LOCAL WATER MANAGEMENT STRATEGY

Lots 526, 300 and 507 Lancaster Road

McKail, WA 6330

Version 2.

29/10/2024

BUSHFIRE | ENVIRONMENTAL | WATER | GIS

DOCUMENT CONTROL

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1 Introduction

Lots 526, 300 and 507 Lancaster Road, McKail Local Water Management Strategy (LWMS) has been prepared by Bio Diverse Solutions on behalf of Acumen Development Solutions in support of an amendment to the Local Planning Scheme and to provide guidance to the Local Structure Plan (LSP) prepared for the site.

The LWMS provides the framework for the application of total water cycle management to the proposed urban structure. This is consistent with the Department of Water and Environmental Regulation (DWER) principles of Water Sensitive Urban Design (WSUD) described in the Stormwater Management Manual (DoW, 2007).

1.1 Key Design Principles and Objectives

The LWMS employs the following key documents to define its content, key principles and objectives:

- Stormwater Management Manual for Western Australia (DoW, 2007).
- Better Urban Water Management (WAPC, 2008).

A summary of the key design principles and objectives from these documents is summarised below and provided in Table 1.

1.1.1 Stormwater Management Manual (DoW, 2007)

The Department of Water (DoW), now Department of Water and Environmental Regulation (DWER) released *A Manual for Managing Urban Stormwater Quality in Western Australia* in 1998. The manual defines and practically describes Best Management Practices (BMP's) to reduce pollutant and nutrient inputs to stormwater drainage systems. The manual also aims to provide guidelines for the incorporation of water sensitive design principles into urban planning and design, which would enable the achievement of improved water quality from urban development.

The document was released to provide a guideline for best planning and management practices and was intended for use by the DoW (now DWER), but also by other State and Local Government Authorities and sectors of the urban development industry.

DoW completed a major review of the manual in consultation with a working team comprising industry and government representatives. The revised manual was officially launched in August 2007.

DWER's current position on urban stormwater management in Western Australia is outlined in Chapter 2: *Understanding the Context of the Stormwater Management Manual for Western Australia* (DoW, 2007), which details the management objectives, principles and a stormwater delivery approach for WA. Principle objectives for managing urban water in WA are stated as:

- Water Quality: To maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions.
- Water Quantity: To maintain the total water cycle balance within development areas relative to the pre-development conditions.
- Water Conservation: To maximise the reuse of stormwater.
- Ecosystem Health: To retain natural drainage systems and protect ecosystem health.
- Economic Viability: To implement stormwater systems that are economically viable in the long-term.
- Public Health: To minimise public risk, including risk of injury or loss of life to the community.
- Protection of Property: To protect the built environment from flooding and water logging.
- Social Values: To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater.
- Development: To ensure the delivery of best practice stormwater management through planning and development of high-quality developed areas in accordance with sustainability and precautionary principles.

1.1.2 Better Urban Water Management (WAPC, 2008)

The guideline document Better Urban Water Management ([BUWM]WAPC, 2008), focuses on the process of integration between land use and water planning. The document specifies the level of investigation and documentation required at various decision points in the planning process, rather than the provision of any specific design objectives and criteria for urban water management.

This LWMS complies with the BUWM process.

Table 1: Summary of design principles and objectives

Key Guiding Principles		
• Facilitate implementation of sustainable best practice urban water management. • Provide integration with planning processes and clarity for agencies involved with implementation. • To minimise public risk, including risk of injury or loss of life. • Protection of infrastructure and assets from flooding and inundation. • Encourage environmentally responsible development. • Facilitate adaptive management responses to the monitored outcomes of development.		
Category	**Key Design Principles & Objectives**	**LWMS Criteria**
Surface Water Management	• Minimise changes in hydrology to prevent impacts on receiving environments. • Manage water flows from major events to protect infrastructure and assets. • Apply the principles of WSUD. • Adopt nutrient load reduction design objectives for stormwater runoff. • Floodplain management. • Adopt treatment train approach.	• Post-development critical peak flows will be consistent with pre-development peak flow at the discharge point of each catchment within the Subject Site up to the 1% AEP. • First 15mm of rainfall from storm events will be treated at source where possible. • Manage surface water flows from major events to protect infrastructure and assets from flooding and inundation. • Provide a treatment train approach, including bio-retention storages for nutrient/contaminant removal.
Groundwater Management	• Manage groundwater levels to protect infrastructure and assets. • Maintain groundwater regimes for the protection of groundwater-dependent ecosystems. • Protect the value of groundwater resources. • Adopt nutrient load reduction design objectives for discharges to groundwater.	• Managing and minimising changes in groundwater levels and groundwater quality following development. • Provide a treatment train approach, including bio-retention storages for nutrient/contaminant removal of stormwater prior to entering the groundwater system.
Monitoring and Implementation	• Adopt an adaptive management approach. • Maintain drainage and treatment structures.	• Design based on methodology in Stormwater Management Manual of adopting a treatment train including: • structural treatment measures (infiltration storages; bio-retention treatment structures). • Non-structural measures to reduce applied nutrient loads. • Maintain groundwater quality at pre-development levels and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems.
Water Conservation	• Adopt drinking water consumption target. • Ensure that non-potable water supply systems deliver a net benefit to the community. • Ensure that non-potable water supply systems are designed as part of an integrated water supply.	• Aim to achieve the State Water Plan target for water use and reduce water use where possible. • Consider alternative fit for purpose water sources where appropriate and cost-effective.

1.2 Suitable Qualified Hydrologist

The original LWMS was been prepared by Chiquita Cramer, who has 14 years of experience working as a hydrologist and hydrogeologist.

Chiquita Cramer has the following tertiary qualifications:

- Bachelor of Science in Natural Resource Management (University of Western Australia); and
- Graduate Certificate in Hydrogeology (University of Western Australia).

Chiquita completed a Bachelor of Science in Natural Resource Management in 2008 at the University of Western Australia. She then went on to work as a hydrologist and senior hydrologist at JDA Consultant Hydrologists in Perth where she worked for 8 years. Chiquita's experience includes preparation of multiple local and urban water management strategies, hydrological and hydraulic investigations, surface water and groundwater monitoring reports and hydrogeological reports. Chiquita furthered her studies in 2012 by completing a Graduate Certificate in Hydrogeology and in 2017 she joined Bio Diverse Solutions to provide expertise in hydrology and hydrogeology to the company.

Subsequent to this original report the proposed lot design was altered to reflect lots with a predominantly east-west arrangement changing the major road direction to north – south. This has minor effects on the catchment sizes but a review of the LMWS was requested for clarity during the planning phases. This review was undertaken by David Lynch.

David is an accredited soil surveyor and has a B.Sc.(Honours) majoring in Geology. He joined BDS in 2024 to provide expertise in hydrology and hydrogeology to the company. David's experience includes assisting in preparation of local and urban water management strategies, hydrological and hydraulic investigations, surface water and groundwater monitoring reports, hydrogeological reports and site soil evaluations for onsite disposal suitability.

1.3 Location

Lots 526, 300 and 507 Lancaster Road, McKail WA (herein referred to as the Subject Site) comprises of ~68 ha and is located ~6.8 km northwest of the Albany town centre. The Subject Site is bound by Gladville Road and an agricultural property to the north, an agricultural property to the west, rural residential lots to the east and rural residential lots and Lancaster Road to the south of the main portion of the Subject Site, with a smaller portion of the Subject Site to the south of Lancaster Road. The location of the Subject Site is shown on Figure 1.

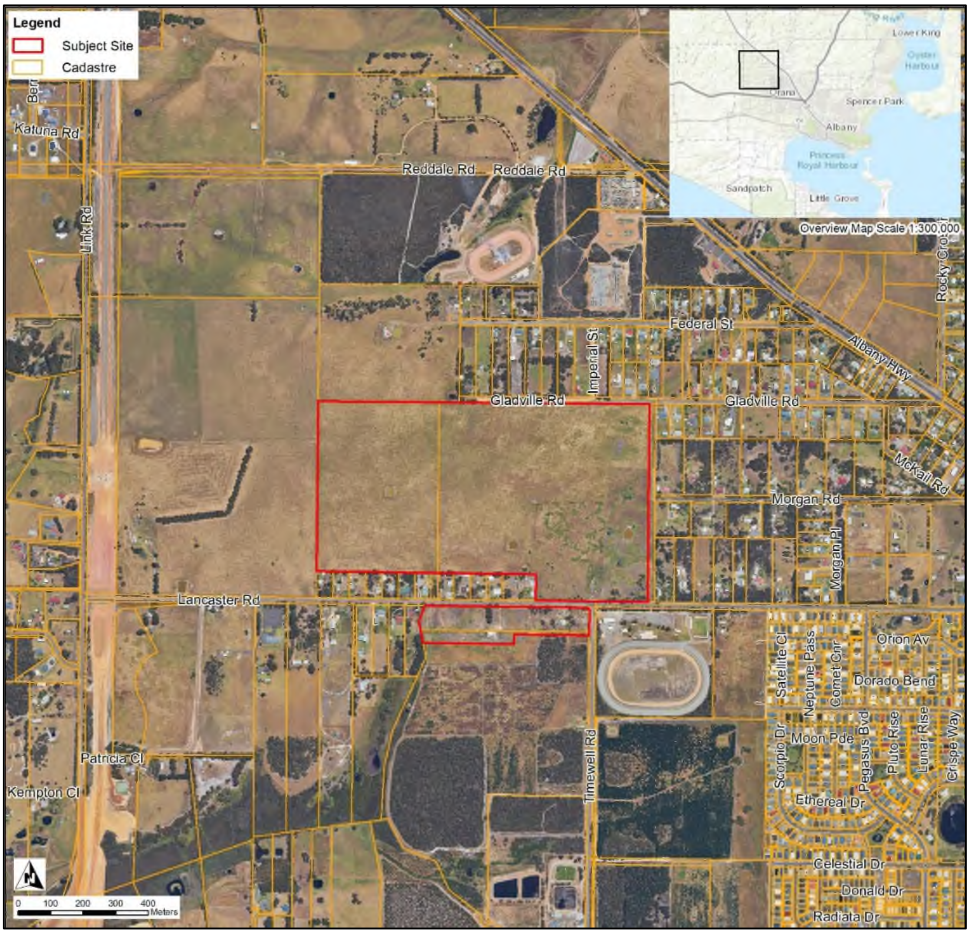

Figure 1: Location Plan

2 Proposed Development

The Subject Site is situated within the City of Albany and zoned *Future Urban* under the City of Albany Local Planning Scheme No. 1 (DPLH, 2014). The Subject Site is also located with the Albany Speedway Noise Special Control Area with the potential implications for the development included in the City of Albany Local Planning Scheme No. 1 (DPLH, 2014). Residential lots range in size from R2.5 on the south side of Lancaster Road to R25 in the northeast of the site. The majority of the Subject Site is proposed to be Residential R15. The LSP also includes two Public Open Space (POS) areas, a district oval and a primary school.

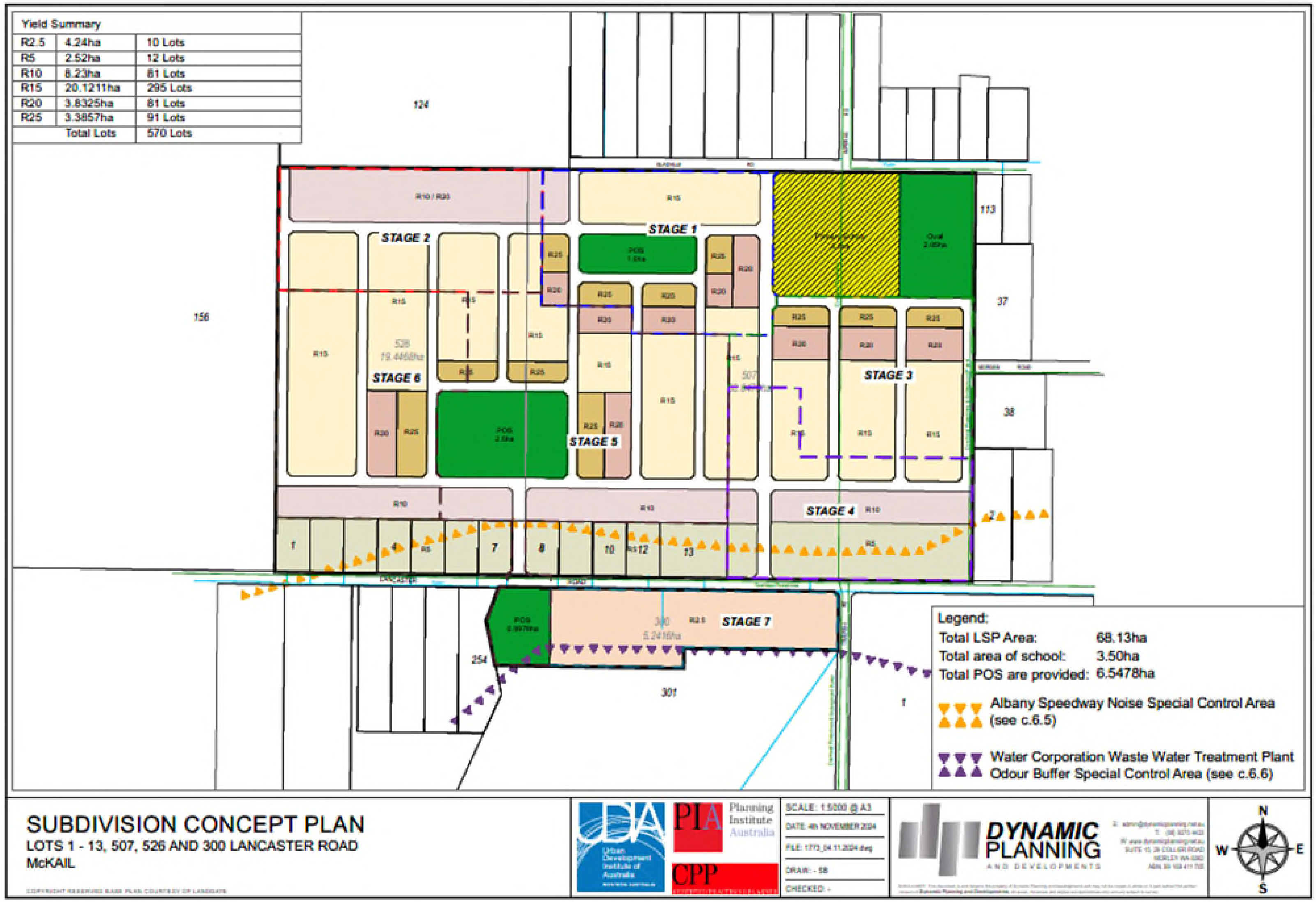

Figure 2: New Proposed Road Layout with LSP

3 Pre-development Environment

3.1 Existing Land Use

The site currently consists of agricultural land used for livestock. There are no residential dwellings located on the site. The Subject Site is surrounded by rural residential lots to the north, south and east and the rural land to the west.

3.2 Topography

The majority of the Subject Site is relatively flat, sloping down in the northeast corner of the site and to the central south. Elevation ranges from a high point of 68m AHD in the southeast and northwest to a low point of 52m AHD in the central south. Topographic contours (2 m) for the Subject Site, are shown in Figure 3.

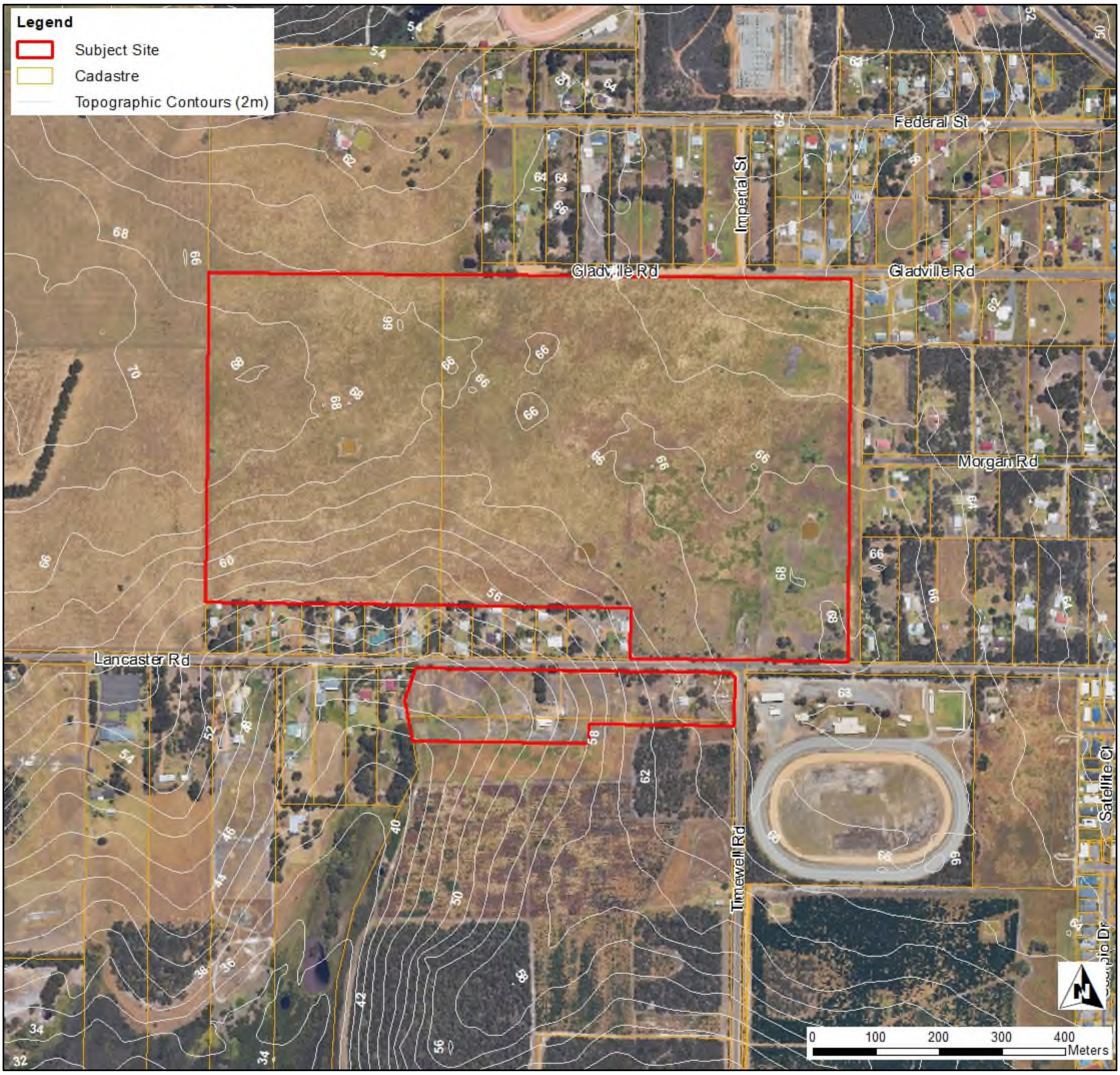

Figure 3: Topography

3.2 Climate

The Albany area has a Mediterranean climate characterised by dry, warm summers and mild, wet winters. The long-term average annual rainfall is 923 mm (1877 to 2023). This average has decreased between 2000 to 2023, to an average annual rainfall of 856 mm, reflecting a 7% reduction compared to the long-term average, consistent with a general drying trend in the Southwest of WA. Rainfall data is from the nearby Bureau of Meteorology (BoM, 2021) Albany Station (Site No. 9500).

The average annual pan evaporation for the Albany area is approximately 1399 mm (Luke *et al* 1988).

3.3 Remnant Vegetation

The Subject Site predominantly consists of cleared agricultural land with only a few scattered paddock trees (eucalyptus) in the southeast.

The Subject Site lies within the JAF – Jarrah Forest Interim Bio-geographic Regional Area (IBRA).

The vegetation has been mapped on a broad scale by J.S. Beard (Shepherd *et al* 2002) in the 1970's, where a system was devised for state-wide mapping and vegetation classification based on geographic, geological, soil, climate structure, life form and vegetation characteristics. A GIS search of J.S. Beards vegetation classification places the Subject Site within one System and Vegetation Association (DPIRD, 2017a):

System Association Name: Albany.
Vegetation Association Number: 978.
Vegetation Description: Jarrah, banksia or casuarina Eucalyptus marginata, Banksia spp., Allocasuarina spp.

There are no Conservation Parks or Class "A" Reserves within the Subject Site or within the vicinity of the Subject Site.

3.4 Acid Sulphate Soils

Acid Sulphate Soils (ASS) are naturally occurring soils and sediments containing sulphide minerals, predominantly pyrite (an iron sulphide). When undisturbed below the water table, these soils are benign and not acidic (potential acid sulphate soils). However, if the soils are drained, excavated or exposed by lowering of the water table, the sulphides will react with oxygen to form sulphuric acid. Acid Sulphate Soil (ASS) Risk Mapping indicates the Subject Site does not lie within any known areas of ASS (DWER, 2017).

3.5 Geology and Soils

Soil mapping – Zones (DPIRD, 2017b) shows the Subject Site lies within one soil zone being; the Albany Sandplain Zone (242). The Albany Sandplain Zone is described as '*Gently undulating plain dissected by a number of short rivers flowing south. Eocene marine sediments overlying Proterozoic granitic and metamorphic rocks. Soils are sandy duplex soils, often alkaline and sodic, with some sands and gravels.'*

Soil mapping – Systems (DPIRD, 2018) shows the Subject Site lies within one soil system being; the King System (253Bv). The King System is described as *'Dissected siltstone and sandstone terrain, on the southern edge of the Albany Sandplain Zone, with shallow gravel, sandy gravel, grey sandy duplex and pale deep sand. Jarrah-marri-sheoak woodland and mallee-heath.'*

The Subject Site is located within two sub-systems of the King System as defined by DPIRD (2017c). The sub-systems are described in Table 2 and shown in Figure 4.

Table 2: Soil Sub-systems (DPIRD, 2017c)

Map Unit Symbol	Map Unit Name	Map Unit Description
242KgDMc	Dempster crest phase	Sands and laterite on elongate crests; Jarrah-Albany Blackbutt-Marri forest.
242KgS7h	Minor Valleys S7 slope phase	Broad valleys in sedimentary rocks; 30 m relief; smooth slopes. Deep sands and iron podzols on slopes; Albany Blackbutt-jarrah-sheoak woodland. Podzols and yellow duplex soils on floors; paperbark woodland, tea tree heath.

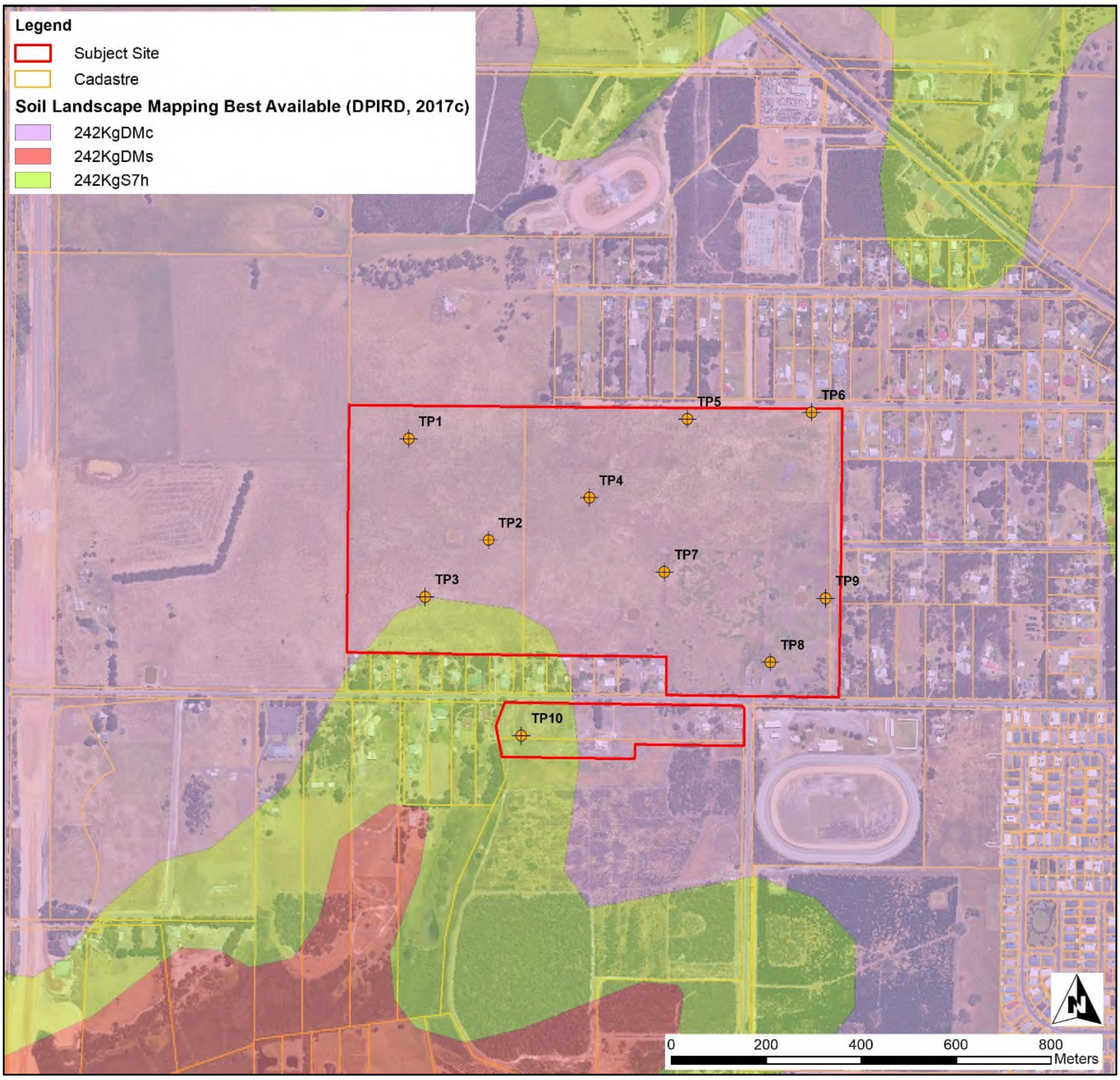

Figure 4: Soil Mapping (DPIRD, 2018)

3.5.1 Site Soil Investigation

A site soil investigation was conducted on the 13th July 2023 by Great Southern Geotechnics. The site investigation included the construction of 10 test holes to a depth of up to 2.5 metres, logging of soils to the depth of the hole with inspection and measuring of the water table. The test holes were constructed using a mini excavator with a 300 mm auger and were left open for 1hr for inspections of water table depth. The soil investigation for the site is shown in Appendix A and the location of the 10 test holes is shown in Figure 4.

The investigation revealed that soils across the site comprised of two main soil types:

- Silty sand topsoil over sandy gravel over sandy clay, with a perched water table encountered at the top of the sandy clay layer. Encountered across the majority of the Subject Site (TP1 – T9); and
- Topsoil (sand with silt) over sand with silt to the depth of the hole. Encountered to the south of Lancaster Road within the lower reaches of the site (TP10).

In-field permeability testing was conducted at TP1, TP5 and TP10 during the site soil investigation by Great Southern Geotechnics, the location of the permeability tests is shown in Figure 4. Permeability testing was conducted using the Talsma-Hallam method, which is a constant head test. The permeability (hydraulic conductivity) recorded at the three testing locations is shown in Table 3.

Table 3: Permeability Results

Permeability Testing Site	Soil type in which permeability testing was applied	Hydraulic conductivity (m/d)
TP1	Sand with silt	No infiltration recorded after 20 minutes of observation
TP5	Sand with silt / Sandy gravel	No infiltration recorded after 20 minutes of observation
TP8	Sand with silt / Sandy gravel	No infiltration recorded after 20 minutes of observation

Testing showed that permeability was low across the site with no permeability evident after 20 minutes of commencing the permeability test at all three testing locations.

3.6 Surface Water Hydrology

The northern portion of the Subject Site drains to the northeast towards Gladville Road and towards the adjacent rural property. The northern portion of the Subject Site ultimately discharges to Willyung Creek further to the northeast. Willyung Creek discharges to the King River and ultimately Oyster Harbour. The southern portion of the site drains south towards a creek line which upper reaches commence within a drainage easement south of the main Subject Site area and north of Lancaster Road. The creek line ultimately discharges to Five Mile Creek south of the Subject Site. Five Mile Creek discharges to Seven Mile Creek further to the southwest and Seven Mile Creek discharges to Powell Lake and ultimately the Torbay Inlet further west. Water features within the Subject Site include the upper reaches of the creek line in the south, three farm dams and a soak/inundated area in the northeast of the site.

The pre-development surface water hydrology of the site and surrounding areas is shown in Figure 5. The general surface water hydrology of the site shall be maintained post-development noting that post-development catchments may be altered by installed drainage and proposed earthworks.

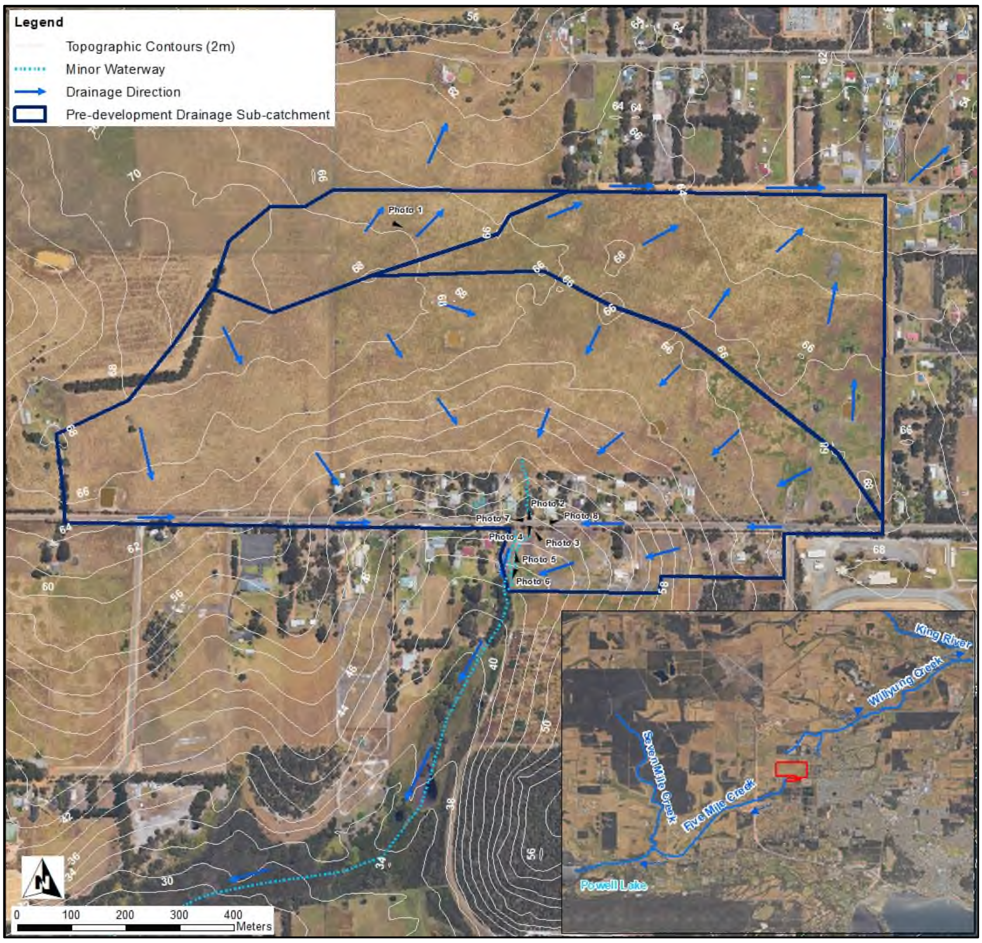

Figure 5: Pre-development Surface Water Hydrology

The northern portion of the Subject Site is located within the Oyster Harbour Kalgan King hydrographic catchment and the King River sub-catchment (DWER, 2018a). The southern portion of the Subject Site is located in the Torbay Inlet hydrographic catchment and the Seven Mile Creek sub-catchment.

3.6.1 Site Hydrological Investigation

A site investigation was conducted on the 3rd July 2023 to confirm the surface water hydrology of the site and guide the post development surface water management strategy. Rainfall prior to the site investigation was significantly higher than average for the months of April and June 2023, as shown in Table 4.

Table 4: 2023 monthly rainfall prior to site investigation

Month	Average rainfall for Albany* (mm)	2023 Rainfall for Albany* (mm)
January	23.6	6.9
February	22.4	3.0
March	38.2	31.3
April	69.3	138.4
May	114.5	49.7
June	131.8	295.6
Total (Jan-Jun)	399.8	524.9

* Rainfall taken from BoM Albany Station (No. 9500).

The following photos show the hydrological features of the site.

Photo 1: View to the southwest of a relatively flat site, with some small localised pockets of seasonal inundation.

Photo 2: View to the north from Lancaster Road of upper reaches of creek line within easement in the central south.

Photo 3: View to the northwest of box culvert (downstream end) under Lancaster Road. Box culvert is 750mm high x 1200mm wide.

Photo 4: View to the south from Lancaster Road of culverts discharging to creek line within the south of the Subject Site. Culverts are 2 x 750mm diameter.

Photo 5: View to the north of creek line in the south of the Subject Site.

Photo 6: View to the south of creek line in the south of the Subject Site.

Photo 7: View to the west of Lancaster Road roadside swale.

Photo 8: View to the northeast of Lancaster Road roadside swale driveway culvert crossing.

3.7 Hydrogeology

Australian Geoscience Mapping and Department of Water and Environmental Regulation 250K Hydrogeological Mapping (DWER, 2001) places the Subject Site within one hydrogeological zone described as:

Geology Type: TP.
Geology Time: TERTIARY - CAINOZOIC - PHANEROZOIC.
Aquifer Description: Sedimentary aquifer with intergranular porosity - extensive aquifers, major groundwater resources.
Geology Description: PLANTAGENET GROUP - siltstone, spongolite; minor sandstone, peat, and conglomerate.

3.8 Groundwater

Pre-development groundwater monitoring was conducted at the Subject Site from early July 2023 to October 2023. Monitoring included 5 rounds of groundwater level monitoring (early Jul, late Jul, early Sep, late Sep and Oct 23) and 2 rounds of water quality monitoring (early Jul and Oct 23). Ten groundwater bores (BH1 to BH10) were monitored as part of the monitoring program, details of the groundwater monitoring bores are presented in Table 5 and the location of the bores is shown in Figure 6.

These bores were not checked during the winter of 2024.

Table 5: Details of monitoring wells

Monitoring well	Co-ordinates		Monitoring well Screening depth (m)	Depth of hole (m)
	Easting	Northing		
BH1	575161.76	6128843.59	2.06 - 3.06	3.06
BH2	575305.61	6128627.29	2.06 - 3.06	3.06
BH3	575162.00	6128463.63	2.04 – 3.04	3.04
BH4	575520.86	6128714.63	2.09 – 3.09	3.09
BH5	575731.12	6128884.77	2.07 – 3.07	3.07
BH6	576018.49	6128882.24	2.10 – 3.10	3.10
BH7	575736.87	6128554.12	2.09 – 3.09	3.09
BH8	575876.52	6128344.01	2.05 – 3.05	3.05
BH9	576016.81	6128601.85	2.09 - 3.09	3.09
BH10	575377.35	6128242.08	2.04 – 3.04	3.04

Groundwater levels and quality should be maintained post-development wherever possible.

3.8.1 Groundwater levels

Monitoring showed groundwater was close to the surface across the site, with maximum recorded levels ranging from 0.32 m above ground level at BH2 in late July 2023 to 0.7 m Below Ground Level (BGL) at BH5 in early July 2023. Groundwater levels across the site generally fluctuated consistent with seasonal rainfall with the highest levels recorded from early July to early September, noting over double the average volume of rainfall was received in June 2023 and lower-than-average rainfall was recorded in October and September 2023. The groundwater levels recorded in the bores from early July to October 2023 are shown in Table 5. The highest recorded groundwater levels are also shown in Figure 6.

Table 6: Groundwater levels (Jul 23 - Oct 23)

Monitoring bore	Groundwater level (m BGL)				
	03/07/2023	24/07/2023	05/09/2023	26/09/2023	31/10/2023
BH1	0.05	0.09	0.06	0.96	Dry
BH2	0.26	-0.32*	0.34	1.30	Dry
BH3	0.64	1.01	0.38	2.59	Dry
BH4	0.09	0.16	0.31	2.49	Dry
BH5	0.70	1.84	2.37	3.15	Dry
BH6	0.21	0.31	0.40	1.38	Dry
BH7	0.42	0.49	0.34	2.38	Dry
BH8	0.28	0.19	0.08	0.82	Dry
BH9	0.24	0.14	0.08	0.94	1.6
BH10	0.40	0.36	0.42	1.02	1.46

Notes: * Groundwater level is above ground level.
Highest recorded groundwater level shaded pink.

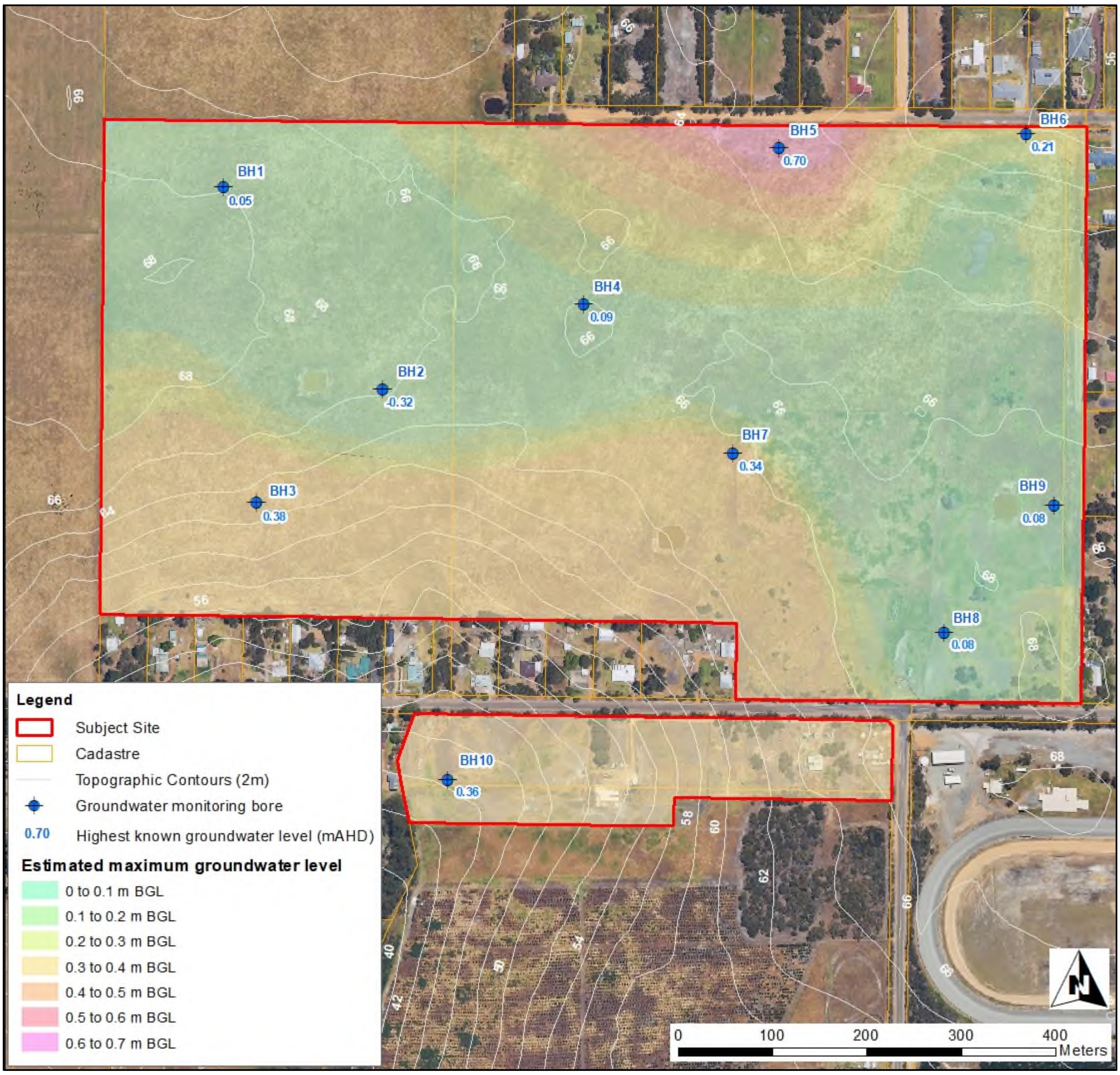

Figure 6: Groundwater levels

3.8.2 Groundwater Quality

In-situ and laboratory water quality testing was conducted at the 10 groundwater bores in early July 2023 and October 2023. In-situ analysis was conducted using a Horiba-50 Water Quality Meter and laboratory samples were sent to NATA accredited laboratory; MPL laboratories, for testing. BH1 to BH8 were found to be dry during the October 2023 monitoring event. Water quality testing results are shown in Appendix B and summarised in the following sections.

3.8.2.1 pH

The pH levels within the groundwater bores were found to be slightly acidic, with results being below the ANZECC and ARMCANZ (2000) lower trigger value for wetland ecosystems in the southwest of Australia (6.5) at each bore. The pH levels were found to be lower at BH10, which correlated with the differing soil type encountered here (deep sands). The pH level at BH9 was significantly lower in October 2023 (5.83) compared to that recorded in early July 2023 (6.29). The pH levels recorded at the bores during the two monitoring events are presented in Figure 7, with the pH data shown in Appendix B.

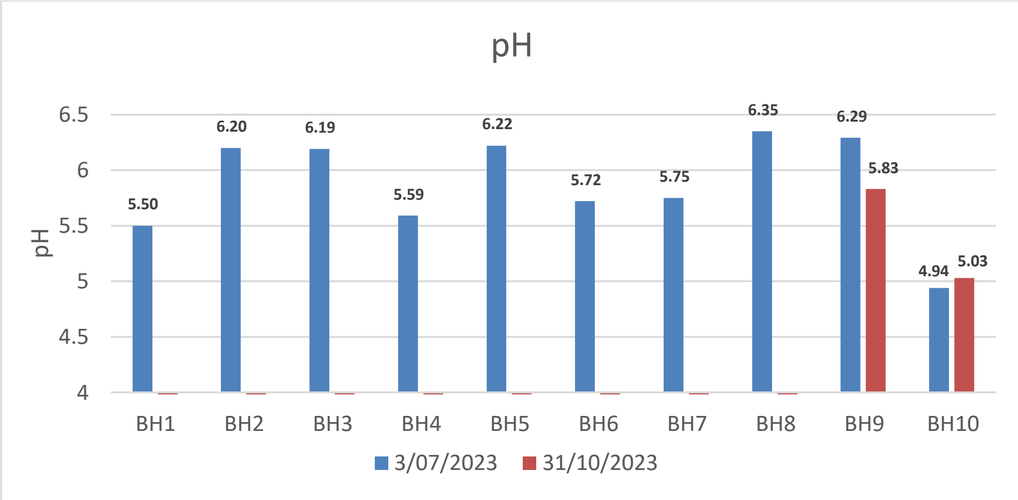

Figure 7: Groundwater pH

3.8.2.2 Electrical Conductivity

The Electrical Conductivity (EC) within the groundwater bores was generally low to moderate, with EC levels across the site below the ANZECC and ARMCANZ (2000) upper trigger value for wetlands in the Southwest of Australia (1500uS/cm). EC levels were found to be considerably higher at BH9 during the October 2023 monitoring round, with the EC level at BH10 during October 2023 also being considerably higher than that recorded during the July 2023 monitoring round. EC levels recorded at each of the bores during the two monitoring events are shown in Figure 8, with the EC data shown in Appendix B.

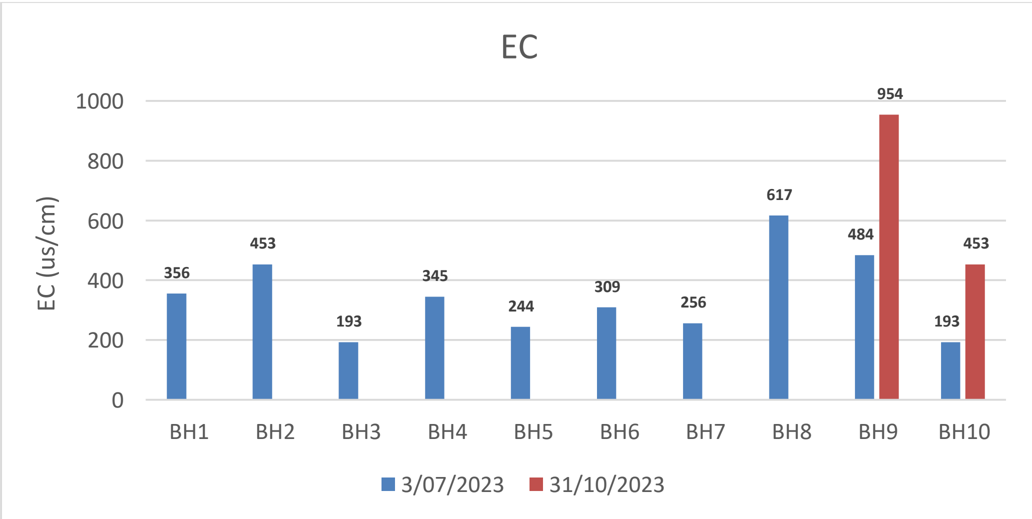

Figure 8: Groundwater EC

3.8.2.3 Total Dissolved Solids

The Total Dissolved Solids (TDS) at the groundwater bores was generally low to moderate, with TDS levels across the site below the ANZECC and ARMCANZ (2000) upper trigger value (1 mg/L). TDS levels were found to be considerably higher at BH9 during the October 2023 monitoring event consistent with the EC levels. TDS levels at BH10 recorded during Oct 23 (0.13 mg/L) were also found to be considerably higher compared to the July 2023 TDS levels (2.9 mg/L). TDS levels at each of the groundwater bores during the two monitoring events are shown in Figure 9, with the TDS data shown in Appendix B.

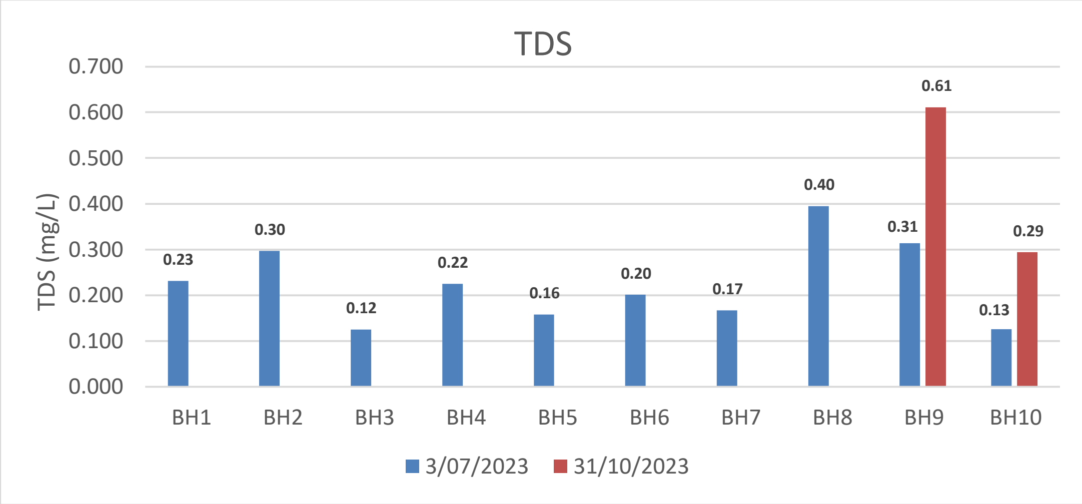

Figure 9: Groundwater TDS

3.8.2.4 Dissolved Oxygen

The Dissolved Oxygen (DO) levels recorded within the groundwater bores were generally low and below the ANZECC and ARMCANZ (2000) lower trigger value for wetlands in the southwest of Australia (90%). Groundwater typically has a much lower DO compared to that of surface water due to the decreased interface with the atmosphere. The DO levels recorded at each of the bores for the two monitoring events are shown in Figure 10, with the DO data shown in Appendix B.

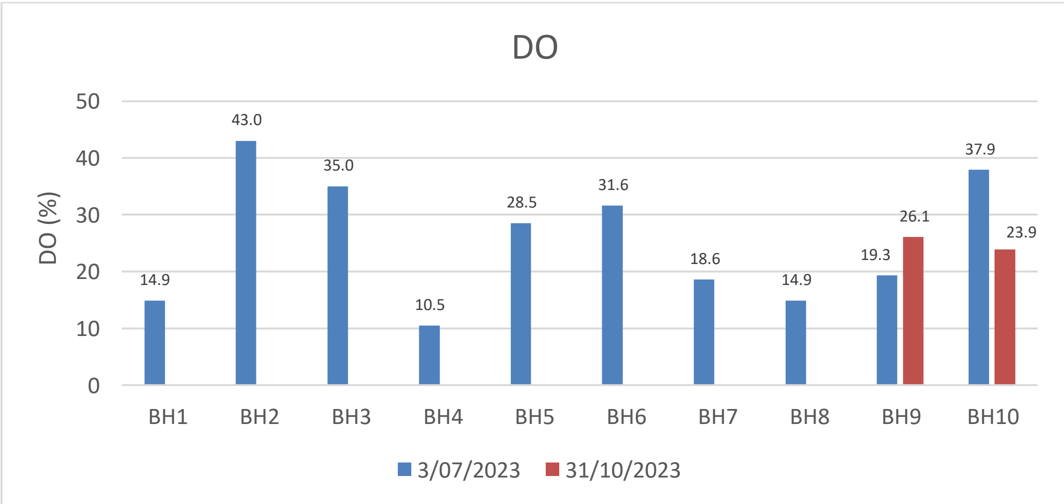

Figure 10: Groundwater DO

3.8.2.5 Nutrients

The Total Nitrogen (TN) levels within the groundwater varied from low to high, with half the results being above the ANZECC and ARMCANZ (2000) upper trigger value for wetlands in the southwest of Australia (1.5 mg/L). TN levels were slightly elevated at BH8 and BH9 (October 2023 only), high at BH10 (July 2023) and exceptionally high at BH10 (October 2023). Noting, at all bores except for BH10, the nitrogen was predominantly in the form of Total Kjeldahl Nitrogen (TKN) and therefore is likely to originate from an organic source. At BH10 over half of the TN was found to be in the form of nitrate, likely originating from an inorganic source i.e. fertiliser. The TN levels recorded at the bores for the two monitoring events is presented in Figure 11, with the nitrogen data shown in Appendix B.

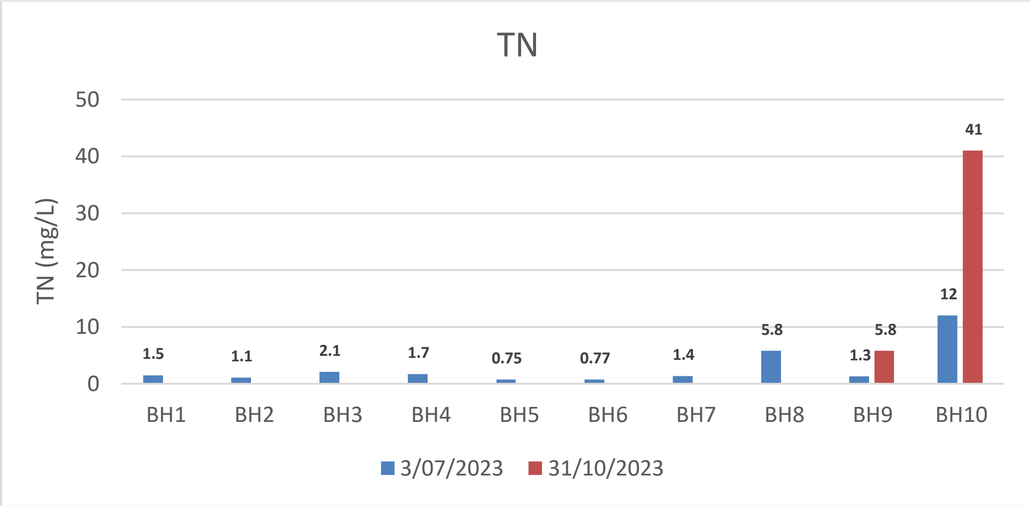

Figure 11: Surface water and groundwater TN

Total phosphorus (TP) levels were elevated and above the ANZECC and ARMCANZ (2000) trigger value (0.06 mg/L) at BH1, BH4, BH8, BH9 and BH10. TP levels were exceptionally high at BH8 and BH10 (October 2023 only). Phosphate (PO_4) levels were found to be low at all bores except BH10, indicating that most of the phosphorus detected is likely to be from an organic source at all bores except BH10. The TP levels recorded at the bores during the two monitoring events is presented in Figure 12, with the phosphorus data shown in Appendix B.

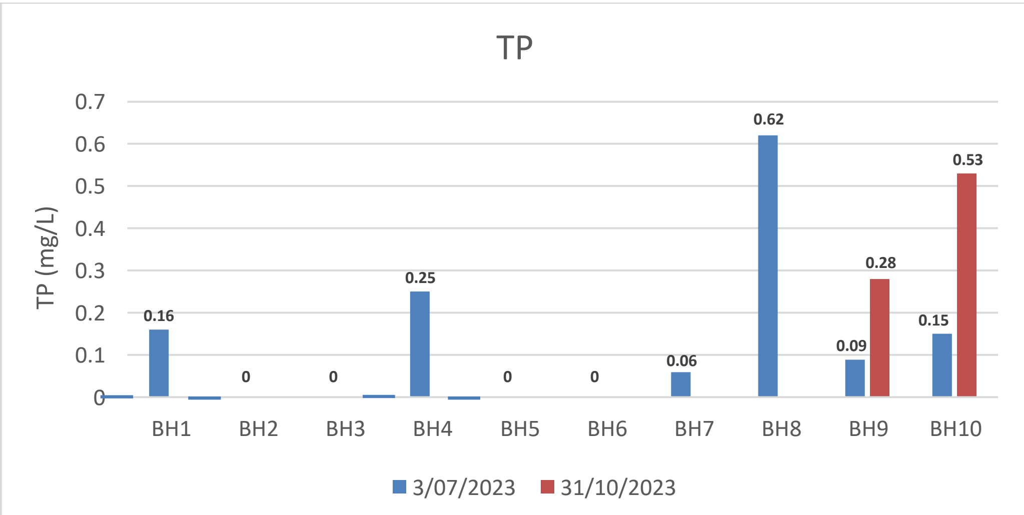

Figure 12: Surface water and groundwater TP

3.8.2.6 Dissolved Metals

Elevated levels of zinc were encountered at all groundwater monitoring bores with levels being above the ANZECC & ARMCANZ (2000) trigger values for toxicants in freshwater ecosystems at 95% level of protection. Elevated levels of copper were encountered at BH1, BH3, BH5, BH6, BH9 (July 2023 only) and BH10 and elevated levels of chromium were encountered at BH3, BH4, BH6, BH7, BH8, BH9 (July 2023 only) and BH10. Arsenic levels were elevated and above ANZECC & ARMCANZ (2000) trigger values at BH3, BH4, BH9 (October 2023 only) and BH10. Cadmium levels were elevated and above ANZECC & ARMCANZ (2000) trigger values at BH8 only. All other dissolved metal levels (mercury, nickel, lead) were found to be below laboratory detection limits. The dissolved metal results are shown in Appendix B.

3.8.2.7 Hydrocarbons

The Volatile Total Recoverable Hydrocarbons (TRH), Methyl tertiary-butyl ether, benzene, toluene, ethylbenzene, xylene and Naphthalene (MBTEXN), and Semi-volatile TRH laboratory results were generally found to be below the laboratory detection limit or very low for all parameters at all groundwater monitoring bores during both monitoring events, with the exception of the semi-volatile TRH levels encountered at BH9 in October 2023 which were found to be low to moderate. The TRH, MBTEXN and semi-volatile TRH levels at each monitoring bore for the two monitoring events are shown in Appendix B.

3.8.2.8 PAHs in Water

Polycyclic Aromatic Hydrocarbons (PAHs) laboratory results were found to be below laboratory detection limits at all groundwater bores during both monitoring events. The PAH levels at each monitoring site for the two monitoring events are shown in Appendix B.

3.8.2.9 Microbial

Thermotolerant Coliform (TC) and *E. coli* levels across the site varied from low to high. TC and *E. coli* levels were found to be below detection limits or very low at BH5, BH6, BH7, BH8, BH9 (July 2023 only) and BH10 (July 2023 only). TC and *E.coli* levels were found to be moderate (10 – 100 cfu/100 ml) at BH4 and BH10 (October 2023 only) and TC and *E.coli* levels were found to be high (>100 cfu/100ml) at BH1, BH2, BH3 and BH9 (October 2023 only). The TC and *E. coli* levels recorded at each bore for the two monitoring events are shown in Appendix B.

3.9 Public Drinking Water Source Area

The Subject Site is not located within a Public Drinking Water Source Area (PDWSA; DWER, 2018b). The nearest PDWSA is the South Coast Water Reserve and Limeburners Creek Catchment Area which is located approximately 3.0 km south-southwest of the Subject Site. The Subject Site does not form part of the South Coast Water Reserve and Limeburners Creek Catchment Area.

3.10 Wetlands and Environmentally Sensitive Areas

There are no South Coast Significant wetlands (DBCA, 2017) or Environmentally Sensitive Areas (ESA; DWER 2018c) within the Subject Site or within the vicinity of the Subject Site. The nearest South Coast Significant Wetland is the Seven Mile Creek wetland which is located ~2.7 km west of the Subject Site. Noting the Subject Site discharges downstream of the Seven Mile Creek significant wetland area. The nearest ESA is located ~4.0 km north-northeast of the Subject Site.

4 Local Water Management Strategy

4.1 Water Sustainability Initiatives

4.1.1 Water Supply

Water supply to households is to be via an extension of the Albany town scheme water system. The project civil engineer will negotiate the extension of the scheme water system with Water Corporation Western Australia.

4.1.2 Wastewater

The Subject Site is situated in an area that does not currently have reticulated sewerage. Reticulated sewerage to households is to be via an extension of the existing Albany town reticulated sewerage system. The project civil engineer will negotiate the extension of the sewerage system with Water Corporation Western Australia.

4.1.3 Water Efficiency Measures

To achieve water efficiency targets, households are to be built consistent with current BCA water efficiency standards. Water efficiency initiatives are proposed to reduce potable water demand for irrigation of residential lots. These include encouragement of:

- Selection of predominantly local native, drought tolerant plants;
- Use of waterwise plants and lawn varieties; and
- Retaining water onsite through soak wells and rainwater tanks as per the City of Albany requirements.

4.1.4 Public Open Space

Three POS and one Co-located Open Space adjacent to the Primry School (COS) areas are proposed within the Subject Site.

It is proposed that the POS in the northeast of the Subject Site co-located with the primary School will include a sports oval, associated amenities and stormwater storage areas for the northern portion of the Subject Site. The POS will predominantly be grassed with potential future tree plantings in the outer extents of the space. A groundwater production bore will be explored for irrigation of the sporting oval. According to the Water Information Reporting Tool (DWER, 2023) a reliable groundwater source has been encountered in the vicinity of the Subject Site between ~40 and 50 m depth. Further investigation is required to confirm the achievable flow rate and water quality of the groundwater supply for irrigation use at the DOS. If an adequate groundwater source is not available for irrigation of the POS, scheme water will be used exclusively or to supplement the groundwater supply.

The central north POS will include a playground, landscaping, hardscape path and some grassed areas (>50%).

The central southern POS will be utilised for stormwater storage and public use with a possible children's playground, grassed areas, and minor landscaping and hardscaping. Grassed areas will be limited to 50% of the total POS and landscaping will comprise of native trees, shrubs and grasses, with irrigation of landscaping limited to the establishment period (average of 2 years). A groundwater source shall also be investigated for irrigation of this POS, with scheme water used if a suitable groundwater source is not available.

The POS area in the south will include the establishment of a living stream, as discussed in more detail in Section 4.2.4 Drainage System Requirements. Irrigation of this POS will be minimal and limited to the establishment of plants (average of 2 years). Therefore, a permanent water supply to this POS is unnecessary with irrigation for the establishment period sourced from the scheme water supply or the groundwater supply provided in the central south POS.

4.2 Stormwater Management

4.2.1 Design Capacity

The stormwater management system for the development has been designed in accordance with the guidelines of the DWER through the Better Urban Water Management framework and the requirements of the City of Albany. The stormwater drainage system has been designed using a major/minor approach.

The minor drainage system has capacity for frequent rainfall events up to the 20% AEP and includes the pipe drainage system, lot attenuation and bioretention storage areas. The minor drainage system is designed to also provide the structural controls for water quality treatment.

The major drainage system is designed to manage a range of rainfall events up to 1% AEP. The major drainage system is designed for rainfall events greater than the 20% AEP, up to the 1% AEP. The major system uses overland flow paths, which includes grading the road network to direct flow to the lowest point of the catchment for flood mitigation.

4.2.2 Runoff coefficients and Sub-catchments

A critical design criterion for the stormwater modelling includes the runoff coefficients for the site. The lot runoff coefficients take into consideration soil type, slope and proposed land use across the site. The pre-development and post-development runoff coefficients assumed for the Subject Site, are shown in Table 7.

Table 7: Runoff coefficients

Land Use	Runoff Coefficient		
	First 15mm	20% AEP	1% AEP
Residential Lots (R2.5)	0	0.30	0.35
Residential Lots (R5)	0	0.35	0.40
Residential Lots (R10-R15)	0	0.40	0.45
Residential (R20)	0	0.45	0.50
Road Reserve	0.80	0.80	0.90
POS/DOS	0.20	0.30	0.40
School	0.20	0.40	0.45
Agricultural land	0	0.20	0.30

For clarity the residential areas have been averaged in all following calculations. There are three post-development sub-catchments proposed, with the general pre-development hydrological regime (Figure 5) being maintained in the post-development scenario. The post-development sub-catchment areas are presented in Table 8 and the sub-catchment boundaries are shown in Figure 13.

Table 8: Post-development sub-catchment areas

Land Use	Landuse Areas		
	A	B	C
Residential	18.352	17.986	12.088
Road Reserve (ha)	8.378	4.664	2.421
POS/DOS/Drainage (ha)	3.052	2.5	0.525
School (ha)	3.51	0	0
Total Area (ha)	**33.292**	**25.15**	**15.034**

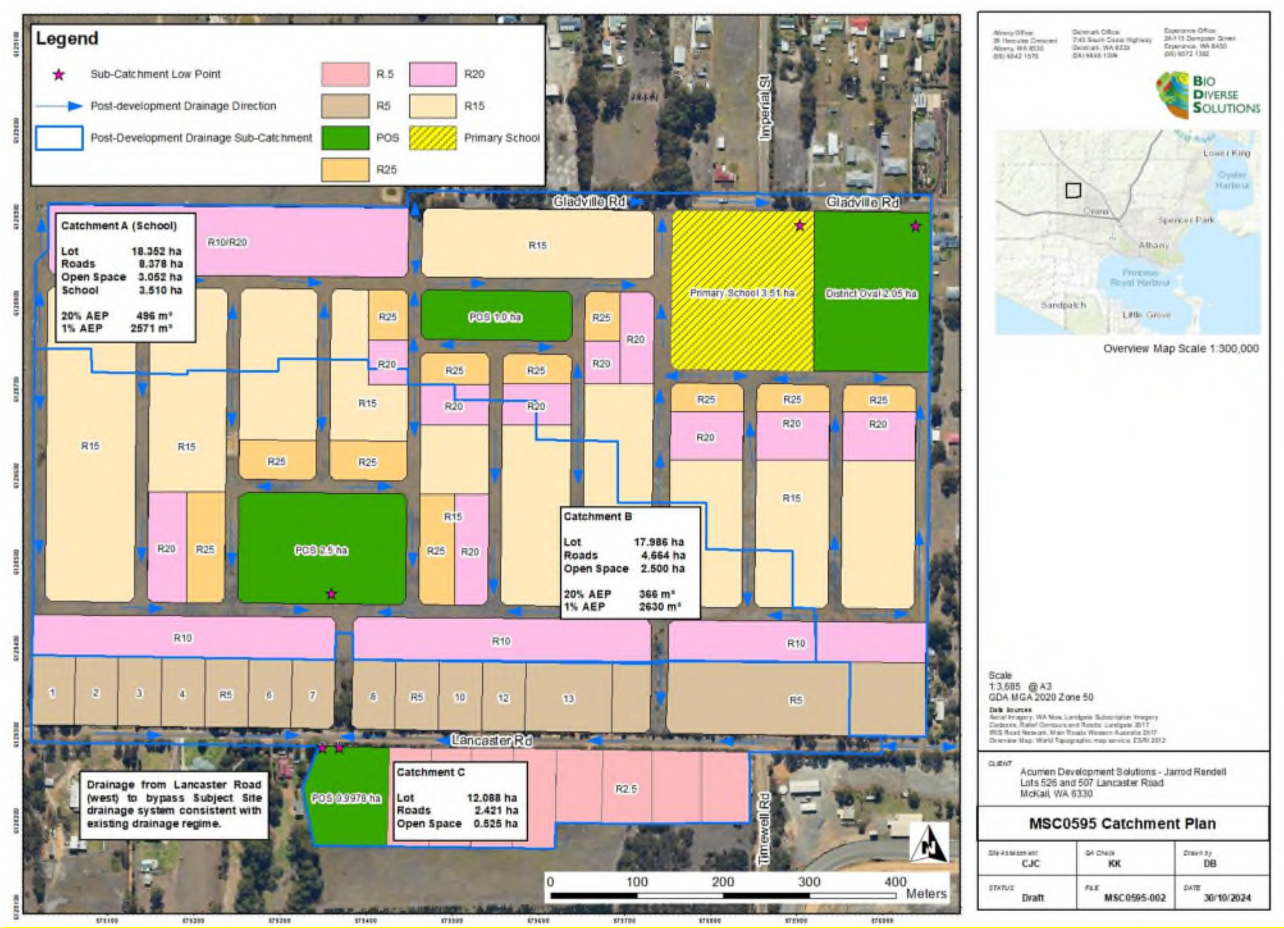

Figure 13: Post-development sub-catchment plan

Currently, drainage from Lancaster Road and the adjacent rural property to the west of the Subject Site discharges unattenuated to the creek line within the proposed POS in the south of the Subject Site, via a series of roadside swales and culverts within Lancaster Road reserve. The drainage strategy here will remain unaltered with any future proposed change in land use within the western adjacent property to attenuate outflows consistent with estimated pre-development flow rates to ensure downstream flow rates within the Subject Site POS are maintained. The portion of Lancaster Road to the east of the road low point (far east portion) will also discharge to the POS within the south of the Subject Site unattenuated consistent with the existing hydrological regime. Any runoff through this area drains larger lots with a lower flow potential.

The majority of this catchment will be unaltered as part of development works, with the only alteration being the inclusion of two relatively small sections of road connecting to Lancaster Road. The downstream impact of the increased flow rate in the post-development scenario here will be minor. Additionally, the proposed improvements to the creek line into a living stream, as discussed in more detail in Section 4.2.4, will reduce the flow rate and velocity of the outflow from this sub-catchment and provide water quality improvement.

It is proposed the lots to the south of Lancaster Road within the Subject Site discharge unattenuated towards the neighbouring property to the south and the proposed living stream to the west of the lots. The lots to the south of Lancaster Road are proposed to be zoned R2.5, and it is assumed that the majority of the lot area will remain grassed or vegetated, with lot attenuation provided for buildings and hardstand areas. As such, the runoff from these lots will be relatively similar to that of the pre-development scenario.

Drainage sub-catchments A and B take into consideration the agricultural land/potential future developable land to the west discharging towards the Subject Site to allow for integration of future development and drainage systems. Noting, that any outflow discharging into the Subject Site shall be attenuated to pre-development flow rates.

Sub-catchment A accounts for runoff from the Co-located Open Space (COS) and the residential area in the north and east. Given drainage from both the residential area and COS areas will be managed in the future by the City of Albany combining the stormwater storage areas for both land uses here allows for the most efficient use of space within the low point of the sub-catchment.

Sub-catchment D is no longer recognised with the re-design but included a proposed Primary School. It is proposed the school retain its own drainage with outflows consistent with pre-development flow rates. The school shall also be responsible for maintenance of its own drainage system. This statement remains unchanged in effect noting that large volumes of runoff cannot be directed at these sites unattenuated.

4.2.4 Drainage System Requirements

Key elements of the proposed drainage system for the Subject Site are as follows:

Lot Attenuation

- It is the landowner's responsibility to manage stormwater runoff from buildings, hard stand (impervious) areas and gardens within the property boundary, consistent with the City of Albany lot attenuation guidelines. As a guide, 0.5m³ of storage is required per 100m² of impervious area. A good way of attenuation is to encourage the use of rainwater tanks which attenuate flows, store water and then re-use the water onsite during summer. The City of Albany can provide information regarding building and planning permissions.
- Soakwells should only be utilised where there is adequate separation to the peak annual water-table from the base of the soakwell (>300 mm), adequate gradient for graduated pipe overflow pipes, and where soils allow suitable infiltration rate (not suitable in medium to heavy clays). In areas with shallow depth to groundwater or medium to heavy clays, as encountered at the Subject Site, attenuation basins integrated into the garden landscaping or underground storage pits will provide the most effective attenuation mechanism. When designing lot stormwater management systems, overland and subsoil flow routes directing runoff away from buildings and adjoining properties shall be considered. Lot

stormwater management systems should be assessed and approved by the City of Albany upon Development Application.

- Many other authorities have useful information published such as *Drainage for Liveability – managing small rainfall events at source*, jointly published electronically by the Water Corporation and DWER.

Stormwater Conveyance

- Pit and pipe network installed within the road reserve sized to convey runoff from the Subject Site for storm events up to the critical 10% AEP.
- Lancaster Road drainage system will remain unaltered and maintain its roadside swales and culvert crossovers. Stormwater runoff from the Subject Site to Lancaster Road will remain relatively unchanged in the post-development scenario.
- Road drainage for storm events greater than the peak 10% AEP event, up to the peak 1% AEP event, will be directed to the lowest point in each catchment via overland flow along the road pavement. The ultimate road low point will be located adjacent to the stormwater storage in each sub-catchment.

Bio-retention and Stormwater Storage

In the original report the use of bio-retention storages was offered. In the strictest sense bio-retention storages rely upon subsoil drainage under an engineered filter to retain and release stormwaters. The basin depth and size is governed by the principle of retaining the first 15mm of collected stormwater in the basin whilst allowing overflow past this level during the event then a slower release through subsoil drainage. Outflow from the filtration is usually set at releasing 150mm of height per hour i.e. a basin with 600mm of depth should drain, filter and discharge within 4 hours, mimicking the pre-development outflows.

Typically, the base of the bio-retention storage shall be underlain with 0.4 m depth of amended soil, 0.15 m depth of a transition layer (coarse sand) and 0.15 m depth of a drainage layer with 100 mm (maximum) perforated collection pipes (subsoils). Bio-retention storages may be considered for a future design as originally proposed if the issues outlined can be overcome. These shall also be planted, the specifications for the amended soil and the planting are provided in Table 10.

In the case of the Lancaster Road subdivision the pure concept of bio-retention basins as discussed above may not be a suitable solution. The site is going to undergo significant earthworks as cut and fill which is likely to mobilise quantities of the clays underlying the site. From experience these clays readily suspend in any water available and hence move downslope into the drainage system before some settling action occurs once flow velocity drops. This would have the immediate effect of beginning to block the filtration layers, possibly rendering the basins increasingly ineffective overtime.

At some future time when the subdivision is completed and residential areas have been built this concept could be retrofitted to the proposed drainage basins.

Other means of localised attenuation such as verge plantings with drainage solutions are already used elsewhere and should strongly be considered here as it is a greenfields site. Such plantings provide traffic calming.

As a means of attenuation for the basin outflow, low maintenance engineering solutions are proposed in the form of either weirs or perforated plate systems, the latter being as simple as a perforated stormwater liner or liners. The drainage basins are still built to required capacities of the bio-retention basin but outflow is controlled by the design of structure itself whereas water rises it encountered more area to outflow volume. This provides a more natural flow using the following concepts;

- The major event stormwater storages will be designed to hold rainfall events greater than the first 15 mm up to the peak 1% AEP storm event. The stormwater storages shall be located in the low point of the sub-catchments and integrated into the POS/DOS with adequate access for maintenance. It is assumed the stormwater storage areas will remain dry for the majority of the year and therefore may be grassed or landscaped in the elevated areas. Subsoils may be required in the lower lying sections of the storages to prevent waterlogging, so the bases of perforated plate design must meet the subsoil levels. The maximum side slopes for the stormwater storages are 1:6 and the storage shall have a minimum grade of 1:200 along its base to ensure stormwater is directed to the outlet. The stormwater storage requirements for each sub-catchment are shown in Table 9.

- Outflow from the major event stormwater storages shall be set at the lowest point of the storage with the outlet sized to match the peak pre-development outflow for the 1% AEP from each sub-catchment.
- Outflow from the stormwater storages in the north will be directed to the existing Gladville Road roadside swale. The outflow from the stormwater storage in sub-catchment B will be directed to the creek line/proposed living stream in the southern POS. Outflow from Stormwater Storage B will be via an outlet pipe that extends to Lancaster Road. Sub-catchment C discharge unattenuated towards the creek line/proposed living stream via existing culverts and roadside swales.
- A stabilised low point in the bank of the stormwater storage shall be provided at the 1% AEP top water level, located downstream in the storage so that stormwater is directed off site when/if the capacity of the storage is exceeded. This low point could take the form of a weir structure to further aid-controlled outflow.

Living Stream

- The POS proposed in Catchment C has potential for a living stream, as does to a lesser extent that in Catchments A and B. The resulting creek line shall be defined and stablised using rock pitching, stabilisation matting and plantings to minimise bank erosion. The plantings should include local native plantings and include both riparian and aquatic vegetation (reeds, grasses and shrubs) which will serve as a biological filter of organic and inorganic material and create habitat for native fauna. The creek line shall meander through the POS to reduce the velocity of the incoming flow and allow for the dropping out of sediment.

  If constructed these living streams will benefit the whole development in attenuating stormwater discharges and velocity, in addition to stripping nutrients, providing habitat and improving amenity.

Flood Protection

- All building pad finished levels shall have a minimum of 0.3 m separation above the estimated 1% AEP top water level in the stormwater storages and any nearby waterways and water bodies consistent with the Local Government Guidelines for Subdivisional Development (IPWEA, 2016).

4.2.5 Stormwater Modelling

Stormwater modelling has been conducted using the Ration Method. Multiple storm events have been modelled, as described in Australian Rainfall and Runoff (ARR) (Engineering Australia, 2001). Pre-development outflow rates have been calculated based upon peak flow stream discharge as determined by Section 1.4 of ARR.

Rainfall intensities for the various storm events and storm durations are calculated and provided by the Bureau of Meteorology (BoM) computerised design Intensity Frequency Duration (IFD) Data System (BoM, 2023). Calculations have been undertaken utilising up to date IFD charts.

The Boyd method has been utilised to calculate the stormwater storage volume required for all sub-catchments based on the post-development runoff from the site and the allowable outflows set for the stormwater storages, which are determined by the peak pre-development outflow rate. The Boyd method is considered a conservative estimate of stormwater storage volume calculation.

At the planning stage of a development many assumptions have to be made due to a number of engineering factors not usually being known until the subdivision design stage near the end of the planning process. Such matters as size of drainage infrastructure, how many nodes the system contains and slopes are present and even the surface roughness of the internal pipe on long runs contribute. These calculations represent the best available estimate based on known and calculated information.

The basin volumes outlined in the original LWMS have been calculated using the Rational Method with a retention of the first 15mm internal to the basins using bioretention principles. The data presented here is calculated as a comparison by retaining the first 15mm on lots and infrastructure, including POS and not entering the storage basins in the first instance. This makes some difference in basin volume calculations because for a 20% AEP very small volumes actually should reach the basin if the 15% retention can be achieved. The 1%AEP will obviously produce much higher stormwater flows and the author has concerns about the assertion that 15% can be retained in the post development landscape, especially if soil moisture is already high prior to the event.

Allowable outflow rates are much higher but the infrastructure design should consider the potential for much higher flow rates.

Storages calculated in the original LWMS are a good response between storing and not storing this initial flow. The original LWMS also calculated allowable outflows and it is recommended that these figures are used to their maximum flow rates when designing outflow structures.

As part of the review the principle used for calculating basin size (based on the allowable outflow per hour) calculated for pre-development conditions and then worked backwards and compared the maximum storm volumes for each period and thence storage requirements.

These are somewhat dissimilar to the initial report before development as would be expected with the differences in storage but with the use of perforated plates design depths and earth construction do not become as critical as relying upon subsurface infiltration working as expected with the risk of overtopping.

In their basic form the drainage basins could be a simple bund on a large grassed area at the downslope end retaining the required volume which totally empties over a few hours period through the plate. Alternatively, part or all could be designed to fully retain a portion of the water in a nutrient stripping, planted basin which becomes an aesthetic, low maintenance water feature within the POS.

Table 9: Stormwater storage requirements

Stormwater storage requirements	A	B	
First 15mm - not to enter basins, onsite storage			
Runoff volume (m^3)	1997	1509	
Peak flow rate from sub-catchment (m^3/s)	0.20	0.18	
Allowable outflow from storage^ (m^3/s)	0.04	0.04	
20% AEP			
Critical storm duration (hours)	60 min	60 min	
Storm duration runoff volume (m^3)	730	547	
Peak flow rate from sub-catchment (m^3/s)	0.76	0.57	Q = 0.0028 x CiA
Total storage volume required (m^3)	496	366	Inflow - Outflow
Allowable outflow from storage (m^3/s)	0.32	0.33	
1 hr outfall max.	233.60	180.51	
1% AEP			
Critical storm duration (hours)	60 min	60 min	
Storm duration runoff volume (m^3)	3639	2402	
Peak flow rate from sub-catchment (m^3/s)	1.44	1.09	Q = 0.0028 x CiA
Total storage volume required (m^3)	2571	2630	Inflow - Outflow
Maximum ponding depth (m) (Design)	0.9	0.9	
Allowable outflow from storage (m^3/s)	0.63	0.56	
1 hr outfall max.	2293	1345	

Basin Depth 0.9m Max. outflow 0.6, retain 0.3m

Land Use	Landuse Areas A	Landuse Areas B	Landuse Areas C	Basin volume - A 20% AEP	Basin volume - A 1% AEP	Basin volume - B 20% AEP	Basin volume - B 1% AEP	Basin volume - C 20% AEP	Basin volume - C 1% AEP	Basin 15mm A 20% AEP	Basin 15mm A 1% AEP	Basin 15mm - B 20% AEP	Basin 15mm - B 1% AEP	Basin 15mm- C 20% AEP	Basin 15mm- C 1% AEP
Residential	18.352	17.986	12.088	1310	2841	1284	2784	863	1871	297	1740	437	1918	294	1289
Road Reserve (ha)	8.378	4.664	2.421	1367	2918	761	1624	395	843	362	1588	105	459	105	459
POS/DOS/Drainage (ha)	3.052	2.5	0.525	187	1297	153	387	32	81	33	145	6	25	6	25
School (ha)	3.51	0	0	286	611	0	0	0	0	38	166	0	0	0	0
Total Area (ha)	**33.29**	**25.15**	**15.03**	*3151*	*7667*	*2198*	*4796*	*1290*	*2796*	730	3639	547	2402	404	1773

Excess over 15mm

20% AE	20.4	mm/hr	5.4
1% AEP	38.7	mm/hr	23.7

Rainfall intensity - centered on development

DURATION	1	2	5	10	20	50	100
5 mins	46.2	62.8	89	109	136	177	213
6 mins	42.9	58.4	82.5	101	125	163	197
10 mins	34.3	46.2	64	77.2	95.1	122	146
20 mins	23.9	31.7	42.2	49.8	60.2	75.5	88.7
30 mins	18.9	24.8	32.4	37.8	45.2	56	65.1
1 hour	12.3	16	20.4	23.4	27.6	33.7	38.7
2 hours	7.95	10.3	12.9	14.7	17.2	20.8	23.7
3 hours	6.15	7.95	9.93	11.3	13.2	15.9	18.1
6 hours	3.97	5.12	6.38	7.22	8.43	10.1	11.6
12 hours	2.55	3.28	4.08	4.62	5.39	6.48	7.39
24 hours	1.59	2.05	2.56	2.89	3.37	4.06	4.62
48 hours	0.959	1.24	1.54	1.75	2.04	2.45	2.79
72 hours	0.701	0.901	1.12	1.27	1.49	1.8	2.05

Notes: * The total stormwater storage required minus the storage provided in the bio-retention storage.

4.3 Groundwater Management

The groundwater management objectives for the Subject Site are to:

- Manage groundwater levels to protect infrastructure and assets;
- Maintain groundwater regimes for the protection of groundwater dependent ecosystems;
- Protect the value of groundwater resources; and
- Adopt nutrient load reduction design objectives for discharges to groundwater.

The following strategies will be implemented for the proposed development of the Subject Site to ensure the above objectives are met:

- To protect infrastructure from high seasonal groundwater levels imported fill will be required to achieve the minimum separation of 2 metres between finished building level and the maximum ground water levels; and
- Where the road finished level is less than 2.0m above the average annual maximum groundwater level subsoil drains will be required.

Groundwater perching was evident across the Subject Site with groundwater encountered near surface across most of the site. Further detail on the use of fill and/or subsoil drains across the site shall be presented in the future Urban Water Management Strategy for the relevant subdivision stage. This shall include the location, depth and details of any fill and/or subsoil drains proposed at the site. Groundwater quality and levels shall be maintained or improved in the post-development scenario. Groundwater monitoring shall be conducted post-development, as discussed in Section 5.3, with results compared to pre-development quality and level results (presented in Section 3.9).

4.4 Water Quality Management

The effective implementation of the structural and non-structural controls as part of the development will enhance water quality from this site as a result of the land use change from agricultural to residential/rural residential.

The Subject Site uses a treatment train of structural and non-structural controls to treat and retain up to the first 15mm of rainfall from storm events. These bioretention storages will treat this first flush preferably prior to water entering the stormwater basins.

Structural controls include the use of:

- A living Stream, in which the creek line will be defined and stablised using rock pitching, stabilisation matting and plantings. The native plantings shall include riparian and aquatic vegetation (reeds, grasses and shrubs) which will serve as a biological filter of organic/inorganic material and create habitat for native fauna. The living stream shall meander through the road network and POS mimicking a natural waterway and allowing for the dropping out of sediment as the velocity of the flow is reduced.

- Bio-retention storages which will receive runoff from the development's internal road network. Bio-retention storages are designed to treat the first flush event. Bio-retention storages allow for infiltration at source, they will be underlain with amended soil where possible and planted to allow for plant root uptake of nutrients and contaminants. The minimum specifications for all bio-retention storages are presented in Table 10.

Table 10: Minimum requirements for bio-retention storages/swales

Item	Specification
Amended soil media	• Well graded sand. • Clay and silt content <3%. • Organic content between 3 and 5%. • Hydraulic Conductivity (sat) >150mm/hour. • Light compaction only. • Infiltration testing of material prior to installation and again once construction is complete. On-going testing as per the monitoring program.
Plant selection	• In accordance with Vegetation Guidelines for Stormwater Biofilters in the South-West of WA (Monash University, 2014). • Tolerant of periodic inundation and extended dry periods. • Spreading root system. • Preferential selection of endemic and local native species. • Planting to provide 70-80% coverage at plant maturity.
Planting density and distribution	• Planting density appropriate for species selection. • Even spatial distribution of plant species.

The bio-retention systems should be sized to function correctly with a hydraulic conductivity (K) (saturated) of at least 3 m/day. Research conducted by the Facility for Advancing Water Biofiltration (FAWB, 2008) indicates that the desired K_{sat} is in the range of 2.5 to 7 m/day, to fulfil the drainage requirements as well as retain sufficient moisture to support the vegetation. The FAWB (2008) research also specifies that for vegetated systems some clogging will occur in the first few years until the vegetation is established. Once the plants are established, the roots and associated biological activity maintain the conductivity of the soil media over time.

Non-structural source controls to reduce nutrient export from the Subject Site will focus on reducing the need for nutrient inputs into the landscape. The following strategies are proposed;

- The use of local plants within the Living Stream / Bioretention areas to increase the chances of survival and maximum plant density.
- Promotion of the use of local native plants for landscaping to new lot owners.
- The use of local native plants will reduce the need for fertilisers across the site.

5 Implementation

5.1 Construction Management

Any temporary stormwater storage required during construction should be built where the final storage area will be located. The temporary storage will be sized to contain the ultimate capacity of stormwater runoff from the connected area. Measures will be taken to prevent the transportation of sediment during the construction phase including infiltrating/retention of stormwater at source where possible and sand bagging/rock placement at the inlet of any pipe systems discharging outside the Subject Site. Remedial measures will be undertaken by the developer if any disturbances are caused downstream of the Subject Site during construction.

Early construction of the stormwater basins will assist in ameliorating any off site disturbance.

5.2 Maintenance of Drainage Systems

The bio-retention storage areas, stormwater storage areas and drainage system will require regular maintenance to ensure efficient operation. It is considered the following operating and maintenance practices will be required and undertaken by the proponent periodically until successful practical completion of the development and handover to the City of Albany. Following handover, it will be the City of Albany's responsibility to maintain drainage structures accordingly:

- Removal of debris to prevent blockages;
- Maintenance of vegetation in bio-retention systems/ storages; and
- Cleaning of sediment build up and litter layer on the bottom of storages.

5.3 Monitoring Program

The monitoring program has been designed to allow a quantitative assessment of hydrological impacts of the proposed development.

5.3.1 Hydraulic Performance Monitoring

The hydraulic performance monitoring aims to measure the movement of storm water through the stormwater storage structures to determine if stormwater conveyance is consistent with the intended design.

If amended soil profiles have been installed in any bio-retention storages or streamways, infiltration testing should be completed to test the hydraulic conductivity of the media. Testing should be repeated every 12 months to ensure clogging of the storages does not occur.

Water levels in the bioretention storages and principal stormwater storages shall be observed during significant storm events to ensure they are consistent with design and not overflowing in an uncontrolled manner. If this occurs then additional openings can be installed in the perforated plate.

5.3.2 Groundwater Monitoring

A series of groundwater monitoring bores (BH1-BH10) have been established across the Subject Site to determine pre-development groundwater levels and quality. If any are retained following development the continued monitoring should occur. Monitoring shall include groundwater level and groundwater quality monitoring, with groundwater quality analysis including the following parameters:

- In-situ: pH, EC and TDS;
- Thermotolerant coliforms & E. coli;
- Nutrient suite;
- Dissolved metals; and
- TRH (C6-C10), MBTEXN & PAH.

Water quality testing shall be conducted by a certified and NATA accredited laboratory.

5.3.3 Surface Water Monitoring

In addition to the post-development groundwater monitoring, surface water quality monitoring will also be conducted at the outlet pipe of the bio-retention storages in Sub-catchment A and B, and at the downstream end of the living stream. Pre-development surface water monitoring was not conducted at the Subject Site. However, post-development water quality results will be compared to relevant guidelines. Water quality parameters will include;

- In-situ: pH, EC and TDS;
- Thermotolerant coliforms & E. coli;
- Nutrient suite;
- Dissolved metals; and
- TRH (C6-C10), MBTEXN & PAH.

Water quality testing shall be conducted by a certified and NATA accredited laboratory.

If surface water quality results are found to exceed relevant guideline trigger values, a review of the drainage/development design and land use will be required and alterations/modifications will be conducted to reduce surface water quality parameters accordingly.

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Appendix A

Site Soil Investigation

(Great Southern Geotechnics, 2023)

Appendix B

Groundwater monitoring Results