Warrell Creek to Nambucca Heads Pacific Highway Upgrade

Year 3 and Final Operational Phase Water Quality Monitoring Annual Report

Roads and Maritime Services | October 2021

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Year 3 and Final Operational Phase Water Quality Monitoring Annual Report – October 2021

Report Prepared for:

NSW Roads and Maritime Services

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Prepared By:

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1 Introduction

1.1 Introduction and Background

The Pacific Highway upgrade between Warrell Creek and Nambucca Heads (WC2NH upgrade) is operational. Surface water and groundwater monitoring has been ongoing in the pre-construction and construction phases according to the Surface Water Monitoring Program (GeoLINK 2013a) and the Groundwater Monitoring Program (GeoLINK 2013b). The operational phase monitoring began in July 2018.

This annual report, the third and final of the operational phase monitoring, presents a detailed summary of the surface water and groundwater monitoring results obtained during the operational phase monitoring between July 2018 and September 2021.

1.1.1 Aims and Objectives

The objective of this final annual report is to provide a detailed summary of the surface water and groundwater quality monitoring activities and results for the operational phase of the WC2NH upgrade. The objective of ongoing surface water and groundwater monitoring is to evaluate the impact of the Pacific Highway upgrade on water quality in the relevant waterways and aquifers from Warrell Creek to Nambucca Heads and to comply with the Department of Planning and Environment (DP&E) Ministers conditions of approval (RTA 2011) for the Warrell Creek to Urunga section of the Pacific Highway upgrade (which includes the WC2NH and the Nambucca Heads to Urunga sections).

The condition of approval that relates to water quality is the *Ministers Condition of Approval (MP 07_0112) B17 – Water Quality*, which requires Roads and Maritime *to prepare and implement a Water Quality Monitoring Program to monitor the impacts of the project on SEPP 14 wetlands, surface water quality and groundwater resources during construction and operation.* In accordance with MCoA B17 Roads and Maritime prepared, and the Department of Planning and Environment approved, the Surface Water Monitoring Program (SWMP) and the Groundwater Monitoring Program (GWMP). These documents provide guidance to:

- monitor the impacts of the project on SEPP 14 wetlands, surface water quality and groundwater resources during construction and operation;

- provide Roads and Maritime with timely advice about surface and groundwater quality and how they compare to relevant and appropriate guideline levels;

This report is required to comply with DP&E MCoA B17.

1.2 Water Quality Guidelines and Objectives

There are a variety of guidelines available for the comparison and assessment of results obtained from surface water and groundwater sampling. Choosing appropriate guidelines to assess water quality depends on the environmental values of the site, human uses, the objectives for water quality, the level of protection required for the site and the issues and associated risks present.

Most often, guidelines are derived from the Australian and New Zealand Environment Conservation Council (ANZECC) Guidelines for Water Quality (ANZECC 2000), The Australian Drinking Water Guidelines, National Health and Medical Research Council (NHMRC) 2004) and the Guidelines for Managing Risks in Recreational Waters (NHMRC 2011).

In the case of large datasets collected regularly over time and with an appropriate sampling design the ANZECC Guidelines suggest the use of median and 80th percentile (P80) concentrations from the gathered data. The SWMP and the GWMP employ a before/after, control/impact (BACI) sampling design to assess the impact of the highway upgrade on water quality. They recommend the use of the median values from the impact (downstream) sites and the P80 values from the control (upstream) sites for assessing impacts with the intention of informing ongoing management of water quality.

The ANZECC guidelines prescribe default guideline values for many water quality parameters. The individual values depend on the desired use of the water, perceived values of the water and the level of protection required. The default guideline values are intended to trigger further water quality investigations and to be used where there is an absence of locally derived guideline values. The ANZECC default guideline concentrations will be used in this report for providing context where potential impacts upon surface water and groundwater from highway operation are identified. The relevant ANZECC guideline concentrations are presented in **Table 1.1**.

The Australian Drinking Water Guidelines (ADWG, NHMRC 2013) provide guideline values for many water quality parameters that have potential impacts upon human health. In accordance

with the Guidelines for the Assessment and Management of Groundwater Contamination (DEC 2007) both the ADWG guidelines and the relevant ANZECC guidelines (default guidelines for Freshwater Aquatic Ecosystem Protection for 95% of species) to provide quantitative context where potential impacts upon groundwater from highway operation are identified. Importantly, results that exceed the ANZECC and ADWG guidelines are not necessarily an indication of an impact resulting from highway operation. The relevant ADWG concentrations are presented in **Table 1.1**.

Table 1.1 Available ANZECC and ADWG guideline concentrations for relevant parameters

Parameter	***ANZECC Guideline Concentrations for Aquatic Ecosystem Protection (95% of spp.) in moderately disturbed ecosystems***		***ADWG Concentrations***
	Freshwater	***Marine***	
Silver (µg/L)	0.05	1.4	100
Aluminium (µg/L)	55	0.5[a]	200[b]
Antimony (µg/L)	9	270	3
Arsenic (V) (µg/L)	13	4.5[a]	10
Cadmium (µg/L)	0.2	5.5	2
Chromium (VI) (µg/L)	1.0	4.4	50
Copper (µg/L)	1.4	1.3	2000
Iron (µg/L)	-	-	300[b]
Manganese (µg/L)	1900	-	500
Nickel (µg/L)	11	7	20
Lead (µg/L)	3.4	4.4	10
Selenium (µg/L)	5	-	10
Zinc (µg/L)	8.0	15	300[b]
Mercury (µg/L)	0.05	0.1	1
Naphthalene (µg/L)	16	70	-
Benzene (µg/L)	950	700	1
Toluene (µg/L)	-	-	800
Ethylbenzene (µg/L)	-	-	300
m&p-Xylenes (µg/L)	200	-	600
o-Xylene (µg/L)	350	-	600
Total Nitrogen in water (mg/L)	0.5	0.3	-
Nitrite as N in water (mg/L)	0.04(NOx)	0.015(NOx)	3
Nitrate as N in water (mg/L)	0.04(NOx)	0.015(NOx)	50
Ammonia as N in water (mg/L)	0.02	0.015	0.5[b]
Total Phosphorus (mg/L)	0.05	0.03	-
Phosphate as P in water (mg/L)	0.02	0.005	-
Chloride, Cl (mg/L)	-	-	250[b]
Sulphate, SO4 (mg/L)	-	-	250[b]
Bicarbonate Alkalinity as CaCO3 (mg/L)	-	-	-
Sodium – Dissolved (mg/L)	-	-	180b
Potassium – Dissolved (mg/L)	-	-	-
Calcium – Dissolved (mg/L)	-	-	-
Magnesium – Dissolved (mg/L)	-	-	-
Hydroxide Alkalinity (OH-) as CaCO3 (mg/L)	-	-	-
Carbonate Alkalinity as CaCO3 (mg/L)	-	-	200[b]
Total Alkalinity as CaCO3 (mg/L)	-	-	-
Total Suspended Solids (mg/L)	-	-	-
Total Dissolved Solids (mg/L)	-	-	600[b]
Temperature (°C)	-	-	-

Parameter	***ANZECC Guideline Concentrations for Aquatic Ecosystem Protection (95% of spp.) in moderately disturbed ecosystems***		***ADWG Concentrations***
	Freshwater	***Marine***	
pH	6.5 – 8.0	7.0 – 8.5	6.5 – 8.5
Conductivity (mS/cm)	0.125 – 2.2	-	-
Turbidity (NTU)	6 - 50	0.5 - 10	5[b]
Dissolved Oxygen (% sat)	85-110% saturation	80 – 110% saturation	85% saturation

a – ANZECC low reliability trigger
b – No health-based guideline value, aesthetic value applied.

2 Methods

2.1 Locations

2.1.1 Surface Water Monitoring Sites

There are five surface water locations (11 sites) where ongoing surface water monitoring is required. Maps of the site locations are presented in **Illustrations 2.1** and **2.2** (GeoLINK 2013a). A key to the site names used over time and in this report is presented in **Table 2.1**.

Table 2.1 Surface water monitoring locations and sites

Waterway	***Site Names***	***New Chainage***	***Old Chainage***
Upper Warrell Creek	SW01 (upstream) SW02 (downstream)	Ch 41565 Ch 42565	Ch -200 Ch 700
Stony Creek	SW03 (upstream) SW04 (downstream)	Ch 45465 Ch 45665	Ch 3700 Ch 3900
Lower Warrell Creek	SW05 (upstream) SW06 (downstream)	Ch 48165	Ch 6400
Unnamed Drainage Line	SW07 (upstream west) SW08 (upstream east) SW09 (downstream)	Ch 50215	Ch 8450
Nambucca River	SW10 (upstream) SW11 (downstream)	Ch 52065	Ch 10300

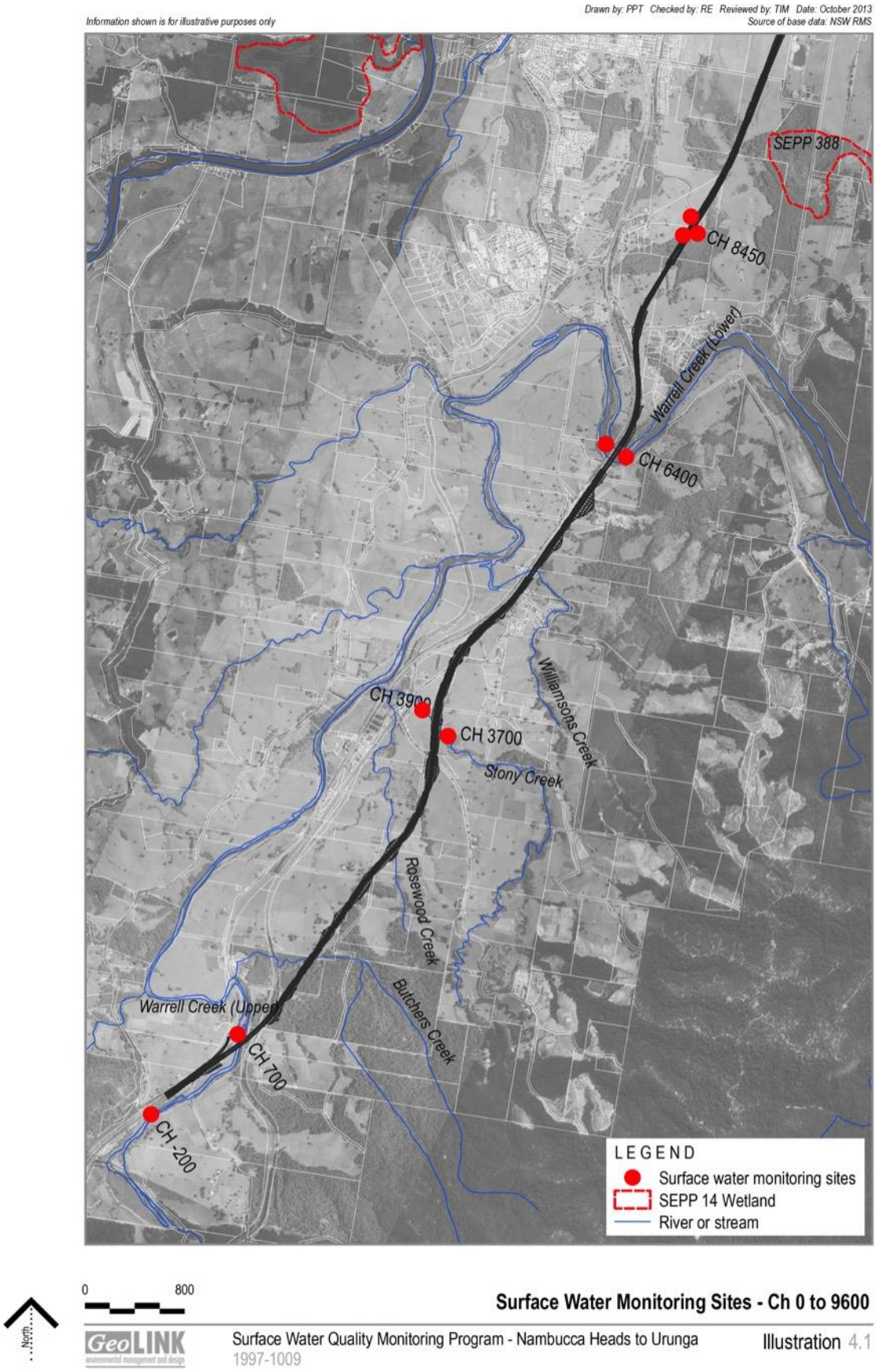

Illustration 2.1 Surface water monitoring sites – Ch 41765 to 51365 (Ch conversion +41765) (GeoLINK 2013a)

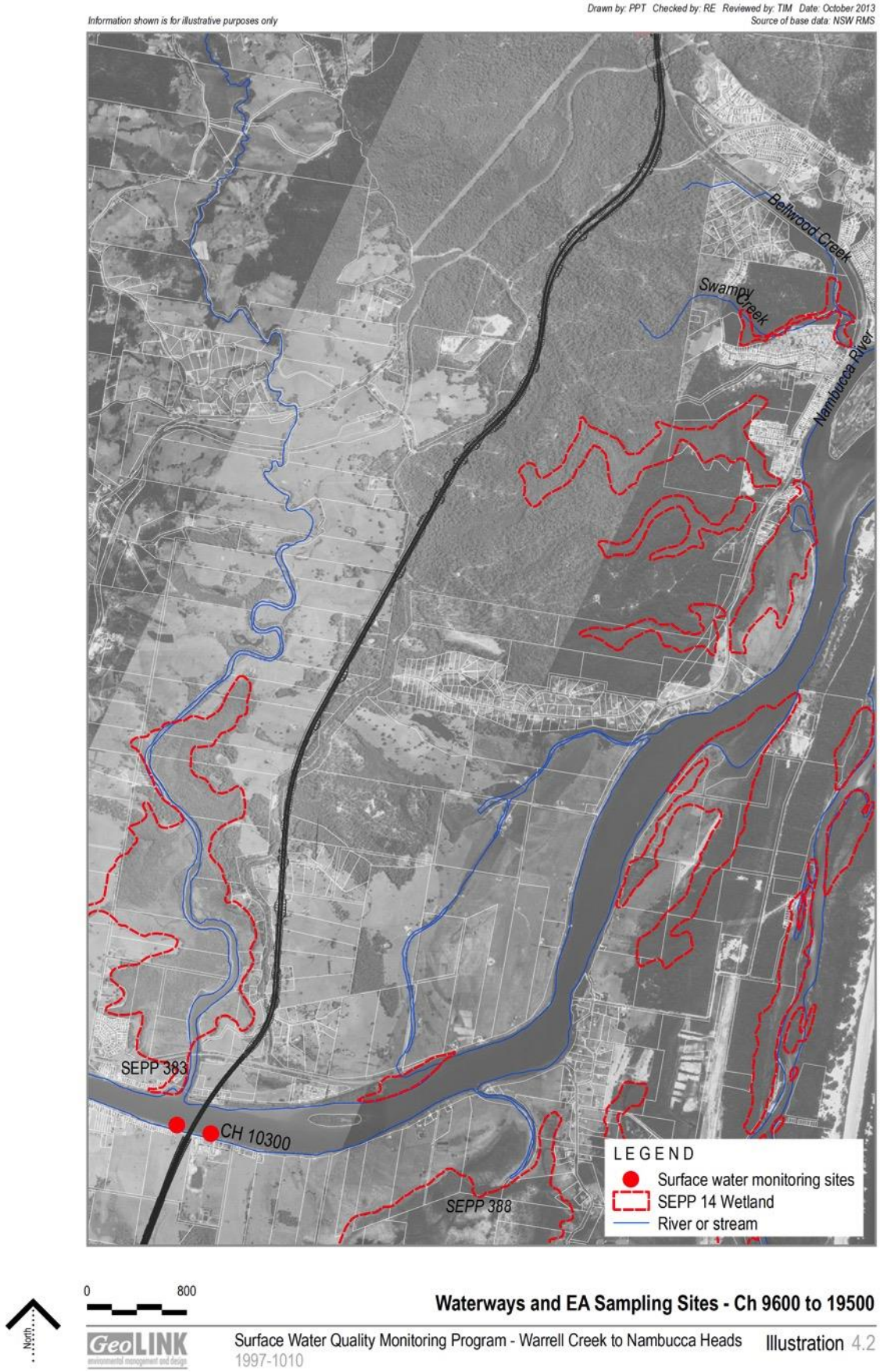

Illustration 2.2 Surface water monitoring sites – Ch 51365 to 71265 (Ch conversion +41765) (GeoLINK 2013a)

2.1.2 Groundwater Monitoring Sites

There are five locations (8 piezometers) where ongoing groundwater monitoring is required. Maps of the site locations are presented in **Illustrations 2.3** and **2.4** (GeoLINK 2013b). The locations (from south to north) are as follows:

- Cutting No. 1.5 on the west of the alignment, approximate chainage 45165, Site Cut 6W (downgradient).
- Cutting No. 1.10 on the east and west of the alignment, approximate chainage 48665, sites Cut 11E (upgradient) and Cut 11W (downgradient).
- Cutting No. 1.11 on the west of the alignment, approximate chainage 49365, site Cut 12W (downgradient).
- Embankment fill adjacent to Gumma Wetland, approximate chainage 50965, sites Fill 15E (upgradient) and Fill 15W (downgradient).
- Cutting No. 2.5 on the east and west of the alignment, approximate chainage 54065, sites Cut 15E (upgradient) and Cut 15W (downgradient).

Monitoring at several other sites where monitoring was undertaken in the pre-construction phase ceased prior to or during the construction phase (see GeoLINK 2013b and Coffey 2015).

Table 2.2 Groundwater monitoring locations and sites

Location	*Site Names*	*New Chainage*	*Old Chainage*
Cutting No. 1.5	Cut 6W (downgradient)	Ch 45165	Ch 3400
Cutting No. 1.10	Cut 11E (upgradient) Cut 11W (downgradient)	Ch 48665	Ch 6900
Cutting No. 1.11	Cut 12 W (downgradient)	Ch 49365	Ch 7600
Embankment Fill Gumma Wetland	Fill 15E (upgradient) Fill 15W (downgradient)	Ch 50965	Ch 9200
Cutting No. 2.5	Cut 15E (upgradient) Cut 15W (downgradient)	Ch 54065	Ch 12300

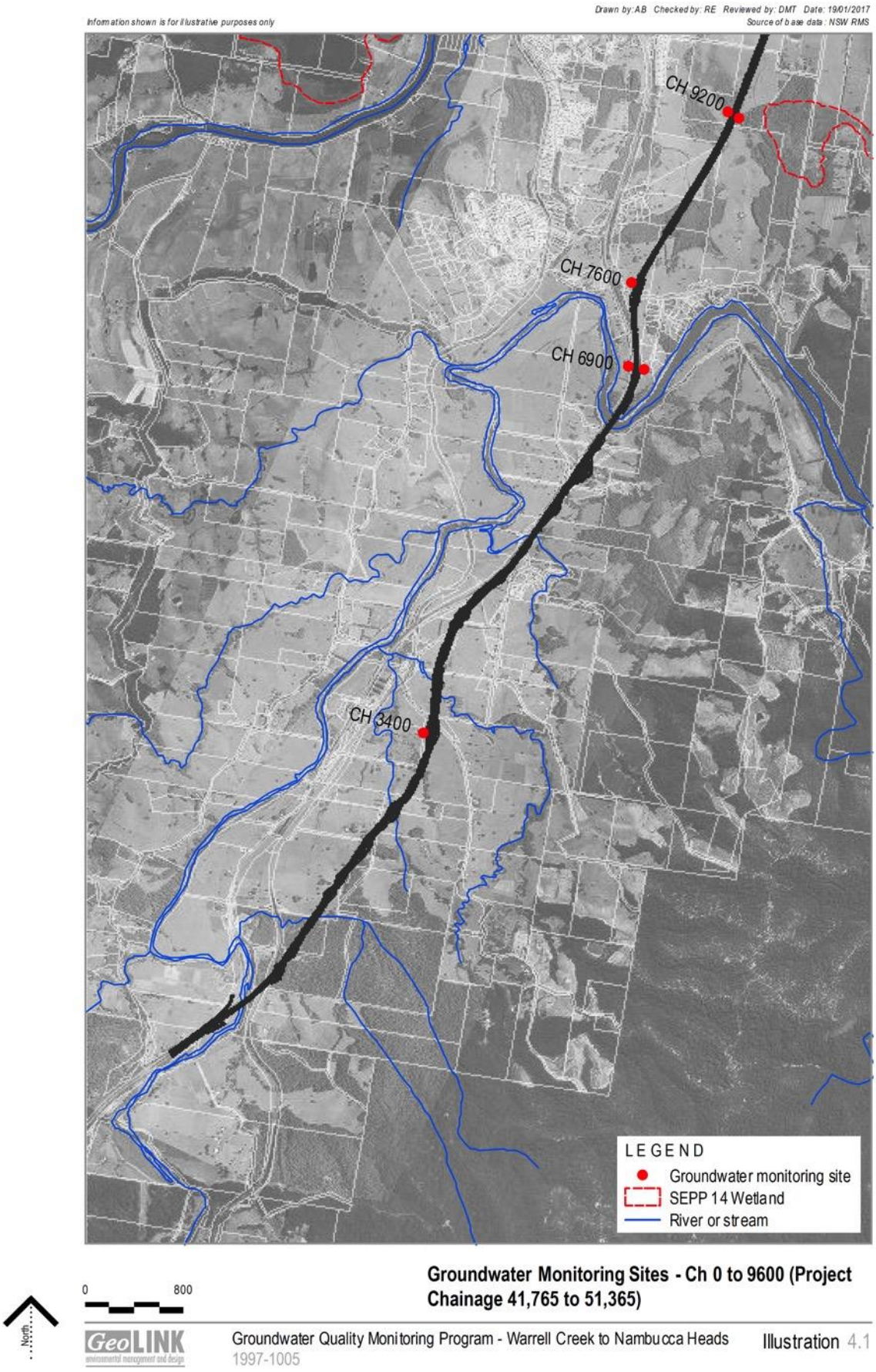

Illustration 2.3 Groundwater monitoring sites – Ch 41765 to 51365 (GeoLINK 2013b)

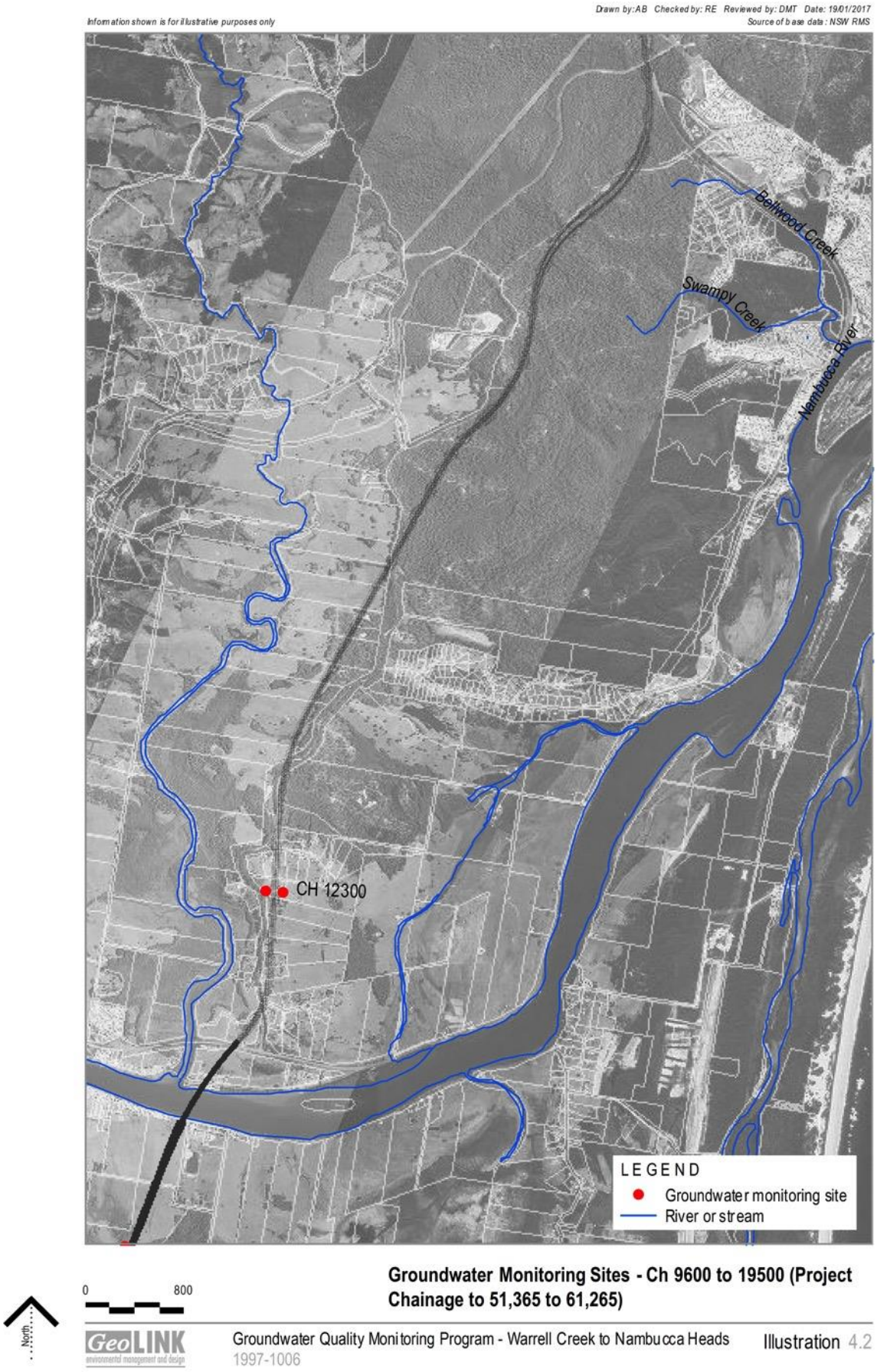

Illustration 2.4 Groundwater monitoring sites – Ch 51365 to 61265 (GeoLINK 2013b)

2.2 Sampling and Analysis

2.2.1 Surface Water Quality Monitoring

The SWMP outlines the parameters required for monitoring in the operational phase of the project. The complete list of parameters monitored is presented in **Table 2.3**.

Table 2.3 Surface water parameters for operational phase monitoring

Group	*Analytes*	*Method of Analysis*
Physicochemical	Temperature	Field measurement – Handheld Probe
	Electrical Conductivity (EC)	Field measurement – Handheld Probe
	pH	Field measurement – Handheld Probe
	Dissolved Oxygen (DO)	Field measurement – Handheld Probe
	Turbidity	Field measurement – Handheld Probe
	Total Dissolved Solids (TDS)	Field measurement – Handheld Probe
	Total Suspended Solids (TSS)	Laboratory Analysis
Hydrocarbons (if visual assessment confirms presence)	TRH C6 - C10	Laboratory Analysis
	TRH >C10 - C16	Laboratory Analysis
	TRH >C16 - C34	Laboratory Analysis
	TRH >C34 - C40	Laboratory Analysis
	Benzene	Laboratory Analysis
	Toluene	Laboratory Analysis
	Ethylbenzene	Laboratory Analysis
	Xylene	Laboratory Analysis
Metals	Aluminium (Al)	Laboratory Analysis
	Arsenic (As)	Laboratory Analysis
	Cadmium (Cd)	Laboratory Analysis
	Chromium (Cr)	Laboratory Analysis
	Copper (Cu)	Laboratory Analysis
	Lead (Pb)	Laboratory Analysis
	Manganese (Mn)	Laboratory Analysis
	Nickel (Ni)	Laboratory Analysis
	Selenium (Se)	Laboratory Analysis
	Silver (Ag)	Laboratory Analysis
	Zinc (Zn)	Laboratory Analysis
	Iron (Fe)	Laboratory Analysis
	Mercury (Hg)	Laboratory Analysis
Nutrients	Total Nitrogen (TN)	Laboratory Analysis
	Total Phosphorus (TP)	Laboratory Analysis
	Nitrate (NO_3)	Laboratory Analysis
	Nitrite (NO_2)	Laboratory Analysis
	Ammonia (NH_4)	Laboratory Analysis
	Phosphate (PO_4)	Laboratory Analysis

The SWMP also defines the sampling frequency for operational monitoring. This is presented in **Table 2.4**. The exact timing of sample collection is dependent upon weather conditions. Where the conditions required for a wet episode or dry episode do not occur in the specified period, or the appropriate conditions are missed due to logistical problems such as staff availability, access restrictions or equipment failure, the approach taken is to collect catch-up samples at the next available opportunity.

Table 2.4 Operational phase sample frequency

Period	*Dates*	*Parameters*	*Sample Frequency*
First Year	July 2018 – September 2019	Physicochemical and Hydrocarbons (if oil and grease is visible)	▪ Once per month during a wet episode (defined as a rainfall event of >10mm in a 24-hour period) ▪ Once every six months during a dry episode (defined as a combination of 96 hours with no rain and 192 hours with <10mm rain)
		Hydrocarbons, Metals, Nutrients and Solids	▪ Once every second month during a wet episode ▪ Once every six months during a dry episode
Second Year	October 2019 – September 2020	Physicochemical and Hydrocarbons (if oil and grease is visible)	▪ Once every second month during a wet episode ▪ Once every six months during a dry episode
		Hydrocarbons, Metals, Nutrients and Solids	▪ Once every six months during a wet episode ▪ Once every six months during a dry episode
Third Year	October 2018 – September 2020	Physicochemical and Hydrocarbons (if oil and grease is visible)	▪ Once every six months during a wet episode ▪ Once every six months during a dry episode
		Hydrocarbons, Metals, Nutrients and Solids	▪ Once every six months during a wet episode ▪ Once every six months during a dry episode

The dates of surface water quality monitoring sampling for the operational phase monitoring are presented in **Table 2.5**. During the operational phase some variation occurred between the planned timing of surface water sampling and the actual timing of surface water sampling. There were some samples collected outside of the proposed timeframes due to a lack of suitable weather events during the proposed timeframes, laboratory closures or restricted access to

private properties. Details of these occasions are provided in the previous two annual reports (TfNSW 2019, 2020). Catch-up samples were collected at suitable timeframes throughout operational phase sampling to address the problem of missed samples and on the 30th September 2021, the scheduled end of the operational phase water quality sampling program, surface water sampling was up-to-date.

Rainfall conditions at the time of sampling are presented in **Figure 3.1**.

Table 2.5 Operational phase sampling dates between 1 July 2018 and 30 September 2021

Month	*Date*	*Sample Type*	*Parameters*				*Notes*
			Physicochemical	*Hydrocarbons*	*Metals*	*Nutrients*	
July 2018	2/07/18	Wet	Y	N	N	N	Construction contractor collected samples.
August 2018	No samples	-	-	-	-	-	No samples collected by construction contractor
September 2018	5/09/18	Wet	Y	N	N	N	Construction contractor collected samples.
October 2018	No samples	-	-	-	-	-	No samples collected due to property access restrictions.
November 2018	8/11/18	Wet	Y	N	N	N	All samples collected.
December 2018	17/12/18	Wet	Y	Y	Y	Y	Water level at SW09 very low.
January 2019	No samples	-	-	-	-	-	No suitable wet event. Dry event samples not captured.
February 2019	22/02/19	Wet	Y	Y	Y	Y	Insufficient water at SW09.
March 2019	17/03/19	Wet	Y	N	N	N	All samples collected.
April 2019	4/04/19	Wet	Y	N	N	N	All samples collected. Samples for lab analysis not collected because samples were

Month	Date	Sample Type	Parameters				Notes
			Physicochemical	Hydrocarbons	Metals	Nutrients	
							collected on a Saturday.
	21/04/19	Wet	Y	Y	Y	Y	Catch-up wet samples. All samples collected.
May 2019	30/05/19	Dry	Y	Y	Y	Y	Catch-up dry samples. Water level at SW09 very low. No suitable wet event.
June 2019	25/06/19	Wet	Y	N	N	N	All samples collected.
July 2019	6/07/19	Wet	Y	N	N	N	All samples collected. Samples for lab analysis not collected because samples were collected on a Saturday.
	29/07/19	Dry	Y	Y	Y	Y	Water level at SW09 very low.
August 2019	30/08/19	Wet	Y	Y	Y	Y	Water level at SW09 very low.
September 2019	20/09/19	Wet	Y	N	N	N	All samples collected.
October 2019	13/10/19	Wet	Y	Y	Y	Y	Catch-up wet sample. All samples collected.
November 2019	No samples	-	-	-	-	-	No suitable wet event. Dry event samples not captured.
December 2019	2/12/19	Wet	Y	Y	Y	Y	Catch-up wet sample. SW07, 08, 09 too dry to sample.
January 2020	20/01/20	Wet	Y	N	N	N	All samples collected.
February 2020	7/02/20	Wet	Y	Y	Y	Y	All samples collected.
March 2020	16/03/20	Wet	Y	N	N	N	All samples collected.

Month	*Date*	*Sample Type*	*Parameters*				*Notes*
			Physicochemical	*Hydrocarbons*	*Metals*	*Nutrients*	
April 2020	27/04/20	Dry	Y	Y	Y	Y	Catch-up dry sample. All samples collected
May 2020	No samples	-	-	-	-	-	No suitable wet event.
June 2020	11/06/20	Wet	Y	N	N	N	All samples collected.
July 2020	27/07/20	Wet	Y	Y	Y	Y	All samples collected.
August 2020	No samples	-	-	-	-	-	No suitable wet event. Dry event samples not captured.
September 2020	11/09/19	Wet	Y	N	N	N	All samples collected.
	30/09/20	Dry	Y	Y	Y	Y	All samples collected
December 2021	30/12/20	Wet	Y	Y	Y	Y	All samples collected
April 2021	15/4/21	Dry	Y	Y	Y	Y	All samples collected
July 2021	2/7/21	Wet	Y	Y	Y	Y	All samples collected.
September 2021	25/9/21	Dry	Y	Y	Y	Y	All samples collected

Surface waters were sampled from a depth of approximately 0.1 – 0.2 m. Samples for parameters requiring laboratory analysis were collected by dipping the sampling vessel into the water by sampling pole. A variety of sample vessels were used, depending upon the suite of parameters being analysed. All samples with a requirement for laboratory analysis were sent in cooled eskys by overnight courier to the processing laboratory on the day of, or day after collection. Where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing. Physicochemical parameters were measured *in situ* using a calibrated HORIBA U52 multiparameter water quality probe.

2.2.2 Groundwater Quality Monitoring

The GWMP outlines the parameters required for monitoring in the operational phase of the project. The complete list of parameters monitored is presented in **Table 2.6**.

Table 2.6 Surface water parameters for operational phase monitoring

Group	*Analytes*	*Method of Analysis*
Physicochemical	Temperature	Field measurement – Handheld Probe
	Electrical Conductivity (EC)	Field measurement – Handheld Probe
	pH	Field measurement – Handheld Probe
	Total Dissolved Solids (TDS)	Field measurement – Handheld Probe
Hydrocarbons	Total Recoverable Hydrocarbons (TRH) C6 - C10	Laboratory Analysis
	TRH >C10 - C16	Laboratory Analysis
	TRH >C16 - C34	Laboratory Analysis
	TRH >C34 - C40	Laboratory Analysis
	Benzene	Laboratory Analysis
	Toluene	Laboratory Analysis
	Ethylbenzene	Laboratory Analysis
	Xylene	Laboratory Analysis
Metals	Aluminium (Al)	Laboratory Analysis
	Arsenic (As)	Laboratory Analysis
	Cadmium (Cd)	Laboratory Analysis
	Chromium (Cr)	Laboratory Analysis
	Copper (Cu)	Laboratory Analysis
	Lead (Pb)	Laboratory Analysis
	Manganese (Mn)	Laboratory Analysis
	Nickel (Ni)	Laboratory Analysis
	Selenium (Se)	Laboratory Analysis
	Silver (Ag)	Laboratory Analysis
	Zinc (Zn)	Laboratory Analysis
	Iron (Fe)	Laboratory Analysis
	Mercury (Hg)	Laboratory Analysis
Nutrients	Total Nitrogen (TN)	Laboratory Analysis
	Total Phosphorus (TP)	Laboratory Analysis
	Nitrate (NO_3)	Laboratory Analysis
	Nitrite (NO_2)	Laboratory Analysis
	Ammonia (NH_4)	Laboratory Analysis
	Phosphate (PO_4)	Laboratory Analysis
Major Anions	Chloride (Cl^-)	Laboratory Analysis
	Sulfate (SO_4^{2-})	Laboratory Analysis
	Bicarbonate (HCO_3^-)	Laboratory Analysis
	Nitrate (NO_3^-)	Laboratory Analysis
Major Cations	Sodium (Na^+)	Laboratory Analysis
	Potassium (K^+)	Laboratory Analysis
	Calcium (Ca^{2+})	Laboratory Analysis
	Magnesium (Mg^{2+})	Laboratory Analysis

The frequency of groundwater monitoring is also defined by the GWMP. This is presented in **Table 2.7**.

Table 2.7 Operational phase sample frequency (GeoLINK 2013b)

Period	***Dates***	***Parameters***	***Sample Frequency***
Operational Phase	July 2018 – September 2021	Physicochemical	1 sample three-monthly
		Hydrocarbons, Metals, Nutrients, Solids, Anions and Cations	1 sample six-monthly

The dates of groundwater measurements collected during the operational phase are presented in **Table 2.8**. The samples were all collected within 10 days of the intervals specified in the GWMP, with the exception of the September 2019 sample which was collected 5 weeks late.

Table 2.8 Operational phase groundwater sampling dates between July 2018 and September 2021

Month	***Date***	***Parameters***					***Notes***
		Physicochemical	***Hydrocarbons***	***Metals***	***Nutrients***	***Major Ions***	
December 2018	19/12/18	Y	N	N	N	N	Dry piezometers at Cut 12W and Cut 15W.
March 2019	27/03/19	Y	Y	Y	Y	Y	Dry piezometers at Cut 12W and Cut 15W. Damage to Cut 6W piezometer.
June 2019	9/07/19	Y	N	N	N	N	Dry piezometers at Cut 6W and Cut 12W.
September 2019	5/11/19	Y	Y	Y	Y	Y	Dry piezometers at Cut 6W and Cut 12W.
December 2019	03/01/20	Y	N	N	N	N	Dry piezometer at Cut 6W and Cut 12W.

Month	Date	Parameters					Notes
		Physicochemical	Hydrocarbons	Metals	Nutrients	Major Ions	
March 2020	30/03/20	Y	Y	Y	Y	Y	All samples collected .
June 2020	29/06/20	Y	N	N	N	N	All samples collected.
September 2020	30/09/20	Y	Y	Y	Y	Y	Dry piezometer at Cut 12W.
December 2020	31/12/20	Y	N	N	N	N	All samples collected .
March 2021	30/03/21	Y	Y	Y	Y	Y	All samples collected .
June 2021	29/06/21	Y	N	N	N	N	All samples collected.
September 2021	5/10/21	Y	Y	Y	Y	Y	Dry piezometer at Cut 12W.

Where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing.

2.2.3 Groundwater Level Monitoring

Groundwater levels were monitored using HOBO U20 data loggers and referenced using physical measurements of depth to water. Data loggers were deployed in all piezometers. The logged data has been corrected for atmospheric pressure fluctuations using an atmospheric pressure logger deployed on the Nambucca to Urunga Pacific Highway upgrade section. Logged groundwater data from the operational phase reporting period was retrieved at the same times as groundwater quality samples were collected. Manual measurements of groundwater levels were also collected at the same time as groundwater quality samples (**Table 2.8**). Measurements were taken as depth to standing water from the top of the piezometer casing using a Heron 'Dipper T'. Manual measurements were translated into relative levels using freely available level data (NSW Spatial Services 2021). The manual measurements collected were used to reference the logged data.

Some of the groundwater piezometers used for monitoring in the pre-construction and early construction monitoring phases were decommissioned during the construction phase and new

piezometers constructed. During the first year of operational phase monitoring a new groundwater piezometer was constructed at Cut 15W and a damaged piezometer at Cut 6W was repaired.

3 Results and Discussion

3.1 Rainfall

The surface water monitoring is governed by rainfall. A rainfall event triggering a wet episode sample is a minimum of 10 mm rain in 24 hours. A dry event is defined as a combination of 96 hours with no rain and 192 hours with <10mm rain. Rainfall data from the Bureau of Meteorology (BOM) station at Nambucca Heads (Bellbrook) and Taylors Arm (the nearest stations to the northern and southern ends of the WC2NH upgrade), is presented in **Figure 3.1**.

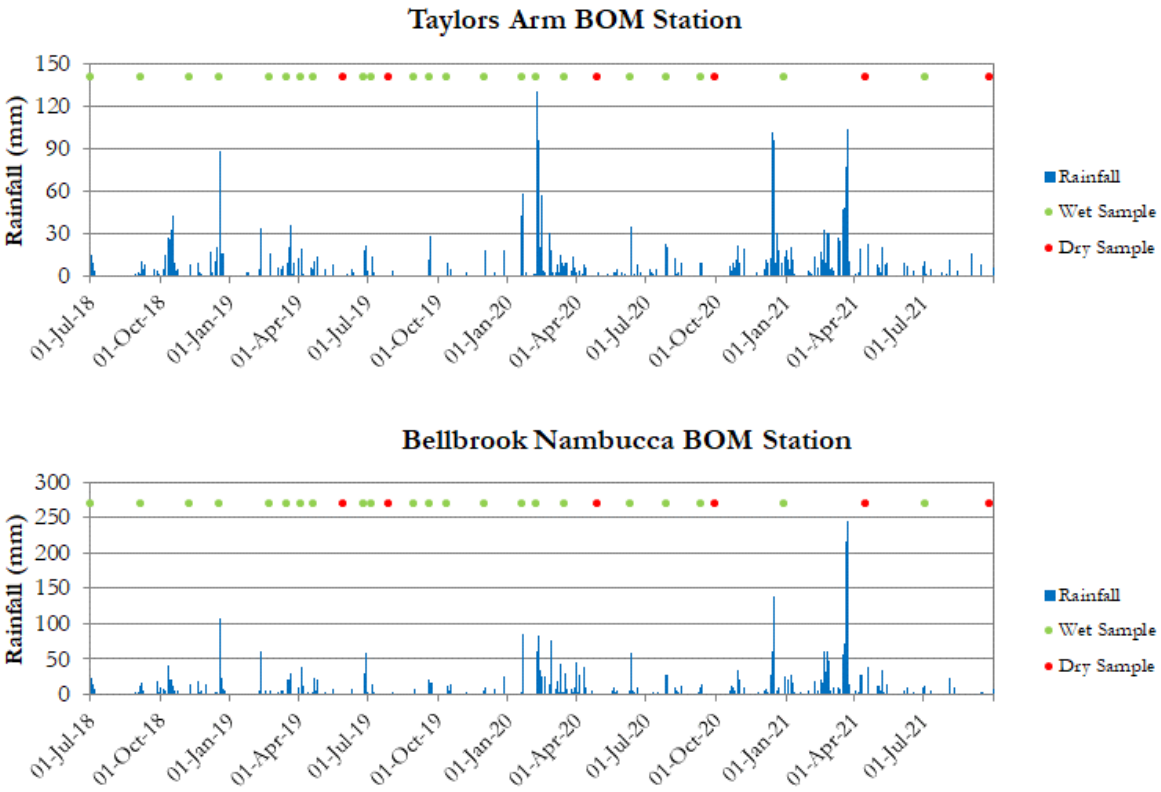

Figure 3.1 Daily rainfall at the Taylors Arm and Nambucca weather stations for the operational phase monitoring period.

Total rainfall for the operational phase monitoring period was close to average. At the Taylors Arm weather station there was a total of 3648 mm rain recorded between July 2018 and September 2021. Average rainfall for that timeframe would have been 3934 mm. At the Nambucca weather station there was 4737 mm recorded and the average rainfall would have been 4418 mm. However, for the first two years of monitoring rainfall was below average and for the final year of monitoring rainfall was above average - mostly due to a large flood event at the end of March 2021.

3.2 Surface Water

A summary of surface water quality results is presented in **Appendix A**.

The SWMP suggests that the analysis of impacts can involve a comparison of the median sampling results from downstream (impact) sites with the 80th percentile (P80) value of upstream (control) sites. The downstream median data for the operational phase monitoring period from each site is presented in **Appendix A** with the upstream P80 values. To provide historical context the downstream median summary data from construction phase monitoring is also presented.

A summary of relevant statistics for each waterway is presented in **Tables A.1** to **A.6** (**Appendix A**). A brief description of the summary results from each waterway follows. For the purposes of analysing the results of operational phase monitoring results of interest are defined as those where the operational phase downstream median is greater than the combined construction and operational phase upstream P80.

3.2.1 Upper Warrell Creek

There were no results of interest from the Upper Warrell Creek monitoring sites (**Table A.1**). and all of the median downstream operational phase measurements were within the relevant default guideline concentrations. During operational phase monitoring the upstream TSS, turbidity and pH measurements from Upper Warrell Creek were almost all higher than the downstream values and were within the ranges of variation measured during the construction phase (except for one upstream and one downstream turbidity measurement and one downstream TSS measurement in February 2020) and therefore do not indicate any impacts from highway operation (**Figures 3.2** to **3.4**).

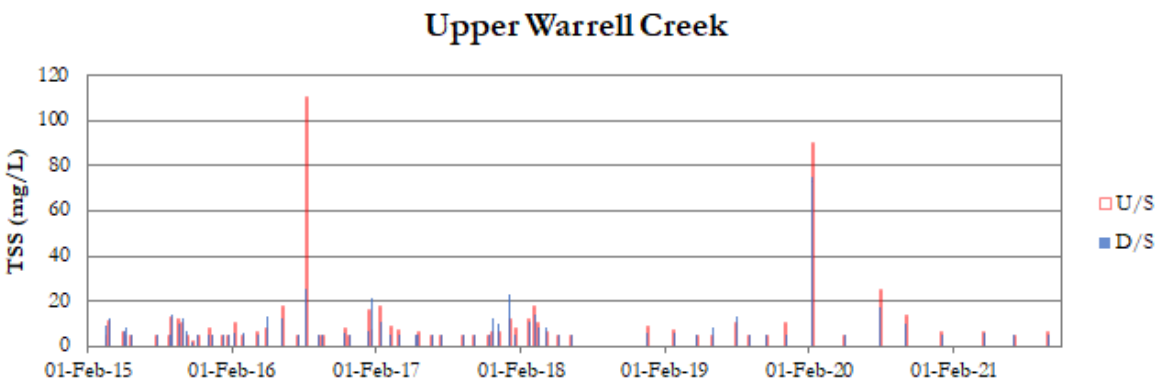

Figure 3.2 Total suspended solid concentrations at Upper Warrell Creek since February 2015.

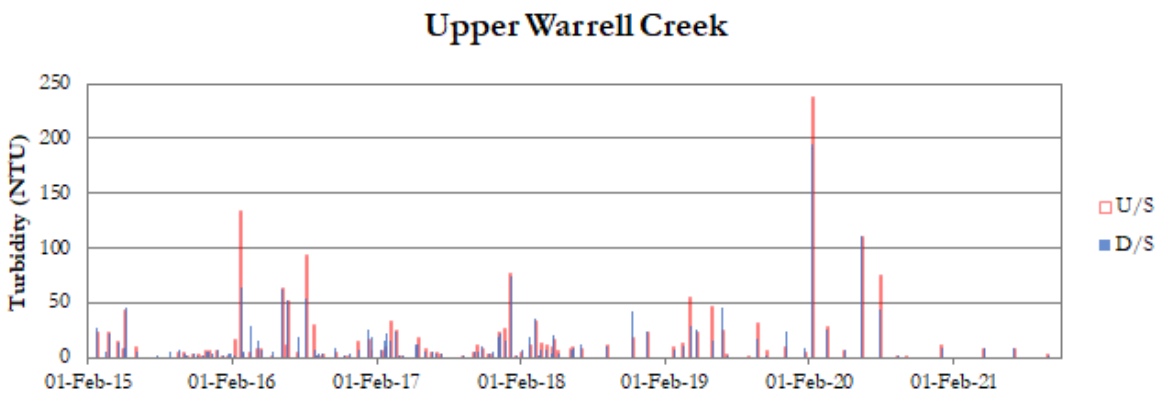

Figure 3.3 Turbidity measurements at Upper Warrell Creek since February 2015.

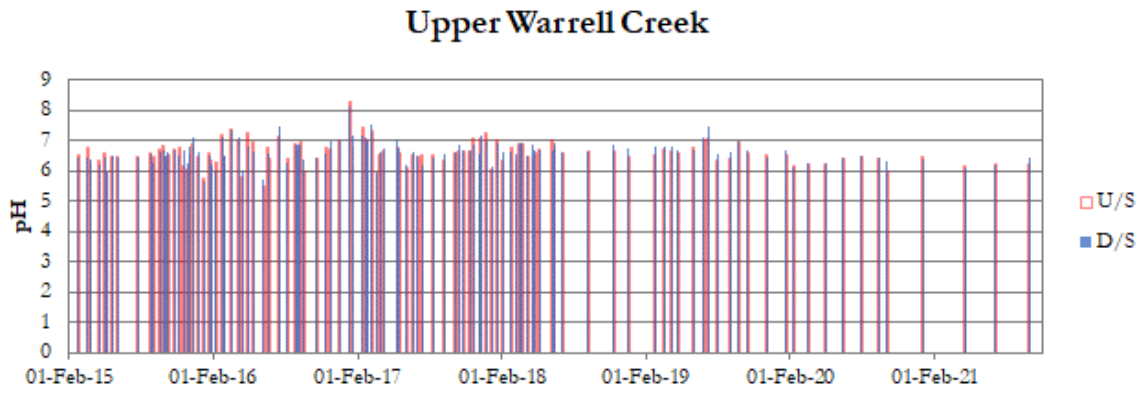

Figure 3.4 pH measurements at Upper Warrell Creek since February 2015.

The operational phase surface water quality monitoring results to date from Upper Warrell Creek do not indicate any significant impacts from highway operation. There are no new recommendations for ongoing water quality management at Upper Warrell Creek.

3.2.2 Stony Creek

There were two results of interest from the Stony Creek monitoring sites (**Table A.2**). These were the operational downstream median Mn and Fe concentrations. While the downstream median operational phase measurements for all parameters complied with the relevant default ANZECC guideline concentrations, there are no relevant ANZECC default guideline concentrations for Fe. Graphs of the Mn and Fe concentrations from Stony Creek (**Figures 3.8** and **3.9**) show that, although downstream concentrations have at times been higher than the upstream concentrations during the operational phase, the highest downstream concentrations have been associated with high upstream concentrations and all but 3 of the results are within the ranges of pre-construction and construction phase monitoring. The observed increases in the downstream construction phase median Fe and Mn relative to the upstream P80 are thus unlikely to be associated with highway operation. Operational phase downstream TSS and pH measurements from Stony Creek were almost all lower than or equal to the upstream measurements and were within the ranges observed during construction phase sampling. These results do not indicate any impacts from highway operation (**Figures 3.5** and **3.7**). The highest downstream turbidity measurements occurred during the operational phase but there is no pattern of increased downstream turbidity measurements (**Figure 3.6**) and the highest downstream turbidity measurement was recorded on 2nd December 2020 when field notes indicate that the downstream and upstream site were hydrologically disconnected due to dry conditions.

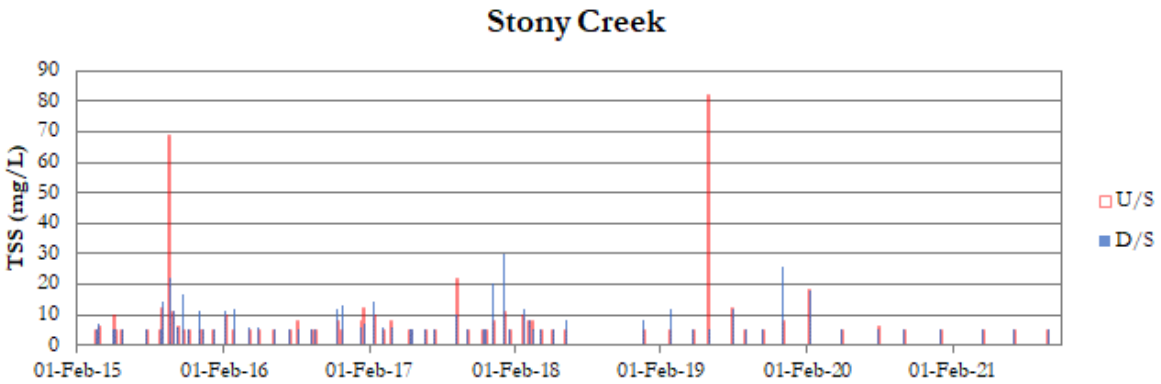

Figure 3.5 Total suspended solid concentrations at Stony Creek since February 2015.

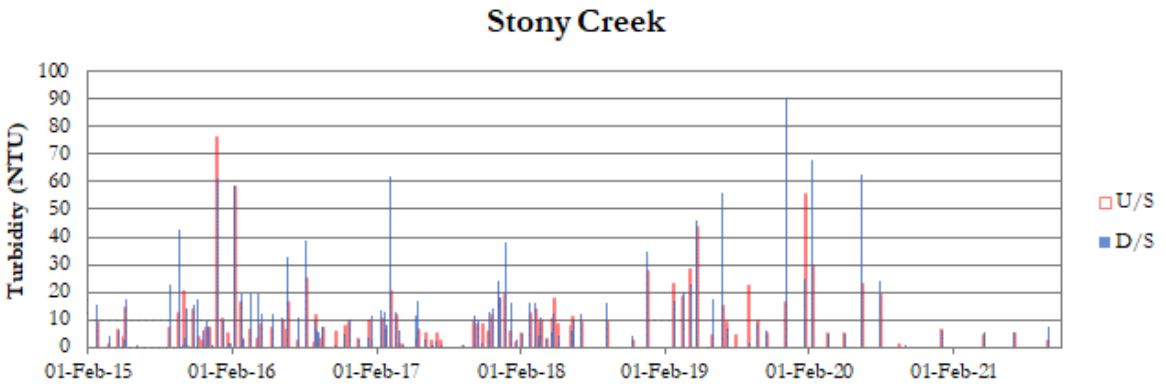

Figure 3.6 Turbidity measurements at Stony Creek since February 2015.

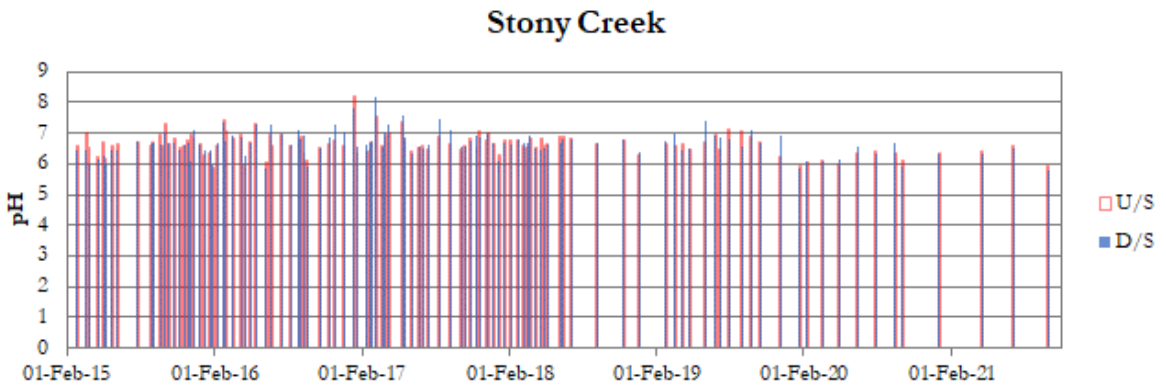

Figure 3.7 pH measurements at Stony Creek since February 2015.

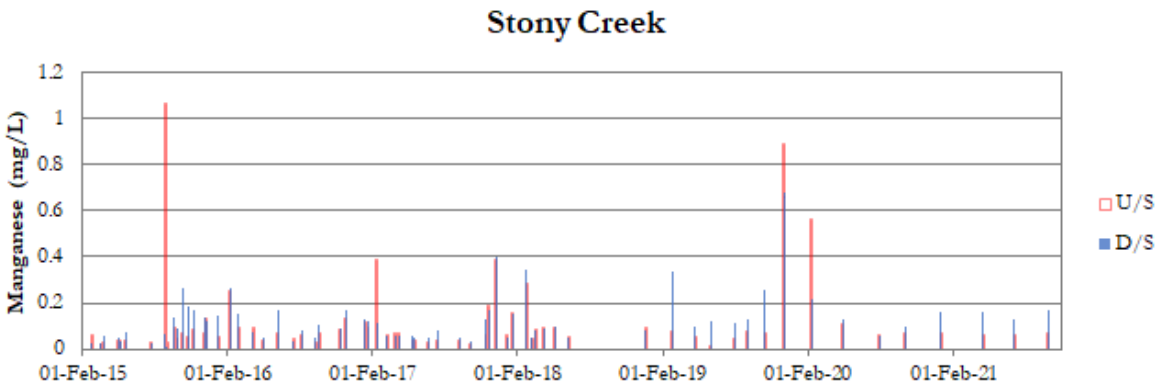

Figure 3.8 Manganese concentrations at Stony Creek since February 2015.

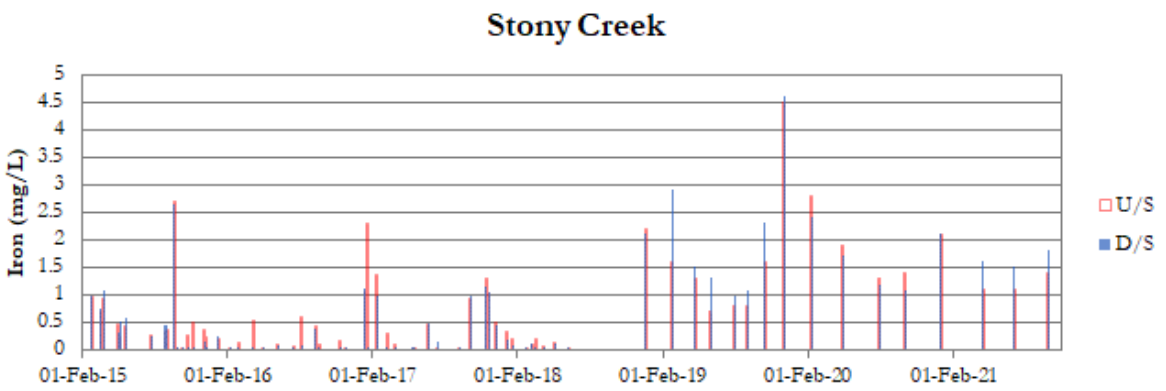

Figure 3.9 Iron concentrations at Stony Creek since February 2015.

Although there were two results of interest among the summary statistics from Stony Creek the operational phase surface water quality monitoring results to date do not indicate any water quality impacts arising from highway operation. The highest downstream concentrations of iron and manganese are commonly associated with elevated upstream concentrations indicating that the source of elevated concentrations is upstream of the highway crossing. There are no new recommendations for ongoing water quality management at Stony Creek.

3.2.3 Lower Warrell Creek

There were two results of interest from the Lower Warrell Creek monitoring sites (**Table A.3**). These were the operational downstream median TDS and conductivity measurements. Both of these values were within the normal ranges for a tidal waterway and reflect increasing salinity resulting from dry conditions during the first two years of operational monitoring rather than any impact from highway operations (see **Section 3.1**). Similar patterns can be seen on numerous occasions throughout the construction phase monitoring (**Figures 3.13** and **3.14**). There was only one operational phase downstream median result that did not comply with the relevant default guideline value, the median ammonia concentration. Although some of the downstream TSS measurements were higher than upstream measurements they were isolated results and the operational phase downstream TSS, along with turbidity and pH, measurements from Lower Warrell Creek were all within the ranges of variation measured during the construction phase and do not indicate any impacts from highway operation (**Figures 3.10** to **3.12**).

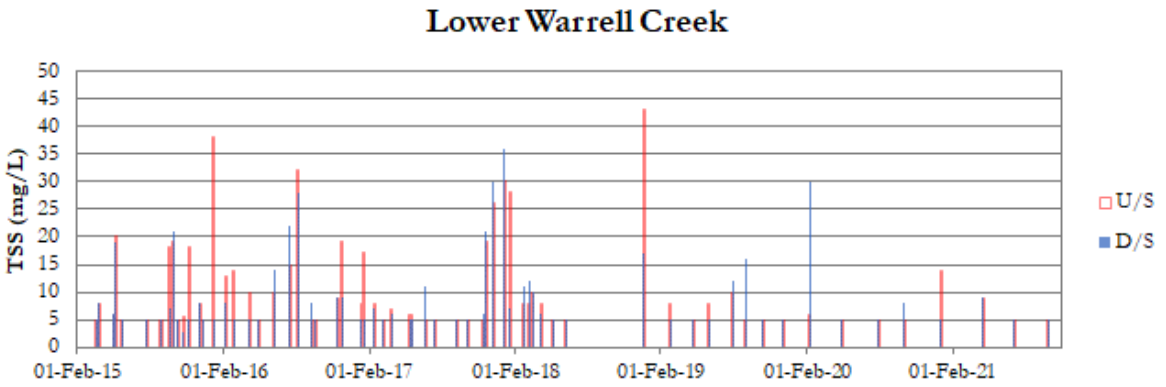

Figure 3.10 Total suspended solid concentrations at Lower Warrell Creek since February 2015.

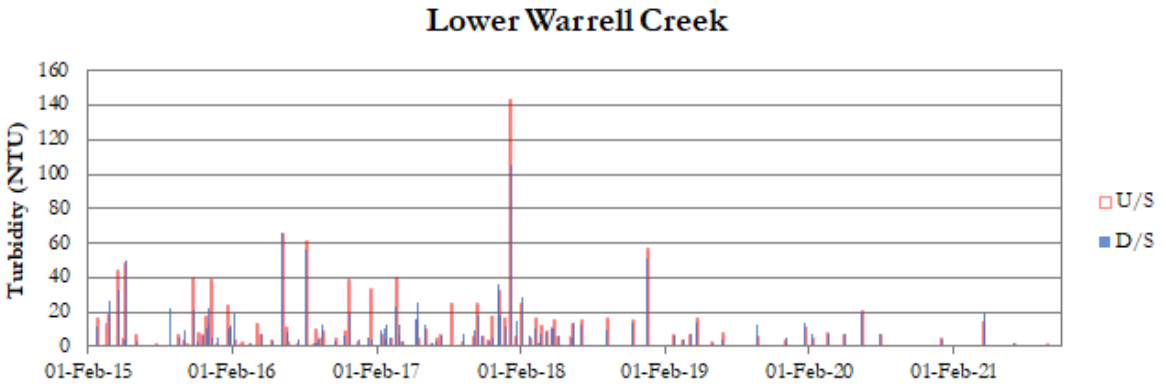

Figure 3.11 Turbidity measurements at Lower Warrell Creek since February 2015.

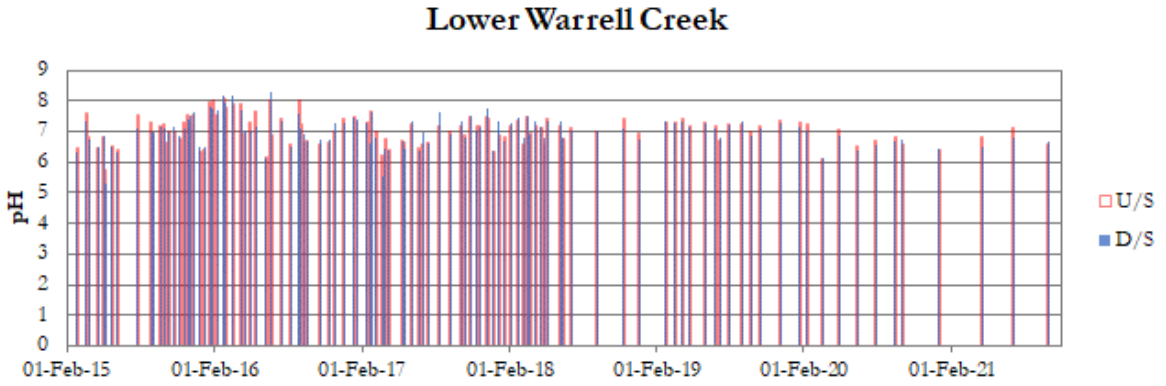

Figure 3.12 pH measurements at Lower Warrell Creek since February 2015.

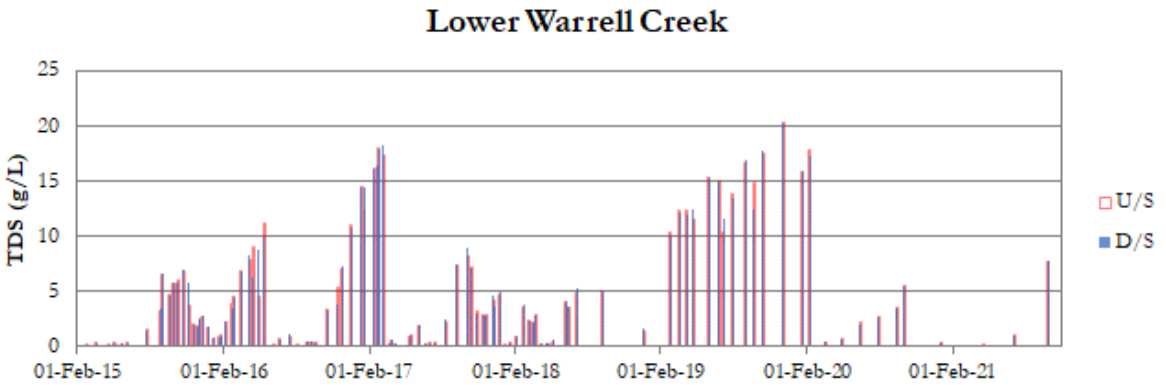

Figure 3.13 Total dissolved solid concentrations at Lower Warrell Creek since February 2015.

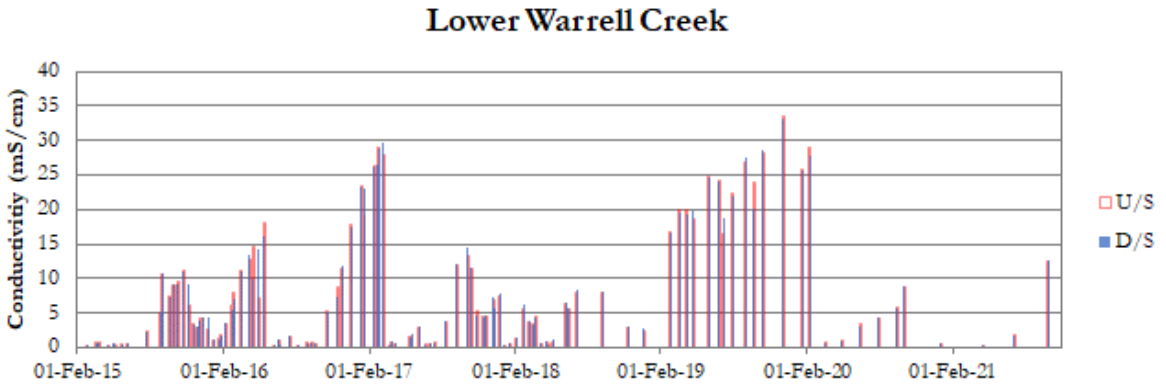

Figure 3.14 Conductivity measurements at Lower Warrell Creek since February 2015.

The operational phase surface water quality monitoring results to date from Lower Warrell Creek do not indicate any impacts from highway operation. There are no new recommendations for ongoing water quality management at Lower Warrell Creek.

3.2.4 Unnamed Creek Gumma West

There were two results of interest from the Unnamed Creek Gumma West monitoring sites (**Table A.4**). These were the operational downstream median Al and Fe concentrations. There is no relevant ANZECC (2000) default guideline for Fe concentration and the median Al concentration measured did not comply with the relevant guideline value. Graphs of Al and Fe concentrations (**Figures 3.18** and **3.19**) show that operational phase measurements have been within the ranges of construction phase measurements, elevated concentrations are isolated incidences and that elevated downstream concentrations are usually accompanied by elevated upstream concentrations. Operational phase TSS and turbidity measurements from the Unnamed Creek Gumma West have been within the ranges of variation measured during the

pre-construction and construction phases and do not indicate any impacts from highway operation (**Figures 3.16** to **3.17**).

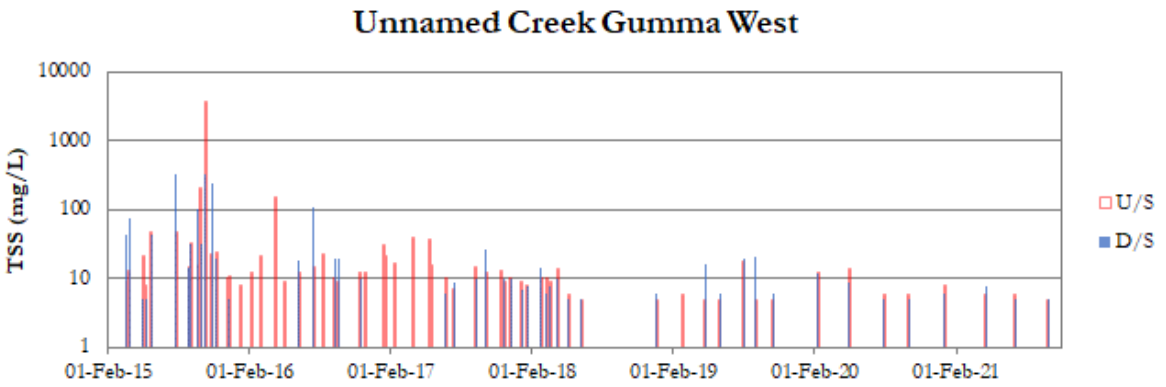

Figure 3.15 Total suspended solid measurements at Unnamed Gumma Creek West since February 2015 (note: Log_{10} scale).

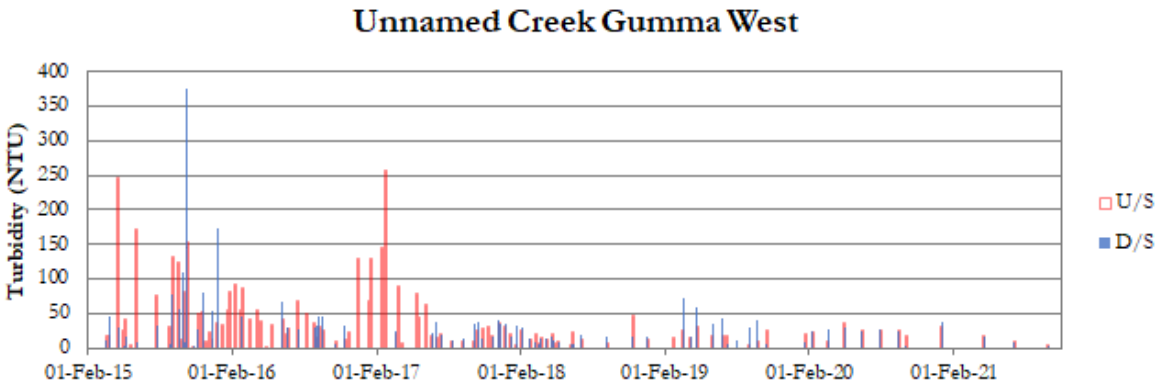

Figure 3.16 Turbidity measurements at Unnamed Gumma Creek West since February 2015.

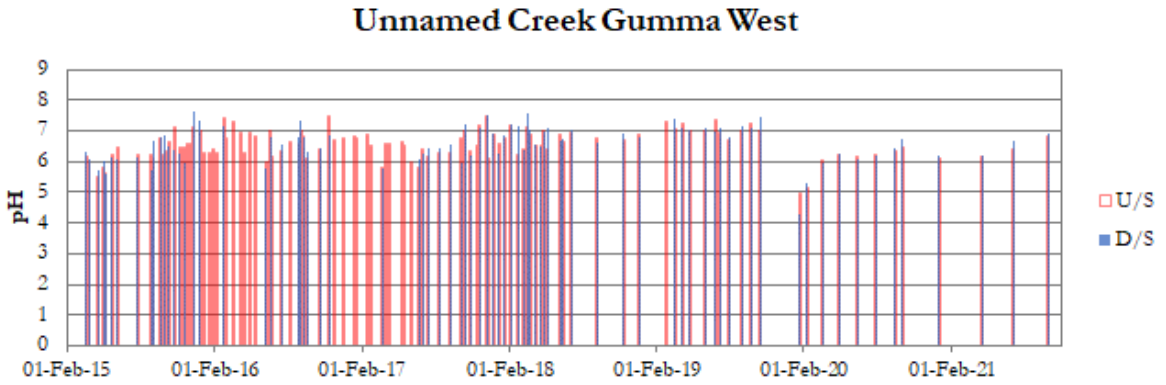

Figure 3.17 pH measurements at Unnamed Gumma Creek West since February 2015.

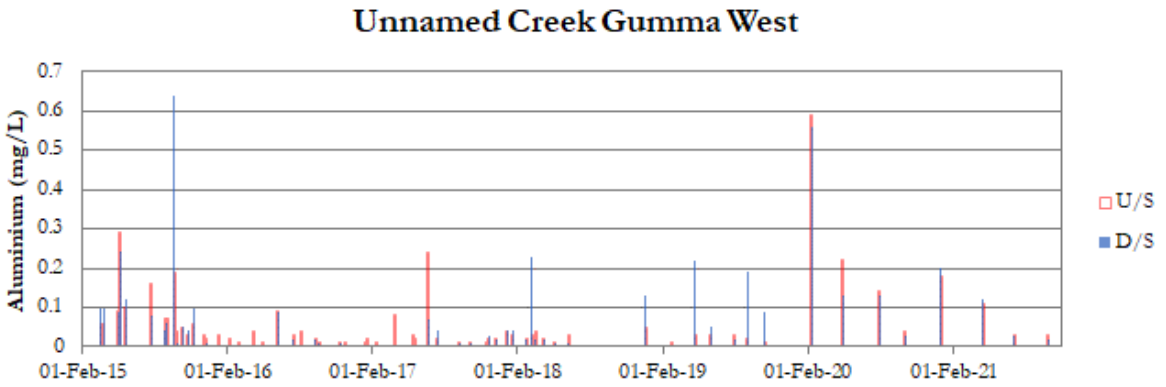

Figure 3.18 Aluminium concentrations at Unnamed Gumma Creek West since February 2015.

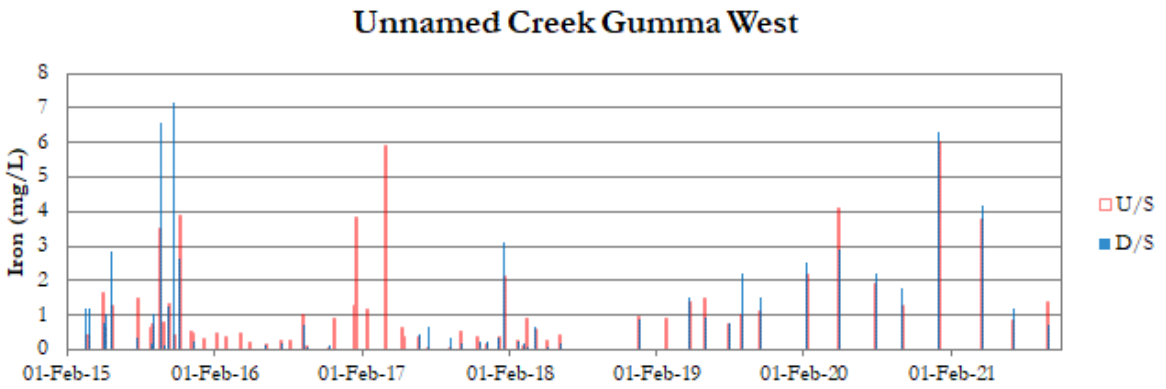

Figure 3.19 Iron concentrations at Unnamed Gumma Creek West since February 2015.

Although there were two results of interest among the summary statistics from Unnamed Creek Gumma West the operational phase surface water quality monitoring results to date do not indicate significant impacts associated with highway operation. There are no new recommendations for ongoing water quality management at Unnamed Creek Gumma West.

3.2.5 Unnamed Creek Gumma East

There was one result of interest from the Unnamed Creek Gumma East monitoring sites (**Table A.5**), the operational downstream median Al concentration. This result only very narrowly exceeded the upstream P80 value, but also did not comply with the relevant default guideline value. A graph of Al concentrations (**Figure 3.27**) shows that downstream operational phase measurements have been within the ranges of construction phase measurements and that most of the highest measurements collected during the operational phase have been from the upstream site. The operational phase median downstream result of interest for Al is therefore not likely to be associated with highway operation. Downstream operational phase TSS, turbidity

and pH measurements from the Unnamed Creek at Gumma East have been within the ranges of variation measured during the pre-construction and construction phases and do not indicate any impacts from highway operation (**Figures 3.18** to **3.20**).

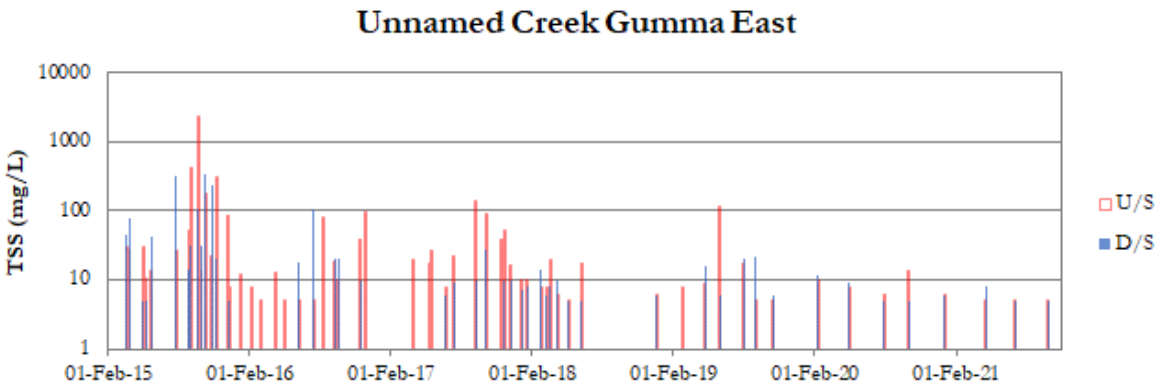

Figure 3.20 Total suspended solid measurements at Unnamed Gumma Creek East since February 2015 (note: Log_{10} scale).

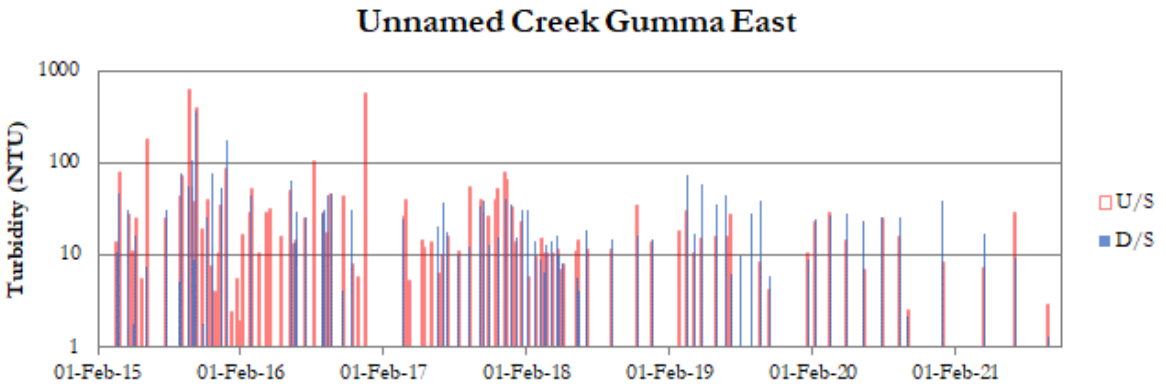

Figure 3.21 Turbidity measurements at Unnamed Gumma Creek East since February 2015 (note: Log_{10} scale).

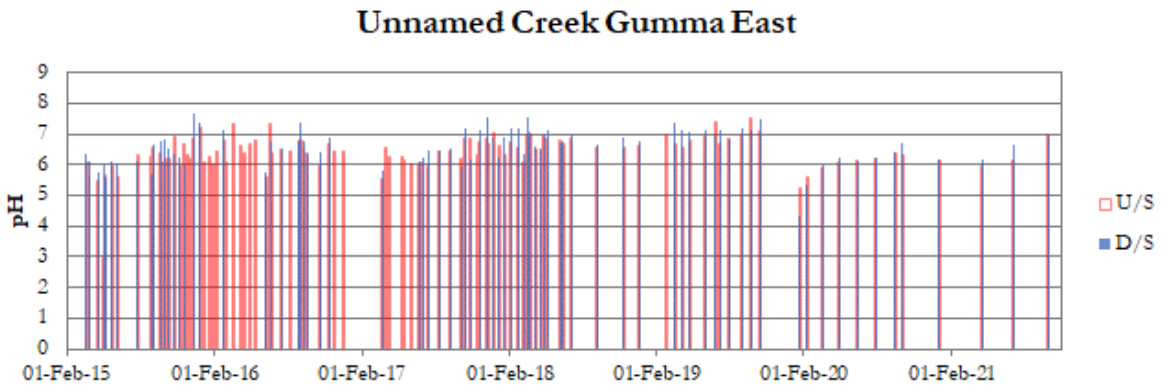

Figure 3.22 pH measurements at Unnamed Gumma Creek East since February 2015.

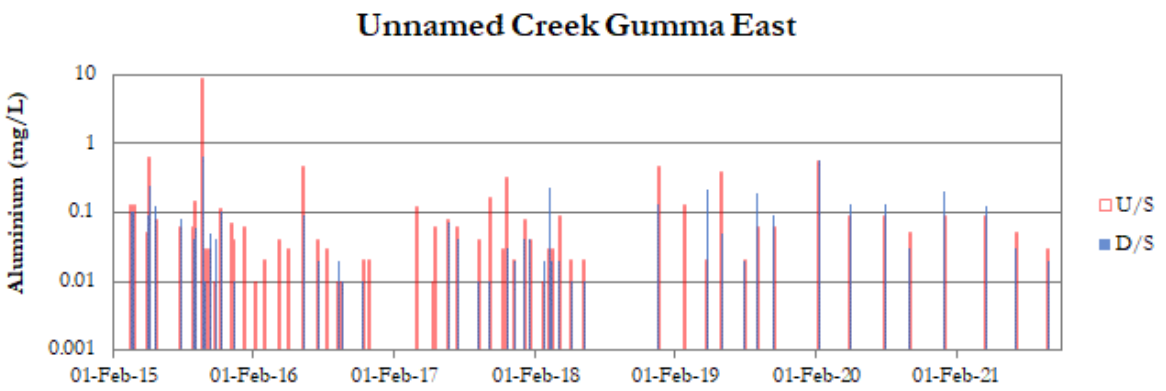

Figure 3.23 Aluminium concentrations at Unnamed Gumma Creek East since February 2015.

The operational phase surface water quality monitoring results to date from Unnamed Creek Gumma East do not indicate any impacts from highway operation. There are no new recommendations for ongoing water quality management at Unnamed Creek Gumma East.

3.2.6 Nambucca River

There was one result of interest from the Nambucca River sites (**Table A.6**), the operational downstream median Al concentration. This result only very narrowly exceeded the upstream P80 value, but also did not comply with the relevant default guideline value. A graph of the Al concentrations in all samples since 2015 shows that the Al measurements collected during the operational phase are all within the pre-construction and construction phase monitoring ranges and that the highest operational phase downstream measurements are usually collected at the same time as elevated upstream measurements. Downstream operational phase TSS, turbidity and pH measurements from the Nambucca River have also been within the ranges of variation measured during the pre-construction and construction phases and do not indicate any impacts from highway operation (**Figures 3.24** to **3.26**).

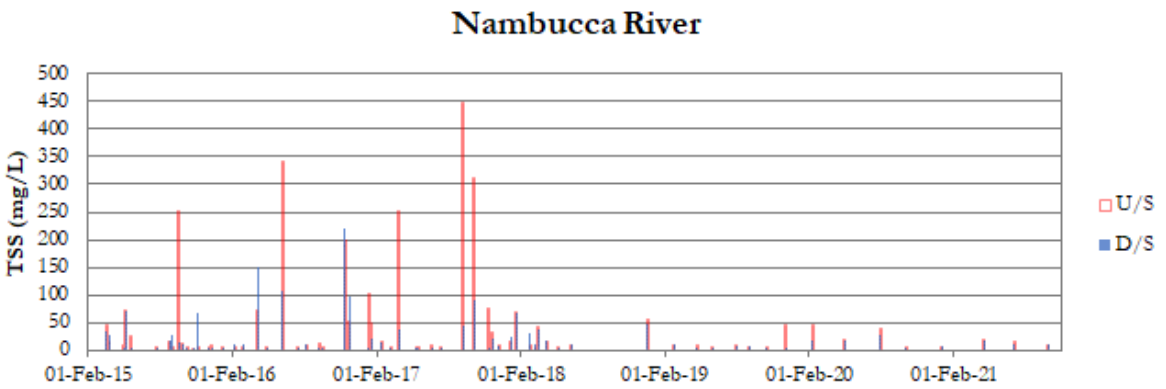

Figure 3.24 Total suspended solid measurements at the Nambucca River since February 2015.

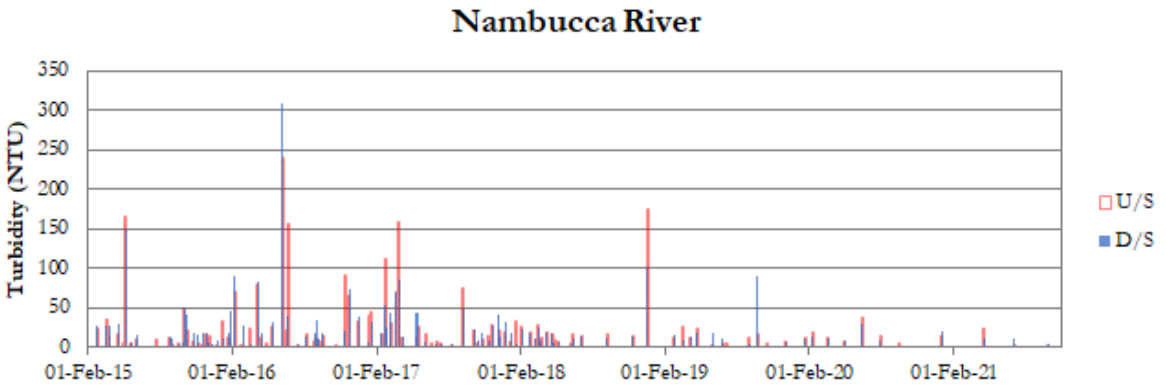

Figure 3.25 Turbidity measurements at the Nambucca River since February 2015.

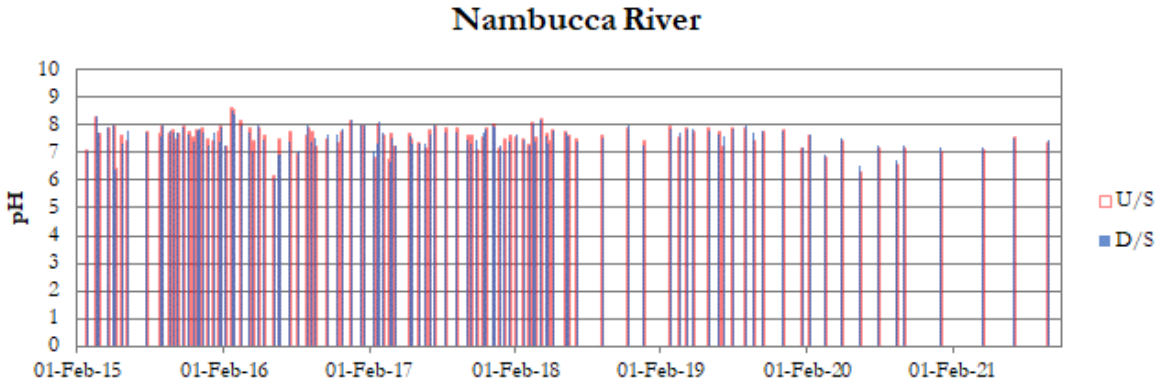

Figure 3.26 pH measurements at the Nambucca River since February 2015.

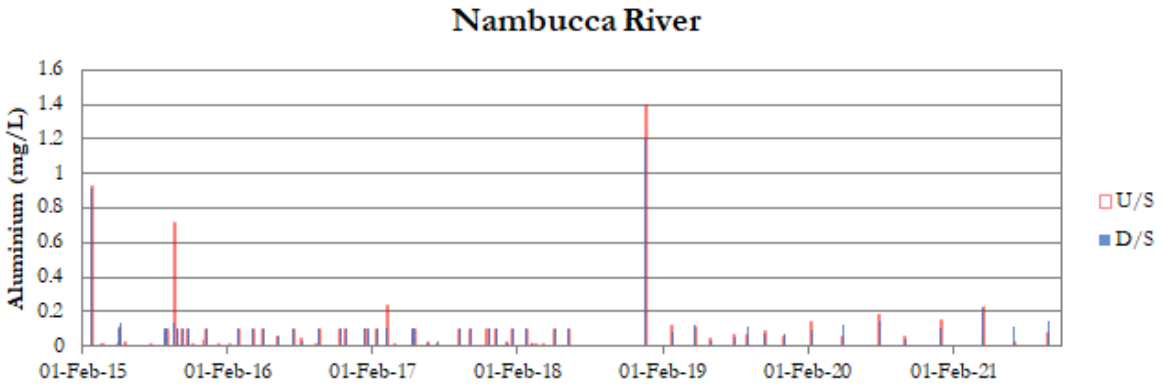

Figure 3.27 Aluminium measurements at the Nambucca River since February 2015.

The operational phase surface water quality monitoring results to date from the Nambucca River do not indicate any impacts from highway operation. There are no new recommendations for ongoing water quality management at the Nambucca River.

3.3 Groundwater Quality

A summary of groundwater quality results from the construction phase monitoring is provided in **Appendix B**.

The GWMP suggests that the analysis of impacts should involve a comparison of the median sampling results from downgradient (impact) sites with the 80th percentile (P80) value of upgradient (control) sites. The summary data from each downgradient site is presented in **Appendix B** with the upgradient P80 values from the construction phase.

The relevant summary statistics for each groundwater site are presented in **Tables B.1** to **B.5**. A description of the summary results from each cut or fill follows. For the purposes of assessing the results of operational phase monitoring with earlier results we have defined results of interest as those where the operational phase downgradient median is greater than the combined construction and operational phase upgradient P80.

3.3.1 Ch 45165 – Cut 6

There were no results of interest from Ch 45165 during this reporting period. There was no upgradient piezometer at Ch 45165 (**Table B.1**). The upgradient piezometer was decommissioned during the construction phase after consultation with Department of Planning and Environment and NSW Government agencies. The downgradient piezometer at Ch 45165 was damaged during the first year of operational monitoring and has since been repaired. It is intermittently dry. As a result, there are fewer operational phase samples from Ch 45165 than some of the other sites. The median pH measurement from the samples collected did not comply with the relevant ANZECC and ADWG guidelines. However, the results were within the variation previously observed at that site (**Figures 3.28** and **3.29**). Several other operational phase downstream median results did not comply with ANZECC and/or ADWG guidelines. However, the results are comparable with the corresponding results from the construction phase monitoring (**Table B.1**) and there is no indication of an impact from highway operation on groundwater at Ch 45165.

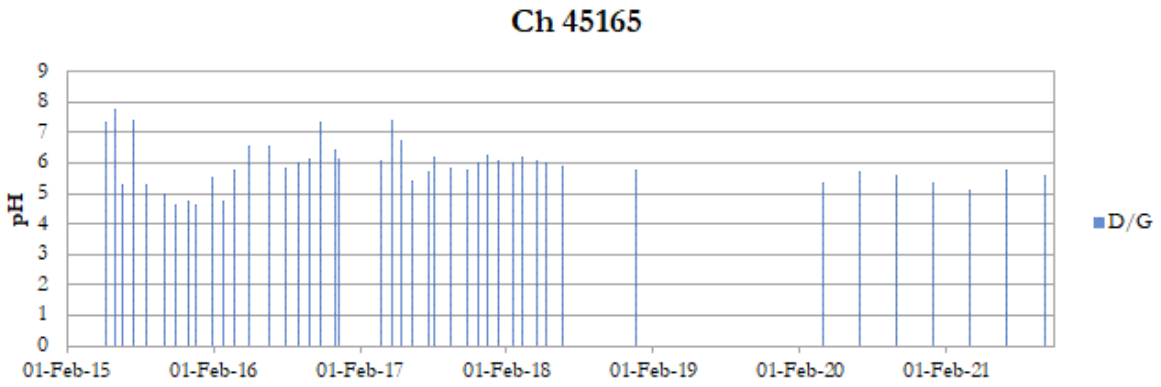

Figure 3.28 Groundwater pH measurements at Ch 45165 since February 2015.

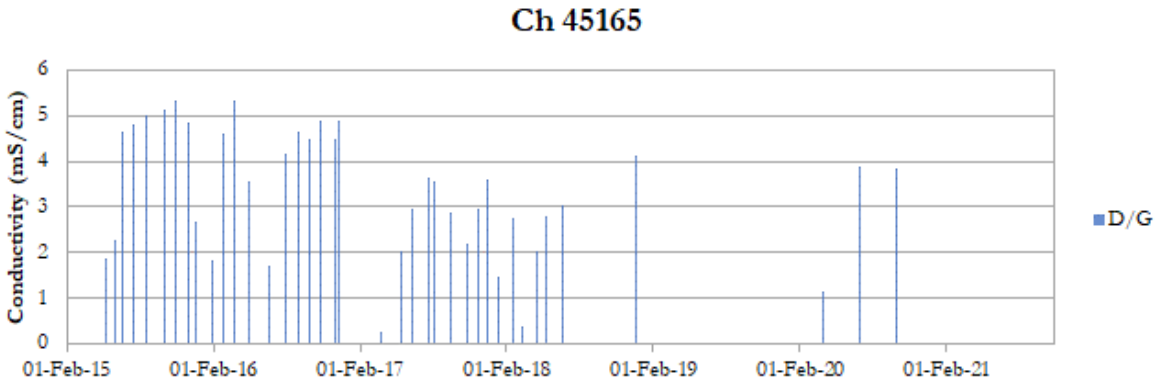

Figure 3.29 Groundwater conductivity measurements at Ch 45165 since February 2015.

3.3.2 Ch 48665 – Cut 11

There were 2 results of interest from Ch 48665 (**Table B.2**). These were the operational downgradient median TP and total alkalinity measurements. The downgradient median TP value also exceeded the relevant ANZECC (2000) guideline concentration for ecosystem protection. There are no relevant guideline values for total alkalinity. Some of the downgradient TP concentrations measured during operational phase monitoring have been higher than those measured in construction phase monitoring (**Figure 3.32**). Total alkalinity measurements (**Figure 3.33**) have only been collected in the operational phase and are no previous data is available for comparisons. The conductivity measurements to date indicate that samples collected from upgradient and downgradient piezometers at Ch 48665 are potentially from different aquifers (**Figure 3.31**). The upgradient conductivity is routinely higher than the downgradient conductivity, despite being further from the tidal influence of Warrell Creek. This

is a strong indication that any results of interest may not be related to impacts from highway operation.

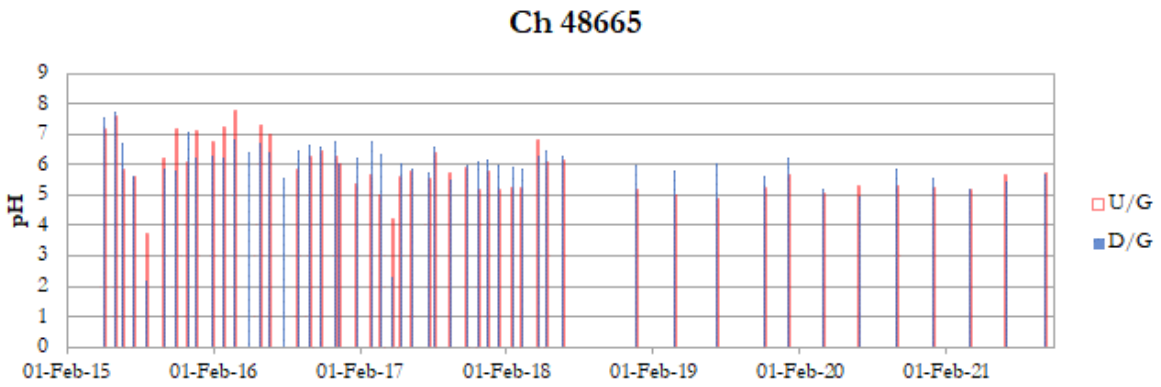

Figure 3.30 Groundwater pH measurements at Ch 48665 since February 2015.

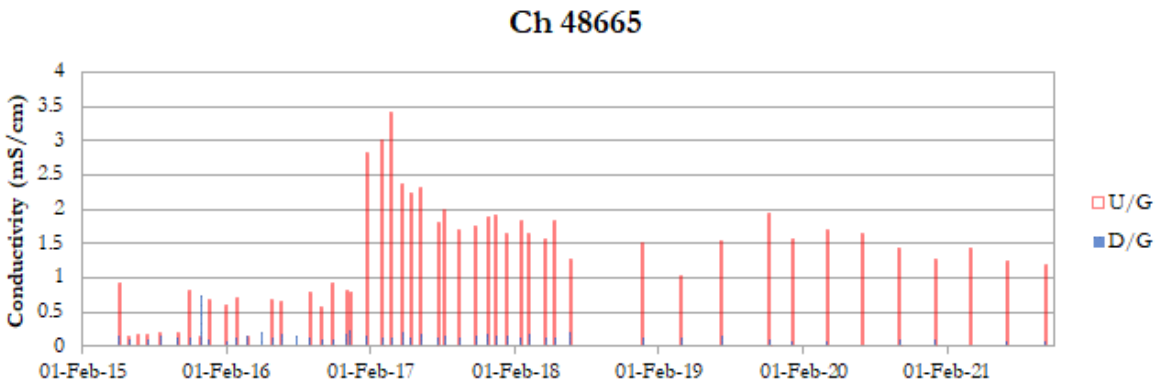

Figure 3.31 Groundwater conductivity measurements at Ch 48665 since February 2015.

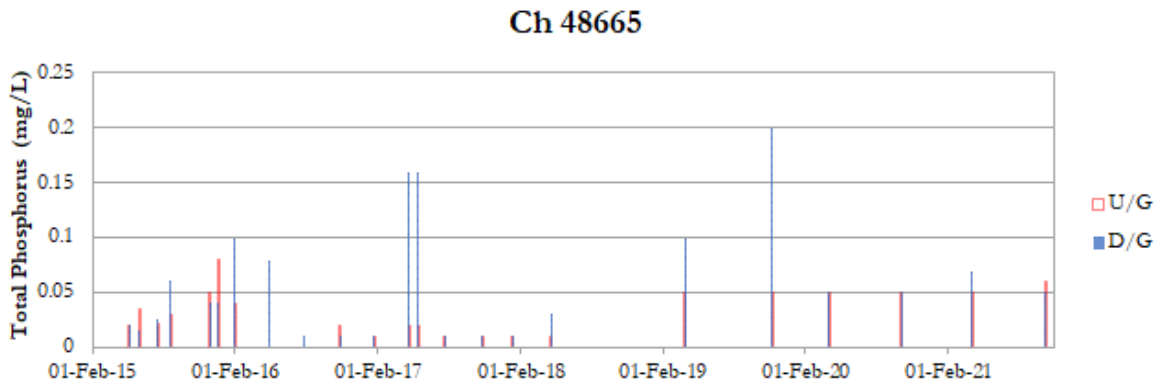

Figure 3.32 Groundwater total phosphorus measurements at Ch 48665 since February 2015.

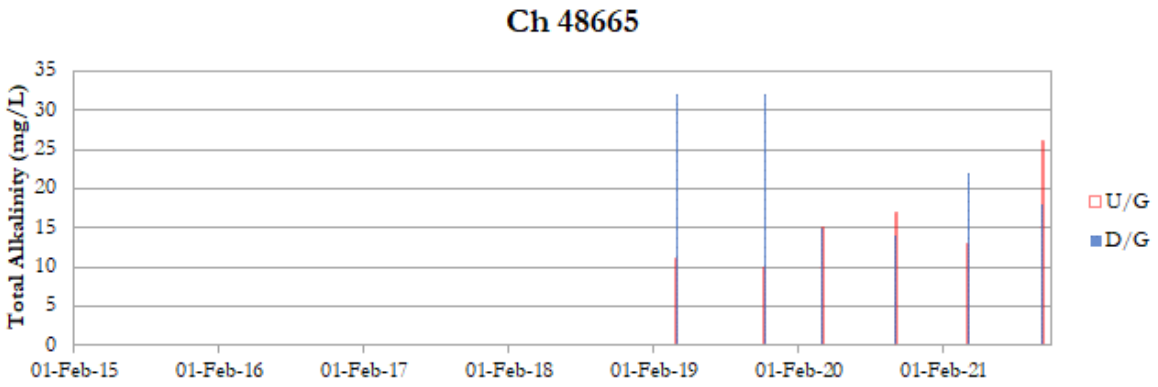

Figure 3.33 Groundwater total alkalinity measurements at Ch 48665 since February 2015.

The operational phase groundwater quality monitoring results to date do not provide a clear indication of impacts associated with highway operation at Ch 48665. Although high downgradient TP measurements have been collected during operational phase monitoring it is possible that these relate to factors not associated with the highway. Significantly elevated TP concentrations in the downgradient piezometer have not been observed consistently during the operational phase and not in the last two years of operational monitoring. There are no new recommendations for ongoing groundwater quality management at Ch 48665.

3.3.3 Ch 49365 – Cut 12

There were no results of interest from Ch 49365 (**Table B.3**). There is no upgradient piezometer at Ch 49365 for the operational monitoring phase. The upgradient piezometer was decommissioned during the construction phase after consultation with Department of Planning and Environment and NSW Government agencies. The downgradient piezometer at Ch 49365 is intermittently dry and has only had water to sample on five occasions since the start of operational monitoring. Some of the operational phase downgradient pH and conductivity measurements from Ch 49365 were outside of the ranges measured in construction phase monitoring but only very slightly so (**Figures 3.34** and **3.35**). It is unlikely that the measured differences are related to highway operation or any other negative impact.

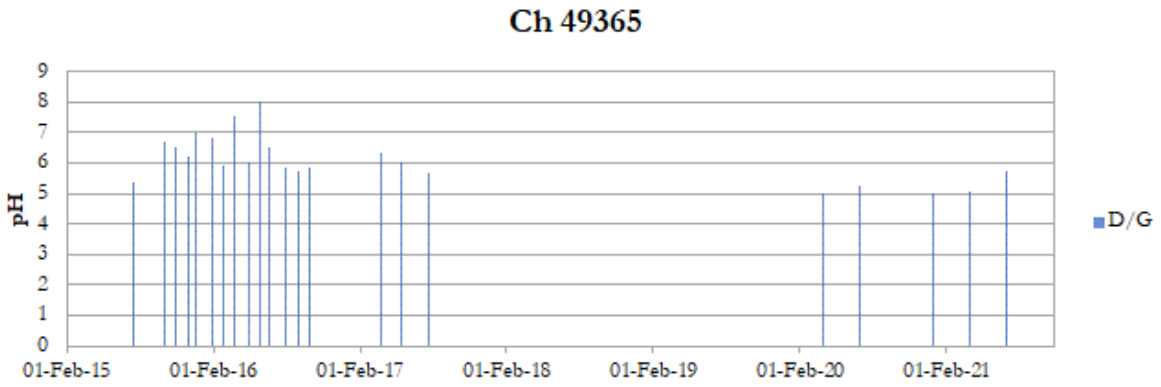

Figure 3.34 Groundwater pH measurements at Ch 49365 since February 2015.

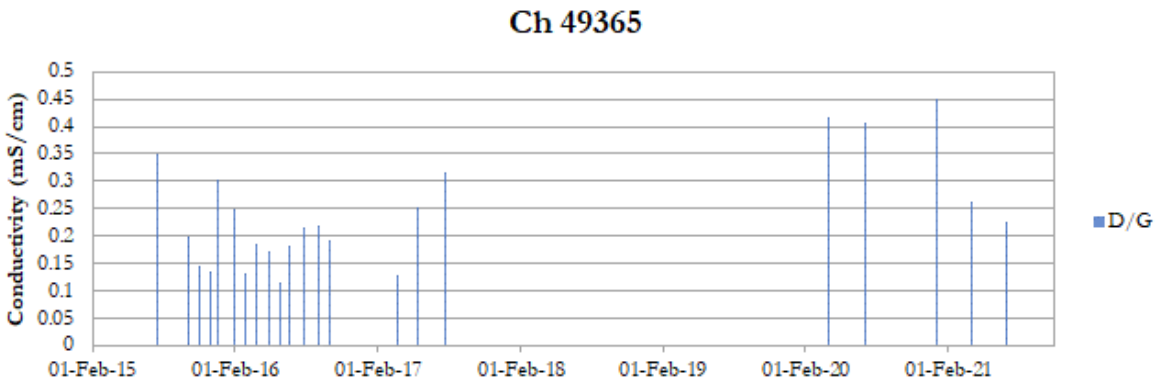

Figure 3.35 Groundwater conductivity measurements at Ch 49365 since February 2015.

The operational phase groundwater quality monitoring results to date do not provide any indication of impacts associated with highway operation at Ch 49365. There are no new recommendations for ongoing groundwater quality management at Ch 49365

3.3.4 Ch 50965 – Fill 15

There were seven results of interest from Ch 50965 (**Table B.4**), being the downgradient median Cu, TN, NO_3, SO_4^{2-}, Ca^{2+}, Mg^{2+} and conductivity measurements. None of these results were within the relevant ANZECC default guideline concentration for ecosystem protection. There are no relevant guidelines for Ca^{2+} and Mg^{2+} concentrations and no ADWG guideline for TN. There were also several results of interest generated for groundwater quality at Ch 50965 during the construction phase monitoring. However, of the results of interest there are none that indicate an impact of highway operation on groundwater at Ch 50965. Conductivity measurements indicate that both upgradient and downgradient groundwater has been subject to saline water encroachment during the operational phase, probably as a result of continued dry weather and the influence of the Nambucca River estuary (**Figure 3.37**). A similar pattern has

been evident in previous monitoring and is also repeated in nearby surface water measurements (see **Section 3.2.4**). This phenomenon also explains the elevated concentrations of Ca^{2+} measured upgradient and downgradient of the highway fill (**Figure 3.41**). The operational phase TN and NO_3 measurements from Ch 50965 have been highly variable. The TN concentrations are mostly within the upgradient and downgradient ranges observed during construction phase monitoring but many of the NO_3 measurements are outside of them (**Figures 3.38** to **3.39**).

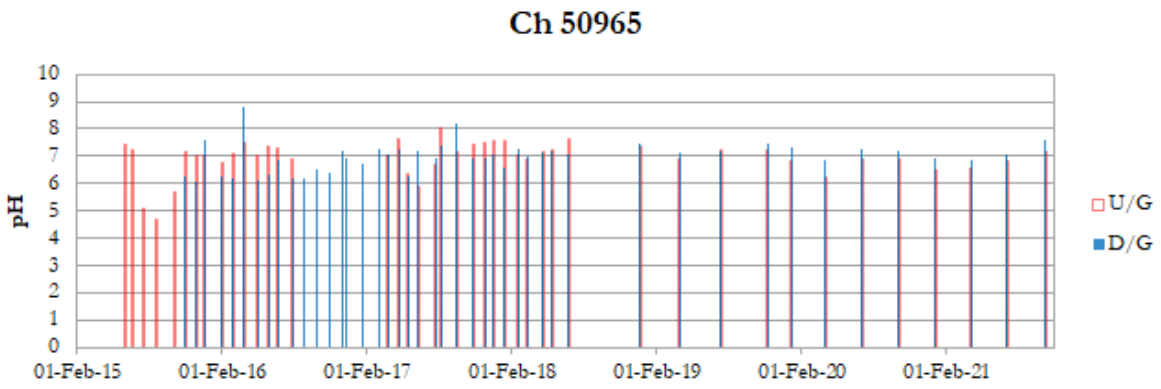

Figure 3.36 Groundwater pH measurements at Ch 50965 since February 2015.

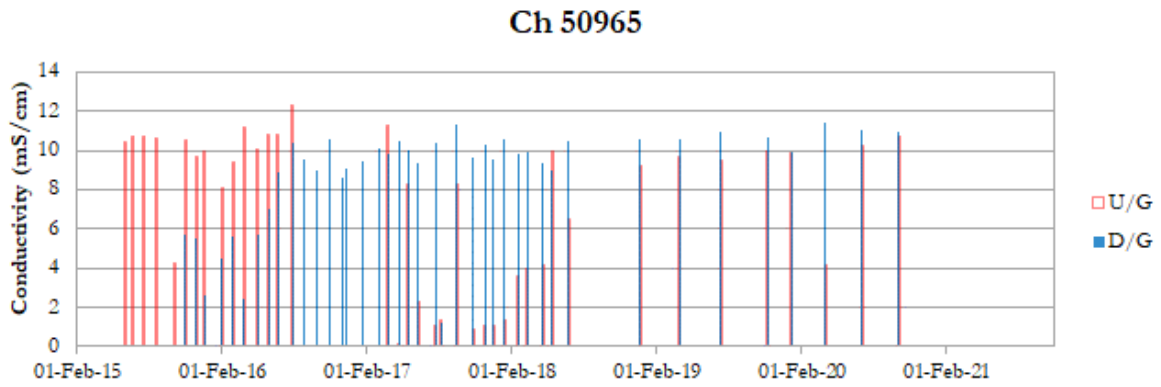

Figure 3.37 Groundwater conductivity measurements at Ch 50965 since February 2015.

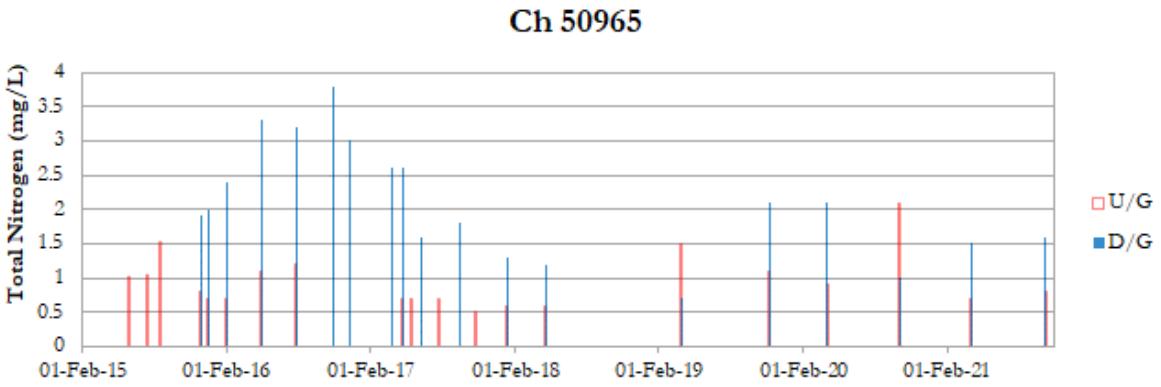

Figure 3.38 Groundwater total nitrogen measurements at Ch 50965 since February 2015.

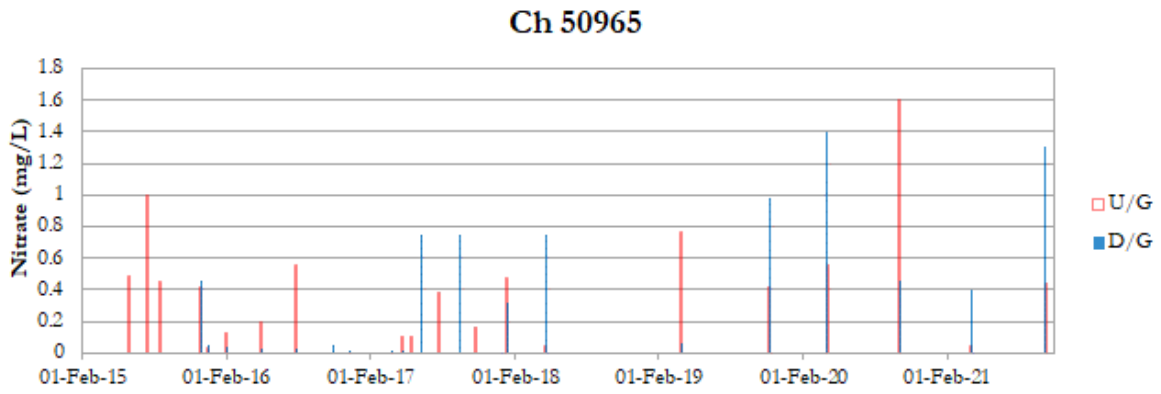

Figure 3.39 Groundwater nitrate measurements at Ch 50965 since February 2015.

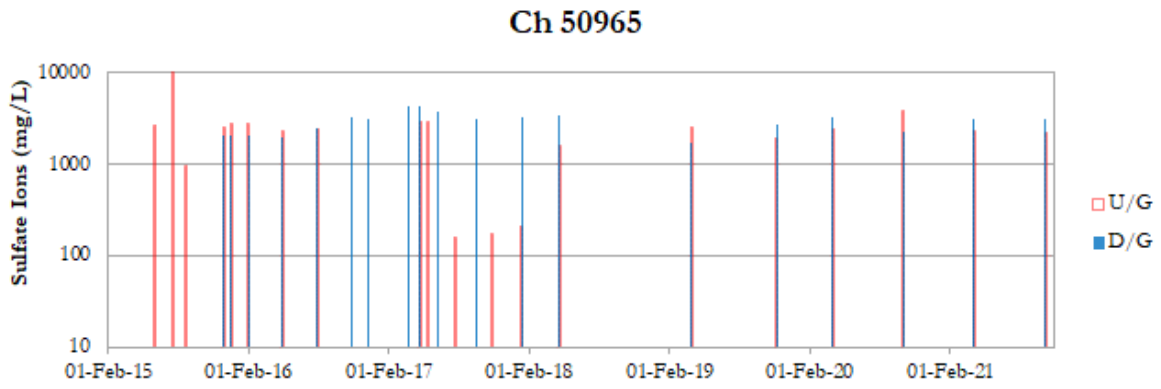

Figure 3.40 Groundwater sulfate ion measurements at Ch 50965 since February 2015 (note: Log_{10} scale).

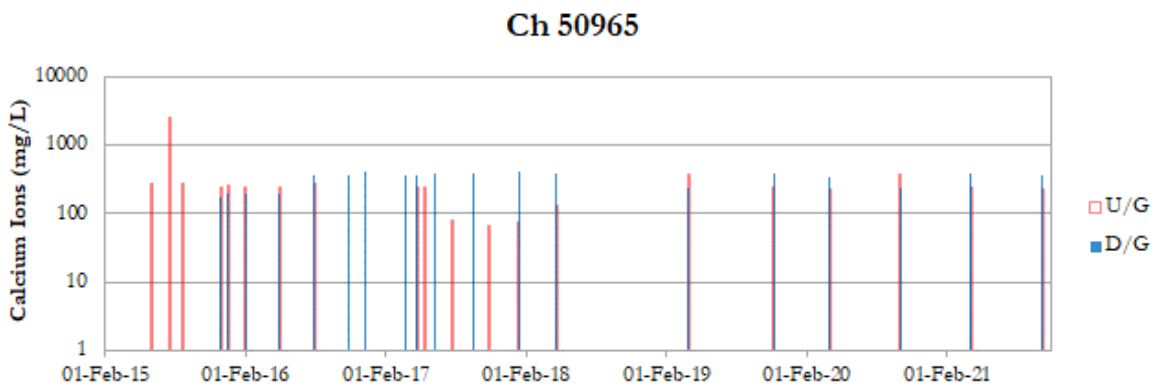

Figure 3.41 Groundwater calcium ion measurements at Ch 50965 since February 2015 (note: Log_{10} scale).

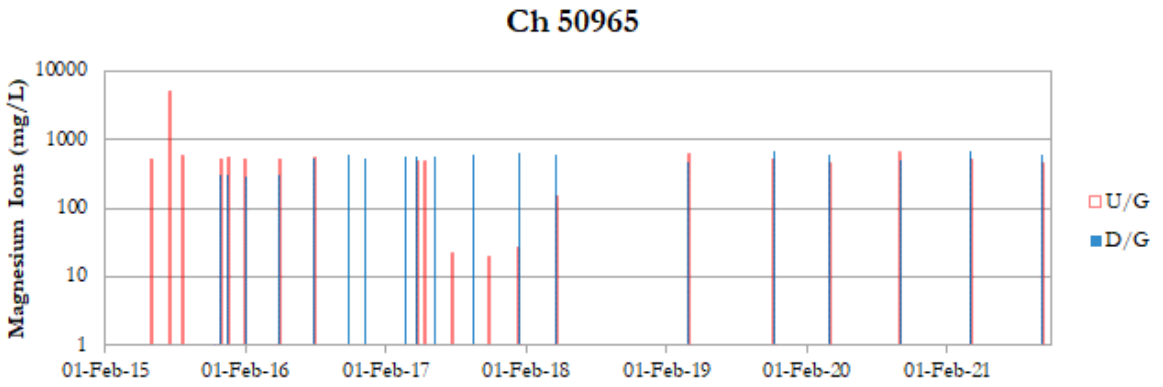

Figure 3.42 Groundwater magnesium ion measurements at Ch 50965 since February 2015 (note: Log_{10} scale).

The operational phase groundwater quality monitoring results to date do not provide a clear indication of impacts associated with highway operation at Ch 50965. Saline encroachment related to long-term dry weather and the influence of the Nambucca River estuary has impacted results and there are no trends apparent in the results. There are no new recommendations for ongoing groundwater quality management at Ch 50965.

3.3.5 Ch 54065 – Cut 15

There was one result of interest from Ch 54065 (**Table B.5**), the downstream median operational phase Hg concentration. This result was also greater than the default guideline value for ecosystem protection. All other operational phase downstream median results to-date comply with relevant guidelines with the exception of the median Cu, NO_3, pH and conductivity

measurements. All of these results are within the ranges observed in the upgradient piezometer during construction phase monitoring and do not indicate any impacts associated with highway operation (**Figure 3.46** and **3.47**). There was no water in the downgradient piezometer at Ch 54065 for the first months of operational monitoring or for the majority of construction phase monitoring. A new downgradient piezometer was constructed at Ch 54065 in July 2019.

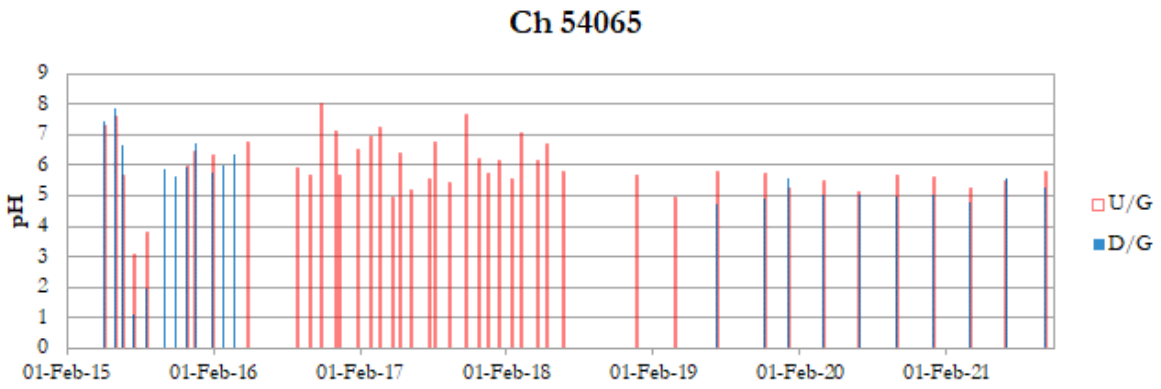

Figure 3.43 Groundwater pH measurements at Ch 54065 since February 2015.

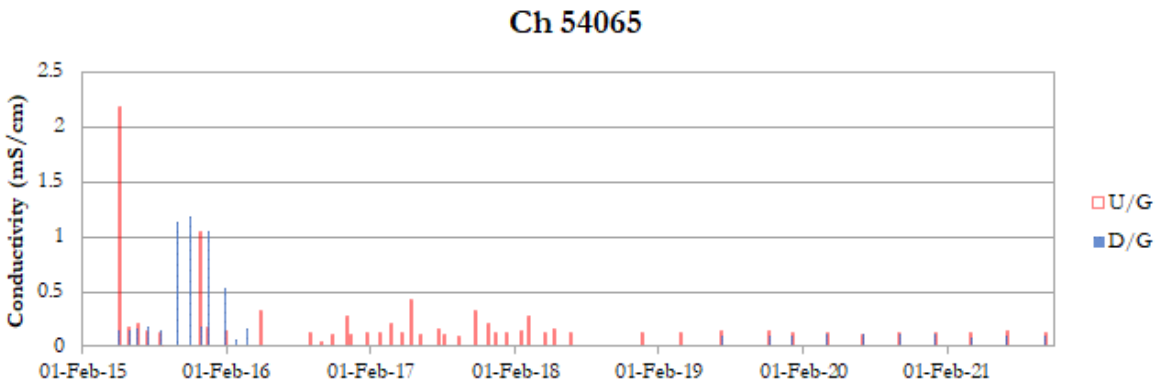

Figure 3.44 Groundwater conductivity measurements at Ch 54065 since February 2015.

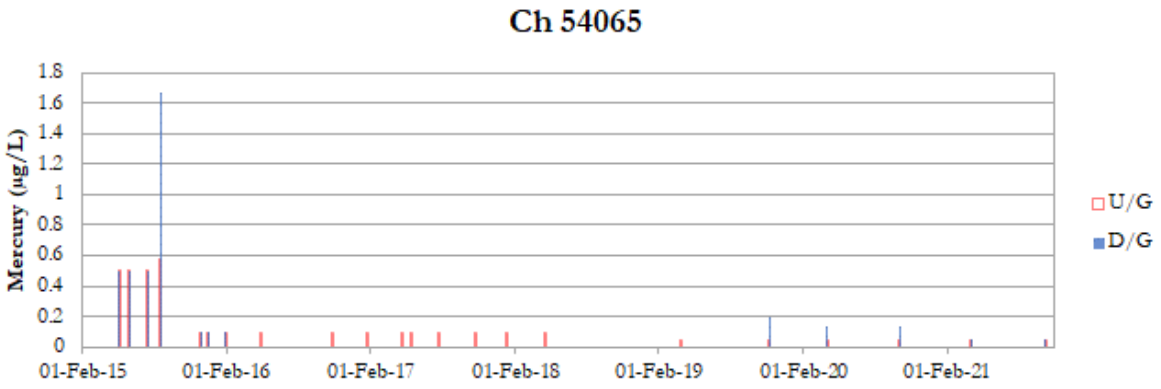

Figure 3.45 Groundwater mercury measurements at Ch 54065 since February 2015.

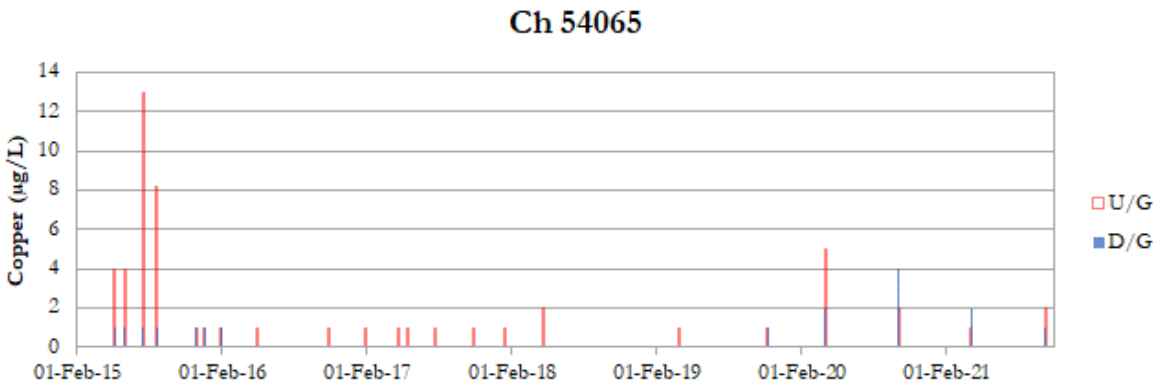

Figure 3.46 Groundwater copper measurements at Ch 54065 since February 2015.

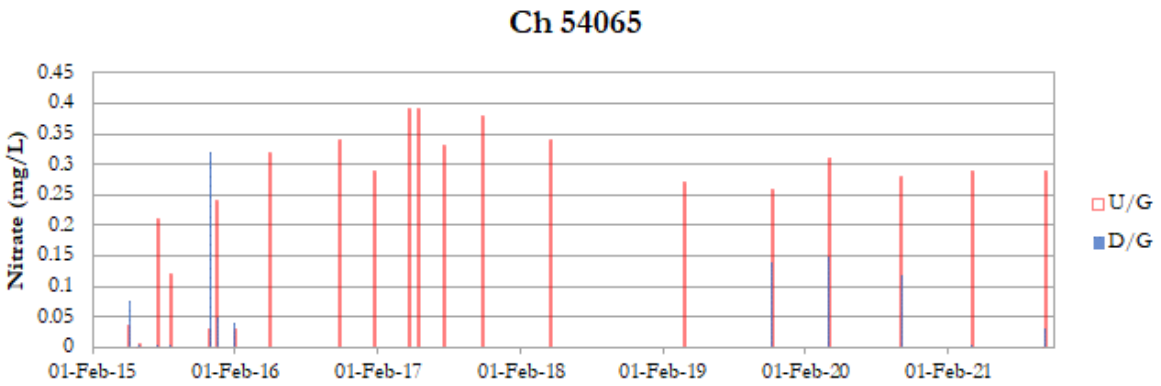

Figure 3.47 Groundwater nitrate measurements at Ch 54065 since February 2015.

The operational phase groundwater quality monitoring results to date do not indicate any impacts associated with highway operation at Ch 54065. There are no new recommendations for ongoing groundwater quality management at Ch 54065.

3.4 Groundwater Level

The logged groundwater level data collected to-date in operational phase monitoring is displayed in **Figures 3.48 to 3.52.**

There is no upgradient piezometer at Ch 45165 (Cut 6). The water level in the downgradient piezometer fluctuated both upwards and downwards during operational phase monitoring (**Figure 3.48**), indicating normal groundwater response to recharge and discharge events. The

piezometer at Ch 45165 dried out during dry weather in the first annual reporting period and no water was detected from the late March 2019 until after heavy rain fell in early February 2020. The median logged depth to water at the Cut 6 downgradient piezometer for the operational phase monitoring period to date was 15.40 m (relative level 8.70 mAHD), higher than the median logged depth to water of 16.12 m from the construction phase monitoring period.

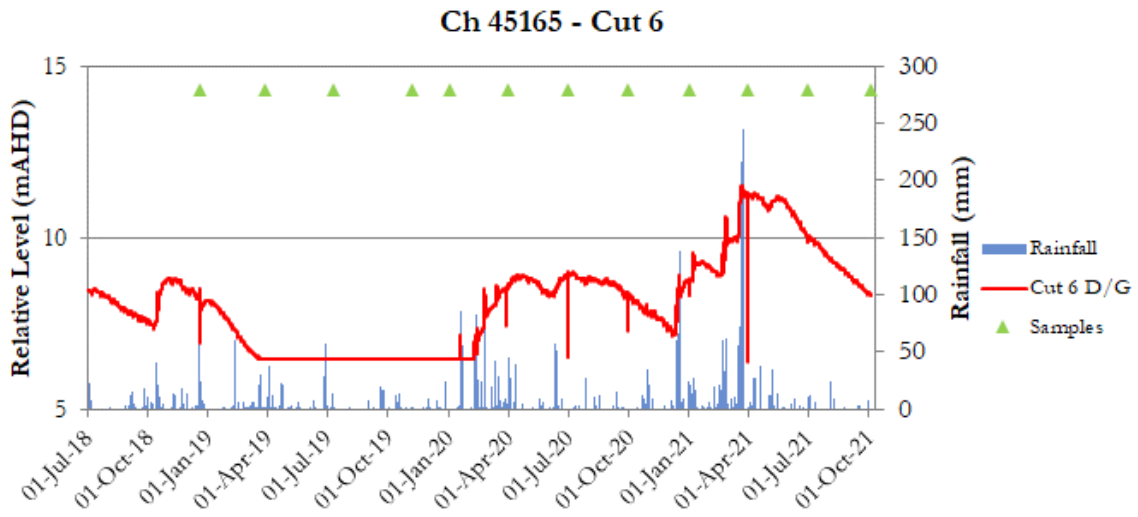

Figure 3.48 Operational phase groundwater levels at chainage 45165

The upgradient and downgradient water levels at Ch 48665 (Cut 11) fluctuated both upwards and downwards during operational phase monitoring (**Figure 3.49**) indicating a normal groundwater response to discharge and recharge events. The upgradient and downgradient piezometers maintained a similar level relative to each other indicating no impact to groundwater levels from highway operation, although the water level in the upgradient piezometer responded to some small to medium rainfall events that did not have an impact on the water level in the downgradient piezometer and the downgradient piezometer responded with greater level variations to very heavy rainfall events. The location of the upgradient piezometer changed during the construction monitoring phase and the new upgradient piezometer is in a position where the groundwater table was much closer to the surface of the ground. The median logged depth to water at the new Cut 11 upgradient piezometer for operational phase monitoring to date was 2.11 m (relative level 16.69 mAHD), deeper than the median logged depth to water of 1.72 m from the construction phase monitoring period. The median logged depth to water at the Cut 11 downgradient piezometer for this reporting period was 7.39 m (relative level 5.11 mAHD), also deeper than the median logged depth to water of 7.25 m from the construction

phase monitoring period. These deeper median depths to water observed during the operational phase are likely to be a result of generally dry weather conditions, rather than any impact from highway operation. There is a period of water level data from the downgradient piezometer that is missing due to battery failure (30th March 2020 until 29th June 2020). It is unlikely to significantly impact the interpretation of results.

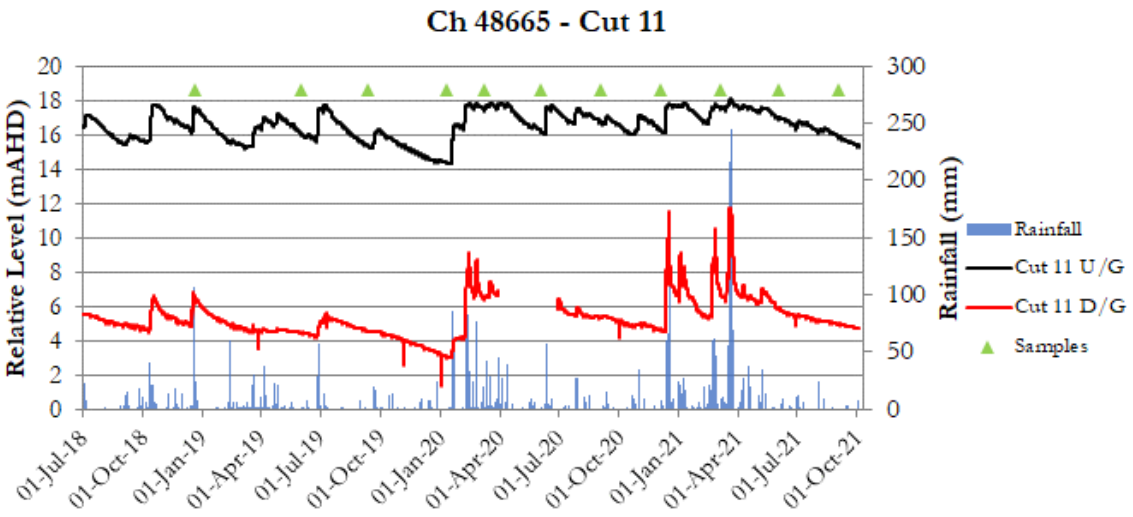

Figure 3.49 Operational phase groundwater levels at chainage 48665

There is no upgradient piezometer at Ch 49365 (Cut 12). The downgradient piezometer at Cut 12 was dry for much of the operational phase monitoring period until heavy rainfall raised groundwater levels in early February 2020 (**Figure 3.50**). After that time the water levels fluctuated upwards and downwards indicating a normal response to groundwater discharge and recharge events. The location of the downgradient piezometer was changed during the construction monitoring period and the available information was limited due to gaps in, and problems with the quality of, the logged data. The median depth to water in the downgradient piezometer for the operational phase monitoring period was 7.33 m (relative level 8.77 mAHD).

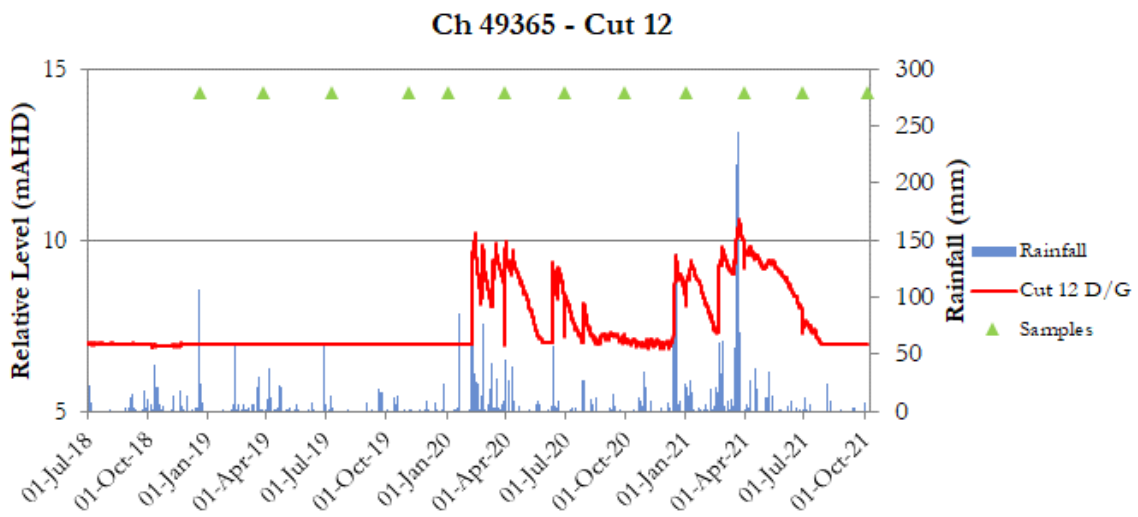

Figure 3.50 Operational phase groundwater levels at chainage 49365

At Ch 50965 (Fill 15) the groundwater levels fluctuated both upwards and downwards during this reporting period indicating a normal response to groundwater discharge and recharge events. The available data shows clearly that groundwater levels upgradient and downgradient fluctuated in a similar way in response to groundwater recharge and discharge events, although the upgradient aquifer is more prone to discharge during periods of dry, hot weather and responds faster to recharge events (**Figure 3.51**). The median logged depth to water at the Fill 15 upgradient piezometer for operational phase monitoring to date was 0.84 m (relative level 1.16 mAHD), similar to the median logged depth to water of 0.89 m from the construction phase monitoring period. The median logged depth to water at the Fill 15 downgradient piezometer for operational phase monitoring was 0.78 m (relative level 1.02 mAHD), comparable to the median logged depth to water of 0.81 m from the construction phase monitoring period.

The upgradient groundwater level at Ch54065 (Cut 15) fluctuated both upwards and downwards indicating a normal response to groundwater recharge and discharge events. The downgradient piezometer was dry at the start of operational phase monitoring but a new piezometer was constructed in July 2019. The water levels in the upgradient and downgradient piezometers respond to wet and dry events in a very similar fashion (**Figure 3.52**). For the period where data from both piezometers is available the groundwater levels upgradient and downgradient of the WC2NH upgrade maintain a similar relative response to groundwater discharge. The locations of both piezometers were changed during construction phase monitoring. The median logged depth to water at the Cut 15 upgradient piezometer for operational phase monitoring to date was 15.45

m (relative level 3.76 mAHD), similar to the median logged depth to water of 15.58 m from the construction phase monitoring period. The operational phase median logged depth to water from the newest downgradient piezometer was 16.43 m (relative level 2.47 mAHD). There is no relevant construction phase median value available for comparison.

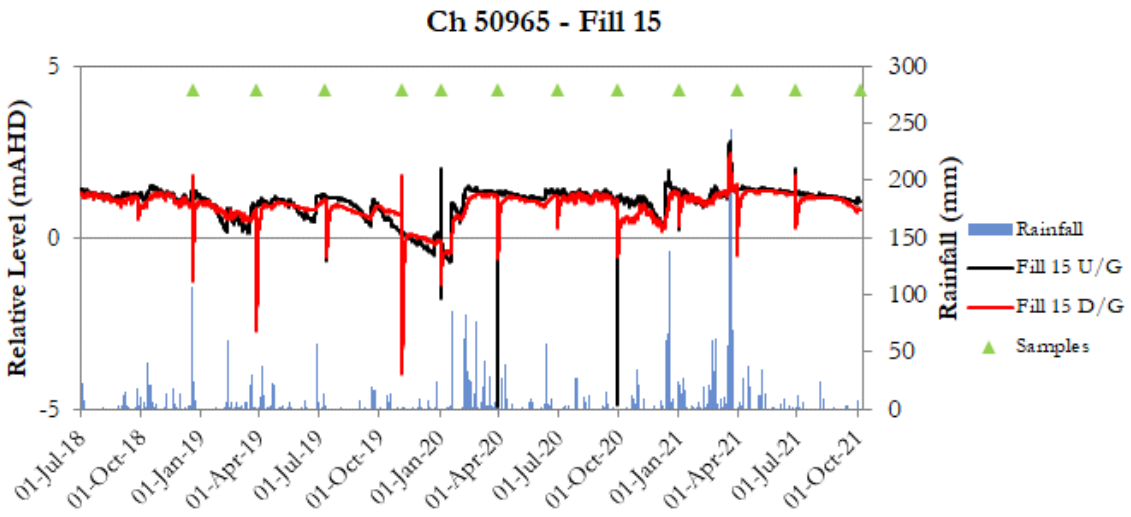

Figure 3.51 Operational phase groundwater levels at chainage 50965

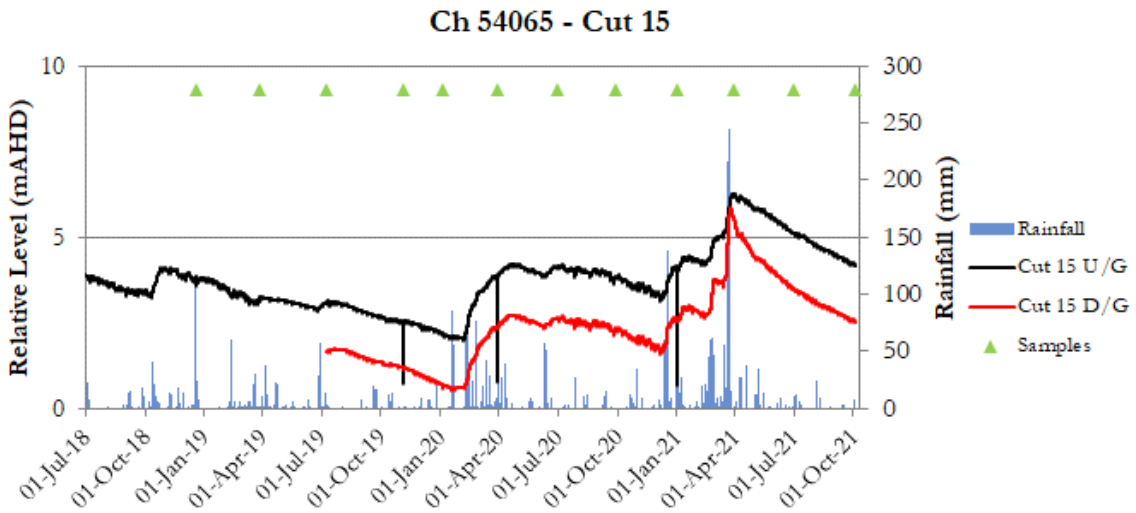

Figure 3.52 Operational phase groundwater levels at chainage 54065

4 Key Observations

4.1 Surface Water Quality

- There was a downward trend in the number of results of interest throughout operational monitoring.
- The results of interest from the data summary (**Appendix A**) have been described in **Section 3.2** and show no clear indications of significant impacts associated with highway operation.
- Guideline concentrations have been referenced to provide context for results of interest.

4.2 Groundwater Quality

- There was a downward trend in the number of results of interest throughout operational monitoring.
- At two of the groundwater monitoring locations, Ch 45165 (Cut 6) and Ch 49365 (Cut 12), there are no upgradient piezometers, limiting the capacity to draw conclusions about the impacts of construction works upon downgradient groundwater quality and levels.
- Three of the downgradient piezometers, at Ch 49365 (Cut 12), Ch 45165 (Cut 6) and Ch 54065 (Cut 15), were dry for parts of the operational phase monitoring period to date, limiting the capacity to draw conclusions about the impacts of highway operation upon downgradient groundwater quality and levels due to a reduced number of samples and data points.
- At some of the groundwater monitoring sites new piezometers were constructed during the construction phase monitoring period to replace piezometers that had dried out, had become inaccessible or were otherwise damaged or not functioning. A new downgradient piezometer was constructed at Ch 54065 (Cut 15) during the operational phase monitoring.
- The results of interest from the data summary (**Appendix B**) have been described in **Section 3.3** and show no clear indication of impacts from highway construction. There

have been some elevated concentrations of some parameters measured but there are no obvious trends among these.

- The conductivity measurements from Ch 48665 (Cut 11) indicate that upgradient and downgradient samples might be drawn from different aquifers.

4.3 Groundwater levels

Groundwater levels were logged at 8 sites during this reporting period. The following conclusions have been drawn from the available logged groundwater level data:

- Groundwater levels rose and fell at all sites in response to recharge and discharge since operational phase monitoring began.
- Where upgradient and downgradient data are available, the data indicates that there has not been a significant change in the relationship between the groundwater levels upgradient and downgradient of the highway during the operational phase.
- Median logged depths to water from this reporting period were generally comparable to the corresponding measurements from construction phase monitoring with the exception of the downgradient piezometer at Ch 54065 (Cut 15), for which there is no relevant corresponding data.

The interpretation of the results presented should consider that where laboratories reported results as lower than the limits of detection, these results were incorporated into databases as the level of detection for the calculation of summary statistics and graphing. Limits of detection have not been consistent for all parameters between construction phase and operational phase monitoring.

5 Conclusions

The operational phase surface water and groundwater monitoring program along the WC2NH upgrade was undertaken generally in accordance with the requirements of the SWMP and GWMP. However, there were some samples collected outside of the intended timeframes for a variety of reasons. These were minor changes that would not materially impact the capacity of the monitoring program to meet its stated aims and the total number of samples was in accordance with the SWMP and GWMP except at sites where there was no water at the time of sampling. This annual report presents a summary of the monitoring activities and for operational phase monitoring.

The collected surface water monitoring results have been summarised according to the requirements of the SWMP. The summary indicates that there are some results of interest, though less than in the previous annual report. There has been a consistent trend of reducing numbers of results of interest throughout the 3-year operational monitoring phase. In addition, further analysis, in **Section 3.2**, reveals that the majority of results of interest do not indicate any impact from highway operation and that none indicate a clear impact or worsening trends in surface water quality.

The collected groundwater quality monitoring results have been summarised in this report according to the requirements of the GWMP. The summary indicates that there are some results of interest, but less than in the previous annual report. There are no clear indications of impacts of highway operation on groundwater quality. Dry, damaged and decommissioned groundwater piezometers have also limited the quantity and utility of the information available.

Groundwater level monitoring has indicated that upgradient and downgradient groundwater levels are fluctuating consistently and are within the ranges measured during construction. At some sites the capacity to draw conclusions is limited by dry and decommissioned piezometers.

Assessed as a complete data set, the summary results indicate that the water quality protection measures implemented during construction and operation have been successful, and that there has not been a significant impact from the operation of the WC2NH upgrade upon surface water or groundwater quality.

The 3-year operational phase surface water quality and groundwater quality monitoring has met the objectives of both the GWMP and SWMP. The results demonstrate that further water quality monitoring is not required or warranted.

6 References

ANZECC (2000) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand

Birch, M. (2019) *Gumma Creek and Wetlands Water Quality and Level Monitoring – Annual Report - 2018*. Report prepared for Nambucca Shire Council

GeoLINK (2013a) *Pacific Highway Upgrade Warrell Creek to Nambucca Heads – Surface Water Monitoring – Pre-construction Report*. Report prepared for NSW Roads and Maritime

GeoLINK (2013b) *Pacific Highway Upgrade Warrell Creek to Nambucca Heads – Groundwater Monitoring – Pre-construction Report*. Report prepared for NSW Roads and Maritime

NHMRC (2011) *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*. National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

NHMRC (2008) *Guidelines for Managing Risks in Recreational Water*. National Health and Medical Research Council, Australian Government.

NSW Department of Natural Resources (2006) *Survey of Tidal Limits and Mangrove Limits in NSW Estuaries 1996 to 2005*.

NSW Spatial Services (2021) Elevation data [Obtained at https://elevation.fsdf.org.au/] Accessed 10/12/2021

RTA (2011) *Upgrading the Pacific Highway, Warrell Creek to Urunga. Project Approval Documents*. RTA Publication 11.282. October 2011.

Appendix A

Surface Water – Summary Monitoring Data

Table A.1 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for Upper Warrell Creek

Parameter	*PQL*	*ANZECC Guideline (freshwater)*	*U/S SW01 Op No.*	*D/S SW02 Op No.*	*U/S SW01 Con/Op P80*	*D/S SW02 Op Med Final*	*D/S SW02 Op Med Mar 2021*	*D/S SW02 Op Med Sep 2020*	*D/S SW02 Op Med Mar 2020*	*D/S SW02 Op Med Sept 2019*	*D/S SW02 Op Med Mar 2019*	*D/S SW02 Con Med*
Aluminium-Total (mg/L)	0.01	0.055	16	16	0.06	0.04	0.04	0.03	0.03	0.03	**0.13**	0.02
Arsenic-Total (mg/L)	0.001	0.013	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Cadmium-Total (mg/L)	0.0001	0.0002	16	16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium-Total (mg/L)	0.001	0.001	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper-Total (mg/L)	0.001	0.0014	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Lead-Total (mg/L)	0.001	0.0034	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manganese-Total (mg/L)	0.005	1.9	16	16	0.37	0.17	0.24	0.31	0.350	0.350	0.375	0.092
Nickel-Total (mg/L)	0.001	0.011	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium-Total (mg/L)	0.001	0.005	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Silver-Total (mg/L)	0.001	0.0005	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zinc-Total (mg/L)	0.001	0.008	16	16	0.006	0.002	0.002	0.002	0.002	0.002	0.003	0.005
Iron-Total (mg/L)	0.01	-	16	16	1.40	1.40	1.45	1.25	1.10	1.10	1.60	0.30
Mercury-Total (mg/L)	0.00005	0.00005	16	16	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	16	16	16	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	16	16	12	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	950	16	16	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	200	16	16	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	350	16	16	1	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.05	16	16	0.05	0.05	0.05	0.05	0.05	0.05	**0.06**	0.02
Phosphate (mg/L)	0.005	0.02	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Total Nitrogen (mg/L)	0.1	0.5	16	16	0.8	0.3	0.3	0.3	0.3	0.30	0.3	0.50
Nitrate (mg/L)	0.005	0.04(NOx)	16	16	0.126	0.020	0.020	0.014	0.008	0.008	0.020	0.050

Parameter	PQL	ANZECC Guideline (freshwater)	U/S SW01 Op No.	D/S SW02 Op No.	U/S SW01 Con/Op P80	D/S SW02 Op Med Final	D/S SW02 Op Med Mar 2021	D/S SW02 Op Med Sep 2020	D/S SW02 Op Med Mar 2020	D/S SW02 Op Med Sept 2019	D/S SW02 Op Med Mar 2019	D/S SW02 Con Med
Nitrite (mg/L)	0.005	0.04(NOx)	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.02	16	16	0.047	0.015	0.012	0.009	0.008	0.005	0.015	0.020
TSS (mg/L)	5	-	16	16	10	6	6	6	6	6	6	5
TDS (g/L)	0.001	-	27	27	0.186	0.170	0.171	0.176	0.174	0.171	0.170	0.164
Temperature (°C)	0.01	-	28	28	22.95	18.47	18.97	18.97	20.11	18.60	23.24	21.51
pH	0.01	6.5 – 8.0	28	28	6.89	6.63	6.65	6.67	6.70	6.74	6.78	6.64
Conductivity (mS/cm)	0.001	0.125 – 2.2	28	28	0.285	0.255	0.266	0.271	0.271	0.261	0.254	0.249
Turbidity (NTU)	0.01	6 – 50	28	28	23.4	10.1	11.4	14.0	15.4	12.6	11.4	6.3
DO (mg/L) (P20)*	0.01	85-110% saturation	28	28	1.88	4.25	4.19	4.19	3.77	4.16	4.02	3.81

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020
Orange shading – Indicates a result of interest at March 2021
Brown shading – Indicates a result of interest at September 2021
Results in Red – Indicates a median result of interest that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80.

Table A.2 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for Stony Creek

Parameter	*PQL*	*ANZECC Guideline (freshwater)*	*U/S SW03 Op No.*	*D/S SW04 Op No.*	*U/S SW03 Con/Op P80*	*D/S SW04 Op Med Final*	*D/S SW04 Op Med Mar 2021*	*D/S SW04 Op Med Sep 2020*	*D/S SW04 Op Med Mar 2020*	*D/S SW04 Op Med Sept 2019*	*D/S SW04 Op Med Mar 2019*	*D/S SW04 Con Med*
Aluminium-Total (mg/L)	0.01	0.055	16	16	0.05	0.03	0.03	0.02	0.02	0.01	**0.22**	0.01
Arsenic-Total (mg/L)	0.001	0.013	16	16	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.001
Cadmium-Total (mg/L)	0.0001	0.0002	16	16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium-Total (mg/L)	0.001	0.001	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper-Total (mg/L)	0.001	0.0014	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Lead-Total (mg/L)	0.001	0.0034	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manganese-Total (mg/L)	0.005	1.9	16	16	0.10	0.13	0.13	0.13	0.13	0.120	0.212	0.081
Nickel-Total (mg/L)	0.001	0.011	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Selenium-Total (mg/L)	0.001	0.005	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Silver-Total (mg/L)	0.001	0.0005	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zinc-Total (mg/L)	0.001	0.008	16	16	0.006	0.002	0.002	0.002	0.002	0.002	0.005	0.005
Iron-Total (mg/L)	0.01	-	16	16	1.30	1.65	1.65	1.60	2.10	1.50	2.50	0.10
Mercury-Total (mg/L)	0.00005	0.00005	16	16	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	16	16	16	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	950	16	16	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	200	16	16	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	350	16	16	1	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.05	16	16	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.02
Phosphate (mg/L)	0.005	0.02	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Total Nitrogen (mg/L)	0.1	0.5	16	16	0.6	0.2	0.2	0.2	0.2	0.10	0.3	0.30
Nitrate (mg/L)	0.005	0.04(NOx)	16	16	0.118	0.020	0.020	0.020	0.020	0.010	0.075	0.060

Parameter	PQL	ANZECC Guideline (freshwater)	U/S SW03 Op No.	D/S SW04 Op No.	U/S SW03 Con/Op P80	D/S SW04 Op Med Final	D/S SW04 Op Med Mar 2021	D/S SW04 Op Med Sep 2020	D/S SW04 Op Med Mar 2020	D/S SW04 Op Med Sept 2019	D/S SW04 Op Med Mar 2019	D/S SW04 Con Med
Nitrite (mg/L)	0.005	0.04(NOx)	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.02	16	16	0.030	0.011	0.010	0.008	0.007	0.005	**0.031**	0.020
TSS (mg/L)	5	-	16	16	8	5	5	5	8	5	10	5
TDS (g/L)	0.001	-	27	27	0.173	0.155	0.159	0.168	0.180	0.180	0.148	0.157
Temperature (°C)	0.01	-	28	28	22.96	16.60	17.31	16.83	18.90	16.11	22.09	20.88
pH	0.01	6.5 – 8.0	28	28	6.88	6.57	6.63	6.69	6.72	6.80	6.77	6.68
Conductivity (mS/cm)	0.001	0.125 – 2.2	28	28	0.261	0.241	0.248	0.255	0.271	0.271	0.239	0.241
Turbidity (NTU)	0.01	6 – 50	28	28	15.1	10.4	14.2	16.4	16.6	16.2	16.4	8.7
DO (mg/L) (P20)*	0.01	85-110% saturation	28	28	3.09	4.68	4.35	4.25	3.96	3.96	4.40	4.69

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020
Orange shading – Indicates a result of interest at March 2021
Brown shading – Indicates a result of interest at September 2021
Results in Red – Indicates a median result that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80.

Table A.3 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for Lower Warrell Creek

Parameter	*PQL*	*ANZECC Guideline (marine)*	*U/S SW05 Op No.*	*D/S SW06 Op No.*	*U/S SW05 Con/Op P80*	*D/S SW06 Op Med Final*	*D/S SW06 Op Med Mar 2021*	*D/S SW06 Op Med Sep 2020*	*D/S SW06 Op Med Mar 2020*	*D/S SW06 Op Med Sept 2019*	*D/S SW06 Op Med Mar 2019*	*D/S SW06 Con Med*
Aluminium-Total (mg/L)	0.01	0.0005	16	16	0.11	**0.05**	**0.05**	**0.04**	**0.03**	**0.03**	**0.21**	0.02
Arsenic-Total (mg/L)	0.001	0.0045	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Cadmium-Total (mg/L)	0.0001	0.0055	16	16	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium-Total (mg/L)	0.001	0.0044	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper-Total (mg/L)	0.001	0.0013	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Lead-Total (mg/L)	0.001	0.0044	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manganese-Total (mg/L)	0.005	-	16	16	0.27	0.18	0.18	0.19	0.30	0.190	0.305	0.165
Nickel-Total (mg/L)	0.001	0.007	16	16	0.003	0.001	0.002	0.002	0.001	0.001	0.002	0.002
Selenium-Total (mg/L)	0.001	-	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Silver-Total (mg/L)	0.001	0.0014	16	16	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zinc-Total (mg/L)	0.001	0.015	16	16	0.012	0.003	0.004	0.004	0.003	0.003	0.008	0.006
Iron-Total (mg/L)	0.01	-	16	16	0.58	0.18	0.15	0.13	0.10	0.10	0.71	0.12
Mercury-Total (mg/L)	0.00005	0.0001	16	16	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	70	16	16	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	16	16	50	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	700	16	16	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	-	16	16	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.03	16	16	0.05	0.05	0.05	0.05	0.05	0.05	**0.06**	0.02
Phosphate (mg/L)	0.005	0.005	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Total Nitrogen (mg/L)	0.1	0.3	16	16	0.7	**0.4**	**0.4**	**0.4**	0.3	0.30	**0.4**	**0.50**
Nitrate (mg/L)	0.005	0.015(NOx)	16	16	0.110	0.008	0.008	0.005	0.005	0.005	**0.043**	**0.060**

Parameter	PQL	ANZECC Guideline (marine)	U/S SW05 Op No.	D/S SW06 Op No.	U/S SW05 Con/Op P80	D/S SW06 Op Med Final	D/S SW06 Op Med Mar 2021	D/S SW06 Op Med Sep 2020	D/S SW06 Op Med Mar 2020	D/S SW06 Op Med Sept 2019	D/S SW06 Op Med Mar 2019	D/S SW06 Con Med
Nitrite (mg/L)	0.005	0.015(NOx)	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.015	16	16	0.080	**0.038**	**0.031**	**0.030**	**0.029**	**0.028**	0.014	0.060
TSS (mg/L)	5	-	16	16	15	5	5	5	5	5	11	6
TDS (g/L)	0.001	-	27	27	9.030	10.200	11.700	12.000	12.400	12.250	5.270	2.625
Temperature (°C)	0.01	-	28	28	27.73	20.63	20.73	20.69	21.42	19.89	25.42	23.58
pH	0.01	7.0 – 8.5	28	28	7.41	7.01	7.04	7.08	7.11	7.11	7.09	7.09
Conductivity (mS/cm)	0.001	-	28	28	14.360	14.550	17.650	19.050	19.900	19.500	8.215	3.780
Turbidity (NTU)	0.01	0.5 - 10	28	28	16.6	6.5	7.0	7.0	6.9	6.0	10.7	6.8
DO (mg/L) (P20)*	0.01	80 – 110% saturation	28	28	3.09	4.54	4.41	4.41	4.36	4.36	4.28	4.43

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021
Brown shading – Indicates a result of interest at September 2021
Results in Red – Indicates a median result that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80.

Table A.4 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for the Unnamed Creek at Gumma Wetland west

Parameter	*PQL*	*ANZECC Guideline (freshwater)*	*U/S SW07 Op No.*	*D/S SW09 Op No.*	*U/S SW07 Con/ Op P80*	*D/S SW09 Op Med Final*	*D/S SW09 Op Med Mar 2021*	*D/S SW09 Op Med Sep 2020*	*D/S SW09 Op Med Mar 2020*	*D/S SW09 Op Med Sept 2019*	*D/S SW09 Op Med Mar 2019*	*D/S SW09 Con Med*
Aluminium-Total (mg/L)	0.01	0.055	15	14	0.08	**0.13**	**0.13**	**0.13**	**0.13**	**0.11**	**0.13**	0.04
Arsenic-Total (mg/L)	0.001	0.013	15	14	0.003	0.003	0.003	0.003	0.003	0.004	0.002	0.001
Cadmium-Total (mg/L)	0.0001	0.0002	15	14	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium-Total (mg/L)	0.001	0.001	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper-Total (mg/L)	0.001	0.0014	15	14	0.001	0.001	0.001	0.001	0.001	0.001	**0.002**	0.001
Lead-Total (mg/L)	0.001	0.0034	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manganese-Total (mg/L)	0.005	1.9	15	14	0.33	0.21	0.21	0.19	0.56	0.375	0.120	0.195
Nickel-Total (mg/L)	0.001	0.011	15	14	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.003
Selenium-Total (mg/L)	0.001	0.005	15	14	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Silver-Total (mg/L)	0.001	0.0005	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zinc-Total (mg/L)	0.001	0.008	15	14	0.011	0.003	0.003	0.003	0.003	0.003	0.006	0.008
Iron-Total (mg/L)	0.01	-	15	14	1.44	1.65	2.00	1.65	1.50	1.23	0.85	0.36
Mercury-Total (mg/L)	0.00005	0.00005	15	14	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	16	15	14	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	15	14	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	15	14	16	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	15	14	16	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	15	14	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	15	14	50	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	15	14	50	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	950	15	14	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	15	14	2	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	15	14	2	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	200	15	14	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	350	15	14	2	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.05	15	14	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.03
Phosphate (mg/L)	0.005	0.02	15	14	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Total Nitrogen (mg/L)	0.1	0.5	15	14	1.7	**0.9**	**1.0**	**1.0**	**1.0**	**0.90**	**0.6**	1.10
Nitrate (mg/L)	0.005	0.04(NOx)	15	14	0.076	0.005	0.005	0.005	0.005	0.005	0.010	0.030

Parameter	PQL	ANZECC Guideline (freshwater)	U/S SW07 Op No.	D/S SW09 Op No.	U/S SW07 Con/ Op P80	D/S SW09 Op Med Final	D/S SW09 Op Med Mar 2021	D/S SW09 Op Med Sep 2020	D/S SW09 Op Med Mar 2020	D/S SW09 Op Med Sept 2019	D/S SW09 Op Med Mar 2019	D/S SW09 Con Med
Nitrite (mg/L)	0.005	0.04(NOx)	15	14	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.02	15	14	0.060	0.007	0.005	0.005	0.009	0.007	0.005	0.030
TSS (mg/L)	5	-	15	14	22	6	7	8	12	11	6	14
TDS (g/L)	0.001	-	26	25	0.534	0.447	0.547	0.582	0.600	0.600	0.472	0.485
Temperature (°C)	0.01	-	27	26	25.32	19.51	19.94	19.94	20.87	20.59	24.55	21.08
pH	0.01	6.5 – 8.0	27	26	6.99	6.81	6.81	6.86	7.01	7.07	6.90	6.54
Conductivity (mS/cm)	0.001	0.125 – 2.2	27	26	0.835	0.701	0.779	0.882	0.935	0.931	0.703	0.745
Turbidity (NTU)	0.01	6 – 50	27	26	53.7	20.9	23.7	23.7	18.4	17.5	16.00	25.3
DO (mg/L) (P20)*	0.01	85-110% saturation	27	26	1.36	4.07	4.05	4.29	4.83	4.85	4.83	3.41

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Results in Red – Indicates a median result that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80.

Table A.5 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for the Unnamed Creek at Gumma Wetland east

Parameter	*PQL*	*ANZECC Guideline (freshwater)*	*U/S SW08 Op No.*	*D/S SW09 Op No.*	*U/S SW08 Con/Op P80*	*D/S SW09 Op Med Final*	*D/S SW09 Op Med Mar 2021*	*D/S SW09 Op Med Sep 2020*	*D/S SW09 Op Med Mar 2020*	*D/S SW09 Op Med Sept 2019*	*D/S SW09 Op Med Mar 2019*	*D/S SW09 Con Med*
Aluminium-Total (mg/L)	0.01	0.055	15	14	0.12	**0.13**	**0.13**	**0.13**	**0.13**	**0.11**	**0.13**	0.04
Arsenic-Total (mg/L)	0.001	0.013	15	14	0.003	0.003	0.003	0.003	0.003	0.004	0.002	0.001
Cadmium-Total (mg/L)	0.0001	0.0002	15	14	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Chromium-Total (mg/L)	0.001	0.001	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Copper-Total (mg/L)	0.001	0.0014	15	14	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.001
Lead-Total (mg/L)	0.001	0.0034	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Manganese-Total (mg/L)	0.005	1.9	15	14	0.38	0.21	0.21	0.19	0.56	0.375	0.120	0.195
Nickel-Total (mg/L)	0.001	0.011	15	14	0.003	0.001	0.002	0.001	0.001	0.001	0.001	0.003
Selenium-Total (mg/L)	0.001	0.005	15	14	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Silver-Total (mg/L)	0.001	0.0005	15	14	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Zinc-Total (mg/L)	0.001	0.008	15	14	0.018	0.003	0.003	0.003	0.003	0.003	0.006	0.008
Iron-Total (mg/L)	0.01	-	15	14	1.84	1.65	2.00	1.65	1.50	1.23	0.85	0.36
Mercury-Total (mg/L)	0.00005	0.00005	15	14	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	16	15	14	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	15	14	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	15	14	10	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	15	14	10	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	15	14	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	15	14	50	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	15	14	50	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	15	14	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	950	15	14	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	15	14	2	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	15	14	1	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	200	15	14	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	350	15	14	1	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.05	15	14	0.12	0.05	0.05	0.05	0.05	0.05	0.05	0.03
Phosphate (mg/L)	0.005	0.02	15	14	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Total Nitrogen (mg/L)	0.1	0.5	15	14	1.9	**0.9**	**1.0**	**1.0**	**1.0**	**0.90**	**0.6**	1.10
Nitrate (mg/L)	0.005	0.04(NOx)	15	14	0.070	0.005	0.005	0.005	0.005	0.005	0.010	0.030

Parameter	PQL	ANZECC Guideline (freshwater)	U/S SW08 Op No.	D/S SW09 Op No.	U/S SW08 Con/Op P80	D/S SW09 Op Med Final	D/S SW09 Op Med Mar 2021	D/S SW09 Op Med Sep 2020	D/S SW09 Op Med Mar 2020	D/S SW09 Op Med Sept 2019	D/S SW09 Op Med Mar 2019	D/S SW09 Con Med
Nitrite (mg/L)	0.005	0.04(NOx)	15	14	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.02	15	14	0.100	0.007	0.005	0.005	0.009	0.007	0.005	0.030
TSS (mg/L)	5	-	15	14	42	6	7	8	12	11	6	14
TDS (g/L)	0.001	-	26	25	0.483	0.447	0.547	0.582	0.600	0.600	0.472	0.485
Temperature (°C)	0.01	-	27	26	23.91	19.51	19.94	19.94	20.87	20.59	24.55	21.08
pH	0.01	6.5 – 8.0	27	26	6.85	6.81	6.81	6.86	7.01	7.07	6.90	6.54
Conductivity (mS/cm)	0.001	0.125 – 2.2	27	26	0.755	0.701	0.779	0.882	0.935	0.931	0.703	0.745
Turbidity (NTU)	0.01	6 – 50	27	26	39.3	20.9	23.7	23.7	18.4	17.5	16.00	25.3
DO (mg/L) (P20)*	0.01	85-110% saturation	27	26	0.46	4.07	4.05	4.29	4.83	4.85	4.83	3.41

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Results in Red – Indicates a median result that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80.

Table A.6 Operational (Op) phase downstream median surface water results and combined construction (Con) and operational phase upstream 80th percentile (P80) results and operational phase sample numbers (No.) for the Nambucca River

Parameter	*PQL*	*ANZECC Guideline (marine)*	*U/S SW10 Op No.*	*D/S SW11 Op No.*	*U/S SW10 Con/Op P80*	*D/S SW11 Op Med Final*	*D/S SW11 Op Med Mar 2021*	*D/S SW11 Op Med Sep 2020*	*D/S SW11 Op Med Mar 2020*	*D/S SW11 Op Med Sept 2019*	*D/S SW11 Op Med March 2019*	*D/S SW11 Con Med*
Aluminium-Total (mg/L)	0.01	0.0005	16	16	0.10	**0.11**	**0.10**	**0.09**	**0.08**	**0.08**	**0.64**	**0.10**
Arsenic-Total (mg/L)	0.001	0.0045	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.004	0.010
Cadmium-Total (mg/L)	0.0001	0.0055	16	16	0.0010	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0010
Chromium-Total (mg/L)	0.001	0.0044	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Copper-Total (mg/L)	0.001	0.0013	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.002	0.010
Lead-Total (mg/L)	0.001	0.0044	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Manganese-Total (mg/L)	0.005	-	16	16	0.07	0.04	0.04	0.04	0.03	0.024	0.102	0.047
Nickel-Total (mg/L)	0.001	0.007	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Selenium-Total (mg/L)	0.001	-	16	16	0.100	0.001	0.001	0.001	0.001	0.001	0.001	0.100
Silver-Total (mg/L)	0.001	0.0014	16	16	0.010	0.001	0.001	0.001	0.001	0.001	0.001	0.010
Zinc-Total (mg/L)	0.001	0.015	16	16	0.050	0.002	0.002	0.002	0.002	0.002	0.005	0.050
Iron-Total (mg/L)	0.01	-	16	16	0.50	0.19	0.17	0.15	0.14	0.16	0.99	0.10
Mercury-Total (mg/L)	0.00005	0.0001	16	16	0.00010	0.00005	0.00005	0.00005	0.00005	0.0001	0.00005	0.0001
Naphthalene (µg/L)	1	70	16	16	1	1	1	1	1	1	1	-
TRH C6 - C9 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	-
TRH C6 - C10 (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C6 - C10 less BTEX (µg/L)	10	-	16	16	10	10	10	10	10	10	10	20
TRH C10 - C14 (µg/L)	50	-	16	16	50	50	50	50	50	50	50	-
TRH C15 - C28 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH C29 - C36 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	-
TRH >C10 - C16 (µg/L)	50	-	16	16	70	50	50	50	50	50	50	100
TRH >C10 - C16 less Naphthalene (µg/L)	50	-	16	16	70	50	50	50	50	50	50	100
TRH >C16 - C34 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
TRH >C34 - C40 (µg/L)	100	-	16	16	100	100	100	100	100	100	100	100
Benzene (µg/L)	1	700	16	16	1	1	1	1	1	1	1	1
Toluene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Ethylbenzene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
m&p-Xylenes (µg/L)	2	-	16	16	2	2	2	2	2	2	2	2
o-Xylene (µg/L)	1	-	16	16	1	1	1	1	1	1	1	2
Total Phosphorus (mg/L)	0.05	0.03	16	16	0.08	0.05	0.05	0.05	0.05	0.05	**0.13**	0.05
Phosphate (mg/L)	0.005	0.005	16	16	0.011	**0.010**	**0.010**	**0.012**	**0.014**	**0.014**	**0.021**	**0.010**
Total Nitrogen (mg/L)	0.1	0.3	16	16	0.7	0.2	0.2	0.2	0.2	0.20	**0.4**	0.50

Parameter	PQL	ANZECC Guideline (marine)	U/S SW10 Op No.	D/S SW11 Op No.	U/S SW10 Con/Op P80	D/S SW11 Op Med Final	D/S SW11 Op Med Mar 2021	D/S SW11 Op Med Sep 2020	D/S SW11 Op Med Mar 2020	D/S SW11 Op Med Sept 2019	D/S SW11 Op Med March 2019	D/S SW11 Con Med
Nitrate (mg/L)	0.005	0.015(NOx)	16	16	0.060	0.005	0.005	0.005	0.005	0.005	0.039	0.030
Nitrite (mg/L)	0.005	0.015(NOx)	16	16	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia (mg/L)	0.005	0.015	16	16	0.080	**0.028**	**0.024**	**0.022**	**0.023**	**0.023**	**0.055**	**0.050**
TSS (mg/L)	5	-	16	16	49	10	8	7	6	6	30	11
TDS (g/L)	0.001	-	27	27	27.200	24.400	24.400	24.500	25.800	27.250	24.300	22.300
Temperature (°C)	0.01	-	28	28	27.06	20.61	20.99	20.61	23.01	20.08	25.03	23.90
pH	0.01	7.0 – 8.5	28	28	7.88	7.57	7.63	7.68	7.73	7.80	7.62	7.64
Conductivity (mS/cm)	0.001	-	28	28	44.500	39.950	39.950	40.100	40.200	44.400	37.050	36.700
Turbidity (NTU)	0.01	0.5 - 10	28	28	28.1	**10.8**	**11.0**	**10.8**	**11.9**	**13.8**	**13.90**	**17.5**
DO (mg/L) (P20)*	0.01	80 – 110% saturation	28	28	4.33	6.02	5.92	5.92	5.71	5.97	6.06	5.58

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Results in Red – Indicates a median result that does not comply with the relevant ANZECC guideline concentration
* - Upstream dissolved oxygen results are P20, not P80

Appendix B

Summary Groundwater Monitoring Data

Table B.1 Operational (Op) monitoring phase and combined operational and construction (Con) phase summary groundwater quality results for approximate chainage 45165 (Cut 6)

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
						Cut 6W		*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*
Aluminium	µg/L	10	55	200	-	4	-	55	50	40	30	-	-	**85**
Arsenic	µg/L	1	13	10	-	4	-	2	1	1	1	-	-	1
Cadmium	µg/L	0. 1	0.2	2	-	4	-	0.1	0.1	0.1	0.1	-	-	0.1
Chromium	µg/L	1	1	50	-	4	-	2	2	2	2	-	-	1
Copper	µg/L	1	1.4	2000	-	4	-	**6**	**6**	**6**	**6**	-	-	**9**
Lead	µg/L	1	3.4	10	-	4	-	1	1	1	1	-	-	1
Manganese	µg/L	1	1900	500	-	4	-	125	140	175	140	-	-	178
Nickel	µg/L	1	11	20	-	4	-	7	7	10	13	-	-	5
Selenium	µg/L	10	5	10	-	4	-	1	1	1	1	-	-	10
Silver	µg/L	1	0.5	100	-	4	-	1	1	1	1	-	-	1
Zinc	µg/L	5	8	300	-	4	-	**17**	**13**	**16**	**21**	-	-	**18**
Iron	µg/L	10	-	300	-	4	-	**16200**	**8400**	**20700**	**8400**	-	-	**5830**
Mercury	µg/L	0.1	0.05	1	-	4	-	0.05	0.05	0.05	0.05	-	-	0.10
C6-C9 Fraction	µg/L	20	-	-	-	4	-	10	10	10	10	-	-	20
C6-C10 Fraction	µg/L	10	-	-	-	4	-	10	10	10	10	-	-	-
C6-C10 less BTEX	µg/L	10	-	-	-	4	-	10	10	10	10	-	-	-
C10-C14 Fraction	µg/L	50	-	-	-	4	-	50	50	50	50	-	-	50
C15-C28 Fraction	µg/L	100	-	-	-	4	-	100	100	100	100	-	-	100
C29-C36 Fraction	µg/L	100	-	-	-	4	-	100	100	100	100	-	-	50
C10-C16 Fraction	µg/L	50	-	-	-	4	-	50	50	50	50	-	-	62
C10-C16 less Naphthalene	µg/L	50	-	-	-	4	-	50	50	50	50	-	-	-
C16-C34 Fraction	µg/L	100	-	-	-	4	-	100	100	100	100	-	-	100
C34-C40 Fraction	µg/L	100	-	-	-	4	-	100	100	100	100	-	-	100
Naphthalene	µg/L	5	16	-	-	4	-	1	1	1	1	-	-	5
Benzene	µg/L	1	950	1	-	4	-	1	1	1	1	-	-	1
Toluene	µg/L	1	-	800	-	4	-	1	1	1	1	-	-	2
Ethylbenzene	µg/L	1	-	300	-	4	-	1	1	1	1	-	-	2
m+p-Xylene	µg/L	2	200	600	-	4	-	2	2	2	2	-	-	2
o-Xylene	µg/L	1	350	600	-	4	-	1	1	1	1	-	-	2
Total Phosphorus	mg/L	0.05	0.05	-	-	4	-	0.05	0.05	0.05	0.05	-	-	0.03
Phosphate	mg/L	0.005	0.02	-	-	4	-	0.005	0.005	0.005	0.005	-	-	0.010

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
						Cut 6W		*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*	*Cut 6W*
Total Nitrogen	mg/L	0.1	0.5	-	-	4	-	0.5	0.4	0.4	0.3	-	-	0.6
Nitrate	mg/L	0.005	0.04(NOx)	50	-	4	-	0.005	0.005	0.005	0.005	-	-	0.020
Nitrite	mg/L	0.001	0.04(NOx)	3	-	4	-	0.005	0.005	0.005	0.005	-	-	0.010
Ammonia	mg/L	0.005	0.02	0.5	-	4	-	0.017	0.015	0.017	0.015	-	-	0.100
TDS	mg/L	5	-	600	-	4	-	**1200**	**1300**	**1800**	**1300**	-	-	-
Chloride	mg/L	0.1	-	250	-	4	-	**670**	**710**	**905**	**710**	-	-	**1108**
Sulfate	mg/L	0.1	-	250	-	4	-	31	41	41	41	-	-	34
Bicarb Alkalinity	mg/L	0.1	-	-	-	4	-	22	25	35	25	-	-	44
Sodium	mg/L	0.1	-	180	-	4	-	**365.0**	**360.0**	**475.0**	**360.0**	-	-	**567.0**
Potassium	mg/L	0.01	-	-	-	4	-	2.2	2.4	2.9	3.3	-	-	2.0
Calcium	mg/L	0.01	-	-	-	4	-	7.9	8.8	11.9	15.0	-	-	5
Magnesium	mg/L	0.1	-	-	-	4	-	53.5	57.0	77.5	57.0	-	-	86.0
OH- Alkalinity	mg/L	5	-	-	-	4	-	5	5	5	5	-	-	-
$CaCO_3$ Alkalinity	mg/L	5	-	200	-	4	-	5	5	5	5	-	-	-
Total Alkalinity	mg/L	5	-	-	-	4	-	22	25	35	25	-	-	-
Temperature	○C	0.01	-	-	-	8	-	21.45	21.45	21.45	22.68	21.83	21.83	21.74
pH	pH	0.01	6.5 – 8.0	6.5 – 8.5	-	8	-	**5.61**	**5.47**	**5.65**	**5.57**	**5.78**	**5.78**	**6.05**
Conductivity	mS/cm	0.001	0.125 – 2.2	-	-	8	-	0.996	**2.500**	**3.870**	**2.635**	**4.12**	**4.12**	**3.30**
Depth to water	m	0.01	-	-	-	8	-	15.42	15.42	15.56	15.56	15.59	15.59	16.18

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Red Results – Result exceeds relevant guideline concentrations.

Table B.2 Operational monitoring phase and combined operational and construction (Con) phase summary groundwater quality results for approximate chainage 48665 (Cut 11)

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Cut 11E	*Cut 11W*	*Cut 11E*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*
Aluminium	µg/L	10	55	200	6	6	400	20	20	15	10	10	10	10
Arsenic	µg/L	1	13	10	6	6	1	1	1	1	1	1	1	1
Cadmium	µg/L	0. 1	0.2	2	6	6	9.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Chromium	µg/L	1	1	50	6	6	1	1	1	1	1	1	1	1
Copper	µg/L	1	1.4	2000	6	6	8	**7**	**6**	**18**	**29**	**33**	**29**	**9**
Lead	µg/L	1	3.4	10	6	6	1	1	1	1	1	1	1	1
Manganese	µg/L	1	1900	500	6	6	1880	11	12	13	12	13	13	7
Nickel	µg/L	1	11	20	6	6	129	3	3	4	3	4	3	3
Selenium	µg/L	10	5	10	6	6	10	1	1	1	1	1	1	10
Silver	µg/L	1	0.5	100	6	6	1	1	1	1	1	1	1	1
Zinc	µg/L	5	8	300	6	6	432	**76**	**89**	**110**	**89**	**110**	**130**	**16**
Iron	µg/L	10	-	300	6	6	120	25	20	17	14	12	10	50
Mercury	µg/L	0.1	0.05	1	6	6	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.10
C6-C9 Fraction	µg/L	20	-	-	6	6	20	10	10	10	10	10	10	20
C6-C10 Fraction	µg/L	10	-	-	6	6	10	10	10	10	10	10	10	-
C6-C10 less BTEX	µg/L	10	-	-	6	6	10	10	10	10	10	10	10	-
C10-C14 Fraction	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	50
C15-C28 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	100
C29-C36 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	50
C10-C16 Fraction	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	50
C10-C16 less Naphthalene	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	-
C16-C34 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	100
C34-C40 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	100
Naphthalene	µg/L	5	16	-	6	6	5	1	1	1	1	1	1	5
Benzene	µg/L	1	950	1	6	6	1	1	1	1	1	1	1	1
Toluene	µg/L	1	-	800	6	6	2	1	1	1	1	1	1	2
Ethylbenzene	µg/L	1	-	300	6	6	2	1	1	1	1	1	1	2
m+p-Xylene	µg/L	2	200	600	6	6	2	2	2	2	2	2	2	2
o-Xylene	µg/L	1	350	600	6	6	2	1	1	1	1	1	1	2
Total Phosphorus	mg/L	0.05	0.05	-	6	6	0.05	**0.06**	**0.07**	**0.08**	**0.10**	**0.15**	**0.10**	0.03

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Cut 11E	*Cut 11W*	*Cut 11E*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*	*Cut 11W*
Phosphate	mg/L	0.005	0.02	-	6	6	0.014	0.014	0.017	**0.053**	**0.088**	**0.090**	**0.091**	0.010
Total Nitrogen	mg/L	0.1	0.5	-	6	6	2.7	0.4	0.5	**0.6**	**0.8**	**0.9**	**0.9**	0.3
Nitrate	mg/L	0.005	0.04(NOx)	50	6	6	2.810	**0.220**	**0.200**	**0.420**	**0.640**	**0.685**	**0.730**	**0.140**
Nitrite	mg/L	0.001	0.04(NOx)	3	6	6	0.010	0.005	0.005	0.005	0.005	0.006	0.005	0.010
Ammonia	mg/L	0.005	0.02	0.5	6	6	0.070	0.011	0.013	0.009	0.013	0.026	0.005	0.040
TDS	g/L	0.001	-	600	6	6	1000	77	80	90	80	90	80	-
Chloride	mg/L	0.1	-	250	6	6	202	14	13	14	13	13	12	14
Sulfate	mg/L	0.1	-	250	6	6	690	6.5	7	8	7	8	7	8
Bicarb Alkalinity	mg/L	0.1	-	-	6	6	36	20	22	24	32	32	32	23
Sodium	mg/L	0.1	-	180	6	6	197.0	15.5	16.0	19.0	16.0	19.0	16.0	18.0
Potassium	mg/L	0.01	-	-	6	6	6.0	1.7	2.1	2.2	2.1	2.2	2.3	1.0
Calcium	mg/L	0.01	-	-	6	6	83.0	2.8	3.3	2.8	2.3	2.8	3.3	1
Magnesium	mg/L	0.1	-	-	6	6	90.0	2.2	2.4	2.5	2.4	2.5	2.5	2.0
OH- Alkalinity	mg/L	5	-	-	6	6	5	5	5	5	5	5	5	-
$CaCO_3$ Alkalinity	mg/L	5	-	200	6	6	5	5	5	5	5	5	5	-
Total Alkalinity	mg/L	5	-	-	6	6	17	20	22	24	32	32	32	-
Temperature	○C	0.01	-	-	12	12	25.02	21.08	21.08	20.54	20.95	20.35	20.35	21.47
pH	pH	0.01	6.5 – 8.0	6.5 – 8.5	12	12	6.56	**5.64**	**5.70**	**5.82**	**5.88**	**5.88**	**5.88**	**6.23**
Conductivity	mS/cm	0.001	0.125 – 2.2	-	12	12	1.856	0.090	0.093	0.096	0.109	0.13	0.127	0.14
Depth to water	m	0.01	-	-	12	12	3.21	7.00	6.50	7.15	7.41	7.41	6.85	7.52

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Red Results – Result exceeds relevant guideline concentrations.

Table B.3 Operational monitoring phase and combined operational and construction (Con) phase summary groundwater quality results for approximate chainage 49365 (Cut 12)

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
						Cut 12W		*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*
Aluminium	µg/L	10	55	200	-	2	-	45	45	30	30	-	-	15
Arsenic	µg/L	1	13	10	-	2	-	1	1	1	1	-	-	1
Cadmium	µg/L	0. 1	0.2	2	-	2	-	0.1	0.1	0.1	0.1	-	-	0.1
Chromium	µg/L	1	1	50	-	2	-	1	1	1	1	-	-	1
Copper	µg/L	1	1.4	2000	-	2	-	**4**	**4**	**3**	**3**	-	-	1
Lead	µg/L	1	3.4	10	-	2	-	2	2	1	1	-	-	1
Manganese	µg/L	1	1900	500	-	2	-	20	20	25	25	-	-	5.5
Nickel	µg/L	1	11	20	-	2	-	2	2	2	2	-	-	1
Selenium	µg/L	10	5	10	-	2	-	1	1	1	1	-	-	10
Silver	µg/L	1	0.5	100	-	2	-	1	1	1	1	-	-	1
Zinc	µg/L	5	8	300	-	2	-	**33**	**33**	**28**	**28**	-	-	**9**
Iron	µg/L	10	-	300	-	2	-	185	185	**340**	**340**	-	-	50
Mercury	µg/L	0.1	0.05	1	-	2	-	0.05	0.05	0.05	0.05	-	-	0.10
C6-C9 Fraction	µg/L	20	-	-	-	2	-	10	10	10	10	-	-	20
C6-C10 Fraction	µg/L	10	-	-	-	2	-	10	10	10	10	-	-	-
C6-C10 less BTEX	µg/L	10	-	-	-	2	-	10	10	10	10	-	-	-
C10-C14 Fraction	µg/L	50	-	-	-	2	-	50	50	50	50	-	-	50
C15-C28 Fraction	µg/L	100	-	-	-	2	-	100	100	100	100	-	-	100
C29-C36 Fraction	µg/L	100	-	-	-	2	-	100	100	100	100	-	-	50
C10-C16 Fraction	µg/L	50	-	-	-	2	-	50	50	50	50	-	-	50
C10-C16 less Naphthalene	µg/L	50	-	-	-	2	-	50	50	50	50	-	-	-
C16-C34 Fraction	µg/L	100	-	-	-	2	-	100	100	100	100	-	-	100
C34-C40 Fraction	µg/L	100	-	-	-	2	-	100	100	100	100	-	-	100
Naphthalene	µg/L	5	16	-	-	2	-	1	1	1	1	-	-	5
Benzene	µg/L	1	950	1	-	2	-	1	1	1	1	-	-	1
Toluene	µg/L	1	-	800	-	2	-	1	1	1	1	-	-	2
Ethylbenzene	µg/L	1	-	300	-	2	-	1	1	1	1	-	-	2
m+p-Xylene	µg/L	2	200	600	-	2	-	2	2	2	2	-	-	2
o-Xylene	µg/L	1	350	600	-	2	-	1	1	1	1	-	-	2
Total Phosphorus	mg/L	0.05	0.05	-	-	2	-	0.05	0.05	0.05	0.05	-	-	**0.06**

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
						Cut 12W		*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*	*Cut 12W*
Phosphate	mg/L	0.005	0.02	-	-	2	-	0.005	0.005	0.005	0.005	-	-	0.010
Total Nitrogen	mg/L	0.1	0.5	-	-	2	-	0.4	0.4	0.2	0.2	-	-	**0.7**
Nitrate	mg/L	0.005	0.04(NOx)	50	-	2	-	**0.090**	**0.090**	0.010	0.010	-	-	**0.350**
Nitrite	mg/L	0.001	0.04(NOx)	3	-	2	-	0.007	0.007	0.005	0.005	-	-	0.010
Ammonia	mg/L	0.005	0.02	0.5	-	2	-	0.020	0.020	0.005	0.005	-	-	**0.035**
TDS	g/L	0.001	-	600	-	2	-	260	260	260	260	-	-	-
Chloride	mg/L	0.1	-	250	-	2	-	104	104	110	110	-	-	33
Sulfate	mg/L	0.1	-	250	-	2	-	5	5	6	6	-	-	6
Bicarb Alkalinity	mg/L	0.1	-	-	-	2	-	22	22	21	21	-	-	14
Sodium	mg/L	0.1	-	180	-	2	-	65.5	65.5	64.0	64.0	-	-	28.5
Potassium	mg/L	0.01	-	-	-	2	-	1.0	1.0	0.9	0.9	-	-	1.0
Calcium	mg/L	0.01	-	-	-	2	-	0.9	0.9	0.9	0.9	-	-	1.0
Magnesium	mg/L	0.1	-	-	-	2	-	4.4	4.4	4.8	4.8	-	-	1.0
OH- Alkalinity	mg/L	5	-	-	-	2	-	5	5	5	5	-	-	-
$CaCO_3$ Alkalinity	mg/L	5	-	200	-	2	-	5	5	5	5	-	-	-
Total Alkalinity	mg/L	5	-	-	-	2	-	22	22	21	21	-	-	-
Temperature	○C	0.01	-	-	-	5	-	22.34	22.92	22.54	23.82	-	-	21.80
pH	pH	0.01	6.5 – 8.0	6.5 – 8.5	-	5	-	**5.05**	**5.03**	**5.11**	**4.99**	-	-	**6.19**
Conductivity	mS/cm	0.001	0.125 – 2.2	-	-	5	-	0.408	0.413	0.413	0.417	-	-	0.193
Depth to water	m	0.01	-	-	-	5	-	7.33	6.94	7.15	6.54	-	-	6.84

Red shading – Indicates a result of interest at March 2019.
Blue shading – Indicates a result of interest at September 2019.
Green shading – Indicates a result of interest at March 2020.
Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Red Results – Result exceeds relevant guideline concentrations.

Table B.4 Operational monitoring phase and combined operational and construction (Con) phase summary groundwater quality results for approximate chainage 50965 (Fill 15)

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Fill 15E	*Fill 15W*	*Fill 15E*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*
Aluminium	µg/L	10	55	200	6	6	10	10	10	10	10	10	10	10
Arsenic	µg/L	1	13	10	6	6	1	1	1	1	1	1	1	1
Cadmium	µg/L	0. 1	0.2	2	6	6	0.5	0.1	0.1	0.1	0.1	0.2	0.2	0.1
Chromium	µg/L	1	1	50	6	6	1	1	1	1	1	1	1	1
Copper	µg/L	1	1.4	2000	6	6	3	**4**	**4**	**3**	**4**	**4**	**4**	1
Lead	µg/L	1	3.4	10	6	6	1	1	1	1	1	1	1	1
Manganese	µg/L	1	1900	500	6	6	1700	**1125**	**2100**	1125	**2100**	**1125**	**2100**	**2500**
Nickel	µg/L	1	11	20	6	6	15	2	2	2	2	3	3	5
Selenium	µg/L	10	5	10	6	6	10	1	1	1	1	1	1	10
Silver	µg/L	1	0.5	100	6	6	1	1	1	1	1	1	1	1
Zinc	µg/L	5	8	300	6	6	38	4	4	4	4	**13**	**21**	**18**
Iron	µg/L	10	-	300	6	6	952	10	10	10	10	10	10	**3050**
Mercury	µg/L	0.1	0.05	1	6	6	0.10	0.05	0.05	0.05	0.05	0.05	0.05	0.10
C6-C9 Fraction	µg/L	20	-	-	6	6	20	10	10	10	10	10	10	20
C6-C10 Fraction	µg/L	10	-	-	6	6	10	10	10	10	10	10	10	-
C6-C10 less BTEX	µg/L	10	-	-	6	6	10	10	10	10	10	10	10	-
C10-C14 Fraction	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	50
C15-C28 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	100
C29-C36 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	50
C10-C16 Fraction	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	-
C10-C16 less Naphthalene	µg/L	50	-	-	6	6	50	50	50	50	50	50	50	-
C16-C34 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	-
C34-C40 Fraction	µg/L	100	-	-	6	6	100	100	100	100	100	100	100	-
Naphthalene	µg/L	5	16	-	6	6	5	1	1	1	1	1	1	5
Benzene	µg/L	1	950	1	6	6	1	1	1	1	1	1	1	1
Toluene	µg/L	1	-	800	6	6	2	1	1	1	1	1	1	2
Ethylbenzene	µg/L	1	-	300	6	6	2	1	1	1	1	1	1	2
m+p-Xylene	µg/L	2	200	600	6	6	2	2	2	2	2	2	2	2
o-Xylene	µg/L	1	350	600	6	6	2	1	1	1	1	1	1	2
Total Phosphorus	mg/L	0.05	0.05	-	6	6	0.28	**0.14**	**0.20**	**0.25**	**0.20**	**0.35**	**0.50**	0.04

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Fill 15E	*Fill 15W*	*Fill 15E*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*	*Fill 15W*
Phosphate	mg/L	0.005	0.02	-	6	6	0.035	0.008	0.008	0.008	0.008	0.007	0.005	0.010
Total Nitrogen	mg/L	0.1	0.5	-	6	6	1.1	**1.6**	**1.5**	**1.5**	**2.1**	**1.4**	**0.7**	**2.4**
Nitrate	mg/L	0.005	0.04(NOx)	50	6	6	0.552	**0.720**	**0.460**	**0.720**	**0.980**	**0.520**	**0.059**	0.050
Nitrite	mg/L	0.001	0.04(NOx)	3	6	6	0.010	0.005	0.005	0.005	0.005	0.005	0.005	0.010
Ammonia	mg/L	0.005	0.02	0.5	6	6	0.230	**0.198**	**0.390**	**0.198**	**0.390**	**0.198**	**0.390**	**0.780**
TDS	g/L	0.001	-	600	6	6	9400	**8950**	**8800**	**8600**	**8000**	**8600**	**8000**	-
Chloride	mg/L	0.1	-	250	6	6	2330	**1900**	**2000**	**1900**	**1700**	**1650**	**1600**	**1710**
Sulfate	mg/L	0.1	-	250	6	6	2796	**2900**	**2700**	**2500**	**2700**	**2200**	**1700**	**3200**
Bicarb Alkalinity	mg/L	0.1	-	-	6	6	892	820	820	830	820	820	820	468
Sodium	mg/L	0.1	-	180	6	6	1716.0	**1400.0**	**1400.0**	**1450.0**	**1400.0**	**1450.0**	**1500.0**	**1340.0**
Potassium	mg/L	0.01	-	-	6	6	96.0	85.0	85.0	81.0	85.0	89.0	85.0	68.0
Calcium	mg/L	0.01	-	-	6	6	270.4	350.0	340.0	285.0	340.0	300	230.0	364
Magnesium	mg/L	0.1	-	-	6	6	565.1	620.0	620.0	560.0	620.0	575.0	470.0	564.0
OH- Alkalinity	mg/L	5	-	-	6	6	5	5	5	5	5	5	5	-
$CaCO_3$ Alkalinity	mg/L	5	-	200	6	6	5	5	5	5	5	5	5	-
Total Alkalinity	mg/L	5	-	-	6	6	840	820	820	830	820	820	820	-
Temperature	○C	0.01	-	-	12	12	23.11	19.59	20.33	19.45	20.33	19.45	20.33	22.34
pH	pH	0.01	6.5 – 8.0	6.5 – 8.5	12	12	7.40	7.17	7.17	7.23	7.24	7.31	7.30	6.94
Conductivity	mS/cm	0.001	0.125 – 2.2	-	12	12	10.660	**10.750**	**10.800**	**10.850**	**10.650**	**10.65**	**10.60**	**9.42**
Depth to water	m	0.01	-	-	12	12	1.16	0.76	0.76	0.80	0.87	0.87	0.87	0.74

Red shading – Indicates a result of interest at March 2019.
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Purple shading – Indicates a result of interest at September 2020.
Orange shading – Indicates a result of interest at March 2021.
Brown shading – Indicates a result of interest at September 2021.
Red Results – Result exceeds relevant guideline concentrations.

Table B.5 Operational monitoring phase and combined operational and construction (Con) phase summary groundwater quality results for approximate chainage 54065 (Cut 15)

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Cut 15E	*Cut 15W*	*Cut 15E*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*
Aluminium	µg/L	10	55	200	6	5	10	10	10	10	10	10	-	5
Arsenic	µg/L	1	13	10	6	5	1	1	1	1	1	1	-	1
Cadmium	µg/L	0. 1	0.2	2	6	5	0.1	0.1	0.1	0.1	0.1	0.1	-	1.0
Chromium	µg/L	1	1	50	6	5	1	1	1	1	1	1	-	1
Copper	µg/L	1	1.4	2000	6	5	4	**2**	**2**	**2**	**2**	1	-	1
Lead	µg/L	1	3.4	10	6	5	1	1	1	1	1	1	-	1
Manganese	µg/L	1	1900	500	6	5	64	7	7	7	6	5	-	363
Nickel	µg/L	1	11	20	6	5	3	1	1	1	1	1	-	3
Selenium	µg/L	10	5	10	6	5	10	1	1	1	1	1	-	10
Silver	µg/L	1	0.5	100	6	5	1	1	1	1	1	1	-	1
Zinc	µg/L	5	8	300	6	5	10	7	**11**	7	**11**	**15**	-	8
Iron	µg/L	10	-	300	6	5	50	10	10	10	10	10	-	**1911**
Mercury	µg/L	0.1	0.05	1	6	5	0.10	**0.14**	**0.14**	**0.14**	**0.17**	**0.20**	-	**0.50**
C6-C9 Fraction	µg/L	20	-	-	6	5	20	10	10	10	10	10	-	20
C6-C10 Fraction	µg/L	10	-	-	6	5	10	10	10	10	10	10	-	-
C6-C10 less BTEX	µg/L	10	-	-	6	5	10	10	10	10	10	10	-	-
C10-C14 Fraction	µg/L	50	-	-	6	5	50	50	50	50	50	50	-	50
C15-C28 Fraction	µg/L	100	-	-	6	5	100	100	100	100	100	100	-	100
C29-C36 Fraction	µg/L	100	-	-	6	5	100	100	100	100	100	100	-	100
C10-C16 Fraction	µg/L	50	-	-	6	5	50	50	50	50	50	50	-	50
C10-C16 less Naphthalene	µg/L	50	-	-	6	5	50	50	50	50	50	50	-	-
C16-C34 Fraction	µg/L	100	-	-	6	5	100	100	100	100	100	100	-	100
C34-C40 Fraction	µg/L	100	-	-	6	5	100	100	100	100	100	100	-	100
Naphthalene	µg/L	5	16	-	6	5	5	1	1	1	1	1	-	5
Benzene	µg/L	1	950	1	6	5	1	1	1	1	1	1	-	1
Toluene	µg/L	1	-	800	6	5	2	1	1	1	1	1	-	2
Ethylbenzene	µg/L	1	-	300	6	5	2	1	1	1	1	1	-	2
m+p-Xylene	µg/L	2	200	600	6	5	2	2	2	2	2	2	-	2
o-Xylene	µg/L	1	350	600	6	5	2	1	1	1	1	1	-	2
Total Phosphorus	mg/L	0.05	0.05	-	6	5	0.31	0.05	0.05	0.05	0.05	0.05	-	0.03

Parameter	*Units*	*PQL*	*ANZECC Guideline*	*ADWG*	*U/G*	*D/G*	*U/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*	*D/G*
					Op No.	*Op No.*	*Con/Op P80*	*Op med Final*	*Op med Mar 2021*	*Op med Sept 2020*	*Op med Mar 2020*	*Op med Sept 2019*	*Op med Mar 2019*	*Con med*
					Cut 15E	*Cut 15W*	*Cut 15E*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*	*Cut 15W*
Phosphate	mg/L	0.005	0.02	-	6	5	0.010	0.005	0.005	0.005	0.005	0.005	-	0.010
Total Nitrogen	mg/L	0.1	0.5	-	6	5	1.3	0.1	0.1	0.1	0.1	0.1	-	0.2
Nitrate	mg/L	0.005	0.04(NOx)	50	6	5	0.340	**0.120**	**0.130**	**0.140**	**0.145**	**0.140**	-	0.040
Nitrite	mg/L	0.001	0.04(NOx)	3	6	5	0.010	0.005	0.005	0.005	0.005	0.005	-	0.003
Ammonia	mg/L	0.005	0.02	0.5	6	5	0.038	0.005	0.005	0.005	0.007	0.009	-	**0.040**
TDS	g/L	0.001	-	600	6	5	100	67	70	67	63	58	-	-
Chloride	mg/L	0.1	-	250	6	5	21	16	17	17	18	17	-	18
Sulfate	mg/L	0.1	-	250	6	5	15.36	12	11	12	12	12	-	19
Bicarb Alkalinity	mg/L	0.1	-	-	6	5	24	8	8	8	8	7	-	31
Sodium	mg/L	0.1	-	180	6	5	32.8	16.0	15.5	16.0	18.0	21.0	-	11.9
Potassium	mg/L	0.01	-	-	6	5	1.0	0.5	0.5	0.5	0.5	0.5	-	1.3
Calcium	mg/L	0.01	-	-	6	5	1.2	0.5	0.5	0.5	0.5	0.5	-	2.36
Magnesium	mg/L	0.1	-	-	6	5	2.7	1.3	1.3	1.2	1.2	1.2	-	7.7
OH- Alkalinity	mg/L	5	-	-	6	5	5	5	5	5	5	5	-	-
$CaCO_3$ Alkalinity	mg/L	5	-	200	6	5	5	5	5	5	5	5	-	-
Total Alkalinity	mg/L	5	-	-	6	5	20	8	8	8	8	7	-	-
Temperature	○C	0.01	-	-	12	10	24.84	21.30	21.30	21.05	21.77	20.65	-	21.37
pH	pH	0.01	6.5 – 8.0	6.5 – 8.5	12	10	6.76	**5.00**	**5.00**	**5.00**	**4.97**	**4.84**	-	**6.06**
Conductivity	mS/cm	0.001	0.125 – 2.2	-	12	10	0.211	**0.107**	**0.108**	**0.108**	**0.106**	**0.11**	-	0.18
Depth to water	m	0.01	-	-	12	10	15.81	16.33	16.45	16.94	17.50	17.50	-	15.97

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Red Results – Result exceeds relevant guideline concentrations.