WATER QUALITY REPORT

Mid Richmond River – Annual Progress Report, January 2022
Data supplied by Southern Cross University

1. Project Background

As part of a collaborative project between Rous County Council, NSE Department of Planning, Industry and Environment, and Southern Cross University, a network of real-time water quality loggers has been installed throughout the mid and lower Richmond River catchment.

The project was commissioned in February 2021.

2. Report Aims and Objectives

The aim of this Annual Progress Report is to present and discuss the data collected for the 12-month period ending January 31st 2022.

3. Project Methodology

3.1. Monitoring sites

The water quality loggers are located at eight sites throughout the mid and lower Richmond River and its key tributaries as shown in Figure 1.

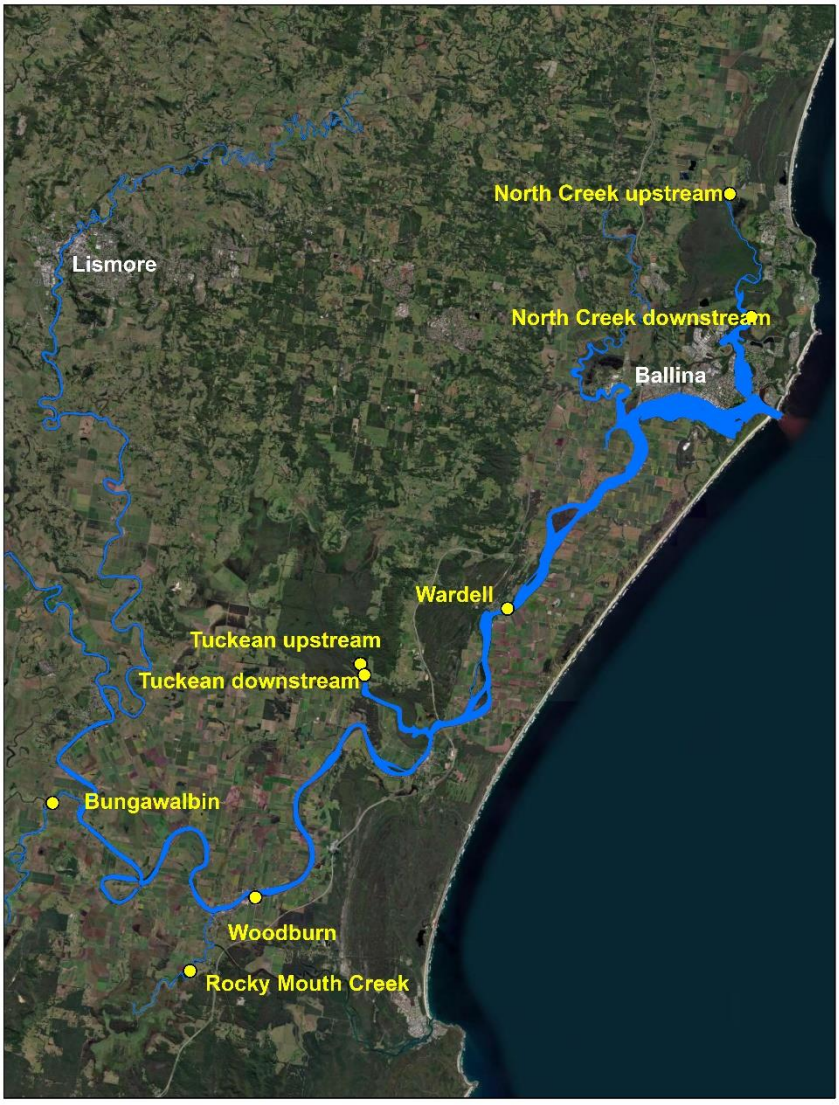

Figure 1 Location of the eight water quality loggers (yellow text).

council@rous.nsw.gov.au 218-232 Molesworth St, Lismore 02 66233 800

3.2. Logger design and function

The loggers were designed, built and installed by the team at Southern Cross University. A key innovation of the loggers includes pumping water samples to a permanent housing that allows samples to be taken with less risk of damage to expensive monitoring equipment. The solar powered housings were designed and installed by the flood mitigation team at Rous County Council (refer to Figure 2 for photos). The loggers are located on the riverbank at each location except for the sentinel site (Wardell) which is deployed on the Wardell Bridge. Upon completion of the installation a joint media release was published on the project.

Figure 2 Rous County Council Flood Mitigation Operators installing a logger housing at the Tuckean Upstream site (left) and SCU staff at the Rocky Mouth Creek site following logger installation (right).

The loggers measure fundamental water quality parameters including:

- Water temperature (^{o}C)
- Dissolved Oxygen (DO) reported as concentration (mg L^{-1}) and percentage saturation (%sat)
- Conductivity (mS cm^{-1})
- Salinity (ppt)
- pH
- Turbidity (NTU) which is a measure of water clarity

At Woodburn and Wardell, the loggers measure the water quality parameters in surface waters and bottom waters. Additional probes are also installed at these sites to measure:

- Chromophoric dissolved organic matter (CDOM; QSE µg L^{-1}) which a measure of dissolved organic carbon
- Chlorophyll a (Chl a; µg L^{-1}) which is a proxy of algal biomass

Measurements are made at either 30 min or 60 min intervals depending on the site.

3.3. Data Accessibility

The data is transmitted after every measurement to a publicly available Dashboard that is linked to the Rous County Council Website (https://rous.nsw.gov.au/water-quality-in-the-richmond).

The Dashboard provides a user-friendly interface for the public to toggle between monitoring sites and view real-time data. Users have the ability to view the data at daily, weekly or monthly time scales. There is also the additional capability of viewing data for a custom period of time within the previous two months. Example screen shots of the dashboard are presented in Figure 3. Data is also stored to an on-board SD card at each site.

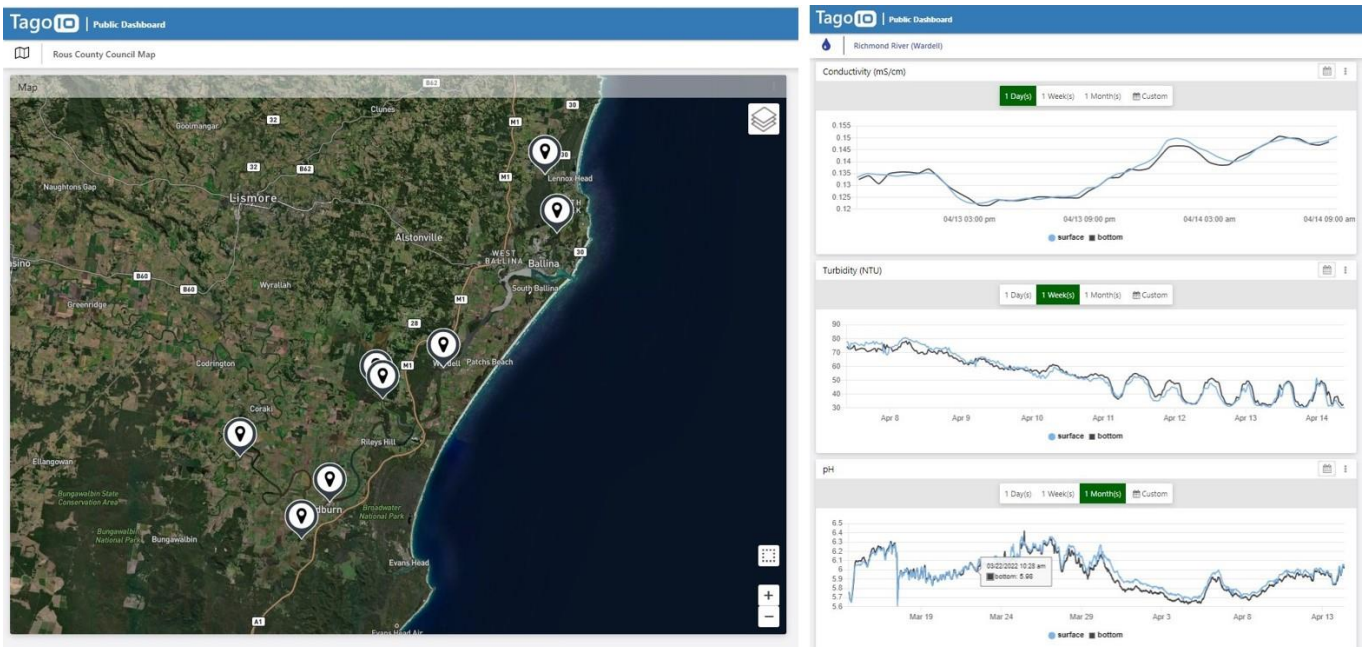

Figure 3 Example screenshots of the Dashboard that is linked to the Rous County Council website. A map shows the location of loggers and allows users to select sites (left). Data can be viewed at daily, weekly, monthly or custom time scales (right).

3.4. Quality Assurance/Quality Control

Southern Cross University is responsible for QA/QC procedures which involve the following:

- Data review: includes assessment of sudden increases or decreases in parameters that cannot be explained by natural processes such as rainfall, tides, diurnal productivity/respiration, etc. The data includes information on system voltage to assist QA/QC e.g. if battery voltage does not drop when the logger pump is running during an analysis data is removed as the pump is faulty.
- Monthly calibration checks of loggers. The calibration procedure varies between sensors and is outlined in Table 1. It is noted that during the commissioning phase, testing revealed that the optical and electrical sensors installed (DO, temperature, conductivity, salinity, turbidity, CDOM and Chl a) have minimal drift over monthly intervals, and pH drift is < 0.1 units per month.

Table 1 Sensor details and calibration procedure.

Parameter	Sensor type	Calibration values	Comments
pH	Double junction industrial pH sensor	4.00, 7.00, 10.00	Drift during commissioning phase found to be <0.1 per month
Conductivity/salinity	Electrical conductivity	0 and 54 mS cm^{-1} (high salinity sites), 0 and 2.76 mS cm^{-1} (low salinity sites)	No calibration drift observed during commissioning phase
Dissolved oxygen	Optode (optical sensor)	100% saturated	No calibration drift observed during commissioning phase
Turbidity	Optical sensor	0, 100 and 900 NTU	No calibration drift observed during commissioning phase
Temperature	Thermistor	Does not require calibration	No calibration drift observed during commissioning phase
Chlorophyll a	Optical sensor	Factory calibrated	No calibration drift observed during commissioning phase
CDOM	Optical sensor	Factory calibrated	No calibration drift observed during commissioning phase

4. Review of Logger Setup

The loggers, which perform measurements every 30-60 minutes of the day, are permanently deployed in the environment which presents challenging conditions for the ongoing operation, performance and security of the system.

The novel utilisation of pumps to transport water samples to a permanent housing has guaranteed the security of the expensive instruments during the first year of operation. However, there have been many unforeseen or underestimated environmental challenges that have resulted in gaps in the data and a higher than anticipated maintenance routine. For example:

- High suspended solid loads, iron floc and biofouling leading to:
  - Compromised pump rates and early pump failure
  - Faster than expected rates of fouling/sediment build up in sampling vessel and on sensors
- Underestimated force of tidal currents leading to hosing becoming kinked and electrical cabling becoming scored or severed
- Fauna eating hosing and electrical cabling

There are also site-specific limitations such as:

- Wardell Bridge – access for maintenance must coincide with NSW RMS dates and times
- North Creek Downstream – the low gradient slope of the bank requires a 20+ metre length of hose to pump the water to the secure housing which has resulted in:
  - poor flow rates
  - artificial heating of the sampling water due to recurrent solar exposure of the hose
  - intermittent periods when the depth of the water is too low for sampling
  - resuspension of bottom sediments inflating turbidity values
- Woodburn – sampling for stratification from the bank is compromised due to the distance required to access waters of an acceptable depth
- Whilst all sites are subject to this issue, poor mobile reception routinely affects the telemetered data transfers at Bungawalbin and North Creek Upstream

Despite these unforeseen challenges and site limitations, the setup has successfully accrued a large dataset that will be presented in the proceeding sections.

5. Climate – February 2021 to January 2022

Climatological data for Lismore and Ballina for the 12-month period ending January 31st 2022 along with long-term monthly averages are presented in Figure 4.

Overall, the reporting period was characterised by wetter and cooler conditions with rainfall skewed towards the beginning and end of the reporting period:

- Ballina recorded 2196 mm which was ~20% higher than its long-term calendar year average of 1784 mm
- Lismore recorded 1566 mm which was ~30% higher than its long-term calendar year average of 1217 mm
- February and March were very wet and capped off the 2020-21 La Niña event which resulted in locations within the catchment recording their highest ever summer rainfall totals – Rock Valley, Nashua, Nimbin, McLeans Ridges, Casino
- Conditions from May through September were relatively dry with total rainfall during this period ~50% below average
- La Niña was declared again in November resulting in above average rainfall during the 2021-22 summer
- The mean daily maximum air temperature for each month was generally below long-term averages – consistent with La Niña events

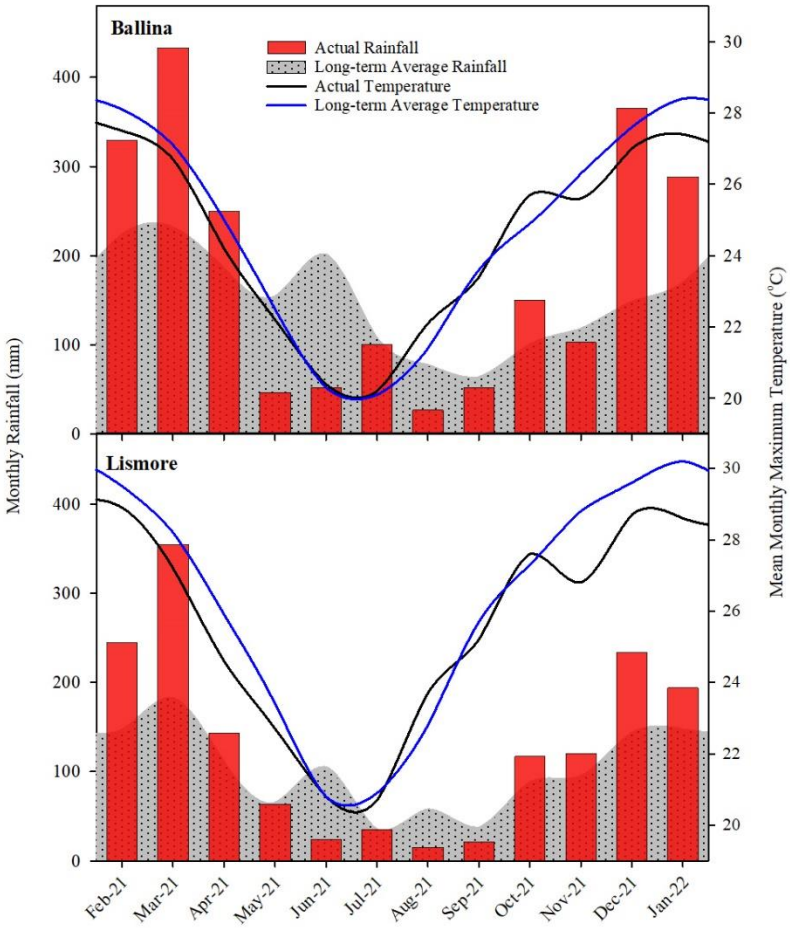

Figure 4 Total monthly rainfall for Lismore and Ballina along with long-term monthly averages. Source www.bom.gov.au

The recorded rainfall pattern is expected to result in highly variable water quality across the sites during the reporting period. Whilst data is limited for the first seven months due to the staged installation of the logger network from March through July, the data set will provide interesting insights into water quality under the following hydrological conditions:

- A period of significant rainfall (February and March) against a backdrop of high antecedent soils moisture levels (following the 2020-21 summer La Niña) and reduced evaporation (due to cloudiness and milder temperatures) resulting in large freshwater inputs from surface water runoff
- A period of relatively dry weather (May through September) with limited surface runoff but inputs from floodplain drainage and tidal ingression
- A return to above-average rainfall conditions with monthly rainfall totals increasing incrementally along with soil moisture levels

6. Water Quality Results

6.1. Overview of results and comparison with ANZECC

Figure 5 and Figure 6 present box and whisker plots for key water quality parameters for each site. The ANZECC default guideline range is included in both figures and is based on the upper and lower trigger values for slightly disturbed Lowland Rivers and Estuaries in south-east Australia.

Table 2 presents the proportion of data points that do not meet the ANZECC guidelines at each site.

It is noted that the ANZECC default trigger values are set conservatively and generic to broad geographical regions and water types. The trigger values can be refined to be site specific when based on local reference data and risk-based decision frameworks. The development of localised guideline values is preferred, however, in their absence the default trigger values have been used for benchmarking water quality.

Key observations include:

- There is considerable intra- and inter-site variability for each parameter
- The range of conductivity values are as to be expected for each site
- DO is generally poor across all of the sites
    - The mean value at each site is below the ANZECC guideline range
    - DO is highest in the main river channel, however, values did not meet ANZECC guidelines ~70% of the time at Woodburn and 80% of the time at Wardell
    - DO is lowest in the tributaries, did not meet guideline values ~95% of the time with anoxic waters observed at Rocky Mouth Creek
- Similarly to DO, pH is lowest in the tributaries and higher in the main river channel
    - pH in the main channel (Woodburn, Wardell) is, on average, within the ANZECC trigger range
    - pH does not meet guideline values 85% of the time at Rocky Mouth Creek and 96-100% of the time at the Tuckean sites and North Creek Upstream
        - pH < 4 occurs in the tributaries
- Turbidity is, on average, within guideline values at Bungawalbin and Rocky Mouth Creek

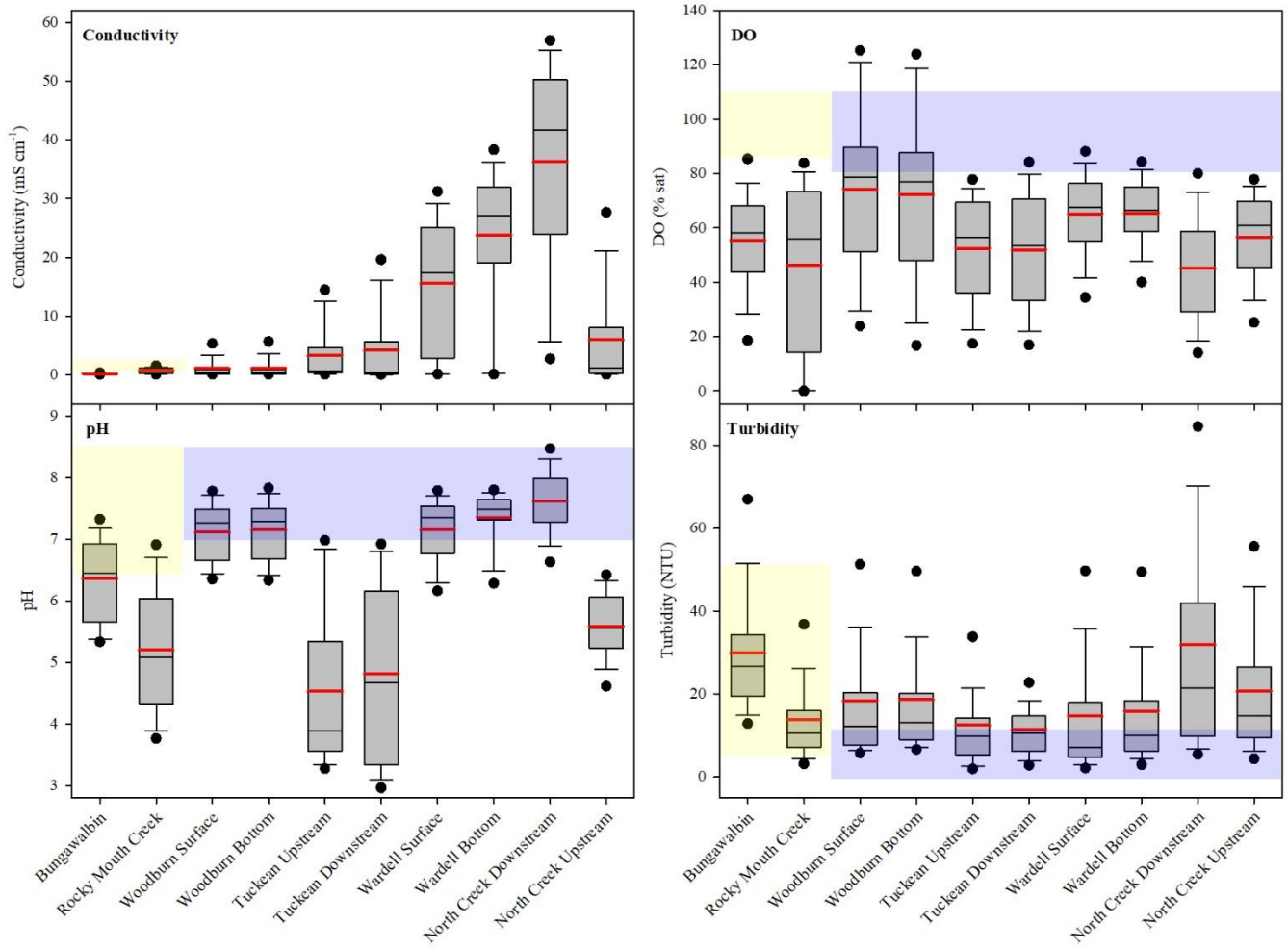

Figure 5 Box and whisker plots for EC, DO, pH and Turbidity for each site showing mean value (red line), median, 25th/75th percentiles (grey box), 10th/90th percentiles (whisker caps) and 5th/95th percentiles (black circles). The shaded areas represent the ANZECC guideline ranges for slightly disturbed Lowland Rivers (yellow) and Estuaries (blue) in south-east Australia.

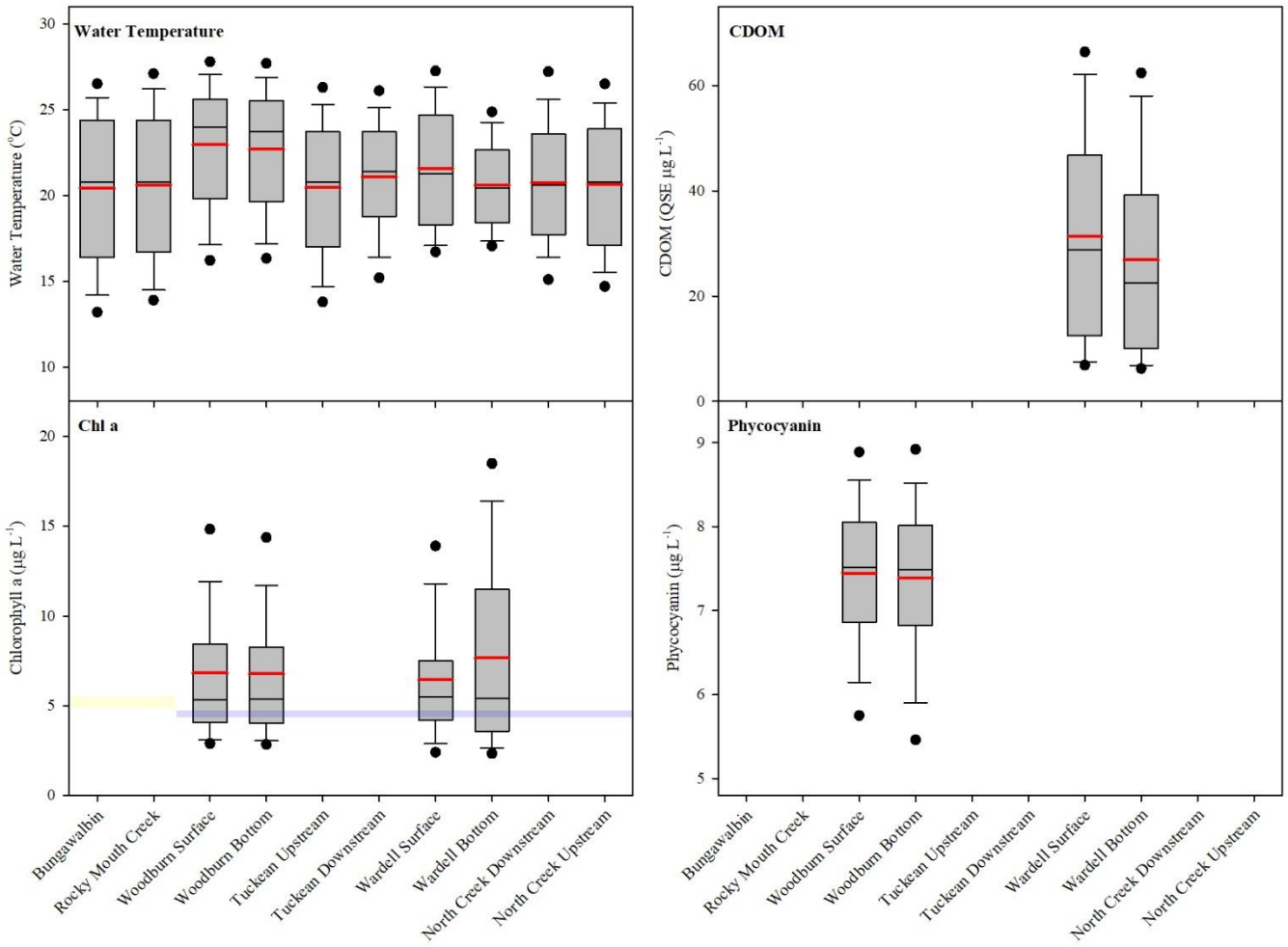

Figure 6 Box and whisker plots for water temperature, CDOM, Chlorophyll a and Phycocyanin for each site showing mean value (red line), median, 25th/75th percentiles (grey box), 10th/90th percentiles (whisker caps) and 5th/95th percentiles (black circles). The shaded areas represent the ANZECC guideline ranges for slightly disturbed Lowland Rivers (yellow) and Estuaries (blue) in south-east Australia.

Table 2 Percentage of samples that did not meet ANZECC guidelines for dissolved oxygen, pH and turbidity at each site (the ANZECC guideline range for Estuaries is shown in *italics* for each parameter).

	Percentage of samples that do not meet ANZECC guidelines		
	Dissolved Oxygen ***(80-110 % sat)***	**pH** ***(7-8.5)***	**Turbidity** ***(0.5-10 NTU)***
Bungawalbin	95%[a]	53%[b]	12%[c]
Rocky Mouth Creek	96%[a]	85%[b]	20%[c]
Woodburn Surface	69%	37%	59%
Woodburn Bottom	69%	32%	67%
Tuckean Upstream	97%	96%	49%
Tuckean Downstream	90%	98%	54%
Wardell Surface	82%	34%	39%
Wardell Bottom	87%	17%	50%
North Creek Upstream	97%	100%	72%
North Creek Downstream	95%	17%	74%

[a] ANZECC guideline range 85-110 %sat
[b] ANZECC guideline range 6.5-8.5
[c] ANZECC guideline range 6-50 NTU

Values of the key water quality parameters DO, pH and turbidity spanned wide ranges across the sites indicating water quality ranged from being anoxic, turbid and acidic (i.e. pH <4) to within or close to ANZECC guidelines. Table 3 shows the percentage of time water quality was quite poor based on DO being < 50 %sat, pH <5 and turbidity > 20 NTU.

Table 3 Percentage of time that DO was < 50 %sat, pH < 5 and turbidity > 20 NTU.

	Percentage of samples that were below the following thresholds		
	DO < 50 %sat	**pH < 5**	**Turbidity > 20 NTU**
Bungawalbin	32%	0%	72%
Rocky Mouth Creek	45%	51%	16%
Woodburn Surface	24%	0%	26%
Woodburn Bottom	28%	0%	25%
Tuckean Upstream	40%	71%	11%
Tuckean Downstream	46%	53%	7%
Wardell Surface	18%	0%	23%
Wardell Bottom	12%	0%	22%
North Creek Upstream	31%	13%	34%
North Creek Downstream	60%	0%	52%

6.2. Times-series results

The following Sections present the time-series data for selected water quality parameters for each site. ANZECC guideline ranges have been included along with daily rainfall. Bungawalbin, Rocky Mouth Creek, Wardell and Woodburn also include water level data sourced from Manly Hydraulics Laboratory.

6.2.1. Bungawalbin

Bungawalbin commenced logging data on the 29th April.

Timeseries data is presented in Figure 7.

Key observations from Bungawalbin:

- DO was only within ANZECC guidelines for 5% of the time which occurred during the dry period (August)
    - Rainfall depresses DO values with large rainfall events resulting in very low that can remain depressed for weeks whilst the floodplain drains e.g.DO dropped to ~10 %sat during December and remained <50 %sat during low tides as water drained the floodplain
- Similarly, rainfall depresses pH to values below ANZECC guidelines with large rain events resulting in pH dropping to ~ 5.5 and remaining depressed as the floodplain drains
- Turbidity is only outside of ANZECC guideline values during rain events and immediately after

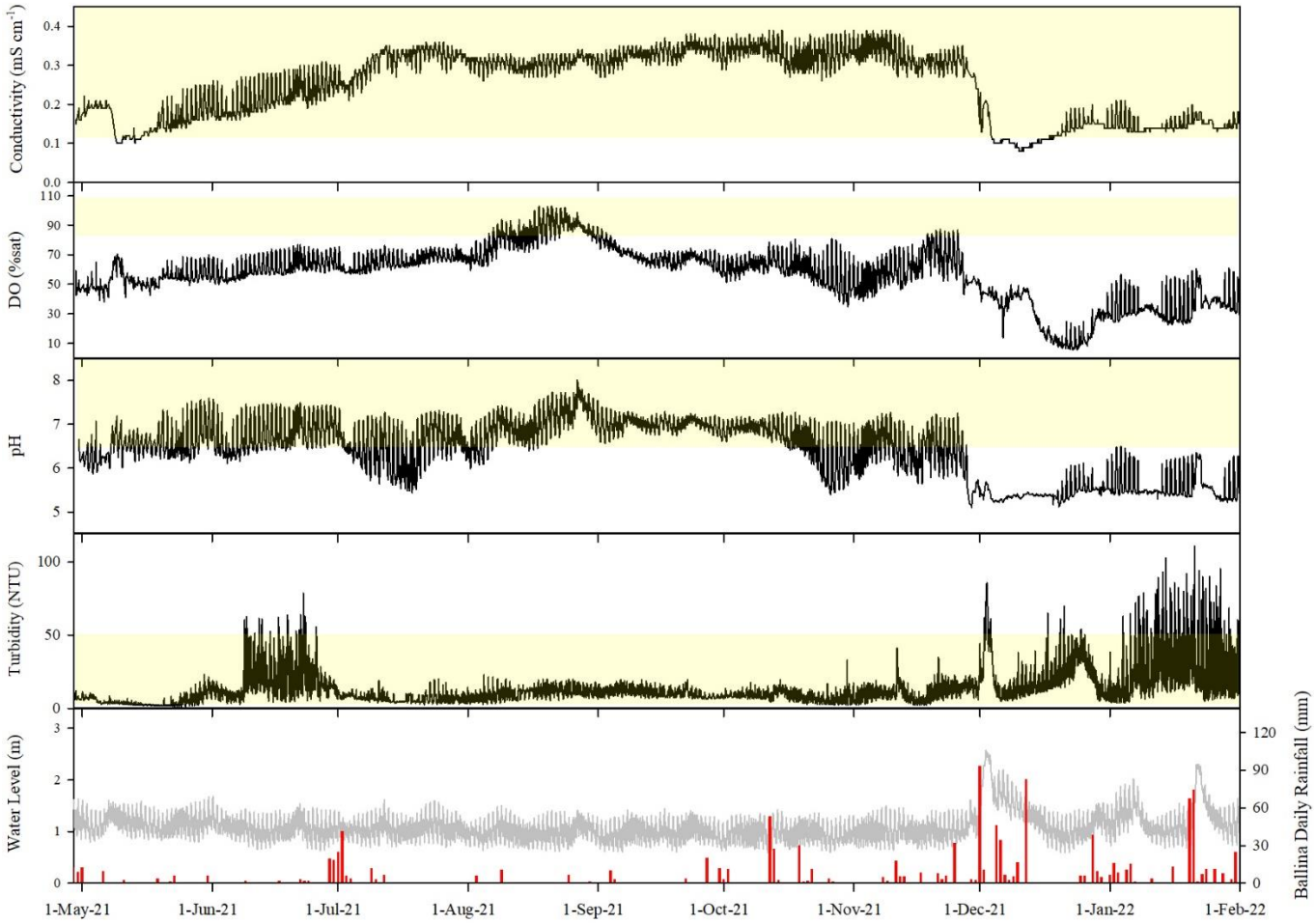

Figure 7 EC, DO, pH, turbidity and water temperature at Bungawalbin. Yellow shaded area represents the ANZECC guideline range for slightly disturbed Lowland Rivers in south-east Australia.

6.2.2. Rocky Mouth Creek

Rocky Mouth Creek commenced logging data on the 3rd March.

Timeseries data is presented in Figure 8.

Key observations from Rocky Mouth Creek:

- DO was only within ANZECC guidelines 4% of the time which occurred on high tides during the dry period
    - Anoxic water is routinely observed following large rain events (e.g. March, April and December) with DO remaining depressed for weeks as the floodplain drains
- Similarly, pH was only within ANZECC guidelines 15% of the time when there had been an extended period without rainfall (i.e. weeks) and intrusion of tidal waters occurred
    - pH routinely drops to <4
    - pH is largely controlled by rainfall and antecedent soil moisture levels which drive the resultant hydraulic gradients between the acidic floodplain soils and the river
- Turbidity is only outside of ANZECC guideline values during rain events and immediately after

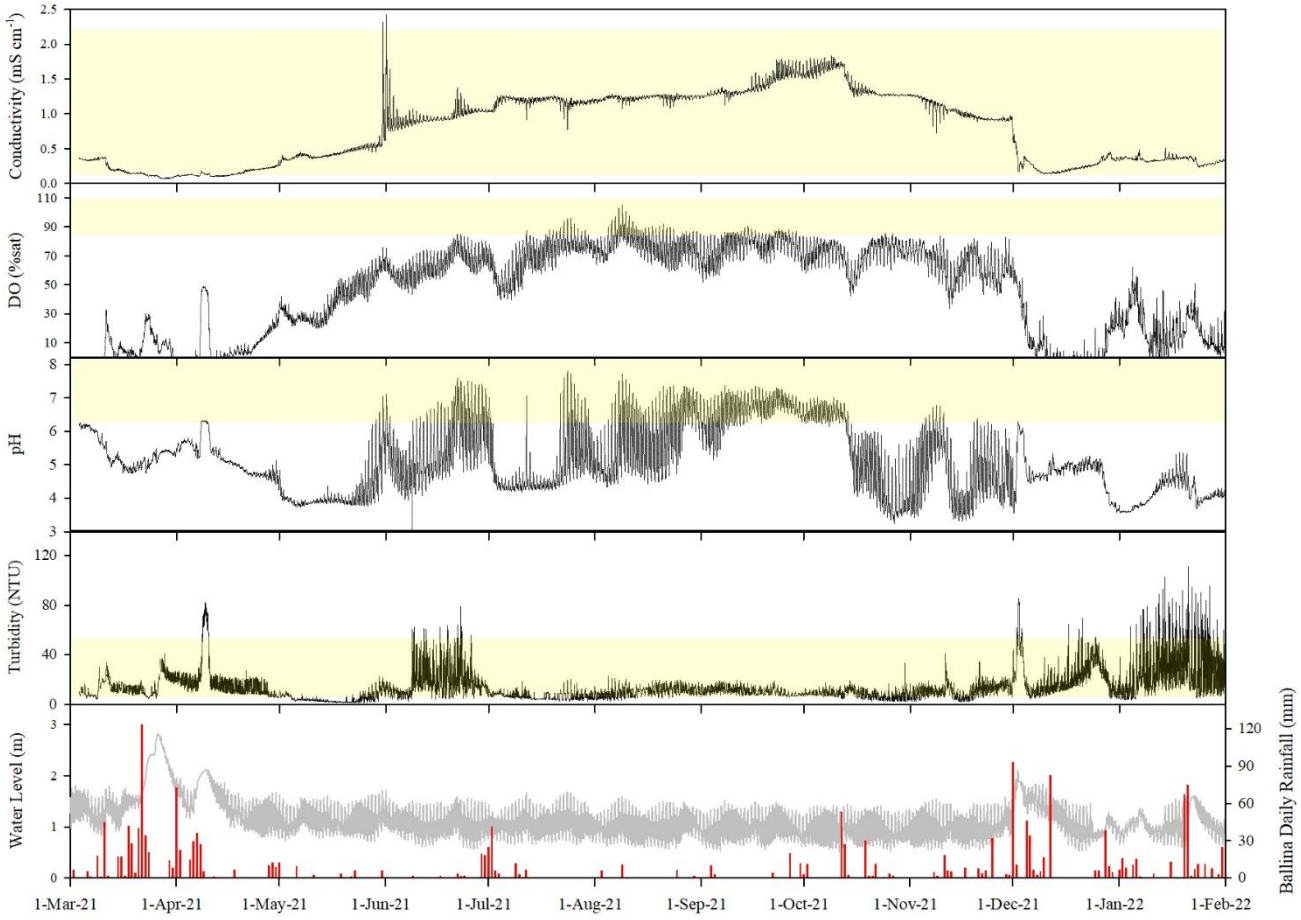

Figure 8 EC, DO, pH, turbidity and water temperature at Rocky Mouth Creek. Yellow shaded area represents the ANZECC guideline range for slightly disturbed Lowland Rivers in south-east Australia.

6.2.3. Woodburn

Woodburn was the last site to be installed, commencing data logging from 28th July 2021.

Timeseries data is presented in Figure 9 and Figure 10.

Key observations include:

- Brackish tidal water dominated the water column during the dry period (August through October)
  - DO was within ANZECC guidelines during this time except the first few weeks of August when waters were super-saturated (>110 %sat) in DO suggesting high primary productivity at that time
  - pH was also within ANZECC guidelines during this period
  - Rainfall in October resulted in a fresh water column for a few weeks but DO and pH still remained within ANZECC
  - Turbidity driven by tidal activity with values generally outside of the guidelines
- Fresh water dominated the water column from mid-November onwards when La Nina re-established
  - Water levels rose to >2m at the start of December and twice in January
  - DO and pH levels dropped considerably towards the end of November and remained below ANZECC guidelines for the remainder of the reporting period
    - The return to more normal water levels following the December peak coincided with the bottoming out of DO (~10 %sat) and pH (~6) as the worst of the water drained the floodplain and moved downstream
  - Turbidity levels spiked immediately with the onset of rain in December and late January

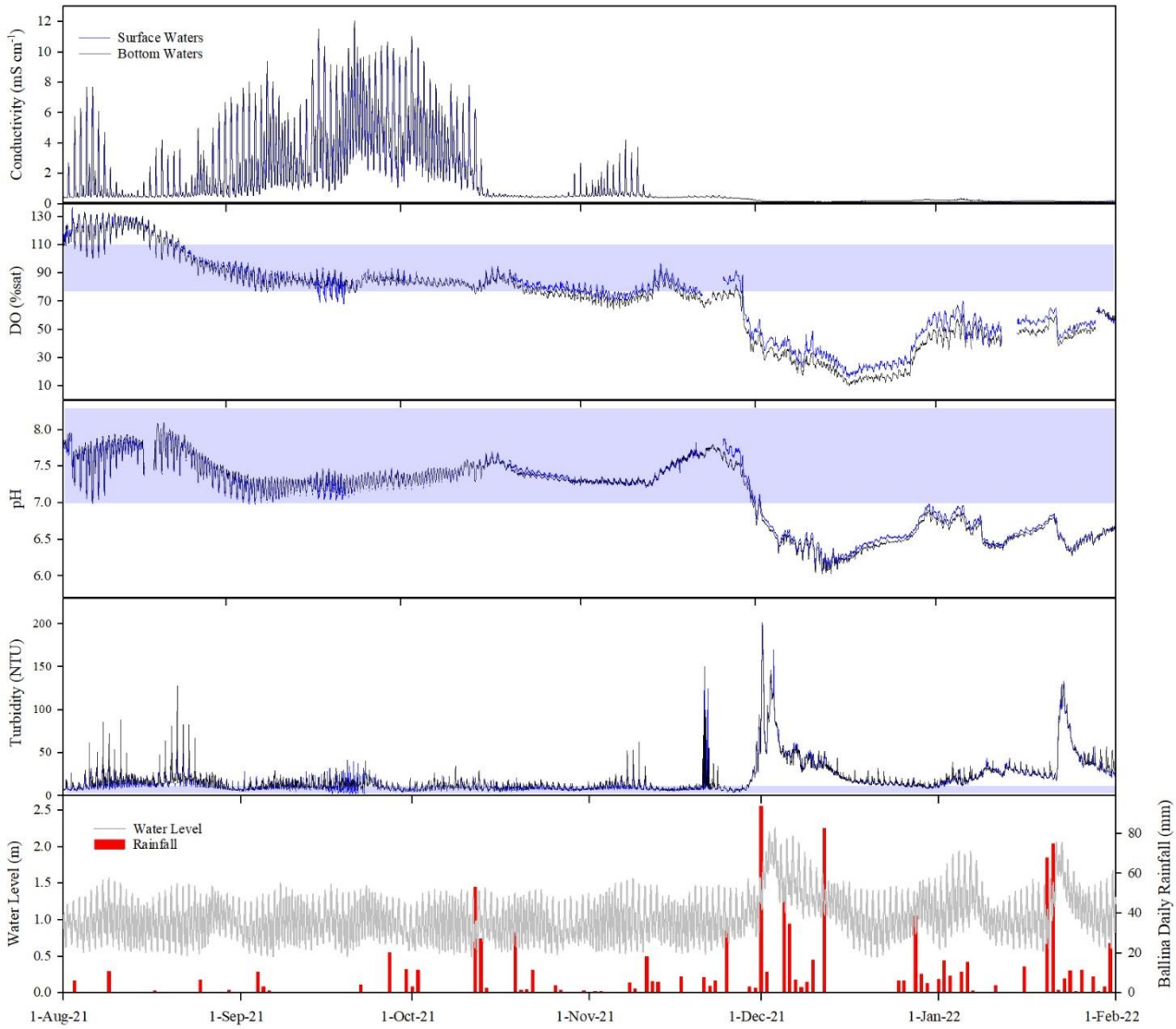

Figure 9 EC, DO, pH and Turbidity at Woodburn. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

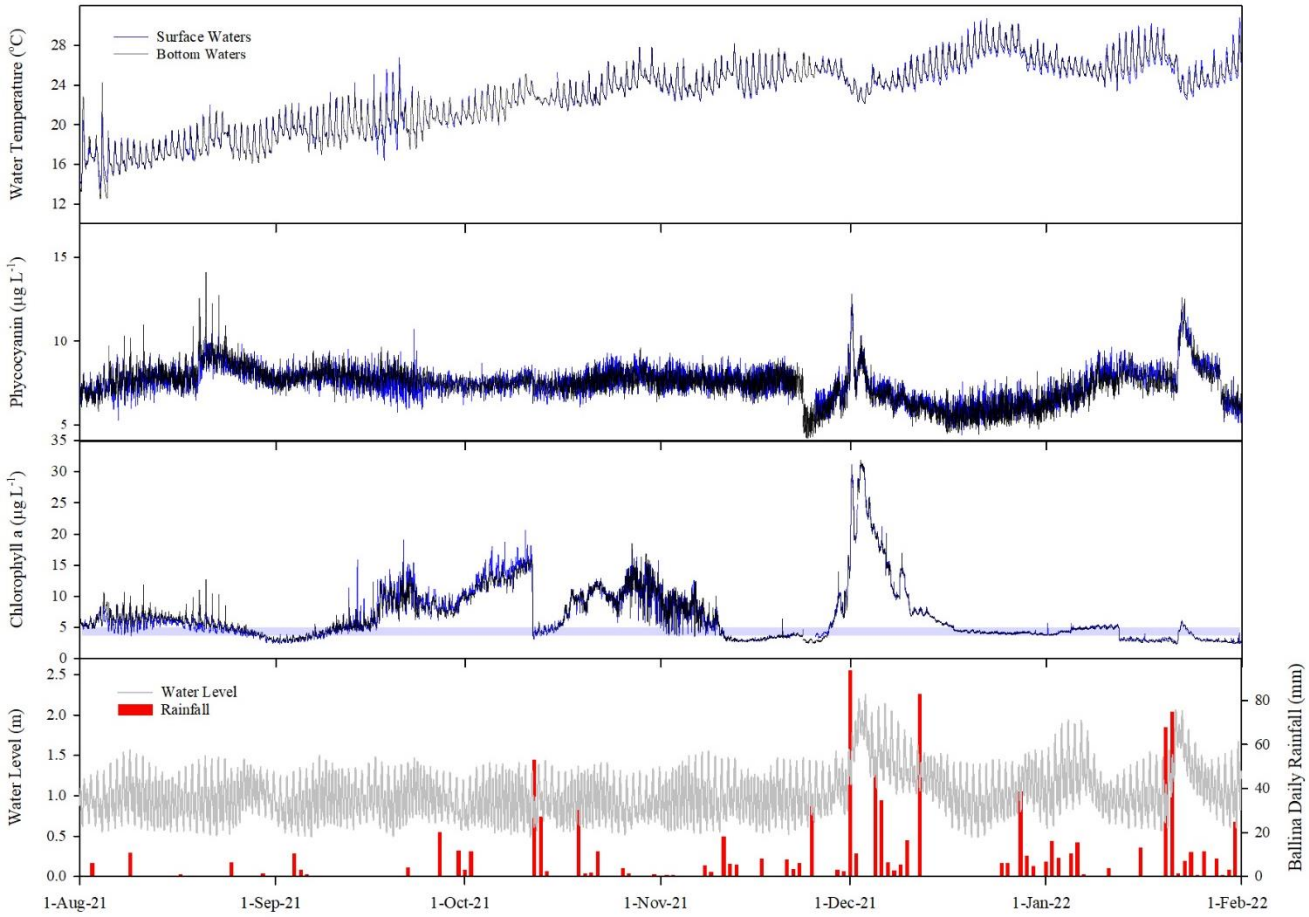

Figure 10 Water temperature, Phycocyanin, and Chlorophyll a at Woodburn. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

6.2.4. Tuckean Downstream and Upstream

Tuckean Downstream and Upstream commenced logging on the 3rd and the 11th March, respectively.

Timeseries data is presented in Figure 11.

Key observations from the Tuckean sites:

- The trends at the Tuckean are similar to those observed at Rocky Mouth Creek
- DO was only within ANZECC guidelines 3% of the time at the Upstream site and 10% of the time at the Downstream site, all of which largely occurred during the dry period when tidal waters intrude the drain
    - Low DO water is routinely observed following large rain events (e.g. March, April and December) with DO remaining depressed for weeks as the floodplain drains
- Similarly, pH was only within ANZECC guidelines ~3% of the time when there had been an extended period without any significant rainfall (i.e. weeks) and intrusion of tidal waters occurred (i.e. September)
    - pH routinely drops to the low 3s
    - pH is largely controlled by rainfall and antecedent soil moisture levels which drive the resultant hydraulic gradients between the acidic floodplain soils and the river
- Turbidity is generally outside of ANZECC guideline values during following rainfall

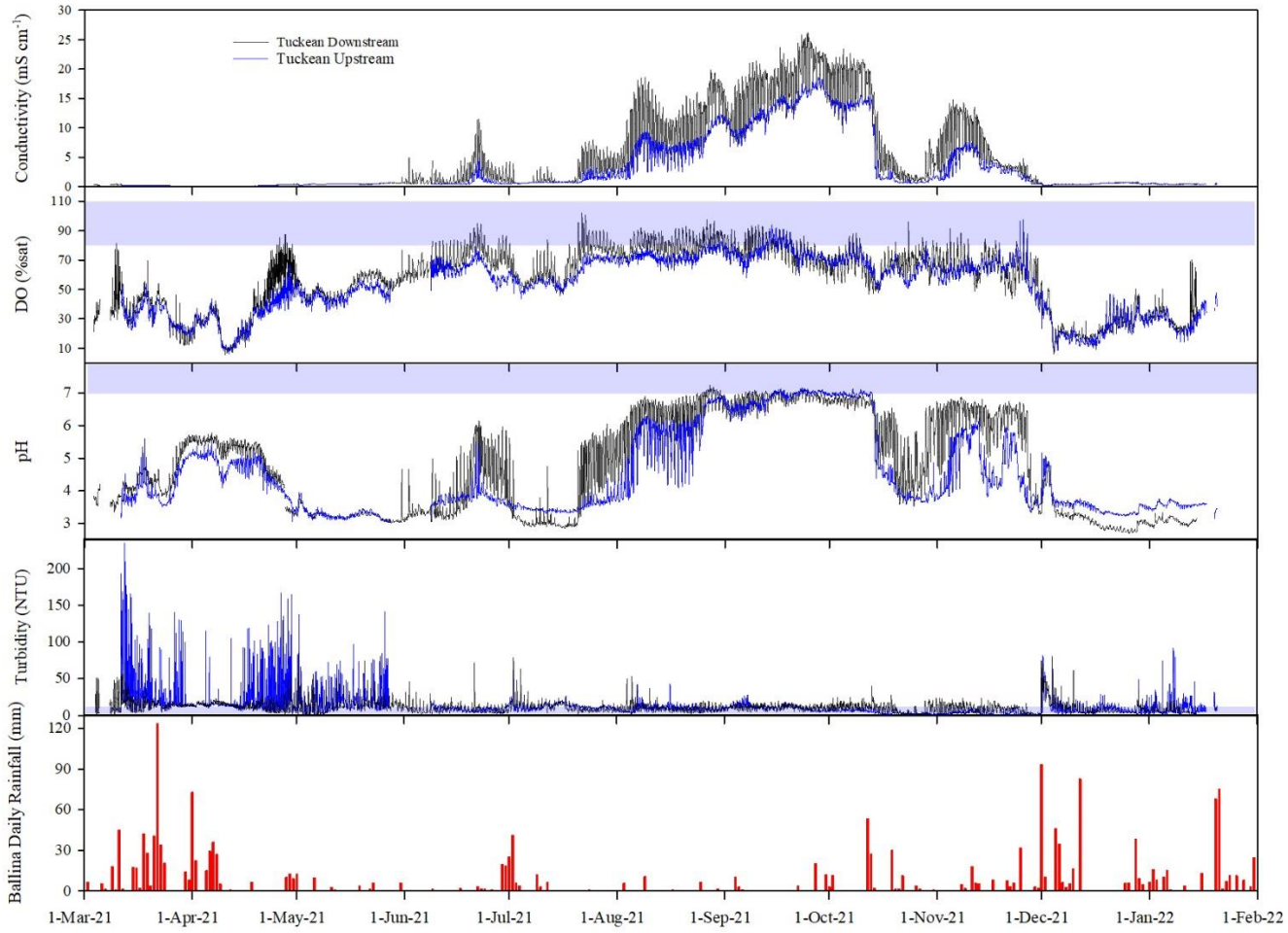

Figure 11 EC, DO, pH, turbidity and water temperature at the Tuckean sites. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

6.2.5. Wardell

The sentinel Wardell logger commenced transmission of data on the 30th March 2021.

The timeseries data is presented in Figure 12 and Figure 13.

Key observations include:

- During the dry period DO and pH are relatively stable (e.g. June through November)
  - pH is generally within ANZECC guidelines during this time
  - The 15% of the time DO is within ANZECC guidelines occurs during dry periods
- The river was flushed fresh to at least Wardell for periods during the wet months (i.e. April, December and January) resulting in considerable drops in DO and pH as the poor water upstream discharges from the system
  - DO dropped to ~10 % sat in April and 30% in December
  - Similarly, pH dropped below ANZECC guidelines during the wet periods
- Stratification of surface and bottom waters can display a spring-neap tidal trend with stratification becoming more pronounced during neap tides – this trend was most prevalent during the dry period (May to September)
- Turbidity values increase to levels well above ANZECC guidelines following rain

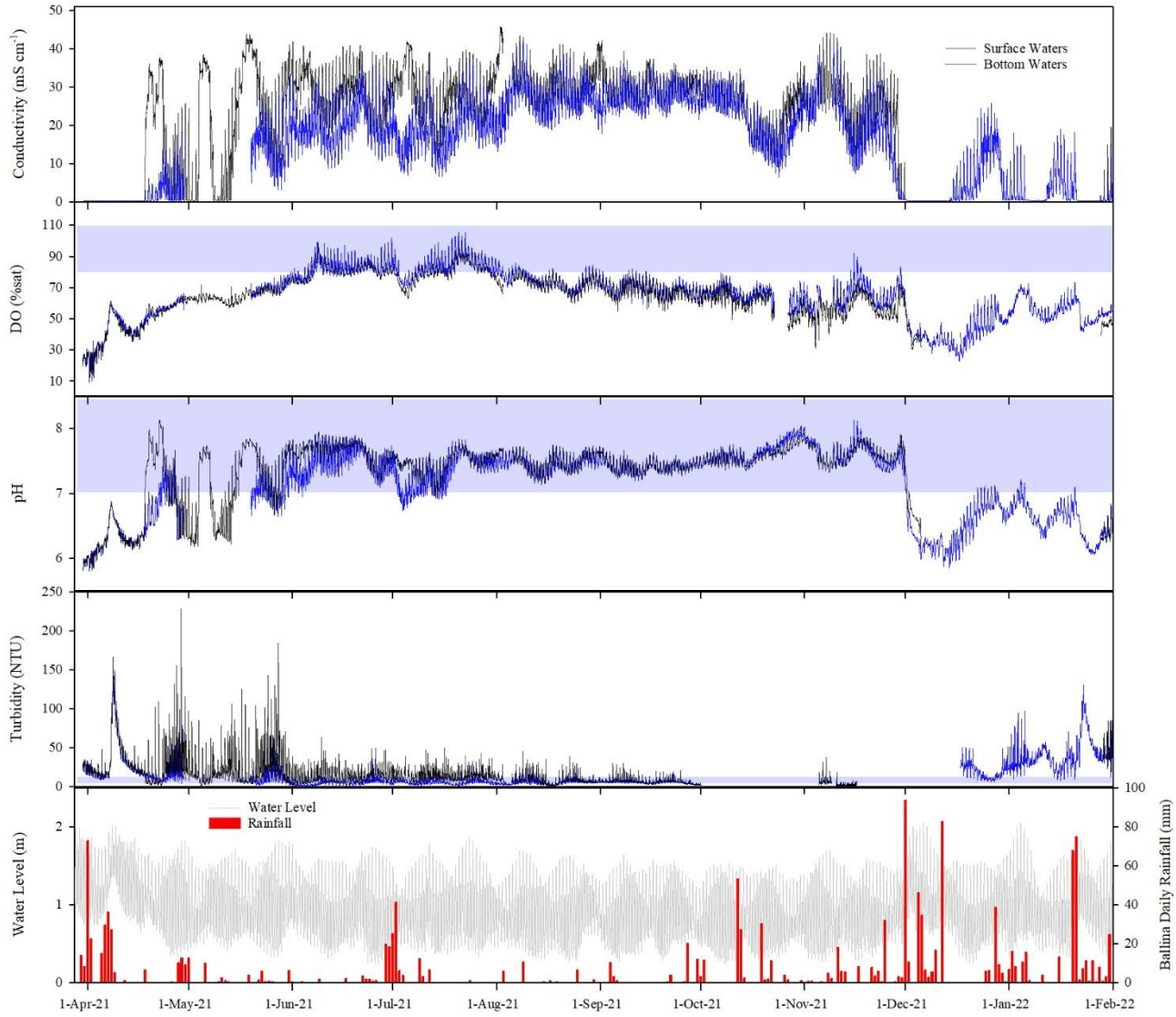

Figure 12 EC, DO, pH and Turbidity at Wardell. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

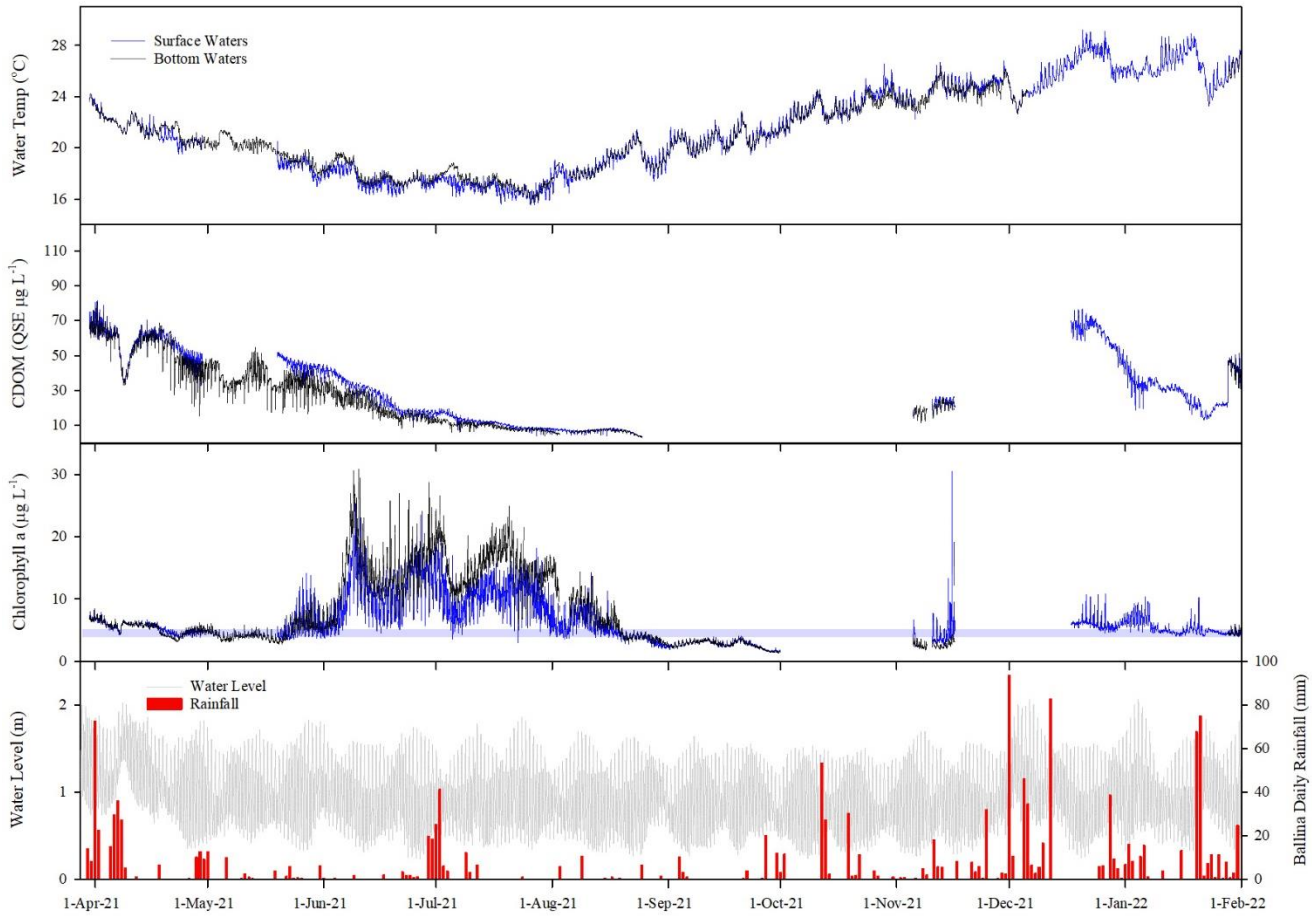

Figure 13 Water temperature, CDOM, and Chlorophyll a at Wardell. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

6.2.6. North Creek Upstream and Downstream

North Creek Upstream and Downstream sites commenced logging on the 8th March and the 28th April, respectively.

Timeseries data is presented in Figure 14 and the average values of water quality data for the reporting period are presented in Table 4.

Key observations from the North Creek sites:

- DO, on average, is higher at the Upstream (57 %sat) versus Downstream (45 %sat)
  - Interesting given the influence of marine water at the Downstream site (average salinity/conductivity 28 PSU/36 mS cm^{-1})
  - Suggests consumption of DO and/or inputs of low DO water between the sites (potential influence from the Nature Reserve)
  - Both sites were only within ANZECC guidelines ~4% of the time which occurred during the dry period
  - Rainfall drives DO lower with anoxic waters occurring after considerable rain events (e.g. March and January)
- pH is much lower, on average, at the Upstream site (5.6) compared to the Downstream site (7.7)
  - Downstream site is buffered by marine waters, thus within ANZECC guideline 83% of the time, only dropping to ~6 after significant rain events (e.g. December) as lower pH water discharges North Creek
  - pH is below ANZECC 100% of the time at the Upstream site, routinely dropping to low 4s following rain and can remain depressed (<5.5) for weeks as acidic water drains the floodplain
- Turbidity levels increase in response to rainfall and fluctuate with tides

Table 4 Average values for water quality parameters for the monitoring period at the North Creek Upstream and Downstream sites

	North Creek Upstream	North Creek Downstream
Conductivity (mS cm^{-1})	6.0	36.3
DO (% sat)	56.6	45.1
pH	5.6	7.7
Temperature (°C)	20.7	20.8
Turbidity (NTU)	20.7	31.9
Salinity (PSU)	4.1	27. 8

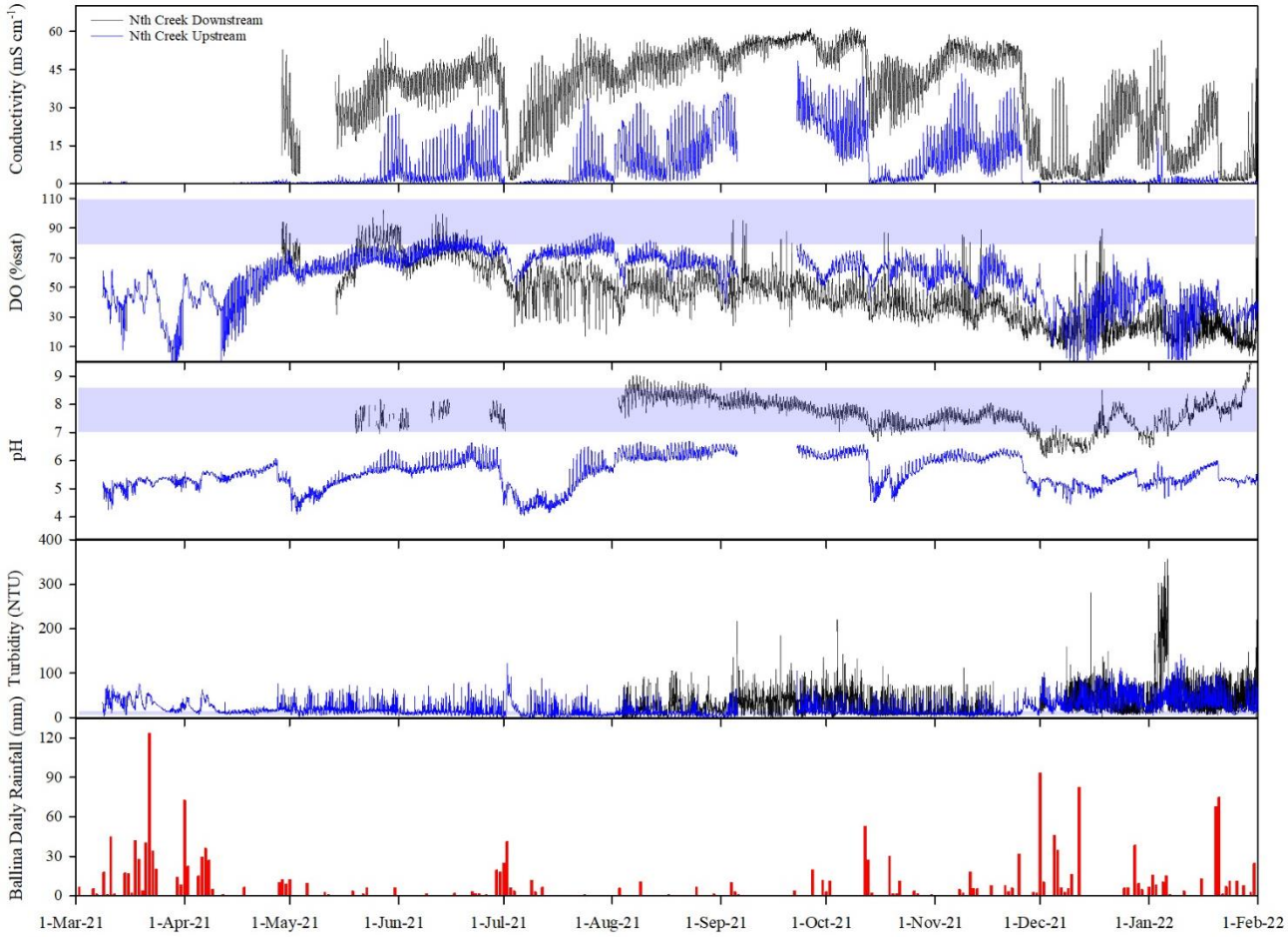

Figure 14 EC, DO, pH, turbidity and water temperature at the North Creek sites. Blue shaded area represents the ANZECC guideline range for slightly disturbed Estuaries in south-east Australia.

7. Conclusions and Recommendations

2021 was wet and cool with rainfall 30% higher than long-term averages. Significant rainfall totals were recorded in February and March, well above average and on the back of a La Nina event that commenced in November 2020 resulting in high antecedent soils moisture levels across the catchment. Whilst May through September was relatively dry with below average rainfall, a double dip La Nina event resulted in a very wet 2021-22 summer.

When compared to the ANZECC default guideline values, the water quality data collected from March 2021, when logger installation commenced, to the end of January 2022, is generally poor:

- DO did not meet guideline values 70-80% of the time in the main channel (i.e. at Woodburn and Wardell) and ~95% of the time in the tributaries
- pH in the main river channel is generally within the guidelines, with values not meeting ANZECC guidelines ~35% of the time, however, in the tributaries, values for pH did not meet the ANZECC guidelines 85-100% of the time
- Turbidity in the main channel was outside of guideline values 50-60% of the time and in the tributaries, the percentage of time values were outside of ANZECC ranged from 10% (Bungawalbin) to 70% (North Creek sites)

It is noted that the ANZECC default trigger values are generic to broad geographical regions and water types and that the development of localised guideline values is preferred. However, in the absence of site-specific guideline values, the ANZECC default trigger values were used as a benchmark.

The poor water quality results were observed following rainfall events. Given the very wet conditions at the beginning and end of 2021, water quality in the main channel during these periods was characterised by low DO, depressed pH and elevated turbidity. Anoxic waters with pH <4 were routinely observed in the tributaries draining the floodplains during the wet periods and for the weeks following. Conversely, during the dry period water quality in the main channel improved such that parameters were either within, or close too, ANZECC guideline values. The water quality in the tributaries also improved once the floodplain had drained and ingression of tidal waters resumed. These observations are based on data captured during the projects first year and will evolve over time.

Overall, the loggers have performed as expected, capturing high resolution measurements of key water quality parameters at eight sites throughout the mid and lower Richmond River and its key tributaries with data provided in real-time via the Rous County Council website. The timeseries data has highlighted the controls rainfall has on water quality and should be used to progress a broader Richmond River water quality model including the development of site-specific water quality guidelines. Modifications of the logger setup at North Creek Downstream is recommended to enable sampling of water further out in the channel which would result in a more robust data set for this site. The modifications could also be replicated at Woodburn to sample bottom waters from a greater depth.