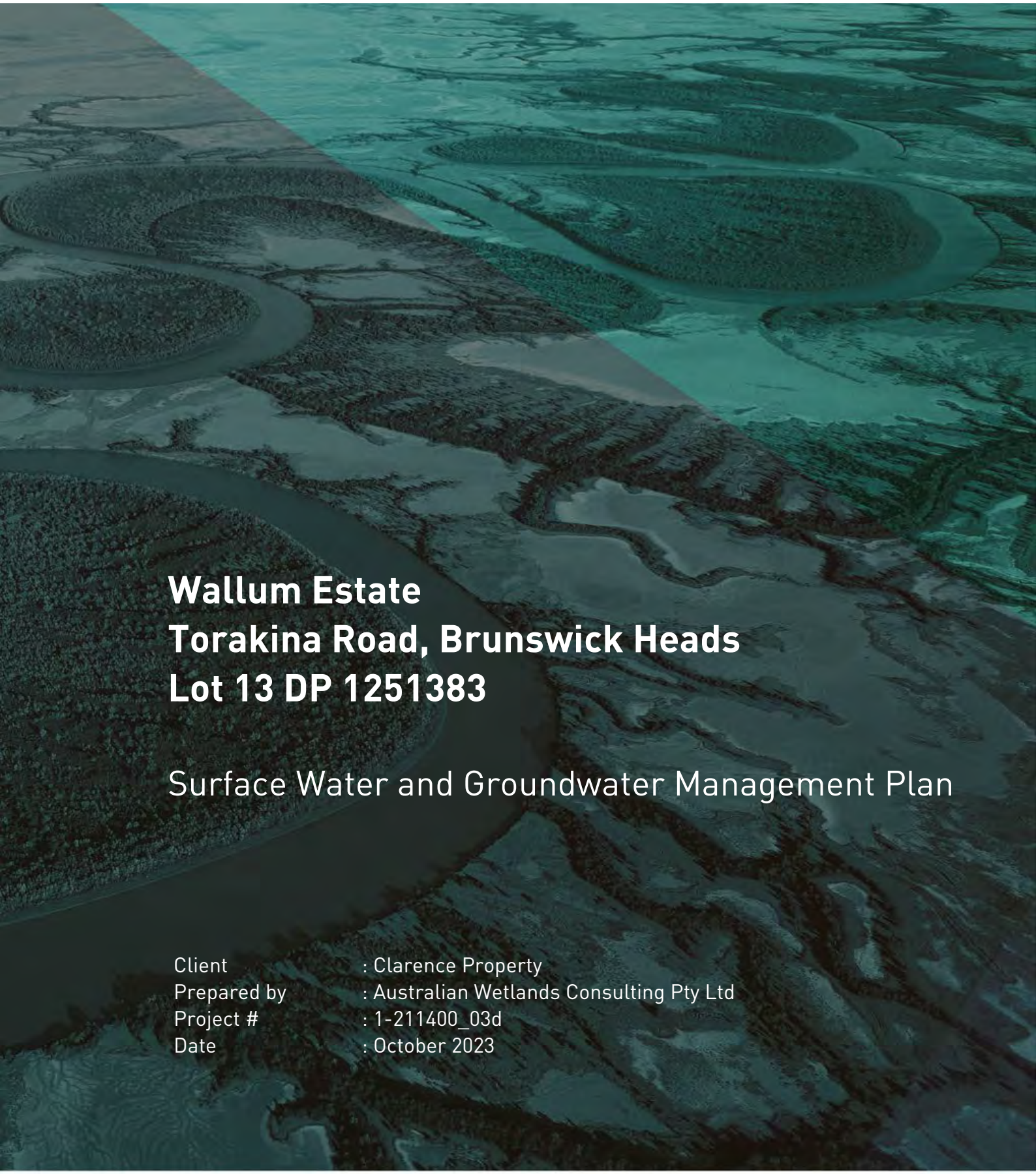

# Wallum Estate
# Torakina Road, Brunswick Heads
# Lot 13 DP 1251383

## Surface Water and Groundwater Management Plan

| | |
|---|---|
| Client | : Clarence Property |
| Prepared by | : Australian Wetlands Consulting Pty Ltd |
| Project # | : 1-211400_03d |
| Date | : October 2023 |

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# Wallum Estate
# Torakina Road, Brunswick Heads
# Lot 13 DP 1251383

Surface Water and Groundwater Management Plan

# Project control

Project name: **Wallum Estate**
**Torakina Road, Brunswick Heads**
**Lot 13 DP 1251383**

Surface Water and Groundwater Management Plan

Job number: 1-211400_03
Client: Clarence Property
Contact: James Fletcher

Prepared by: Australian Wetlands Consulting Pty Ltd

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| Date: | Revision: | Prepared by: | Reviewed by: | Distributed to: |
|---|---|---|---|---|
| 20/08/2021 | A | Jesse Munro | Damian McCann | James Fletcher (Clarence Property) |
| 14/09/2022 | B | Jesse Munro | Minor amendment only | James Fletcher (Clarence Property) |
| 20/06/2023 | C | Adrian Leader | Jesse Munro | James Fletcher (Clarence Property) |
| 24/10/2023 | D | Jesse Munro | Damian McCann | James Fletcher (Clarence Property) |

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# 1 Introduction and Background

## 1.1 Proposed Development

AWC has been engaged to prepare a Surface and Groundwater Management Plan for the proposed Wallum Estate development (formerly known as the Bayside Brunswick Estate). The Development Application (DA) has been submitted and approved; this version responds to consent conditions from Byron Shire Council (BSC). Approval was granted for a staged subdivision to create 131 lots upon land described as 15 Torakina Road, Brunswick Heads, being Lot 13 in Deposited Plan (DP) 1251383 (refer Figure 1-1). The development occupies approximately 13.33 ha (43.7 %) of the site. Residual land outside of the development footprint (~17.2 ha) will be managed for biodiversity and comprises public reserves (P1, P2, P3 and P4). Public reserves will be dedicated to Council once required works are completed. The portion of the site east of the road reserve flanking Simpsons Creek (10.24 ha) will also be dedicated to Council.

## 1.2 Site Detail

### 1.2.1 Topography

The site is relatively flat with a slight rise in the west. A central constructed drainage line dominates the surface drainage, with lateral flows of groundwater expressing and flowing from the site. The drainage line flows in a southerly direction towards Everitt's Creek and on to Simpsons Creek, and the Brunswick River.

The drainage line accepts surface flows (stormwater) from the existing urban area to the north. There are various smaller constructed drainage lines delivering surface flows to the primary drainage line.

### 1.2.2 Soil

The New South Wales Department of Planning, Industry and Environment's *eSPADE 2.1* (https://www.environment.nsw.gov.au/eSpade2WebApp) shows the site to be located on the Black Rock (br) Landscape in which sediments are of aeolian origin. The following is a summary of the soil landscape description found in *Soil Landscapes of the Lismore Ballina 1:100,000 Sheet* (Morand 1994):

| | |
|---|---|
| **Soils:** | Deep (>300cm), well drained Podzols on dunes; Deep (>300cm), imperfectly drained Humus Podzols and Peaty Podzols in depressions and deep (>200cm), waterlogged Acid Peats in swales; Deep (>300cm), rapidly drained Siliceous Sands on newer, seaward dunes. |
| **Colour:** | brownish black to black (topsoil-$A_1$ horizon); light grey to brownish grey ($A_2$ horizon; brownish black to reddish black with depth |
| **Texture:** | organic loamy sand (often fibric) or coarse sand in topsoils grading to fibric spongy loam to light clay with depth |
| **Structure:** | single grained in topsoil, massive at depth |
| **pH:** | 4.0 to 6.0 |
| **Geology:** | Quaternary (Pleistocene) beach and dune sands. |
| **Limitations:** | Non-cohesive, highly permeable, **highly acid soils** of low fertility. Organic |

soils in swales with permanently high water tables

Soil investigations show the soils to be generally sand based with some areas of peat and organic matter. There is an aquitard comprised of a dense sand layer, forming indurated sands which forms a perched aquifer. There is notably routine surface water accumulated in depressions on site suggesting infiltration rates are relatively low.

Several acid sulfate soil (ASS) assessments have been undertaken at the site which determined there was no acid sulfate soil. Notwithstanding, the site has been classified as Class 3 on the ASS risk mapping as detailed in the Byron Local Environmental Plan 2014 (LEP 2014), and an Acid Sulfate Soil Management Plan has been prepared primarily aimed at monitoring for detection.

## 1.3 Document Scope

This document provides a framework to monitor and detect adverse impacts to the groundwater and surface water reserves of the property and management strategies to protect the downstream aquatic habitat. The primary objectives include:

- Groundwater level and quality data have been collected forming a baseline data set with targets determined to detect adverse impacts
- Surface water quality data have been collected forming a baseline data set with targets determined to detect adverse impacts
- Specify a monitoring program for construction and occupational phases
- Establish action criteria for construction and occupation phase monitoring
- Provide an action response plan

## 1.4 Adaptive Management

This document is designed to be adaptive and will be reviewed and amended intermittently after evaluation of conditions, data and management strategies if required. Adaptive management considers all data collection and re-evaluates management.

## 1.5 CEMP

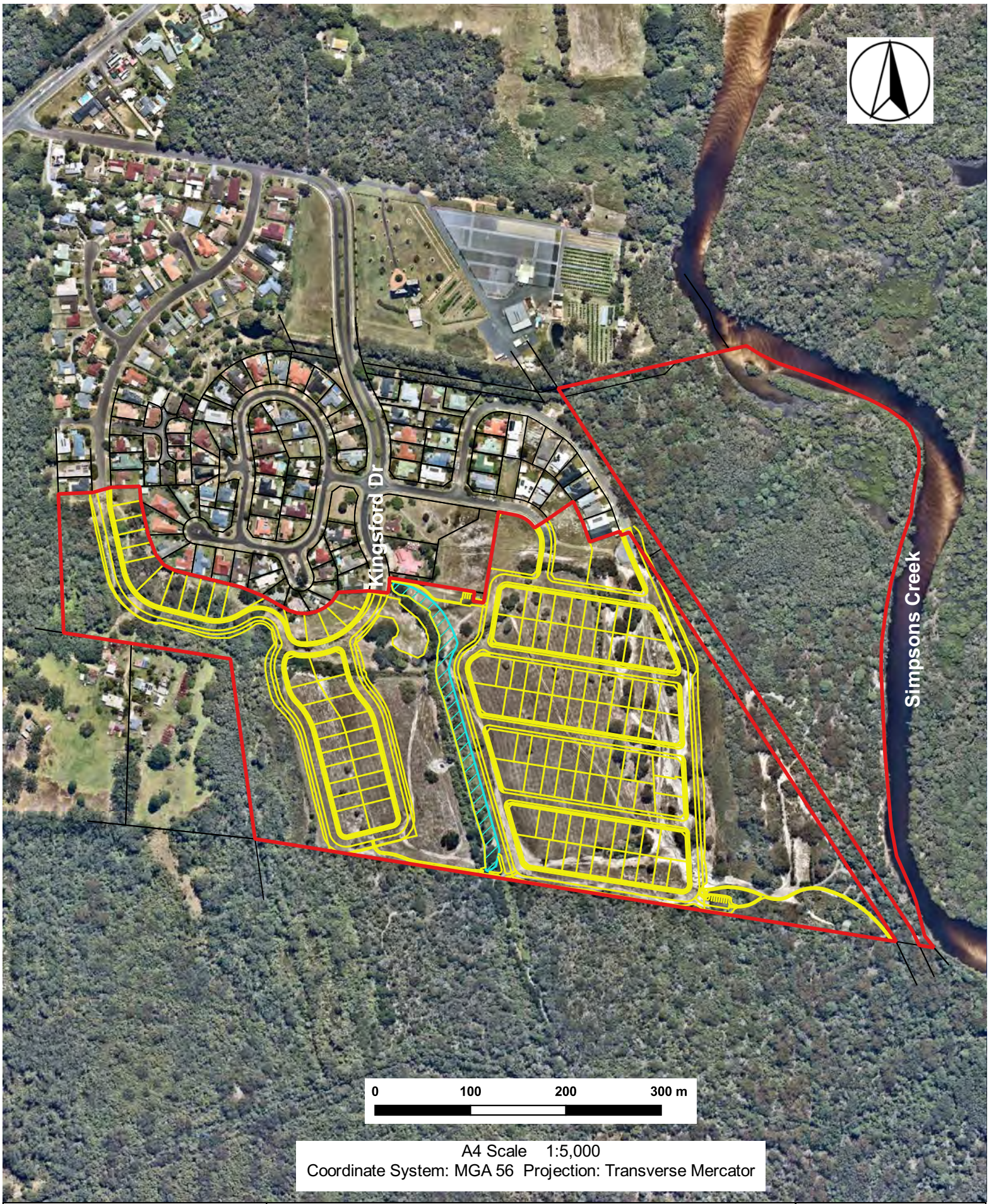
All overall Construction Environmental Management Plan (CEMP) has been prepared by AWC (2023) that details all required construction stage monitoring. The preparation stage specific CEMPs is the responsibility of the lead contractor and will be prepared to the satisfaction of the consent authority. CEMPs will detail the environmental management hierarchy (e.g. Site Superintendent, Environmental Manager) and relevant responsibilities.

## 1.6 Consent Conditions

This SWGMP responds to consent conditions from BSC. Table 1-1 guides the reader to relevant sections of this document that respond to the relevant conditions.

*Table 1.1 Byron Shire Conditions and AWC response*

| Condition | Response |
|---|---|
| ***9. Surface and Groundwater Management Plan***<br>*Prior to issue of a subdivision works certificate for each stage, an updated Surface and Groundwater Monitoring Plan (GMP) shall be prepared and provided to Council for approval*<br>*The SWGMP (AWC, 1-211400_03b, 14/09/2022) shall be updated to include monitoring of groundwater levels and quality prior to, during and following construction of the subdivision works as they progress, including, but not limited to:* | This document is the updated SWGMP |
| *a. Monitoring results of groundwater levels and quality from the commencement of Early Stage 1 works until the issue of a subdivision certificate for Stage 5 with submission of an updated report to Council prior to the issue of the subdivision works certificate for each stage of works;* | Refer to sections 3.2.1, 3.2.3 and 4.1 |
| *b. Monitoring of groundwater levels and quality at the end of each Stage;* | Refer to sections 3.3 and 4.2 |
| *c. Monitoring of groundwater levels and quality monthly for 12 months following the issue of a subdivision certificate for stage 5; and* | Refer to sections 3.3 and 4.2 |
| *d. Targets for groundwater quality and levels and the commitment to use these targets in required routine reporting.* | Refer to sections 3.2.2 3.2.5 and 4.1.2 |
| *e. Groundwater data to be compiled and analysed and uploaded into a groundwater modelling report with updated results analysed; and* | Groundwater data will be provided to Martens quarterly throughout the project |
| *f. Contingency Management to resolve any unforeseen groundwater matters.* | Refer to section 6 |




A4 Scale 1:5,000
Coordinate System: MGA 56 Projection: Transverse Mercator

AWC

Disclaimer:
Care was taken in the creation of this map. AWC should be consulted as to the suitability of the information shown herein prior to the commencement of any works based on the information provided. AWC cannot accept any responsibility for errors, omissions or positional accuracy. There are no warranties expressed or implied as to the suitability of this map for a particular purpose. However, notification of any errors will be appreciated.

## Legend

- Site
- Layout
- Side Swale

Figure 1.1 Proposed Development

Data source:
Aerial - Nearmaps
Layout - Cilviltech

Date:7-09-22
Job No:211400
Drawn:ED
Checked:DM

# 2 Groundwater and Surface Water Management

## 2.1 Potential Impacts to Groundwater and Surface Water

Land use change has the potential to modify hydrology of a site. Urbanisation reduces infiltration through soil to groundwater and increase overland through an increase in impervious surfaces (roads and roofs). Although best practice stormwater management is proposed at the Wallum Estate through treatment and infiltration, groundwater and surface waters will be monitored to detect changes.

Surface water quality typically degrades with urbanization, with higher sediment, nutrient and other contaminant loads common. A Stormwater Management Plan (SWMP) has been prepared by Civiltech (2023) to address potential water quality impacts and reduce the risk of declining water quality discharging from the site during construction and operational phases to downstream environments.

The primary potential impacts to ground and surface water are discussed in the below sections.

### 2.1.1 Reduction of Groundwater Level

Reduction of infiltration area and groundwater recharge will potentially cause impacts to the following:

- Impacts to groundwater dependent ecosystems (GDE)
- Modified hydrology in the downstream receiving environment
- Reduced groundwater levels can cause exposure of acid sulfate soils (ASS) to oxygen and subsequent acid production and metal mobilisation (No ASS identified)

### 2.1.2 Contamination

Groundwater and surface water contamination from nutrients, heavy metals and hydrocarbons is a potential issue through the construction and occupation phases of the Wallum Estate development. Groundwater at the site expresses to the surface water drains and eventually discharges to Everitt's Creek, Simpsons Creek and the Brunswick River.

### 2.1.3 Sedimentation

Erosion and sedimentation are a key concern for both the construction and operational phases. Sedimentation of water courses smother aquatic habitats and modify hydrological flow paths, flow rates and volumes.

### 2.1.4 Acid Sulfate Soils

Although there has not been ASS detected on site, despite several investigations the site is mapped as having a moderate probability of ASS. If ASS is exposed through excavations or groundwater lowering, acid production may result in dissolved iron and aluminum entering ground water reserves and subsequently discharging to the surface water drainage system. These elements are known to be toxic and cause other associated detrimental impacts to downstream aquatic environments. An Acid Sulfate Soil and Water Management Plan (ASSWMP) has been prepared that

provides specific detail on the practical management of the acid sulfate risks for the site. The site is a naturally occurring acid environment with protection of habitat for acid frog species an important consideration. Neutralisation of acidic water, both surface and ground, is not recommended for this site.

### 2.1.5 Groundwater Dependent Ecosystems

The development poses a risk to groundwater dependant ecosystems (GDEs) through modification (reduced or increased) in groundwater levels and groundwater quality. Changes in groundwater hydrology could adversely impact forested wetland communities – with either too little water causing a transition to more terrestrial vegetation assemblages and too much water causing localised die-back and potential intrusion of aquatic vegetation.

The NSW State Groundwater Dependent Ecosystems Policy (NSW Department of Land & Water Conservation (DLWC, 2002) has five key principles that aim to manage and protect these valuable systems in a practical sense. Table 2-1 provides commentary on the principles in relation to the proposed Wallum Estate development.

Vegetation assessments completed (JWA, 2011) show a varied assemblage of vegetation communities over the site including forest, heath and estuarine groups. There are several swamp sclerophyll forest and woodland communities which include key species as *Eucalyptus robusta* (Swamp Mahogany), *Melaleuca quinquenervia* (Broad Leaved Paperbark). Much of the site is covered with low closed wet heath that is routinely slashed. Three Endangered Ecological Communities (EEC) are located on the subject site including 'Swamp sclerophyll forest on coastal floodplain', 'Swamp oak forest flood plain forest', and 'Coastal saltmarsh'. The vegetation types along with the known shallow water table suggest a high likelihood of GDEs occurring on site. There are expansive areas of retained vegetation and habitat creation proposed in the development layout.

GDEs will be monitored as a proxy to detect change in groundwater levels and quality.

*Table 2.1 Principles of the NSW State Groundwater Dependent Ecosystems Policy in relation to the proposed development*

| NSW GDE Policy Principles | Comment |
|---|---|
| ***Principle One:*** *The scientific, ecological, aesthetic and economic values of groundwater-dependent ecosystems, and how threats to them may be avoided, should be identified and action taken to ensure that the most vulnerable ecosystems are protected.* | Site groundwater hydrology will be maintained through the infiltration of the stormwater treatment systems. |
| ***Principle Two:*** *Groundwater extractions should be managed within the sustainable yield of aquifer systems, so that the ecological processes and biodiversity of their dependent ecosystems are maintained and/or restored. Management may involve establishment of threshold levels that are critical for ecosystem health, and controls on extraction in the proximity of groundwater dependent ecosystems.* | There is no long term groundwater extraction planned as part of the proposed development. Short term dewatering may be required in some excavation works. |
| ***Principle Three:*** *Priority should be given to ensuring that sufficient groundwater of suitable quality is available at the times when it is needed:*<br>• *For protecting ecosystems which are known to be, or are* | There is not expected to be a shortage of groundwater in the locality, due to the low-lying topography and proximity to Everitt's Creek and Simpson Creek. The threat to groundwater levels is |

| NSW GDE Policy Principles | Comment |
|---|---|
| *most likely to be, groundwater dependent; and,*<br>• *For groundwater dependent ecosystems which are under an immediate or high degree of threat from groundwater-related activities.* | not considered 'high degree'. |
| ***Principle Four:***<br>*Where scientific knowledge is lacking, the Precautionary Principle should be applied to protect groundwater dependent ecosystems. The development of adaptive management systems and research to improve understanding of these systems is essential to their management.* | There is ongoing monitoring of GDE health and distribution, groundwater levels and groundwater quality planned through the construction and occupation phase of the development (refer Section 3). |
| ***Principle Five:***<br>*Planning, approval and management of developments and land use activities should aim to minimise adverse impacts on groundwater dependent ecosystems by:*<br>• *Maintaining, where possible, natural patterns of groundwater flow and not disrupting groundwater levels that are critical for ecosystems;*<br>• *Not polluting or causing adverse changes in groundwater quality; and*<br>• *Rehabilitating degraded groundwater systems where practical.* | The Wallum Estate has a proposed stormwater management strategy that includes infiltration to recharge groundwater storage and maintain groundwater levels. Additionally, stormwater management treat stormwater, reducing pollutants to levels appropriate for receiving environments. Further details are provided in the stormwater management plan prepared by Civiltech (2021).<br><br>GDEs will be protected in residual land and habitat creation. |

### 2.1.6 Construction of New North South Drain

Construction of the new North South Drain is planned during Stage 1. The detailed methodology for the excavation and construction of the drain has not yet been determined (DA phase only) however BSC has concerns for surface water and groundwater impacts associated with this phase of the development. It is proposed to undertake a more stringent monitoring regimen during the construction of the North South Drain as a result.

While active excavations are being undertaken to construct the new North South Drain a daily test of field parameters (EC, pH, temperature, redox potential) will be taken at surface water sites SW02 and SW03, and groundwater test bores MW110 and MW113. This is in addition to the monthly routine monitoring during the construction phase detailed below (refer Section 3.5).

Daily monitoring will be done by the lead civil contractor's Environmental Manager with data provided weekly to the developments Environmental Representative.

# 3 Monitoring

## 3.1 Detecting Adverse Impacts

Management of any detrimental impacts to groundwater, Simpsons Creek, Everitt's Creek and GDE's will firstly need to recognise when adverse impacts are occurring. Results of monitoring during the construction and operational phases will be compared with the collated baseline data set. Action criteria has been established based on statistical analysis from baseline monitoring. Table 3-1 provides a summary of the monitoring in relation to surface and groundwater.

*Table 3.1 Groundwater monitoring Summary*

| | Aim | Section |
|---|---|---|
| Groundwater level | Determine change in groundwater levels resulting from the proposed development. | Section 3.2.2 |
| Groundwater quality | Determine if there is a reduction in groundwater quality resulting from the proposed development. | Section 3.2.5 |
| Surface water quality | Determine if there is a reduction in surface water quality resulting from the proposed development. | Section 4.1.2 |
| Acid Sulfate Soil | Determine if there is disturbance of acid sulfate soils and subsequent impact on surface and groundwater | Section 3.2.5 and Section 3.2.5 |
| GDE | Determine if there is a detrimental impact on GDEs because of the proposed development | Section 3.3.3 |

## 3.2 Groundwater Monitoring

A baseline data set of groundwater quality and groundwater level has been collected, with targets established for use as action criteria ('trigger') values during the construction and operation phases. Details and results are provided below.

### 3.2.1 Existing Monitoring Wells and Relocation Schedule

Of the nine existing monitoring bores at the subject site, six need to be relocated as they are within a proposed construction zone. Table 3.2 shows the bores (refer Figure 3-1) their use and the Construction Stage in which they are located. The bores will be relocated as early as possible (early works stage) to collect an overlap in groundwater level and groundwater quality data to allow a similarity assessment and calculation of relevant action criteria.

Two bores (BS-MW110 and BS-MW113) are located in Construction Stage 3, both close to the proposed new drainage line. As the proposed new drainage line will be constructed as part of the early works, it is essential that these two existing bores are retained through that works period with new bores installed as soon as possible after construction.

*Table 3.2 Existing bores to be relocated and Construction Stage*

| Bore | Use* | Relocation required? | #ConSt | ##Install ConST |
|---|---|---|---|---|
| BS-MW101 | GWQ | Y | 4 | EW |
| BS-MW104 | GWQ, GWL | Y | 2 | EW |
| BS-MW110 | GWQ | Y | 3 | EW/St1 |
| BS-MW113 | GWQ, GWL | Y | 3 | EW/St1 |
| BS-MW114 | GWQ | Y | 1 | EW |
| BS-MW120 | GWL | Y | 5 | EW |
| | | | | |
| BS-MW102 | GWQ, GWL | N | | |
| BS-MW109 | GWQ, GWL | N | | |
| BS-MW112 | GWQ, GWL | N | | |
| # ConSt = Within which delineated Construction Stage zone<br>## Install ConSt – Which construction stage to form the new bore; EW = Early works, St1 = Stage 1<br>*GWQ = groundwater quality; GWL = groundwater level | | | | |

#### *3.2.1.1 Decommissioning of Existing Bores*

The bores that require decommissioning will be done so in accordance with *Fact sheet Decommission a water bore Information for approval holders and licensed drillers* (Water NSW, 2023) and *Minimum Construction Requirements for Water Bores in Australia (MCR)* (National Uniform Drillers Licensing Committee, 2020). Decommissioning of bores may require approval from WaterNSW.

All bores are for monitoring purposes only (not for water extraction) and are shallow (<4m deep) hence will be relatively easy to decommission.

#### *3.2.1.2 Installation of Replacement Bores*

Replacement bores are to be installed in accordance with *Minimum Construction Requirements for Water Bores in Australia (MCR)* (National Uniform Drillers Licensing Committee, 2020). If required, all new bores are to be licenced with WaterNSW.

## 3.3 Groundwater Level

The objective of monitoring groundwater levels across the site is to determine whether the proposed development has any discernible effect on groundwater regime in the short to long term. There will be a substantial difference in surface conditions post construction (namely an increase in impervious surfaces such as roofs and roads) and subsequent effect on infiltration which is to be ameliorated through the development design. The hydrogeological assessment report (Martens 2021) shows an expected decreases in groundwater levels of up to 0.4 m in the developed portions of the site however in the surrounding areas, including wallum frog habitat, reductions in groundwater levels are limited to <.1m.

### 3.3.1 Baseline Groundwater Level

AWC have monitored groundwater levels at six locations on the site since January 2022, locations of the bores are shown on Figure 3-1. A summary of the data is provided in Table 3-2 with the data set graphed against daily rainfall, sourced from the Byron Bay BOM station (Cape Byron AWS # 058216) (see Figure 3-2).

The data shows groundwater levels vary across the site:

- Minimum levels range from 2.80 mAHD (MW-109) to 3.76 mAHD (MW-120), a difference of 0.96 m illustrating the groundwater gradient towards the Simpsons Creek
- Groundwater reacts rapidly to rainfall, increasing with rainfall and decreasing in dry times which is to be expected with the shallow nature of the aquifer and the high infiltration rates of the site sandy soils

*Table 3.3 Summary groundwater level statistics for groundwater bores*

| | mAHD | | | | | |
|---|---|---|---|---|---|---|
| | MW-113 | MW-102 | MW-104 | MW-109 | MW-112 | MW-120 |
| **Min** | 3.36 | 3.61 | 3.12 | 2.80 | 3.59 | 3.76 |
| **Max** | 4.14 | 4.49 | 4.07 | 4.09 | 4.76 | 4.79 |
| **Median** | 3.83 | 4.10 | 3.69 | 3.22 | 4.02 | 4.20 |
| **Average** | 3.80 | 4.07 | 3.65 | 3.24 | 4.03 | 4.23 |
| **20th %ile** | 3.61 | 3.92 | 3.45 | 2.86 | 3.83 | 4.01 |
| **80th%ile** | 3.98 | 4.22 | 3.82 | 3.55 | 4.19 | 4.51 |

### 3.3.2 Setting Action Criteria for Groundwater Levels

Table 3-3 provides action criteria for groundwater levels which have been determined through interrogation of the baseline data. The action criteria have been set at +/-5% of the existing range of levels for sites in close proximity to key habitat areas (eg Wallum Frog habitat and/or GDEs) being MW102, MW109 and MW112. As an example, MW102 has maximum and minimum values of 4.49 mAHD and 3.61 mAHD and a range of 0.88 m (4.49 m -3.61 m = 0.88 m); 5% of the range is 0.044 m; therefore, action criteria are > 4.53 mAHD (4.49 mAHD + 0.044 m), and <3.57 mAHD (3.61 mAHD – 0.044 m).

MW113, MW104 and MW120 have the upper action criteria calculated as the maximum level (baseline) plus the predicted 0.2m increase in groundwater levels as sourced from the Hydrogeological Assessment (Martens 2021). The lower action criteria for the monitoring wells is calculated as per the above (ie the baseline minimum level less 5% of the range).

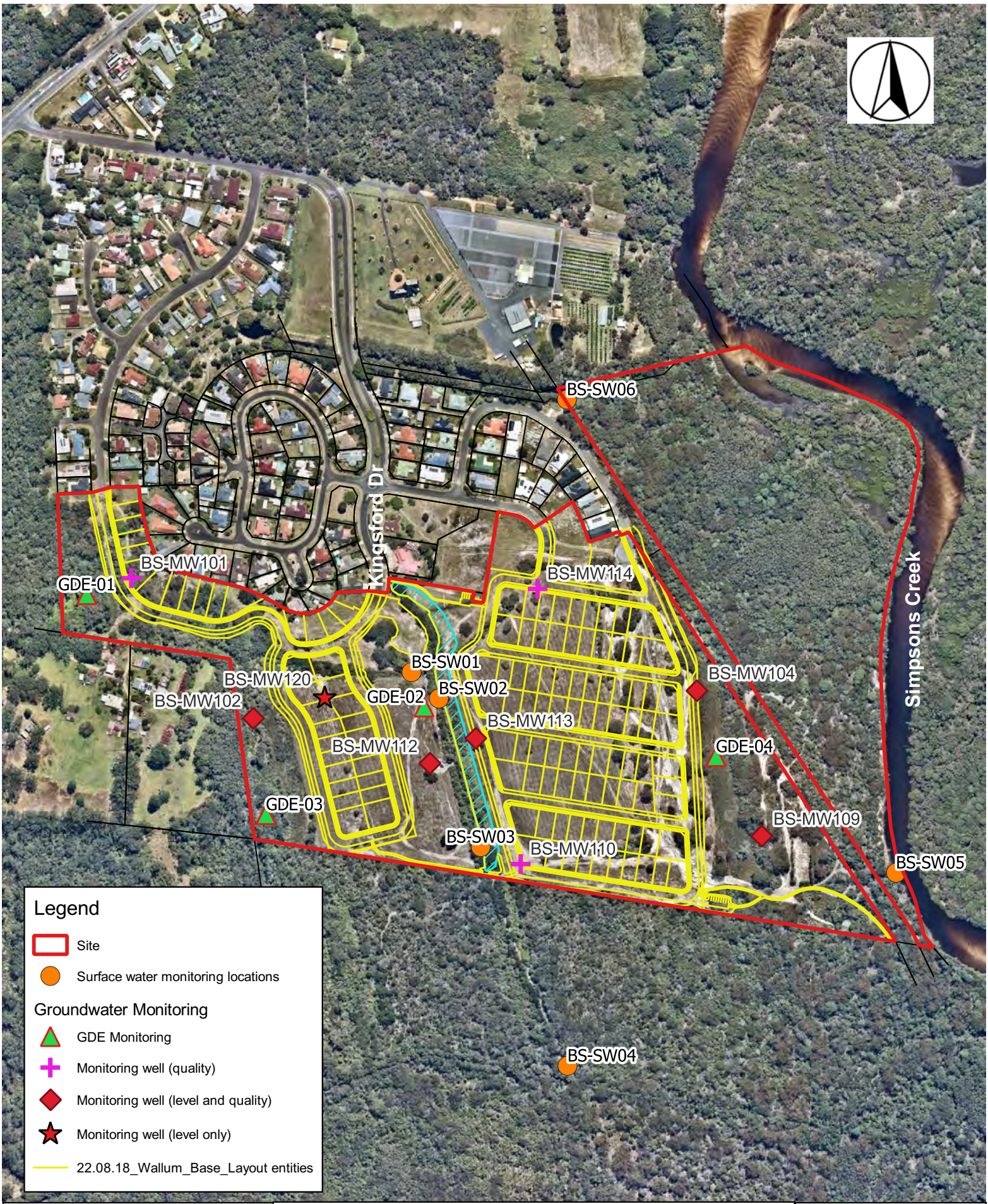
During monitoring of construction and operational phases, the consultant will calculate the 30, 60 and 90 day rolling average groundwater level value and compare each of these values against the action criteria established at each monitoring location (refer Table 3-3). This will assist with determining whether trends in water levels are due to discrete events (e.g. high rainfall events), longer term climate patterns, or site-based activity. Exceedance of the action criteria at a monitoring point(s) will trigger investigations of potential causes and depending on findings, rectification actions or adaptive management within the estate.

*Table 3.4 Action criteria for groundwater level*

| | MW-113 | MW-102 | MW-104 | MW-109 | MW-112 | MW-120 |
|---|---|---|---|---|---|---|
| Min. (mAHD) | 3.36 | 3.61 | 3.12 | 2.80 | 3.63 | 3.76 |
| Max. (mAHD) | 4.14 | 4.49 | 4.07 | 4.09 | 4.76 | 4.79 |
| Range (m) | 0.78 | 0.88 | 0.95 | 1.28 | 1.13 | 1.02 |
| **Lower action criteria** | **3.16*** | **3.57** | **2.92*** | **2.02** | **3.61** | **3.56*** |
| function | -0.2m | -5% | -0.2m | -5% | -5% | -0.2m |
| **Upper action criteria** | **4.18** | **4.53** | **4.12** | **4.15** | **4.90** | **4.84** |
| function | +5% | +5% | +5% | +5% | +5% | +5% |

Note: Action criteria will be compared with the 30, 60 and 90 day rolling average values from the collected monitoring data

* Upper action criteria based on predicted 0.2m decrease in groundwater levels (Martens, 2021)

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0 100 200 300 m

Figure 3.1 Groundwater monitoring wells (quality and level), surface water monitoring and GDE monitoring locations

Data source:
Aerial - Nearmaps
Layout - Cilviltech

Date:14-09-22
Job No:211400
Drawn: ED/JM
Checked: JM

A4 Scale 1:5,000
Coordinate System: MGA 56 Projection: Transverse Mercator

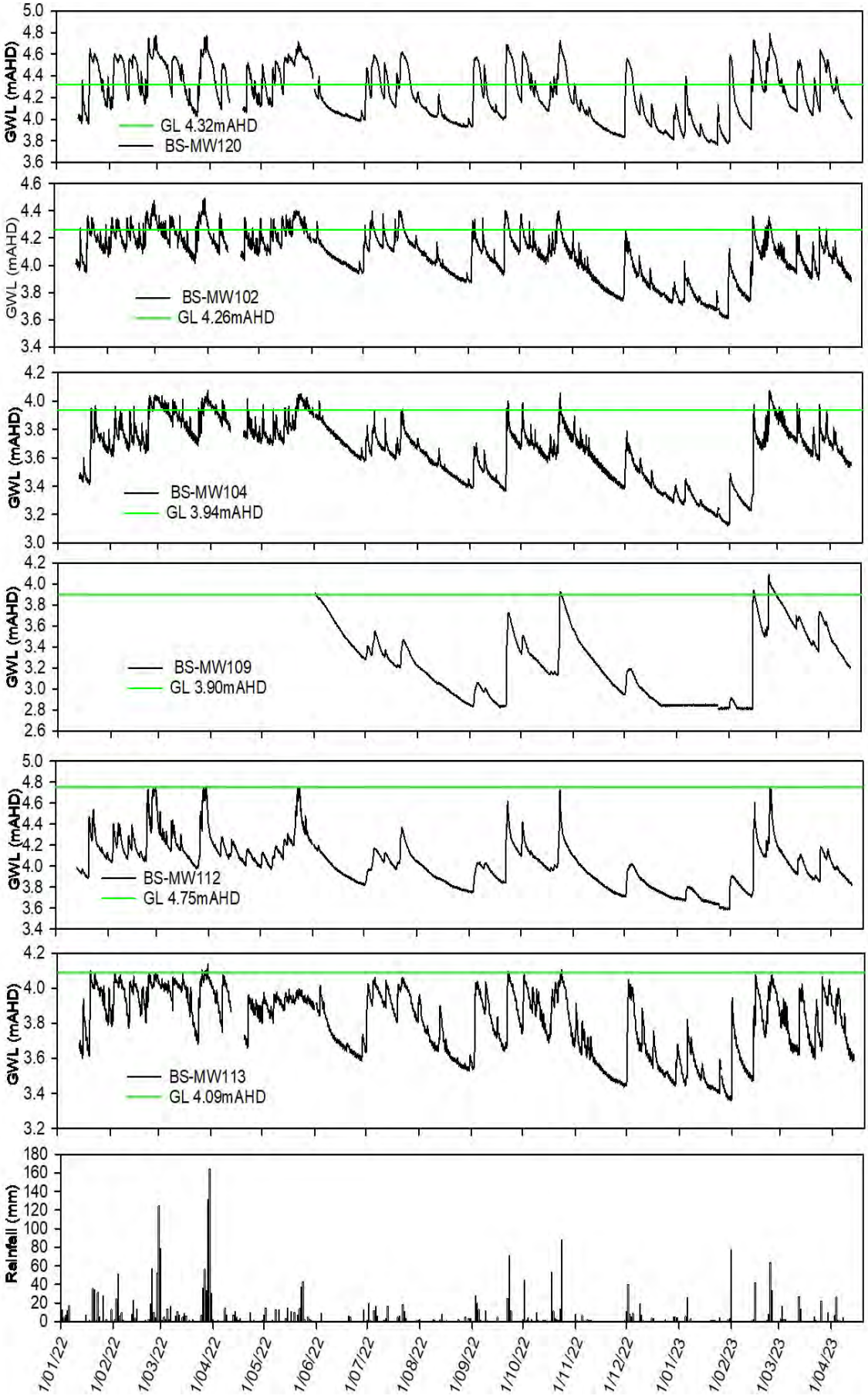


*Figure 3-2 Groundwater levels graphed against daily rainfall (BOM St 058216)*

## 3.4 Groundwater Quality

AWC collected a baseline data set of groundwater quality across the site from 2021 to 2022. There are six groundwater bores being used for collection of samples for analysis; Figure 3-1 shows their locations. Groundwater sample collection was in accordance with *Groundwater Sampling and Analysis – A Field Guide* (Sundarum *et al*, 2009). Groundwater was collected using a 50mm bore pump or hand bailer. Sample bottles/jars were suitable for the relevant analytes and to the satisfaction of the selected analysis laboratory. Purging of groundwater from each sampling bore was undertaken prior to the sample collection; briefly, at least three times the volume of the bore (3 x $\pi r^2$ x height) is purged prior to sample collection. Samples are stored on ice and delivered to the laboratory for analysis as soon as possible.

All laboratory analysis was undertaken by EAL a NATA accredited laboratory The analysis suite is provided in Table 3.5.

*Table 3.5 Groundwater monitoring analytes*

| Groundwater Quality Sampling – Water Quality Analytes | | | |
|---|---|---|---|
| Phys/chem | Nutrients | Salts | ASS Parameters: |
| pH *<br>Conductivity *<br>Total Dissolved Salts (TDS) *<br>Total Suspended Solids (TSS) | Total Phosphorus (TP)<br>Phosphate<br>Total Nitrogen (TN)<br>Nitrite<br>Total Kjeldahl Nitrogen<br>Nitrate<br>Ammonia | Calcium<br>Magnesium<br>Potassium<br>Sodium<br>Chloride<br>Sulfur | Fe (total)*<br>Al (total*<br>Cl:$SO_4$ ratio* |
| * = also used for ASS indicators (refer Section 3.2.4.3) | | | |

### 3.4.1 Baseline Groundwater Quality

A summary of the data collected at each bore is provided in table format in Appendix A. Collated groundwater quality data files and laboratory results sheets can be provided on request. The summary data includes minimum, maximum, mean and median values along with 20$^{th}$ percentile (20$^{th}$ %ile) and 80$^{th}$ percentile (80$^{th}$ %ile) values that have been calculated from the total data set. Results show varying quality between the sites with elevated levels of pollutants routinely seen across all sites.

#### *3.4.1.1 pH*

Groundwater across the site is acidic with all mean values below 5.0. The range of pH values at each site varies between 0.14 and 1.7 which is due to acid production through humic acid and peat reserves, and dilution from rainfall. Wallum environments are naturally acidic with pH values routinely below 5.

#### *3.4.1.2 Nutrients*

Nitrogen and phosphorus are routinely elevated across all bores. All samples were reported to have total phosphorus (TP) values above the ANZECC (2000) default of 0.035 mg/L TP. Similarly all results from all bores showed total nitrogen (TN) values above the ANZECC (2000) default of 0.3 mg/L TN.

Recorded TN values exceed the ANZECC default trigger value of 0.3 mg/L during all sampling events at all sites with mean values ranging from 2-51-15.00 mg/L. Monitoring bore MW 113 recorded the highest value for TN (58.8 mg/L). Interpretation of results show that the majority of TN within groundwater at site comprises of organic nitrogen. Mean Ammonia concentrations, with a range of 0.0-0.38 mg/L with a high of 0.67 mg/L recorded at MW-101.

Mean TP values range from 0.17-5.56 mg/L which is above the default trigger values of 0.05 mg/L as determined by ANZECC (2000) for slightly disturbed ecosystems, lowland rivers in SE Australia. Similarly the ANZECC default trigger value for filterable reactive phosphorus (phosphate) value of 0.02 mg/L is generally exceeded. MW 101 recorded the highest mean TP value of 5.56 mg/L.

The variability in values across the site, and within the data collected at each site, suggests there is an external influence on groundwater quality. Surrounding land use is confined to urban to the north, with a wholesale production nursery included though there is a constructed drain separating the nursery from the subject site. The source of the elevated nutrients has not been identified at this stage, though it may not be anthropogenic.

#### *3.4.1.3 Acid Sulfate Soil Indicators*

ASS is thought to exist in the catchment (although extensive testing suggests there is none on the subject site) and its influence on water quality is indicated by the $SO_4$/Alkalinity ratio, the Al/Ca and the $SO_4$/Cl ratios routinely above the indicative values of 0.2, 1, and 0.5 respectively (Sullivan et al (2018)). Sullivan et al (2018) also suggest an Aluminium value of >1 mg/L is an indicator of mobilisation; all sites show a median value of >1 mg/L.

### 3.4.2 Setting Action Criteria for Groundwater Quality

Analysis of the baseline data set has been undertaken to determine action criteria for a range of analytes at each of the groundwater bores. The baseline data set shows the groundwater quality is relatively poor with recorded concentrations generally exceeding default ANZECC (2000) trigger values. Current (pre-development) groundwater quality is affected by historic land use including agricultural clearing and drain formation, urban development upstream. The aim of the proposed action criteria is to maintain the groundwater quality within the range of existing variations established during the baseline monitoring and characterisation. The primary risk of further degradation of groundwater quality is to the downstream aquatic environments and GDE's.

Table 3.6 discusses the use of the ANZECC (2000) framework and details relevant decisions to determine the proposed action criteria for groundwater quality. Table 3.7 provides proposed indicator analytes to detect impact to groundwater quality with commentary.

*Table 3.6 Framework to determine appropriate guideline values (ANZECC (2000) and discussion*

| ANZECC (2000) | Comment discussion relevant to the proposed development |
|---|---|
| **Define Primary Management Aims** | |
| Define the water body | The groundwater aquifer bounded by the project extents which surfaces and discharges to the Everitts/Simpson Creek aquatic environment. |
| Determine environmental values to be protected | The primary environmental value is for the downstream aquatic ecosystem (Simpson and Everitt's Creek) and GDE's |
| Determine level of protection | The results of the groundwater and surface water quality suggest the systems are 'highly disturbed' because of current and historic land use in the catchment.<br>The level of protection will reflect the current condition with the proposed development management aim to be 'non-worsening'. |
| Identify environmental concerns | Main concerns are:<br>• The proposed development will increase nutrients and other pollutants in the groundwater<br>• Additionally, reduction of groundwater levels would impact GDE |
| Determine major natural and anthropogenic factors affecting the ecosystem | Primary factors include:<br>• Increased nutrients and pollutants in the groundwater/surface water system sourced from the proposed development (anthropogenic)<br>• Increase pH of groundwater<br>• Acid sulfate soil processes impacting the downstream aquatic ecosystems (natural, anthropogenic acceleration) |
| Determine 'management goals' | The management goal is to achieve no-worsening of the groundwater quality and subsequent impact to the downstream aquatic environment resulting from the proposed development. |
| **Determine appropriate Guideline Trigger Values for selected indicators** | |
| Select indicators relevant to concerns and goals | Refer Table 3-12 |
| Determine appropriate guideline trigger values | Review of the baseline data set for groundwater quality it was determined the default guideline values in ANZECC (2000) are too conservative, and will be routinely exceeded as a result of the existing and historic catchment land use. A set of action criteria (upper threshold for all except pH) for each bore have been determined based on the 80$^{th}$ %ile values of the baseline data set. An action criteria range has been applied to the pH values of the baseline data set; the range is the minimum and maximum values detected. Refer Table 3.13 |
| Determine specific indicators to be applied | The indicators are aimed at detection of a change in water quality values that may impact the downstream aquatic environment resulting from the proposed development.<br>Refer above and Table 3.13 |

*Table 3.7 Indicator analytes for detection of groundwater impact*

| Analyte | Comment – potential indicator |
|---|---|
| pH | Groundwater acidity change can indicate groundwater level lowering and ASS processes |
| EC (dS/cm) | Indicate saline water intrusion, or increased freshwater recharge |
| TSS (mg/L) | Indicate soil disturbance and pollution from construction works and occupation phase |
| TP (mg/L) | Urbanisation and stormwater impacts |
| TN (mg/L) | Urbanisation and stormwater impacts |
| **ASS indicators** | |
| Al (mg/L) | Increased acidity causes mobilisation of aluminum and iron |
| Fe (mg/L) | |
| Sulfate/Chloride Ratio | Changes in ASS indicator ratios can indicate construction phase dewatering impacts, groundwater level lowering through reduced recharge and other ASS disturbance and poor management |
| Al/Ca ratio | |
| SO4/alkalinity ratio | |

The selected action criteria are based on the 80th %ile value of the baseline data set for that bore (refer Section 3.2.4); pH action criteria are based on the preferred range being within the existing recorded range. Table 3.8 shows the action criteria associated with the groundwater quality at each test bore. The different values adopted for each monitoring well reflect the spatial variability of groundwater quality across the site. Should these action criteria be exceeded in the routine construction and occupation phase monitoring, additional assessment and management actions are to be conducted as per the groundwater action response plan (refer Section 6).

*Table 3.8 Action criteria - Groundwater quality*

| | MW101 | MW102 | MW109 | MW112 | MW113 | MW114 |
|---|---|---|---|---|---|---|
| pH # | <4.06 or >5.76 | <4.28 or >5.24 | <3.78 or >4.19 | <4.3 or >5.32 | <4.27 or >5.25 | <4.68 or >5.25 |
| EC (dS/cm) | 0.12 | 0.09 | 0.17 | 0.11 | 0.13 | 0.17 |
| TSS (mg/L) | 11328 | 2400 | 580 | 1340 | 2408 | 121 |
| TP (mg/L) | 2.61 | 0.88 | 0.35 | 0.52 | 1.24 | 0.28 |
| TN (mg/L) | 15.68 | 2.94 | 3.74 | 4.56 | 18.58 | 3.13 |
| Ammonia | 0.44 | 0.17 | 0.24 | 0.26 | 0.19 | 0.2 |
| **ASS indicators** | | | | | | |
| Al (mg/L)- dissolved | 5.02 | 0.99 | 0.48 | 1.53 | 9.76 | 2.09 |
| Fe (mg/L) dissolved | 2.2 | 0.46 | 0.59 | 0.41 | 1.34 | 0.72 |
| Sulfate/Chloride Ratio | 0.31 | 0.24 | 0.57 | 0.28 | 0.19 | 0.27 |
| Al/Ca ratio | 4.02 | 0.74 | ND | 4.46 | 8.15 | 1.61 |
| SO4/alkalinity ratio | ND | 2.36 | 0.02 | 1.42 | 5.10 | 1.22 |
| # pH action criteria based on the range between the minimum and maximum values detected in the baseline data<br>ND = not detected/below detectable limits<br>Note: when action criteria are exceeded, the Groundwater Action Response Plan will be enacted (refer Section 5) | | | | | | |

Action criteria values are generally above default trigger levels assigned by the ANZECC guidelines. This is a function of the existing condition of the groundwater reserves being impacted from the existing land uses in the catchment. Urban development is located to the north of the subject site.

Not all routine monitoring analytes are a first order indicator or subject to action criteria. If there is an exceedance of one of the action criteria and the Groundwater Action Response Plan is enacted, assessment of other analytes and potentially previous results may be informative.

## 3.5 Groundwater Monitoring Plan

### 3.5.1 Construction Phase

All existing monitoring bores will be monitored for groundwater level and quality during the entire construction phase. The 'construction phase' includes the time period from commencement of subdivision construction works for Early Works and continues until construction is complete. A report will be prepared at the end of each construction stage to be issued to council.

Amendments to the groundwater management plan and monitoring program can be made for each stage based on site conditions, previous monitoring, type, and methods of subdivision works. Table 3.9 provides the schedule for construction phase groundwater monitoring and reporting.

While active excavations are being undertaken to construct the new North South Drain a daily test of field parameters (EC, pH, temperature, redox potential) groundwater test bores MW110 and MW113. This is in addition to the monthly routine monitoring during the construction phase detailed below. Daily monitoring will be done by the lead civil contractor's Environmental Manager with data provided weekly to the developments Environmental Representative.

*Table 3.9 Construction phase groundwater monitoring*

| Groundwater attribute | Monitoring program | Schedule/Timing | Reporting |
|---|---|---|---|
| Groundwater quality including ASS indicators | Collection of groundwater samples and analysis from the six existing bores (refer Section 3.3 and Figure 3-1) and existing analytes (refer Table 3-4) | Monthly – between commencement of subdivision construction works and the issue of a subdivision works certificate for each stage<br>See Note ** below | * At the end of each subdivision works stage (required prior to council issuing subdivision stage certificate)<br><br># Six monthly monitoring report to be provided to council |
| Groundwater level | ^^ In-situ water level loggers – retain the six existing water level loggers through to the occupation phase of the development | One (1) hourly data point<br>See Note ** below | |
| GDEs | Vegetation monitoring of GDEs (as per Section 3.3.4) | Annual | |

* Provide all monitoring data to the Project Environmental Manager for dispersal to relevant people (e.g. groundwater quality data for Acid Frog management purposes)

** During excavation and construction of the new North South Drain, daily field parameters (pH, EC, NTU, temperature and redox potential) and dip measurements of groundwater level are to be tested at monitoring bores MW110 and MW113

# Reporting is to comply with Condition 9 of the consent conditions (refer Section 1.5)

- Analysis of all monitoring and sampling data against baseline data and approved thresholds (in the approved CEMP), limits and triggers
- At least six (6) monthly reporting during subdivision construction works for at least five (5) years or until the issue of a subdivision certificate for Stage 5, whichever is the later

^^ Some wells (BS-MW101, BS-MW120, BS-MW114, BS-MW110 and BS-MW104) will be destroyed during the construction phase; these will be replaced in a nearby location where construction will not impact. A time overlap between installation of the new well and the removal of the existing well is required to compare data and perform similarity testing between data.

### 3.5.2 Occupational Phase

From the issue of the final subdivision certificate from Council, monthly sample collection and level data logging will continue for a further 12 months. Six monthly reports will be prepared detailing results and comparisons to the action criteria stipulated, or as amended in the interim. Table 3-9 provides detail on the monitoring program, schedule and reporting for the occupation phase.

*Table 3.10 Occupation phase groundwater monitoring*

| Groundwater attribute | Monitoring program | Schedule/Timing | Reporting* |
|---|---|---|---|
| Groundwater quality including ASS indicators | Collection of groundwater samples and analysis from the six existing bores (refer Section 3.3 and Figure 3-1) and existing analytes (referTable 3-5) | Monthly – between issue of a subdivision works certificate for a period of 12 months | * Quarterly data provisions<br><br># Six monthly monitoring report to be provided to council |
| Groundwater level | ^^ In-situ water level loggers – retain the six existing water level loggers through the first 12 months of the occupation phase of the development | One (1) hourly data point | |
| GDEs | Vegetation monitoring of GDEs (as per Section 3.3.4) | Annual | |

* Provide all monitoring data to the Project Environmental Manager for dispersal to relevant people (e.g. groundwater quality data for Acid Frog management purposes)

# Reporting is to comply with Condition 9 of the consent conditions (refer Section 1.5)

- Monitoring results of groundwater levels and quality from the commencement of Early Stage 1 works until the issue of a subdivision certificate for Stage 5 with submission of an updated report to Council prior to the issue of the subdivision works certificate for each stage of works
- Analysis of all monitoring and sampling data against baseline data

^^ Some wells (BS-MW101, BS-MW120, BS-MW114, BS-MW110 and BS-MW104) will be destroyed during the construction phase; these will be replaced in a nearby location where construction will not impact. A time overlap between installation of the new well and the removal of the existing well is required to compare data and perform similarity testing between data.

### 3.5.3 Groundwater Dependent Ecosystem Monitoring

Monitoring of groundwater levels, groundwater quality, and surface water quality will inform potential impacts to the groundwater dependent ecosystems at the site. However, detecting detrimental impacts to the groundwater dependant vegetation will also be monitored. Annual vegetation surveys will be undertaken at four permanent locations within groundwater dependent ecosystems at the site. The aim will be to determine if there is a shift in vegetation assemblage and vegetation health resulting from a potential change in groundwater characteristics.

Four permanent monitoring sites have been installed and assessed in accordance with the Biodiversity Assessment Method (DPIE 2020) to determine a Vegetation Integrity Score (VIS) for each vegetation plot of 20 x 50 m (0.1 ha). Each plot has been permanently marked using star pickets, GPS coordinates and mapped. Preliminary locations of proposed monitoring sites are shown on Figure 3-1.

Vegetation plots also include a permanent photo point to assess vegetation cover over time. At each inspection a visual assessment will be completed within the vegetation community to assess general health of vegetation and note any dieback or other signs of stress.

### 3.5.4 Data Provision

Monitoring data (groundwater level and quality) is to be provided to the Project Environmental

Manager and project Ecologist for inclusion in Acid Frog management and monitoring purposes.

### 3.5.5 Groundwater Action Response Plan

Should the results of groundwater sampling and analysis be outside the relevant trigger values be recorded the Groundwater Action Response Plan will be enacted (refer Section 6).

# 4 Surface Water Management

## 4.1 Surface Water Monitoring

A baseline data set of surface water quality has been collected, with targets established for use as 'trigger' values during the construction and operation phases. Details and results are provided below.

### 4.1.1 Baseline Surface Water Quality

AWC collected a baseline data set of surface water quality across the site from 2021 to 2022. There are six sample locations being used for collection of samples for analysis; Figure 3-1 shows their locations. SW1 to SW3 are located within the project site while SW6 is upstream and SW4 and SW5 are downstream of the site.

All laboratory analysis was undertaken by EAL a NATA accredited laboratory The analysis suite is provided in Table 4.1.

*Table 4.1 Surface water monitoring analytes*

| Surface Water Quality Sampling – Water Quality Analytes | | | | |
|---|---|---|---|---|
| **Phys/chem**<br>pH *<br>Conductivity *<br>Total Dissolved Salts (TDS) *<br>Total Suspended Solids (TSS) | **Nutrients**<br>Total Phosphorus (TP)<br>Phosphate<br>Total Nitrogen (TN)<br>Nitrite<br>Total Kjeldahl Nitrogen<br>Nitrate<br>Ammonia | **Salts**<br>Calcium<br>Magnesium<br>Potassium<br>Sodium<br>Chloride<br>Sulfur | **ASS**<br>Fe (total)<br>Al (total<br>Cl:$SO_4$ ratio<br>**Biological**<br>Chlorophyll '*a*'<br>Algal biomass | **Hydrocarbons**<br>Total Recoverable Hydrocarbons (TRH - speciated)<br>**Metals**<br>Lead<br>Arsenic<br>Mercury |

A summary of the data collected at each sampling location is provided in the tables in Appendix B. The summary data incudes minimum, maximum, mean, median, 20$^{th}$ percentile (20$^{th}$ %ile) and 80$^{th}$ percentile (80$^{th}$ %ile) values that have been calculated from the total baseline data set. Results show varying quality between the sites with elevated levels of pollutants routinely seen across all sites.

#### *4.1.1.1 pH*

Surface water across the site is acidic with mean values at SW01-SW03 below 5.0 with variations in pH values at these sites between 0.53 and 1.69 pH points. SW04-SW06 showed greater variation in pH values (1.34-2.39 pH points) likely contributed to saltwater intrusion from Simpsons Creek during high tides. Wallum environments are naturally acidic (acidophilic) with pH values routinely below 5.

#### *4.1.1.2 Nutrients*

TN and TP are routinely elevated across all monitoring locations. Recorded TN mean values ranging from 0.66-2.10 mg/L. SW 01 recorded the highest TN value of 6.85 mg/L.

Mean TP values range from 0.17-0.61 mg/L which is above the default trigger values of 0.05 mg/L as determined by ANZECC (2000) for slightly disturbed ecosystems, lowland rivers in SE Australia. Similarly the ANZECC default trigger value for filterable reactive phosphorus (phosphate) value of 0.02 mg/L is generally exceeded. SW 06 recorded the highest mean TP value of 1.31 mg/L.

#### *4.1.1.3 Acid Sulfate Soil Indicators*

ASS is thought to exist in the catchment (although extensive testing suggests there is none on the subject site) and its influence on water quality is indicated by the $SO_4$/Alkalinity ratio, the Al/Ca and the $SO_4$/Cl ratios routinely above the indicative values of 0.2, 1, and 0.5 respectively (Sullivan et al (2018). Sullivan et al (2018) also suggest an Aluminium value of >1 mg/L is an indicator of mobilisation; all sites show a median value of >1 mg/L.

### 4.1.2 Setting Action Criteria for Surface Water Quality

Analysis of the baseline data set has been undertaken to determine action criteria for a range of analytes at each of the surface water monitoring locations. The baseline data set shows the surface water quality is relatively poor with recorded concentrations generally exceeding default ANZECC (2000) trigger values. Current (pre-development) water quality is affected by historic land use including agricultural clearing, drain formation and urban development upstream. The aim of the proposed action criteria is to maintain the surface water quality within the range of existing variations established during the baseline monitoring and characterisation. The primary risk of further degradation of surface water quality is to the downstream aquatic environments.

Table 4.2 provides proposed indicator analytes to detect impact to surface water quality with commentary.

*Table 4.2 Indicator analytes for detection of groundwater impact*

| Analyte | Comment – potential indicator |
|---|---|
| pH | Surface water acidity change can indicate groundwater level lowering and ASS processes |
| EC (dS/cm) | Indicate saline water intrusion |
| TSS (mg/L) | Indicate soil disturbance and pollution from construction works and occupation phase |
| TP (mg/L) | Urbanisation and stormwater impacts |
| TN (mg/L) | Urbanisation and stormwater impacts |
| **ASS indicators** | |
| Al (mg/L) | Increased acidity causes mobilisation of aluminium and iron |
| Fe (mg/L) | |
| Sulfate/Chloride Ratio | Changes in ASS indicator ratios can indicate construction phase dewatering impacts, groundwater level lowering through reduced recharge and other ASS disturbance and poor management |
| Al/Ca ratio | |
| SO4/alkalinity ratio | |

The selected action criteria are based on the 80th %ile value of the baseline data set for that monitoring site (refer Section 4.1.1 ). Action criteria for pH across all sites and conductivity within estuarine sites (SW04 & SW05) are based on the preferred range being within the existing recorded range. Table 4.3 shows the surface water quality action criteria at each monitoring location. The different values adopted for each monitoring site reflect the spatial variability of surface water quality across the site (ie, Lowland river (SW01, SW02, SW03 & SW06) and Estuarine (SW04-SW05). Should these action criteria be exceeded in the routine construction and occupation phase monitoring, additional assessment and management actions are to be conducted as per the surface water action response plan (refer section 6).

*Table 4.3 Action criteria – Surface water quality*

| Parameter | SW01 | SW02 | SW03 | SW04 | SW05 | SW06 |
|---|---|---|---|---|---|---|
| pH # | <4.05 or >4.58 | <4.17 or >5.21 | <4.17 or >5.86 | <4.17 or >6.07 | <5.69 or >8.03 | <5.46 or >6.85 |
| EC (dS/cm) | 0.14 | 0.13 | 0.11 | <0.09 or >0.15 | <0.06 or >43.80 | 1.56 |
| TSS (mg/L) | 28.50 | 35.60 | 87.20 | 17.27 | 9.67 | 5.00 |
| TP (mg/L) | 0.51 | 0.29 | 0.28 | 0.22 | 0.28 | 1.16 |
| TN (mg/L) | 2.36 | 1.97 | 2.10 | 1.38 | 0.94 | 1.69 |
| Ammonia | 0.16 | 0.14 | 0.15 | 0.13 | 0.12 | 0.31 |
| **ASS indicators** | | | | | | |
| Al (mg/L)- dissolved | 0.73 | 0.99 | 0.87 | 0.67 | 0.42 | 0.46 |
| Fe (mg/L) dissolved | 0.48 | 0.73 | 0.55 | 2.17 | 1.52 | 0.80 |
| Sulfate/Chloride ratio | 0.33 | 0.39 | 0.38 | 0.32 | 0.19 | 0.71 |
| Al/Ca ratio | 0.88 | 0.51 | 1.00 | 0.44 | 0.08 | 0.08 |
| SO4/alkalinity ratio | ND | 1.68 | 2.72 | 5.58 | 21.47 | 3.44 |
| # pH action criteria based on the range between the minimum and maximum values detected in the baseline data<br>Note: when action criteria are exceeded, the Groundwater Action Response Plan will be enacted (refer Section 6) | | | | | | |

## 4.2 Surface Water Monitoring Plan

### 4.2.1 Construction Phase

All existing surface water monitoring locations will be monitored for quality during the entire construction phase. The 'construction phase' includes the time period from commencement of subdivision construction works for Early Works and continues until all subdivision construction work is complete. A report will be prepared at the end of each construction stage to be issued to council prior to the subdivision works certificate being released.

Amendments to the groundwater and surface water management plan and monitoring program can be made for each stage based on site conditions, previous monitoring, type, and methods of subdivision works. Table 4.4 provides the schedule for construction phase groundwater monitoring and reporting.

While active excavations are being undertaken to construct the new North South Drain a daily test of field parameters (EC, pH, temperature, redox potential) will be taken at surface water sites SW02 and SW03. This is in addition to the monthly routine monitoring during the construction

phase detailed below. Daily monitoring will be done by the lead civil contractor's Environmental Manager with data provided weekly to the developments Environmental Representative.

*Table 4.4 Construction phase surface water monitoring*

| Groundwater attribute | Monitoring program | Schedule/Timing | Reporting |
|---|---|---|---|
| Surface water quality including ASS | Collection of groundwater samples and analysis from the six existing locations (refer Figure 3-1) and existing analytes (refer Table 4.1) | Monthly – between commencement of subdivision construction works and completion of construction for each stage<br>See Note ** below | * At the end of each subdivision works stage (required prior to council issuing subdivision stage certificate)<br><br># Six monthly monitoring report to be provided to council (unless annual monitoring) |
| * Provide all monitoring data to the Project Environmental Manager for dispersal to relevant people<br>** During excavation and construction of the new North South Drain, daily field parameters (pH, EC, NTU, temperature and redox potential) at surface water sites SW02 and SW03<br># Reporting is to comply with Condition 9 of the consent conditions (refer Section 1.6)<br>• Analysis of all monitoring and sampling data against baseline data and approved thresholds (in the approved CEMP), limits and triggers<br>• At least six (6) monthly reporting during subdivision construction works for at least five (5) years or until the issue of a subdivision certificate for Stage 5, whichever is the later | | | |

### 4.2.2 Occupation Phase

From the issue of the final subdivision certificate from Council, monthly sample collection will continue for a further 12 months. Six monthly reports will be prepared detaining results and comparisons to the action criteria stipulated, or as amended in the interim. Table 4.5 provides detail on the monitoring program, schedule and reporting for the occupation phase.

*Table 4.5 Occupation phase groundwater monitoring*

| Groundwater attribute | Monitoring program | Schedule/Timing | Reporting* |
|---|---|---|---|
| Surface water quality including ASS | Collection of surface water samples and analysis from the six existing locations (refer Section 3.3 and Figure 3-1) and existing analytes (refer Table 4-1) | Monthly – between issue of a subdivision works certificate for a period of 12 months | * Annual<br><br># Annual monitoring report to be provided to council |
| * Provide all monitoring data to the Project Environmental Manager for dispersal to relevant people (e.g. groundwater quality data for Acid Frog management purposes)<br># Reporting is to comply with Condition 9 of the consent conditions (refer Section 1.6)<br>• Monitoring results of groundwater levels and quality from the commencement of Early Stage 1 works until the issue of a subdivision certificate for Stage 5 with submission of an updated report to Council prior to the issue of the subdivision works certificate for each stage of works<br>• Analysis of all monitoring and sampling data against baseline data and approved thresholds (in the approved CEMP), limits and triggers | | | |

## 4.3 Surface Water Response Plan

Should the results of surface water monitoring be outside the relevant action criteria the Groundwater and Surface Water Action Response Plan will be enacted (refer Section 6 and Table 6.1).

# 5 Management Strategies

Ongoing monitoring and comparison with the baseline data set and adopted action criteria will alert management to a development related impact. Rectification of the impact will need to be investigated with consideration of spatial and temporal effects, stakeholder values and practicality. Discussion and potential contingency actions are provided below.

## 5.1 Maintenance of Groundwater Levels

The increase in imperviousness, soil compaction and trunk drainage system could alter groundwater levels across the site. The stormwater management strategy for the site includes infiltration to recharge groundwater as a priority. It is known that groundwater levels may decrease by up to 0.4 m under the developed areas (refer Hydrogeological Assessment by Martens (2021). The action criteria has considered this predicted (modelled) decrease in groundwater under the developed areas, however outside the footprint where high value habitat (eg Wallum Froglet and GDE) is located the action criteria is more stringent to detect change and impact. If a decrease in groundwater level is detected by exceedance of the assigned action criteria, the following may be considered:

- Assessment of spatial differences in groundwater levels and determine priority action areas
- Inspection of the stormwater treatment and infiltration systems to ensure functionality
- Creation of additional infiltration systems; these could be inground, open base cells in public areas or private properties
- Injection of additional water to recharge groundwater (e.g. recycled water from Brunswick Valley STP or other viable sources)

## 5.2 Groundwater Quality

It may be difficult to determine the source of poor groundwater quality. There are several land-uses in the catchment that are capable of polluting groundwater including agriculture and existing urban/industrial areas that have inadequate stormwater treatment. The baseline groundwater quality shows existing impact and poor quality. If groundwater monitoring shows a reduction in groundwater quality contingencies for rectification may include:

- Assessments to isolate sources (i.e. internal or external to the Wallum Estate, e.g. may be sewer infiltration off site)
- Assessment of surface/stormwater monitoring results to detect a correlation
- Extraction of groundwater, treatment and re-injection
- Modification of works practices
- Specialist consultants may need to be engaged

## 5.3 Surface Water Quality

Surface water quality can affect groundwater quality through infiltration of contaminated water. Surface water monitoring is proposed as part of the overall environmental monitoring of the proposed development. The Environmental Manager will consider results of the surface water monitoring program if deleterious results of the groundwater quality monitoring are detected.

## 5.4 Risk Assessment and Emergency Response Plan

BSC provided an RFI that included the following:

> *"the SWGWMP does not provide details of the likely events that may impact surface and groundwater and provide details of measures to manage these...*
>
> *Therefore, provide a table using a risk rating tool (refer consequence table below) to identify the:*
> - *Risks*
> - *Likelihood*
> - *Consequence*
> - *Rating*
> - *Risk Mitigation*
> - *Response Action*
>
> *Use the resulting data from the table to prepare an Emergency Response Plan.*
> - *Emergency*
> - *Remedial / Clean up Protocols*
> - *Monitoring*
> - *Notification*
> - *Training"*

The sections below respond to this RFI component.

#### *5.4.1.1 Risk Assessment*

The Risk Assessment used the matrix as per Table 5.1. Potential events that may impact surface water and groundwater at the site are assessed in Table 5.2 with the emergency response required provided.

The routine monitoring of groundwater and surface water quality proposed in this SWGWP and the associated action criteria (refer Section 6) provide for general impacts resulting from the proposed development during the construction phase. The section below is aimed at point source, or direct impact from a defined event that may detrimentally impact groundwater and/or the surface water on the subject site and in the downstream aquatic environment.

*Table 5.1 Risk rating matrix tool*

| Consequence ⇨ / Likelihood ⇩ | Insignificant | Minor | Significant | Major | Severe |
|---|---|---|---|---|---|
| Almost Certain | Medium | High | Very High | Extreme | Extreme |
| Likely | Medium | Medium | High | Very High | Extreme |
| Moderate | Low | Medium | Medium | High | Very High |
| Unlikely | Very Low | Low | Medium | Medium | High |
| Rare | Very Low | Very Low | Low | Medium | Medium |

#### *5.4.1.2 Monitoring of Emergency Response Events*

After an emergency response has been initiated and amelioration is complete, the rectification is to be monitored in accordance with relevant legislation and guidelines and/or to the satisfaction of the relevant expert and BSC.

#### *5.4.1.3 Training*

All subcontractors are required to include relevant training in their inductions to ensure all personnel are familiar with the requirements of the project and relevant work health and safety

protocols. Where emergency response actions have been initiated, all staff are to be adequately informed of the process and learn from the event to reduce impact if it happens again.

*Table 5.2 Risk assessment results table and Emergency Response Plan*

| Possible Event | Con# | Lik## | Risk Rating | Emergency Response |
|---|---|---|---|---|
| **High intensity rainfall event:** Impact downstream water course from high turbidity water and sedimentation | Significant | Likely | High | • Reinstate and reevaluate SECP* measures<br>• Remove accumulated sediment and rectify erosion<br>• Report significant breaches to relevant authority |
| **Chemical spill:** Uncontrolled spill of chemicals (fuel, pesticides, flocking agents, cement, lime) | Major | Unlikely | Medium | • Reinstate and reevaluate chemical storage and handling protocols<br>• Get appropriate advice and remove, remediate spill site<br>• Report significant breaches to relevant authority |
| **Acid Sulfate Soil leachate** detected:<br>• Excavation and oxidation of ASS causing high strength (<4.17 pH**) acid leachate discharge to existing water course and downstream environment.<br>• (Note: extensive testing for ASS on the subject site failed to detect the presence of ASS) | Significant | Rare | Low | • Cease excavations immediately<br>• Detain where possible acid leachate for treatment (bring to >4.17 pH)<br>• Get appropriate advice and reevaluate excavations and management of potential ASS<br>• Consider buffering capacity of EC and alkalinity in receiving waters<br>• Refer ASS Management Plan (AWC, 2021)<br>• Remediate all excavated ASS<br>• Report significant breaches to relevant authority |
| **Bushfire**:<br>Although bushfire is a naturally occurring event, detrimental impacts could occur to the groundwater and surface water as a result, including:<br>• Ash and debris washed into the water course<br>• Higher groundwater recharge rates from loss of vegetation<br>• Increased surface water discharge and associated erosion and water quality impacts | Minor | Rare | Very Low | • Be aware of potential storms and high intensity rainfall events (>20 mm)<br>• – monitor weather predictions<br>• Stabilise any concentrated surface water flow paths<br>• Restrict ash and debris movement<br>• Establish stabilisation vegetation as soon as possible |
| **Unexpected finds:**<br>During excavations or general works on site, unexpected finds may occur, these may include, but not limited to rubbish dumps, human remains, Aboriginal heritage items, unexploded ordinances and oil soaks | Minor | Unlikely | Low | • Cease excavation/work immediately<br>• Get advice form Site Superintendent and relevant consultant<br>• Remediate as required<br>• Report significant breaches to relevant authority |
| * SECP = Sediment and Erosion Control Plan<br>** pH of <4.17 = action criteria in existing drain (refer SW02, SW03 and SW04 in Table 4.3)<br># = Consequence, ## = Likelihood | | | | |

# 6 Action Response Plan

Should the results of routine groundwater and surface water monitoring during the construction and occupation phase of the development be outside the relevant action criteria the Groundwater and Surface Water Action Response Plan will be enacted (refer Table 6.1). Refer also Section 5.4 and Table 5.2 for emergency response plan.

*Table 6.1 Groundwater and Surface Water Action Response Plan*

| Performance Criteria | Action | Response |
|---|---|---|
| **Groundwater quality** | | |
| No decrease in groundwater quality due to proposed development (construction and operational stages) | 1. Check and validate data<br>a. Re take sample to confirm concentration/value<br>2. Notify management (Site Superintendent, Environmental Manager)<br>3. Undertaken Phase 1 investigation to confirm trigger exceedance is development (construction/operation) related<br>a. If necessary engage suitably qualified person<br>b. Review/consider recent conditions (weather, land use activities, construction activities)<br>c. Review/consider other relevant monitoring data<br>d. If investigation confirms trigger exceedance is not related to construction activities, record data and cease investigation<br>4. If trigger level exceedance is development related confirm if the activities have caused or have the potential to cause substantial environmental harm<br>a. Notify Environmental Manager, Site Superintendent and relevant agencies as soon as practicable (whether or not it is development related)<br>5. Notify Environmental Manager and other relevant agencies if performance measures are exceeded as soon as practicable<br>6. Complete an Investigation Report and provide to all stakeholders and other relevant agencies with 21 days of identifying the incident<br>7. Prepare rectification proposal, engage stakeholders and remediate | Where it has been determined that development related impacts have caused a trigger exceedance, implementation of contingency and remedial measures is required. These may include, but not limited to, the following:<br>• Review monitoring program and Groundwater Management Plan and revise if necessary<br>• Investigate reasonable and feasible remedial measures<br>• Review water management infrastructure (e.g. WSUD) and repair/renew if necessary |
| **Groundwater Level** | | |
| No significant decrease or increase in groundwater levels due to the proposed development | 1. Check and validate data<br>2. Notify management (Site Superintendent, Environmental Manager)<br>3. Undertaken Phase 1 investigation to confirm trigger exceedance is development (construction/operation) related<br>a. If necessary, engage suitably qualified person<br>b. Review/consider recent conditions (weather, land use activities, construction activities)<br>c. Review/consider other relevant monitoring data | Where it has been determined that development related impacts have caused a trigger exceedance, implementation of contingency and remedial measures is required. These may include, but not limited to, |

| Performance Criteria | Action | Response |
|---|---|---|
| | d. If investigation confirms trigger exceedance is not related to construction activities, record data and cease investigation<br>4. If trigger level exceedance is development related confirm if the activities have caused or have the potential to cause substantial environmental harm<br>a. Notify Environmental Manager, Site Superintendent and relevant agencies immediately as soon as practicable (whether or not it is development related)<br>5. Notify Environmental Manager and other relevant agencies if performance measures are exceeded as soon as practicable<br>6. Complete an Investigation Report and provide to all stakeholders and other relevant agencies with 21 days of identifying the incident<br>7. Prepare rectification proposal, engage stakeholders and remediate | the following:<br>• Review monitoring program and Groundwater Management Plan and revise if necessary<br>• Investigate reasonable and feasible remedial measures<br>• Review water management infrastructure (e.g. WSUD) and repair/renew if necessary |
| **Surface Water** | | |
| No significant increase in pollutant concentrations in surface water due to the proposed development | 1. Check and validate data<br>a. Retake sample and analysis to confirm exceedance<br>2. Notify management (Site Superintendent, Environmental Manager)<br>3. Undertaken Phase 1 investigation to confirm trigger exceedance is development (construction/operation) related<br>a. If necessary engage suitably qualified person<br>b. Review/consider recent conditions (weather, land use activities, construction activities)<br>c. Review/consider other relevant monitoring data<br>d. If investigation confirms trigger exceedance is not related to construction activities, record data and cease investigation<br>4. If trigger level exceedance is development related confirm if the activities have caused or have the potential to cause substantial environmental harm<br>a. Notify Environmental Manager, Site Superintendent and relevant agencies immediately as soon as practicable (whether or not it is development related)<br>5. Notify Environmental Manager and other relevant agencies if performance measures are exceeded as soon as practicable<br>6. Complete an Investigation Report and provide to all stakeholders and other relevant agencies | Where it has been determined that development related impacts have caused a trigger exceedance, implementation of contingency and remedial measures is required. These may include, but not limited to, the following:<br>• Review monitoring program and Groundwater Management Plan and revise if necessary<br>• Investigate reasonable and feasible remedial measures<br>• Review water management infrastructure (e.g. WSUD) and repair/renew if |

| Performance Criteria | Action | Response |
|---|---|---|
| | with 21 days of identifying the incident<br>7. Prepare rectification proposal, engage stakeholders and remediate | necessary |

# 7 References

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AWC (2021) *Wallum Estate – Acid Sulfate Soil Management Plan.* A report prepared for Clarence Property (Revision D)

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Martens (2021) *Preliminary Hydrogeological Assessment: Proposed Residential Subdivision, 15 Torakina Road, Brunswick Heads, NSW*. A report prepared for Clarence Property. (P2008063JR02V03 – August 2021)

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# Appendix A

## Groundwater quality summary tables

*Table A0.1 Summary statistics - groundwater quality in MW101*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 5.76 | 4.06 | 4.41 | 4.35 | 4.13 | 4.50 |
| Conductivity (EC) (dS/m) | 0.22 | 0.10 | 0.12 | 0.11 | 0.11 | 0.12 |
| Total Dissolved Salts (mg/L) | 148.24 | 65.28 | 82.56 | 76.84 | 72.62 | 81.33 |
| Total Suspended Solids (mg/L) | 19390 | 480 | 7029 | 6300 | 2992 | 11328 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | 29.80 | 11.60 | 20.70 | 20.70 | 15.24 | 26.16 |
| Water Hardness (mg/L CaCO3 equivalent) | 184.92 | 14.52 | 32.25 | 17.06 | 15.86 | 22.16 |
| Total Phosphorus (mg/L P) | 25.50 | 0.27 | 3.56 | 1.44 | 0.43 | 2.61 |
| Phosphate (mg/L P) | 0.63 | 0.15 | 0.27 | 0.24 | 0.20 | 0.31 |
| Total Nitrogen (mg/L N) | 22.30 | 2.26 | 9.80 | 8.06 | 4.69 | 15.68 |
| Total Kjeldahl Nitrogen (mg/L N) | 22.23 | 2.15 | 9.72 | 7.99 | 4.68 | 15.61 |
| Nitrate (mg/L N) | 0.12 | 0.01 | 0.04 | 0.02 | 0.01 | 0.06 |
| Nitrite (mg/L N) | 0.14 | 0.07 | 0.09 | 0.08 | 0.07 | 0.09 |
| Ammonia (mg/L N) | 0.67 | 0.14 | 0.39 | 0.39 | 0.32 | 0.46 |
| Sodium (mg/L) | 38.12 | 11.64 | 15.92 | 13.40 | 12.82 | 16.85 |
| Potassium (mg/L) | 2.78 | 1.09 | 1.80 | 1.63 | 1.34 | 2.41 |
| Calcium (mg/L) | 32.76 | 0.40 | 3.78 | 1.22 | 0.74 | 1.66 |
| Magnesium (mg/L) | 25.04 | 2.99 | 5.54 | 3.56 | 3.24 | 4.61 |
| Sodium Absorption Ratio (SAR) | 1.85 | 1.19 | 1.40 | 1.34 | 1.22 | 1.50 |
| Chloride (mg/L) | 129.71 | 13.23 | 37.49 | 28.81 | 22.20 | 39.17 |
| Sulfur | 4.69 | 0.50 | 1.98 | 1.35 | 0.91 | 3.07 |
| Sulfate (mg/L SO42-) | 14.07 | 1.49 | 5.93 | 4.06 | 2.74 | 9.21 |
| Chloride/Sulfate Ratio | 34.00 | 2.78 | 11.91 | 6.05 | 3.26 | 19.35 |
| Silver (mg/L) | ND | ND | ND | ND | ND | ND |
| Aluminium (mg/L) | 18.59 | 1.10 | 4.22 | 2.31 | 1.79 | 5.02 |
| Arsenic (mg/L) | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.002 |
| Cadmium (mg/L) | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 | 0.001 |
| Chromium (mg/L) | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.002 |
| Copper (mg/L) | 0.382 | 0.004 | 0.067 | 0.015 | 0.005 | 0.07 |
| Iron (mg/L) | 5.67 | 0.70 | 1.73 | 1.02 | 0.79 | 2.20 |
| Manganese (mg/L) | 0.51 | 0.01 | 0.07 | 0.02 | 0.02 | 0.06 |
| Nickel (mg/L) | 0.026 | 0.002 | 0.005 | 0.002 | 0.002 | 0.003 |
| Lead (mg/L) | 0.006 | 0.001 | 0.002 | 0.002 | 0.001 | 0.003 |
| Selenium (mg/L) | ND | ND | ND | ND | ND | ND |
| Zinc (mg/L) | 0.49 | 0.04 | 0.20 | 0.13 | 0.04 | 0.37 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

*Table A0.2 Summary statistics - groundwater quality in MW102*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 5.24 | 4.28 | 4.75 | 4.70 | 4.47 | 5.17 |
| Conductivity (EC) (dS/m) | 0.10 | 0.07 | 0.08 | 0.08 | 0.07 | 0.09 |
| Total Dissolved Salts (mg/L) | 67.32 | 48.28 | 55.82 | 54.40 | 48.96 | 61.88 |
| Total Suspended Solids (mg/L) | 5355 | 310 | 1736 | 1070 | 657 | 2400 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | 11.92 | 2.20 | 7.28 | 7.38 | 5.12 | 9.66 |
| Water Hardness (mg/L CaCO3 equivalent) | 19.17 | 8.05 | 13.68 | 13.67 | 10.81 | 16.24 |
| Total Phosphorus (mg/L P) | 0.92 | 0.12 | 0.47 | 0.29 | 0.15 | 0.88 |
| Phosphate (mg/L P) | 0.33 | 0.01 | 0.07 | 0.02 | 0.01 | 0.08 |
| Total Nitrogen (mg/L N) | 5.83 | 1.10 | 2.51 | 1.69 | 1.51 | 2.94 |
| Total Kjeldahl Nitrogen (mg/L N) | 5.80 | 0.96 | 2.45 | 1.64 | 1.42 | 2.90 |
| Nitrate (mg/L N) | 0.14 | 0.03 | 0.06 | 0.05 | 0.04 | 0.08 |
| Nitrite (mg/L N) | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 |
| Ammonia (mg/L N) | 0.14 | 0.05 | 0.07 | 0.06 | 0.05 | 0.08 |
| Sodium (mg/L) | 0.21 | 0.07 | 0.13 | 0.12 | 0.10 | 0.17 |
| Potassium (mg/L) | 10.93 | 7.97 | 9.20 | 9.11 | 8.40 | 9.65 |
| Calcium (mg/L) | 1.53 | 0.56 | 0.87 | 0.80 | 0.67 | 0.98 |
| Magnesium (mg/L) | 4.41 | 0.46 | 2.19 | 2.21 | 1.53 | 2.98 |
| Sodium Absorption Ratio (SAR) | 2.76 | 1.67 | 1.99 | 1.98 | 1.77 | 2.12 |
| Chloride (mg/L) | 1.35 | 0.91 | 1.10 | 1.08 | 0.99 | 1.20 |
| Sulfur | 98.71 | 11.77 | 41.63 | 22.98 | 18.78 | 68.48 |
| Sulfate (mg/L SO42-) | 20.21 | 1.14 | 8.12 | 4.98 | 4.65 | 12.77 |
| Chloride/Sulfate Ratio | 20.10 | 3.25 | 8.00 | 5.12 | 4.10 | 10.29 |
| Silver (mg/L) | ND | ND | ND | ND | ND | ND |
| Aluminium (mg/L) | 1.44 | 0.39 | 0.75 | 0.69 | 0.41 | 0.99 |
| Arsenic (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Cadmium (mg/L) | ND | ND | ND | ND | ND | ND |
| Chromium (mg/L) | ND | ND | ND | ND | ND | ND |
| Copper (mg/L) | 0.116 | 0.001 | 0.033 | 0.012 | 0.003 | 0.057 |
| Iron (mg/L) | 1.17 | 0.14 | 0.39 | 0.28 | 0.15 | 0.46 |
| Manganese (mg/L) | 0.03 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 |
| Nickel (mg/L) | 0.08 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 |
| Lead (mg/L) | 0.01 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 |
| Selenium (mg/L) | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Zinc (mg/L) | 3.00 | 0.05 | 1.29 | 1.31 | 0.15 | 2.37 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

*Table A0.3 Summary statistics - groundwater quality in MW109*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 4.19 | 3.78 | 3.95 | 3.95 | 3.82 | 4.05 |
| Conductivity (EC) (dS/m) | 0.20 | 0.08 | 0.15 | 0.16 | 0.11 | 0.17 |
| Total Dissolved Salts (mg/L) | 133.62 | 56.44 | 98.81 | 107.44 | 74.39 | 116.96 |
| Total Suspended Solids (mg/L) | 935 | 69 | 302 | 98 | 80 | 580 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | ND | ND | ND | ND | ND | ND |
| Water Hardness (mg/L CaCO3 equivalent) | 12.10 | 4.14 | 9.92 | 10.98 | 8.23 | 12.01 |
| Total Phosphorus (mg/L P) | 1.91 | 0.06 | 0.41 | 0.22 | 0.10 | 0.35 |
| Phosphate (mg/L P) | 0.30 | 0.02 | 0.09 | 0.06 | 0.03 | 0.11 |
| Total Nitrogen (mg/L N) | 39.12 | 1.21 | 7.03 | 2.54 | 1.73 | 3.74 |
| Total Kjeldahl Nitrogen (mg/L N) | 38.99 | 1.18 | 6.97 | 2.50 | 1.62 | 3.74 |
| Nitrate (mg/L N) | 0.04 | 0.01 | 0.02 | 0.01 | 0.01 | 0.02 |
| Nitrite (mg/L N) | 0.24 | 0.05 | 0.10 | 0.09 | 0.05 | 0.12 |
| Ammonia (mg/L N) | 0.27 | 0.10 | 0.19 | 0.20 | 0.13 | 0.24 |
| Sodium (mg/L) | 20.92 | 7.32 | 14.12 | 15.08 | 10.59 | 16.34 |
| Potassium (mg/L) | 1.19 | 0.25 | 0.76 | 0.74 | 0.60 | 1.00 |
| Calcium (mg/L) | 1.32 | 0.21 | 0.59 | 0.52 | 0.32 | 0.73 |
| Magnesium (mg/L) | 2.75 | 0.75 | 2.05 | 2.27 | 1.59 | 2.54 |
| Sodium Absorption Ratio (SAR) | 2.63 | 1.50 | 1.94 | 1.89 | 1.64 | 2.14 |
| Chloride (mg/L) | 46.87 | 20.25 | 30.32 | 27.14 | 21.76 | 39.58 |
| Sulfur | 12.64 | 0.86 | 5.08 | 1.73 | 1.21 | 8.28 |
| Sulfate (mg/L SO42-) | 37.92 | 2.57 | 15.23 | 5.18 | 3.62 | 24.83 |
| Chloride/Sulfate Ratio | 7.87 | 1.24 | 4.69 | 4.95 | 2.72 | 6.70 |
| Silver (mg/L) | ND | ND | ND | ND | ND | ND |
| Aluminium (mg/L) | 0.61 | 0.12 | 0.34 | 0.30 | 0.21 | 0.48 |
| Arsenic (mg/L) | ND | ND | ND | ND | ND | ND |
| Cadmium (mg/L) | ND | ND | ND | ND | ND | ND |
| Chromium (mg/L) | ND | ND | ND | ND | ND | ND |
| Copper (mg/L) | 0.10 | 0.00 | 0.02 | 0.01 | 0.00 | 0.02 |
| Iron (mg/L) | 0.99 | 0.15 | 0.41 | 0.32 | 0.17 | 0.59 |
| Manganese (mg/L) | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 |
| Nickel (mg/L) | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Lead (mg/L) | 0.01 | 0.001 | 0.003 | 0.002 | 0.001 | 0.005 |
| Selenium (mg/L) | ND | ND | ND | ND | ND | ND |
| Zinc (mg/L) | 0.08 | 0.02 | 0.04 | 0.03 | 0.02 | 0.06 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

*Table A0.4 Summary statistics - groundwater quality in MW112*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 5.32 | 4.30 | 4.58 | 4.48 | 4.39 | 4.65 |
| Conductivity (EC) (dS/m) | 0.12 | 0.08 | 0.10 | 0.09 | 0.08 | 0.11 |
| Total Dissolved Salts (mg/L) | 84.32 | 51.00 | 64.86 | 62.56 | 55.49 | 73.44 |
| Total Suspended Solids (mg/L) | 2960 | 505 | 1149 | 878 | 679 | 1340 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | 13.29 | 10.10 | 11.70 | 11.70 | 10.74 | 12.65 |
| Water Hardness (mg/L CaCO3 equivalent) | 19.78 | 8.64 | 13.85 | 13.41 | 9.82 | 17.82 |
| Total Phosphorus (mg/L P) | 0.62 | 0.11 | 0.38 | 0.41 | 0.22 | 0.52 |
| Phosphate (mg/L P) | 0.23 | 0.01 | 0.07 | 0.04 | 0.02 | 0.12 |
| Total Nitrogen (mg/L N) | 7.91 | 1.50 | 3.61 | 3.03 | 2.19 | 4.56 |
| Total Kjeldahl Nitrogen (mg/L N) | 7.91 | 1.46 | 3.54 | 2.93 | 2.10 | 4.50 |
| Nitrate (mg/L N) | 0.00 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 |
| Nitrite (mg/L N) | 0.06 | 0.04 | 0.07 | 0.07 | 0.05 | 0.08 |
| Ammonia (mg/L N) | 0.27 | 0.10 | 0.21 | 0.21 | 0.17 | 0.26 |
| Sodium (mg/L) | 16.90 | 8.58 | 12.71 | 12.28 | 9.73 | 16.02 |
| Potassium (mg/L) | 2.33 | 0.29 | 0.85 | 0.41 | 0.32 | 1.14 |
| Calcium (mg/L) | 4.87 | 0.24 | 1.12 | 0.60 | 0.25 | 0.87 |
| Magnesium (mg/L) | 3.92 | 1.72 | 2.57 | 2.30 | 1.89 | 3.27 |
| Sodium Absorption Ratio (SAR) | 1.94 | 0.84 | 1.58 | 1.63 | 1.58 | 1.83 |
| Chloride (mg/L) | 91.69 | 14.38 | 41.01 | 31.39 | 18.24 | 53.67 |
| Sulfur | 5.31 | 0.27 | 3.54 | 3.55 | 1.37 | 5.63 |
| Sulfate (mg/L SO42-) | 15.93 | 0.81 | 10.61 | 10.64 | 4.12 | 16.89 |
| Chloride/Sulfate Ratio | 6.08 | 2.64 | 8.06 | 5.36 | 3.85 | 11.19 |
| Silver (mg/L) | ND | ND | ND | ND | ND | ND |
| Aluminium (mg/L) | 2.03 | 0.43 | 1.17 | 1.10 | 0.83 | 1.53 |
| Arsenic (mg/L) | ND | ND | ND | ND | ND | ND |
| Cadmium (mg/L) | ND | ND | ND | ND | ND | ND |
| Chromium (mg/L) | ND | ND | ND | ND | ND | ND |
| Copper (mg/L) | 0.15 | 0.00 | 0.05 | 0.02 | 0.01 | 0.10 |
| Iron (mg/L) | 0.68 | 0.18 | 0.33 | 0.27 | 0.22 | 0.41 |
| Manganese (mg/L) | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 |
| Nickel (mg/L) | 0.003 | 0.001 | 0.002 | 0.001 | 0.001 | 0.002 |
| Lead (mg/L) | 0.02 | 0.00 | 0.01 | 0.01 | 0.00 | 0.01 |
| Selenium (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Zinc (mg/L) | 2.61 | 0.01 | 0.35 | 0.02 | 0.01 | 0.04 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

*Table A0.5 Summary statistics - groundwater quality in MW113*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 5.25 | 4.27 | 4.48 | 4.40 | 4.31 | 4.52 |
| Conductivity (EC) (dS/m) | 0.14 | 0.10 | 0.12 | 0.11 | 0.11 | 0.13 |
| Total Dissolved Salts (mg/L) | 97.92 | 67.32 | 78.88 | 76.16 | 72.62 | 85.14 |
| Total Suspended Solids (mg/L) | 10080 | 82 | 2238 | 1160 | 686 | 2408 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | 23.92 | 1.34 | 12.27 | 11.56 | 5.43 | 18.98 |
| Water Hardness (mg/L CaCO3 equivalent) | 91.10 | 14.56 | 31.51 | 24.28 | 17.22 | 35.87 |
| Total Phosphorus (mg/L P) | 4.53 | 0.07 | 0.98 | 0.36 | 0.22 | 1.24 |
| Phosphate (mg/L P) | 0.62 | 0.01 | 0.12 | 0.04 | 0.02 | 0.14 |
| Total Nitrogen (mg/L N) | 58.81 | 1.20 | 15.00 | 9.00 | 3.59 | 18.58 |
| Total Kjeldahl Nitrogen (mg/L N) | 58.74 | 1.14 | 14.94 | 8.96 | 3.53 | 18.53 |
| Nitrate (mg/L N) | 0.03 | 0.01 | 0.02 | 0.02 | 0.01 | 0.03 |
| Nitrite (mg/L N) | 0.15 | 0.03 | 0.06 | 0.06 | 0.03 | 0.06 |
| Ammonia (mg/L N) | 0.20 | 0.08 | 0.13 | 0.12 | 0.10 | 0.19 |
| Sodium (mg/L) | 17.98 | 11.06 | 15.94 | 16.09 | 15.02 | 17.76 |
| Potassium (mg/L) | 2.70 | 0.51 | 0.93 | 0.62 | 0.53 | 1.04 |
| Calcium (mg/L) | 4.03 | 0.34 | 1.39 | 0.94 | 0.51 | 2.02 |
| Magnesium (mg/L) | 19.68 | 3.29 | 6.81 | 4.51 | 3.81 | 7.96 |
| Sodium Absorption Ratio (SAR) | 1.77 | 0.81 | 1.36 | 1.41 | 1.21 | 1.54 |
| Chloride (mg/L) | 70.40 | 16.60 | 35.47 | 35.44 | 23.02 | 40.38 |
| Sulfur | 3.58 | 0.19 | 1.91 | 1.72 | 1.03 | 2.98 |
| Sulfate (mg/L SO42-) | 10.73 | 0.57 | 5.73 | 5.16 | 3.08 | 8.93 |
| Chloride/Sulfate Ratio | 29.13 | 3.49 | 12.69 | 9.08 | 6.38 | 17.56 |
| Silver (mg/L) | 0.00 | 0.00 | NA | NA | NA | #NUM! |
| Aluminium (mg/L) | 15.21 | 0.89 | 6.16 | 4.46 | 2.15 | 9.76 |
| Arsenic (mg/L) | 0.003 | ND | 0.003 | 0.003 | 0.003 | 0.00 |
| Cadmium (mg/L) | ND | ND | ND | ND | ND | ND |
| Chromium (mg/L) | ND | ND | ND | ND | ND | ND |
| Copper (mg/L) | 0.32 | 0.00 | 0.06 | 0.03 | 0.01 | 0.04 |
| Iron (mg/L) | 3.26 | 0.35 | 1.05 | 0.65 | 0.43 | 1.34 |
| Manganese (mg/L) | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 |
| Nickel (mg/L) | 0.15 | 0.00 | 0.03 | 0.01 | 0.00 | 0.03 |
| Lead (mg/L) | 0.26 | 0.00 | 0.04 | 0.01 | 0.00 | 0.01 |
| Selenium (mg/L) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Zinc (mg/L) | 1.04 | 0.01 | 0.16 | 0.04 | 0.02 | 0.10 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

*Table A0.6 Summary statistics - groundwater quality in MW114*

| Parameter | Max | Min | Ave | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|
| pH | 5.25 | 4.68 | 4.99 | 5.01 | 4.86 | 5.09 |
| Conductivity (EC) (dS/m) | 0.19 | 0.14 | 0.15 | 0.15 | 0.14 | 0.17 |
| Total Dissolved Salts (mg/L) | 129.88 | 92.82 | 103.96 | 98.60 | 93.57 | 112.74 |
| Total Suspended Solids (mg/L) | 298.00 | 8.00 | 88.97 | 61.00 | 26.60 | 121.83 |
| Bicarbonate (Alkalinity) (mg/L CaCO3 equivalent) | 10.56 | 4.00 | 7.02 | 6.72 | 5.66 | 8.78 |
| Water Hardness (mg/L CaCO3 equivalent) | 25.85 | 17.25 | 22.60 | 21.93 | 19.24 | 25.72 |
| Total Phosphorus (mg/L P) | 0.39 | 0.03 | 0.17 | 0.18 | 0.05 | 0.28 |
| Phosphate (mg/L P) | 0.03 | 0.01 | 0.03 | 0.02 | 0.01 | 0.05 |
| Total Nitrogen (mg/L N) | 4.83 | 0.81 | 2.06 | 1.31 | 0.88 | 3.13 |
| Total Kjeldahl Nitrogen (mg/L N) | 4.83 | 0.79 | 2.03 | 1.27 | 0.86 | 3.12 |
| Nitrate (mg/L N) | 0.02 | 0.02 | 0.04 | 0.02 | 0.02 | 0.05 |
| Nitrite (mg/L N) | 0.03 | 0.01 | 0.02 | 0.02 | 0.02 | 0.03 |
| Ammonia (mg/L N) | 0.15 | 0.10 | 0.15 | 0.14 | 0.11 | 0.20 |
| Sodium (mg/L) | 31.39 | 17.20 | 22.24 | 20.68 | 18.22 | 25.55 |
| Potassium (mg/L) | 2.16 | 0.17 | 0.72 | 0.56 | 0.32 | 0.89 |
| Calcium (mg/L) | 1.97 | 0.57 | 1.34 | 1.27 | 0.95 | 1.79 |
| Magnesium (mg/L) | 5.08 | 3.42 | 4.67 | 4.44 | 4.20 | 5.18 |
| Sodium Absorption Ratio (SAR) | 2.69 | 1.48 | 2.04 | 2.10 | 1.77 | 2.22 |
| Chloride (mg/L) | 99.50 | 23.39 | 54.78 | 48.68 | 42.38 | 68.54 |
| Sulfur | 1.38 | 0.67 | 2.30 | 1.17 | 0.85 | 3.30 |
| Sulfate (mg/L SO42-) | 4.13 | 2.00 | 6.90 | 3.52 | 2.55 | 9.90 |
| Chloride/Sulfate Ratio | 18.40 | 2.46 | 13.65 | 18.40 | 8.83 | 19.41 |
| Silver (mg/L) | ND | ND | ND | ND | ND | ND |
| Aluminium (mg/L) | 3.22 | 0.87 | 1.52 | 1.12 | 0.92 | 2.09 |
| Arsenic (mg/L) | ND | ND | ND | ND | ND | ND |
| Cadmium (mg/L) | ND | ND | ND | ND | ND | ND |
| Chromium (mg/L) | ND | ND | ND | ND | ND | ND |
| Copper (mg/L) | 1.10 | ND | 0.18 | 0.01 | 0.003 | 0.18 |
| Iron (mg/L) | 1.01 | 0.30 | 0.55 | 0.48 | 0.35 | 0.72 |
| Manganese (mg/L) | 0.018 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 |
| Nickel (mg/L) | 0.004 | 0.001 | 0.003 | 0.003 | 0.003 | 0.004 |
| Lead (mg/L) | 0.034 | 0.001 | 0.008 | 0.002 | 0.001 | 0.008 |
| Selenium (mg/L) | ND | ND | ND | ND | ND | ND |
| Zinc (mg/L) | 0.33 | 0.03 | 0.13 | 0.10 | 0.05 | 0.21 |
| Mercury (mg/L) | ND | ND | ND | ND | ND | ND |
| ND = not detected/below detectable limits | | | | | | |

# Appendix B

## Surface water quality summary tables

*Table B0.1 Summary statistics – surface water quality in SW1*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 4.58 | 4.05 | 4.26 | 4.21 | 4.08 | 4.43 |
| Conductivity (EC) (dS/m) | | 0.14 | 0.07 | 0.11 | 0.12 | 0.09 | 0.14 |
| Total Dissolved Salts (mg/L) | | 97.92 | 47.60 | 76.95 | 79.22 | 58.07 | 92.75 |
| Total Suspended Solids (mg/L) | 50 ## | 310.00 | 1.00 | 40.79 | 8.67 | 2.22 | 28.50 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 0 | 0 | 0 | 0 | 0 | 0 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 23.15 | 7.40 | 15.20 | 15.93 | 9.98 | 19.31 |
| Total Phosphorus (mg/L) | 0.03 # | 0.73 | 0.04 | 0.33 | 0.30 | 0.11 | 0.51 |
| Phosphate (mg/L ) | 0.005 # | 0.47 | 0.02 | 0.23 | 0.23 | 0.03 | 0.44 |
| Total Nitrogen (mg/L ) | 0.3 # | 6.85 | 1.04 | 2.10 | 1.48 | 1.19 | 2.36 |
| Total Kjeldahl Nitrogen (mg/L ) | | 6.80 | 1.00 | 2.06 | 1.46 | 1.14 | 2.32 |
| NOx | 0.015 # | 0.05 | 0.01 | 0.04 | 0.03 | 0.02 | 0.05 |
| Nitrate (mg/L) | | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| Nitrite (mg/L ) | | 0.09 | 0.03 | 0.04 | 0.04 | 0.04 | 0.05 |
| Ammonia (mg/L ) | 0.015 # | 0.21 | 0.07 | 0.13 | 0.11 | 0.09 | 0.16 |
| Sodium (mg/L) | | 17.17 | 8.05 | 12.34 | 12.27 | 8.92 | 15.19 |
| Potassium (mg/L) | | 2.23 | 0.32 | 0.96 | 0.85 | 0.64 | 1.28 |
| Calcium (mg/L) | | 3.54 | 0.39 | 1.78 | 2.07 | 0.52 | 2.57 |
| Magnesium (mg/L) | | 3.47 | 1.54 | 2.61 | 2.68 | 2.08 | 3.17 |
| Sodium Absorption Ratio (SAR) | | 1.74 | 1.18 | 1.38 | 1.31 | 1.24 | 1.50 |
| Chloride (mg/L) | | 486.76 | 15.42 | 81.12 | 24.83 | 19.74 | 52.45 |
| Sulfur | | 12.73 | 1.04 | 3.89 | 2.21 | 1.48 | 5.97 |
| Sulfate (mg/L SO42-) | | 38.19 | 3.11 | 11.67 | 6.64 | 4.43 | 17.91 |
| Chloride/Sulfate Ratio | ### 0.5 | 12.75 | 1.26 | 5.16 | 3.86 | 3.04 | 7.65 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.53 | 0.01 | 0.08 | 0.03 | 0.02 | 0.09 |
| Algal Biomass (mg/L) | | 35.40 | 0.30 | 5.63 | 2.05 | 1.10 | 6.10 |
| Aluminium (mg/L) | ### 0.005 | 0.89 | 0.37 | 0.59 | 0.57 | 0.44 | 0.73 |
| Iron (mg/L) | ### 0.5 | 0.50 | 0.09 | 0.33 | 0.35 | 0.20 | 0.48 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | 88 | 88 | 88 | 88 | 88 | 88 |
| C15-C28 Fraction | | 120 | 120 | 120 | 120 | 120 | 120 |
| C29-C36 Fraction | | 110 | 56 | 92 | 110 | 78 | 110 |
| C10-C16 Fraction | | 84 | 84 | 84 | 84 | 84 | 84 |
| C16-C34 Fraction | | 200 | 200 | 200 | 200 | 200 | 200 |
| C34-C40 Fraction | | 0 | 0 | #DIV/0! | #NUM! | #NUM! | #NUM! |
| Sum C10-C36 Fraction | | 320 | 180 | 243 | 230 | 200 | 284 |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)

*Table B0.2 Summary statistics – surface water quality SW2*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 5.21 | 4.17 | 4.49 | 4.47 | 4.25 | 4.61 |
| Conductivity (EC) (dS/m) | | 0.15 | 0.08 | 0.11 | 0.11 | 0.10 | 0.13 |
| Total Dissolved Salts (mg/L) | | 104.04 | 55.08 | 77.24 | 74.12 | 68.00 | 86.77 |
| Total Suspended Solids (mg/L) | 50 ## | 300.00 | 1.00 | 45.88 | 15.63 | 4.40 | 35.60 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 11.14 | 0.00 | 83.67 | 6.00 | 0.96 | 88.91 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 19.87 | 13.00 | 17.03 | 17.44 | 14.23 | 19.55 |
| Total Phosphorus (mg/L) | 0.03 # | 0.40 | 0.05 | 0.23 | 0.21 | 0.09 | 0.29 |
| Phosphate (mg/L ) | 0.005 # | 0.58 | 0.02 | 0.19 | 0.18 | 0.03 | 0.28 |
| Total Nitrogen (mg/L ) | 0.3 # | 5.04 | 1.15 | 1.97 | 1.55 | 1.27 | 1.97 |
| Total Kjeldahl Nitrogen (mg/L ) | | 5.01 | 1.13 | 1.93 | 1.54 | 1.24 | 1.93 |
| NOx | 0.015 # | 0.20 | 0.00 | 0.04 | 0.03 | 0.03 | 0.04 |
| Nitrate (mg/L) | | 0.04 | 0.02 | 0.03 | 0.03 | 0.02 | 0.03 |
| Nitrite (mg/L ) | | 0.16 | 0.01 | 0.05 | 0.04 | 0.04 | 0.06 |
| Ammonia (mg/L ) | 0.015 # | 0.39 | 0.05 | 0.13 | 0.12 | 0.08 | 0.14 |
| Sodium (mg/L) | | 19.23 | 10.08 | 13.89 | 12.82 | 11.38 | 16.94 |
| Potassium (mg/L) | | 2.55 | 0.42 | 0.99 | 0.87 | 0.55 | 1.19 |
| Calcium (mg/L) | | 3.27 | 1.57 | 2.41 | 2.39 | 1.80 | 3.07 |
| Magnesium (mg/L) | | 3.05 | 2.07 | 2.67 | 2.69 | 2.46 | 2.99 |
| Sodium Absorption Ratio (SAR) | | 2.00 | 1.12 | 1.47 | 1.33 | 1.21 | 1.76 |
| Chloride (mg/L) | | 257.98 | 14.01 | 60.78 | 32.57 | 20.85 | 82.71 |
| Sulfur | | 10.94 | 0.72 | 3.39 | 2.29 | 1.41 | 4.79 |
| Sulfate (mg/L SO42-) | | 32.83 | 2.17 | 10.17 | 6.87 | 4.22 | 14.38 |
| Chloride/Sulfate Ratio | ### 0.5 | 29.29 | 1.80 | 8.41 | 4.61 | 2.58 | 12.71 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.51 | 0.01 | 0.10 | 0.02 | 0.01 | 0.07 |
| Algal Biomass (mg/L) | | 33.90 | 0.50 | 6.52 | 1.05 | 0.52 | 4.50 |
| Aluminium (mg/L) | ### 0.005 | 4.21 | 0.53 | 1.10 | 0.81 | 0.64 | 0.99 |
| Iron (mg/L) | ### 0.5 | 0.94 | 0.27 | 0.56 | 0.55 | 0.38 | 0.73 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | ND | ND | ND | ND | ND | ND |
| C15-C28 Fraction | | 170 | 170 | 170 | 170 | 170 | 170 |
| C29-C36 Fraction | | 200 | 97 | 148.5 | 148.5 | 117.6 | 179.4 |
| C10-C16 Fraction | | ND | ND | ND | ND | ND | ND |
| C16-C34 Fraction | | 310 | 240 | 275 | 275 | 254 | 296 |
| C34-C40 Fraction | | ND | ND | ND | ND | ND | ND |
| Sum C10-C36 Fraction | | 380 | 260 | 320 | 320 | 284 | 356 |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)

*Table B0.3 Summary statistics – surface water quality SW3*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 5.86 | 4.17 | 4.56 | 4.37 | 4.24 | 4.84 |
| Conductivity (EC) (dS/m) | | 0.13 | 0.09 | 0.10 | 0.10 | 0.10 | 0.11 |
| Total Dissolved Salts (mg/L) | | 85.00 | 61.88 | 71.29 | 70.38 | 65.42 | 76.16 |
| Total Suspended Solids (mg/L) | 50 ## | 302.00 | 2.00 | 77.29 | 67.83 | 7.40 | 87.20 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 12.00 | 2.58 | 6.10 | 4.26 | 2.92 | 9.34 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 23.19 | 8.29 | 14.13 | 13.89 | 11.49 | 16.14 |
| Total Phosphorus (mg/L) | 0.03 # | 0.40 | 0.05 | 0.21 | 0.20 | 0.10 | 0.28 |
| Phosphate (mg/L ) | 0.005 # | 0.19 | 0.02 | 0.09 | 0.07 | 0.02 | 0.17 |
| Total Nitrogen (mg/L ) | 0.3 # | 4.29 | 0.93 | 1.83 | 1.85 | 1.11 | 2.10 |
| Total Kjeldahl Nitrogen (mg/L ) | | 4.24 | 0.93 | 1.79 | 1.81 | 1.09 | 2.07 |
| NOx | 0.015 # | 0.06 | 0.00 | 0.04 | 0.04 | 0.03 | 0.05 |
| Nitrate (mg/L) | | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| Nitrite (mg/L ) | | 0.06 | 0.02 | 0.04 | 0.04 | 0.04 | 0.06 |
| Ammonia (mg/L ) | 0.015 # | 0.17 | 0.06 | 0.12 | 0.13 | 0.07 | 0.15 |
| Sodium (mg/L) | | 18.00 | 9.86 | 12.90 | 11.58 | 11.11 | 15.54 |
| Potassium (mg/L) | | 2.68 | 0.28 | 0.96 | 0.82 | 0.55 | 1.26 |
| Calcium (mg/L) | | 4.15 | 0.38 | 1.67 | 1.61 | 1.01 | 2.06 |
| Magnesium (mg/L) | | 3.12 | 1.78 | 2.42 | 2.43 | 2.05 | 2.78 |
| Sodium Absorption Ratio (SAR) | | 2.04 | 1.20 | 1.51 | 1.51 | 1.29 | 1.69 |
| Chloride (mg/L) | | 187.72 | 13.90 | 50.10 | 28.02 | 23.76 | 62.82 |
| Sulfur | | 10.94 | 0.97 | 3.41 | 2.02 | 1.22 | 4.52 |
| Sulfate (mg/L SO42-) | | 32.83 | 2.92 | 10.24 | 6.05 | 3.67 | 13.55 |
| Chloride/Sulfate Ratio | ### 0.5 | 25.00 | 1.89 | 6.89 | 5.45 | 2.63 | 7.29 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.09 | 0.01 | 0.04 | 0.04 | 0.02 | 0.07 |
| Algal Biomass (mg/L) | | 5.70 | 0.50 | 2.92 | 2.70 | 1.40 | 4.76 |
| Aluminium (mg/L) | ### 0.005 | 1.59 | 0.41 | 0.82 | 0.77 | 0.65 | 0.87 |
| Iron (mg/L) | ### 0.5 | 3.47 | 0.24 | 0.65 | 0.37 | 0.31 | 0.55 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | ND | ND | ND | ND | ND | ND |
| C15-C28 Fraction | | 180 | 140 | 160 | 160 | 148 | 172 |
| C29-C36 Fraction | | 100 | 77 | 89 | 89 | 82 | 95 |
| C10-C16 Fraction | | ND | ND | ND | ND | ND | ND |
| C16-C34 Fraction | | 270 | 270 | 270 | 270 | 270 | 270 |
| C34-C40 Fraction | | ND | ND | ND | ND | ND | ND |
| Sum C10-C36 Fraction | | 280 | 220 | 250 | 250 | 232 | 268 |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)

*Table A0.4 Summary statistics – surface water quality SW4*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 6.07 | 4.17 | 5.19 | 5.35 | 4.42 | 5.86 |
| Conductivity (EC) (dS/m) | | 0.15 | 0.09 | 0.11 | 0.11 | 0.10 | 0.13 |
| Total Dissolved Salts (mg/L) | | 102.68 | 63.92 | 76.95 | 73.10 | 65.96 | 85.82 |
| Total Suspended Solids (mg/L) | 50 ## | 35.00 | 1.33 | 12.53 | 11.50 | 2.00 | 17.27 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 20.98 | 0.00 | 8.80 | 9.50 | 2.42 | 12.39 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 27.16 | 10.89 | 17.08 | 17.06 | 13.00 | 19.01 |
| Total Phosphorus (mg/L) | 0.03 # | 1.45 | 0.05 | 0.28 | 0.13 | 0.07 | 0.22 |
| Phosphate (mg/L ) | 0.005 # | 1.13 | 0.01 | 0.19 | 0.04 | 0.02 | 0.12 |
| Total Nitrogen (mg/L ) | 0.3 # | 1.96 | 0.73 | 1.20 | 1.16 | 0.88 | 1.38 |
| Total Kjeldahl Nitrogen (mg/L ) | | 1.83 | 0.71 | 1.11 | 1.14 | 0.84 | 1.26 |
| NOx | 0.015 # | 0.76 | 0.01 | 0.08 | 0.02 | 0.01 | 0.04 |
| Nitrate (mg/L) | | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 | 0.72 |
| Nitrite (mg/L ) | | 0.05 | 0.02 | 0.03 | 0.03 | 0.03 | 0.04 |
| Ammonia (mg/L ) | 0.015 # | 0.17 | 0.06 | 0.10 | 0.08 | 0.07 | 0.13 |
| Sodium (mg/L) | | 17.96 | 10.50 | 13.99 | 13.85 | 11.48 | 17.16 |
| Potassium (mg/L) | | 5.12 | 0.14 | 1.37 | 0.99 | 0.46 | 1.84 |
| Calcium (mg/L) | | 6.11 | 0.85 | 2.79 | 2.83 | 1.58 | 3.55 |
| Magnesium (mg/L) | | 3.37 | 1.83 | 2.46 | 2.45 | 2.10 | 2.63 |
| Sodium Absorption Ratio (SAR) | | 2.15 | 1.16 | 1.49 | 1.42 | 1.22 | 1.69 |
| Chloride (mg/L) | | 108.33 | 13.95 | 40.34 | 27.66 | 17.24 | 42.26 |
| Sulfur | | 9.19 | 0.40 | 4.23 | 2.03 | 1.66 | 8.17 |
| Sulfate (mg/L SO42-) | | 27.56 | 1.21 | 12.70 | 6.09 | 4.99 | 24.50 |
| Chloride/Sulfate Ratio | ### 0.5 | 14.24 | 1.00 | 4.80 | 4.18 | 3.22 | 4.85 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.07 | 0.01 | 0.03 | 0.01 | 0.01 | 0.05 |
| Algal Biomass (mg/L) | | 4.80 | 0.40 | 1.77 | 0.95 | 0.54 | 3.18 |
| Aluminium (mg/L) | ### 0.005 | 0.82 | 0.29 | 0.53 | 0.53 | 0.39 | 0.67 |
| Iron (mg/L) | ### 0.5 | 3.86 | 0.37 | 1.48 | 1.15 | 0.50 | 2.17 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 | 57.00 |
| C15-C28 Fraction | | 1800 | 100 | 673.3 | 120.0 | 108.0 | 1128.0 |
| C29-C36 Fraction | | 2600 | 130 | 1365 | 1365 | 624 | 2106 |
| C10-C16 Fraction | | ND | ND | ND | ND | ND | ND |
| C16-C34 Fraction | | 3700 | 220 | 1960 | 1960 | 916 | 3004 |
| C34-C40 Fraction | | 1300 | 1300 | 1300 | 1300 | 1300 | 1300 |
| Sum C10-C36 Fraction | | 650 | 100 | 353 | 310 | 184 | 514 |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)

*Table A0.5 Summary statistics – surface water quality SW5*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 8.03 | 5.69 | 6.58 | 6.43 | 5.91 | 7.22 |
| Conductivity (EC) (dS/m) | | 43.80 | 0.06 | 8.47 | 0.41 | 0.15 | 18.09 |
| Total Dissolved Salts (mg/L) | | 29780.60 | 37.40 | 5757.62 | 280.50 | 101.05 | 12304.33 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 21.50 | 1.00 | 7.07 | 5.75 | 1.70 | 9.67 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 115.00 | 8.20 | 41.47 | 22.50 | 13.05 | 71.29 |
| Total Suspended Solids (mg/L) | 50 ## | 6692 | 17 | 1645 | 89 | 35 | 3444 |
| Total Phosphorus (mg/L) | 0.03 # | 0.52 | 0.03 | 0.17 | 0.13 | 0.04 | 0.28 |
| Phosphate (mg/L ) | 0.005 # | 0.48 | 0.01 | 0.08 | 0.03 | 0.01 | 0.09 |
| Total Nitrogen (mg/L ) | 0.3 # | 1.07 | 0.18 | 0.66 | 0.73 | 0.39 | 0.94 |
| Total Kjeldahl Nitrogen (mg/L ) | | 1.05 | 0.13 | 0.63 | 0.72 | 0.39 | 0.90 |
| NOx | 0.015 # | 0.09 | 0.00 | 0.02 | 0.02 | 0.00 | 0.03 |
| Nitrate (mg/L) | | 0.07 | 0.01 | 0.03 | 0.02 | 0.01 | 0.06 |
| Nitrite (mg/L ) | | 0.04 | 0.01 | 0.02 | 0.02 | 0.01 | 0.02 |
| Ammonia (mg/L ) | 0.015 # | 0.14 | 0.02 | 0.08 | 0.07 | 0.05 | 0.12 |
| Sodium (mg/L) | | 12218.1 | 11.5 | 2971.2 | 137.3 | 39.3 | 5900.4 |
| Potassium (mg/L) | | 432.82 | 0.52 | 107.22 | 5.80 | 2.86 | 208.82 |
| Calcium (mg/L) | | 442.50 | 3.32 | 111.99 | 9.79 | 4.78 | 232.46 |
| Magnesium (mg/L) | | 1356.82 | 2.18 | 331.46 | 15.97 | 5.67 | 695.41 |
| Sodium Absorption Ratio (SAR) | | 64.95 | 1.00 | 21.23 | 5.99 | 2.86 | 43.60 |
| Chloride (mg/L) | | 21462.85 | 32.41 | 5159.22 | 225.97 | 90.24 | 10622.59 |
| Sulfur | | 988.34 | 0.94 | 248.93 | 16.21 | 3.45 | 512.56 |
| Sulfate (mg/L SO42-) | | 2965.03 | 2.83 | 746.78 | 48.62 | 10.34 | 1537.68 |
| Chloride/Sulfate Ratio | ### 0.5 | 12.48 | 2.90 | 6.97 | 6.74 | 5.27 | 8.32 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.05 | 0.00 | 0.02 | 0.01 | 0.01 | 0.02 |
| Algal Biomass (mg/L) | | 3.30 | 0.10 | 1.08 | 0.70 | 0.32 | 1.60 |
| Aluminium (mg/L) | ### 0.005 | 2.25 | 0.02 | 0.46 | 0.32 | 0.08 | 0.42 |
| Iron (mg/L) | ### 0.5 | 4.09 | 0.10 | 1.33 | 1.29 | 0.48 | 1.52 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | ND | ND | ND | ND | ND | ND |
| C15-C28 Fraction | | ND | ND | ND | ND | ND | ND |
| C29-C36 Fraction | | ND | ND | ND | ND | ND | ND |
| C10-C16 Fraction | | ND | ND | ND | ND | ND | ND |
| C16-C34 Fraction | | ND | ND | ND | ND | ND | ND |
| C34-C40 Fraction | | ND | ND | ND | ND | ND | ND |
| Sum C10-C36 Fraction | | ND | ND | ND | ND | ND | ND |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)

*Table B0.6 Summary statistics – surface water quality SW6*

| Parameter | Default trigger value | Max | Min | Mean | Median | 20th %ile | 80th %ile |
|---|---|---|---|---|---|---|---|
| pH | 7.0-8.5 # | 6.85 | 5.46 | 5.89 | 5.77 | 5.59 | 6.16 |
| Conductivity (EC) (dS/m) | | 16.77 | 0.10 | 1.56 | 0.13 | 0.11 | 1.56 |
| Total Dissolved Salts (mg/L) | | 11400.20 | 65.62 | 1059.19 | 87.89 | 77.11 | 110.09 |
| Total Suspended Solids (mg/L) | 50 ## | 61.82 | 1.50 | 8.77 | 3.00 | 2.25 | 5.00 |
| Bicarbonate (Alkalinity) (mg/L $CaCO_3$ equivalent) | | 95.00 | 7.20 | 21.83 | 10.99 | 9.10 | 18.54 |
| Water Hardness (mg/L $CaCO_3$ equivalent) | | 1665.60 | 19.85 | 165.43 | 26.11 | 21.49 | 28.23 |
| Total Phosphorus (mg/L) | 0.03 # | 1.31 | 0.05 | 0.68 | 0.75 | 0.25 | 1.16 |
| Phosphate (mg/L ) | 0.005 # | 1.22 | 0.01 | 0.61 | 0.71 | 0.17 | 1.04 |
| Total Nitrogen (mg/L ) | 0.3 # | 1.83 | 0.37 | 1.30 | 1.42 | 0.94 | 1.69 |
| Total Kjeldahl Nitrogen (mg/L ) | | 1.67 | 0.36 | 1.07 | 1.09 | 0.87 | 1.31 |
| NOx | 0.015 # | 0.47 | 0.00 | 0.23 | 0.25 | 0.06 | 0.38 |
| Nitrate (mg/L) | | 0.45 | 0.04 | 0.25 | 0.33 | 0.08 | 0.36 |
| Nitrite (mg/L ) | | 0.08 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| Ammonia (mg/L ) | 0.015 # | 0.42 | 0.07 | 0.19 | 0.14 | 0.09 | 0.31 |
| Sodium (mg/L) | | 2901.27 | 8.24 | 261.94 | 14.21 | 10.68 | 19.91 |
| Potassium (mg/L) | | 104.30 | 1.99 | 12.49 | 4.28 | 2.81 | 5.57 |
| Calcium (mg/L) | | 121.44 | 4.30 | 15.34 | 5.77 | 4.96 | 6.86 |
| Magnesium (mg/L) | | 330.83 | 2.03 | 30.87 | 2.76 | 2.31 | 3.25 |
| Sodium Absorption Ratio (SAR) | | 30.91 | 0.80 | 4.01 | 1.17 | 1.02 | 1.71 |
| Chloride (mg/L) | | 5021.70 | 10.36 | 543.06 | 21.99 | 18.45 | 277.10 |
| Sulfur | | 235.54 | 2.02 | 26.02 | 5.31 | 3.43 | 11.53 |
| Sulfate (mg/L SO42-) | | 706.61 | 6.07 | 78.05 | 15.92 | 10.29 | 34.58 |
| Chloride/Sulfate Ratio | ### 0.5 | 14.76 | 0.67 | 4.55 | 2.11 | 1.41 | 7.11 |
| Chlorophyll 'a' (mg/L) | 0.004# | 0.08 | 0.01 | 0.03 | 0.01 | 0.01 | 0.02 |
| Algal Biomass (mg/L) | | 5.60 | 0.70 | 1.71 | 1.00 | 0.80 | 1.34 |
| Aluminium (mg/L) | ### 0.005 | 0.49 | 0.17 | 0.38 | 0.40 | 0.30 | 0.46 |
| Iron (mg/L) | ### 0.5 | 1.92 | 0.32 | 0.71 | 0.64 | 0.42 | 0.80 |
| **Total Recoverable Hydrocarbons (TRH)** (µg/L or ppb) | | | | | | | |
| C10-C14 Fraction | | ND | ND | ND | ND | ND | ND |
| C15-C28 Fraction | | 130 | 130 | 130 | 130 | 130 | 130 |
| C29-C36 Fraction | | 130 | 130 | 130 | 130 | 130 | 130 |
| C10-C16 Fraction | | ND | ND | ND | ND | ND | ND |
| C16-C34 Fraction | | 220 | 220 | 220 | 220 | 220 | 220 |
| C34-C40 Fraction | | ND | ND | ND | ND | ND | ND |
| Sum C10-C36 Fraction | | 250 | 250 | 250 | 250 | 250 | 250 |

ND = not detected/below detectable limits
# = ANZECC default trigger vale (estuaries)
## = standard construction discharge limit
### = Indicator value for ASS (ASSMAC)


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