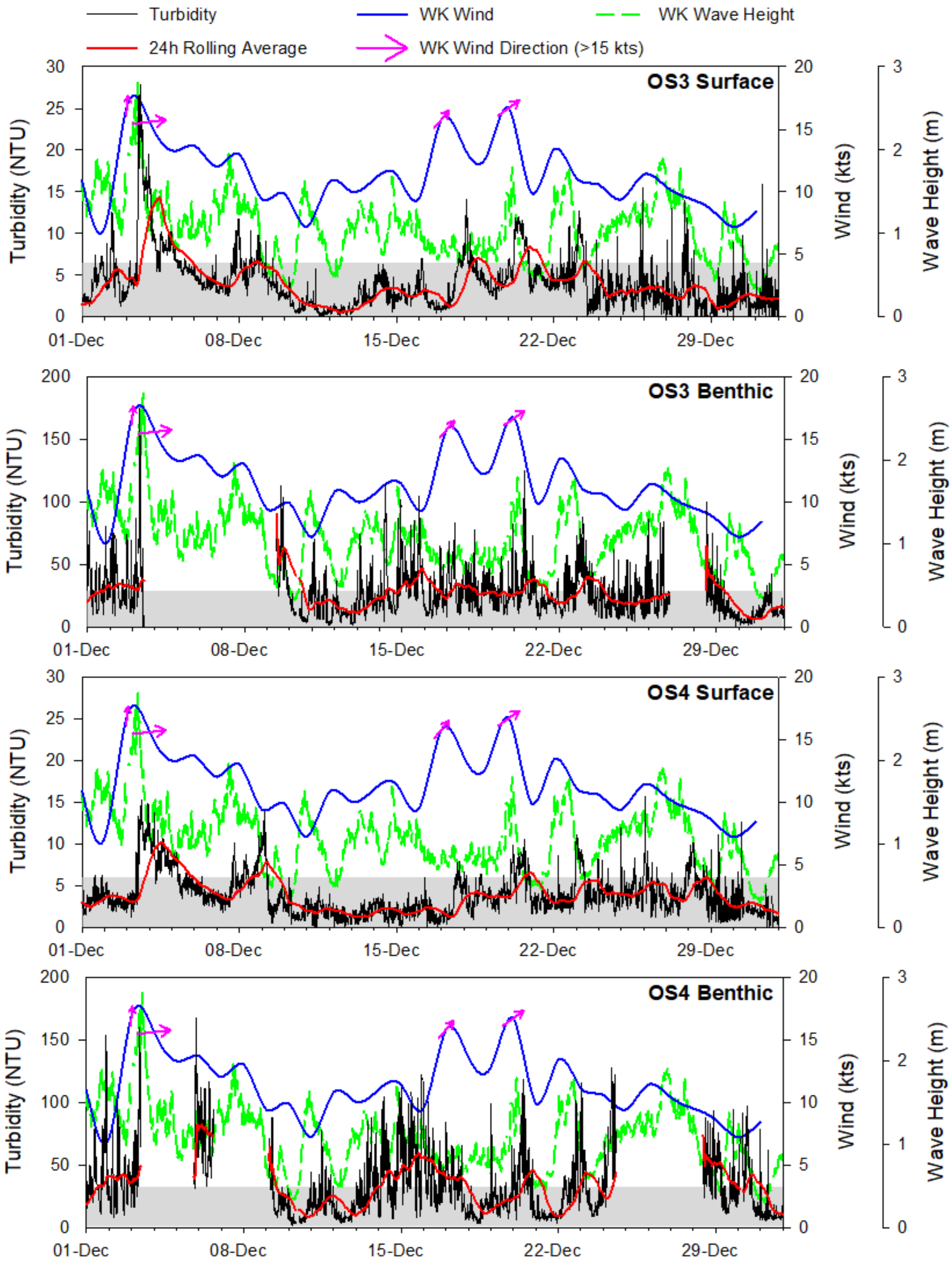


Figure 10 Surface and benthic turbidity and daily averaged winds at nearshore sites (OS3 and OS4) during December 2019.

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.

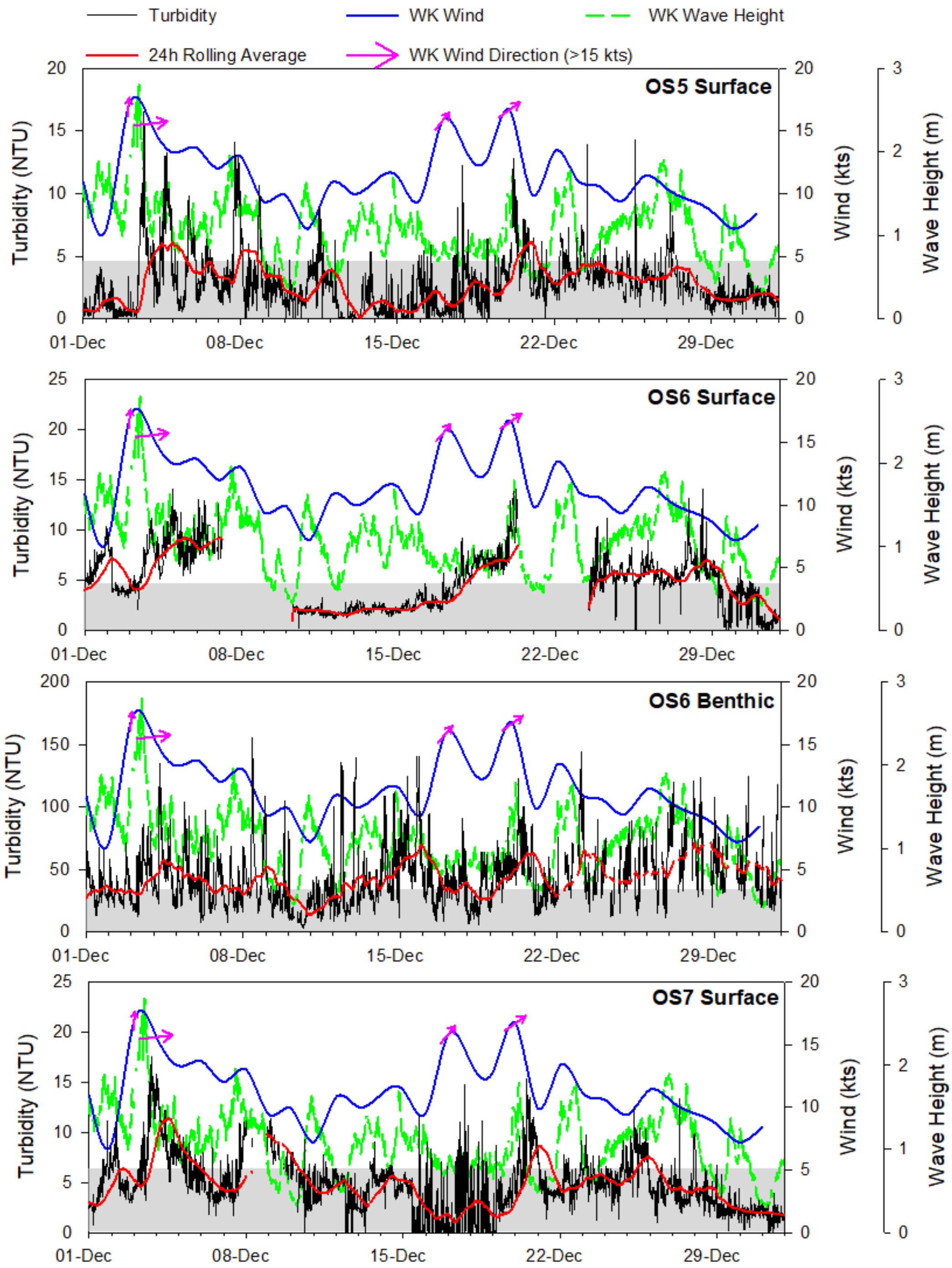


Figure 11 Surface and benthic turbidity and daily averaged winds at nearshore and offshore sites (OS5, OS6 and OS7) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.

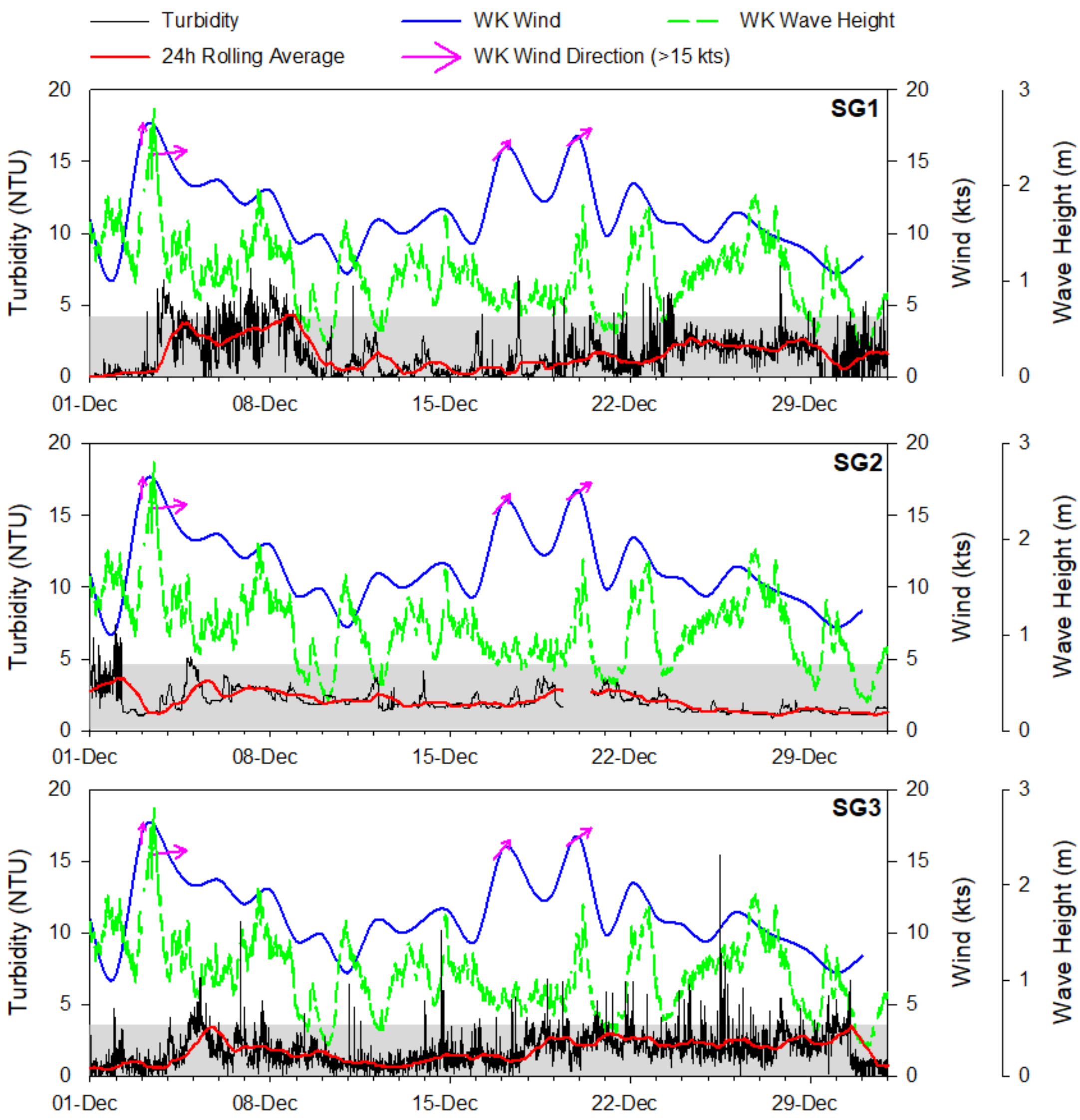


Figure 12 Surface turbidity at spoil ground sites (SG1, SG2b and SG3) during December 2019. *Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Grey shading indicates the baseline mean turbidity.*

3.2.2 Dredge Compliance Trigger Values

Management of dredge operations was guided using three tier levels of turbidity trigger values based on the higher order percentiles of baseline data (refer Section 2.1.2). Tier 1 (80th percentile) and Tier 2 (95th percentile) intensity values are designated for LPC internal use and provide early warning mechanisms for elevated turbidity conditions. A compliance alert is 'tripped' if:

1) The current KZ smoothed turbidity reading is above the relevant Tier 3 (99th percentile) intensity level; **and**
2) The cumulative time of exceedances defined in 1) during the current 30-day rolling window exceeds the allowable hours given.

The Tier 1 to 3 intensity levels for KZ smoothed data and allowable hours calculated for the project (Fox, 2018), are outlined in Table 6.

Table 6 Site turbidity intensity values and allowable hours of exceedance in rolling 30-day period. *Allowable hours for Tiers 1 and 2 are indicative only and non-binding as these are for internal LPC use only.*

Site	Tier 1	Tier 2	Tier 3
UH1	15.1	21.7	42.9
UH2	13.0	19.6	30.2
CH1	11.6	17.6	28.1
CH2	10.4	15.2	22.7
OS1	9.9	15.1	23.4
OS2	8.9	12.4	17.3
OS3	8.9	14.2	30.6
OS4	Reference site		
OS5	6.2	11.2	18.3
OS6	7.3	11.5	18.8
OS7	9.2	14.2	22.7
SG1	6.3	9.6	13.9
SG2	6.9	10.6	20.1
SG3	4.7	7.4	13.1
Allowable hours	144	36	7.2

3.2.2.1 P99 Exceedance Counts

During December the Tier 3 intensity values were not exceeded at any site within the monitoring network (Table 7, Figures 12 to 14).

Table 7 Tier 3 intensity value exceedances and maximum hour counts during December 2019.

Site	P99 Count >7.2 Hours Start Time	P99 Count >7.2 Hours End Time	Maximum P99 Count (Hours)
UH1	-	-	0.00
UH2	–	–	0.00
CH1	–	–	0.00
CH2	–	–	0.00
OS1	–	–	0.00
OS2	–	–	0.00
OS3	–	–	0.00
OS4	Reference site		
OS5	–	–	0.00
OS6	–	–	0.00
OS7	–	–	0.00
SG1	–	–	0.00
SG2	–	–	0.00
SG3	–	–	0.00

3.2.2.2 P99 Exceedance Counts Consented Removal

No validated P99 exceedance counts were removed during December 2019 (Table 8).

Table 8 Hour counts removed from monitoring statistics during December 2019.

Site	Start Time (NZST)	End Time (NZST)
–	–	–

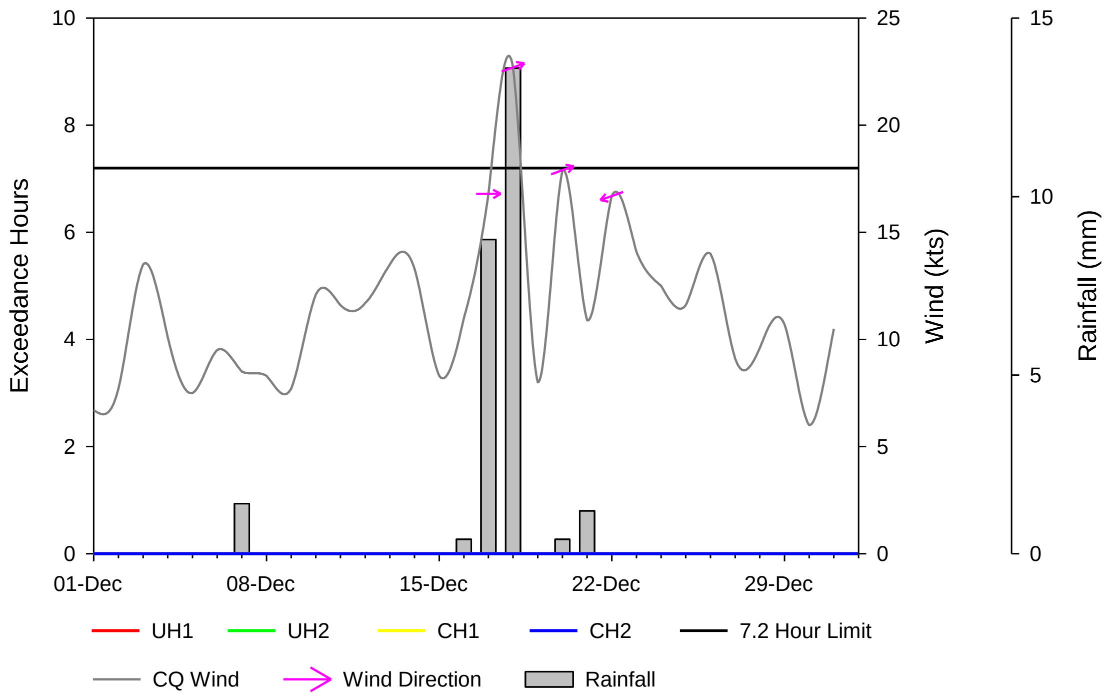


Figure 13 Tier 3 allowable hour counts at UH1, UH2, CH1 and CH2 after exceedance of the intensity values during December 2019.

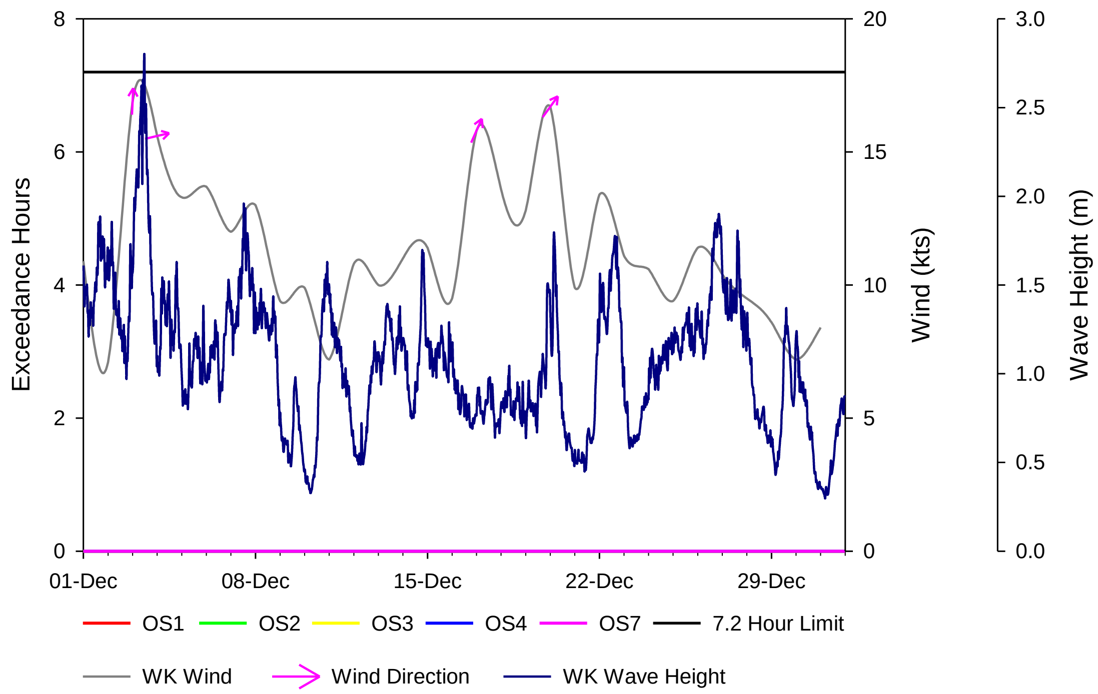


Figure 14 Tier 3 allowable hour counts at OS1-OS3, and OS7 after exceedance of the intensity values during December 2019.
Note there is no trigger value for the reference site OS4.

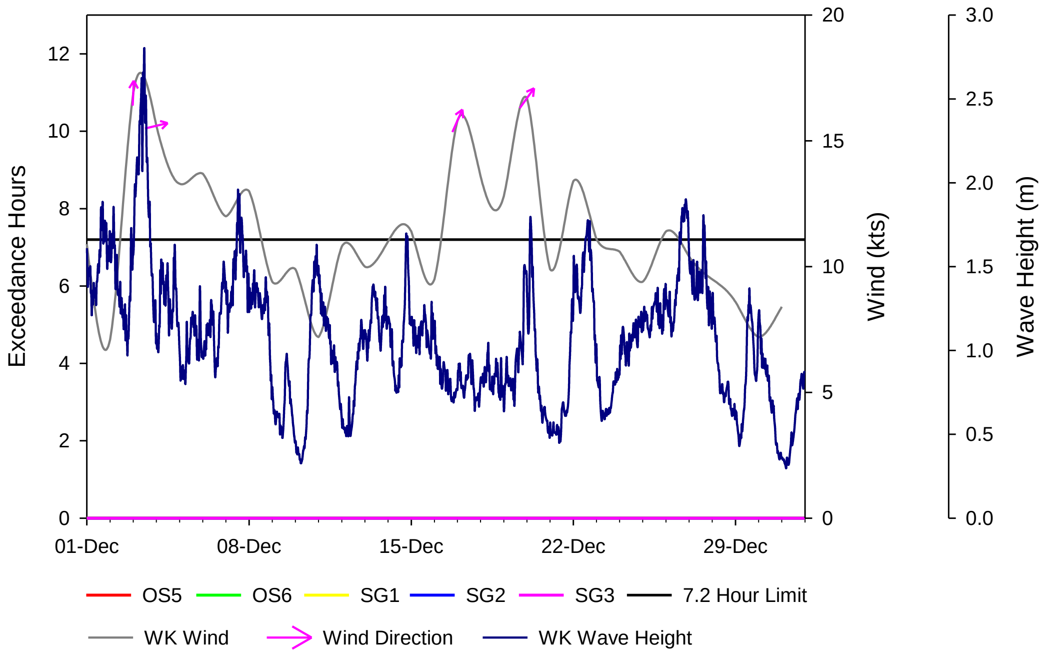


Figure 15 Tier 3 allowable hour counts at OS5, OS6, SG1, SG2b and SG3 after exceedance of the intensity values during December 2019.

3.2.3 Temperature

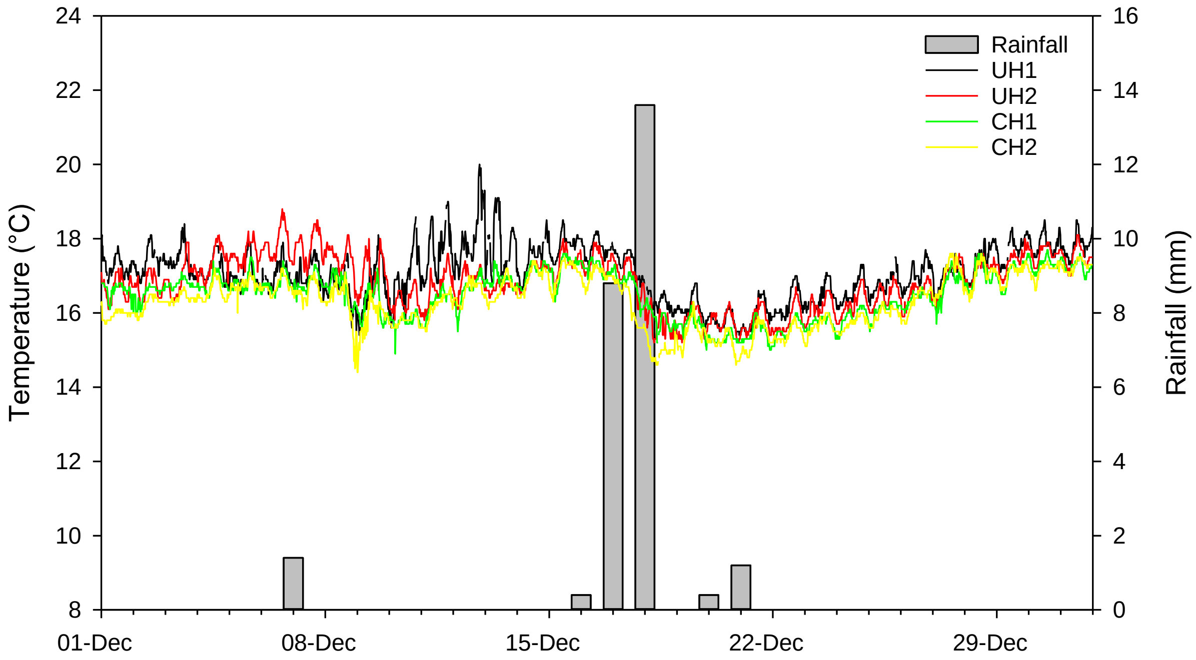
Mean monthly sea surface temperatures during December (15.1 to 17.1 °C) were warmer than those experienced during November (14.1 to 15.8°C) indicating the continuation of seasonal warming noted in previous months (Table 9). The temperature trend for December was an overall increase at all sites, with lower temperatures on 8 and 18 December following periods of rainfall, high river flow and lower air temperatures (Figures 16 and 17).

Table 9 Mean temperature at inshore, spoil ground and offshore water quality sites during December 2019.
Values are means ± se (n = 2869 to 2976).

Site	Temperature (°C)	
	Surface loggers	Benthic loggers
UH1	17.1 ± 0.0	–
UH2	16.8 ± 0.0	–
CH1	16.5 ± 0.0	–
CH2	16.3 ± 0.0	–
SG1	15.4 ± 0.0	–
SG2	15.4 ± 0.0	–
SG3	15.2 ± 0.0	–
OS1	16.0 ± 0.0	14.8 ± 0.0
OS2	15.6 ± 0.0	14.3 ± 0.0
OS3	15.3 ± 0.0	14.1 ± 0.0
OS4	15.1 ± 0.0	14.0 ± 0.0
OS5	15.6 ± 0.0	–
OS6	15.4 ± 0.0	13.9 ± 0.0
OS7	16.0 ± 0.0	–

Similar to November, slightly warmer temperatures were recorded in the shallower waters of the upper and central harbour in comparison with offshore sites during December. 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 slightly lower than the overlying surface waters and displayed the same surface trends indicating a well-mixed water column.



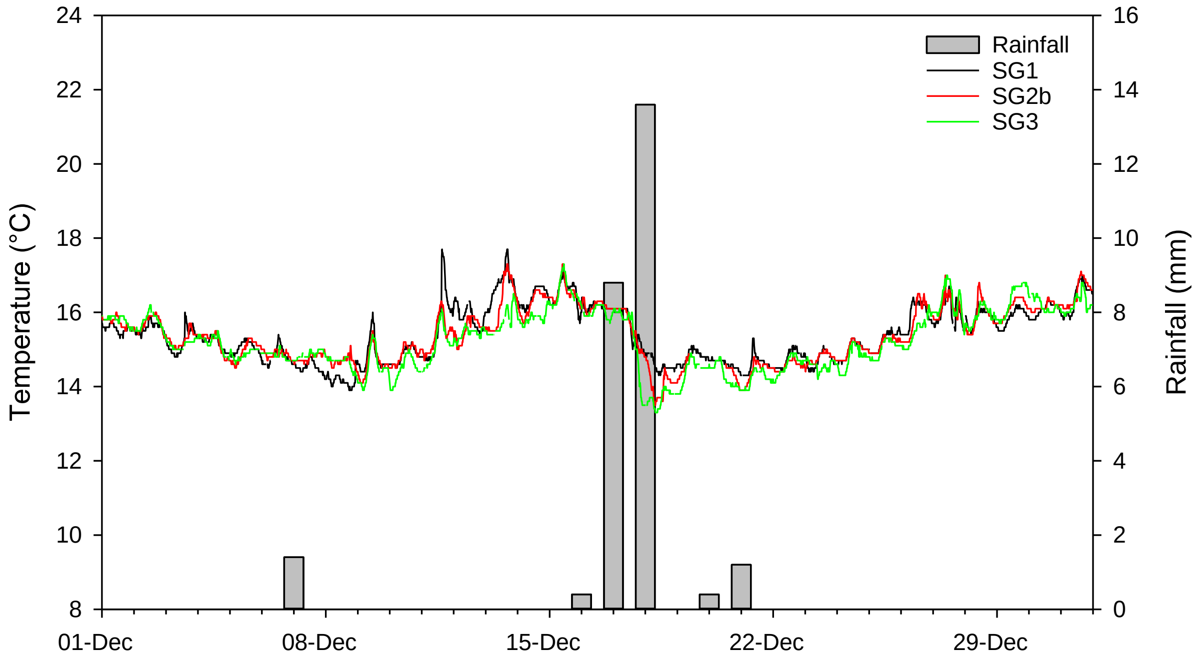


Figure 16 Surface temperature at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites and rainfall during December 2019.

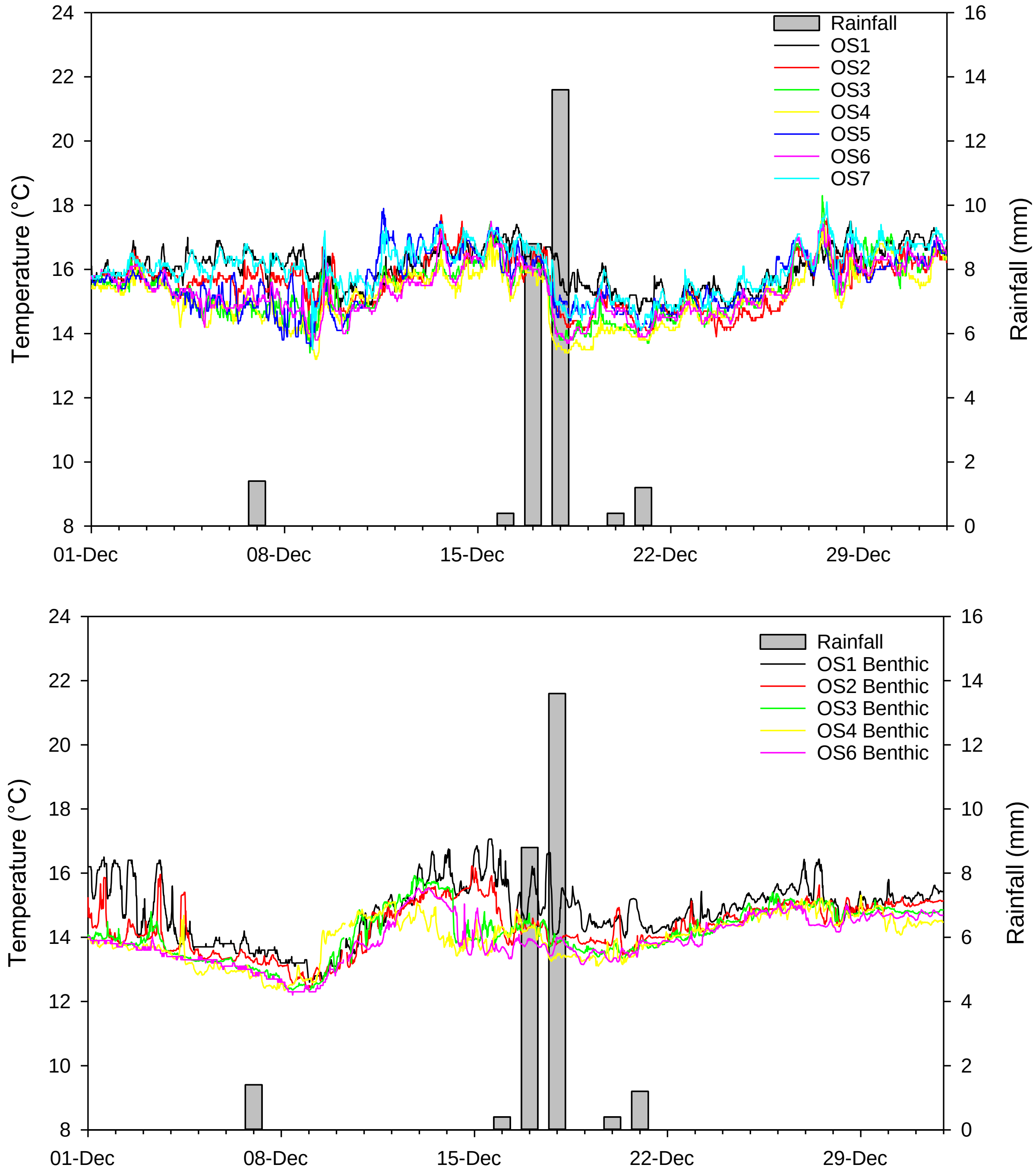


Figure 17 Surface temperature (OS1 to OS7) and benthic temperature (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during December 2019.

3.2.4 pH

The pH remained reasonably consistent across surface and benthic sites, with monthly means ranging between 7.9 and 8.2 (Table 10, Figures 18 and 19).

Table 10 Mean pH at inshore, spoil ground and offshore water quality sites during December 2019. *Values are means ± se (n = 1228 to 2976).*

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

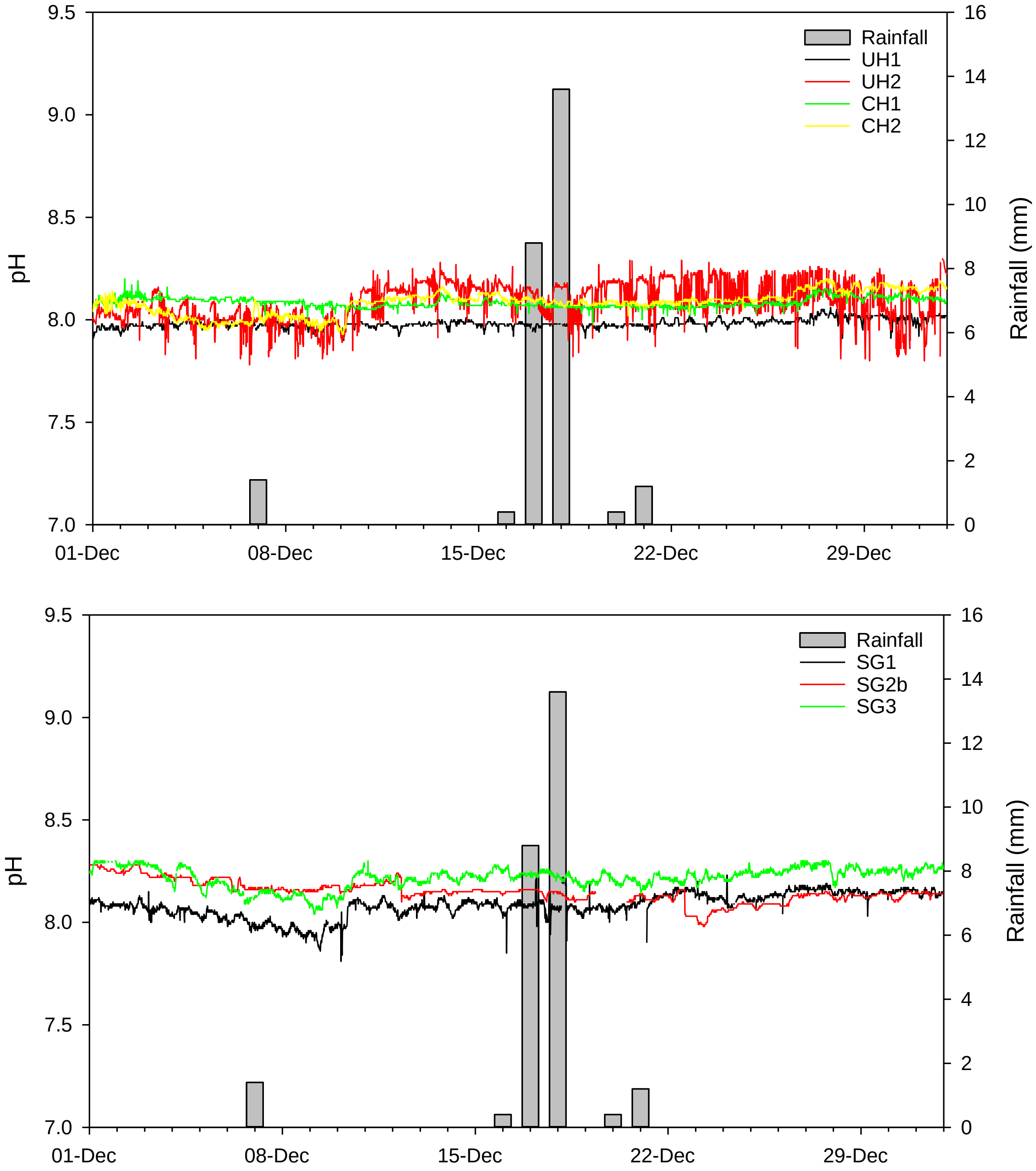
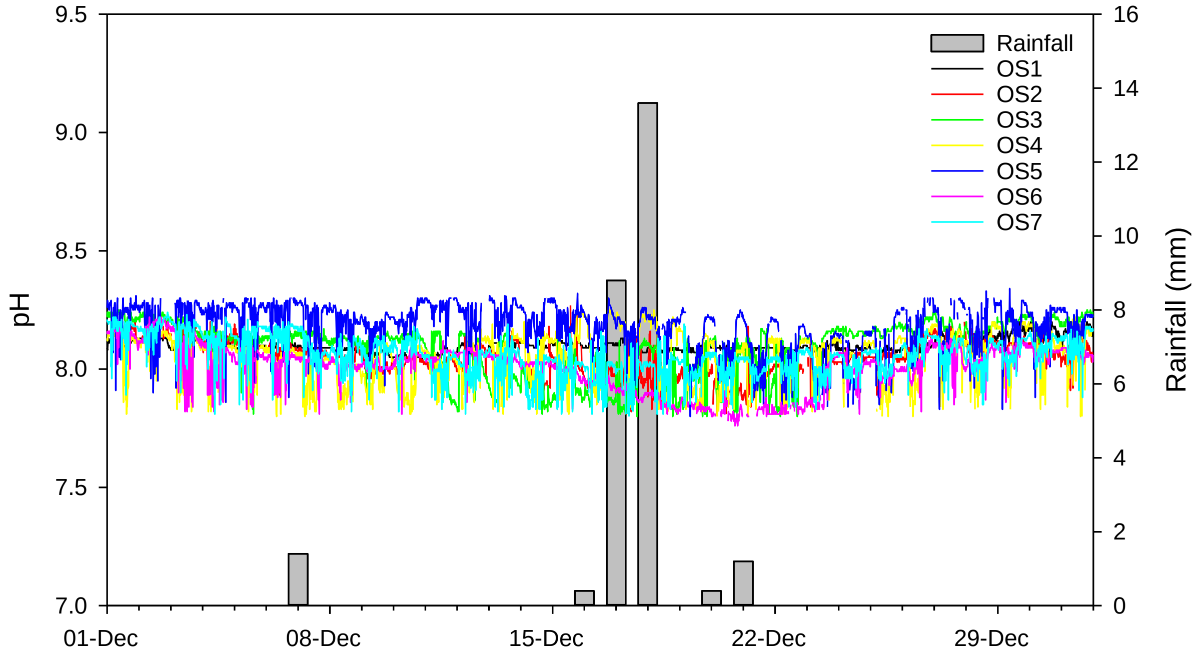


Figure 18 Surface pH at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2019.



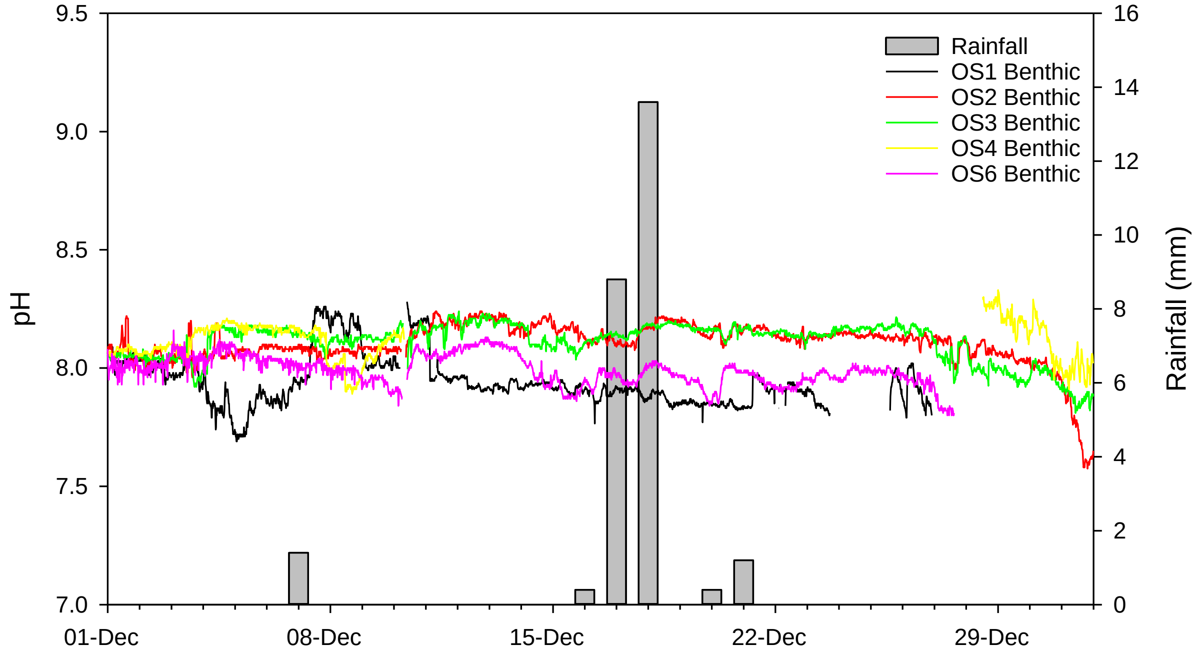


Figure 19 Surface pH (OS1 to OS7) and benthic pH (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during December 2019.

3.2.5 Conductivity

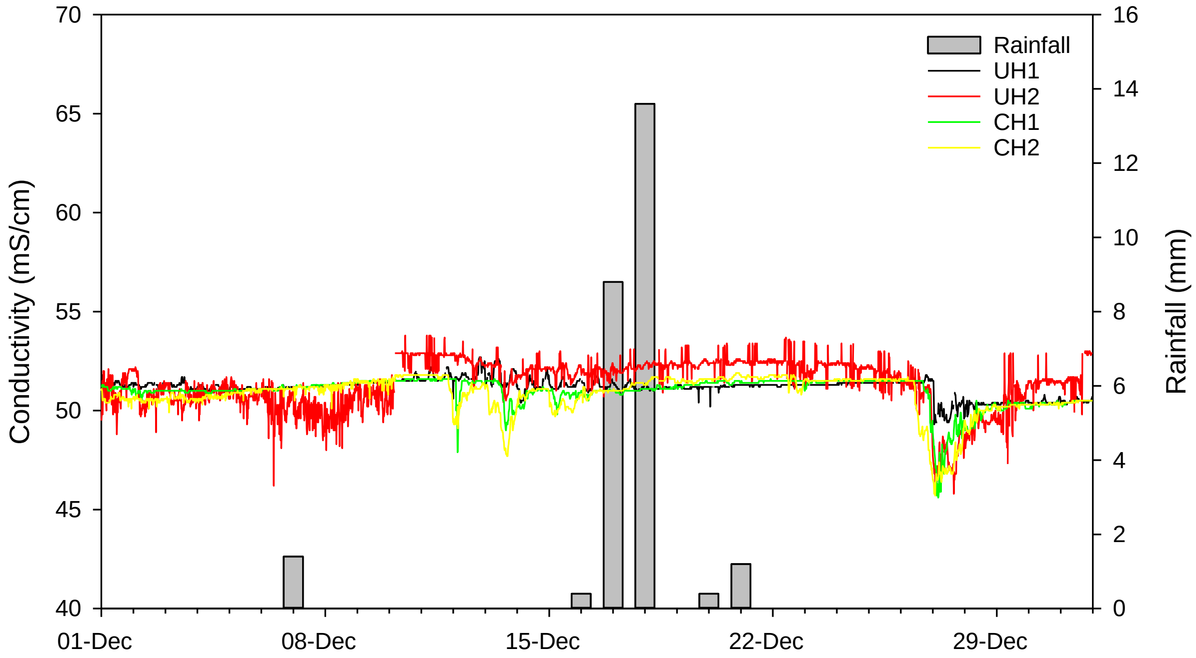
Surface conductivity in December ranged from 50.7 mS/cm to 53.2 mS/cm (Table 11, Figure 20 and 21), with benthic conductivity at similar levels, ranging from 52.7 mS/cm to 53.9 mS/cm.

Inner harbour sites recorded slightly lower mean conductivity values than offshore and spoil ground sites. Higher flows from the Waimakariri River from 3 to 9 December appeared to have impacted conductivity at OS5 on 10 December followed by the spoil ground sites on 12 to 14 December (SG2 dipping to 45 mS/cm), followed by other inshore and nearshore sites (CH1, CH2, OS5, OS6 and OS7). The latter sites are furthest from the source point and therefore there is a longer delay before the freshwater reaches these sites. A second decrease in conductivity on 25 to 28 December occurred at all sites with reduced conductivity initially starting at OS5 (25 December), followed by SG1 and then remaining sites (26 to 27 December), including inshore. This is likely related to a short acute flow of >600 m^3/s from the Waimakariri River flow which occurred on 20 December but may have been delayed in reaching Lyttelton Harbour as the current hugged the coast.

Seawater at the benthos was not as impacted by the flow events, with the lower density freshwater remaining mostly in the surface layers during these events.

Table 11 Mean conductivity at inshore, spoil ground and offshore water quality sites during December 2019.
Values are means ± se (n = 2196 to 2976).

Site	Conductivity (mS/cm)	
	Surface loggers	Benthic loggers
UH1	51.2 ± 0.0	–
UH2	51.4 ± 0.0	–
CH1	51.0 ± 0.0	–
CH2	50.8 ± 0.0	–
SG1	52.6 ± 0.0	–
SG2	51.0 ± 0.0	–
SG3	53.1 ± 0.0	–
OS1	50.7 ± 0.0	53.3 ± 0.0
OS2	51.7 ± 0.0	53.9 ± 0.0
OS3	52.5 ± 0.0	53.8 ± 0.0
OS4	53.2 ± 0.0	53.8 ± 0.0
OS5	52.2 ± 0.0	–
OS6	52.3 ± 0.0	52.7 ± 0.0
OS7	51.8 ± 0.0	–



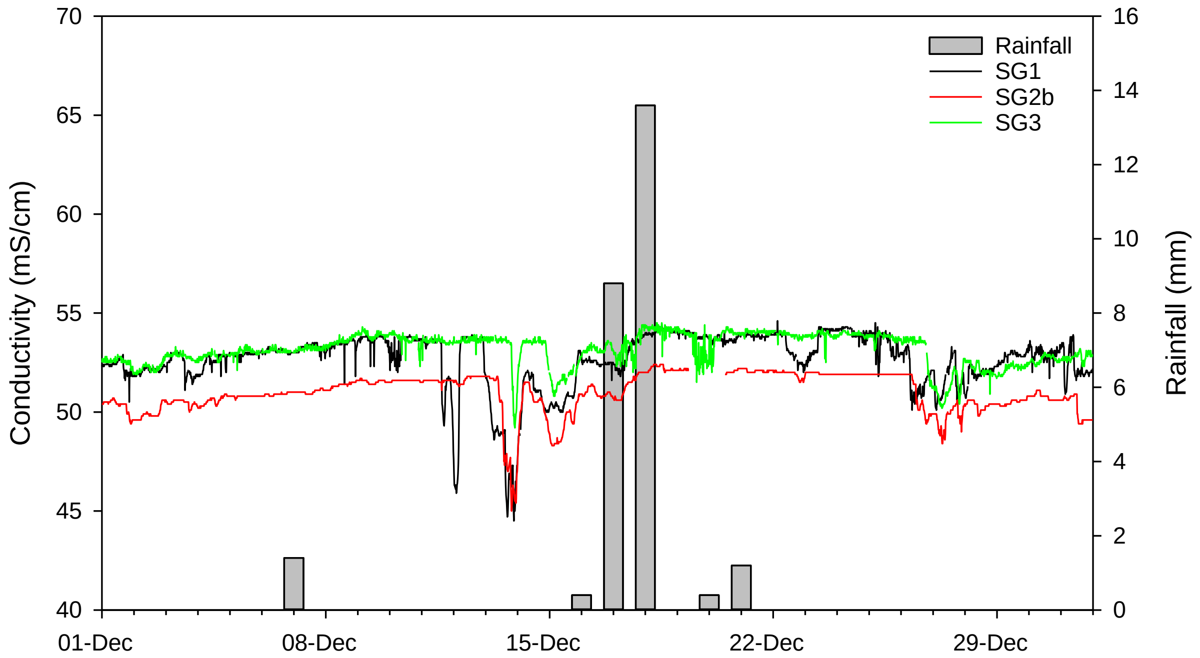


Figure 20 Surface conductivity at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2019.

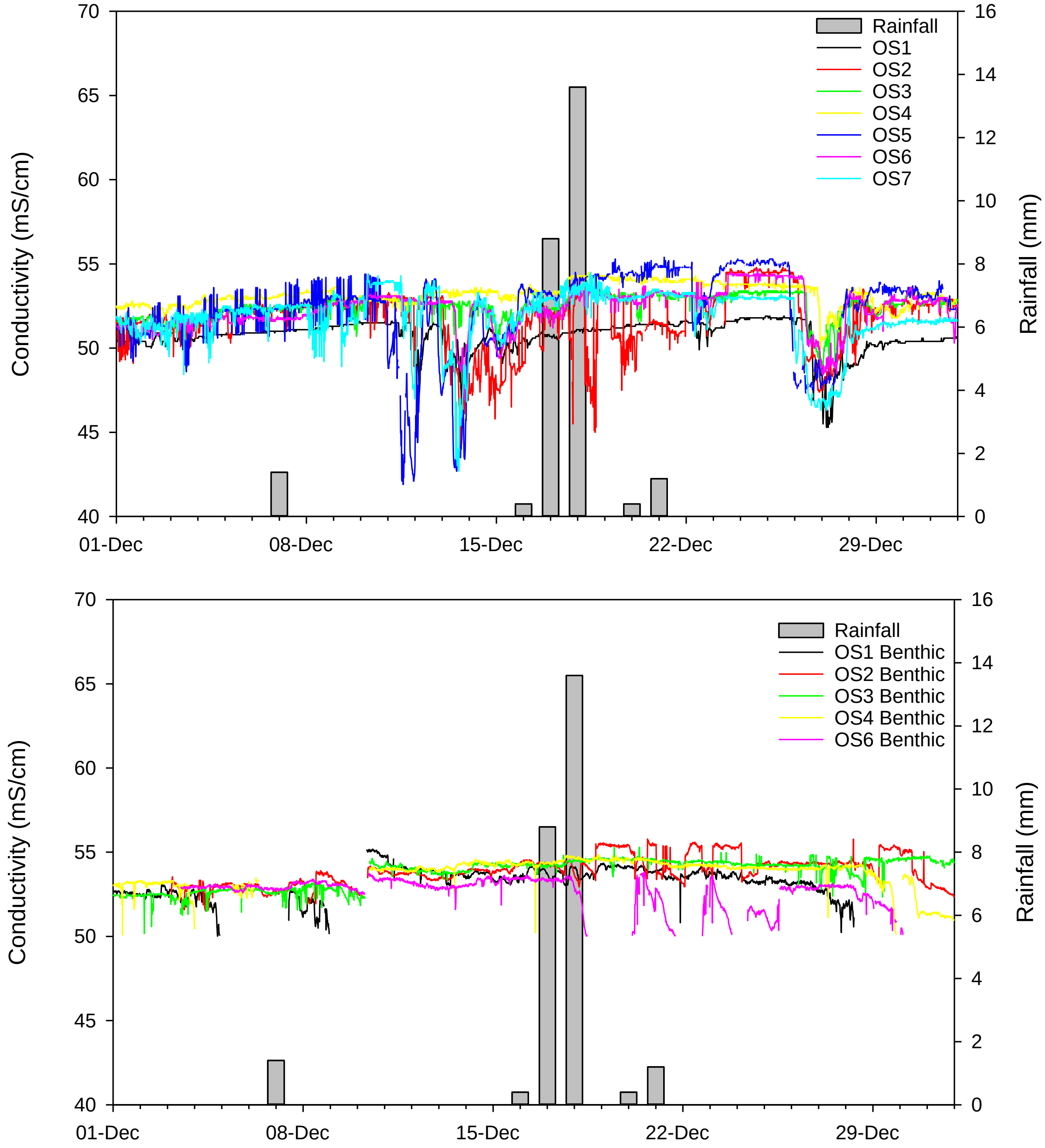


Figure 21 Surface conductivity (OS1 to OS7) and benthic conductivity (OS1 to OS4 and OS6) at nearshore and offshore water quality sites during December 2019.

3.2.1 Dissolved oxygen

Mean monthly surface DO concentrations in December ranged from 96 to 104% saturation. DO concentrations were observed to be lower around the 8 and 20 December following periods of rainfall concurrently with lower water temperatures. Noticeably declining DO (<90% saturation) at SG1 and SG3 on 9 December 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 and increased photosynthesis, and therefore increased DO concentrations. A similar recovery would have occurred after periods of rainfall in mid-December. Flows from the Waimakariri River may have also introduced nutrients contributing to algal growth.

Mean monthly benthic DO concentrations were lower than corresponding surface readings ranging from 85 to 94% saturation (Table 12, Figures 22 and 23), indicative of lower photosynthesis at the benthos. Benthic DO however displayed a similar trend to surface cohorts.

Table 12 Mean dissolved oxygen at inshore, spoil ground and offshore water quality sites during December 2019.
Values are means ± se (n = 2595 to 2976).

Site	Dissolved oxygen (% saturation)	
	Surface loggers	Benthic loggers
UH1	97 ± 0	–
UH2	96 ± 0	–
CH1	99 ± 0	–
CH2	101 ± 0	–
SG1	98 ± 0	–
SG2	104 ± 0	–
SG3	103 ± 0	–
OS1	101 ± 0	89.4 ± 0
OS2	100 ± 0	84.9 ± 0
OS3	101 ± 0	88.9 ± 0
OS4	100 ± 0	93.5 ± 0
OS5	98 ± 0	–
OS6	100 ± 0	87.7 ± 0
OS7	100 ± 0	–

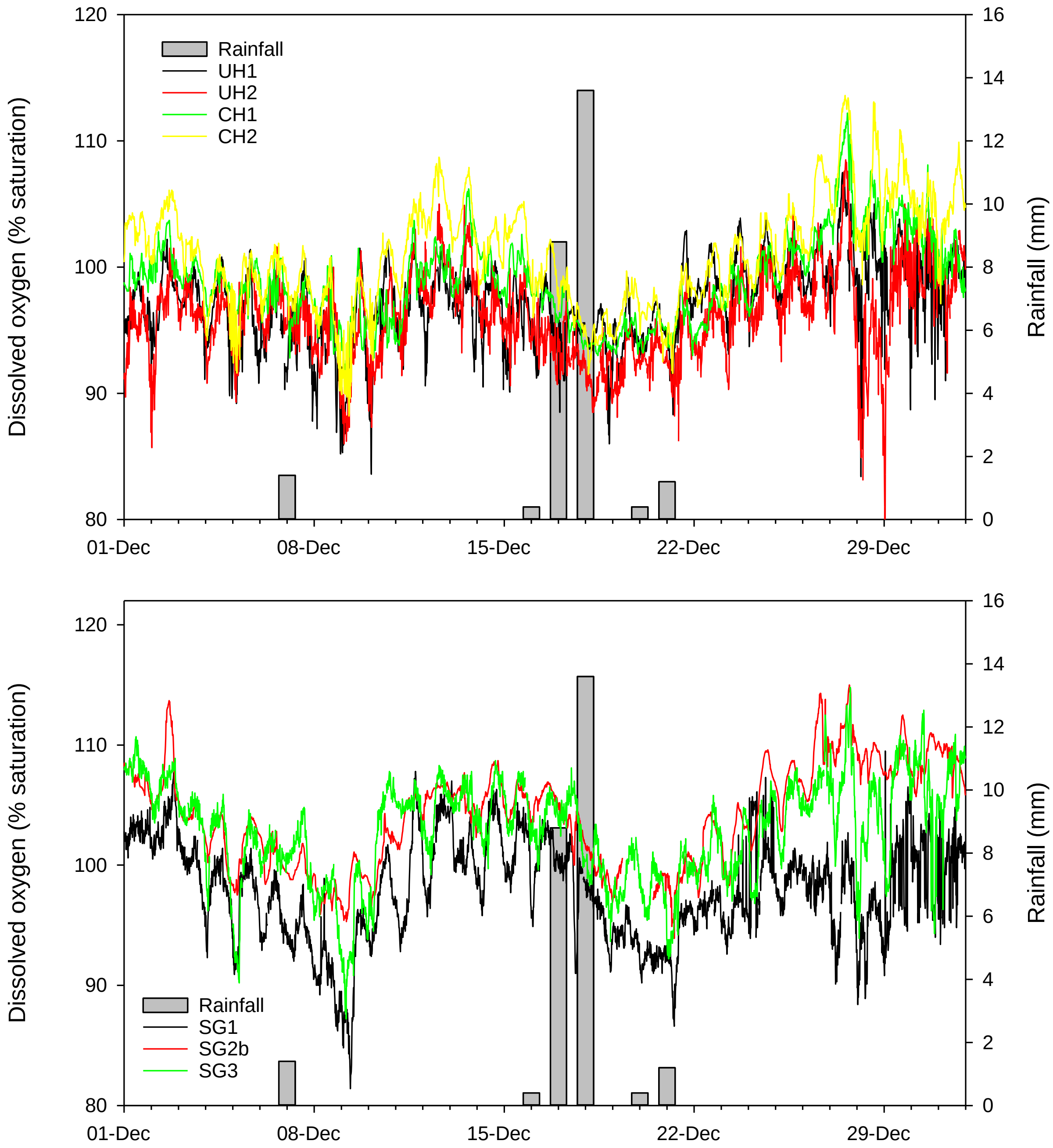
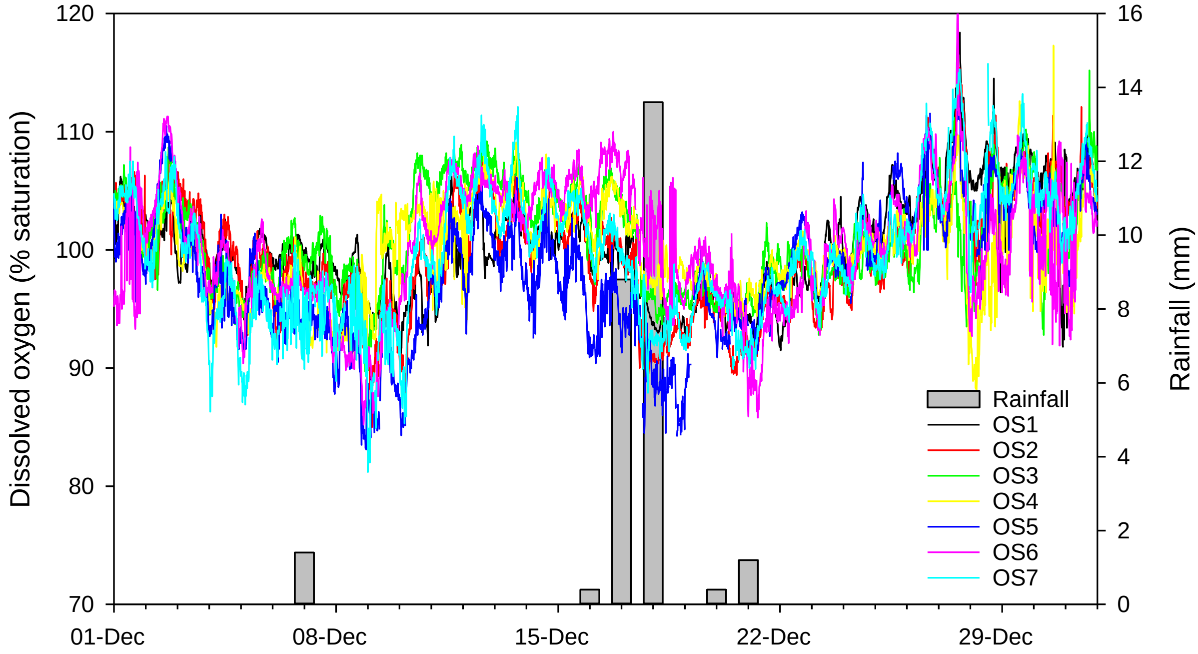


Figure 22 Surface DO at inshore (UH1, UH2, CH1 and CH2) and spoil ground (SG1, SG2b and SG3) water quality sites during December 2019.



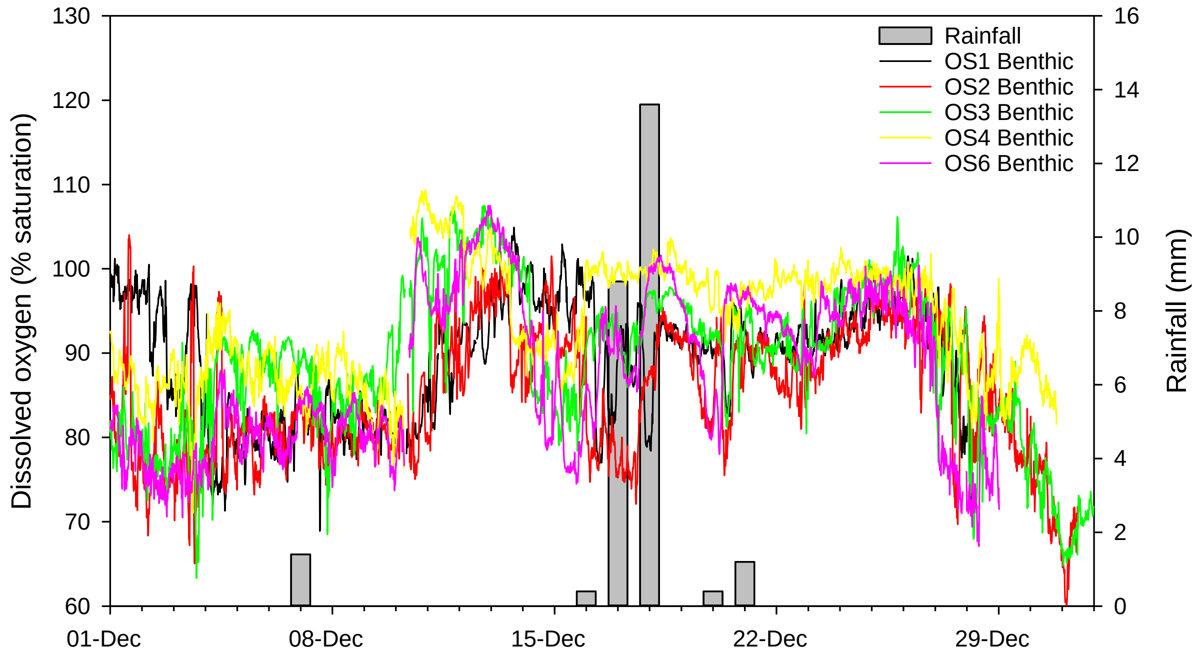


Figure 23 Surface DO (OS1 to OS7) and benthic DO (OS1 to OS 4 and OS6) at nearshore and offshore water quality sites during December 2019.

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 12 December 2019. 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 13 to 15, with depth profile plots presented in Figures 24 to 26.

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. The exceptions were CH1 and CH2, where the top 2 m was characterised by lower conductivity, while UH2 recorded an elevated turbidity (concentration 65 NTU) within the subsurface layer (Figure 24). This increase of turbidity was noted only in the second depth profile and demonstrates that a passing turbidity plume occurred while taking the second readings. Similar to the continuous loggers, the uppermost harbour sites of UH3 and UH1 exhibited the lowest conductivity within the harbour and higher temperatures.

Within the nearshore region, physicochemical profiles for OS2, OS3 and OS4 remained relatively consistent through the water column for all parameters (Figure 25). However, OS1 and OS7 displayed lower conductivity concentrations in the surface while temperature, DO and pH decreased in concentrations at 5 m depth. The decline in DO from the surface to benthos was most likely due to decreasing photosynthesis with depth. Slightly increased turbidity near the benthos was also recorded at these sites, which is often observed due to shear forces (friction between the overlying moving water and the stationary seabed) providing energy for sediment resuspension.

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 26), unlike November that displayed a dominant seasonal thermocline. DO concentrations, however, did markedly decrease closer to the benthos due to lower photosynthesis at this depth. Turbidity remained stable until >10 m where it increased with depth due to benthic resuspension at all sites.

The shallowest euphotic depth of 5.6 m occurred within upper harbour monitoring sites UH3 (Table 13), which reflects the typically higher levels of turbidity experienced in this area (Figure 24). The deepest euphotic depth was calculated to be 23 m at OS6 (Table 15) where turbidity throughout the column was low. During December only one exceedance was recorded with elevated turbidity at UH2 likely due to a transient sediment plume passing by. No other exceedances were recorded in December.

Table 13 Discrete physicochemical statistics from depth-profiling of the water column at inshore sites during the December 2019 sampling event. *Values are means ± se (n = 6 for sub-surface, n = 20 to 37 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	12/12/2019 06:34	Sub-surface	17.2 ± 0	8 ± 0	51.9 ± 0	97 ± 0	5.2 ± 0	6	0.8 ± 0	6.0
		Whole column	17.1 ± 0.8	8 ± 0	51.9 ± 0	97 ± 0	5.5 ± 0.1	–		
UH2	12/12/2019 07:04	Sub-surface	16.6 ± 0	8.1 ± 0	51.7 ± 0	101 ± 0	34.7 ± 26.2	4	0.6 ± 0	7.2
		Whole column	16.5 ± 0.7	8.1 ± 0	51.7 ± 0	101 ± 0	18.7 ± 8.1	–		
UH3	12/12/2019 06:48	Sub-surface	18.3 ± 0	8 ± 0	52.2 ± 0	99 ± 0	5.7 ± 0.1	6	0.8 ± 0.1	5.6
		Whole column	18.3 ± 1.2	8 ± 0	52.2 ± 0	99 ± 0	5.9 ± 0.2	–		
CH1	12/12/2019 07:37	Sub-surface	15.9 ± 0	8.1 ± 0	50.7 ± 0	101 ± 0	3.3 ± 0.1	33	0.7 ± 0	6.3
		Whole column	16.1 ± 0.8	8.1 ± 0	51.4 ± 0.1	99 ± 0	9.6 ± 4.7	–		
CH2	12/12/2019 07:25	Sub-surface	16.2 ± 0	8.1 ± 0	50.5 ± 0.1	104 ± 0	2.6 ± 0	3	0.5 ± 0	10.0
		Whole column	16.1 ± 0.8	8.1 ± 0	51.2 ± 0.1	102 ± 0	3.3 ± 0.2	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	–

Table 14 Discrete physicochemical statistics from depth-profiling of the water column at offshore sites during the December 2019 sampling event. *Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 31 to 39 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	12/12/2019 07:58	Sub-surface	15.9 ± 0	8.1 ± 0	49.1 ± 0.3	103 ± 0	2.4 ± 0	4	0.6 ± 0	7.8
		Mid	15.5 ± 0.1	8.1 ± 0	51.8 ± 0	99 ± 1	3.7 ± 0.2	5		
		Benthos	14.9 ± 0	8 ± 0	51.8 ± 0	92 ± 0	11.8 ± 1.8	6		
		Whole column	15.5 ± 0.6	8.1 ± 0	51 ± 0.2	99 ± 1	5 ± 0.7	–		
OS2	12/12/2019 08:36	Sub-surface	15.7 ± 0	8.1 ± 0	51.8 ± 0	103 ± 0	2.4 ± 0.2	5	0.4 ± 0	11.7
		Mid	15.2 ± 0	8.1 ± 0	51.9 ± 0	104 ± 0	3 ± 0.3	<3		
		Benthos	14.9 ± 0	8.1 ± 0	51.9 ± 0	99 ± 1	34.8 ± 19.7	3		
		Whole column	15.3 ± 0.6	8.1 ± 0	51.8 ± 0	103 ± 0	8.3 ± 3.5	–		
OS3	12/12/2019 09:19	Sub-surface	15.5 ± 0	8.2 ± 0	51.6 ± 0	107 ± 0	1.5 ± 0	3	0.3 ± 0	16.2
		Mid	15.4 ± 0	8.2 ± 0	51.6 ± 0	106 ± 0	1.5 ± 0	<3		
		Benthos	15.4 ± 0	8.2 ± 0	51.7 ± 0	105 ± 0	2.7 ± 0.7	<3		
		Whole column	15.4 ± 0.6	8.2 ± 0	51.6 ± 0	106 ± 0	1.7 ± 0.1	–		
OS4	12/12/2019 09:49	Sub-surface	15.5 ± 0	8.2 ± 0	51.6 ± 0	105 ± 0	1.8 ± 0	4	0.5 ± 0	9.8
		Mid	15.1 ± 0	8.2 ± 0	51.6 ± 0	104 ± 0	3.1 ± 0.2	9		
		Benthos	14.6 ± 0	8.2 ± 0	51.7 ± 0	100 ± 0	4.8 ± 0.1	10		
		Whole column	15.1 ± 0.6	8.2 ± 0	51.6 ± 0	103 ± 0	3.2 ± 0.2	-		
OS7	12/12/2019 08:14	Sub-surface	16.2 ± 0	8.1 ± 0	49.8 ± 0.3	102 ± 0	2.5 ± 0.1	<3	0.5 ± 0	8.9
		Mid	15.2 ± 0.1	8.1 ± 0	51.8 ± 0	100 ± 1	3.3 ± 0.3	5		
		Benthos	14.9 ± 0	8.1 ± 0	51.9 ± 0	94 ± 0	5.2 ± 0.1	9		
		Whole column	15.5 ± 0.7	8.1 ± 0	51.1 ± 0.2	99 ± 1	3.5 ± 0.2	–		
WQG			–	**7.0 – 8.5**	–	**80 – 110**	**10**	–	–	

Table 15 Discrete physicochemical statistics from depth-profiling of the water column at offshore and spoil ground sites during the December 2019 sampling event.
Values are means ± se (n = 6 for sub-surface, mid and benthos, n = 38 to 48 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	12/12/2019 11:38	Sub-surface	15.8 ± 0	8.2 ± 0	51.5 ± 0	107 ± 0	1.6 ± 0	<3	0.3 ± 0	13.7
		Mid	15 ± 0	8.2 ± 0	51.9 ± 0	105 ± 0	1.9 ± 0.1	4		
		Benthos	14.7 ± 0.1	8.1 ± 0	51.9 ± 0	99 ± 1	5.2 ± 1.4	17		
		Whole column	15.3 ± 0.6	8.2 ± 0	51.7 ± 0	105 ± 0	2.3 ± 0.3	–		
OS6	12/12/2019 09:00	Sub-surface	15.3 ± 0	8.2 ± 0	51.6 ± 0	107 ± 0	1.2 ± 0	4	0.2 ± 0	23.0
		Mid	15.1 ± 0	8.2 ± 0	51.6 ± 0	106 ± 0	1.1 ± 0	<3		
		Benthos	15 ± 0	8.1 ± 0	51.8 ± 0	103 ± 0	5.2 ± 0.8	<3		
		Whole column	15.2 ± 0.5	8.2 ± 0	51.7 ± 0	106 ± 0	1.8 ± 0.2	–		
SG1	12/12/2019 11:11	Sub-surface	15.9 ± 0	8.2 ± 0	51.8 ± 0	105 ± 0	1.2 ± 0	<3	0.3 ± 0	17.0
		Mid	14.6 ± 0	8.2 ± 0	51.9 ± 0	108 ± 0	1.3 ± 0	<3		
		Benthos	13.8 ± 0	8.1 ± 0	52.1 ± 0	96 ± 2	7.6 ± 2.7	<3		
		Whole column	14.8 ± 0.5	8.2 ± 0	51.9 ± 0	105 ± 1	2.2 ± 0.5	–		
SG2	12/12/2019 10:48	Sub-surface	15.4 ± 0	8.2 ± 0	51.7 ± 0	106 ± 0	1.1 ± 0.1	<3	0.3 ± 0	15.1
		Mid	15 ± 0	8.2 ± 0	51.7 ± 0	106 ± 0	1.8 ± 0	<3		
		Benthos	14.5 ± 0	8.2 ± 0	51.9 ± 0	100 ± 0	24.7 ± 17	3		
		Whole column	15 ± 0.5	8.2 ± 0	51.7 ± 0	104 ± 0	4.7 ± 2.3	–		
SG3	12/12/2019 10:19	Sub-surface	15.5 ± 0	8.2 ± 0	51.8 ± 0	105 ± 0	1 ± 0	<3	0.2 ± 0	18.8
		Mid	14.7 ± 0	8.2 ± 0	51.8 ± 0	104 ± 0	1.1 ± 0	<3		
		Benthos	13.9 ± 0	8.1 ± 0	52 ± 0	92 ± 1	9 ± 4.4	7		
		Whole column	14.8 ± 0.5	8.2 ± 0	51.8 ± 0	102 ± 1	2.4 ± 0.6	–		
WQG			**–**	**7.0 – 8.5**	**–**	**80 – 110**	**10**	**–**	**–**	

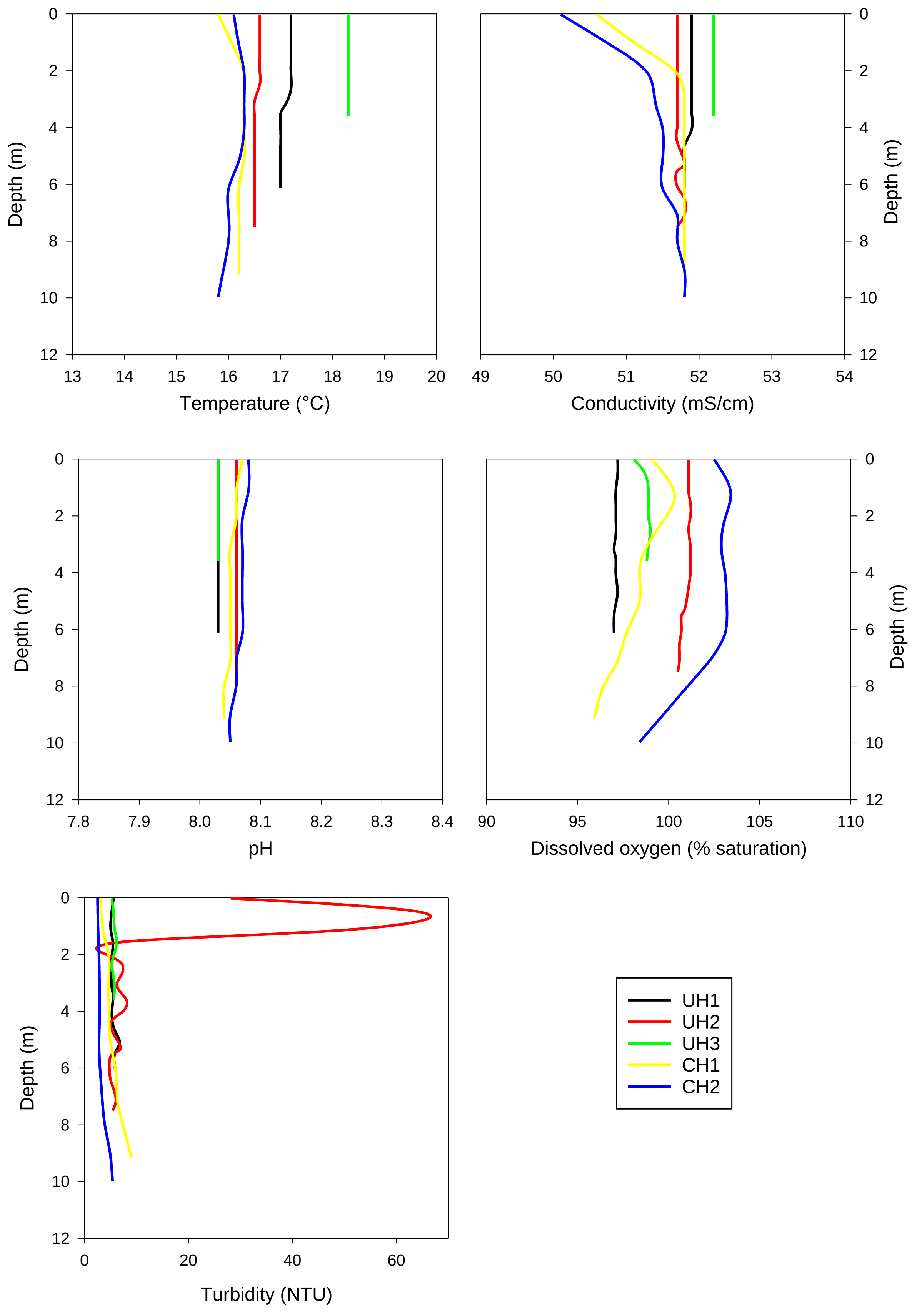


Figure 24 Depth-profiled physicochemical parameters at sites UH1, UH2, UH3, CH1 and CH2 on 12 December 2019.

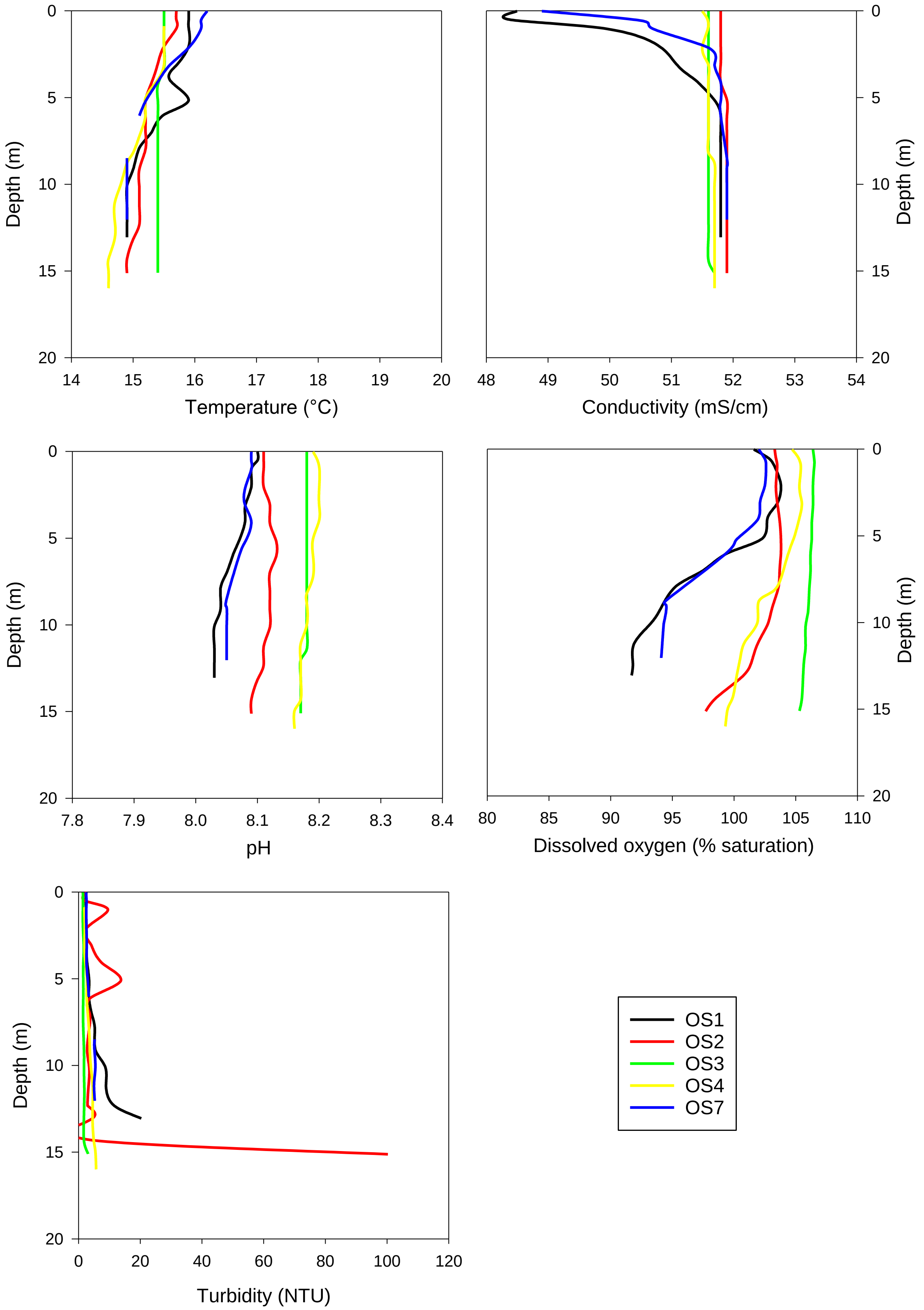


Figure 25 Depth-profiled physicochemical parameters at sites OS1, OS2, OS3, OS4 and OS7 on 12 December 2019.

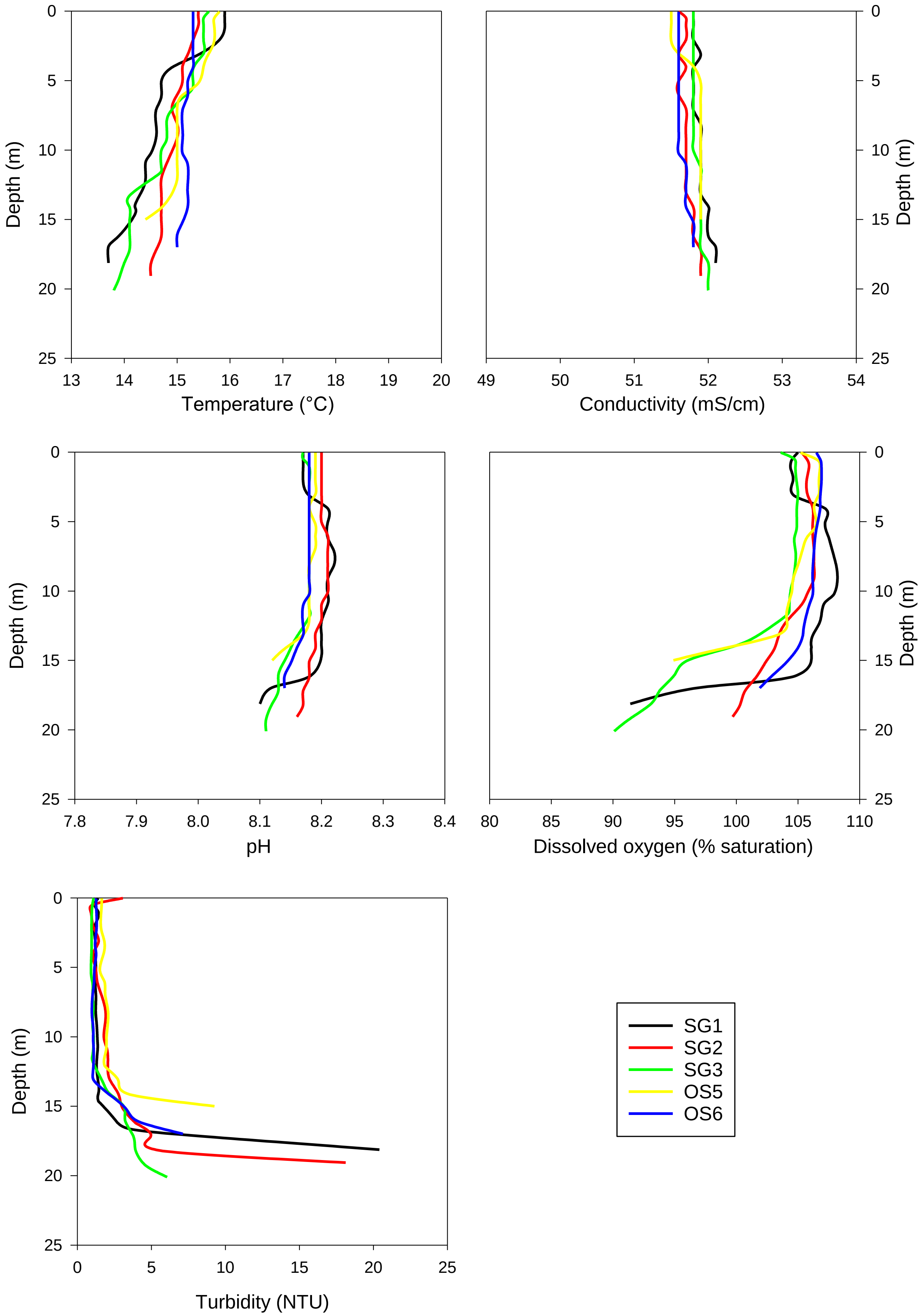


Figure 26 Depth-profiled physicochemical parameters at sites SG1, SG2, SG3, OS5 and OS6 on 12 December 2019.

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 16, with the collected data from benthic and VBCC sensors presented in Figure 27. Data from the logger exchange date (10 December) were removed from the analyses.

Table 16 Total Daily PAR (TDP) statistics during December 2019.
Values are means ± se (n = 29 to 30). Note data from the BPAR exchange day on 10 December were not utilised in plots or statistics for sites OS2 and OS3.

Site	Depth (m)	TDP (mmol/m^2/day)		
		Mean ± se	Median	Range
Base	-	43,300 ± 2,154	44,500	13,800 – 59,100
OS2	17	859 ± 242	200	<0.1 – 5,242
OS3	14	619 ± 255	61	<0.1 – 6,600

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 13,800 to 59,100 mmol/m^2/day (Table 16), which was similar to the range recorded during November (7,070 to 63,000 mmol/m^2/day). With the increase in longer day lengths in December, mean TDP (43,300 mmol/m^2/day) was higher than that observed during November (31,517 mmol/m^2/day).

Despite the increased ambient PAR, mean BPAR at both OS2 and OS3 was lower in December (859 and 619 mmol/m^2/day respectively) than November (2,367 and 2,301 mmol/m^2/day, respectively). This was due to a period of low BPAR experienced at OS2 and OS3 at the start of December and later in December when turbidity was consistently elevated. Noticeable BPAR peaks > 4000 mmol/m^2/day were noted on 11 December at OS2 and OS3 due to low turbidity, while a second peak occurred only at OS2 at the end of December.

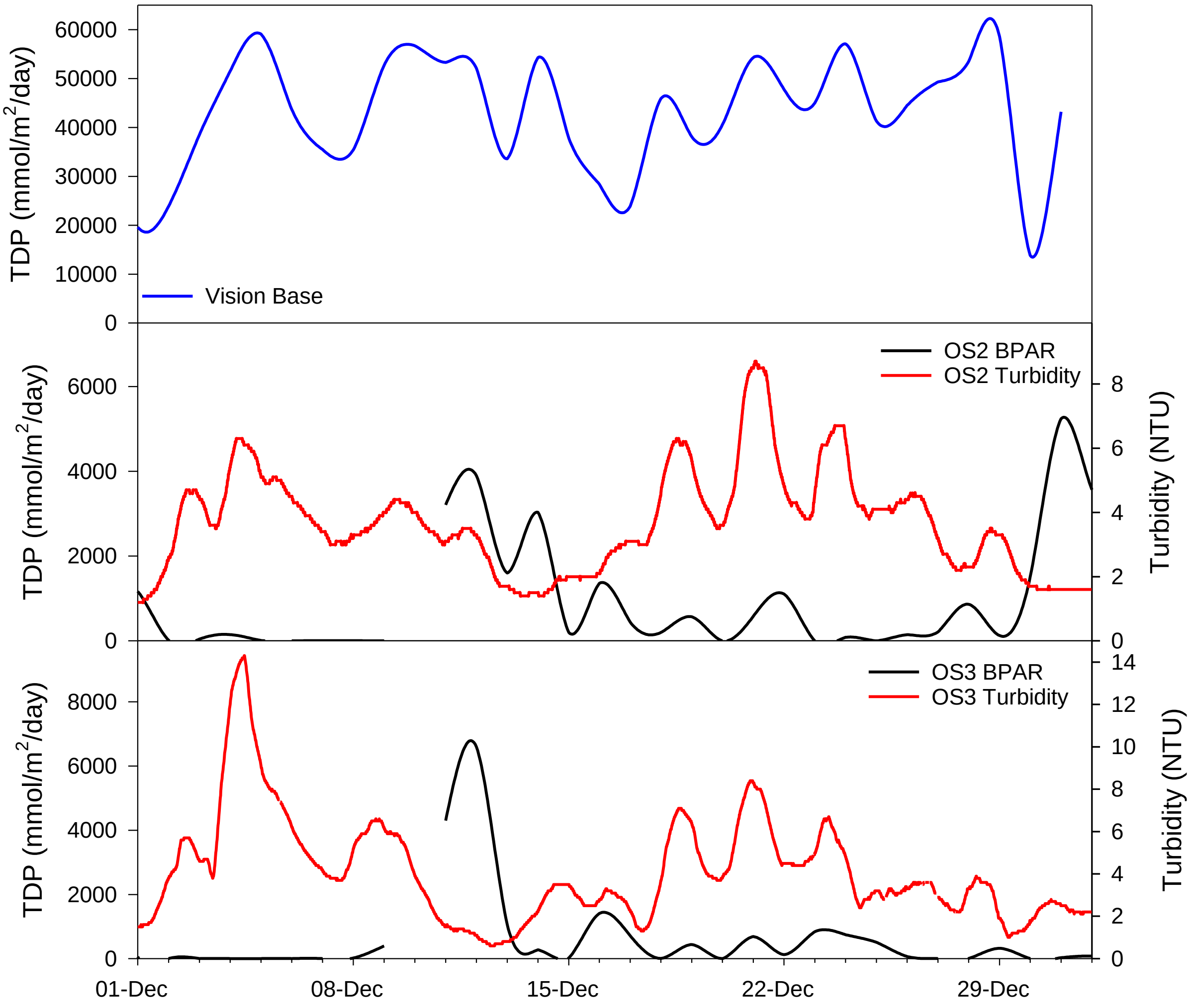


Figure 27 Total daily BPAR at OS2 and OS3 during December 2019 compared to ambient PAR and corresponding surface turbidity (24 hour rolling average).
Note data from the BPAR exchange day on 10 December were not utilized in plots or statistics.

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.

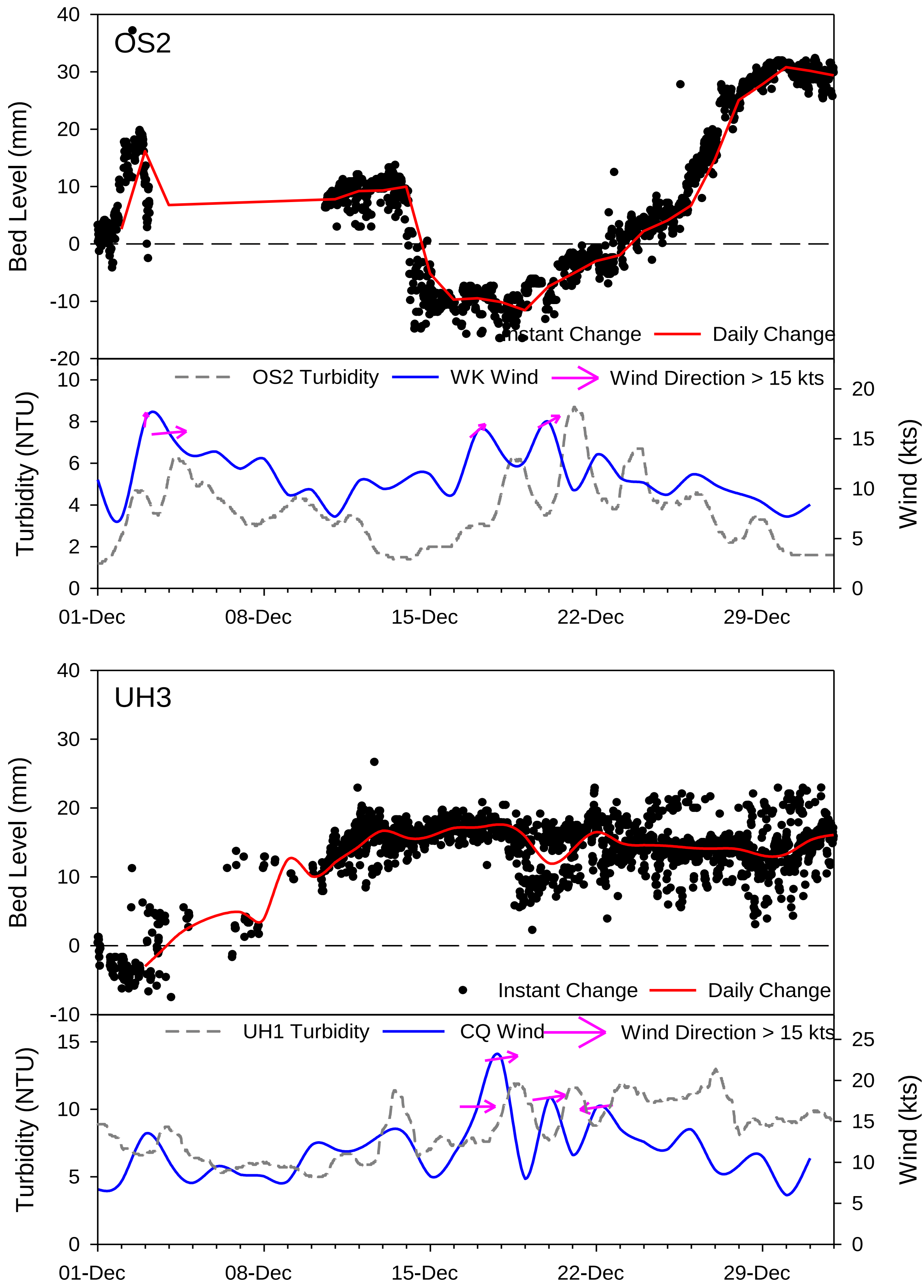


Figure 28 Mean instantaneous and daily averaged bed level change at OS2 and UH3 during December 2019 compared to ambient surface turbidity (24 hour rolling average), wind speed and direction.
Note: Arrows indicate the direction of travel for winds greater than 15 knots.
Limited data was recovered at both sites in early December before exchange.

Bed level at the offshore site OS2 was quite dynamic in December with the start of the month recording a short period of accretion and erosion of 20 mm, most likely in response to the high offshore winds and significant wave event on 3 December. Altimeter data was not available until exchange on 10 December, due to unknown reasons. Bed level was then relatively stable until the 14 December where the bed level then experienced ~20mm erosion. For the remainder of December approximately 50 mm of sediment was deposited at the site. This period corresponded to declining elevated offshore winds. An overall accumulation of 29 mm was recorded in December 2019 (Table 17).

As typically observed, bed level within the sheltered upper harbour at UH3 was more stable than that at OS2. Beginning of December was a period of limited data that demonstrated high sediment flux at UH3, with an overall accretion of 15 mm. Bed level was then relatively stable for the remainder of December, except for a period of high flux and shifting bed level corresponding to the elevated inshore winds in mid-December. An overall accumulation of 16 mm was recorded in December 2019 (Table 17).

Table 17 Net Bed Level Change statistics from data collected from altimeters deployed at OS2 and UH3 during December 2019.

Site	December 2019 Net bed level change (mm)
OS2	+29
UH3	+16

3.6 Water Samples

Discrete water sampling was conducted on 12 December 2019, 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 25 of the Appendix.

3.6.1 Nutrients

Total phosphorous concentrations exhibited a typical spatial pattern with higher concentrations within the inner harbour and lowest concentrations at the spoil ground. Total phosphorous remained below the WQG of 30 µg/L at all sites. Consistent with November, dissolved reactive phosphorous concentrations were below the WQG of 5 µg/L at the offshore and spoil ground sites, with two UH sites reporting values > WQG (5 µg/L). This may be a result of warmer temperatures stimulating algal growth with the utilisation of some available nutrients in the offshore areas. Both total nitrogen and total kjeldahl nitrogen (TKN) were < LOR and < WQG at all sites, except for UH2 where the WQG and LOR value of 300 µg/L was equalled.

Total ammonia ranged from 6 to 10 µg/L and in contrast to previous months all sites were below the WQG (15 µg/L). This month continued the trend from September of low nitrogen oxide values, with all sites reporting values below the WQG (15 µg/L). Again, this may be due to utilisation by increasing algal populations.

Table 18 Concentrations of nutrients and chlorophyll *a* at monitoring sites during December 2019.
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	20	7.4	<300	<200	10	6.3	3.2
UH2	18	5	300	300	6	6.6	2.5
UH3	22	8.8	<300	<200	6	<1	2.2
CH1	16	4.1	<300	<200	6	<1	3.7
CH2	13	2.4	<300	<200	6	1.2	3.3
OS1	12	1.9	<300	<200	6	<1	4
OS2	12	2.7	<300	<200	6	<1	2.5
OS3	8	<1	<300	<200	6	<1	1.4
OS4	8	<1	<300	<200	9	1.3	1.4
OS5	10	<1	<300	<200	6	1	1.7
OS6	8	<1	<300	<200	6	<1	1.4
OS7	14	2.4	<300	<200	7	1.7	3.3
SG1	10	<1	<300	<200	6	1.8	1.1
SG2	8	<1	<300	<200	6	5.1	0.9
SG3	7	<1	<300	<200	8	<1	1
WQG	**30**	**5**	**300**	**-**	**15**	**15**	**4**

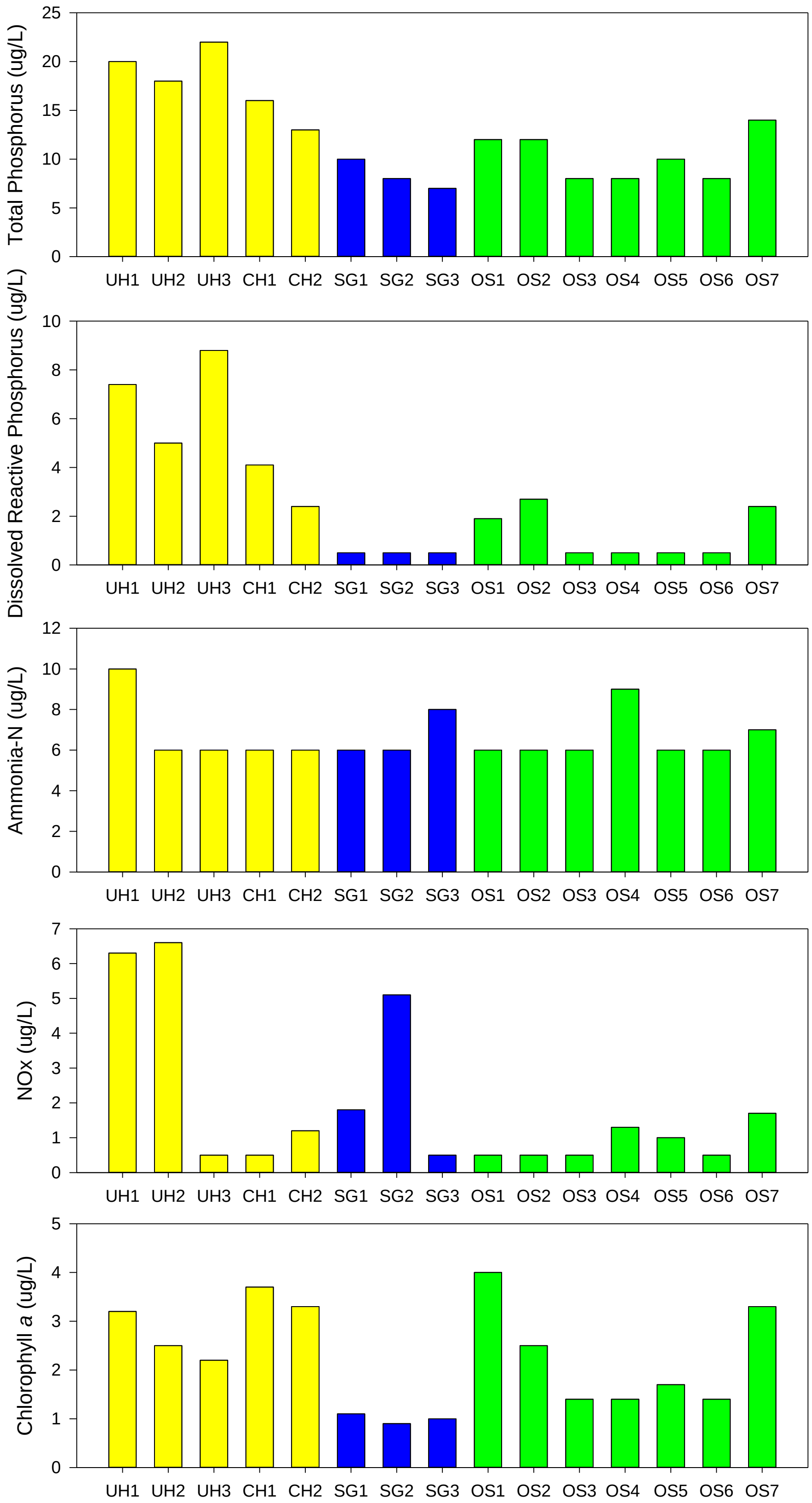


Figure 29 Nutrient and chlorophyll *a* concentrations at monitoring sites during December 2019. *Values which were <LOR, were plotted as half LOR. Total nitrogen and TKN were not plotted as all or most sites were <LOR.*

Concentrations of chlorophyll *a*, an indicator of phytoplankton biomass, recorded moderate concentrations at all sites ranging from 0.9 at SG2 to 4 µg/L at OS1, with OS1 recording equal to the WQG value (4 µg/L) (Table 18). It should be noted that sampling was conducted earlier in the month and did coincided with recovering elevated DO concentrations.

3.6.2 Total and Dissolved Metals

Concentrations of several metals (Tables 19 to 21) were reported as below the limit of reporting (LOR) at all sites, including total and dissolved arsenic (<4 µg/L), cadmium (<0.2 µg/L), cobalt (<0.6 µg/L), copper (1.1 µg/L), lead (1.1 µg/L), mercury (<0.08 µg/L), nickel (<7 µg/L), silver (<0.4 µg/L), tin (<5 µg/L) and zinc (4.2 µg/L). Total and dissolved selenium was <LOR at majority of sites, except at UH1, CH1 and OS5 where the dissolved fraction reported values >LOR (4 µg/L). The sample contamination of elevated copper, lead and zinc at UH2 in November was not present in December.

While concentrations of total aluminium and iron were detected, dissolved concentrations of these metals were > LOR at a few sites, indicating bioavailability. Dissolved aluminium was < LOR at all sites except for 13 µg/L recorded at CH2 this value is < WQG (<24 µg/L). Dissolved iron was reported at values of 5 to 16 µg/L within the inner harbour and values of 6 to 10 µg/L at the nearshore sites. Concentrations of total aluminium (23 to 165 µg/L) were higher than the designated 95% species protection trigger value of 24 µg/L at all sites except the spoil ground sites where values were below the WQG. However, as the WQG is applicable to the dissolved fraction only (ANZG, 2018), no exceedances were recorded. As usually reported, both total aluminium and iron appeared to be generally higher at the inshore sites (49 to 165 µg/L and 79 to 260 µg/L, respectively) associated with increased suspended sediments, with minimum concentrations at the offshore and spoil ground sites (<21 to 46 µg/L and 5.1 to 45 µg/L, respectively).

Chromium, manganese, molybdenum and vanadium were recorded at the majority of sites in both total and dissolved forms. Chromium concentrations across the sites (<1 to 2.1 µg/L) were well below the 95% species protection trigger value of 4.4 µg/L from CrVI and 27.4 µg/L for CrIII. Similarly, recorded vanadium concentrations (1.4 to 2.6 µg/L) were 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 to 19.7 µg/L at inshore and offshore sites and were lower at spoil ground sites (<1 to 1.9 µg/L). Total and dissolved molybdenum concentrations exhibited little spatial variation, ranging from 9.9 to 12.2 µg/L, which is similar to previous monitoring results.

Table 19 Total and dissolved metal concentrations at inshore monitoring sites during December 2019. *Values above recommended WQG are highlighted in blue.*

Metal (µg/L)		Sites					WQG
		UH1	UH2	UH3	CH1	CH2	
Aluminium	Dissolved	<12	<12	<12	<12	13	24
	Total	133	101	165	63	49	
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	2.1	<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	<1.1	<1.1	<1.1	<1.1	<1.1	
Iron	Dissolved	<4	<4	5	6	16	-
	Total	171	132	260	87	79	
Lead	Dissolved	<1	<1	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	<1.1	<1.1	
Manganese	Dissolved	12.8	6.9	13	6	2.9	-
	Total	18.8	11.2	19.7	8.5	4.5	
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	11.2	10.9	11.4	11.4	11.1	-
	Total	11.8	12	11.8	11.7	11.4	
Nickel	Dissolved	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	
Selenium	Dissolved	8	<4	<4	5	<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	2.1	1.8	1.6	2.4	2.1	100
	Total	2.6	2.2	2.1	2.1	2.3	
Zinc	Dissolved	<4	<4	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	<4.2	<4.2	

Table 20 Total and dissolved metal concentrations at offshore monitoring sites during December 2019. *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	29	<21	33	24	23	46	
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	Cr(III) 27.4 Cr(VI) 4.4
	Total	<1.1	1.2	1.2	<1.1	<1.1	<1.1	1.6	
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	6	<4	10	8	<4	<4	-
	Total	44	37	30	34	12.6	17.9	45	
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	2.8	1.9	1.4	1.6	<1	<1	2.4	-
	Total	4.2	3	1.5	1.9	2.1	1.5	5	
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	10.1	11.2	11.1	11.1	11.2	11.6	9.9	-
	Total	11	12.2	11.7	11.8	11.7	12.1	10.8	
Nickel	Dissolved	<7	<7	<7	<7	<7	<7	<7	70
	Total	<7	<7	<7	<7	<7	<7	<7	
Selenium	Dissolved	<4	<4	<4	<4	5	<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	1.5	2.2	1.5	2	1.4	1.6	1.8	100
	Total	2.1	2.5	1.6	2.4	2.1	1.8	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 21 Total and dissolved metal concentrations at spoil ground monitoring sites during December 2019.
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	<1.1	
Iron	Dissolved	<4	<4	<4	-
	Total	9.1	5.1	6.3	
Lead	Dissolved	<1	<1	<1	4.4
	Total	<1.1	<1.1	<1.1	
Manganese	Dissolved	1.6	<1	1	-
	Total	1.9	<1	<1	
Mercury	Dissolved	<0.08	<0.08	<0.08	0.4
	Total	<0.08	<0.08	<0.08	
Molybdenum	Dissolved	11.4	11	11.1	-
	Total	11.7	11.8	11.9	
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	2.3	1.7	1.9	100
	Total	1.5	2.2	1.9	
Zinc	Dissolved	<4	<4	<4	15
	Total	<4.2	<4.2	<4.2	

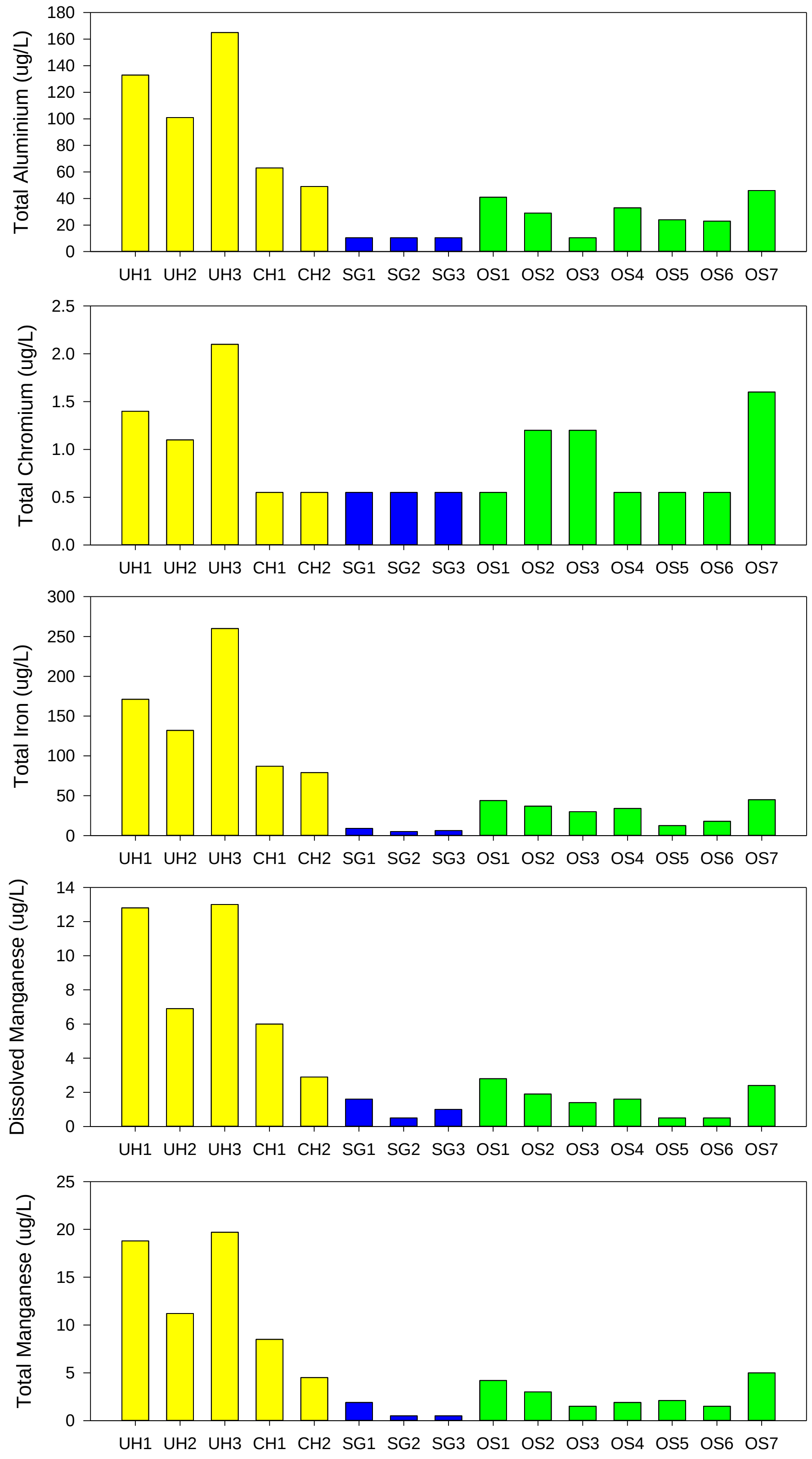


Figure 30 Total aluminium, total chromium, total iron, and total and dissolved manganese concentrations at monitoring sites during December 2019.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

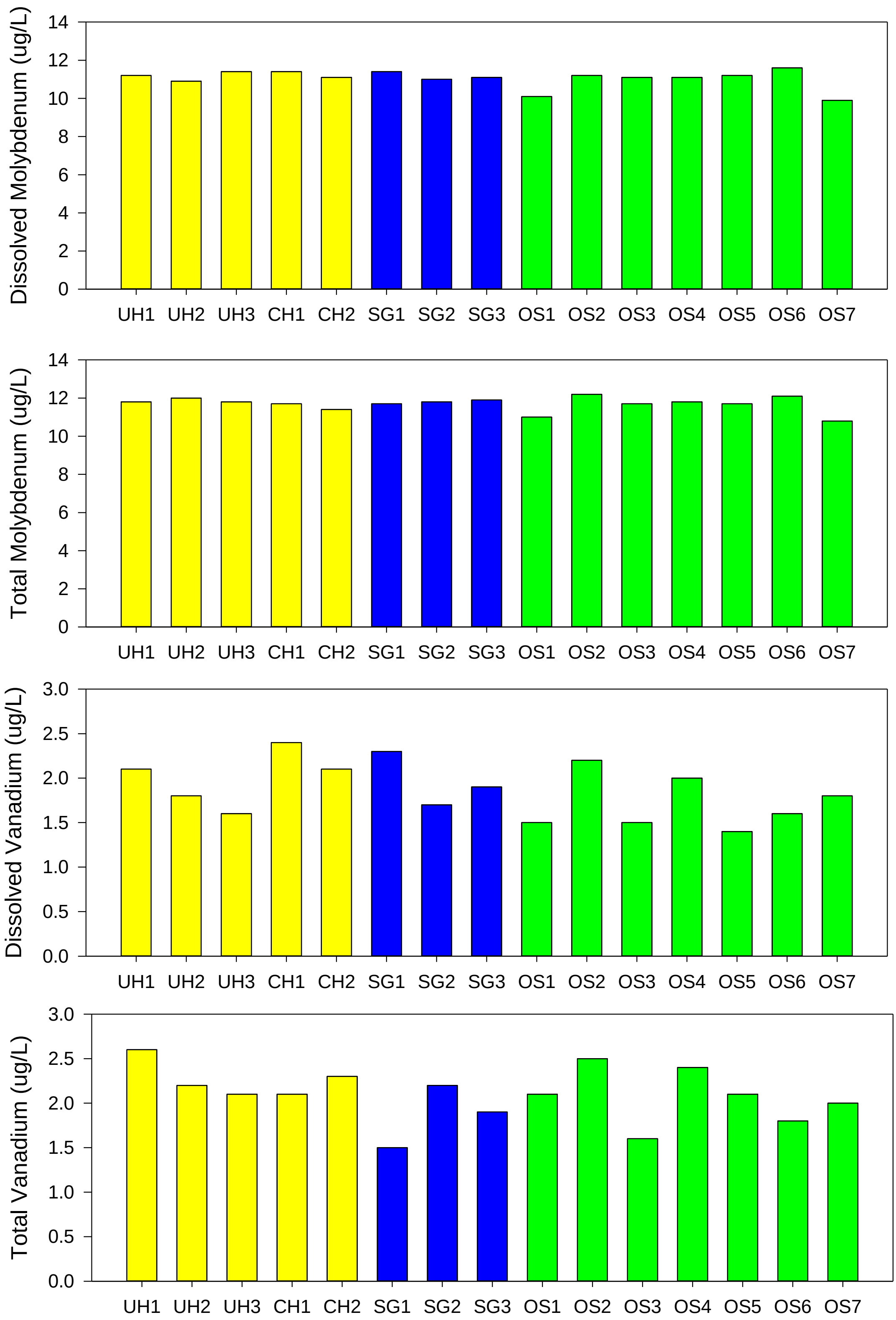


Figure 31 Total and dissolved molybdenum and vanadium concentrations at monitoring sites during December 2019.
Values which were <LOR, were plotted as half LOR. Metals that were below LOR at most sites were not plotted.

3.6.3 Organics

Organic compounds (herbicides, pesticides and hydrocarbons) are biannually measured as part of the monitoring project. Of the 210 compounds that were analysed: total petroleum hydrocarbons (C6 – C36) including PAH, multiresidue pesticides (179 individual), and acid herbicides (22 individual herbicides), all were below LOR (Table 22), except for one site where low values were recorded. The one site that recorded values was OS6 where values were slightly > LOR were recorded for C10-C14 (300 µg/L), C15-C36 (500 µg/L) and Total hydrocarbons (C7 - C36) (900 µg/L), suggesting potential contamination of the sample, possibly by transient fuel. The below LOR values has been a consistent finding throughout the monitoring project.

Table 22 Organic compound concentrations at monitoring sites during December 2019.

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	300	<200	<200	<200	<200
C15 - C36	<400	<400	<400	<400	<400	<400	<400	<400	<400	<400	500	<400	<400	<400	<400
Total hydrocarbons (C7 - C36)	<700	<700	<700	<700	<700	<700	<700	<700	<700	<700	900	<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)	<0.6	<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
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<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
2,4'-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)	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
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)	<0.6	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Acifluorfen	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Atrazine-desethyl	<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
Atrazine-desisopropyl	<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
Azaconazole	<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
Azinphos-methyl	<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
Benalaxyl	<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
Bendiocarb	<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
Benodanil	<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
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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Bitertanol	<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
Bromacil	<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
Bromophos-ethyl	<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
Bromopropylate	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Buprofezin	<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
Butachlor	<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
Captafol	<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
Captan	<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

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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Carbofenothion	<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
Carbofuran	<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
Carboxin	<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
Chlorfenvinphos	<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
Chlorfluazuron	<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
Chlorothalonil	<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
Chlorpropham	<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
Chlorpyrifos	<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
Chlorpyrifos-methyl	<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
Chlortoluron	<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
Chlozolinate	<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
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	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Cyanazine	<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
Cyfluthrin	<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
Cyhalothrin	<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
Cypermethrin	<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
Cyproconazole	<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
Cyprodinil	<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
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	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Diazinon	<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
Dicamba	<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

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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Dichlofenthion	<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
Dichlofluanid	<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
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	<0.6	<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
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	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Dicrotophos	<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
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	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Dinocap	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Diphenylamine	<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
Disulfoton	<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
Diuron	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Esfenvalerate	<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
Ethion	<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
Etrimfos	<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
Famphur	<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
Fenamiphos	<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
Fenarimol	<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
Fenitrothion	<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
Fenpropathrin	<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
Fenpropimorph	<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
Fensulfothion	<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
Fenthion	<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
Fenvalerate	<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
Fluazifop	<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
Fluazifop-butyl	<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
Fluometuron	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<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	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Furalaxyl	<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
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	<0.6	<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
Haloxyfop-methyl	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Hexazinone	<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
Hexythiazox	<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

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	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Indoxacarb	<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
Iodofenphos	<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
IPBC (3-Iodo-2-propynyl-n-butylcarbamate)	<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
Isazophos	<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
Isofenphos	<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
Kresoxim-methyl	<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
Leptophos	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Methacrifos	<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
Methidathion	<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
Methiocarb	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Mevinphos	<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
Molinate	<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
Myclobutanil	<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
Naled	<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
Nitrofen	<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
Nitrothal-Isopropyl	<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
Norflurazon	<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

Parameter (µg/L)	Site														
	UH1	**UH2**	**UH3**	**CH1**	**CH2**	**OS1**	**OS2**	**OS3**	**OS4**	**OS5**	**OS6**	**OS7**	**SG1**	**SG2**	**SG3**
Oryzalin	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1	<1.1
Oxadiazon	<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
Oxychlordane	<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
Oxyfluorfen	<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
o-Xylene	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Paclobutrazol	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Parathion-ethyl	<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
Parathion-methyl	<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
Penconazole	<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
Pendimethalin	<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
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	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08	<0.08
Phosmet	<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
Phosphamidon	<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
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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pirimiphos-methyl	<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
Prochloraz	<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
Procymidone	<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
Prometryn	<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
Propachlor	<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
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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Pyrazophos	<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
Pyrifenox	<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
Pyrimethanil	<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
Pyriproxyfen	<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
Quintozene	<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
Quizalofop	<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
Quizalofop-ethyl	<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
Simazine	<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
Simetryn	<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
Sulfentrazone	<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
Sulfotep	<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
TCMTB [2-(thiocyanomethylthio) benzothiazole,Busan]	<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
Tebuconazole	<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
Tebufenpyrad	<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
Terbacil	<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
Terbufos	<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
Terbumeton	<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
Terbuthylazine	<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
Terbuthylazine-desethyl	<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
Terbutryn	<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
Tetrachlorvinphos	<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
Thiabendazole	<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
Thiobencarb	<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
Thiometon	<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

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	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<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	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Triazophos	<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
Triclopyr	<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
Trifluralin	<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
Vinclozolin	<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

4 REFERENCES

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5 APPENDIX

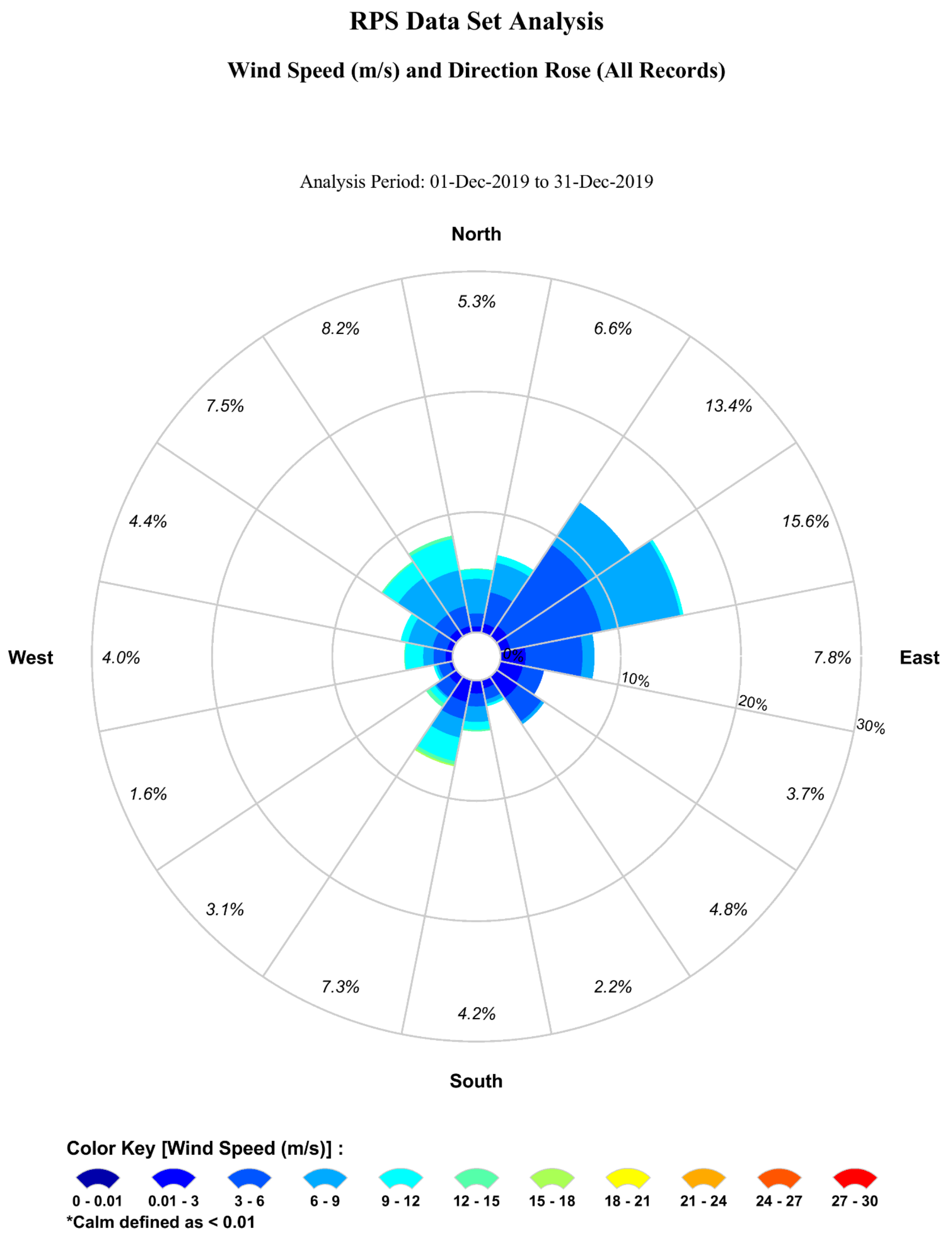


Figure 32 WatchKeeper wind speed (m/s) and direction rose (%) during December 2019.

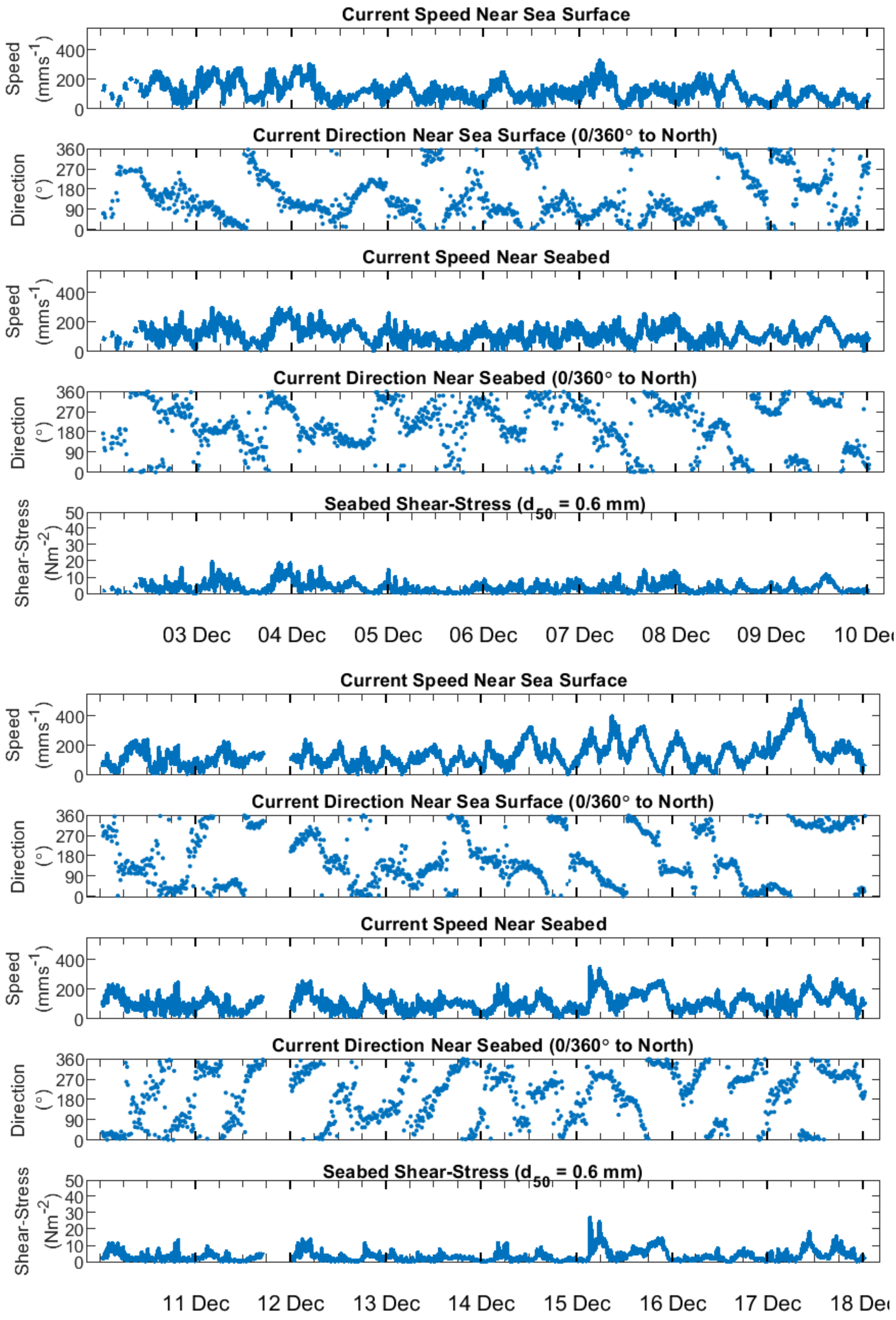


Figure 33 SG1 current speed, direction and shear bed stress 1 to 18 December 2019.

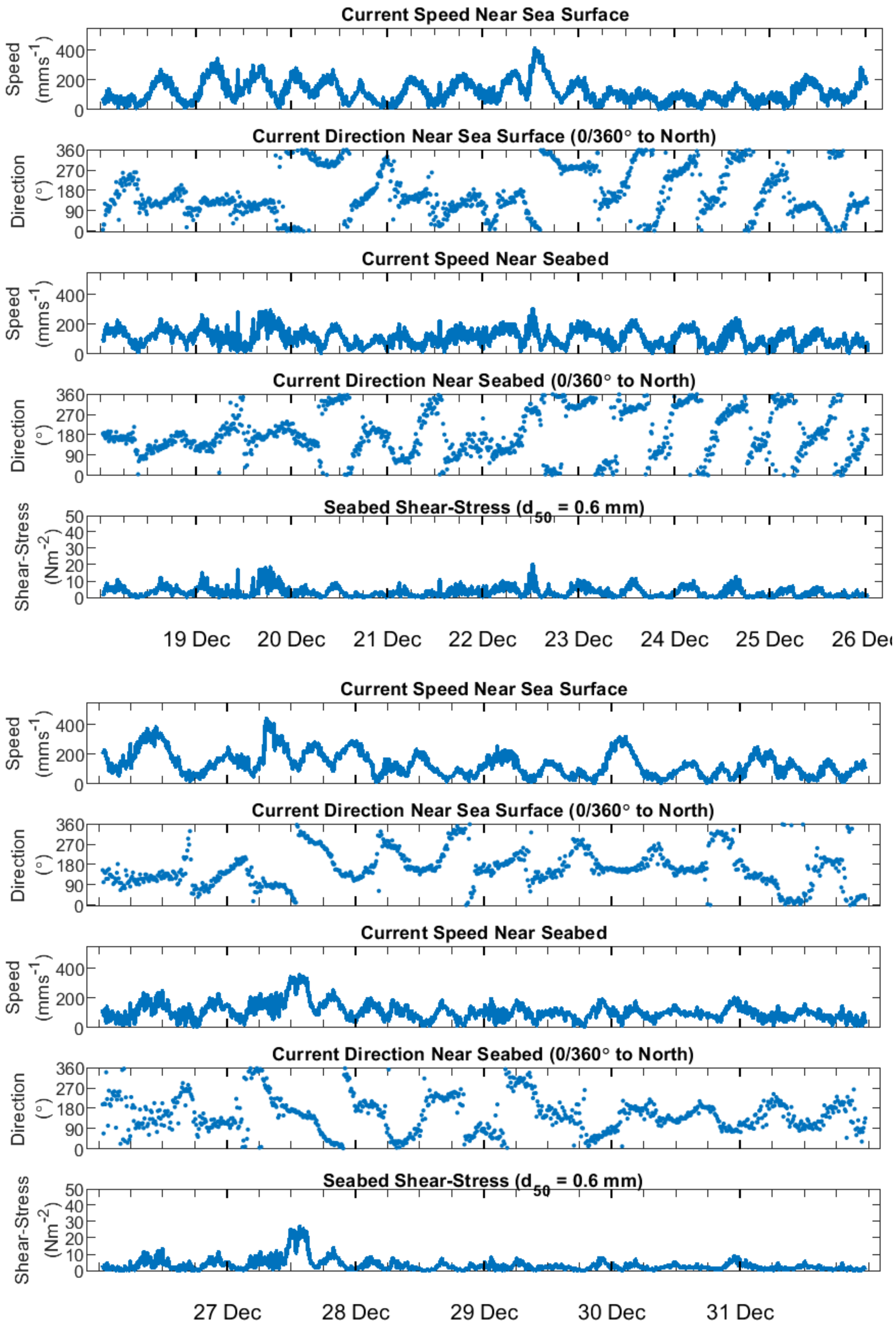


Figure 34 SG1 current speed, direction and shear bed stress 18 to 31 December 2019.

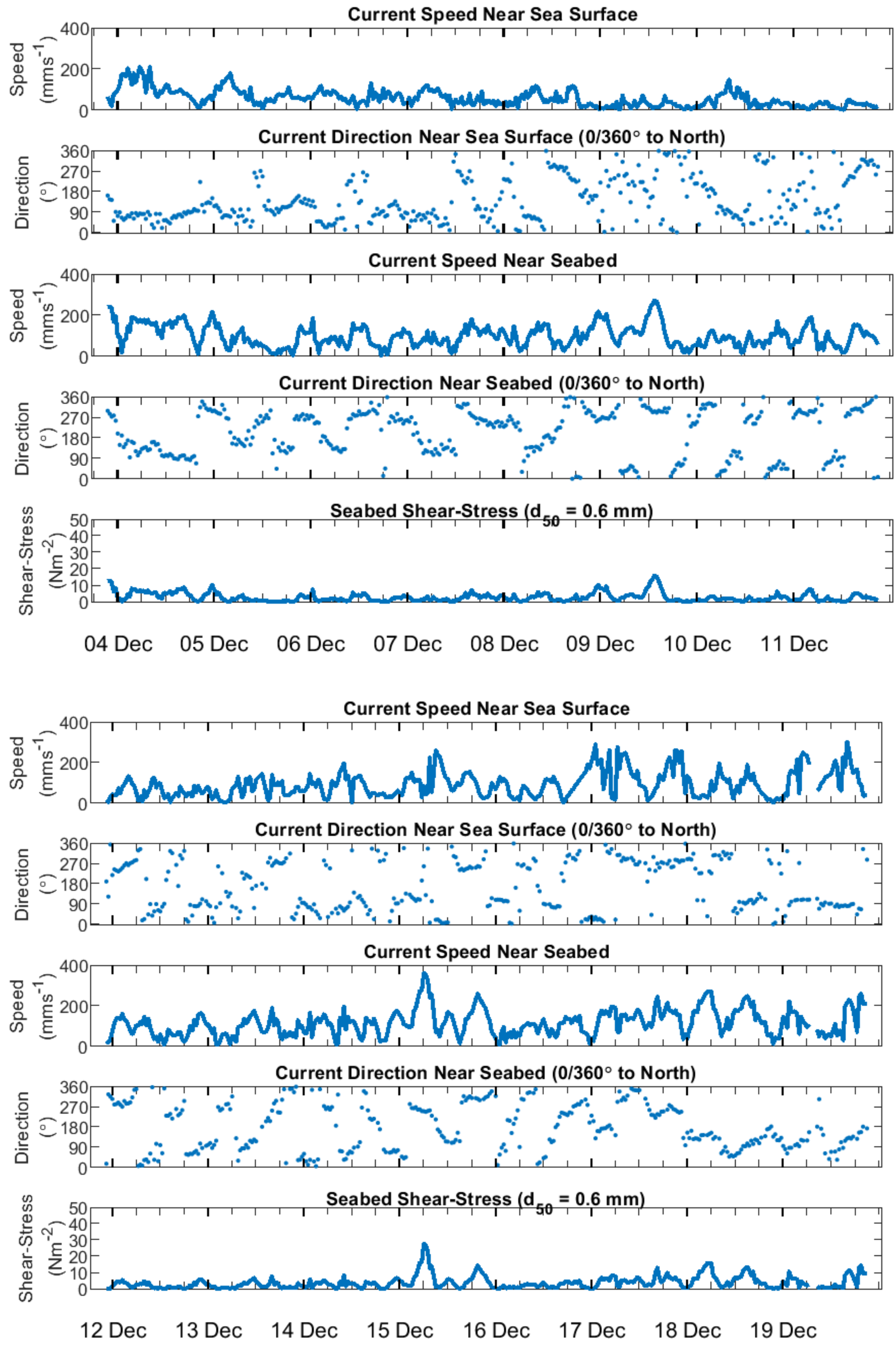


Figure 35 SG2a (WatchKeeper) current speed, direction and shear bed stress 1 to 19 December 2019.

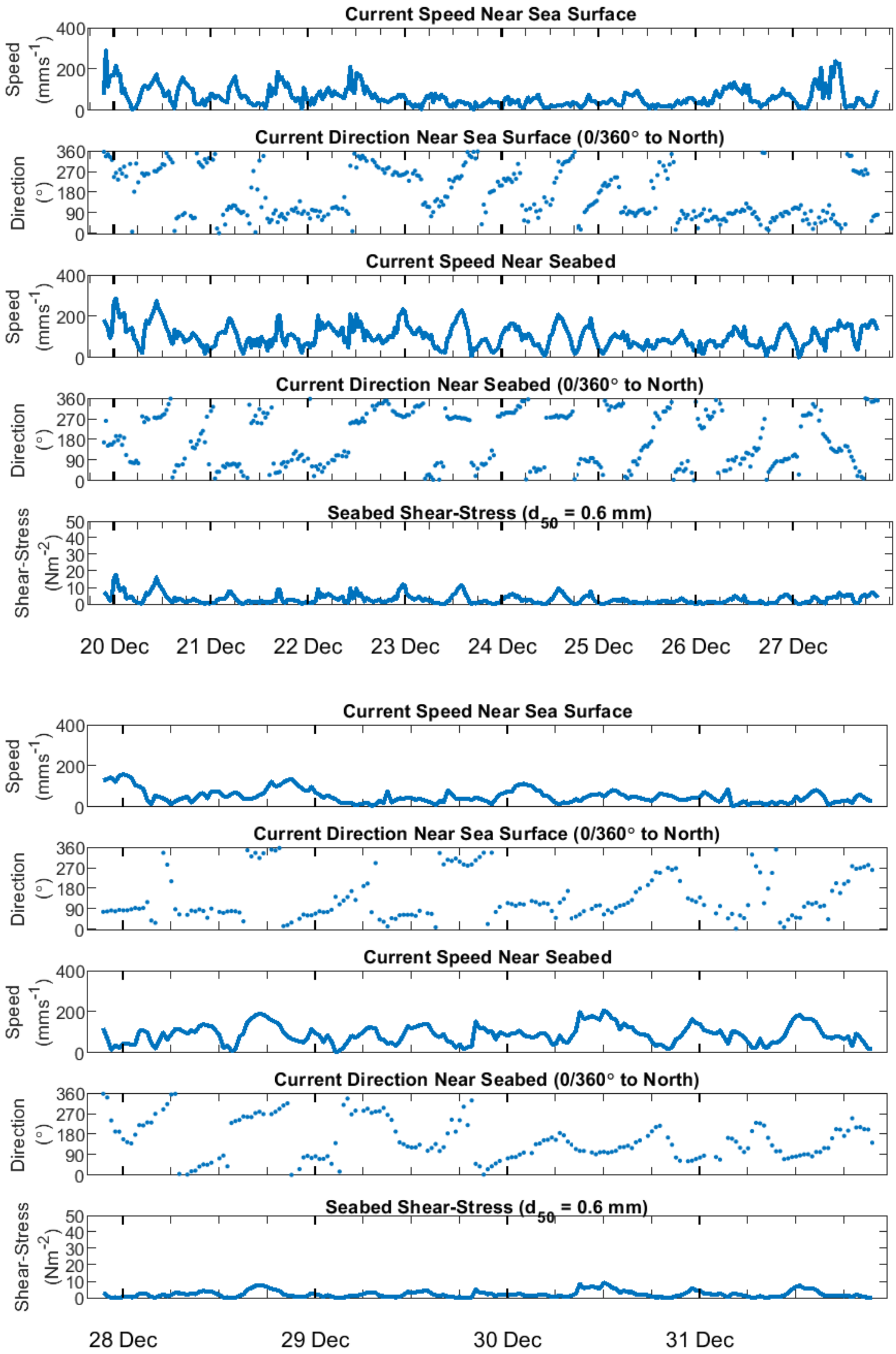
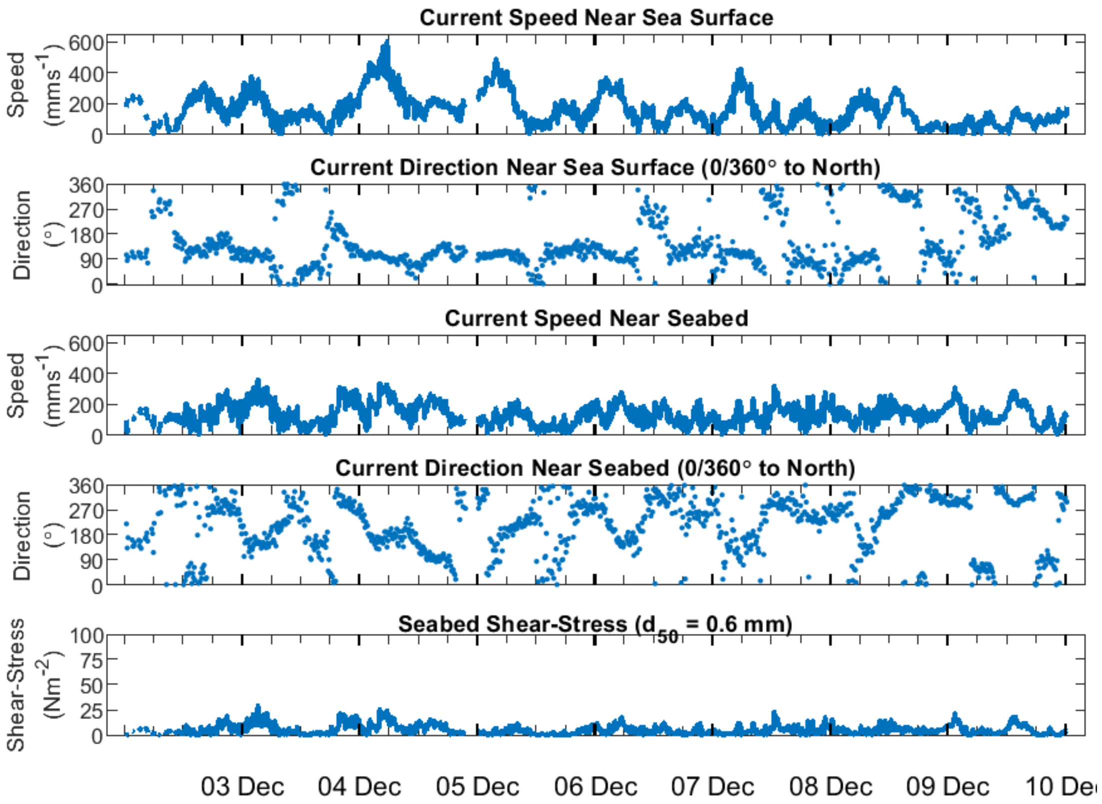


Figure 36 SG2a (WatchKeeper) current speed, direction and shear bed stress 19 to 31 December 2019.



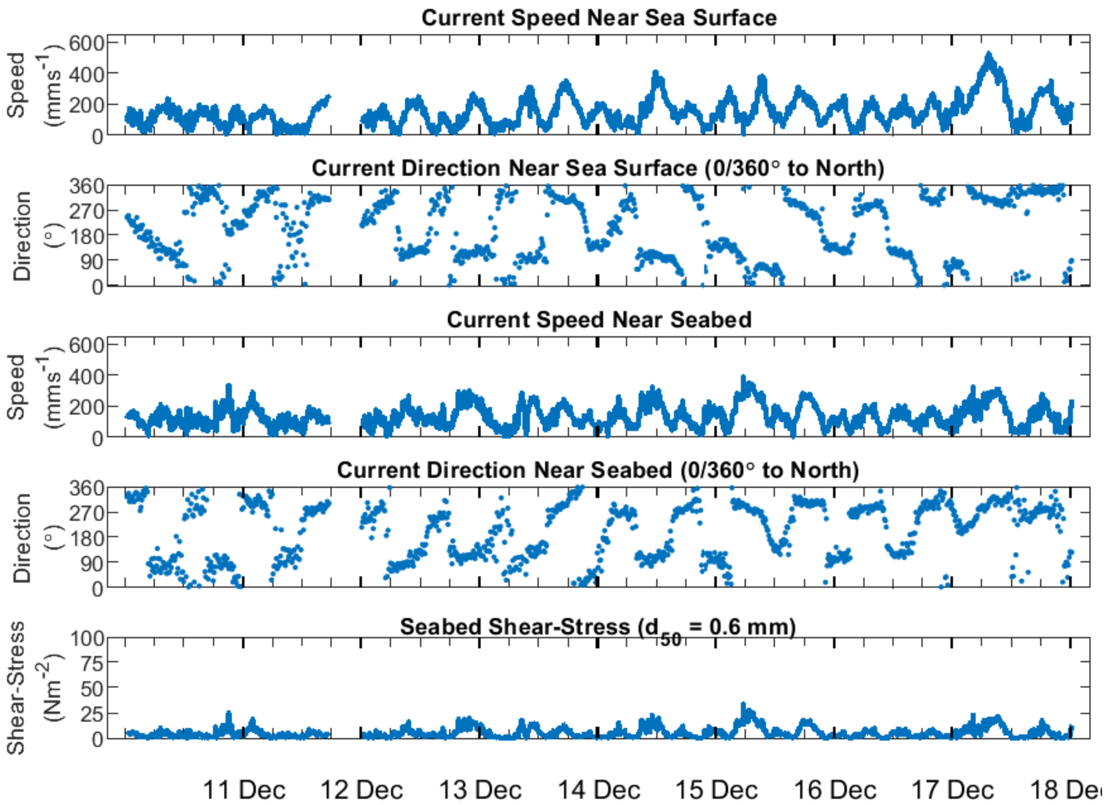


Figure 37 SG3 current speed, direction and shear bed stress 1 to 18 December 2019.

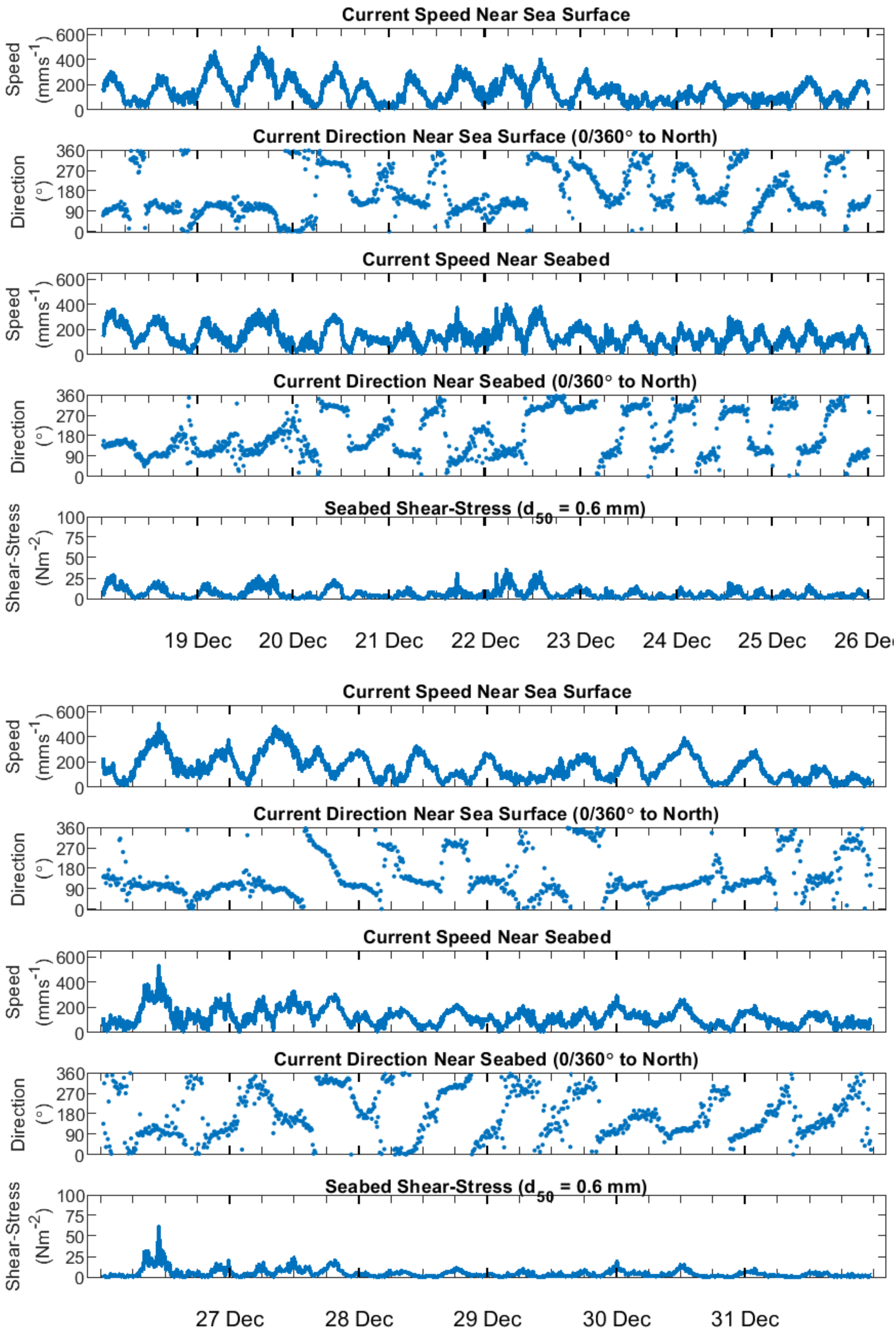


Figure 38 SG3 current speed, direction and shear bed stress 18 to 31 December 2019.

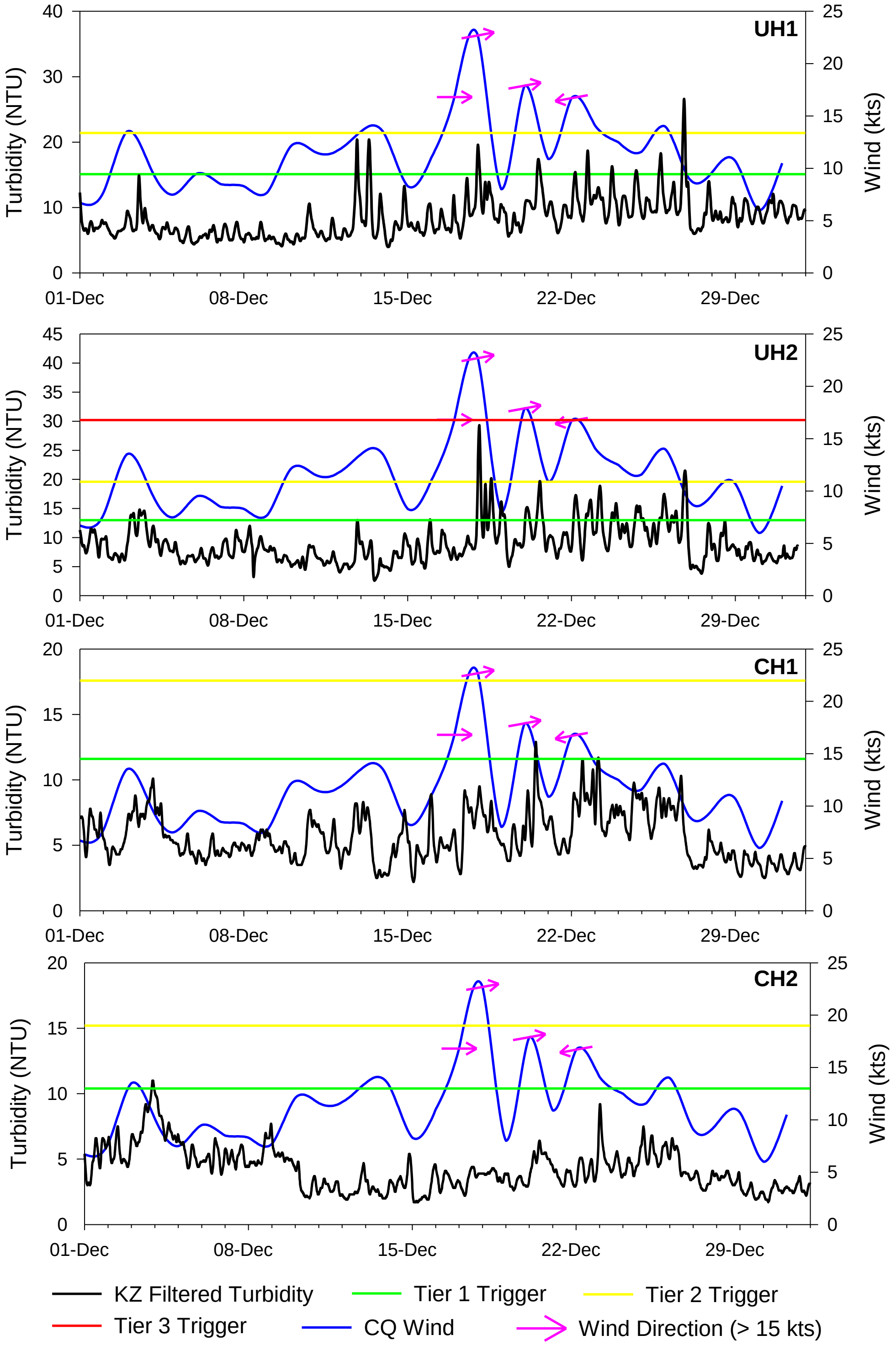


Figure 39 Surface KZ filtered turbidity and inshore daily averaged winds at inshore sites (UH1, UH2, CH1 and CH2) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for inshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

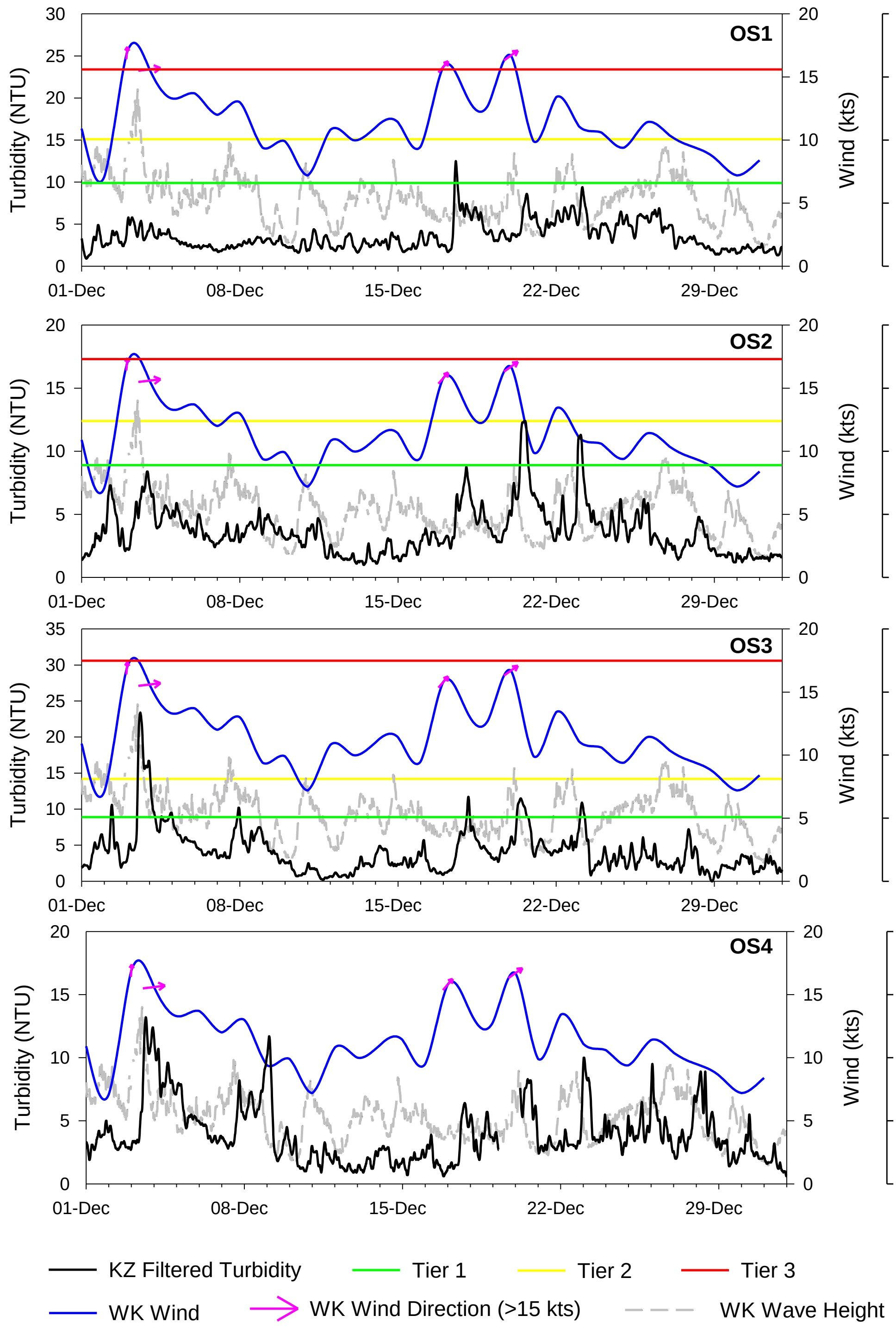


Figure 40 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS1 to OS4) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

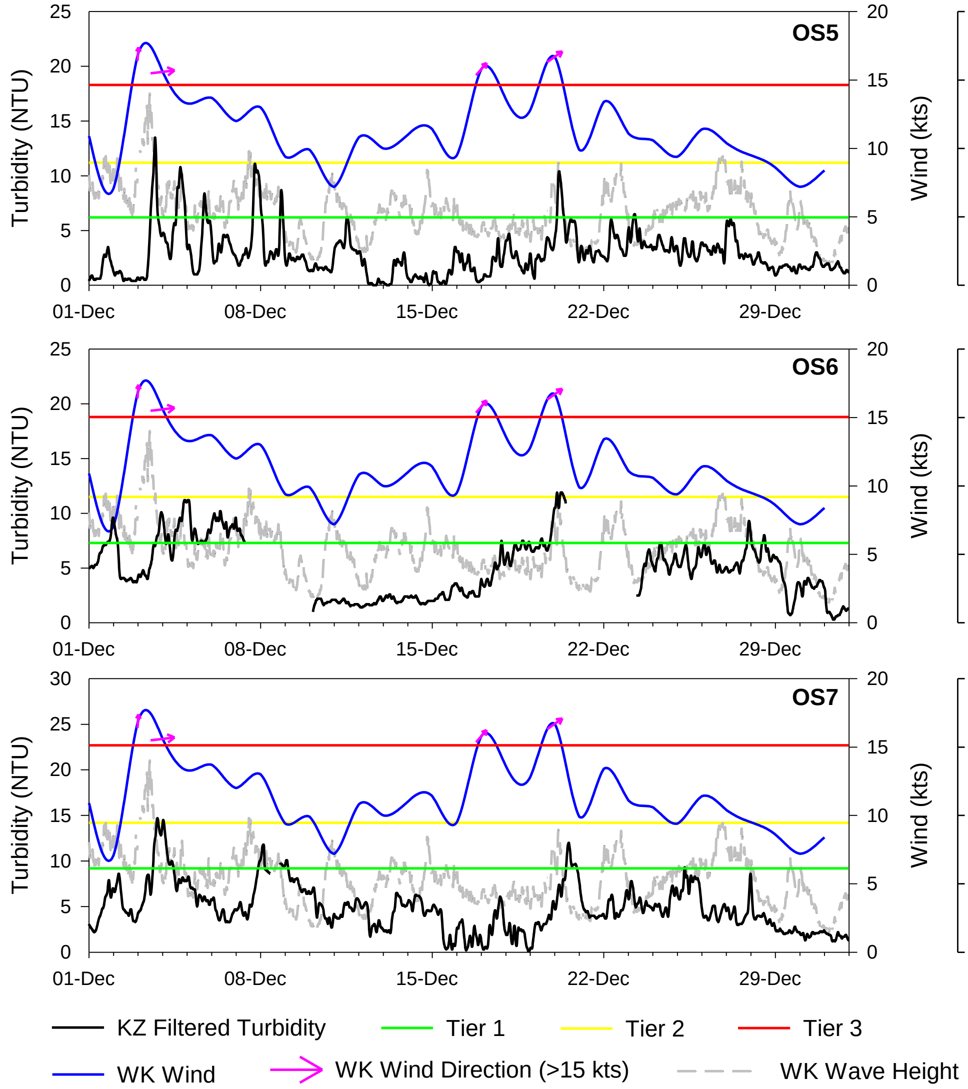


Figure 41 Surface KZ filtered turbidity and daily averaged winds at offshore sites (OS5 to OS7) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

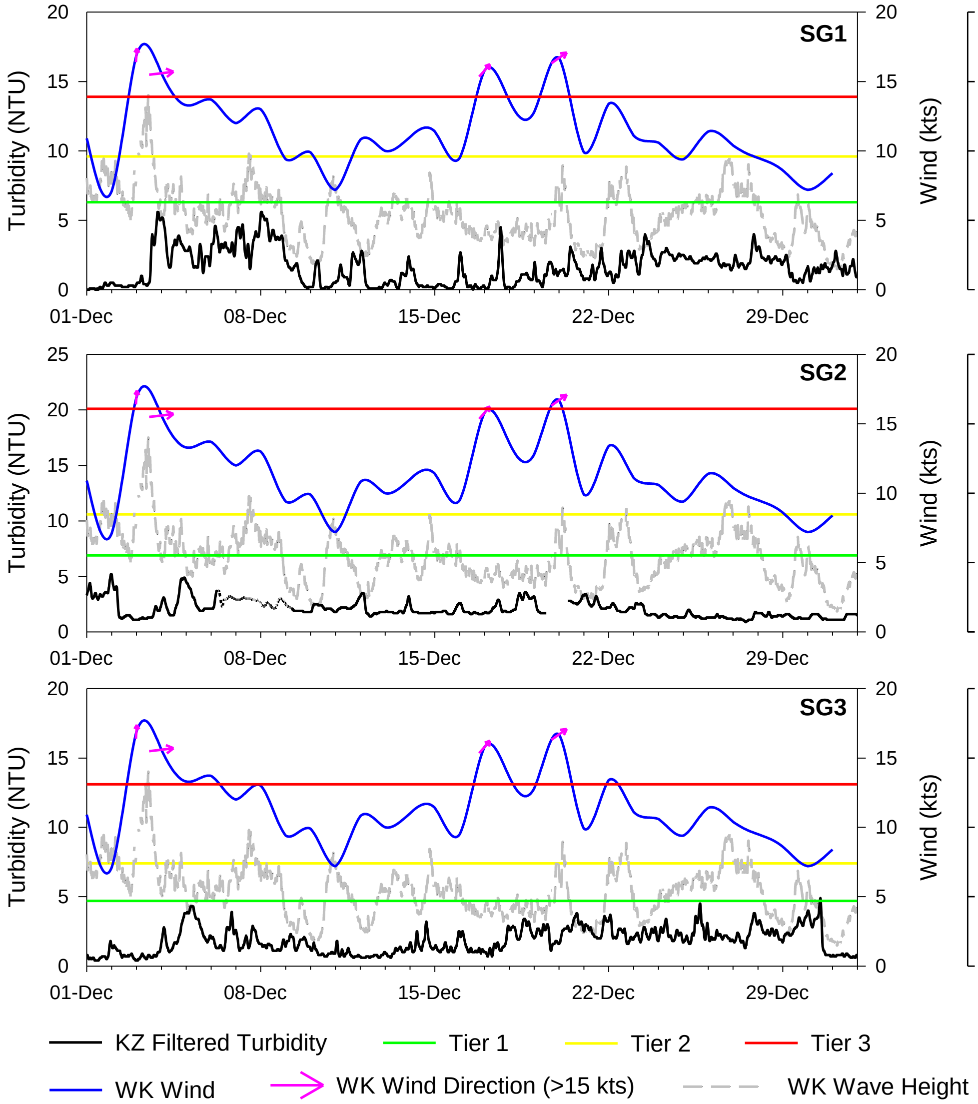


Figure 42 Surface KZ filtered turbidity and daily averaged winds at the spoil ground sites (SG1 to SG3) during December 2019.
Note differing scales for each plot. Arrows indicate the direction of travel for offshore winds greater than 15 knots. Horizontal lines indicate turbidity intensity tier levels.

Table 23 Mean KZ filtered turbidity and statistics at inshore water quality logger sites during December 2019 and baseline period 1 November 2016 to 31 October 2017
Values for December are means ± se, range and percentiles (n = 2945 - 2976). Baseline values modified from Fox 2018.

Site	KZ Filtered Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
UH1	Mean ± se	8.4 ± 0.1	12
	Range	4 – 26.6	2 – 155
	99th	18.7	37
	95th	14.1	21
	80th	10.6	15
UH2	Mean ± se	8.9 ± 0.1	9.9
	Range	2.6 – 29.3	2 – 59
	99th	19.5	29
	95th	15.2	19
	80th	11.2	13
CH1	Mean ± se	5.6 ± 0.0	8.8
	Range	2.2 – 12.9	<1 – 50
	99th	10.7	27
	95th	8.8	17
	80th	7.4	12
CH2	Mean ± se	4.2 ± 0.0	7.6
	Range	1.7 – 11	<1 – 39
	99th	9.4	22
	95th	7.0	15
	80th	5.4	10

Table 24 Mean KZ filtered turbidity and statistics at spoil ground water quality logger sites during December 2019 and baseline period 1 November 2016 to 31 October 2017.
Values for December are means ± se, range and percentiles (n = 2822 - 2976). Baseline values modified from Fox 2018.

Site	KZ Filtered Turbidity (NTU)		
	Statistic	Surface December	Surface Baseline
SG1	Mean ± se	1.6 ± 0.0	4.2
	Range	<1 – 5.6	<1 – 31
	99th	5.1	14
	95th	3.9	9.5
	80th	2.6	6.1
SG2	Mean ± se	2.0 ± 0.0	4.6
	Range	<1 – 5.2	<1 – 33
	99th	4.7	20
	95th	3.5	10
	80th	2.6	6.9
SG3	Mean ± se	1.8 ± 0.0	3.6
	Range	<1 – 4.9	<1 – 22
	99th	4	13
	95th	3.4	7.3
	80th	2.6	4.7

Table 25 Mean KZ filtered turbidity and statistics at offshore water quality logger sites during December 2019 and baseline period 1 November 2016 to 31 October 2017.
Values for December are means ± se, range and percentiles (n = 2437 to 2976). Baseline values modified from Fox 2018.

Site	Statistic	KZ Filtered Turbidity (NTU)	
		Surface December	Surface Baseline
OS1	Mean ± se	3.5 ± 0.0	7.5
	Range	<1 – 12.5	<1 – 99
	99th	8.6	23
	95th	6.6	15
	80th	4.9	9.7
OS2	Mean ± se	3.7 ± 0.0	6.4
	Range	1.0 – 12.4	<1 – 36
	99th	11.2	17
	95th	7.1	12
	80th	4.9	8.9
OS3	Mean ± se	4.1 ± 0.1	6.5
	Range	<1 – 23.4	<1 – 110
	99th	16.2	27
	95th	9.5	14
	80th	5.6	8.9
OS4	Mean ± se	3.9 ± 0.0	5.9
	Range	<1 – 12.2	<1 – 35
	99th	11.5	18
	95th	8.6	13
	80th	5.4	8.1
OS5	Mean ± se	2.8 ± 0.0	4.6
	Range	<1 – 13.5	<1 – 35
	99th	10.4	18
	95th	6.5	11
	80th	3.9	6.1
OS6	Mean ± se	4.9 ± 0.0	4.7
	Range	<1 – 11.9	<1 – 37
	99th	11.3	18
	95th	9.5	11
	80th	7.3	7.1
OS7	Mean ± se	4.8 ± 0.0	6.3
	Range	<1 – 14.7	<1 – 48
	99th	13.1	22
	95th	9.6	14
	80th	6.7	9.1

Table 26 Summary of Vision Environment quality control data for December 2019 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		
			OS 4 (A) (µg/L)	OS 4 (B) (µg/L)	Variation (%)
TSS	<3	<3	4	<3	ND
Dissolved Aluminium (µg/l)	<3	<3	<12	14	ND
Total Aluminium (µg/l)	<3.2	<3.2	33	30	10
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	<1.1	<1.1	ND
Dissolved Iron (µg/l)	<20	<20	10	4	86
Total Iron (µg/l)	<21	<21	34	35	3
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	1.6	1.7	6
Total Manganese (µg/l)	<0.53	<0.53	1.9	1.8	5
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	11.1	11.3	2
Total Molybdenum (µg/l)	<0.21	<0.21	11.8	11.8	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	<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	2	1.8	11
Total Vanadium (µg/l)	<1.1	<1.1	2.4	2.5	4
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	8	9	12
Dissolved Reactive Phosphorus (µg/l)	<4	<4	<1	< 1	ND
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	9	9	0
Nitrate-N + Nitrite-N (µg/l)	<2	<2	1.3	6.3	132
Chlorophyll *a* (µg/L)	<0.2	<0.2	1.4	1.4	0

Table 27 Summary of Vision Environment quality control data for December 2019 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		
			OS 4 (A) (µg/l)	OS 4 (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	<0.6	<0.6	ND
2,4,5-trichlorophenoxypropionic acid (245TP,Fenoprop, Silvex)	<0.4	<0.4	<0.6	<0.6	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	<1.1	<1.1	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	<0.6	<0.6	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	<0.6	<0.6	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	ND
Bromacil	<0.04	<0.04	<0.04	<0.04	ND
Bromophos-ethyl	<0.04	<0.04	<0.04	<0.04	ND
Bromopropylate	<0.04	<0.04	<0.04	<0.04	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			OS 4 (A) (µg/l)	OS 4 (B) (µg/l)	Variation (%)
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	<0.6	<0.6	<0.6	<0.6	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	<0.6	<0.6	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
Dimethoate	<0.08	<0.08	<0.08	<0.08	ND
Dinocap	<0.3	<0.3	<0.3	<0.3	ND

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			OS 4 (A) (µg/l)	OS 4 (B) (µg/l)	Variation (%)
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	<0.6	<0.6	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	<0.6	<0.6	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
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

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			OS 4 (A) (µg/l)	OS 4 (B) (µg/l)	Variation (%)
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	<1.1	<1.1	<1.1	<1.1	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
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

Parameter	VE Field Blank (µg/l)	VE Lab Blank (µg/l)	Duplicate		
			OS 4 (A) (µg/l)	OS 4 (B) (µg/l)	Variation (%)
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	<0.6	<0.6	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	<0.6	<0.6	ND
Trifluralin	<0.04	<0.04	<0.04	<0.04	ND
Vinclozolin	<0.04	<0.04	<0.04	<0.04	ND