Southern River Precinct 3D
Local Water Management Strategy

September 2017

Southern River Precinct 3D
Local Water Management Strategy

Prepared for:
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Document Control

Issue	Date	Author	Reviewer	Approved
1	05/07/2012	R. Bromfield	P. Keating	P. Keating
2	18/12/2012	R. Bromfield	P. Keating	P. Keating
3	28/07/2014	R. Bromfield	J. Cousins	P. Keating
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6	23/03/2016	R. Bromfield	N. Benker	P. Keating
7	10/02/2017	T. Lynn	P. Keating	P Keating
8	05/09/2017	T. Lynn	D. Alanoix	P. Keating

The amendments are highlighted in yellow in the report.

ADDENDUM TO SOUTHERN RIVER 3D LWMS (ISSUE 7) IN RESPONSE TO COG'S COMMENTS DATED 22 MAY 2017					
Section	**Reference Section**	**Comment on**	**Required Action**	**Bioscience Response**	**LWMS (Issue 8) PDF Page**
		Required numbers of hard copies and soft copies are to be submitted according to the checklist provided at City of Gosnells website. This will help minimizing the time required for the assessment as three different departments are being involved in assessment. Go to the City of Gosnells home page and follow the link provided below. Gosnells Home page eCity Engineering Subdivisions of subdivision documents	Provide numbers of copies as per the checklist	3 hardcopies and 1 soft copy were sent to the City of Gosnells	n/a
		Provide a separate sheet attached to the front of the report with responses to the City's previous comments and reference to the updated sections. This will facilitate easy of our assessment and outline where the previous comments have been addressed or indicate why not been addressed.	Provide responses as requested before update the document. Happy to have a meeting if required	This is it.	n/a
5.3	Development Water Balance	"No detail has been provided to date about the landscaping" and then there is reference to the landscape concept plan - Figure 10b - however the landscape concept plan still does not provide details as previously requested (the plan should show the proposed POS treatments and irrigation areas (and provide details on the plan of the area figures - area of the POS, show the 1:1, 1:5 and 1:100 rain events, show the path network). The revised Structure Plan shows a new "POS" to break up the extent of the noise wall (222sqm) - this hasn't been included in the LWMS.	Provide additional detail for the POS	The following sentence "*No detail has been provided to date about the landscaping"* was removed from the text. The proposed POS treatments, bore, irrigation areas and extents of the 1:1, 1:5, and 1:100 events are provided on the landscape concept plan. In regards to the path network, please note this level of detail is more appropriately established at the subdivision stage when the detailed land development engineering requirements are better understood. The revised structure plan was finalized in April 2017 while the LWMS was submitted in February. This explains why this "POS" was not mentioned in the LWMS. This small POS will be converted to a Public Access Way (PAW) and will no longer be a small POS.	45 And Figure 10a and Figure 10b
6.0	Stormwater	Flush kerbing is proposed around the POS	No flush kerbs	Barrier kerbing (and no bollards) is now proposed around the	Page

	Management Strategy	areas (this is included in the text and on drawings) - the City requires barrier kerbing (and no bollards) around POS areas.	around the POS	POS areas. Text and drawings have been amended accordingly.	46
6.4	Public Open Space and Basins	The text gives a figure for the basin for the 100 year event (3200sqm) in the POS (5720sqm) - the 100 year event can be turf; details are required for the 1:1 and 1:5 events (as these impact on the POS design) - these areas and the areas should be provided on the POS landscape concept plan. The unrestricted POS should be provided recreational, usable areas.	Provide additional information on landscape plans	Details are provided in Appendix C. Also, as discussed above, extents of the 1:1, 1:5, and 1:100 events are provided on the landscape concept plan.	Figure 10a and Figure 10b And page 81 (App. C)
Figures	Landscape Concept Plan	Landscape Concept Plan - additional information required as previously requested: Better Urban Water Management requires the following in a LWMS - Landscape Plan - showing proposed POS areas, POS credits (show on the plan the 1:1, 1:5 and 1:100 year events), water source, bore(s) and irrigation areas. In addition the path network in the POS should be shown on the landscape concept plan - path provision is a requirement of minimum standard landscaping as per Liveable Neighborhoods - there is concern as to the access and usability of the POS provided around the Forrestdale Main Drain. Clarification required as to the future maintenance of the Main Drain (Water Corporation?) - And the accessibility to the POS - for example the portion between the drain, noise wall and grouped housing site. Will there be paths / pedestrian bridges across the Main Drain?	Additional information to be provided	As discussed above, the proposed POS treatments, bore, irrigation areas and extents of the 1:1, 1:5, and 1:100 events are provided on the landscape concept plan. In regards to the accessibility to the POS, if necessary, the City will be granted access rights through the Grouped Housing site or through the Watercorp drain (given that the drain has been designed as a gradual living stream). This will be further addressed at the subdivision stage.	Figure 10a and Figure 10b
Executive Summary	Table 1- Compliance with BUWM checklist	The site topography varies between 20mAHD and 24mAHd but not only between 20mAHD and 22mAHD.	Update the document as per the comment	The report was updated to reflect your comment.	Page 9
Stormwater Management Strategy	DoW comments, Appendix C,	Flush Kerbings are not acceptable at any locations specially at adjacent to open space and the drainage corridors. The city prefers to have a kerb opening or double side entry pits	Update the strategy as per the council comment.	Agreed, a kerb opening will be used at these locations.	page 81 (App. C)

		arrangement as per the City of Gosnells standard drawings.			
Regional Drainage Strategy	4.8.1	This comment is more relates to the structure plan. But it directly effect to the drainage assessment and should be address at this stage but not later. The study area is not following at least the property boundaries. As per this drainage assessment and with refers to the FMDADS, the study boundary area should be covered by extending the boundaries to cover at least the properties that require for regional drainage requirements. As per FMDADS, this catchment requires three main storage areas. They are Holmes St CB (4830m3), Matison St CB (1920m3) and 1.5ha online compensating basin (14228m3). All the three storage basins were proposed to be located at within this proposed structure plan area indicatively. The current structure plan shows only two basins and the City's drainage assessment confirmed that they are located at the most suitable locations however the confirmation of the volumes and the areas of inundation are required. The storage requirement of the third basin can be easily incorporated in to the water corporation's 1.5ha on line basin. However this needs confirmation from the water corporation.	Study area needs to be revisited as per the comment	The LWMS boundaries are dictated by the LSP boundaries. The LSP boundaries were set by the WAPC (not by us) through their decision in 2014 to lift the urban deferment over the area of land illustrated in the attached plan. The area in the attached plan is the only area that we can encompass within the LSP. Therefore, we have no control over the development of land outside of the LSP area. All areas outside of the LSP are subject to future planning. It is therefore not appropriate for our LWMS to relate to any area of land outside of our LSP area. In regards to the basins, the issue was solved with the Water Coporation's modeling which has confirmed the compensating basin can accommodate the proposed flows. Please see details in the Water Corporations' Comments section below.	n/a
Regional Drainage Strategy	4.8.1	The allowable peak discharge flow rates of the Forrestdale main drain at Holmes Street are 6.4m3/s for 10 year event and 7.8m3/s for 100 year event respectively. These flow rates are to be maintaining at the Holmes Road at the given flow rates by providing any suitable infrastructure. Then only the expected storage can be held within the 1.5ha basin.	Update the LWMS to reflect the comment	This was resolved with the Water Corporation modeling. Please see Water Corporation's comments and our response in the next section of this addendum.	n/a
Table 9	Shawmac Pre-development Flow Rates	It shows that the pre-development flow rates calculated by Shawmac are not aligning with the FMDADS study. The proposed rates are much higher than the values given in FMDADS. However it is not a major concern as far as the total storage and the peak flow	Update the LWMS to reflect the comment	The LWMS was amended to reflect this comment.	Page 37

		rates are maintained as per the FMDADS.			
6.4	Public Open Space and Basins	The LWMS should cover the whole area but not only the residential sites. What are the proposed likely finished surface levels for School site and the Playing field? What is the storage volumes required? This comments is again relates to both planning and drainage assessment. The city is happy to discuss. This comment was provided by the City earlier too.	Additional information is required	As explained previously, the LSP area has been defined by the WAPC and does not extend into the school site or adjacent reserves to the south. Furthermore, the City is currently progressing an amendment to remove the school site.	n/a
6.4	Public Open Space and Basins	Typical cross-sectional details of the FMDADS and the Balannup Lake drain as per previous comments. What is the total storage that provided due to widening of FDMD for each and every design rainfall event? Provide the critical dimensions of the widened FDMD on a plan?	Additional information is required	Plans were updated accordingly to address the following. Please refer to Appendix C for details.	page 81 (App. C)
Groundwater Monitoring	4.7.2	The correction factor (Groundwater level) calculation shows some inconsistencies between MGL and AAMGL calculations. Why it is used 20 years to find the highest MGL but not the whole set of data for 39 years. Why it is used 39 years to calculate the AAMGL? Bioscience has provided 39 years data and most of the MGLs recorded within the first 19 years are more critical than the latest 20 years. The Bioscience needs to recalculate the corrected ground water levels by considering the total set of groundwater monitoring data. Then the LWMS document should be amended based on the corrected MGL contours as this may influence on the proposed fill levels, drainage design and finally on the likely finish surface levels proposed for the site.	Re do the MGL and the AAMGL calculations	On 20 June 2017, an email from Bioscience (Didier Alanoix) was sent to the City of Gosnells (Dumal Kannangara) addressing these comments. After discussion with the City it was agreed to determine the MGLs from the full dataset (1975 - 2013). MGLs calculations are provided in Appendix A.	Page 30
ADDENDUM TO SOUTHERN RIVER 3D LWMS (ISSUE 7) IN RESPONSE TO WATERCORP'S COMMENTS DATED 13 JUNE 2017					
Section	**Reference Section**	**Comment on**	**Required Action**	**Bioscience Response**	**LWMS (Issue 8) PDF Page**
		The LWMS does not meet drainage planning requirements, as the required 10 and 100 year		Both issues were solved. Water Corporation modeling show that the storage volume currently proposed for the development will	n/a

		storage volumes at the future Holmes Street CB is not provided in the cross sectional areas that are proposed for the Forestdale MD and the Balannup Lake Drain. It is likely that the cross section will need to be wider thus requiring more land to be set aside for drainage.		be sufficient to compensate flows on the Forrestdale Main Drain to the required 10% and 1% AEP. Please see Christina's Young's (Water Corporation) feedback below: " **From: Christina Young [mailto:Christina.Young@watercorporation.com.au]** **Sent: Monday, 7 August 2017 3:39 PM** **Subject:** RE: Southern River Precinct 3D LWMS - Request for info - Storage Requirements Hi Ryan, Thank you for your patience. As agreed, modelling of the storage requirements for the above development was undertaken to determine if there could be savings made in the regional and local storage volumes required within this development using an online storage option in place of the offline storage strategy currently endorsed in the ADS. For this analysis modifications were made to the original sub-catchment boundaries and land uses for Precinct 3D based on the proposed ODP outlined in the LWMS plus the future Holmes Street dual carriageway. Other model assumptions such as catchment losses and groundwater inputs were maintained as per the post-development scenario in the ADS. In summary, our findings show that the storage volume currently proposed for the development in the Precinct 3D LWMS (based on drawings 1201008-201 & -501 in Appendix C) will be sufficient to compensate flows on the Forrestdale Main Drain to the required 10% and 1% AEP. It is therefore accepted in-principle by the Corporation that in terms of the hydraulic drainage requirements for the site, additional storage will not be required to be provided by the developer if an online storage strategy is used. This acceptance however is subject to the following: • Approval in writing from DWER and the City of Gosnells of the change in the approved Arterial Drainage Strategy for the development from an offline to an online storage option.	
		The existing culverts under Holmes Street need to remain in place so the note on Drawing Number 1201008-201 “Upgrade Existing Culverts” is not correct and any reference to it needs to be removed.			

				• Minimum fill levels are maintained as per drawing 1201008-201 (Appendix C of the proposed LWMS). Please note that this is not an acceptance of the design for the proposed living stream profile for the Forrestdale Main Drain which is still undergoing assessment. If you have any questions regarding the above please feel free to contact me to discuss. Regards, **Christina Young** Senior Asset Investment Planner Asset Investment Planning Metro **Water Corporation** **T:** (08) 9420 3673 " Note that both the City of Gosnells and DWER approved the change in writing on 7 August 2017 and 8 August 2018 respectively.	
		Land matter issues will also need to be addressed with the creation of a Maintenance Agreement for the living stream between the City of Gosnells and the Water Corporation.		This will be addressed by both involved parties	n/a

Executive Summary

This Local Water Management Strategy (LWMS) developed by Bioscience Pty Ltd has been commissioned by the land owners of Lots 9 and 1792 Holmes Street to support the submission of an Outline Development Plan (ODP) for a portion of the Southern River Precinct 3D. The LWMS demonstrates the development will be undertaken in a sustainable manner through total water cycle management in accordance with Water Sensitive Urban Design (WSUD) principles.

Table 1: Compliance with BUWM Checklist

Key LWMS Element	Compliance with Objectives
Topography	• The site has a low relief with minor variation in topography between 20mAHD and 24mAHD. The highest point of the site is slightly above 24m AHD
Geology & Geotechnical Investigation	• The site is generally Bassendean sand over Guilford formation clays, with the thickness of the sand varying with position in the landscape • Clays are moderately reactive but there is sufficient sand cover in most location to negate the effect of the clays supporting a "Class A" classification • The sand exhibits high permeability rates; tested to be over 10m/day
Groundwater	• Groundwater at the site has been monitored to determine groundwater levels and quality • MGL have been calculated against DoW long term bore data • Groundwater flows northwest through the site towards the Southern River and Forrestdale Main Drain • Groundwater peaks at around 21m AHD over most of the site
Surface Water & Wetlands	• The major surface water feature of the site is the Forrestdale Main Drain which runs through the site flowing from Ranford road to Holmes Street • There are numerous wetlands in and around the site from multiple use to conservation status
Acid Sulphate Soils	• There is a risk of acid sulphate soils occurring on the site based on preliminary investigation • Any site works that disrupt the natural soils will require an acid sulphate investigation to determine management requirements
Vegetation	• Precinct 3D has numerous areas of vegetation in various condition • Much of the area has been cleared at some point in the past and much of the vegetation is in poor condition • There are numerous bush forever sites within the vicinity and within precinct 3D
Water Use &	• Water efficient fixtures and fittings installed as standard

Sustainable Initiatives	• Encouraging all residents to install rainwater tanks • Promote water wise landscaping and the use of drought tolerant native species in all POS.
Surface and Stormwater Management	• 1 year events infiltrated close to source and treated through rain gardens and other bioretention systems • 100 year events to be conveyed overland to basins once piped drainage system capacity is reached • Soakwells will be used in the development as imported fill will ensure 1.7m separation to MGL is achieved • Predevelopment flows to be maintained across Precinct 3D • 0.5m separation from the base of rain gardens to MGL will be maintained to promote infiltration • Provide adequate clearance from 100 year ARI flooding to protect people and property from flooding • Building habitable floor levels will be at least 0.3m above the 100 year ARI flood height of the urban drainage system and at least 0.5m above the 100 year ARI flood height of waterways to protect people and property from flooding • Forrestdale Main Drain (FMD) to be rehabilitated into a living stream which can provide multiple benefits including online compensation
Groundwater Management	• To maximise infiltration opportunities, rain gardens, open based manholes, and swales. • Bio-retention areas set to treat and infiltrate the 1y 1h ARI event (at least 15mm) • Subsoil drainage is not planned for the precinct. • Maintaining predevelopment hydrology
Construction Management	• Should dewatering be required, care must be taken to ensure neighbouring wetlands or groundwater dependent ecosystems are not adversely affected.
Monitoring	• The monitoring program is designed to operate over a three-year post-development period including construction and establishment to allow for time lag for full impacts of development on the receiving environment to occur • Post development trigger values will be described in the UWMP.
Implementation	• The roles and responsibilities involved in the implementation of LWMS have been identified.
Future Work	• Additional/Future work required for the Urban Water Management Plan (UWMP).

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Appendix F: Geotechnical Investigation 2011 & Permeability Test Results
Appendix G: Addendum to July 2014 LWMS

Definition

To avoid confusion, the term "Living Stream" in this report refers to a rehabilitated waterway designed to manage water runoff, filter pollutants and increase rainwater infiltration while mimicking the characteristics of a natural waterway.

1.0 Introduction

This Local Water Management Strategy (LWMS) has been produced by Bioscience Pty Ltd to support the submission of the Outline Development Plan (ODP) developed by TPG and Dynamic Planning and Developments for Lots 8, 9 and 1792 Holmes St and Lot 6 Matison Street of Precinct 3D of the Southern River Precinct 3.

The study area covers approximately 17.8 hectares of land and is located about 20km south east of Perth CBD within the City of Gosnells (**Figure 1**).

1.1 Total Water Cycle Management Objectives

This LWMS will ensure the proposed development manages the total water cycle in a sustainable manner, whilst adhering to the principles of Water Sensitive Urban Design (WSUD). This LWMS provides concept designs, guideline controls and management measures for:

- **Water Conservation -** Maximise the efficient use of water resources
- **Water Quantity -** To maintain pre-development total water cycle balance within development areas
- **Water Quality -** To maintain surface and groundwater quality at pre-development levels and, if possible, improve the quality to maintain and restore ecological systems
- **Ecosystem Health –** To prevent the deterioration of ecosystem health
- **Protection of Property -** To protect infrastructure and assets from flooding and water logging
- **Public Health -** To minimise the public risk, including risk of injury or loss of life to the community
- **Social Values -** Recognise and maintain social, aesthetic and cultural values
- **Development -** Deliver best practice water management taking due cognisance of sustainability and precautionary principles

This LWMS is consistent with the following State Government Policies and published guidelines to achieve a sustainable environment and urban development:

- *State Water Strategy (Government of WA, 2003).*
- *State Water Plan (Government of WA, 2007)*
- *Liveable Neighbourhoods (WAPC, 2009)*
- *Statement of Planning Policy No 3 Urban Growth and Settlement (WAPC, 2006a)*
- *State Planning Policy 2.9 Water Resources (WAPC, 2006b)*
- *Planning Bulletin 92 Urban Water Management (WAPC, 2008b).*

- *Planning Bulletin 64/2009 Acid Sulphate Soils (WAPC, 2009).*
- *Liveable Neighbourhoods (WAPC, 2009)*
- *Better Urban Water Management (WAPC, 2008a)*
- *Developing a Local Water Management Strategy (DoW, 2008)*
- *Stormwater Management Manual for Western Australia (DoW, 2004-2007)*
- *Decision Process for Stormwater Management in Western Australia (DoW, 2009)*
- *Stormwater Quality Management Manual for WA (DoE, 2004).*
- *National Water Quality Management Strategy (ANZECC, 2000)*

1.2 Planning Background

The Southern River Sub-Precinct 3D Outline Development Plan (ODP) by TPG Town Planning, Urban Design and Heritage on behalf of landowners of Lots 9 and 1792 Holmes Street seeks approval for the proposed development under the provisions of the City of Gosnells (CoG) Town Planning Scheme No.6 (TPS6).

The ODP (**Figure 2**) provides a planning framework to guide future development and establishes a context for subdivision within the Southern River Sub-Precinct 3D. This LWMS, to support the ODP, will guide future subdivision to ensure that the land is developed in a sustainable manner, fulfil the objectives of the WAPC as described in Liveable Neighbourhoods (WAPC, 2009) and in accordance with the objectives of the Department of Water (DoW) and the CoG and as such provides the necessary water management strategies to guide the subsequent Urban Water Management Plan (UWMP) required for subdivision.

Initially, an ODP for the whole of the Precinct 3D was proposed, though due to planning constraints has been reduced to northern most 17.8 hectares. Much of the environmental investigations and assessments (e.g. groundwater monitoring and geotechnical investigations) have been undertaken across the whole area and this information has been included in this LWMS.

1.2.1 Zoning

The site is currently zoned as "General Rural" under the CoG TPS6. The site is currently zoned “Urban Deferred” under the Metropolitan Region Scheme (MRS). The ODP is to be adopted and approved prior to subdivision and development of the site to form the basis for initiating the lifting of the urban deferment.

The ODP has been prepared in accordance with the requirements of Clause 7.3 of TPS6 and CoG's Local Planning Policy No. 6.3.3.1 Southern River Precinct 3 Planning

Framework. This essentially refines the land use elements stipulated within the Southern River/ Forrestdale/ Brookdale/ Wungong District Structure Plan (2001) and the Southern River Precinct 3 Local Structure Plan (2008).

1.2.2 District Structure Plan

On a district scale the site is located within the area of the Southern River/ Forrestdale/ Brookdale/ Wungong District Structure Plan (DSP). Prepared by the Western Australian Planning Commission (WAPC) in 2001, the DSP provides a broad framework for land use and development including major community facilities, conservation areas, public open space (POS) and potential areas for development together with the management of key environmental issues for a region facing increasing development pressures.

In 2002, the WAPC commissioned JDA to develop a district Urban Water Management Strategy (UWMS) for the area. The UWMS included goals which aimed to protect water resources, ensure an enhanced living environment for the community and provide protection from flooding. After reviewing the UWMS, the EPA expressed significant concerns with the planned urbanisation of the area, which led to a Memorandum of Understanding (MOU) being entered into by a range of agencies involved in land use and water management, including the DEC, the Water and Rivers Commission (now DoW), the Department of Planning (DoP), Water Corporation (WC), Armadale Redevelopment Authority and the Cities of Armadale and Gosnells. Under the terms of the MOU, the WC was made responsible for the coordination and project management of the development and a Water Cycle Plan, in consultation and agreement with all parties, was completed.

The aims of the Water Cycle Plan were to achieve the objectives and recommendations of the UWMS. It was intended to be performance-based and detail the management requirements of the WC and the Cities of Armadale and Gosnells in relation to 'total water cycle management', including water conservation, excess water management during storm events, water quality, monitoring, reporting and cost recovery. Early in the process of addressing implementation of the UWMS and total water cycle management, the importance of integrating the total water cycle management approach with land development processes was recognised. This was reflected in the title of the project being changed to an Integrated Land and Water Management Plan (ILWMP).

The subsequent Southern River ILWMP was gazetted by the DoW in January 2009. Both documents recognised water and drainage as one of the key issues for development in the Southern River area.

1.2.3 Precinct 3

Within the Southern River Region, the City of Gosnells identified several precincts, of which the site is located within Precinct 3. Precinct 3 ODP is bounded by Southern River Road, Ranford Road, Matison Road and the Southern River and is characterised by areas of flat, low lying land and a relatively high water table. There are dominant surface water features such as the Southern River, Forrestdale Main and Balannup Lake Drains. The Precinct also contains significant areas of wetlands that have hydrological groundwater linkages with these waterways.

The Precinct has also been affected by current and previous land uses, such as intensive agriculture, animal-based industries, other rural pursuits and a former waste disposal site, which have left a legacy for water management plans to address. Further, as Precinct 3 lies towards the bottom of a large regional drainage catchment, there is a need to ensure stormwater is managed to avoid flooding and to address water quality issues. Water management is therefore a significant and important consideration for the planning and development of Precinct 3.

Precinct 3D covers the eastern margin of the Precinct 3 area and is bounded by Holmes street, Matison Street, Passmore Street and the boundary of the Kennel Zone. Much of the Precinct 3D area is vegetated and contains wetland, with the remainder cleared for buildings and grazing horses on pastures. The Forrestdale Main Drain (FMD) runs through the area and has lowered groundwater levels within the vicinity of Precinct 3D. The area is considered suitable for urban development due to the degraded nature of much of the land, however development must address water and environmental issues present within the site.

1.3 Local Studies

Other relevant previous studies into land and water management in the area include:

- *Southern River Area: Groundwater modelling to assess effects of climate variation, and proposed development (Rockwater, 2005)*
- *Forrestdale Main Drain Arterial Drainage Strategy (DoW, 2009)*
- *Precinct 3 Environmental Review undertaken by ENV for City of Gosnells*
- *Wetland Reclassification - Lot 9 Holmes St, Southern River (MWH, 2009)*
- *Environmental Assessment - Lot 9 Holmes St, Southern River (MWH, 2008)*
- *Results of Floristic Assessment of Lot 1790 Passmore Street, Southern River, 21 September 2011 (ENV, 2011)*
- *Southern River Integrated Land and Water Management Plan (DoW, Jan 2009)*
- *Southern River/Forrestdale/Brookdale/Wungong District Structure Plan UWMS (WRC, 2002)*

2.0 Proposed Development

The proposed development within Sub-Precinct 3D covers approximately 17.8ha and is located 20km south east of Perth CBD within the City of Gosnells (**Figure 1**). The site is bounded by Matison Street and Forrestdale Main Drain (FMD) to the North West, Holmes Street to the north east, Passmore Street to the east and rural land to the south west.

The site currently consists of rural lots and bushland with Lots 9 and 1792 Holmes Street used as horse paddocks and other lots within the area have been grazed in the past. FMD runs through the precinct exiting through culverts under Holmes Street.

The ODP in **Figure 2** has been designed to be sensitive to the site restrictions and is to incorporate the following development categories:

- Residential Zones of R30 and R40
- Public Open Space (POS)
- Drainage areas
- FMD and Balannup drain to be widened and turned into a living stream
- Local roads

The ODP within the Southern River Sub-Precinct 3D has been developed in accordance with the Southern River / Forrestdale / Brookdale / Wungong Structure Plan (DSP), the Southern River Integrated Land and Water Management Plan (ILWMP) and the Southern River Precinct 3 Local Structure Plan (LSP).

Key landscape features will include landscaped rain gardens for water management, areas of POS to double as stormwater retention basins and an upgrade of the Balannup and FMD. The upgrade will provide an online compensation basin for stormwater management in flood and infrequent storm events in accordance with the FMD Arterial Drainage Strategy.

3.0 Design Principles and Criteria

This LWMS will create a development that manages the total water cycle in a sustainable, well integrated manner, whilst adhering to the principles of Water Sensitive Urban Design (WSUD) as outlined in the State Planning Policy 2.9 Water Resources (WAPC, 2006), Liveable Neighbourhoods (WAPC, 2007) and Stormwater Management Manual for WA (DoW, 2007).

The LWMS will tie in with regional and local principles and objectives of total water cycle management (Table 2).

Table 2: Water Management Design Principles and Objectives

Principle	Key LWMS Element
Water Conservation Control the use of potable scheme water throughout the development	• Target consumption rates for scheme water both internally and externally of buildings including; State Water Plan target for water use of 100kL/person/yr with no more than 60kL/person/yr by utilising fit-for-purpose infrastructure and water efficient fixtures and fittings in buildings • 6750kL/ha/year of water irrigation in landscaped areas • Maximise infiltration opportunities • Use of rainwater harvesting systems • Use of native plantings and minimal lawn areas to minimise irrigation dependency • Reduce evaporation losses of irrigated water
Water Quality Maintain surface and ground water quality at pre-development winter levels and if possible, improve the quality to maintain and restore ecological systems in the downstream receiving environment	• Monitor pollutant and nutrient outputs of the development to not exceed ambient conditions to establish ambient conditions and trigger values. If catchment ambient conditions have not been determined, relevant Healthy Rivers Action Plan and/or ANZECC water quality guidelines shall apply • Both structural and non-structural best management practices and source controls to be implemented across the precinct • Management of fertilizer use across the development to limit nutrient export • Infiltrate frequently occurring rainfall events close to source • Raingarden areas set to treat and infiltrate the 1y 1h ARI event (at least 15mm) • Regeneration of existing drains to living streams • Manage contaminated areas and acid sulfate soils in accordance with DEC and DoW guidance • Ongoing predevelopment and post development monitoring programs and performance reviews
Water Quantity	• Management of run-off up to 1 in 100 year ARI storm event

A relative comparison between pre and post-development for discharge volume and peak flow to be maintained	throughout the development • Maintain existing natural flow paths where feasible to create a *"liveable neighbourhood"* design • Restoration of drains to improve capacity • Retain the 1 year 1 hour event from modified surfaces at source • Retain flows from 5 to 100 year ARI storm events within the boundary of the development to maintain predevelopment peak flow rates across the development • Minor roads to remain passable in the 5 year ARI event • Major roads to remain passable during the 100 year ARI storm event • Post development peak flow rates from 100 year ARI event will be equal or less than 100 year ARI pre-development peak flow rates • Implement plan to maximise infiltration where possible i.e. in the sandy area onsite • All drainage design in relation to maximum groundwater level (MGL) • All building habitable floor levels should be at least 1.2m above MGL • Provide adequate clearance from 100 year ARI flooding to protect people and property from flooding • Building habitable floor levels will be at least 0.3m above the 100 year ARI flood height of the urban drainage system and at least 0.5m above the 100 year ARI flood height of waterways to protect people and property from flooding • Balannup and FMD to be rehabilitated into a living stream which can provide multiple benefits including online compensation
Ecosystem Health Determine of ecological requirements to maintain and improve sensitive areas	• Frequently occurring events to receive primary treatment in vegetated Raingarden areas or at source infiltration • Existing resource enhancement wetlands to be rehabilitated, revegetated, and retained • Creation of vegetation and habitat linkage via multiple use corridors
Economic Viability To implement stormwater systems that are economically viable in the long term	• Minimise pollutant and sediment entering the drainage infrastructure requiring further maintenance
Public Health To minimise the public risk, including risk of	• All drainage infrastructure to infiltrate retained water within 96 hours, where not flowing, to minimise disease vectors and nuisance insect growth

injury or loss of life to the community	
Protection of Property To protect the built environment from flooding	• Provision of 1 in 100 year ARI flood protection • Protection of downstream areas by restricting stormwater discharge to existing pre-development levels • Fill used to provide separation between groundwater and foundations of building and facilitate effective drainage • Maintain a minimum separation distance of 0.3m between 100 year ARI flood levels and habitable floors
Social Values To ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater	• Integration of drainage and POS functions to enhance and improve the local residential community • Existing resource enhancements wetland areas to be rehabilitated and retained as POS • Regeneration of existing drains to living streams • Integration of drainage and POS functions

4.0 Predevelopment Environment

4.1 Land Use

Precinct 3D consists predominantly of rural lots and bushland. Lots 9 and 1792 Holmes Street are currently used as horse paddocks; most lots within the area have historically held free-to-graze animal stock. Most residential buildings have associated sheds. There are some building debris and concrete pads associated from past activities. The degrading building of a small piggery remains on Lot 9 Holmes Street.

FMD is the predominant drainage feature running through the site south west to north east between Lot 8 Matison Street and Lot 9 Holmes Street through culverts under Holmes Street. The Balannup Lake Drain connects to FMD from culverts under Matison Street. Both drains are open channel drains with culverts under roads.

4.2 Climate

The south west of Western Australia is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. According to the Bureau of Meteorology (BOM) the long term mean annual rainfall within the vicinity of the proposed development is 829.1mm (Jandakot Aero No. 009172) (**Table 3**). The average annual evaporation of the area is 1800 mm (Davidson and Yu, 2006).

Table 3: Monthly Rainfall and Mean Maximum Temperature at Jandakot

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	14.0	16.0	16.1	42.4	107.7	158.4	174.3	126.4	88.4	46.4	29.4	10.7	829.1

4.3 Topography

The site has a low relief with minor variations in topography, with elevations generally between 20m AHD and 22m AHD. The highest point is in the middle of Lot 1792 Holmes street at 24.14mAHD. This can be seen in the feature survey in **Figure 3 and 3a**. The FMD dissects the site with a lowest point of 19.05mAHD prior to Holmes Street.

4.4 Geology and Geomorphology

The site is located on the Swan Coastal Plain within the Bassendean dune system, an area characterised by low dunes of siliceous sand interspersed with poorly drained areas or wetlands. Soils tend to be a deep bleached grey colour sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than 2 m.

Underlying the Bassendean formation is the Guildford formation. The soils of the Guildford formation are complex, and comprise a successive layering of soils formed from erosion of material from the scarp to the east. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium. The Guildford formation is characterised by poor drainage due to the low permeability of sub-soil clays which prevent the downward infiltration of rainfall, consequently during the winter month's water logging and surface inundation can occur. In addition, the clay fraction of the Guildford formation is known to have highly variable Plasticity Indices (Hillman et al., 2003).

The geology at the site as per the Geological Survey of Western Australia 1:50000 Environmental Geological Series Armadale Map part of sheet 2033 I and part of sheet 2133 IV (**Figure 4**) is:

- S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted of eolian origin
- S10 – SAND – As S8 over sandy clay to clayey sand of the Guilford formation
- SP1 – PEATY SAND – Grey to black, fine to medium grained, moderately sorted quartz sand, slightly peaty of lacustrine origin

4.5 Geotechnical Site Investigation

A geotechnical investigation was carried out in May 2011 during the installation of 12 groundwater monitoring piezometers across Precinct 3D (**Figure 5**). Soil cores were collected using a hollow stem auger fitted with a sampling tube.

Inspection of the soil cores showed the majority of the site to have a soil profile of a thin topsoil layer over a medium textured grey to white Bassendean sand to depths of at least 2 metres. Below this is a weakly cemented iron rich organic layer was generally intersected before the soils became loamy sands with colours varying between grey, orange and brown. Exceptions to this general trend was observed at holes D3 and D11 with roughly half a meter of light brown sand over white loamy sand before the soil became orange sandy loam at 1.25m in D3 and 2.25m in D11. This is a typical profile in keeping with the local geology.

Particle size distribution (PSD) analysis for 12 representative soil samples taken during the investigation demonstrated that the majority of the soils are medium textured sands with greater than 90% of particles within the 2mm to 0.075mm range (sand fraction). Three samples were classified as loamy sands as each had 80-90% of particles within the sand fraction range; and another two were classified as sandy loams as each had 70-80% of particles in the sand fraction.

The Atterberg limits tests are standardized tests that were developed to determine the water contents that will induce particular behaviour in soil; and provides a useful measure of potential soil reactivity resulting from groundwater movement. The two samples with a silt and clay fraction higher than 20% underwent Atterberg testing. Both samples plotted above the "A" Line, with sample D7 2900-4400mm classified as a clay of low plasticity. Sample D3 1200-1500mm classified as a clay of high plasticity. The results for these tests are summarised in **Table 4**.

Table 4: Atterberg Limits

Atterberg Limits Results											
Borehole	Sample Depth (mm)		Cobble (%)	Gravel (%)	Sand (%)	Silt/Clay (%)	Fines (%)	LL	PL	PI	LS
			>6.3mm	>2mm	<2mm	<0.075mm	<0.425mm	(%)	(%)	(%)	(%)
D3	1200	1500	0.0	0.15	73.4	26.5	42.7	92.9	27.6	65.4	6.7
D7	2900	4400	0.0	0.0	75.6	24.4	60.0	31.6	17.7	13.9	8.0

Both soils have a high sand fraction and are classified as "clayey sands" reducing the reactivity of the clay and potential ground movements in comparison to pure clays. The depth of the sand cover at D7 limits any impact the clay would have on the surface.

The Geotechnical Investigation is included within **Appendix F**.

4.5.3 Site Classification

The geotechnical investigation concluded that the majority of the site be classified as Class A as there is greater than 1.5 m of sand cover over clayey sands, with the area around D3 classified as Class S due to the reactive fraction of clay in the clayey sand soils. Further investigation will be performed to determine the extent of the formation in that area and will be completed as part of future UWMP(s).

4.5.4 Soil Permeability

Using constant head permeameter apparatus, the in-situ saturated field hydraulic conductivity, Ks, for the soil 800mm below current ground level was tested at the location of the proposed drainage basin area in Lot 1792 (**Figure 5**). The soil was loose Bassendean Sand with a surface level of approximately 21.55mAHD and groundwater was at the minimum as the test was conducted in April 2014. Hydraulic conductivity was measured to be 423mm/hr or 10.15m/day (results are included in **Appendix F**). It should be noted the recorded value is for unsaturated soil state and at the current

density. Any changes to moisture content and density will have effects upon infiltration rates. The recorded value of hydraulic conductivity shows the Study Area is suitable for onsite disposal of stormwater.

4.6 Acid Sulfate Soils

4.6.1 Desktop Investigation

Acid sulfate soils (ASS) are naturally occurring soils which contain iron sulphides, most commonly pyrite (DEC, 2009). These soils can produce a variety of iron compounds and sulphuric acid conditions when exposed to air. The resulting low pH can release other substances such as heavy metals into the surrounding environment which potentially threatens the health of receiving ecological systems (DEC, 2009). Minimising the disturbance of acid sulfate soils is recommended so as to prevent any detrimental impacts on the environment and its surroundings.

Disturbance risk is assessed on the basis of depth from natural ground-surface on the precept that most land development activities including drainage, excavations and dewatering generally do not extend to greater than 3m below natural ground-level. The map includes areas where ASS risk has been predicted using available desk-top information and limited ground-truthing with areas where intensive on-ground mapping and soil analysis work has been carried out.

DEC has compiled maps of ASS risk areas for several coastal regions of Western Australia. These maps are not an accurate representation of the risk areas but rather give a general indication and encourage site-specific investigations to determine management strategies. The land generally holds a moderate-low risk of ASS occurring within 3m of the natural soil surface with some areas holding a moderate-high risk of ASS occurring within 3m of the natural soil surface. (**Figure 9**).

4.6.2 Field Investigation

Selected soil samples collected during the geotechnical investigation were analysed using the DEC field test procedure as well as LECO carbon sulphur analyser and redox potential. Overall these give an indication of whether or not soils are actual, potential or non-acid sulfate soils. Twenty samples underwent these tests and three samples came back as being potential ASS. These soils are generally soils deeper than 2.5 metres with higher clay contents, or the presence of coffee rock. Sixteen samples returned results that indicate they are not ASS but have a sulphur content above the 0.03% threshold for treatment of ASS. A summary of results can be seen in **Appendix D**.

Table 5: Acid Sulfate Soils Test Results

Sample ID	Depth	pHF	pHFOX	ΔpH	Reaction	Sulphur %	Redox
D1	3950-4200	4.44	3.72	0.72	L	0.08451	329.9
D2	2750-3500	4.72	3.52	1.2	L	0.03371	300.2
D2	3500+	4.54	2.1	2.44	L	0.041	401.8
D3	750-1200	7.37	6.27	1.1	L	0.01417	286.9
D3	1200-1500	7.2	6.05	1.15	L	0.02193	315.7
D3	1500-2200	7.88	6.47	1.41	L	0.00993	306.5
D3	2200-3500	7.6	5.62	1.98	L	0.02398	265.3
D4	2250-2500	5.4	3.91	1.49	L	0.2006	392.3
D4	3000-3750	4.42	3.33	1.09	L	0.03832	371.8
D4	4250+	4.95	3.19	1.76	L	0.2666	347.1
D5	2250-2550	5.51	4.49	1.02	L	0.02606	355.9
D5	2550-3150	5.37	3.73	1.64	L	0.07597	305.2
D5	3150+	5.54	3.23	2.31	L	0.07045	339.9
D7	2750-2900	4.53	3.45	1.08	L	0.05975	386.1
D7	4400+	5.24	2.8	2.44	L	0.1041	321.7
D8	3450-3700	4.62	3.22	1.4	L	0.08865	359.3
D8	3700-4350	4.84	3.59	1.25	L	0.03415	319.7
D8	4350+	5.08	3.34	1.74	L	0.1025	340.2
D9	3500+	5.66	4.2	1.46	L	0.06156	333.9
D10	3500+	4.63	3.19	1.44	L	0.03358	364.4

4.7 Groundwater

4.7.1 Regional Hydrology

The hydrology of the Southern River area is typically characterised by Bassendean sand dunes of low relief hosting a superficial aquifer which is about 30 m thick. The Southern River itself acts as a local discharge point for this superficial aquifer. The Perth Groundwater Atlas (2004) shows the groundwater contours slope downwards in a north easterly direction towards the Southern River. Groundwater monitoring and

modelling of the Southern River District was conducted initially by JDA in 2002 and then by Rockwater in 2005. Both the JDA and Rockwater reports indicate that groundwater flow on the site is in a westerly direction towards the FMD. The Perth Groundwater Atlas indicates that the historical maximum drops from approximately 22.8mAHD at the corner of Furley Road and Passmore Street to 20.0mAHD at the corner of Matison Street and Holmes Street (**Figure 6**). Groundwater is locally controlled by the FMD intersecting groundwater levels.

4.7.2 Groundwater Monitoring

12 monitoring bores were installed by Bioscience in 2011 to determine local groundwater conditions across Precinct 3D. The results are shown in **Figure 1** and provided in **Appendix A**. To determine the MGL across Precinct 3D, the Department of Water long term data for bore T85-Thompsons Lake was used to calibrate locally recorded monitoring data with long term trends. T85 was installed in 1975 and is located on the corner of Furley Road and Passmore Street.

After discussion with the City of Gosnells, it was agreed to use the full dataset (1975 - 2013) to determine MGLs. The MGL within this period occurred in 1975 at 21.846 mAHD which was 0.702 m above the long term annual average maximum groundwater level (AAMGL). The 0.702 m difference is applied to the local site AAMGL to calculate the MGL across the site.

The corrected levels for Precinct 3D are mapped in **Figures 7** with the methodology provided in **Appendix A**.

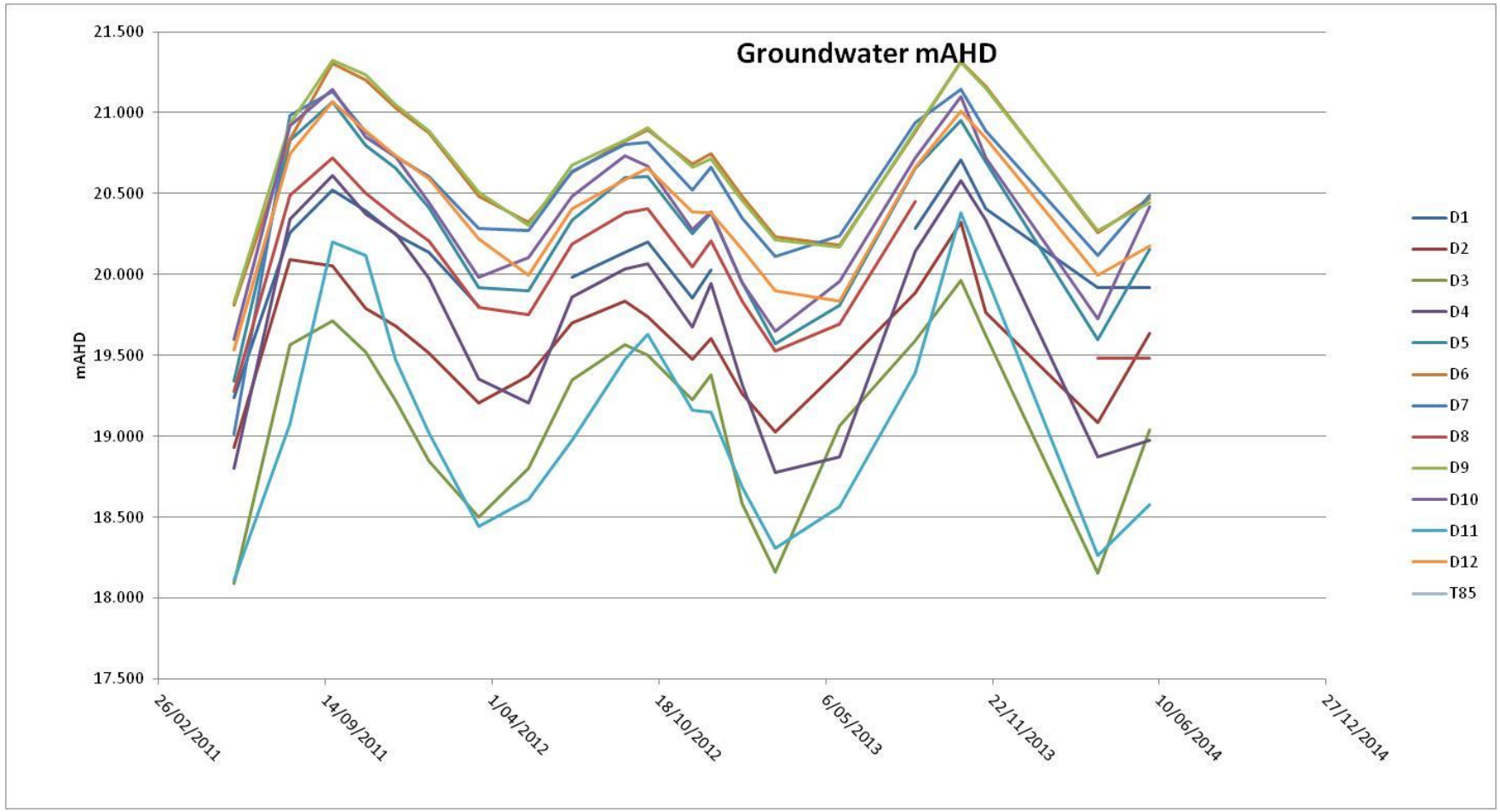

Figure 1: Monitoring Bores Groundwater Levels

The corrected MGLs in **Figure 7** show that local groundwater is flowing in an east to north eastern direction towards the FMD. The FMD acts as a local groundwater discharge point and intercepts groundwater above 19.05mAHD (the culvert invert of FMD under Holmes Street). Bores D2 and D3 have corrected MGLs of 20.128mAHD and 19.814mAHD respectively and would discharge into FMD. These bores have the lowest groundwater levels and the least separation to the surface level; approximately 0.3m from corrected MGL.

4.7.3 Pre-Development Groundwater Quality

Groundwater has been monitored to establish the predevelopment groundwater quality conditions. Groundwater was tested for pH, electrical conductivity (EC), Total Nitrogen (TN), Nitrate (NO_3), Ammonia Nitrate, Total Phosphorus (TP), Filterable Reactive Phosphorus (FRP), Chloride (Cl), Sulfate (SO_4), and Iron (Fe). A summary of results (average and standard deviations) are provided in **Table 6** with full results provided in the **Appendix A.**

Table 6: Groundwater Quality Results

Sample Bore		pH	EC (mS)	Total N (mg/L)	Nitrate NO_3 (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
D1	AVG	4.72	1.18	1.765	2	0	17.75	18.828	148	30.53	0.559
	STND DEV	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
D2	AVG	5.68	0.51	0.37	0.01	0.21	2.23	2.14	51.07	27.68	2.07
	STND DEV	0.22	0.09	0.21	0.02	0.25	0.45	0.58	57.78	9.29	2.28
D3	AVG	5.86	2.42	0.20	0.00	0.23	0.16	0.74	460.84	90.51	39.38
	STND DEV	0.24	0.26	0.14	0.00	0.21	0.15	1.08	732.44	116.02	28.11
D4	AVG	4.72	1.08	1.62	0.00	0.32	15.44	16.13	85.24	97.93	1.34
	STND DEV	0.38	0.40	0.41	0.00	0.29	1.89	1.28	44.89	33.76	0.48
D5	AVG	4.29	0.10	0.26	0.68	0.16	1.63	1.63	8.16	11.33	0.77
	STND DEV	0.58	0.02	0.15	0.54	0.15	0.73	0.63	6.23	13.82	0.46
D6	AVG	6.03	0.21	0.08	1.79	0.15	0.03	0.05	1.65	2.50	0.04
	STND DEV	0.28	0.13	0.07	0.87	0.14	0.01	0.05	2.44	4.42	0.03
D7	AVG	5.67	0.24	0.19	0.61	0.08	0.03	0.17	139.33	8.38	7.60
	STND DEV	0.54	0.03	0.22	0.47	0.09	0.01	0.21	190.74	11.85	1.87
D8	AVG	4.32	0.23	0.33	0.11	0.61	0.70	1.00	10.90	6.60	0.68
	STND DEV	0.40	0.01	N/A	0.16	0.19	#DIV/0!	0.52	#DIV/0!	0.28	0.72
D9	AVG	5.91	0.21	0.07	0.53	0.10	0.03	0.07	5.28	3.24	0.41

	STND DEV	0.44	0.06	0.04	0.45	0.20	0.03	0.11	5.46	3.39	0.32
D10	AVG	3.99	0.32	0.45	0.00	0.27	0.02	0.66	7.18	13.75	0.54
	STND DEV	0.20	0.11	0.00	0.00	0.25	0.03	0.41	1.74	5.93	0.20
D11	AVG	5.82	5.58	0.17	0.00	0.26	0.05	0.02	2001.07	181.43	1.05
	STND DEV	0.06	0.66	0.16	0.00	0.14	0.04	0.03	754.97	61.68	1.14
D12	AVG	3.70	0.22	0.09	0.05	0.23	0.14	0.12	17.31	6.64	0.59
	STND DEV	0.14	0.05	0.05	0.07	0.16	0.14	0.09	0.01	2.28	0.20

Table 7: Water Quality Parameters and Targets

Quality Parameter	Guideline Values (Guideline Reference)	
Electrical Conductivity ($mS.cm^{-1}$)	0.3 - 1.5 (2)	ANZECC ARMCANZ (2000) 1. Fresh water ecosystems 2. Wetlands 3. Long term irrigation 4. Short term irrigation Department of Health (2006) 5. Domestic non potable groundwater use Swan River Trust 6. Swan canning clean up targets
pH	6.5-8.5 (1) 6.0-8.5 (3)	
Total P (mg/L)	0.2mg/L (1) 0.1mg/L (6)	
PO_4-P (mg/L)	0.03 (2)	
Total N (mg/L)	2.0mg/L (1) 1.0mg/L (6)	
NH_4-N (mg/L)	0.04mg/L (2)	
NO_3-N (mg/L)	0.1mg/L (2)	
Fe (mg/L)	0.3mg/L (1) 0.2mg/L (3) 3mg/L (5) 10mg/L (4)	
SO4 (mg/L)	5000mg/L (5)	
Cl (mg/L)	2500mg/L (5)	

pH was highly variable across the precinct; ranging from an average of 3.7 in D12 to 6.03 in D6. pH affects the amount of nutrients that are soluble in soil water i.e. nutrients for plant growth. Many wetlands have near-neutral pH (approximately 7), but considerable variation in either direction occurs naturally and in diurnal cycles. Rainwater is naturally slightly acidic (as low as pH 5.5), due to dissolved atmospheric carbon dioxide, but the pH may be rapidly modified by chemical and biological processes once the water enters the wetland (e.g. carbonate buffering, photosynthesis) (DEC, 2013). In wetlands with little biological activity and few reactive minerals, the pH may remain mildly acidic. Bassendean sands are also naturally acidic and can directly influence the pH of groundwater.

Very low pH in wetlands can be a cause for concern, as it may cause the mobilisation of toxic metals or other contaminants (DEC, 2013). Wetlands can also be acidified by acid sulfate soils. These soils contain acidity stored as sulfide minerals in permanently waterlogged sediments that, if exposed to the air by falling water levels, can result in generation of strongly acidic soils and waters that can potentially flow into receiving waters. In areas expressing highly acid groundwater values further acid sulfate soil investigation should be implemented if excavation is proposed.

Salinity, or electrical conductivity (EC) (mS/cm) ranged from 0.1mS/cm in D5 to 5.77mS/cm in D11. EC values estimate soluble salt content and can be elevated by fertilisers and sulfates that can flow to low lying areas during rainfall events before percolating into soils and groundwater. Seasonally dry areas increase the concentration of salts in the soil and hence groundwater by evaporative processes and decreasing water volumes. This is a natural process but should be monitored. Excessive drying of naturally water logged wetlands by future drainage shall be avoided.

Nutrients in groundwater are substances that provide nourishment for the promotion of life. Generally, the two main nutrients of interest are phosphorus and nitrogen. These nutrients are often present in different forms and influence the type and abundance of living things contained within the study area. Nutrients are carried into the study area by water movements i.e. rainwater generated surface water flows and groundwater flows. They can also be induced by natural or man-made sources i.e. breakdown of organic matter, grazing or migrating animals, leaching from septic tanks, pollutant spills, fertiliser application, past human activities and industry. The concentration of dissolved nutrients in groundwater is normally elevated relative to surface water due to uptake from soils and rocks; the greater the input of water then the greater the potential increase in nutrient levels. This leads to the requirement of nutrient management i.e. reduced fertiliser usage, treatment train approaches to promote a higher quality water reaching receiving waters. Export of nutrients can be regulated by implementing structural control systems to reduce discharge flow rates and hence reduce water level fluctuations.

Total Phosphorus ranged from 0.02mg/L in bores D7 and D10 to 15.44 and 17.75mg/L in bores D4 and D1 respectively. High phosphorus levels can be indications of past human or animal activity i.e. surface water runoff from developed areas, application of nutrients in agricultural management systems and animal grazing. Also the breakdown of organic matter can result in phosphorus leaching. Bores D1 and D4 are located relatively close spatially and the surrounding bores do not present similar elevated values indicating little export of nutrients through the sandy soil. Bassendean sand also has a low nutrient holding capacity (Phosphorus Retention Index < 2mL/g) suggesting a short life of nutrients before export. The high levels are believed to be associated with

the small piggery and slurry holding ponds that operated on Lot 9 between the mid 1970s and early 1980s. No sub-soil drainage will be used in this area to avoid nutrient export into the surrounding environment (section 8.3 covers groundwater management).

Total Nitrogen levels are generally below the Swan River Trust long term target of 1mg/L except at D1 and D4. Nitrate occurs naturally in plants but levels can become elevated if the plants are affected by drought before decomposing and leaching with runoff. Often higher levels are generated with application of fertilisers (ammonia based) and animal grazing. Both nitrogen and phosphorus levels are elevated in bores D1 and D4 indicating the result is caused by past landuse. Groundwater quality targets will be set for post development based on pre development levels.

4.7.4 Groundwater Licences

There is currently one groundwater extraction licences within the proposed development area which is on Lot 6 Matison Street. The licence draws from the superficial aquifer with an allocation of 9,650kL. Groundwater licenses are available for extraction from the superficial aquifer within the City of Gosnells groundwater sub-area.

4.8 Surface Water

4.8.1 Regional Drainage Strategy

The regional drainage strategy for the area has been prepared by the Water Corporation for the Department of Water. It provides the details of the Arterial Drainage Strategy (ADS) for the Forrestdale Main Drain (FMD) catchment discussed in the Southern River ILWMP.

The FMD connects Forrestdale Lake to the Southern River. It was constructed as a rural drain in the 1970s to manage the regional groundwater level and prevent the Westfield Wastewater Treatment site from being flooded. The FMD has levee banks along much of its length and it passes through or adjacent to a number of Bush Forever sites and wetlands.

According to JDA (2002) the FMD is currently 1.5 m to 2.0m below natural surface and currently designed to handle a 3 to 5 year ARI. The FMD ADS (DoW, 2009) states that the FMD requires widening within a linear POS to create online flood storage areas between Phoebe Road and Holmes Street. It states that this should be in the form of a 1.5ha online compensation basin (Figure 3 of the FMD ADS). This widening is incorporated into the drainage strategy and plans for the sub-development.

4.8.2 Site Surface Drainage

Given the relatively flat topography and sandy soil profile of the site, much of the surface water will infiltrate directly at source. The vegetated bushland areas of the precinct also intercept rainfall through evapotranspiration.

The major surface water drainage feature of the site is the FMD which runs along the north western boundary before bisecting Precinct 3D and eventually exiting the site under Holmes Street between Lots 8 Matison Street and Lot 9 Holmes Street. The Balannup Lake Drain connects into the FMD within the Precinct approximately 100m south of culverts under Holmes Street. These drains are significant features in the conveyance of regional stormwater and the drainage of properties in Precinct 3D. There are also some minor depressions across the study area that express groundwater.

Within the Study Area any runoff generated will flow overland to the FMD and minor surface depression. The slight high point in Lot 1792 Holmes Street will drain east to the EPP lake area. Catchments for site are determined from the FMD Arterial Drainage Strategy (ADS).

4.8.3 Estimation of Flows

Estimation of the ***ultimate development*** flow rates for the catchment areas as defined in FMD ADS are shown in **Table 8** below. These flows are based on the 10 and 100 year ARI events for catchment areas defined in the strategy. The catchments in the table reflect the areas that are to be developed in Precinct 3D with CATF11B on the east side of the drain, CATF11C on the west side and CATF11D on the area defined as playing fields and school site in the ODP. Exact locations of the catchments can be seen in Figure A1 of the FMD ADS (**Appendix B**).

Table 8: FMD Ultimate Development Catchment Flow Rates

Catchment	Area (Ha)	Peak Flow (m^3/s)		Detention Volume (m^3)	
		10 year	100 year	10 year	100 year
CATF11B	24.81	0.1	0.2	4340	4830
CATF11C	13.64	0.2	0.2	1420	1920
CATF11D	18.76	0.0	0.3	2480	2890

Shawmac have also prepared predevelopment water quantity calculations as part of the Drainage Summary (**Appendix C**) specific to the proposed ODP area (**Table 9**).

Table 9: Shawmac Pre-Development Flow Rates (Whole ODP Area)

Catchment Code	Description	Flow Path	Area	tc (mins)	Q5 (m^3/s)	Q100 (m^3/s)
A	Eastern portion of site around low point	To existing low point	66,390	22.5	0.38	0.71
B	Portion east of FMD	FMD	76,330	34	0.33	0.62
C	Portion west of FMD	FMD	28,570	24	0.15	0.29

A runoff coefficient of 0.4 was assumed which is in accordance with the FMD study.

Note that this table shows that the pre-development flow rates calculated by Shawmac are not aligning with the FMDADS study. The proposed rates are much higher than the values given in FMDADS. However it is not a major concern as the total storage and the peak flow rates are maintained as per the FMDADS.

4.8.4 Surface Water Quality

The FMD ADS states the typical existing concentrations of total nitrogen and total phosphorus in the FMD are 3.2mg/L and 0.5mg/L respectively. As the drain runs into the Southern River, water quality target for this river must be met, with long term targets for Southern River being 1.0mg/L Total Nitrogen and 0.1mg/L Total Phosphorus. The agreed condition for development by the Swan River Trust is that there is no deterioration in water quality in both the FMD and the Southern River. The water in FMD was sampled and analysed on the 29/05/2014 (**Table 10**).

Table 10: Water Quality Results for Forrestdale Main Drain

Sample Bore	pH	EC (mS)	Total N (mg/L)	Nitrate NO_3 (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
FMD	7.09	1.026	0.582	0.25	0.01	0.066	0.098	507.8	19.23	0.869

4.9 Wetlands

The Geomorphic Wetlands Dataset displays the location, boundary, geomorphic classification and management category of wetlands on the Swan Coastal Plain. According to the dataset the whole Precinct 3D has numerous Multiple Use Wetlands (MUW) (15792 Dampland, 15810 Dampland, 15633 Dampland), two Rescource Enhancement Wetlands (REW) (15728 Dampland, 15793 Dampland), (**Figure 8**). To the north of Holmes Street off the site, there is also a Conservation Category Wetland (CCW) (Dampland 7720).

Around one third of Lot 1792 has been classified as an *Environmental Protection Policy (Swan Coastal Plains)* 1992 (EPP) lake (**Figure 8**). EPP wetlands are generally recognised as having significant conservation value; however this seems to contradict the current MUW classification in regards to both management category and boundaries.

Since 2010, Bioscience has been liaising with the Department of Environment Regulation (DER) and City of Gosnells in regards to the incorrect demarcation of the EPP Lake classification. The reason for the anomaly is firstly, because the area is not a Lake as defined within the policy, and secondly it has low environmental values due to extensive grazing by horses.

It is noted that there is no mechanism for correcting anomalies in the mapping of EPP Lakes, however the Minister for Environment has the discretionary power to cast aside the classification in the event that a development application is received. In this instance, the development application would take the form of the proposed ODP and therefore the formal lodgement of the ODP will enable the Minister to exercise such discretion.

4.10 Vegetation

The whole Precinct D area has around 60 percent remnant bushland. The remaining area has been cleared for building envelopes and grazing for horses and as such generally contains introduced grasses. A large percentage of the bushland areas belong to Bush Forever sites 340 and 465 and contain a combination of *Eucalyptus* and *Banksia* woodland.

The *Bush Forever* site description states that six Floristic Communities Types (Gibson et al., 2000) within three supergroups are likely to reside within the site; including,

Supergroup 2: Seasonal Wetlands

- *4 *Melaleuca preissiana* damplands
- *5 Mixed shrub damplands
- *8 Herb-rich shrublands in clay pans
- *15 Forests and woodlands of deep seasonal wetlands

Supergroup 3: Uplands centred on Bassendean Dunes and Dandaragan Plateau

- *23a Central *Banksia attenuata — B. menziesii* woodlands

Supergroup 4: Uplands centred on Spearwood and Quindalup Dunes

- *group with which upland Muchea Limestone communities have been associated

*Not sampled, types inferred

Considering the site has not been surveyed and inferences have been based on aerial photography the likelihood of supergroup 4 existing within the subject site is not likely. It is likely that supergroup 2 and 3 exist within the subject site with floristic community types 4, 5, 15, and 23a possible. It is worth noting that floristic community type 15 is listed as vulnerable under the DEC's Threatened Ecological Community Database.

The subject site has also been mapped by Heddle et al (1980) as Southern River Complex. The Southern River Complex has as little as 19.72% remaining with only 2.18% protected according to the Perth Biodiversity Project (WALGA, 2010). According to the EPA 30% is the threshold level at which species loss accelerates exponentially at an ecosystem level (EPA, 2000a). The EPA Position Statement No. 2 (2000a) considers any complex <30% as 'Endangered'.

4.11 Fauna

A desktop of potential rare and endangered fauna listed under the *Wildlife and Conservation Act 1950* and *EPBC Act 1999* was undertaken by analysis of *NatureMap:* Western Australia's biodiversity online mapping (DEC, 2011).

A site investigation was conducted by Bioscience for the presence of rare and endangered fauna and fauna habitat. Fauna survey of the subject land involved a careful walk-through of the subject area documenting all native species present as well as presence of fauna habitat.

Native Fauna within Western Australia are protected under the *Wildlife and Conservation Act 1950* however greater protection is placed on fauna considered rare or threatened. Australia has also signed agreements with China (CAMBA) and Japan (JAPAN) for protection of migratory birds and migratory bird habitat. The DEC classifies rare native fauna under 6 conservation codes.

A search on DEC's *NatureMap* online indicated that 1 Threatened and 1 Priority fauna exists within 3km of the centre of the subject site (32° 06' 31 S, 115° 58' 12 E). Of the Threatened and Priority fauna one is listed under the EPBC Act (1999) as Endangered.

Table 11: Threatened and Priority Fauna within Search Area

Species	DEC Conservation Code	EPBC Act Category
Calyptorhynchus latirostris (Carnaby's Cockatoo)	T	Endangered
Isoodon obesulus ssp. fusciventer	P5	-

(Southern Brown Bandicoot, Quenda)

ENV Australia conducted a fauna field survey in 2006 as part of the entire Precinct 3 Environmental assessment. Ground fauna trapping was carried out under CALM licence SF005124. Only one trap was placed within the subject area within Bush Forever site 340. The fauna survey revealed a total of 4 Amphibians, 10 Reptiles, 2 Mammals and 1 insect observed/captured within the subject site (**Table 11**).

Table 12: Ground Fauna observed and/or trapped within subject area (ENV Australia, 2006)

Group	Species	Common Name
Amphibians	*Crinia glauerti*	Glauert's Froglet
	Crinia insignifera	Squelching Froglet
	Heleioporus eyrei	Moaning Frog
	Litoria moorei	Motorbike Frog
Reptiles	*Chelodina oblonga*	Long-necked Tortoise
	Pletholax gracilis gracilis	Slender Snake Lizard
	Pogona minor	Western Bearded Dragon
	Varanus gouldii	Gould's Sand Monitor
	Acritoscincus trilineatum	South-west Cool Skink
	Cryptoblepharus plagiocephalus	Fence Skink
	Lerista distinguenda	South-Western Four-toed Lerista
	Menetia greyii	Dwarf Skink
	Tiliqua rugosa	Bobtail
	Notechis scutatus	Tiger Snake
Mammals	*Macropus fuliginosus*	Western Grey Kangaroo
	*Vulpes vulpes**	Red Fox
Insect	*Apis mellifera**	Feral Honey Bee

**Introduced feral species*

Of the ground fauna observed and/or trapped within the subject area none are listed as threatened under state legislation. The South Western Bandicoot or Quenda (*Isoodon obesulus fusciventer*) was however trapped 19 times within the entire Precinct 3 (although not within the subject area). The South Western Bandicoot is listed as a Priority species under state legislation.

A further 64 bird species were observed within the entire Precinct 3, two of which are listed as Threatened under state legislation, including; Carnaby's Cockatoo (*Calyptorhynchus latirostris*) (Endangered under EPBC Act 1999), and Forest Red-Tailed Black Cockatoo (*Calyptorhynchus banksii naso*) (Vulnerable under EPBC Act

1999). Precinct 3 was examined by ENV Australia (2006) for potential breeding sites for Black Cockatoos, Owls, and Peregrine Falcons. Only one hollow was considered potentially suitable for Black Cockatoos and/or Owls however was not in use nor was it within this Study Area.

According to ENV Australia (2006) Precinct 3 is potentially inhabited or frequented by around 221 species of vertebrae fauna with 92 species confirmed (**Appendix E**).

5.0 Water Use and Sustainability Initiatives

Developments increase water resource demands and the Better Urban Water Management (WAPC, 2008) guidelines indicate that a development should sustainably manage and utilise the supply and usage of water within it. This LWMS includes strategies aimed at achieving a better management of water resources to reduce the impact that the development has on resources and the surrounding environment.

5.1 Water Conservation

Water is an essential requirement and valuable resource for all developments and practical water conservation methods should be considered to maintain an appropriate efficiency of water consumption. Conservation methods should incorporate both the use of potable and non-potable water sources. There are several methods utilised in planning to achieve the Better Urban Water Management target consumption reductions discussed within this section.

5.1.1 Fixtures and Fittings

All homes shall be designed to the current Building Codes for Australia and the City's own efficiency ratings. All development within the precinct will be required to meet minimum WELS water efficiency requirements, with WELS 3 star showerheads and WELS 4 star taps and dual flush toilets.

5.1.2 Rainwater Harvesting

As large percentages of potable scheme water are used externally on landscaped areas it is possibly the greatest opportunity to reduce total usage. Rainwater tanks are employed as a method of retaining runoff onsite to be used in dry periods. They also, in effect, work as a peak water retention device as the lot owner/ user will release flow gradually whilst reducing the dependence on potable scheme water. Rainwater from roofs and other large impermeable areas can be collected in rainwater tanks and used.

5.1.3 Waterwise Landscaping

Waterwise landscaping forms a large portion of water conservation strategy as successful approaches reduce the quantity of water required for irrigation and also reduce the total runoff. Landscaped drainage within the site boundaries will be located in road reserves, drainage basins and any open space where possible and designed to meet the requirements of Liveable Neighbourhoods (WAPC, 2009a) and the City's planning guidelines. Any irrigation required should be from an appropriate source i.e. treated wastewater, licensed bore, rainwater harvesting. An average water irrigation rate of 6750/ha/year is expected across the development.

The development will achieve water conservation through landscaping by planting drought tolerant indigenous species, reducing the area of lawn, increasing pervious areas, improving soil water holding capacity and, where irrigation is required, the installation of water efficient systems. Soak away systems should also be incorporated to maximise infiltration where possible.

Indigenous vegetation have minimal or no irrigation requirements and should be planted throughout the development including within the road reserves and basins. Such plants also help to promote a natural healthy ecological environment and minimise the introduction of alien species whilst offering a habitat for native species. Where irrigation of vegetated areas cannot be avoided, it should be restricted during the day as evaporation rates are at the greatest. Plant species will be indigenous and suitable to the Swan Coastal Plain.

Road reserve vegetation shall be protected from vehicular damage by a kerb stone perimeter when required. The road gradient should also act to convey surface water directly into the entry points in an efficient manner to achieve rapid entry into infiltration drainage systems. Appropriate ground surfaces should also be chosen where possible to achieve higher infiltration and lower the evaporation rate i.e. mulch, porous paving, gravel. Maintenance of landscaped areas should be easily achieved by incorporating access points. The plant species should also facilitate low maintenance with minimal requirements for irrigation and upkeep.

A concept landscape plan is included in **Figure 10a-10b**. The plan shows the POS areas and Raingardens as well as indicating where irrigation is required and water quantities.

5.2 Groundwater Use

Approximately one third of all households in Perth use groundwater for irrigation purposes. The shallow depth to groundwater in the Southern River area makes this a cost effective option. Residential bores do not require extraction licences for areas less than 2000m². Residential landscape packages are to be waterwise and incorporate features to reduce groundwater dependency i.e. native species of plants and small lawn areas. Rainwater harvesting tanks will also be offered to residents to further reduce groundwater extraction.

Currently the DoW considers the City of Gosnells groundwater supplies are not fully allocated, thus groundwater licences are available for irrigation or large public open space and school district playing fields. Groundwater licences will be applied for prior to

commencement of UWMP stage. Any landscaped areas will be planted with low water use native species to reduce requirement for irrigation.

5.3 Development Water Balance

This water balance aims at assessing the impacts of the development on wetlands through groundwater changes and therefore does not consider potable scheme water. It is a simplistic approach for assessment of project feasibility. The calculations will be refined at subdivision stage as more detailed design is complete.

Table 13: Water Balance

Water Balance				
Rainfall				
mm	m			
829.1	0.8291	Rainfall Total	**123.66**	**ML**
PRE DEVELOPMENT				
Evapotranspiration rural 600mm (JDA 2009)	149153	0.6	**74.20**	**ML**
Recharge Pre Development			**49.47**	**ML**
POST DEVELOPMENT				
	m2	Recharge Coefficient		
Park (POS, FMD, REW)				
Catchment A	5720	0.8	3.79	ML
Catchment B	4932	0.8	3.27	ML
Catchment C	5144	0.8	3.41	ML
		0.8	0.00	ML
		0.8	0.00	ML
		0.8	0.00	ML
Residential				
Catchment A	34954	0.5	14.49	ML
Catchment B	46318	0.5	19.20	ML
Catchment C	11831	0.5	4.90	ML
Road				
Catchment A	17086	0.25	3.54	ML
Catchment B	24220	0.25	5.02	ML
Catchment C	5725	0.25	1.19	ML
Water Courses				

Catchment A	3200	0.4	1.06	ML
Recharge Post Development	**159130**		**59.88**	**ML**
Difference			**10.41**	**ML**

Note: Runoff coefficients and catchment areas in accordance with Shawmac drainage design assumptions.

The potential recharge is a best estimate at this stage and will be refined at UWMP stage when more detail is available.

Irrigation Requirements

The Shawmac Drainage Summary and post development catchments indicate that there will be a total of 5,720m^2 of POS in catchment A and the total area of the basin is 3,200m^2 which can be planted with native vegetation (**Figure 10a**). The remaining area would require approximately 6,750kL/ha/year for irrigation.

There will be no need of irrigation within Catchment B due to native vegetation in the resource enhancement wetland.

Catchment C comprises of the Forrestdale Main Drain. As indicated in the landscape concept plan (**Figure 10b)**, with the main drain and the widening being native vegetation and the POS fronting the road reserve and the R25 residential lots, the total area of irrigated POS would total 5,144m^2.

Based on above assumptions, the total irrigated area would be less than 1.1ha requiring 6,750kl/ha/year, i.e. 7425kL/year. The existing groundwater licence allocation is 9650kL and would be sufficient at this stage.

However, the final irrigation requirements will be refined at subdivision stage when detailed landscape plans have been produced to support the assumptions and calculations.

The use of native vegetation will help in reducing the overall irrigation requirements.

6.0 Stormwater Management Strategy

The site falls within the area covered by the Forrestdale Main Drain Arterial Drainage Strategy (FMD ADS) (DoW, 2009). This was commissioned by the Water Corporation to gain a better understanding of the FMD and the catchments which feed it, as well as determining how it will be impacted by future development. The strategy provides guidance on flood protection and fill requirements as well as stormwater retention and flow rate requirements to ensure the capacity of the drain is not exceeded.

This stormwater management proposal is consistent with water sensitive urban design practices (WSUD) and aims to meet the objectives outlined as per the design criteria (Section 3). The management of stormwater will focus on infiltration and treatment of 1 in 1 year ARI events and the detention and treatment of 1 in 5 year ARI events, with water from events exceeding this to be discharged into the FMD following treatment of the first flush (1y 1h volume). The FMD ADS provides flow and levels of the FMD at the subject site and defines the allowable flow rate from defined catchments into the drain.

The stormwater system has been modelled by Shawmac (**Appendix C**) to allow for appropriate sizing and treatment of Raingardens, pipes and basins to ensure flows and volumes from the site are within the requirements specified in the FMD ADS.

As seen on **Appendix C,** the extent of pit and pipe network has been reduced as directed. Barrier kerbing (and no bollards) is now proposed adjacent to all open space and the drainage corridor.

6.1 Forrestdale Main Drain Widening

The FMD requires widening as per the ADS. The ODP is to provide a 1.5ha online compensation basin as shown in Figure 3 of the ADS (**Appendix B**). The online basin has been included in the Shawmac drainage design plans (**Appendix C**). The FMD living stream cross section has been amended as directed, to provide max 1:9 slopes.

The widened drain section consists of a main drainage channel that will contain winter base flow and small storm events, this will then extend out to a broader channel that will contain up to 100year events. The channels will be supported by walls or rocks with native planting on slopes of 100 year flow channel. Planting will consist of appropriate native species that will improve general the aesthetics of the drain and providing habitat for fauna.

The FMD ADS also includes an online compensation basin to the north of Lots 32 & 33 Phoebe Street, and Bush Forever site 465. This is land outside of the ODP area but any

additional storage volume provided along the FMD will benefit Precinct 3D. The ADS also shows some overland flows passing through Bush Forever site 340 in larger events; these natural flow paths will not be inhibited by the proposed ODP as no development will occur within Bush Forever areas.

The Balannup Drain will also be maintained and rehabilitated as a living stream as per the requirements of the City. It will also be formed into the drainage concept for the online compensation basin required in the FDM ADS.

6.2 Lot Drainage

Lot levels have been set to gain the 1.7m separation to MGL and allow for frequently occurring rainfall events to be infiltrated close to source. This will be largely achieved naturally and will require some import of fill material in order to allow soakwells to be used across the development. Soakwells have been sized to the 5 minute 20 year event and will be 1.2m deep by 1.8m in diameter. Bases will be 0.5m above MGL levels.

Note that, rainwater harvesting has not been considered while sizing the soakwells. As said previously, soakwells are provided for the 1:20, 5 minute event in accordance with CoG and BCA requirements. Rainwater harvesting may be implemented by individual owners, but this will not impact soakwell sizing due to these other requirements. Soakwell sizing has been undertaken based on the method outlined in the Stormwater Management Manual of WA. Lot drainage management will involve roof and impervious areas being directed to soakwells (and rainwater tanks if provided), flows in excess of this capacity will be directed to the street drainage network via overland flow.

6.3 Street Drainage

Street drainage will consist of road side Raingardens to infiltrate and treat 1yr 1hr events. As detailed in the Drainage Summary (**Appendix C**), Raingarden sizing has been recalculated, based on the first 15mm of rainfall from the connected impervious areas. Raingardens are to be 300mm deep with hard vertical retaining walls to mitigate nuisance insect breeding. Water storage depth will not exceed 250mm. The onsite permeability was assessed to be in excess of 10m/day; Raingardens have been designed to a conservative 5m/day. Bases of rain gardens will be 0.5m above MGL.

Events between 1 and 5 years will be conveyed by piped drainage to either a retention basin in Catchment A or FMD. The Shawmac Drainage Summary provides management details of 5 year events with allowable post development flows calculated proportionally to predevelopment catchments.

Rainfall events greater than 5 years will be conveyed via overland flow once pipe drainage capacity is exceeded; into either the retention basin in Catchment A or FMD. Management details are provided in the Shawmac Drainage Summary (**Appendix C**).

6.4 Public Open Space and Basins

Shawmac have developed the drainage plan for the ODP; in keeping with the FMD ADS and Section 7.1, FMD will be widened to provide online storage within the main drain. This will provide a 0.27ha area that will be seasonally inundated with water. The embankments and top of embankments offer potential for planting of native species and revegetation.

A retention basin is proposed within Catchment A, Basin CA. Basin CA is located in the POS towards the east of the site and will require an area of 3,200m² to fully retain and infiltrate the critical 100 year ARI storm event. The basin is not connected to an overflow and will have a minimum separation from the base to the MGL of 0.5m. The POS area in Catchment A will total 5,720m²; the remaining area not required actively for drainage will be vegetated with native species and have a surface covering of mulch whilst leaving an allocation of irrigated turf for public use. Basin and POS cross sections have been provided by Shawmac. Innovatively, the design allows for maximum usage in events up to 5 years by providing a raised central profile with perimeter rain gardens to ensure that much of the basin remains dry and accessible. The Shawmac proposal identifies the required storage areas for different storm events.

The current basin design are schematic only to show indicative volume requirements. Landscape design and management plans will be developed at subdivision stage and will include a "naturalistic" approach to create habitats for fauna and flora. Upon advice from the DoW, landscaping concepts should utilise natural topographical features, such as, surface depressions and existing flow paths, to best manage water resources and provide a sensible approach to hydrological and ecological management.

7.0 Groundwater Management Strategy

There are three primary objectives for groundwater protection and management for the proposed development, these include:

- Protection of infrastructure and assets from flooding and inundation which may be brought about by high groundwater levels.
- Protection of groundwater dependent ecosystems from modified groundwater hydrology following development.
- Maintaining and managing groundwater levels and quality following development.

7.1 Protection of Infrastructure and Assets

Fluctuating groundwater levels can have damaging consequences to the structural integrity of infrastructure. Excessive water leads to soil swelling and reduced soil moisture content creates shrinkage. Both can induce excessive deflections and cracking in foundations, building structures, pipes etc.

Common post development influences on groundwater are;

- Increased runoff resulting in reduced localised infiltration
- Excessive infiltration and localised groundwater mounding
- Increased groundwater extraction for development use (irrigation)

The AAMGL and MGL have been previously calculated (Section 6.4.2) using three years of onsite monitoring data calibrated against DoW long term monitoring levels. All lot levels will be a minimum 1.7m above MGL allowing soakwells to be used throughout the development for frequently occurring events. All basins and rain gardens will have a clear separation of 0.5m over the MGL.

7.2 Protection of Groundwater Dependent Ecosystems

The groundwater dependent ecosystems that could be impacted by the proposed development are REW Dampland 15793, CCW Dampland 15728 and CCW Dampland 7720 to the north of Holmes Road. Ensuring groundwater flows and quality are retained and improved is the key to protection of the groundwater dependant ecosystems.

Potential threats to groundwater dependent ecosystems will be managed by:

- Lots provided with waterwise landscaped gardens with rainwater harvesting systems to minimise private groundwater bore dependency
- POS to have waterwise landscaping and irrigated through water efficient system
- No use of subsoil drains
- Infiltrate water close to source to minimise hydrological changes

7.3 Groundwater Quality

Groundwater quality is variable across the site, with legacy nutrients present in some bore sampling locations associated with past land use. The key objective of this LWMS is to maintain and, if possible, improve the groundwater quality post development. This will be achieved by not using subsoil drainage that can mobilise groundwater and alter groundwater levels. Frequently occurring rainfall events will be infiltrated at source, replicating the existing scenario, and vegetated bio-retention areas strip nutrients from runoff biologically before it infiltrates.

Fertiliser application will be managed throughout the POS with landscaped areas planted with native species suited to sandy sites. Information packs will be supplied to home buyers offering tips of reducing external water and fertiliser use. A soil amendment with a reasonable phosphorus retention index, while allowing reasonable infiltration (such as a sandy loam), is required to be incorporated into bases of rain gardens and basins.

8.0 Construction Management

8.1 Imported Fill Material and Compaction

The permeability of an imported fill is proportional to the fine particle fraction (i.e. <0.075mm). Bioscience considers most sandy soils on site are suitable fill material as they contains less than 5% fines and have a maximum particle size of less than 10 mm; they are mostly free of any organic or deleterious material. However given the conditions of the site, it is likely that fill material will have to be sourced from elsewhere and transported to the site.

Fill materials, placement and compaction methods and quality control should apply with relevant structure fill requirements according to standard industry practice and AS 3798 “Guidelines on Earthworks for Commercial and Residential Developments”. The fill should generally be placed in loose layers not exceeding 300mm thickness and each layer should be compacted with suitable equipment to a minimum of 95% modified maximum density or 70% density index as appropriate.

8.2 Dewatering

Throughout the construction phase of the development dewatering may be required. Prior to the commencement of any dewatering a licence to take water will be required through application to the DoW. If possible, site preparation should occur during dry periods to reduce or eliminate dewatering requirements. Should dewatering be required, a monitoring and treatment program must be implemented as outlined in *Treatment and management of soils and water in acid sulfate soil landscapes* (DEC 2011) after an ASS investigation has been undertaken according to *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* (DEC 2009) to ensure construction and dewatering activities effectively manage disturbances to ASS and treat dewatering effluent appropriately.

Dewatering management plans cover the full spectrum of treatment and management of groundwater required when undertaking dewatering. This includes but is not limited to acidity monitoring and neutralisation, heavy metal monitoring and nutrient monitoring. The management of dewatering requires that all monitored levels are to remain within set guidelines and have contingency plans enacted if guidelines are exceeded. All effluent is to be infiltrated as close to source as possible to limit groundwater drawdown outside the area required for excavation. The legacy nutrients present in some locations of the site will require more stringent management to ensure groundwater with high nutrient levels is not exported from the site. If remediation is possible to soils from areas with elevated nutrients it should be undertaken to compliment the groundwater

treatment whilst dewatering. A full dewatering management plan will be provided as part of subsequent UWMP(s).

9.0 Monitoring

A monitoring program has been designed in accordance with the joint Australian/New Zealand Standards (1998 a, b, c) to allow quantitative assessment of hydrological impacts of proposed development within the area. In particular the program addresses the monitoring of surface water quality, and seasonal fluctuation of groundwater levels and quality within the development area. The program may need to be modified as data is collected to increase or decrease the monitoring effort in a particular area or to alter the scope of the program itself. Any modification to the program would require the agreement of all parties (DoW, CoG, and the developer). The program is designed to operate over a three year post-development period (After completion of 80% of the lots) including throughout construction to allow for time lag for full impacts of development on the receiving environment to occur (**Table 13**).

Table 14: Monitoring Schedule

Monitoring Type	Parameter	Location	Method	Frequency	Reporting
Groundwater Levels	Water levels (mAHD)	12 monitoring bores pre-development and 8 monitoring bores post-development providing spatial coverage.	Water Interface Probe/meter	Monthly for 2 pre-development and 3 years post-development.	Annual assessment reports to be submitted to DoW & CoG for 3 years post-development. Suitability of existing monitoring and reporting frequencies to be assessed annually with any modifications requiring agreement by all parties (DoW, CoG, & Developer)
Groundwater Quality	pH, EC, Nitrogen, Phosphorus, major Cation and Anions	12 monitoring bores pre-development and 8 monitoring bores post-development providing spatial coverage	Pumped bore sample	Quarterly for 2 pre-development and 3 years post-development (typically Jan, Apr, Jul and Oct).	
Surface Water Quality	pH, EC, TSS, Nitrogen, Phosphorus, major Cation and Anions	At inflow points to infiltration and/or water quality treatment areas and, at outflow from the water quality treatment areas. FMD at entry to Precinct 3D and at exit point (Holmes street)	Surface collection	Monthly sampling when flowing, typically June to October for 5 years. Frequency to be reviewed following initial 12 month sampling period.	

POS Usability	Water levels (mAHD)	Water level recorder at POS flood storage area frequency and duration of inundation to be assessed.	Continuous water level measurements via water level data logger and periodic visual inspections.	3 years post-development	
Vegetation	Number of dead plants and weeds	Areas where plants have been planted in POS areas.	Visual inspection	3 years post-development	
Erosion	Signs of erosion	Along the entire drainage corridor.	Visual inspection	3 years post-development	

10.0 Implementation

Roles and responsibilities for the Precinct 3D development are detailed in **Table 14**:

Table 15: Table of Responsibility

Item	Development	Interim Maintenance (first three years)	Long-term Maintenance
Waterwise Fittings	Developer in consultation with Residents	Residents	Residents
Residential landscaping Packages	Developer	Residents	Residents
Rainwater tanks	Developer in consultation with Residents	Residents	Residents
Raingardens and Drainage	Developer	Developer	Council
Monitoring the Development	Developer	Developer	Council
Public Open Space Landscaping	Developer	Developer	Council

11.0 Future Work - Subdivision and UWMP

The Urban Water Management Plan (UWMP) is mostly an extension of the work developed through the LWMS and requires further work to help define detailed design. The additional work includes:

- Continue predevelopment groundwater and surface water quality monitoring to develop trigger values and water quality improvement targets
- Determination of post development monitoring points for groundwater and surface water quality and quantity
- Detailed landscape management plans and irrigation plans for drainage and public open space areas
- Refinement of stormwater system to final design levels (detailed design)
- Detailed geotechnical investigation across building/ construction footprints
- Application for any groundwater extraction licences
- A dewatering management plan, as required
- Acid sulfate soils management plan, as required

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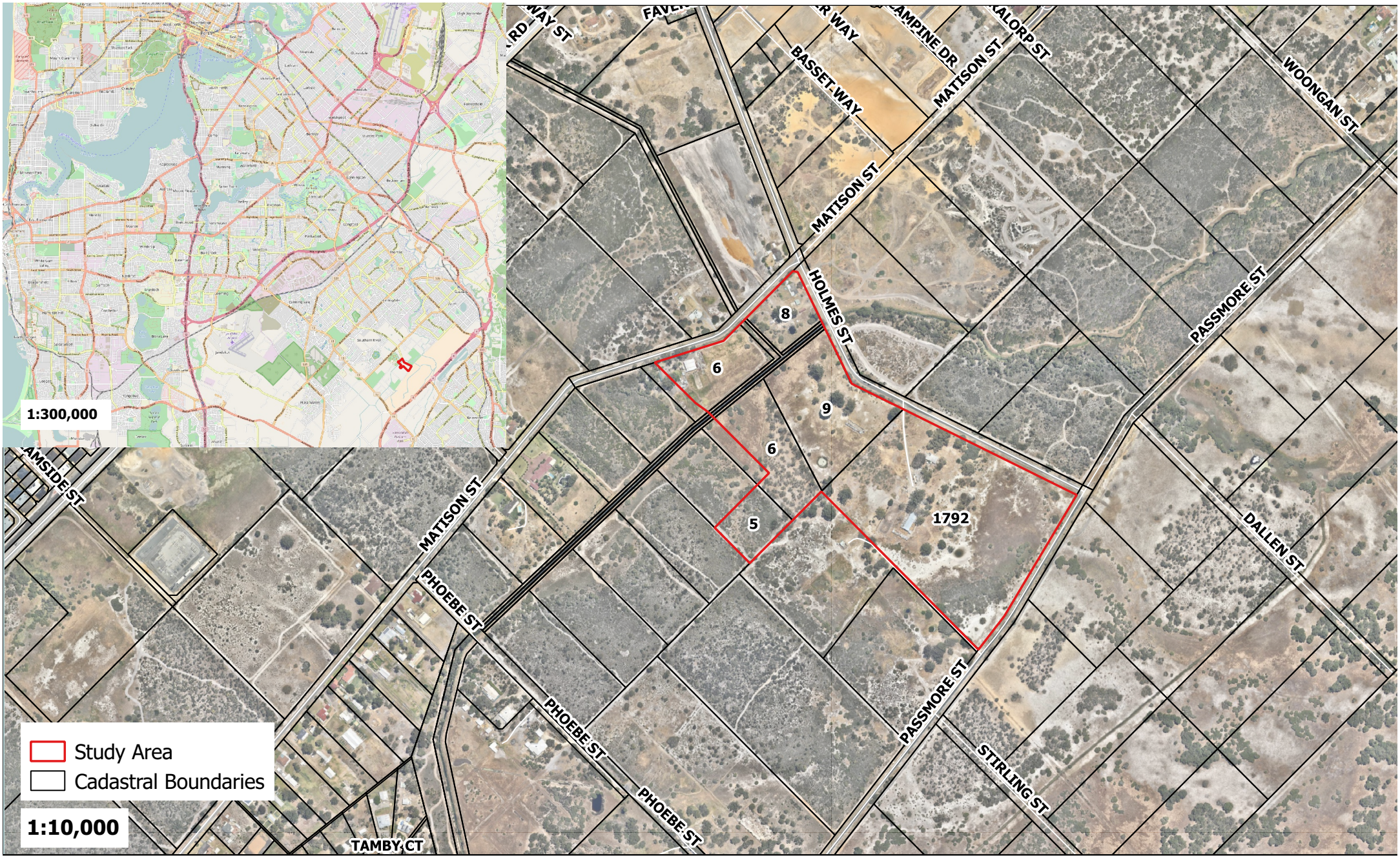

Bioscience

Integrating Resource Management

Project Title: Southern River 3D Local Water Management Strategy
Client: Dynmaic Planning
Date: 13/12/2016
Drawn: TL
Checked:
Revision: 1

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FIGURE 1. Site Location

Southern River Precinct 3D

Source: Aerial (Nearmaps 13/12/2016); Cadastre (Landgate 21/07/2016); Streetmap (OpenStreetMap 13/12/2016)

FORRESTDALE MAIN DRAIN AND BALANNUP LAKE DRAIN TO BE CONVERTED INTO LIVING STREAM

UPGRADE EXISTING CULVERTS

HOLMES STREET TO BE REALIGNED

HOLMES STREET

MATISON STREET

PASSMORE STREET

BASIN CA
TOP AREA 3200m²
BOTTOM AREA 972m²
TOP LEVEL 22.50m
BOTTOM LEVEL 21.50m

FLUSH KERB ADJACENT TO POS AREAS

FORRESTDALE MAIN DRAIN
COMPENSATION AREA 1.6Ha
BASE LEVEL 19.05m TO 19.26m
TOP LEVEL 21.40
TOTAL STORAGE PROVIDED 15,700m³

FLUSH KERB ADJACENT TO FMD/POS AREAS

LEGEND

- EXISTING CADASTRAL BOUNDARY
- PROPOSED CADASTRAL BOUNDARY
- SITE CATCHMENT BOUNDARY
- PROPOSED NOISE WALL
- PROPOSED FLUSH KERB
- PROPOSED DRAINAGE PIT & PIPE
- PROPOSED CULVERT & HEADWALLS
- 22.0 DESIGN EARTHWORKS/ROAD CHANNEL LEVEL
- PROPOSED RAIN GARDEN
- DRAINAGE BASIN

0 10 20 30 40 50m
1 : 2000 (A3) 1 : 1000 (A1)

REV	DATE	DESCRIPTION	APPROVED
D	30.01.17	GENERAL AMENDMENTS. ISSUED TO D.O.W.	RN
C	22.03.16	MINOR AMENDMENTS	RN
B	18.12.15	MINOR AMENDMENTS	RN
A	12.11.15	ISSUED FOR LWMS REVIEW	RN

ISSUE AND REVISION HISTORY

CLIENT: DYNAMIC PLANNING AND DEVELOPMENTS

LOCAL GOVERNMENT AUTHORITY: CITY OF GOSNELLS

SCALE @A1 HORIZ: 1:1000

DATUM
HORIZONTAL: PCG94
VERTICAL: AHD

SHAWMAC
1ST FLOOR
908 ALBANY HIGHWAY
EAST VICTORIA PARK
WA 6101
P 9355 1300
E admin@shawmac.com.au
CONSULTING CIVIL AND TRAFFIC ENGINEERS

DATE DRAWN:	30.10.15
DESIGNED:	RN
DRAWN:	CRF
CHECKED:	RN
APPROVED:	BH

CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D CONCEPT PLAN

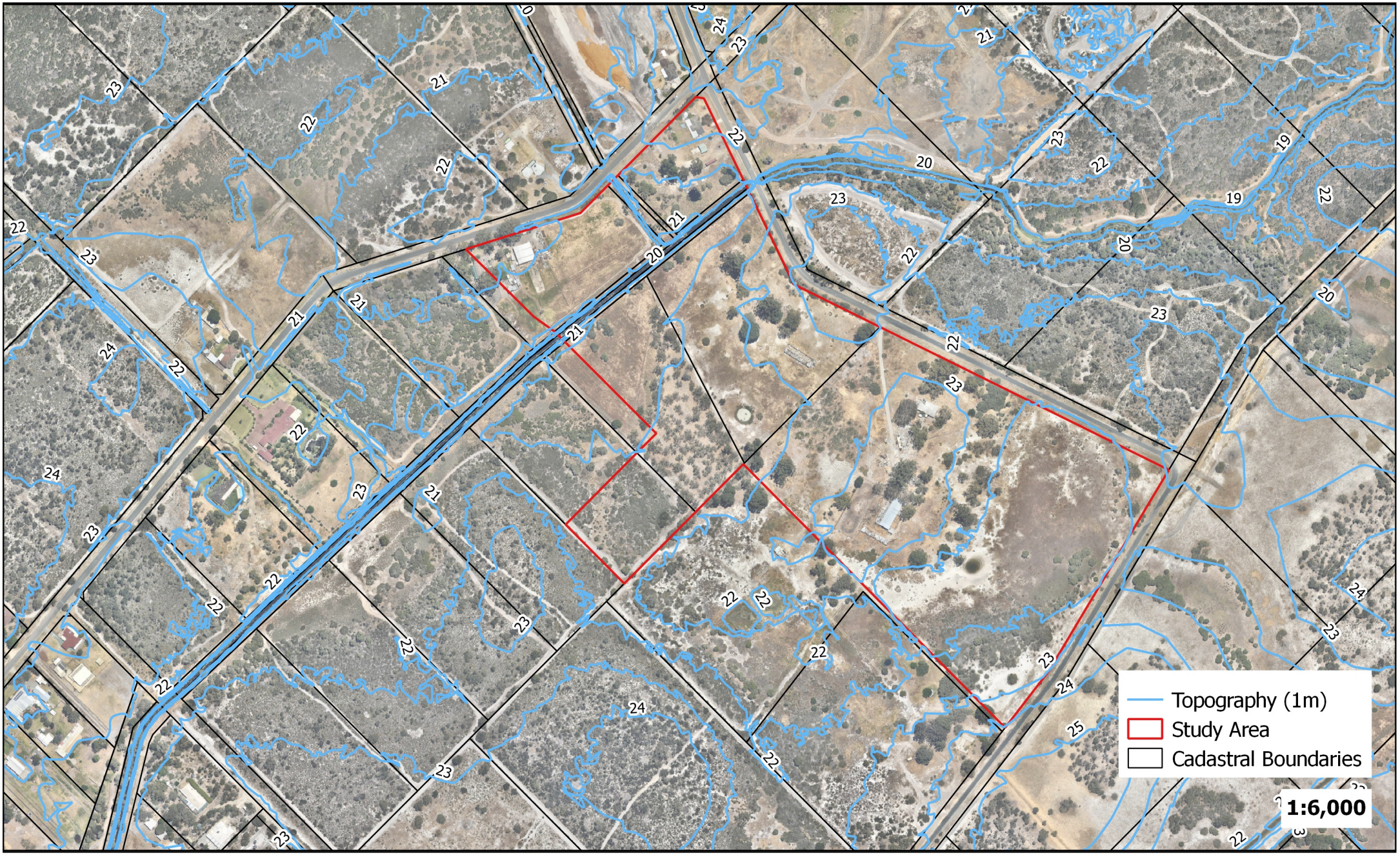
FIGURE 2. ODP

DRAWING NUMBER: 1201008-201

REV. D

FILE REF: Z:\Jobs Active 2012\CE - Land Development\1201008-Bioscience - Southern River Precint 3D\Drawings\1201008-200 Plans

LAST SAVED BY: Cameron DATE: 30 January 2017 1:56 PM



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Integrating Resource Management

Project Title: Southern River 3D Local Water Management Strategy
Client: Dynmaic Planning
Date: 13/12/2016
Drawn: TL
Checked:
Revision: 1

BIOSCIENCE PTY LTD

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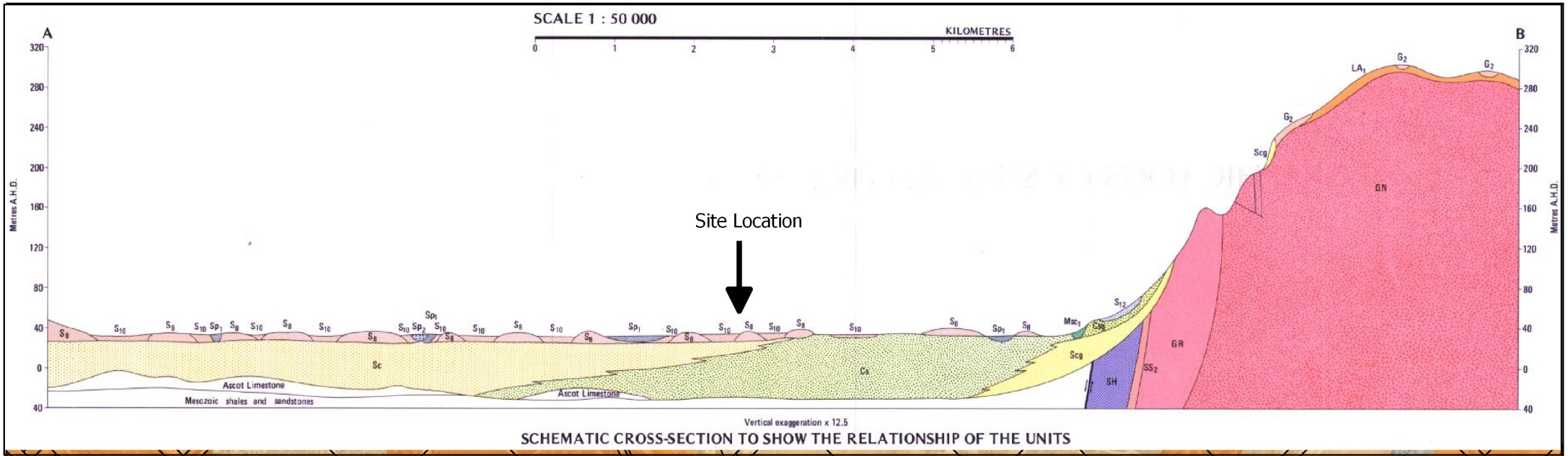
EMAIL: bioscience@biosciencewa.com
WEBSITE: www.biosciencewa.com

FIGURE 3. Topography

Southern River Precinct 3D

Source: Cadastre (Landgate 13/12/2016); Topogrpahy (DoW - LiDar, 02/09/2013); Aerial (Nearmap, 13/12/2016)



S8 - SAND - white to pale grey at surface, yellow at depth, fine to medium-grained, moderately sorted, subangular to subrounded, minor heavy minerals, of eolian origin

S10 - SAND - as S8 over sandy clay to clayey sand of the Guildford Formation, of eolian origin

Sc - CLAYEY SAND - silty in part, pale grey to brown, medium to coarse-grained, poorly sorted, subangular to rounded, frequent heavy minerals, rare feldspar, of alluvial origin

Sp1 - PEATY SAND - grey to black, fine to medium-grained, moderately sorted quartz sand, slightly peaty, of lacustrine origin

Cs - SANDY CLAY - white-grey to brown, fine to coarse-grained, subangular to rounded sand, clay of moderate plasticity gravel and silt layers near scarp

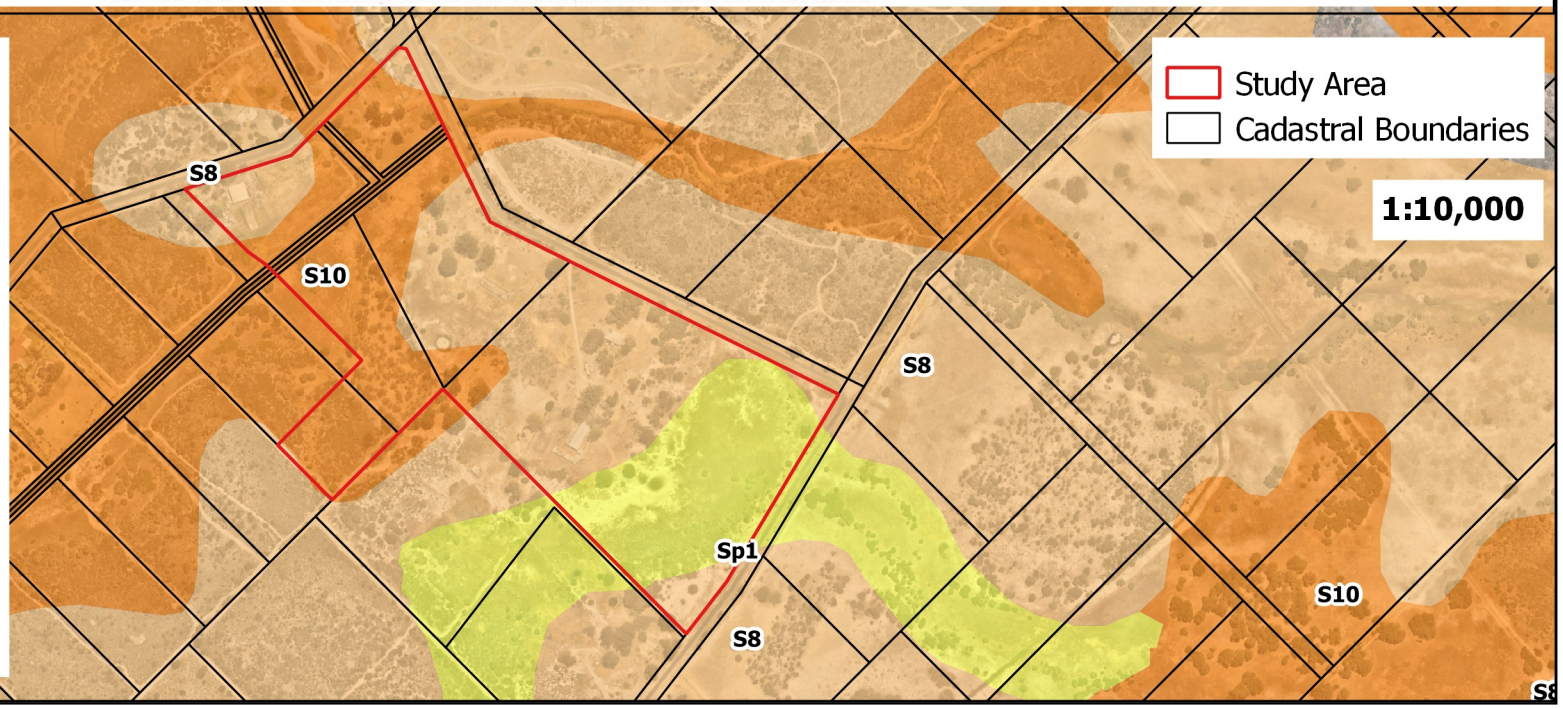


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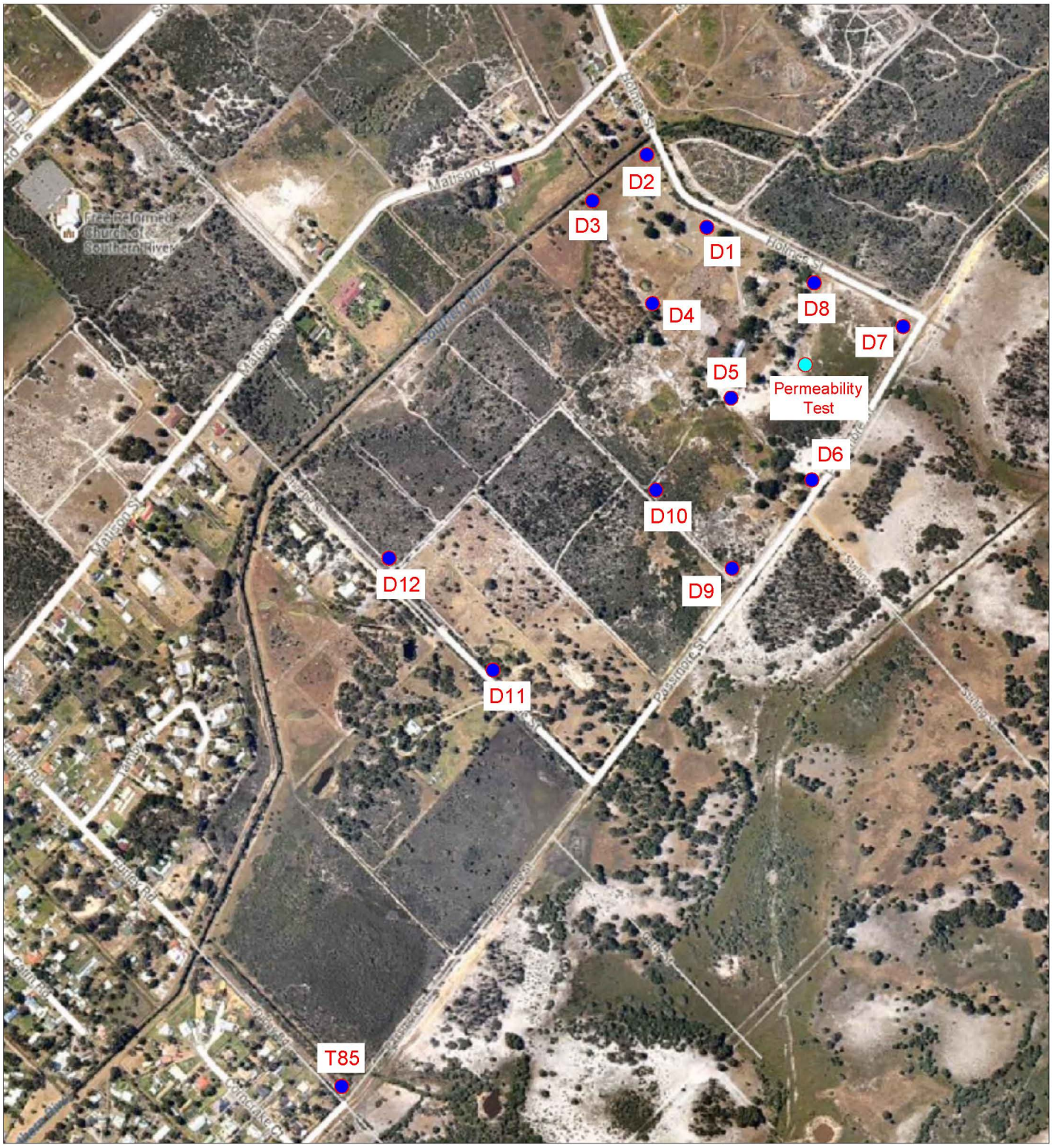
FIGURE 4. Surface Geology

Southern River Precinct 3D

Source: Cadastre (Landgate 13/12/2016); Geology (GSWA, 13/12/2016); Aerial (Nearmap, 13/12/2016)



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- Groundwater monitoring bore location
- Permeability testing location

Data Source: Google Map

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Southern River 3D, City of Gosnells,Perth, WA

Local Water Management Strategy
10/11/2015

Figure 5: Bore Locations

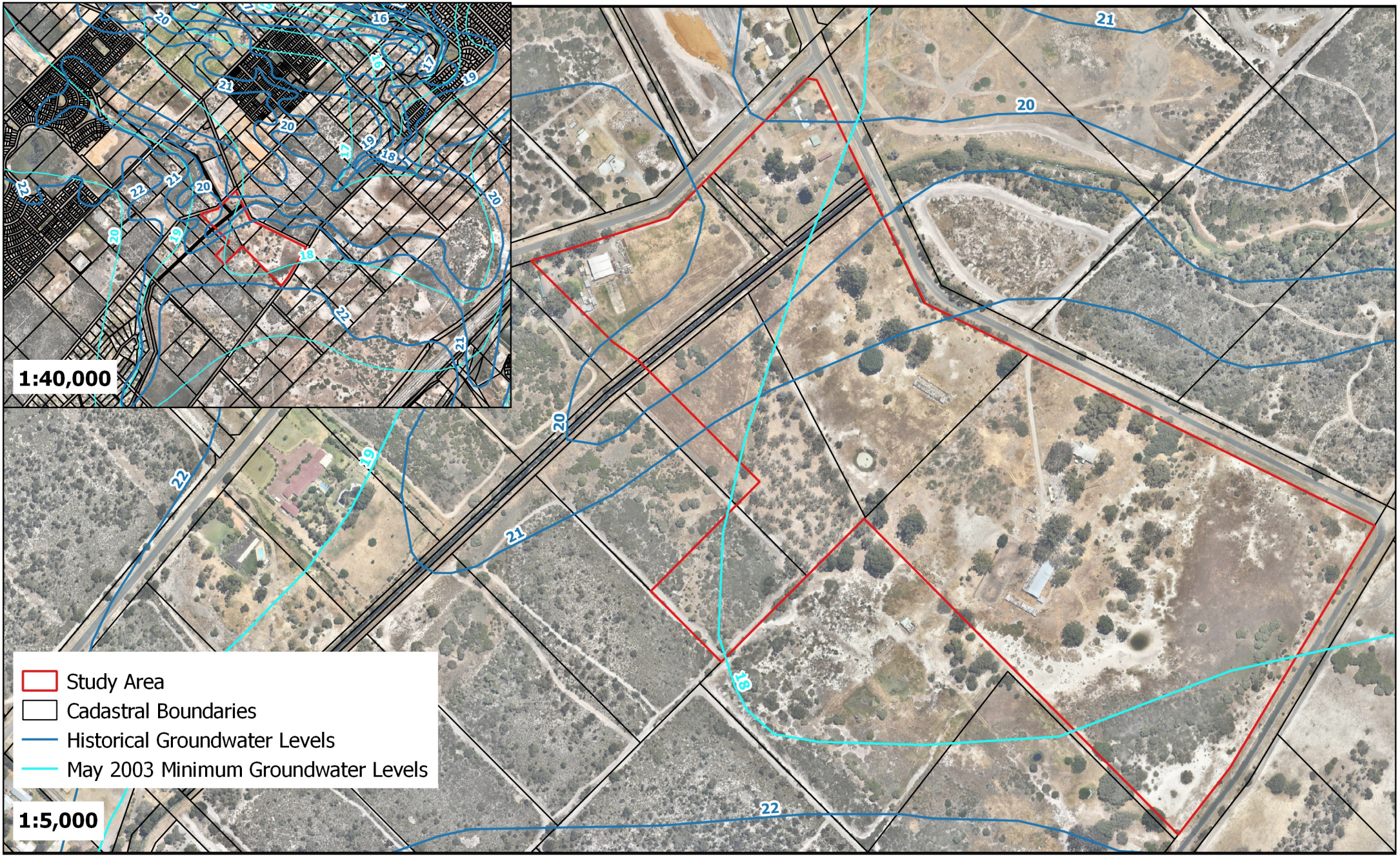

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FIGURE 6. Regional Groundwater Levels

Southern River Precinct 3D

Source: Cadastre (Landgate 13/12/2016); Aerial (Nearmap, 13/12/2016); Historical Max. Groundwater Levels (DoW, 13/12/2016);

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- PROPOSED CULVERT & HEADWALLS
- 22.0 DESIGN EARTHWORKS/ROAD CHANNEL LEVEL
- OVERLAND FLOW PATH
- 20.6 MGL CONTOURS
- 22.0 EXISTING CONTOURS
- PROPOSED RAIN GARDEN
- DRAINAGE BASIN

0 10 20 30 40 50m
1 : 2000 (A3) 1 : 1000 (A1)

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SCALE @A1 HORIZ: 1:1000

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SHAWMAC
1ST FLOOR
908 ALBANY HIGHWAY
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E admin@shawmac.com.au
CONSULTING CIVIL AND TRAFFIC ENGINEERS

DATE DRAWN:	30.10.15
DESIGNED:	RN
DRAWN:	CRF
CHECKED:	RN
APPROVED:	BH

FIGURE 7. MGL

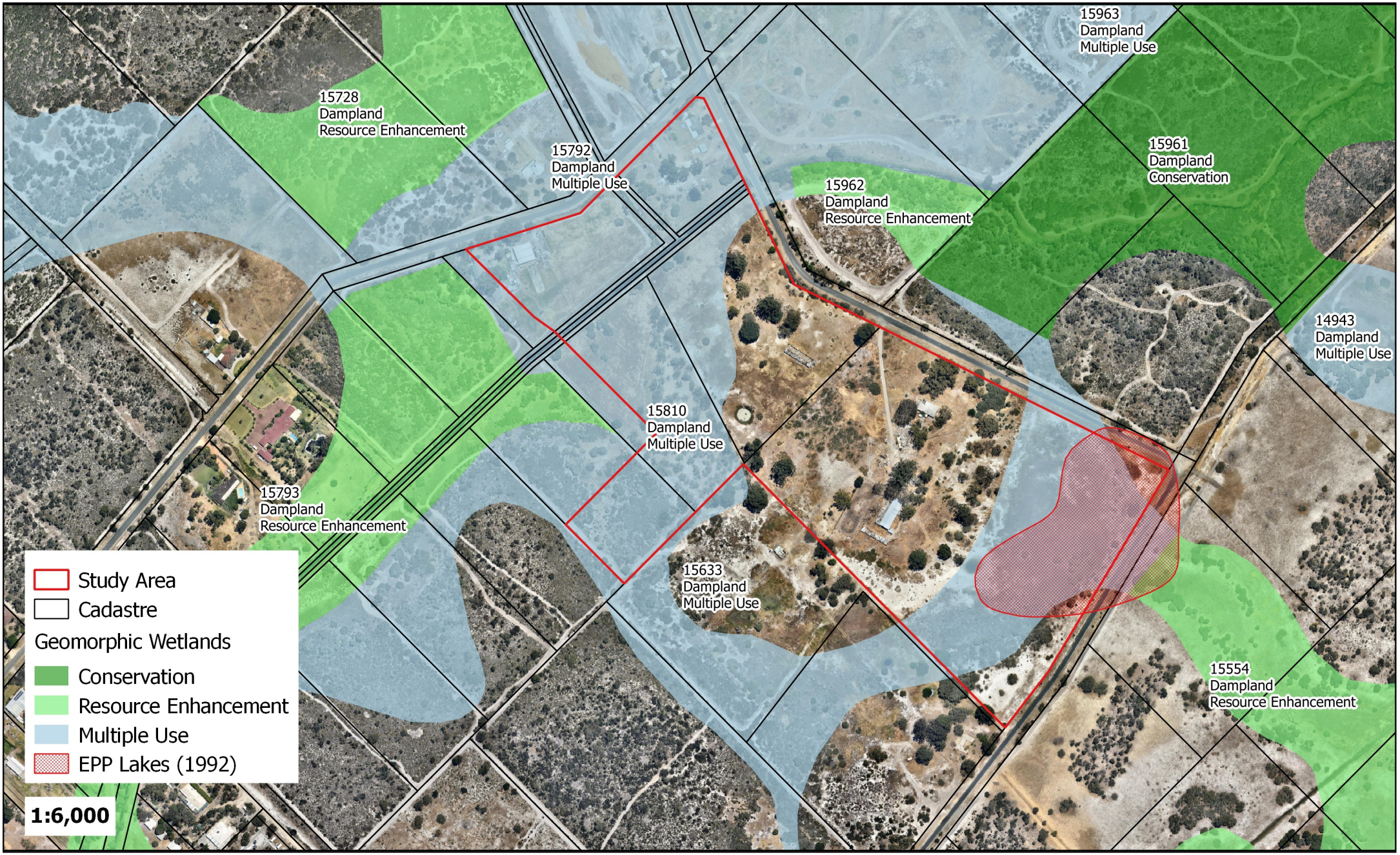
CITY OF GOSNELLS
UTHERN RIVER PRECINCT 3D EARTHWORKS PLAN

DRAWING NUMBER: 1201008-202

REV. D

FILE REF: Z:\Jobs Active 2012\CE - Land Development\1201008-Bioscience - Southern River Precint 3D\Drawings\1201008-200 Plans

LAST SAVED BY: Ryan N DATE: 3 February 2017 11:10 AM



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Client: Dynmaic Planning
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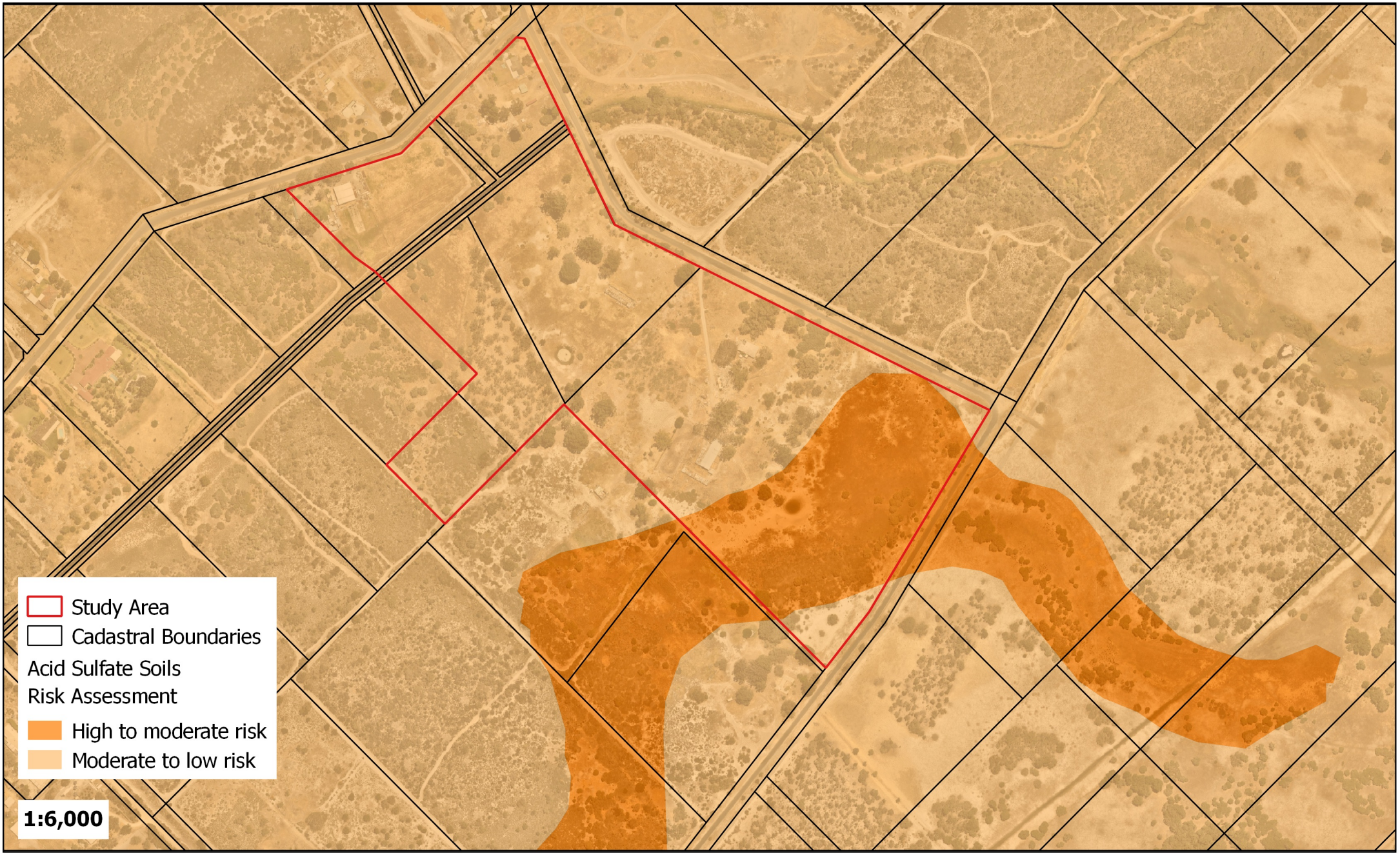
FIGURE 8. Geomorphic Wetlands

Southern River Precinct 3D

Source: Cadastre (Landgate 13/12/2016); Wetlands (DEC, 21/07/2016); Aerial (Nearmap, 13/12/2016)



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Client: Dynmaic Planning
Date: 13/12/2016
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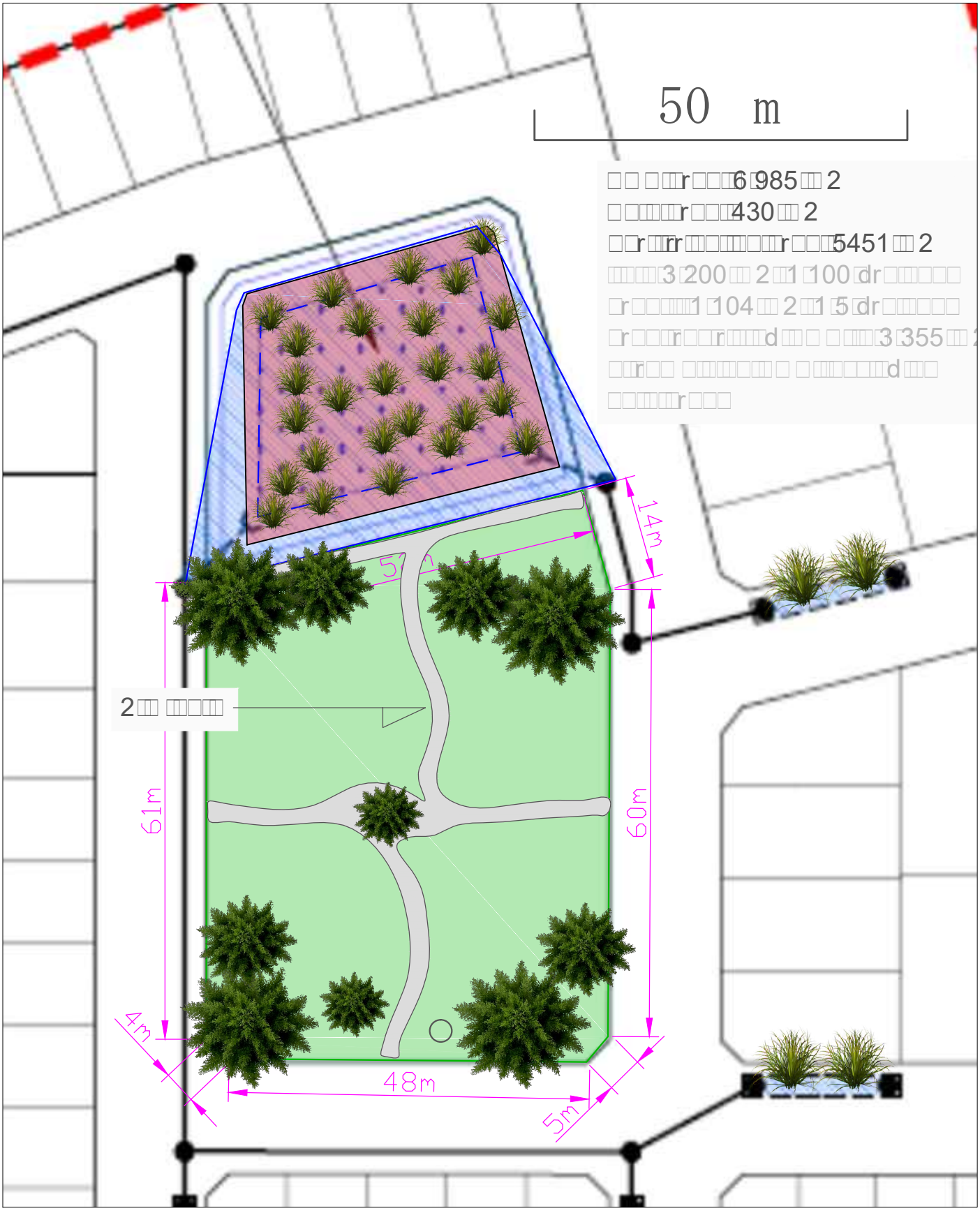
FIGURE 9. Acid Sulfate Soils Risk Assessment

Southern River Precinct 3D

Source: Cadastre (Landgate 13/12/2016); ASS (DECr, 16/07/2016); Aerial (Nearmap, 13/12/2016)



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Legend:

- Rain garden (1 year ARI) nutrient stripping vegetation
- Irrigation bore
- Drainage area (5 year ARI) vegetated to landscape architects detail

Irrigation area includes:

- Drainage area (100 year ARI)
- Remaining POS

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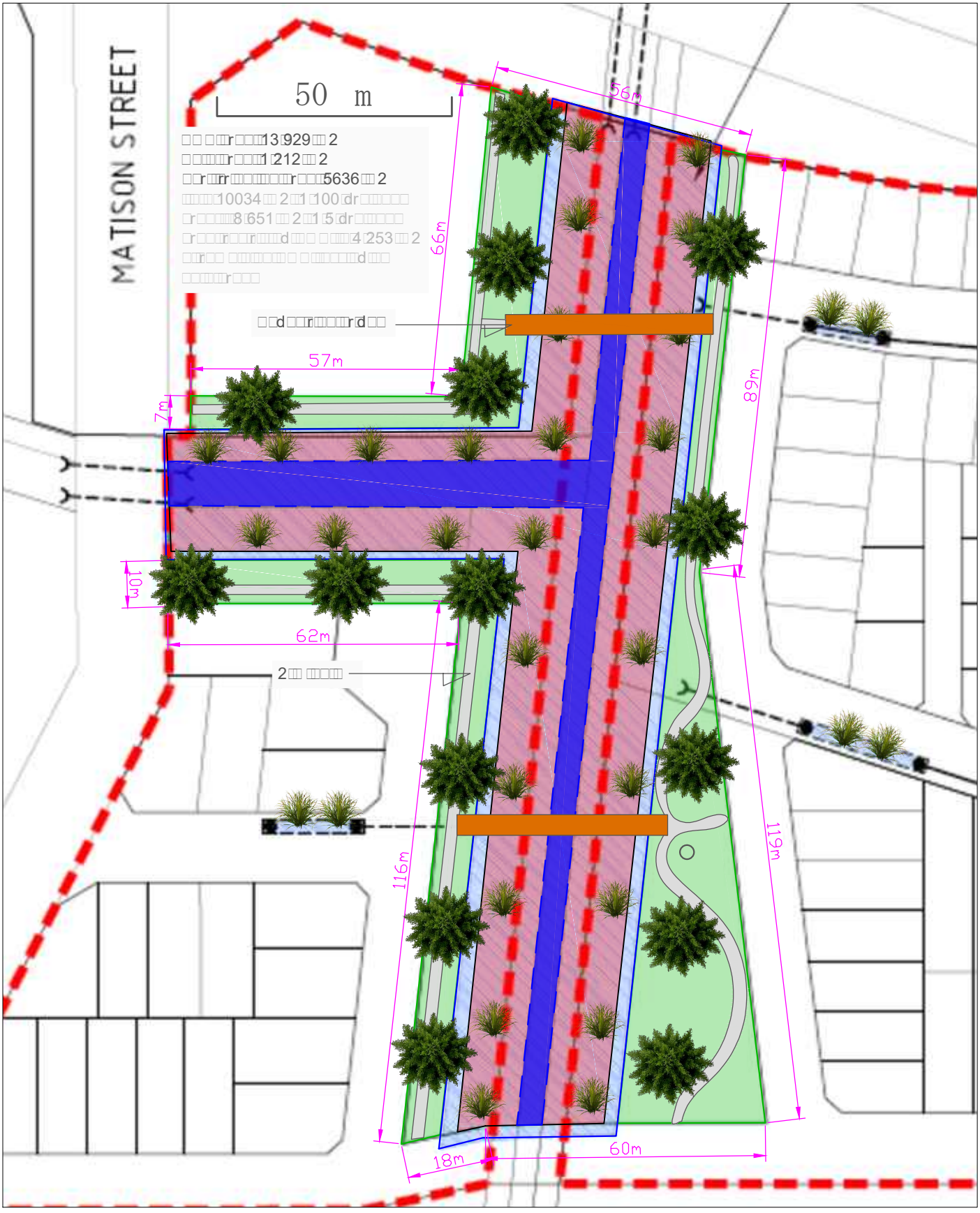
Southern River 3D, City of Gosnells, Perth, Western Australia

Local Water Management Strategy
12/10/2017

Figure 10a: Landscape Concept Plan Basin CA



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WEBSITE: www.biosciencewa.com

Legend:

- Extent of the 1 year ARI event
- Rain garden (1 year ARI) nutrient stripping vegetation
- Irrigation bore
- Drainage area (5 year ARI) vegetated to landscape architects detail

Irrigation area includes:

- Drainage area (100 year ARI)
- Remaining POS

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Southern River 3D, City of Gosnells, Perth, Western Australia

Local Water Management Strategy
12/10/2017

Figure 10b: Landscape Concept Plan FMD

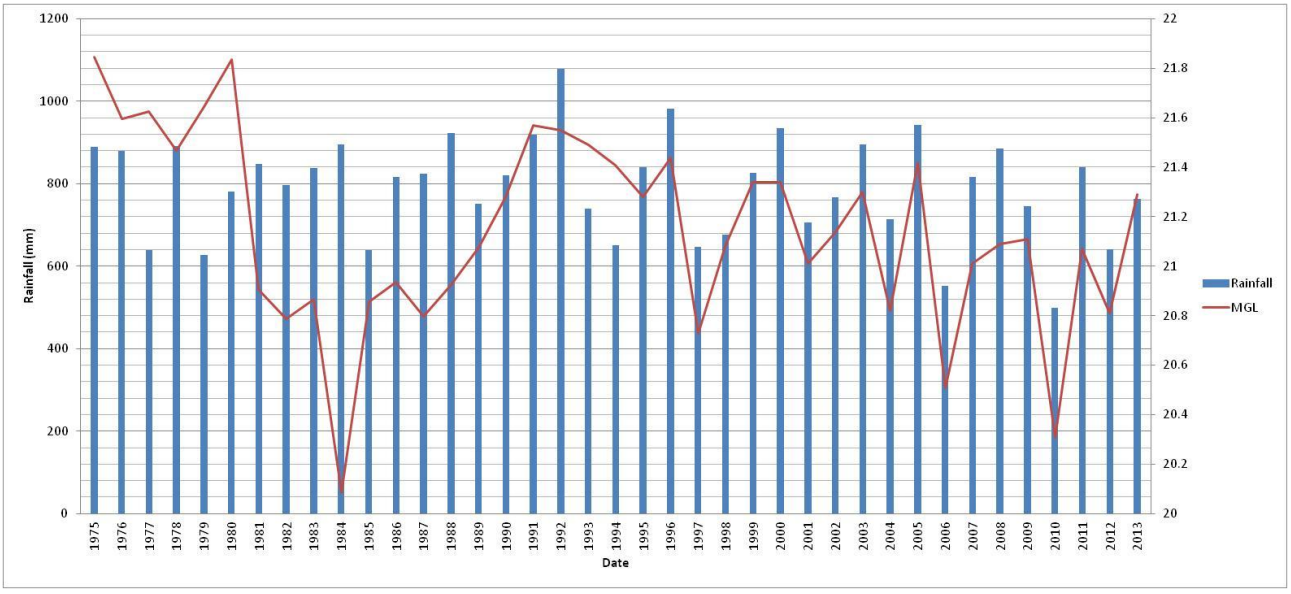
Appendix A: MGL Calculations & Groundwater Monitoring

Department of Water Long Term Maximum Groundwater Level (MGL) data for groundwater monitoring bore T85- Thompsons Lake (1975-2013)

Collect Year	Determinand	Reading Value
1975	Water Level (AHD) | m	21.846
1976	Water Level (AHD) | m	21.596
1977	Water Level (AHD) | m	21.626
1978	Water Level (AHD) | m	21.466
1979	Water Level (AHD) | m	21.646
1980	Water Level (AHD) | m	21.836
1981	Water Level (AHD) | m	20.906
1982	Water Level (AHD) | m	20.786
1983	Water Level (AHD) | m	20.866
1984	Water Level (AHD) | m	20.086
1985	Water Level (AHD) | m	20.856
1986	Water Level (AHD) | m	20.936
1987	Water Level (AHD) | m	20.796
1988	Water Level (AHD) | m	20.926
1989	Water Level (AHD) | m	21.076
1990	Water Level (AHD) | m	21.279
1991	Water Level (AHD) | m	21.569
1992	Water Level (AHD) | m	21.549
1993	Water Level (AHD) | m	21.489
1994	Water Level (AHD) | m	21.409
1995	Water Level (AHD) | m	21.279
1996	Water Level (AHD) | m	21.439
1997	Water Level (AHD) | m	20.729
1998	Water Level (AHD) | m	21.079
1999	Water Level (AHD) | m	21.339
2000	Water Level (AHD) | m	21.339
2001	Water Level (AHD) | m	21.009
2002	Water Level (AHD) | m	21.139
2003	Water Level (AHD) | m	21.299
2004	Water Level (AHD) | m	20.819
2005	Water Level (AHD) | m	21.419
2006	Water Level (AHD) | m	20.509

Collect Year	Determinand	Reading Value
2007	Water Level (AHD) | m	21.009
2008	Water Level (AHD) | m	21.089
2009	Water Level (AHD) | m	21.109
2010	Water Level (AHD) | m	20.309
2011	Water Level (AHD) | m	21.069
2012	Water Level (AHD) | m	20.809
2013	Water Level (AHD) | m	21.289

Graph of Total Annual Rainfall in Gosnells and MGL for DoW Bore T-85



Average Annual Maximum Groundwater Level (AAMGL) = ***21.144mAHD***
MGL between 1975 - 2013 = ***21.846mAHD***
i.e 0.0.702m above long term AAMGL. The 0.702m difference is applied to the calculated AAMGL of local site monitoring bores to calculate the MGL across the site.

Recorded Southern River Precinct 3D Groundwater Monitoring Data (*27/05/11-28/03/14*)

	27/05/2011	3/08/2011	22/09/2011	1/11/2011	7/12/2011	16/01/2012	16/03/2012	15/05/2012	6/07/2012	7/09/2012
D1	19.236	20.258	20.520	20.396	20.246	20.136	19.804		19.982	20.134
D2	18.933	20.093	20.056	19.793	19.679	19.513	19.205	19.373	19.703	19.832
D3	18.088	19.568	19.713	19.521	19.218	18.847	18.503	18.802	19.346	19.569
D4	18.804	20.339	20.609	20.372	20.255	19.976	19.351	19.206	19.861	20.036
D5	19.344	20.831	21.065	20.795	20.655	20.414	19.916	19.899	20.334	20.599
D6	19.810	20.835	21.304	21.205	21.028	20.875	20.485	20.321	20.632	20.822
D7	19.014	20.984	21.131	20.879	20.728	20.607	20.286	20.272	20.635	20.805
D8	19.275	20.489	20.722	20.505	20.358	20.206	19.800	19.754	20.190	20.384
D9	19.829	20.931	21.322	21.231	21.045	20.888	20.508	20.304	20.673	20.829
D10	19.597	20.920	21.142	20.852	20.726	20.445	19.980	20.102	20.482	20.733
D11	18.109	19.077	20.203	20.119	19.467	19.023	18.446	18.610	18.978	19.474
D12	19.533	20.747	21.067	20.887	20.734	20.591	20.221	19.998	20.404	20.585
T85			21.069							

	5/10/2012	27/11/2012	19/12/2012	25/01/2013	7/03/2013	23/05/2013	21/08/2013	15/10/2013	14/11/2013	28/03/2014
D1	20.198	19.856	20.026				20.286	20.706	20.404	19.916
D2	19.739	19.475	19.601	19.266	19.026	19.411	19.886	20.325	19.763	19.083
D3	19.504	19.223	19.381	18.584	18.159	19.065	19.593	19.962	19.626	18.153
D4	20.066	19.674	19.947	19.319	18.774	18.872	20.141	20.582	20.338	18.874
D5	20.603	20.253	20.381	19.952	19.574	19.812	20.660	20.955	20.695	19.596
D6	20.896	20.685	20.745	20.483	20.233	20.182	20.884	21.319	21.163	20.260
D7	20.818	20.523	20.664	20.350	20.114	20.239	20.939	21.142	20.889	20.120
D8	20.408	20.050	20.206	19.833	19.525	19.693	20.452			19.480
D9	20.906	20.664	20.712	20.457	20.216	20.170	20.897	21.308	21.153	20.271
D10	20.670	20.279	20.390	19.952	19.648	19.959	20.719	21.097	20.719	19.726
D11	19.629	19.163	19.148	18.688	18.308	18.568	19.395	20.378	19.994	18.262
D12	20.655	20.384	20.379	20.155	19.899	19.836	20.664	21.010	20.842	19.993
T85	20.809							21.289		

Groundwater Levels Corrected to DoW Long Term Bore T85

Bore Ref.	MGL Date				
	22-09-11	05-10-12	15-10-13	AAMGL	MGL (0.702 correction)
T85	21.069	20.809	21.289	21.056	
Diff. To AAMGL (21.144mAHD)	0.075	0.335	-0.145		
Corrected Values					
D1	20.595	20.533	20.561	20.563	21.265
D2	20.131	20.074	20.180	20.128	20.830
D3	19.788	19.839	19.817	19.814	20.516
D4	20.684	20.401	20.437	20.508	21.210
D5	21.140	20.938	20.810	20.962	21.664
D6	21.379	21.231	21.174	21.261	21.963
D7	21.206	21.153	20.997	21.119	21.821
D8	20.797	20.743		20.770	21.472
D9	21.397	21.241	21.163	21.267	21.969
D10	21.217	21.005	20.952	21.058	21.760
D11	20.278	19.964	20.233	20.158	20.860
D12	21.142	20.990	20.865	20.999	21.701

Groundwater Quality Data

Sample Analysis Datasheet

Site: Southern River 3D | Analysis By:

Collection Date: 21/08/2013 | Completion Date:

Collected By: R.B.

Sample	pH	EC (mS)	Total N (mg/L)	Nitrate N (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
D1	-	-			-		-			
D2	5.72	0.476		0	0.386		2.602	6.924	15.59	0.712
D3	5.9	2.52		0	0.563		2.602	23.494	40.2	68.55
D4	4.28	1.417		0	0.401		15.248	61.825	59.06	1.893
D5	4.45	0.069		0.47	0.378		1.493		7.88	0.98
D6	5.7	0.142		1.72	0.252		0.123		0.9	0.051
D7	-	-			-		-			
D8	4.04	0.242		0.22	0.752		1.362		6.4	1.185
D9	6.19	0.225		0.9	0.403		0.232		7.38	0.697
D10	3.86	0.396		0	0.482		1.123		11.24	0.771
D11	5.9	6.19		0	0.450		0.058		159.97	1.196
D12	3.57	0.272		0.14	0.274		0.210		4.02	0.605

Sample Analysis Datasheet

Site: Southern River 3D | Analysis By:

Collection Date: 07/03/2013 | Completion Date:

Collected By: R.B.

Sample	pH	EC (mS)	Total N (mg/L)	Nitrate N (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
D1	-	-		-				-		
D2	5.52	0.575	0.659	0	0	2.646	2.169	56.4	20.28	0.508
D3	5.56	2.05	0.233	0	0.088	0.372	0.059	109	50.7	0.461
D4	-	-	-	-	-	-	-	-	-	-
D5	4.68	0.117	0.191	0.055	0.229	2.602	2.652	11.4	35.81	0.556
D6	6.38	0.398	0.128	3.04	0.28	0.022	0.015	4.45	0	0.0006
D7	5.05	0.274	-	-	-	-	-	-	-	-
D8	4.6	0.226	0.33	0	0.477	0.7	0.63	10.9	6.8	0.165
D9	5.26	0.117	0.048	0	0	0.066	0.015	4.95	0.76	0.0941
D10	-	-	-	-	-	-	-	-	-	-
D11	5.75	5.71	0.031	0.006	0.123	0.022	0	1652	175.84	0.216

D12	3.68	0.164	0.056	0	0.367	0.241	0.037	17.3	8.2	0.375

Sample Analysis Datasheet

Site: Southern River 3D — Analysis By:

Collection Date: 16/01/2012 — Completion Date:

Collected By: R.B.

Sample	pH	EC (mS)	Total N (mg/L)	Nitrate N (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
D1	4.72	1.18	1.765	2	0	17.75	18.828	148	30.53	0.559
D2	5.92	0.578	0.371	0.043	0	2.276	2.047	148	37.36	6.02
D3	6.22	2.77	0.316	0	0	0.127	0.227	1755	293.66	63.4
D4	4.93	1.18	1.332	0	0	16.77	17.6	137	114.77	0.994
D5	4.53	0.102	0.129	1.2	0	1.512	1.342	14.3	6.18	1.48
D6	6.08	0.17	0	1.2	0	0.032	0.023	0.495	9.1	0.0839
D7	-	-	-	-	-	-	-	-	-	-
D8	-	-	-	-	-	-	-	-	-	-
D9	6.04	0.251	0.113	0.9	0	0.008	0.023	10.9	4.64	0.171
D10	4.22	0.191	0.453	0	0	0	0.523	8.41	9.49	0.404

Sample Analysis Datasheet

Site: Southern River 3D — Analysis By:

Collection Date: 27/11/2012 — Completion Date:

Collected By: R.B.

Sample	pH	EC (mS)	Total N (mg/L)	Nitrate N (mg/L)	Amm. N (mg/L)	Total P (mg/L)	Filterable Rea. P (mg/L)	Cl (mg/L)	SO_4 (mg/L)	Fe (mg/L)
D1	-	-	-	-	-	-	-	-	-	-
D2	5.85	0.562	0.323	0	0.1	2.413	2.659	9.892	31.49	2.0078
D3	5.82	2.38	0	0	0.223	0.095	0.789	327.7	1.87	39.9
D4	4.95	0.642	1.911	0	0.572	14.102	15.548	56.9	119.96	1.1381
D5	4.51	0.105	0.234	1.3	0.063	1.562	1.69	0	3.09	0.5473
D6	5.95	0.132	0.097	1.2	0.067	0.024	0.023	0	0	0.0317
D7	6.03	0.224	0.031	0.94	0.149	0.024	0.315	4.45	0	6.2793
D8	-	-	-	-	-	-	-	-	-	-
D9	6.15	0.245	0.043	0.31	0.007	0.024	0.023	0	0.19	0.6815
D10	3.88	0.382	0.448	0	0.342	0.047	0.338	5.95	20.52	0.4483
D11	5.82	4.65	0.343	0	0.253	0.095	0	1483.8	122.31	0.1686
D12	3.85	0.223	0.124	0.024	0.048	0.047	0.113	17.31	7.69	0.78

Appendix B: Extracts from FMD ADS

Figure A1 FDM ADS

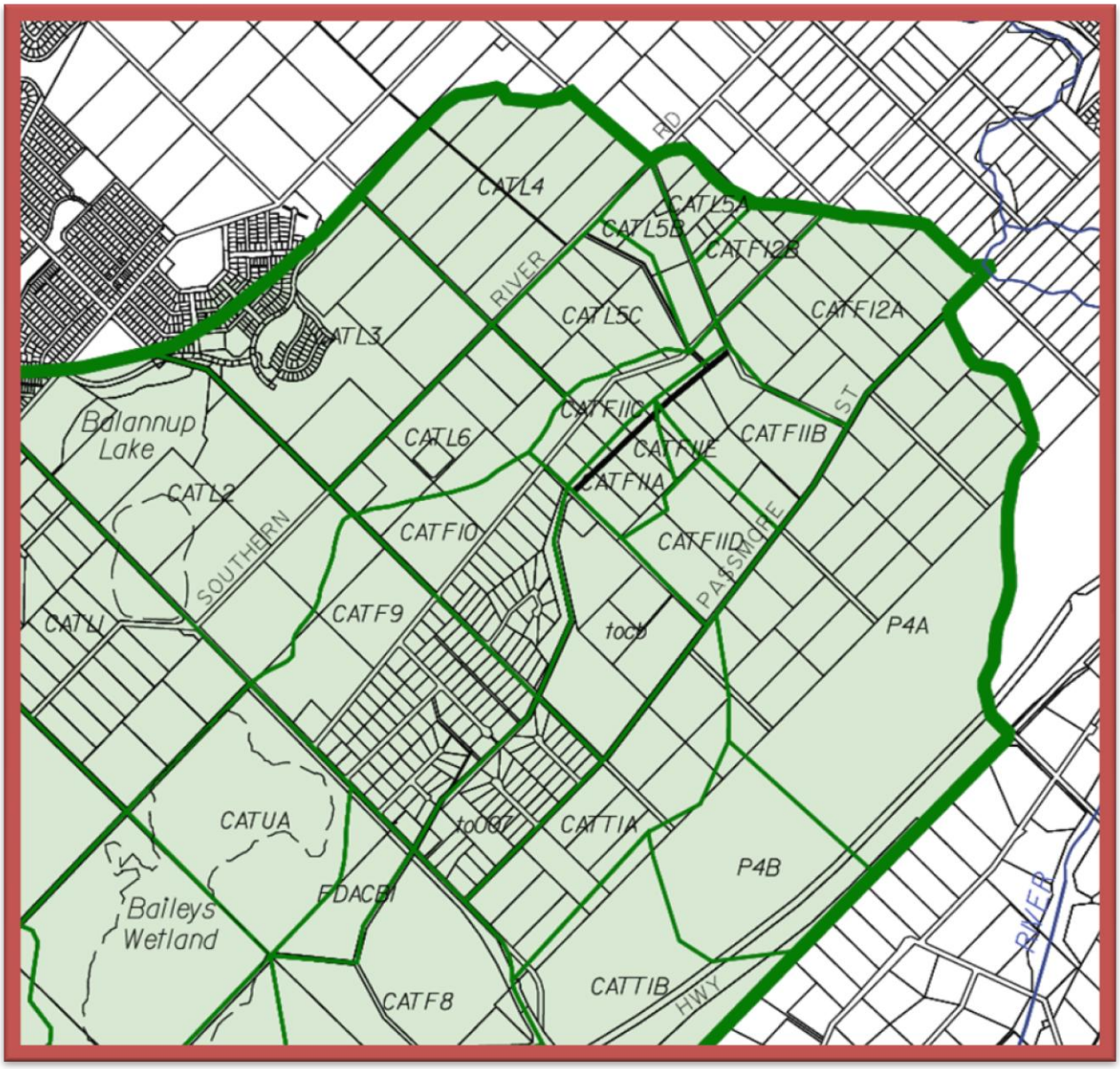
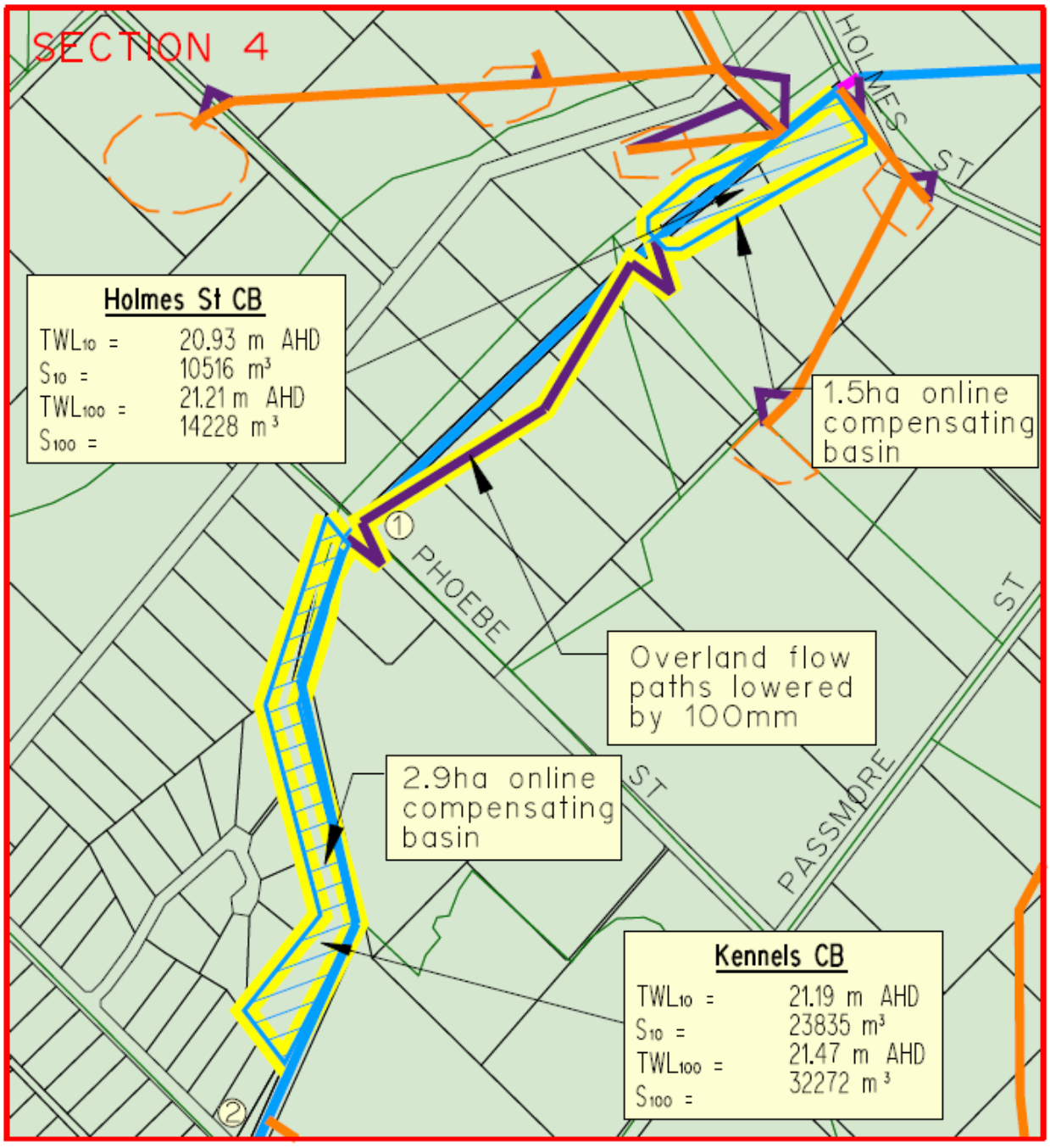


Figure 3 FDM ADS



Appendix C: Shawmac Drainage Summary and Drainage Plans

CONSULTING CIVIL & TRAFFIC ENGINEERS, RISK MANAGERS.

Project:	Southern River Precinct 3D – Drainage Summary
Client:	
Job Number:	1201008
Author:	Ryan Needham
Signature:	
Date:	03-02-17

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Contents

1. PRE-DEVELOPED ENVIRONMENT

Catchment Code	Description	Flow Path	Area	tc (mins)	Q5 (m3/s)	Q100 (m3/s)
A	Eastern portion of site around low point	To existing low point	66,390	22.5	0.38	0.71
B	Portion east of FMD	FMD	76,330	34	0.33	0.62
C	Portion west of FMD	FMD	28,570	24	0.15	0.29

1. Coefficient of Runoff = 0.4 (in accordance with FMD study)

2. 1 YEAR EVENT

Raingarden Sizing

Catchment	Impervious Area (m^2)	Vin (m^3)	Depth (m)	Width (m)	L (m)	Vinfil (m^3)	Vstored (m^3)	Area (m^2)	2% area check (m^2)
CA01	1491	22.4	0.30	3.0	15.0	9.4	13.5	45.0	29.8
CA02	2450	36.8	0.30	3.0	25.0	15.6	22.5	75.0	49.0
CA03	915	13.7	0.30	3.0	9.0	5.6	8.1	27.0	18.3
CA04	1072	16.1	0.30	3.0	11.0	6.9	9.9	33.0	21.4
CA05	1173	17.6	0.30	3.0	12.0	7.5	10.8	36.0	23.5
CA06	2414	36.2	0.30	3.0	24.0	15.0	21.6	72.0	48.3
CA07	863	12.9	0.30	3.0	9.0	5.6	8.1	27.0	17.3
CA08	1250	18.8	0.30	3.0	13.0	8.1	11.7	39.0	25.0
CA09	872	13.1	0.30	3.0	9.0	5.6	8.1	27.0	17.4
CA10	5966	89.5	0.30	3.0	59.0	36.8	53.1	177.0	119.3
CB01	981	14.7	0.35	3.0	9.0	5.6	9.5	27.0	19.6
CB02	2301	34.5	0.35	3.0	21.0	13.1	22.1	63.0	46.0
CB03	884	13.3	0.35	3.0	8.0	5.0	8.4	24.0	17.7
CB04	790	11.9	0.35	3.0	8.0	5.0	8.4	24.0	15.8
CB05	764	11.5	0.35	4.0	6.0	5.0	8.4	24.0	15.3
CB06	1520	22.8	0.35	3.0	14.0	8.7	14.7	42.0	30.4
CB07	1470	22.1	0.35	3.0	14.0	8.7	14.7	42.0	29.4
CB08	1892	28.4	0.35	3.0	17.0	10.6	17.9	51.0	37.8
CB09	1491	22.4	0.35	3.0	14.0	8.7	14.7	42.0	29.8
CB10	2450	36.8	0.35	3.0	22.0	13.7	23.1	66.0	49.0
CB11	572	8.6	0.35	3.0	6.0	3.7	6.3	18.0	11.4
CB12	1167	17.5	0.35	3.0	11.0	6.9	11.6	33.0	23.3
CB13	1098	16.5	0.35	3.0	10.0	6.2	10.5	30.0	22.0
CB14	1984	29.8	0.35	3.0	18.0	11.2	18.9	54.0	39.7
CC01	907	13.6	0.35	3.0	9.0	5.6	9.5	27.0	18.1

1. Sizing based on 15mm from impervious areas
2. Infiltration rate of 5m day assumed.

3. 1.2m deep by 1.8m dia. Soakwells proposed for lot drainage up to 5min 20 year event, soakwell bases set 0.5m above CGL/MGL

3. 5 YEAR EVENT

Post-Developed Catchment	Comments	Catchment Area (m^2)	Allowable Post Developed 5yr Flow (m^3/s)
A	New urban area, east portion of site	57,760	N/A (drains to low point)
B	New urban area, east of FMD (part pre-dev. catchment B)	75,470	N/A drains direct to FMD, but catchment peak not to coincide with FMD peak (6.4m^3/s for 10 year ARI)
C	New urban area, west of FMD (part pre-dev. Catchment D)	22,700	N/A drains direct to FMD, but catchment peak not to coincide with FMD peak (6.4m^3/s for 10 year ARI)

5yr Summary of post development Hydrological Analysis				
Catchment Area	Road Area (m^2)	Residential Area (m^2)	POS (m^2)	5yr Peak Runoff (L/s)
CA	17,086	34,954	5,720	361
CB	24,220	46,318	4,932	486
CC	5,725	11,831	5,144	129

1. Road C = 0.75, Lot C = 0.5 POS, C = 0.2
2. Storage in road/raingardens excluded

5yr Summary of Basin Details								
Basin	Top Level (mAHD)	Base Level (mAHD)	Top Area (m^2)	Base Area (m^2)	5 Year Water Level (mAHD)	5 Year Area (m^2)	5 Year Vol (m^3)	Peak outflow (L/s)
CA	22.5	21.5	3,200	972	22.0	1,104	519	0

1. Basin base levels 0.5m min above MGL as per CoG requirements

Lot Area (m^2)	200	250	300	350	400	450	500	550
Inflow Volume	1.66	2.07	2.49	2.90	3.31	3.73	4.14	4.56
Volume per soakwell	3.10	3.10	3.10	3.10	3.10	3.10	3.10	3.10
No. Soakwells Required (1.8dia x 1.2 deep)	1	1	1	1	2	2	2	2

4. 100 YEAR EVENT

Post-Developed Catchment	Comments	Catchment Area (m^2)	Allowable Post Developed 100yr Flow (m^3/s)
A	New urban area, east portion of site	57,760	N/A (drains to low point)
B	New urban area, east of FMD (part pre-dev. catchment B)	75,470	N/A drains direct to FMD, but catchment peak not to coincide with FMD peak (7.8m^3/s for 10 year ARI)
C	New urban area, west of FMD (part pre-dev. Catchment D)	22,700	N/A drains direct to FMD, but catchment peak not to coincide with FMD peak (7.8m^3/s for 10 year ARI)

1. Allowable post developed flows calculated proportionally from of pre-developed catchment areas

100yr Summary of post development Hydrological Analysis				
Catchment Area	Road Area (m^2)	Residential (m^2)	POS (m^2)	100yr Peak Runoff (L/s)
CA	17,086	34,954	5,720	978
CB	24,220	46,318	4,932	1,303
CC	5,725	11,831	5,144	357

1. Road C = 0.9, Residential C = 0.8, POS C = 0.4
2. Storage in road/raingardens excluded

100yr Summary of Basin Details								
Basin	Top Level (mAHD)	Base Level (mAHD)	Top Area (m^2)	Base Area (m^2)	100 Year Water Level (mAHD)	100 Year Area (m^2)	100 Year Vol (m^3)	Peak outflow (L/s)
CA	22.5	21.5	3,200	972	22.5	3,200	2,086	0

1. Basin base levels 0.5m min above CGL/MGL as per CoG requirements

5. FORRESTDALE MAIN DRAIN LIVING STREAM

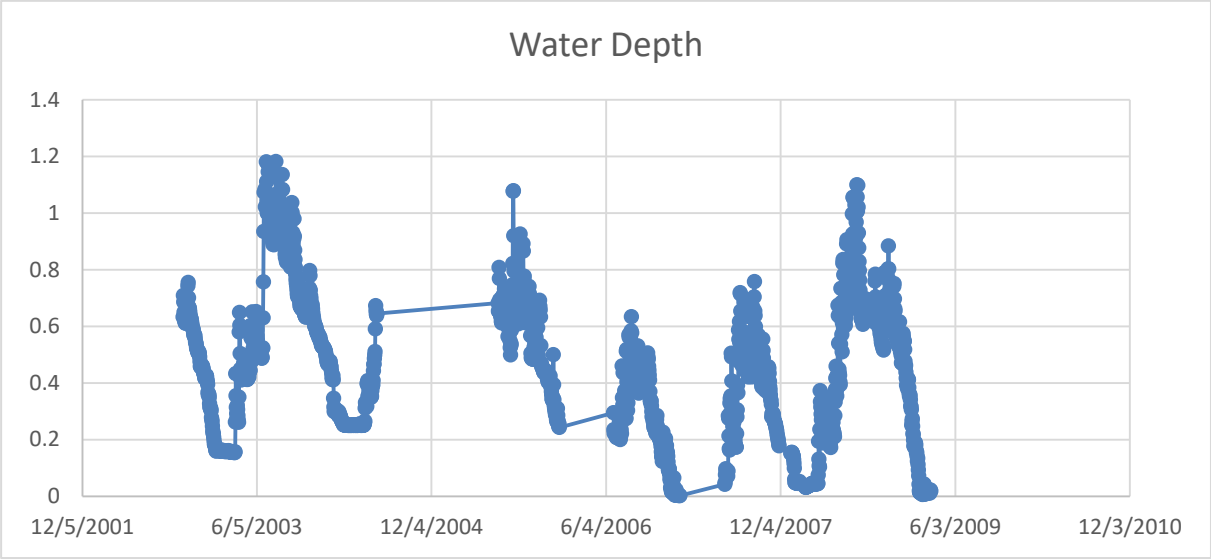
Channel cross were designed based on the cross section of the existing drain, historical gauging data from DoW's WIN site 23003406 located immediately upstream of the Holmes Street culverts and the Department of Water's living stream guidelines.

The image below shows the drain conditions immediately upstream of the Holmes St culverts on 5/11/15. The drain width is approximately 6m and depth of flow was 550mm

The image below shows the drainage conditions immediately downstream of the Holmes St culverts on 5/11/15,

The significant different in flow conditions upstream and downstream of the culverts indicates that there is likely a blockage in the culverts and accordingly, the channel conditions are not considered an accurate representation of the usual conditions.

Data for the gauging station located upstream of the culverts was sourced from DoW records. Regular monitoring was undertaken between October 2002 and March 2009. The chart below summarises the data records.



A regression analysis was undertaken which indicated that the 1.5 ARI flow depth is approximately 300mm.

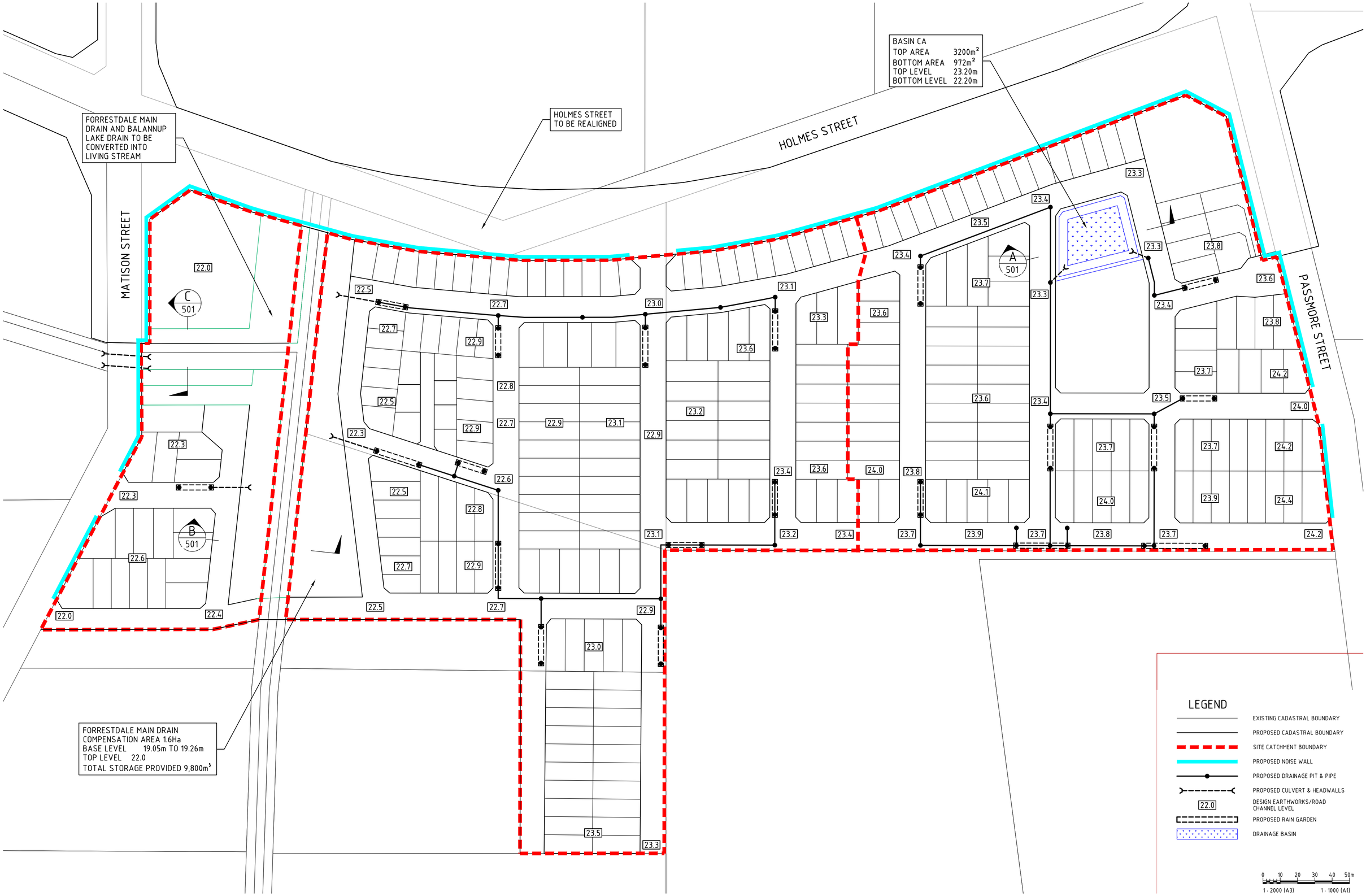
Accordingly, this value was adopted for the bankfull depth, with width equal to the existing drain.

Based on the adopted bankfull depth and width, the 1.5 ARI flow was estimated from Mannings equation at 0.5m^3/s based on the following factors

n = 0.03 (clean channel with low grass)

S = .0027m/m

For the 10 and 100 year events, the design peak flow was sourced from the FMD Arterial Drainage study at 6.4m^3/s and 7.8m^3/s respectively, just prior to the Holmes Street culverts.



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D	30.01.17	GENERAL AMENDMENTS. ISSUED TO D.O.W.	RN
C	22.03.16	MINOR AMENDMENTS	RN
B	18.12.15	MINOR AMENDMENTS	RN
A	12.11.15	ISSUED FOR LWMS REVIEW	RN

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CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D CONCEPT PLAN

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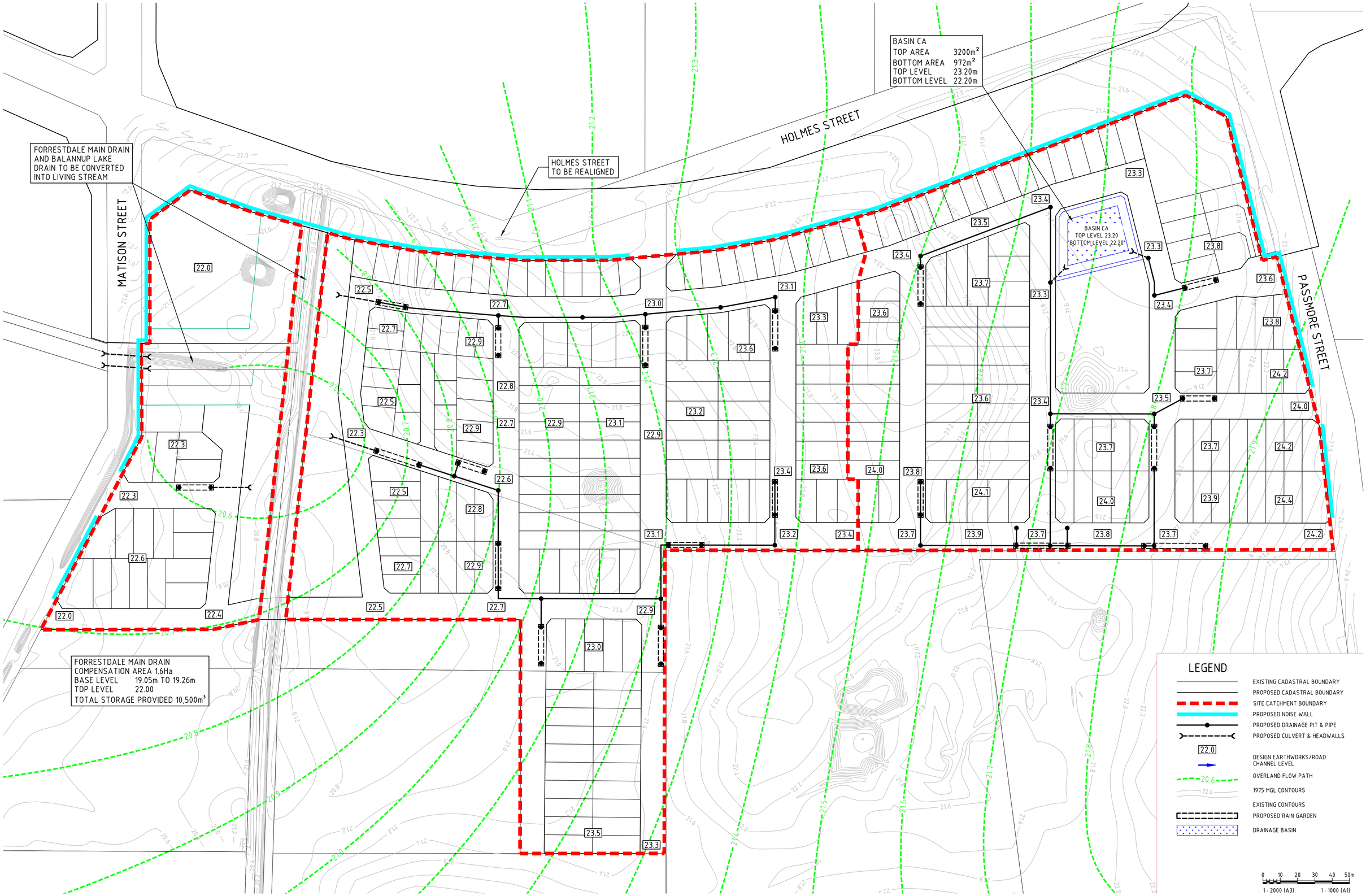

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A	12.11.15	ISSUED FOR LWMS REVIEW	RN

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CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D EARTHWORKS PLAN

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HOLMES STREET

MATISON STREET

PASSMORE STREET

CATCHMENT A
66,390m²

CATCHMENT B
76,330m²

CATCHMENT C
28,570m²

LEGEND

- EXISTING CADASTRAL BOUNDARY
- PROPOSED CADASTRAL BOUNDARY
- PRE-DEVELOPMENT CATCHMENT BOUNDARY
- 22.0 EXISTING CONTOURS

0 10 20 30 40 50m

1 : 2000 (A3) 1 : 1000 (A1)

REV	DATE	DESCRIPTION	APPROVED
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CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D
PRE-DEVELOPMENT CATCHMENT PLAN

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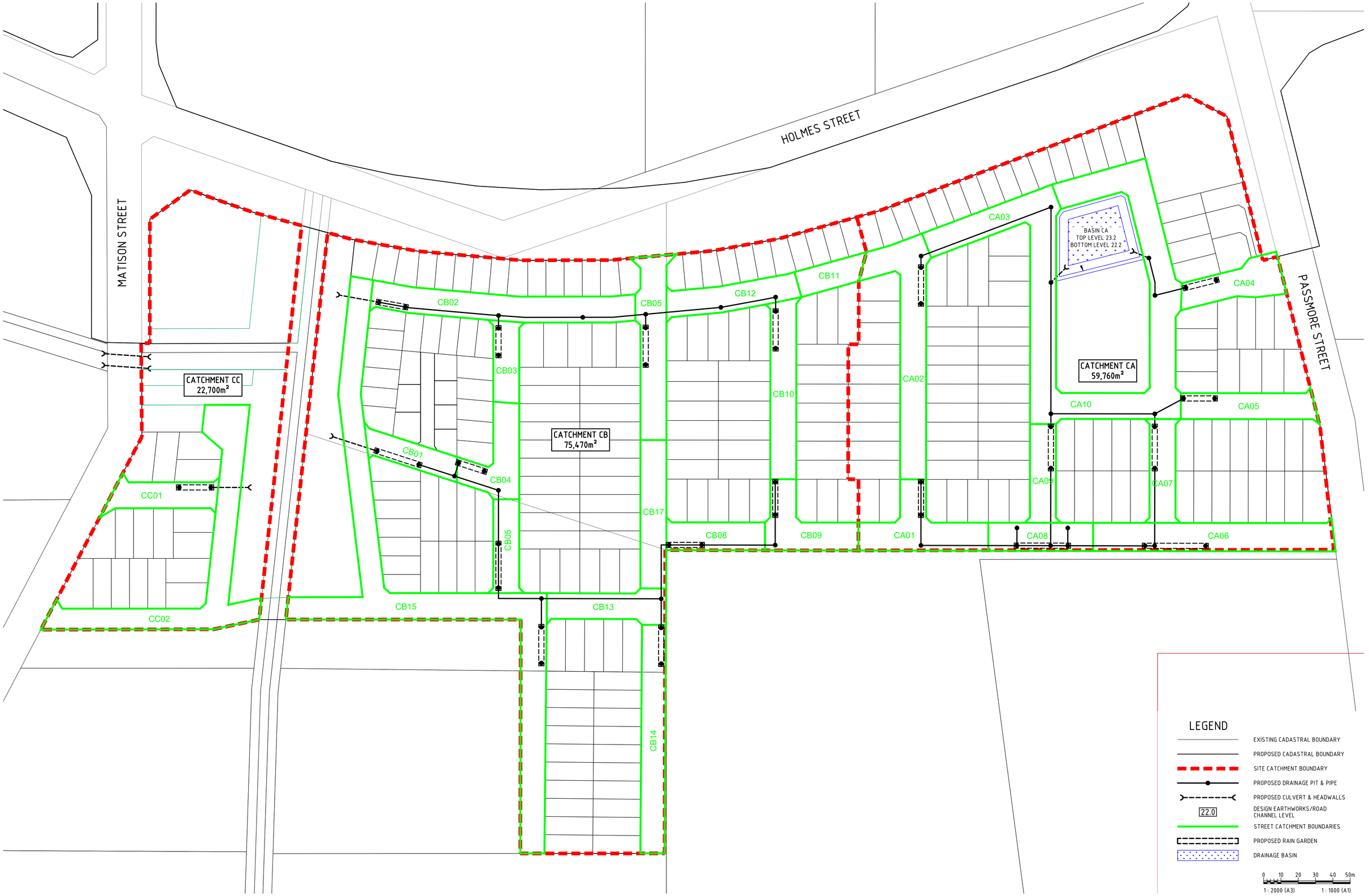

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CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D
POST DEVELOPMENT CATCHMENT PLAN

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B	18.12.15	MINOR AMENDMENTS	RN
A	12.11.15	ISSUED FOR LWMS REVIEW	RN

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SOUTHERN RIVER PRECINCT 3D
1 YEAR EVENT PLAN

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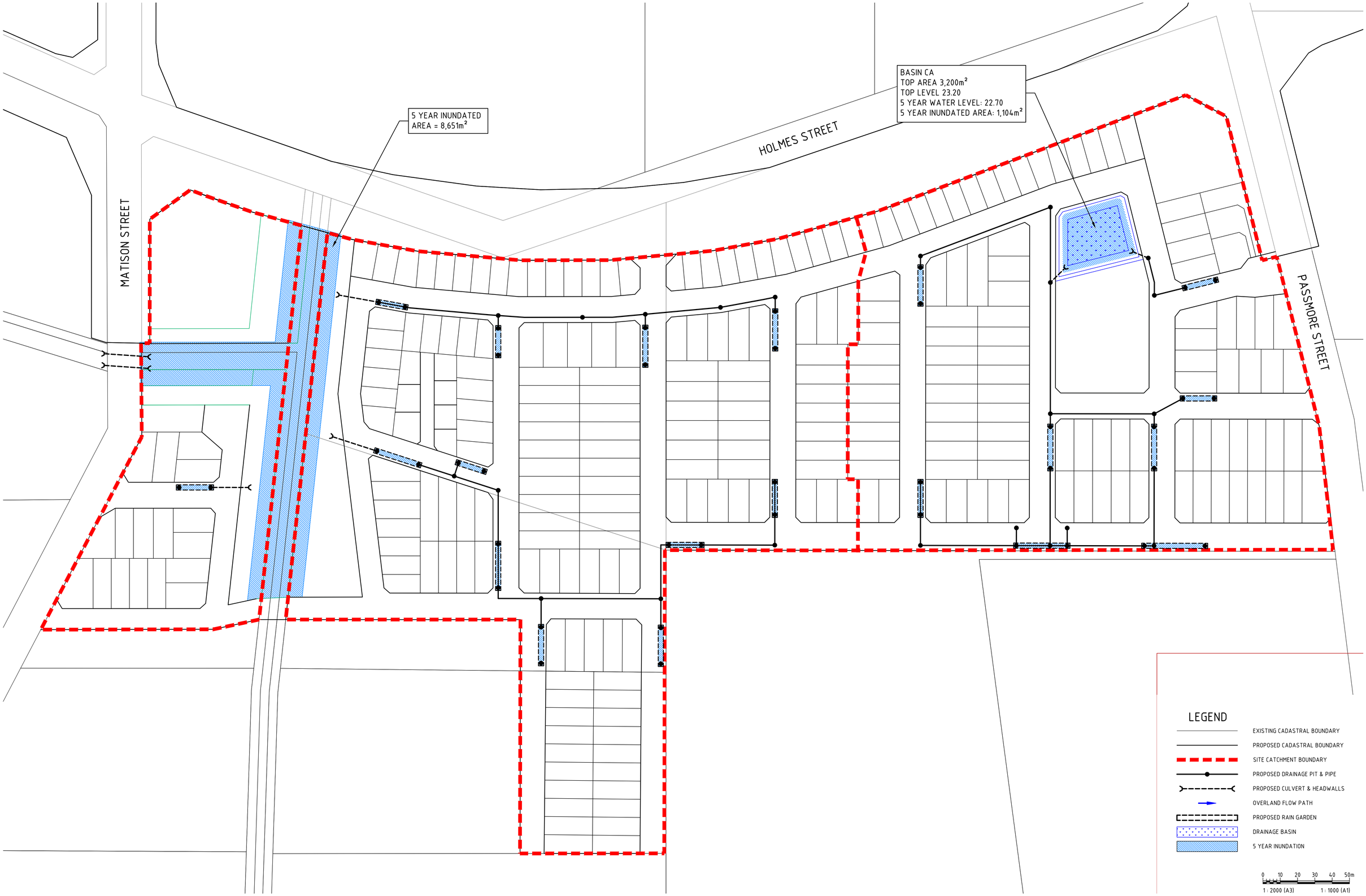

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SOUTHERN RIVER PRECINCT 3D
5 YEAR EVENT PLAN

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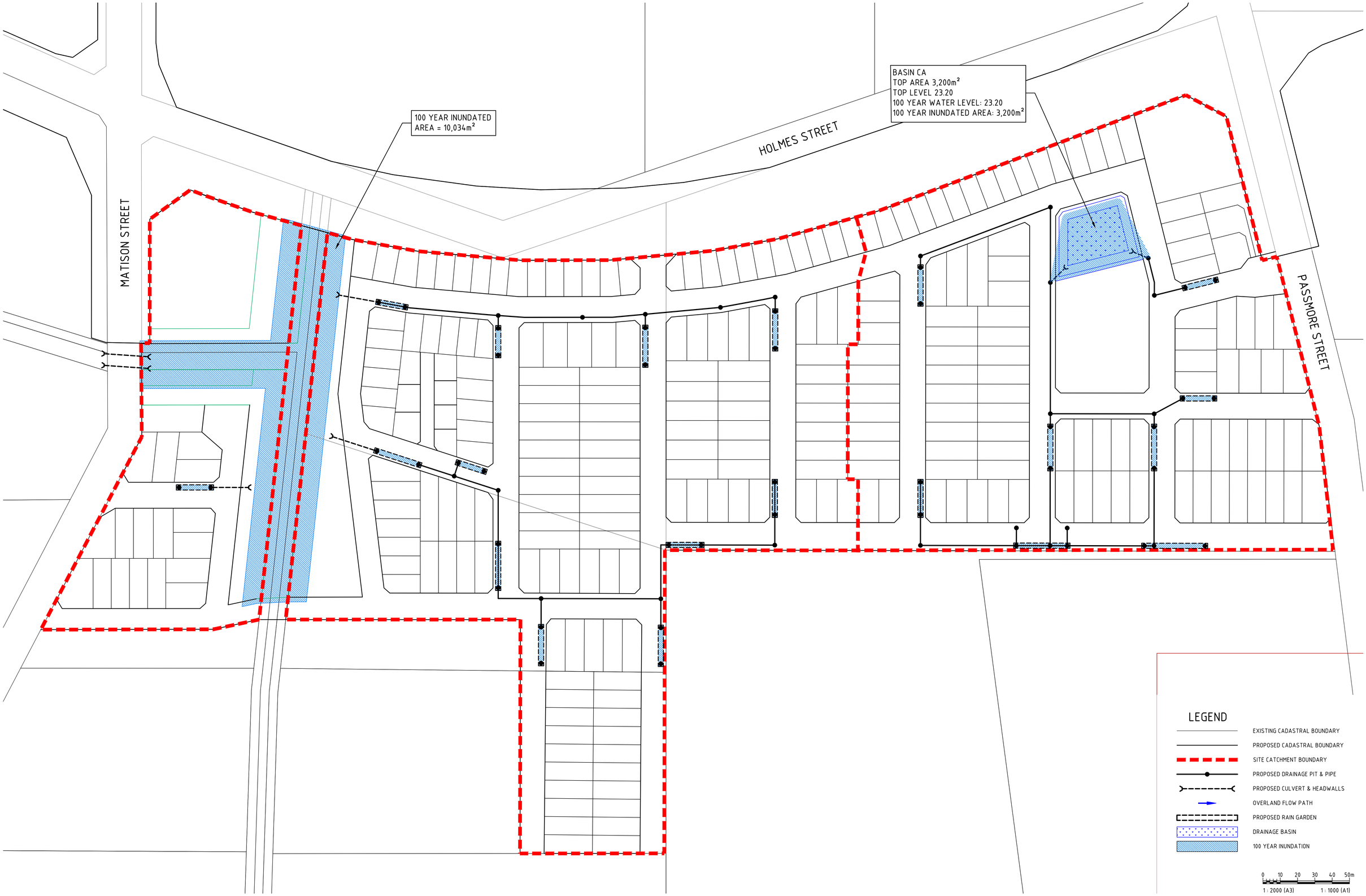

REV	DATE	DESCRIPTION	APPROVED
E	04.09.17	ISSUED FOR LWMS REVIEW	RN
D	30.01.17	GENERAL AMENDMENTS. ISSUED TO D.O.W.	RN
C	22.03.16	MINOR AMENDMENTS	RN
B	18.12.15	MINOR AMENDMENTS	RN
A	12.11.15	ISSUED FOR LWMS REVIEW	RN

ISSUE AND REVISION HISTORY

CLIENT

DYNAMIC PLANNING AND DEVELOPMENTS

LOCAL GOVERNMENT AUTHORITY

CITY OF GOSNELLS

SCALE @A1
HORIZ: 1:1000

DATUM
HORIZONTAL: PCG94
VERTICAL: AHD

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DRAWN:	CRF
CHECKED:	RN
APPROVED:	BH

CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D
100 YEAR EVENT PLAN

DRAWING NUMBER: 1201008-207

REV. E

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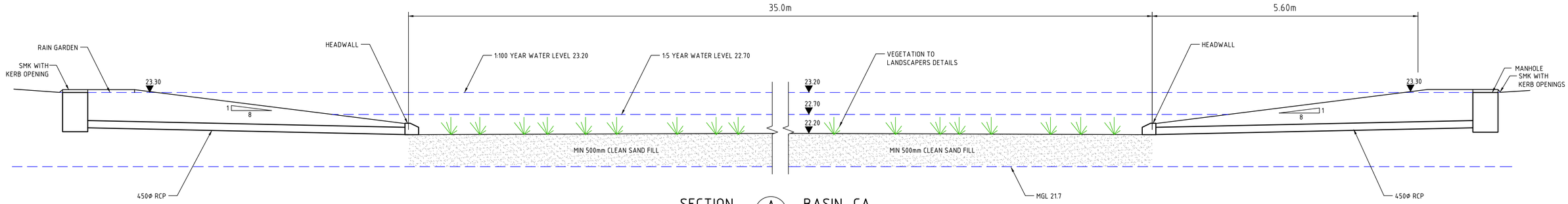
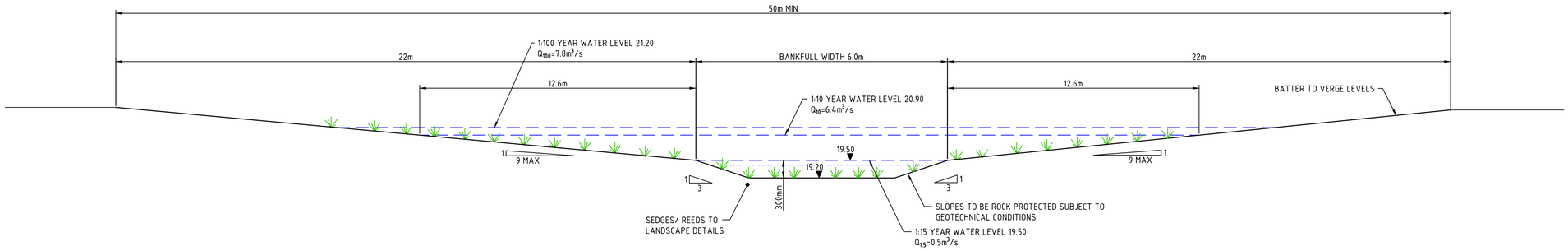


SECTION A 201 NTS — BASIN CA



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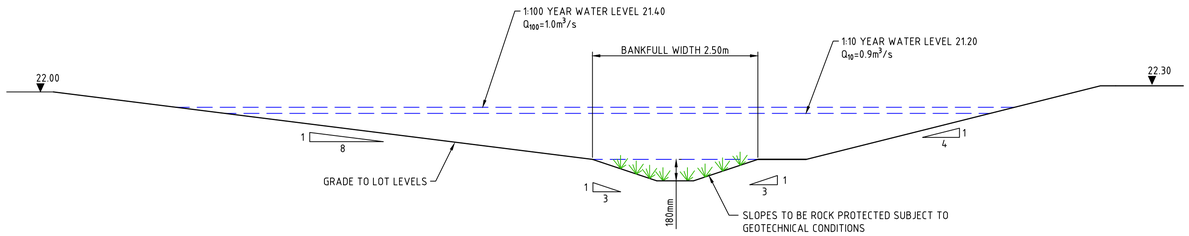
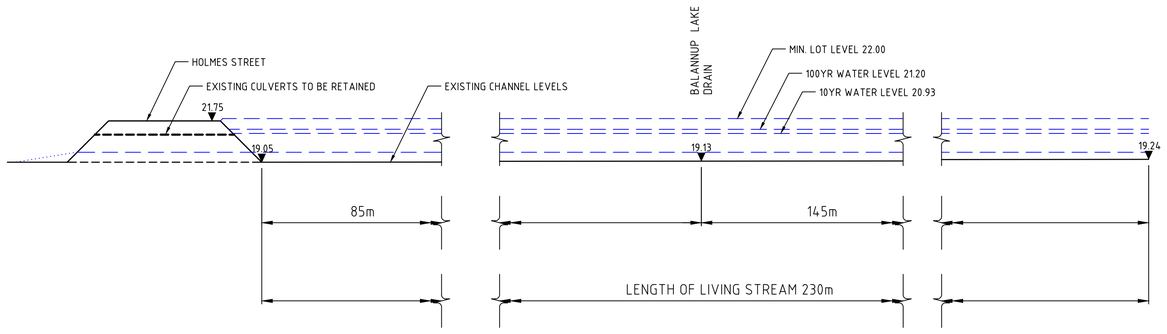


SECTION C 201 NTS — TYPICAL BALANNUP LAKE DRAIN CROSS SECTION



PROFILE THOUGH LIVING STREAM SECTION OF FORRESTDALE MAIN DRAIN
NTS

REV	DATE	DESCRIPTION	APPROVED
E	04.09.17	ISSUED FOR LWMS REVIEW	RN
D	30.01.17	GENERAL AMENDMENTS. ISSUED TO D.O.W.	RN
C	25.11.16	LIVING STREAM CROSS SECTION AMENDED	RN
B	18.11.15	MINOR AMENDMENTS	RN
A	12.11.15	ISSUED FOR LWMS REVIEW	RN

ISSUE AND REVISION HISTORY

CLIENT: DYNAMIC PLANNING AND DEVELOPMENTS

LOCAL GOVERNMENT AUTHORITY: CITY OF GOSNELLS

SCALE @A1: HORIZ: 1:1000

DATUM: HORIZONTAL: MGA94; VERTICAL: AHD

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CHECKED:	RN
APPROVED:	BH

CITY OF GOSNELLS
SOUTHERN RIVER PRECINCT 3D
TYPICAL SECTIONS

DRAWING NUMBER: 1201008-501

REV.: E

FILE REF: Z:\Jobs Active 2012\CE - Land Development\1201008-Bioscience - Southern River Precint 3D\Drawings\1201008-500 Details

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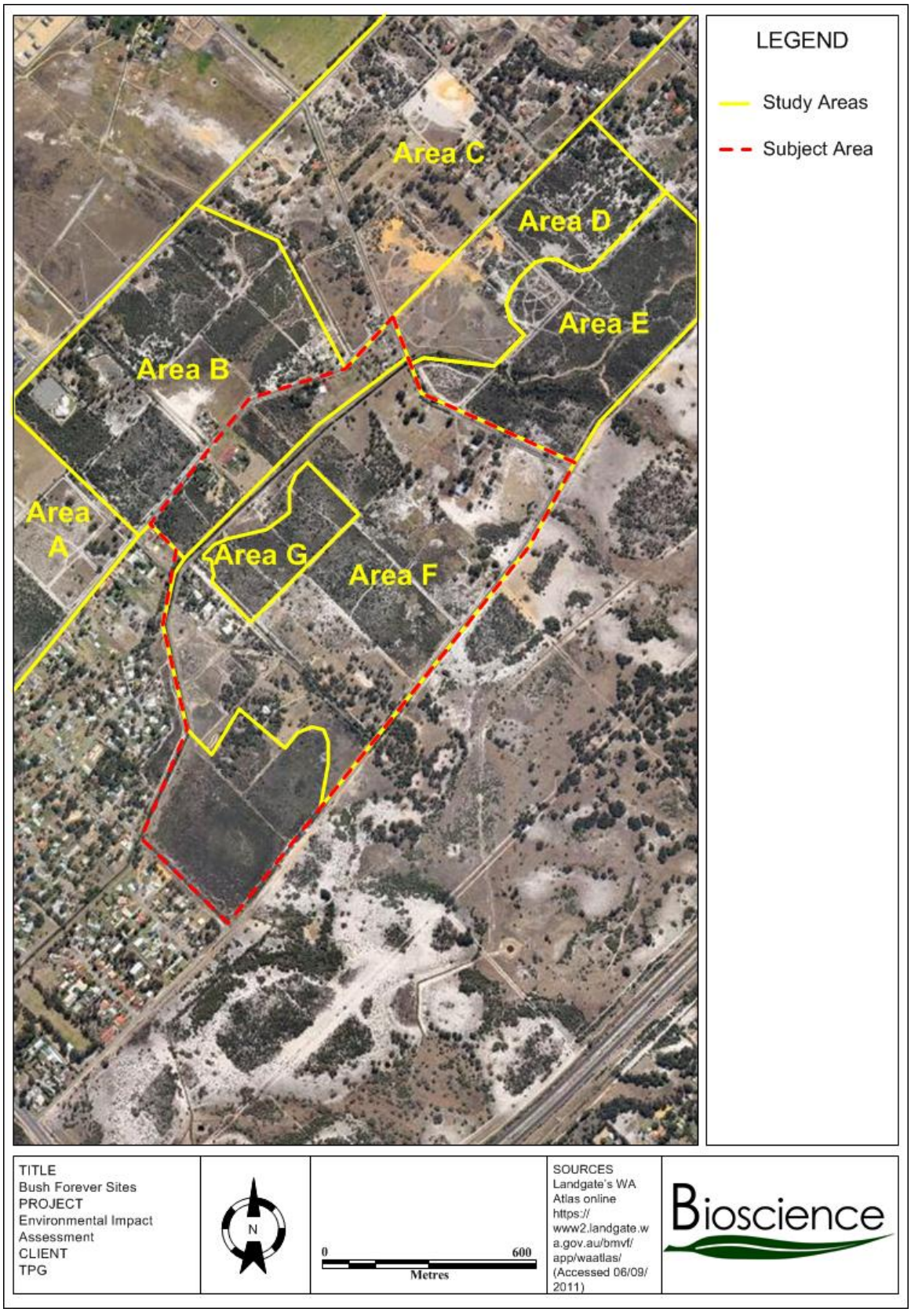
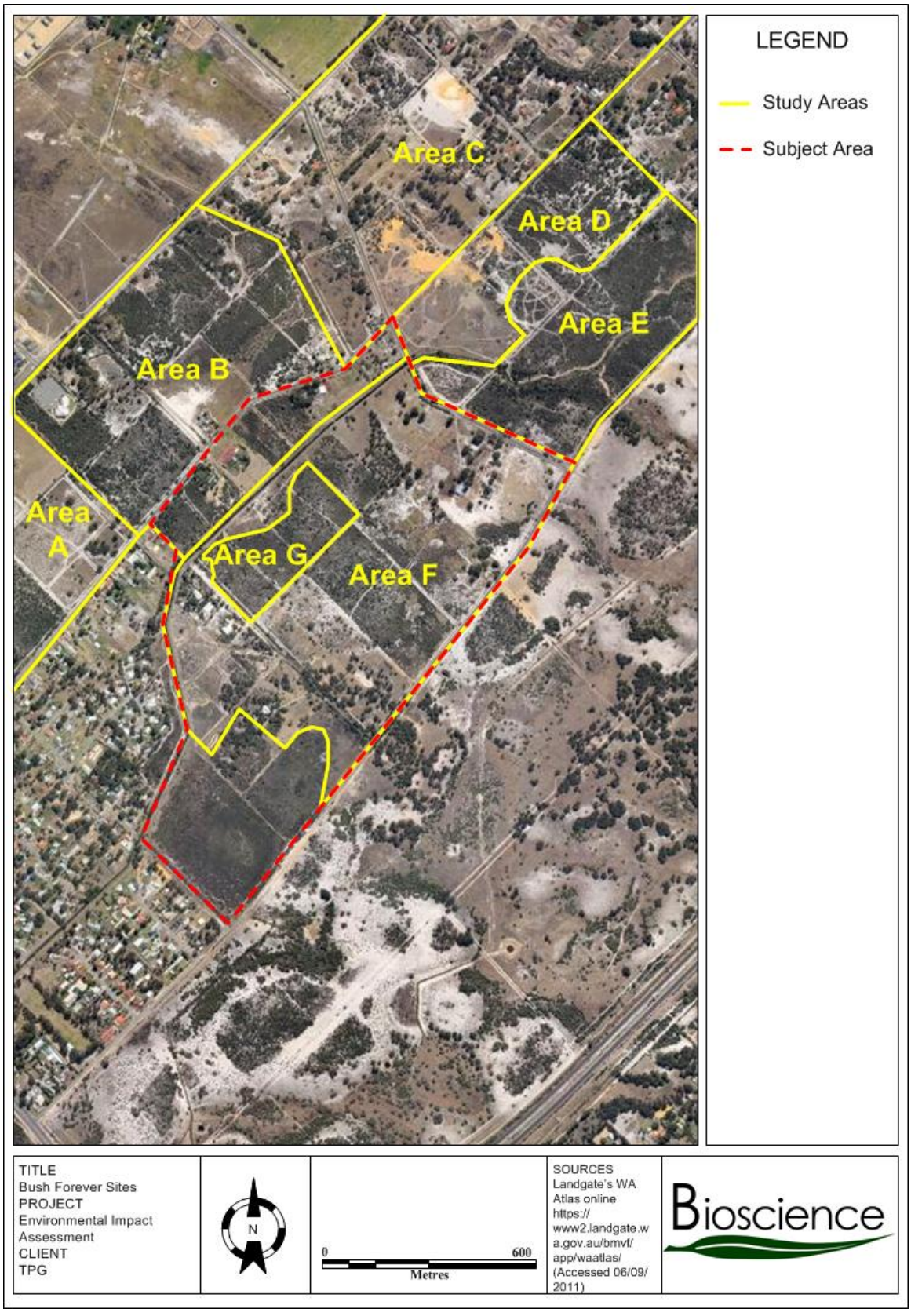
Appendix D: Acid Sulfate Soil Results

Sample ID	Depth	pH_F	pH_{FOX}	ΔpH	Reaction	Sulphur %	Redox
D1	3950-4200	4.44	3.72	0.72	L	0.08451	329.9
D2	2750-3500	4.72	3.52	1.2	L	0.03371	300.2
D2	3500+	4.54	2.1	2.44	L	0.041	401.8
D3	750-1200	7.37	6.27	1.1	L	0.01417	286.9
D3	1200-1500	7.2	6.05	1.15	L	0.02193	315.7
D3	1500-2200	7.88	6.47	1.41	L	0.00993	306.5
D3	2200-3500	7.6	5.62	1.98	L	0.02398	265.3
D4	2250-2500	5.4	3.91	1.49	L	0.2006	392.3
D4	3000-3750	4.42	3.33	1.09	L	0.03832	371.8
D4	4250+	4.95	3.19	1.76	L	0.2666	347.1
D5	2250-2550	5.51	4.49	1.02	L	0.02606	355.9
D5	2550-3150	5.37	3.73	1.64	L	0.07597	305.2
D5	3150+	5.54	3.23	2.31	L	0.07045	339.9
D7	2750-2900	4.53	3.45	1.08	L	0.05975	386.1
D7	4400+	5.24	2.8	2.44	L	0.1041	321.7
D8	3450-3700	4.62	3.22	1.4	L	0.08865	359.3
D8	3700-4350	4.84	3.59	1.25	L	0.03415	319.7
D8	4350+	5.08	3.34	1.74	L	0.1025	340.2
D9	3500+	5.66	4.2	1.46	L	0.06156	333.9
D10	3500+	4.63	3.19	1.44	L	0.03358	364.4

Appendix E: Flora and Fauna





Appendix F: Geotechnical Investigation and Permeability Certificate

Geotechnical Report

Southern River Precinct 3D
Lots 9 and 1792 Holmes Street and 11 Passmore Street
Southern River

July 2012

Southern River Precinct 3D
Lots 9 and 1792 Holmes Street and 11 Passmore Street, Southern River
Geotechnical Report

July 2012

Prepared for: Land owners of lots 9 and 1792 Holmes Street and 11 Passmore Street, Southern River

Prepared by:

Bioscience Pty Ltd

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Prepared by: Robert Bromfield
Approved by: Peter Keating

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1.0 Executive Summary

This report covers lots 9 and 1792 Holmes street, and lot 11 Passmore street Southern River, contained within precinct 3D of the Southern River structure plan. The objective of this report is to determine the suitability of the area for urban development from a geotechnical perspective. The site is gently undulating Bassendean sand ranging in height from 21 - 24m AHD, with the Forrestdale main drain forming the northwest boundary of the site. Groundwater occurs between 0.7 and 2.6 metres below ground level over the site at maximum levels.

Bioscience undertook field and laboratory investigations of the soils over the site to determine their physical and chemical properties to in relation to soil profiles, permeability, reactivity and acid sulphate potential. Field investigation consisted of ten mechanically augered holes from which soils profiles were logged, and samples taken for laboratory analysis.

Acid sulphate soil testing showed low acid sulphate potential, with none of the tested samples displaying properties of potential acid sulphate soils, however, soils are generally acid in nature and further investigation would be required if there is to be large scale excavation of natural soils.

Soil profiles show the site to be Bassendean sand of varying depth over Guilford formation clays of low reactivity. Sands were found to be medium textured with thickness ranging from 2.25 to 4.2 metres, whilst clays are sandy clays. Coffee rock (indurated iron rich silty sands) was intersected in some of the holes at varying depths generally at the interface between the clays and sandy clays.

The majority of the site is Class A" as defined in the Residential Slab and Footings (Australian Standard 2870). A small area with sandy clay at the surface is Class H.

2.0 Introduction

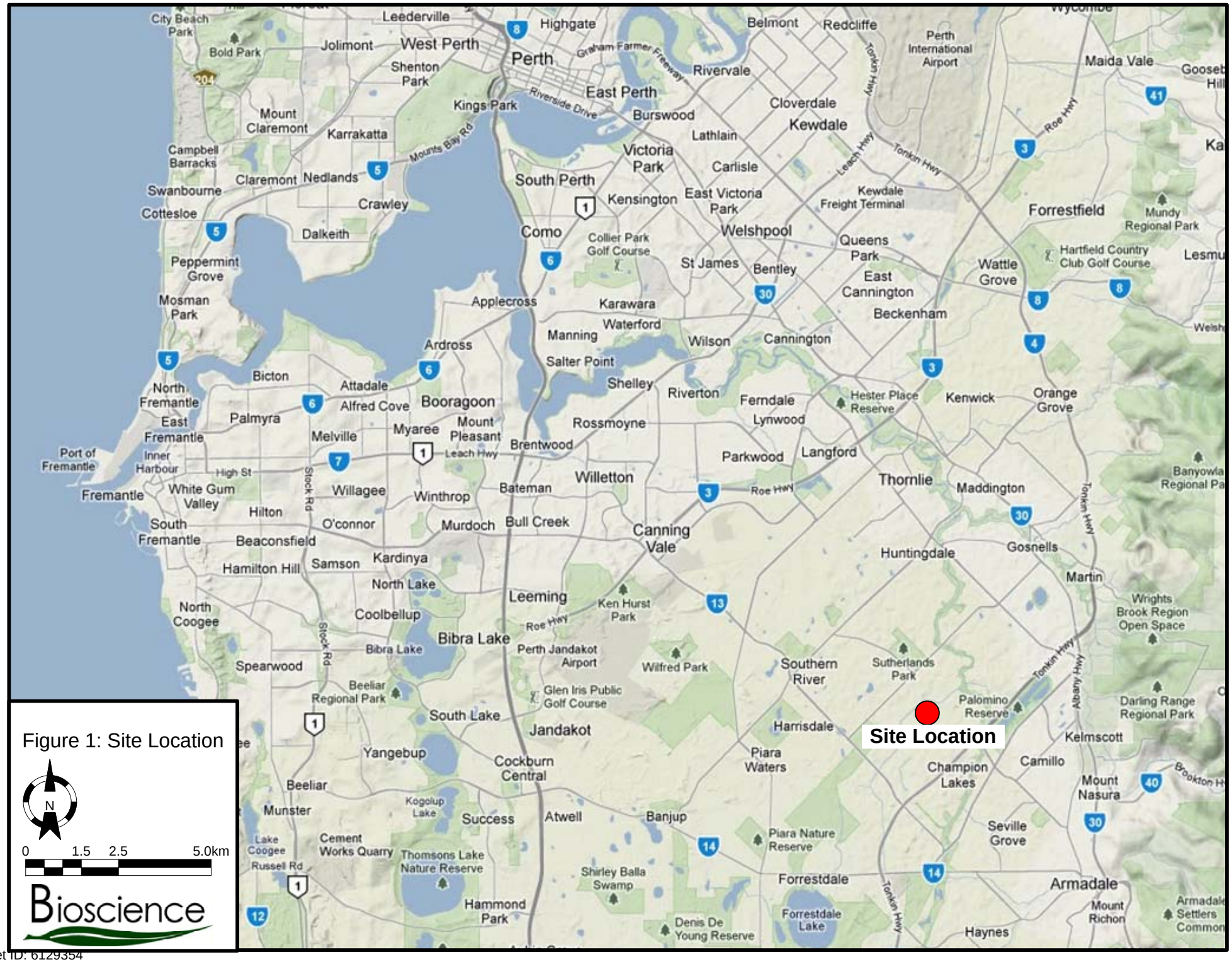
This report describes the geotechnical investigations undertaken by Bioscience Pty Ltd in the precinct 3D area of Southern River, with a specific focus on Lots 9 and 1792 Holmes street and lot 11 Passmore street, Southern River (figure1). The investigation was commissioned by the owners of the properties who are seeking to develop the land into an urban subdivision. The lots collectively cover 16.5ha,

This report has been developed for the owners, based on the proposals presented and their contained terms of reference which have been accepted. The advice contained within this report is based on the information obtained and the assumptions which are expressed herein. Should the information received or the assumptions be incorrect, then Bioscience shall accept no liability in respect of the advice whether under law of contract, tort or otherwise.

Within Southern River region, the City of Gosnells has identified several precincts, of which the site is located within Precinct 3D. Precinct 3D is bounded by Passmore street, Holmes Street, Matison street, Phoebe street, the Forrestdale main drain and Furley road and is characterised by areas of flat, low lying land and a relatively high water table. Bioscience was asked to investigate the land, with the objective of determining the geotechnical condition present, and whether it is suitable for rezoning to urban, and any requirements to enable development.

3.0 Proposed Development

The site is proposed to be developed into a residential subdivision consisting of varying densities of housing, a retirement living area, a commercial area and areas of public open space. (figure 2).



DRAFT

SOUTHERN RIVER ROAD

STREET

500m KENNEL BUFFER

R25 8414m²

R25 2958m²

R25 2941m²

R25 2439m²

R40 1383m²

P.O.S. & DRAINAGE 4.809ha

R40 3977m²

R40 3379m²

R40 3491m²

R25 2405m²

R25 1605m²

R25 1720m²

HOLMES STREET

R30 4068m²

R30 4482m²

R30 9350m²

R40 9262m²

R25 6626m²

R25 8138m²

R25 9630m²

R30 9350m²

R50 1980m²

P. O. S. 4800m²

R30 1929m²

R30 8153m²

R25 3902m²

R25 4517m²

R30 3085m²

R30 2620m²

REW. 6.6862ha

DRAIN

MAIN

FORRESTDALE

Light Industry 2.1556ha

Bush Forever 8.42ha

High School 11ha

District Open Space 14.76ha

Rural 11.2ha

Bush Forever 19.24ha

MATISON

PHOEBE

STREET

PASSMORE STREET

500m KENNEL BUFFER

TAMBY CT

FURLEY ROAD

CORNCRAKE CT

PASSMORE STREET

LEGEND

- RESIDENTIAL R25
- RESIDENTIAL R30
- RESIDENTIAL R40
- RESIDENTIAL R50
- PARKS & RECREATION
- HIGH SCHOOL
- REW
- PUBLIC OPEN SPACE
- LIGHT INDUSTRY
- BUSH FOREVER
- RURAL
- DISTRICT OPEN SPACE
- RESOURCE ENHANCEMENT WETLAND (REW) AREA
- 30m REW BUFFER

0 125 250 m

SOUTHERN RIVER SUB-PRECINCT 3D O.D.P.

Date: 14-06-12
Scale: 1:2500 @ A1, 1:5000 @ A3
Designer: AR
Drawn: TC
Drawing No.: 710-085 CP 110812.dwg

TOWN PLANNING AND URBAN DESIGN

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The Planning Group WA Pty Ltd ABN: 99 097 273 222

4.0 Site Description

4.1 Land Use

The land is used for horse paddocks and stables, with horses grazing lots 9 and 1972 Holmes street, and a stable on lot 1792. Lot 11 Passmore street is vacant, but has previously been cleared and has remnants of buildings on the site. There are fences around the lots and numerous rubbish and rubble piles. The remnants of a small piggery are present on lot 1792 Holmes street.

4.2 Topography

The area has a low relief with minor variations in topography. The area generally lies between 20m AHD and 22m AHD with some areas above 22m AHD (figure 3).

4.3 Vegetation

The site is mostly devoid of native vegetation as it has been cleared for grazing. The majority of vegetation on the site are introduced trees, pasture and low scrub.

4.4 Geology and Geomorphology

The subject site is located on the Swan Coastal Plain within the Bassendean dune system, an area characterised by low dunes of siliceous sand interspersed with poorly drained areas or wetlands. Soils tend to be a deep bleached grey colour sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than 2 m.

Underlying the Bassendean formation is the Guildford formation. The soils of the Guildford formation are complex, and comprise a successive layering of soils formed from erosion of material from the scarp to the east. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium. The Guildford formation is characterised by poor drainage due to the low permeability of sub-soil clays which prevent the downward infiltration of rainfall, consequently during the winter month's water logging and surface inundation can occur. In addition, the clay fraction of the Guildford formation is known to have highly variable Plasticity Indices (Hillman et al., 2003).

The geology at the site as per the Geological Survey of Western Australia 1:50000 Environmental Geological Series Armadale Map part of sheet 2033 I and part of sheet 2133 IV is:

- S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted of eolian origin
- S10 – SAND – As for S8 over sandy clay to clayey sand of the Guilford formation, of eolian origin
- Sp1 – PEATY SAND – grey to black, fine to medium grained, moderately sorted quartz sand, slightly peaty, of lacustrine origin

A soil geology map can be seen in figure 4.

4.5 Groundwater

The hydrology of the Southern River area on a broad scale is characterised by flat land of Bassendean sand dunes with quite low relief hosting a superficial aquifer which is about 30 m thick. The Southern River itself acts as a local discharge point for this superficial aquifer and is thus the lowest local groundwater level. The Perth Groundwater Atlas (2004) shows the groundwater contours slope downwards in a north easterly direction towards the Southern River, but also strongly influenced by the Forresdale main drain. The groundwater atlas suggests that groundwater is approximately 2.5 m below the surface across the site, based on May 2003 data when local groundwater would be approaching annual minimum levels (Figure 3). Groundwater monitoring and modelling of the southern river district was conducted initially by JDA (2002) and then by Rockwater (2005). Both the JDA and Rockwater reports indicate that groundwater flow on the site is in a north easterly direction towards the Southern River with an Average Annual Maximum Groundwater Levels (AAMGL) of 20 mAHD.

4.6 Site Surface Drainage

The major surface water drainage feature of the site is the Forrestdale main drain which forms the north west boundary of the site, whilst in the eastern portion of the site, a seasonal lake forms as an expression of the groundwater, but is also a significant drainage feature. The topography of the site, with the high central area splits the surface drainage between west and east.

4.7 Wetlands

The Geomorphic Wetlands Dataset displays the location, boundary, geomorphic classification and management category of wetlands on the Swan Coastal Plain. The information contained within the dataset was originally digitised from the *Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas*, which was captured at a

scale of 1:25,000 (Hill et al. 1996b). According to the dataset the site has areas of Multiple Use Wetlands (MUW) (15633 Dampland, 15772 Dampland, and 15781 Dampland). On the north site of Holmes street there is a Conservation Category Wetland (CCW), Dampland 7720. Both Dampland 15781 and 15633 which are on the site abut the CCW. Forrestdale main drain also flows into the CCW as a natural floodplain area before discharging into the Southern River. There are also numerous Resource Enhancement Wetlands (REW) near the site. The location of the wetlands can be seen in figure 5.

Around one third of lot 1792 has been classified by the City of Gosnells as an *Environmental Protection Policy (Swan Coastal Plains)* 1992 (EPP) lake in their 2004 structure plan (Figure 7). EPP lakes are generally recognised as having significant conservation value; however this seems to contradict the current MUW classification in regards to both management category and boundaries. The lake also appears to be experiencing increasing dry periods as observed by aerial photography. Bioscience is preparing a request to have the wetland removed from the EPP lakes register by following the guidance for modifying wetlands.

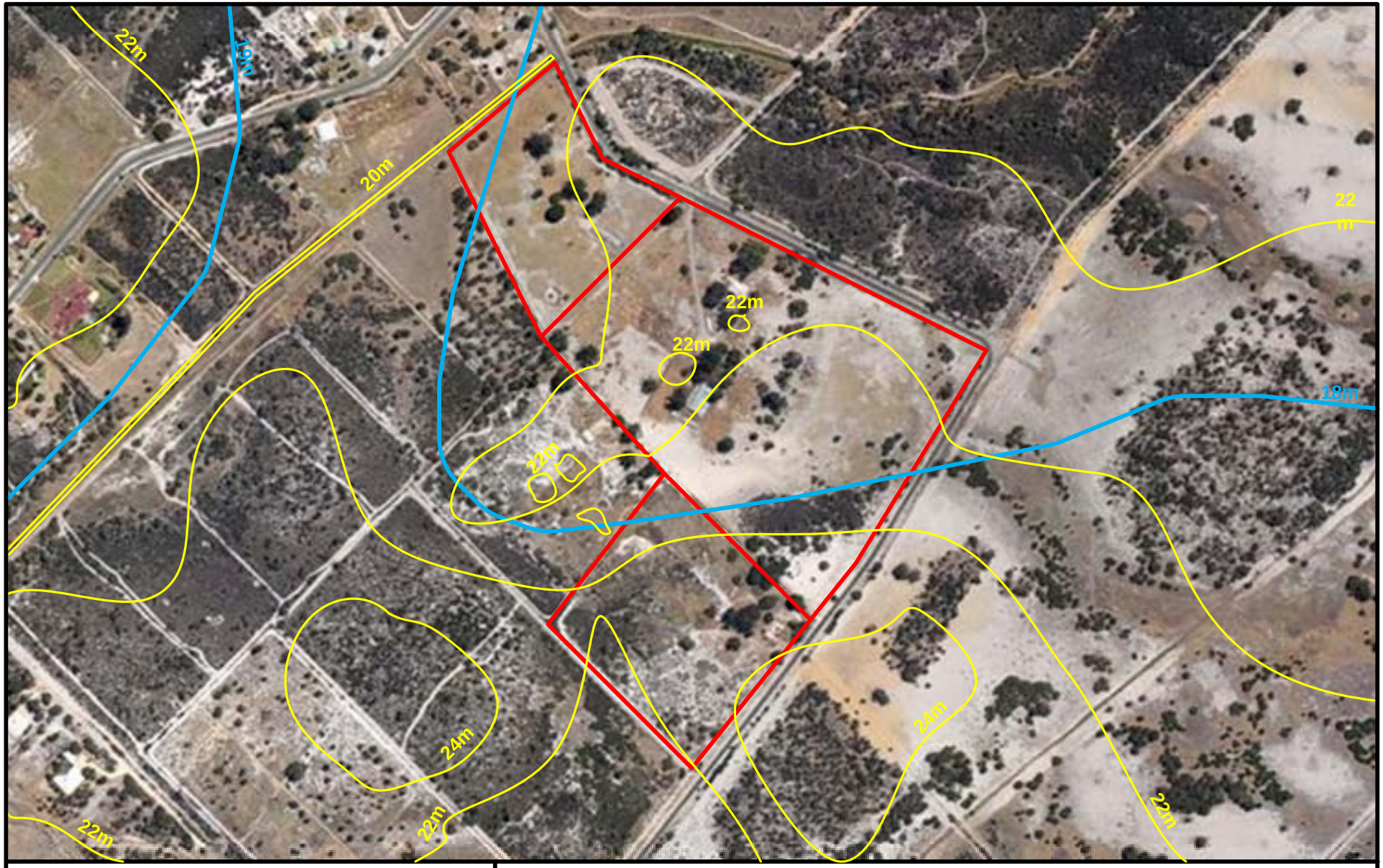


Figure 3: Topography and DoW Groundwater Contours

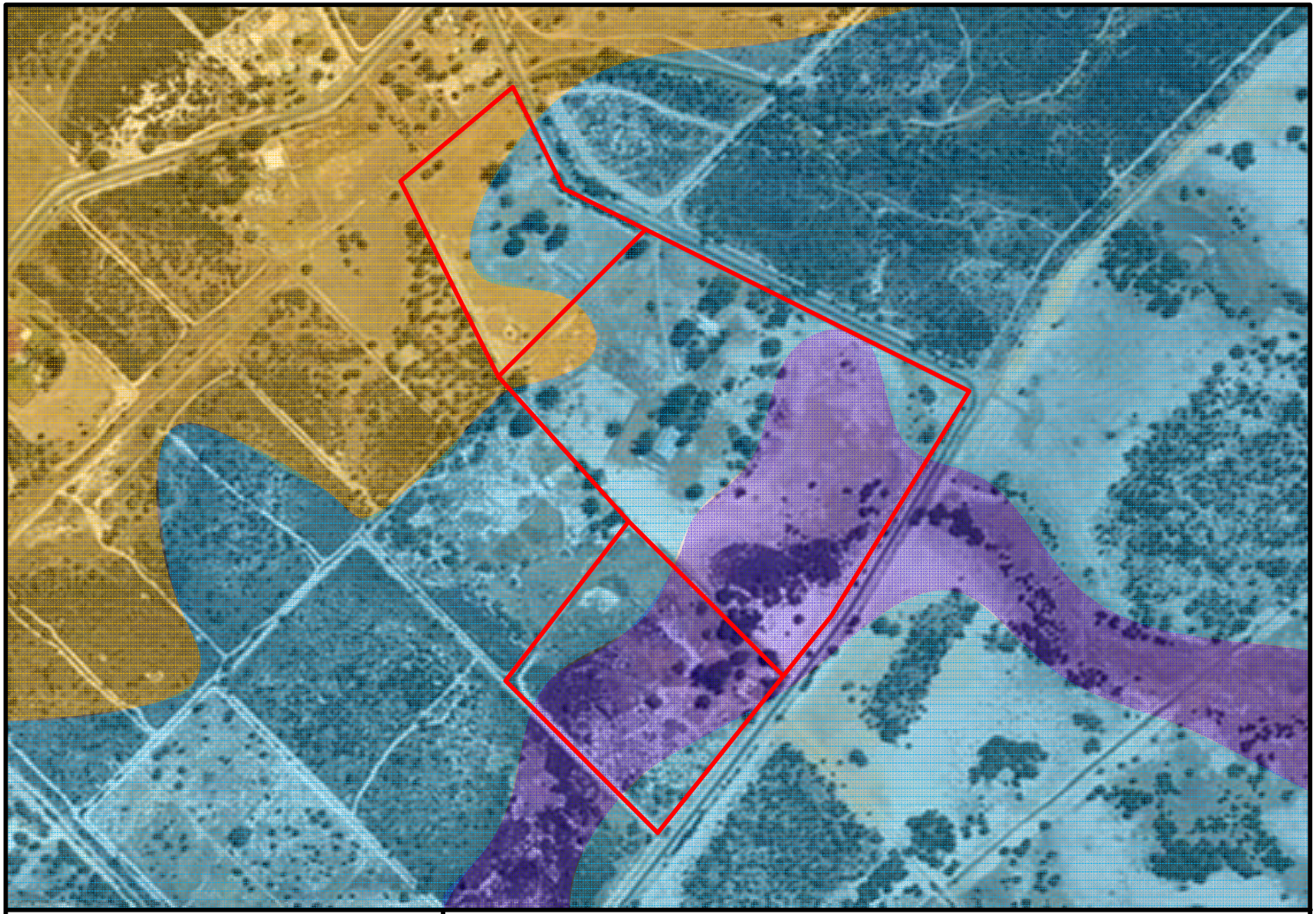
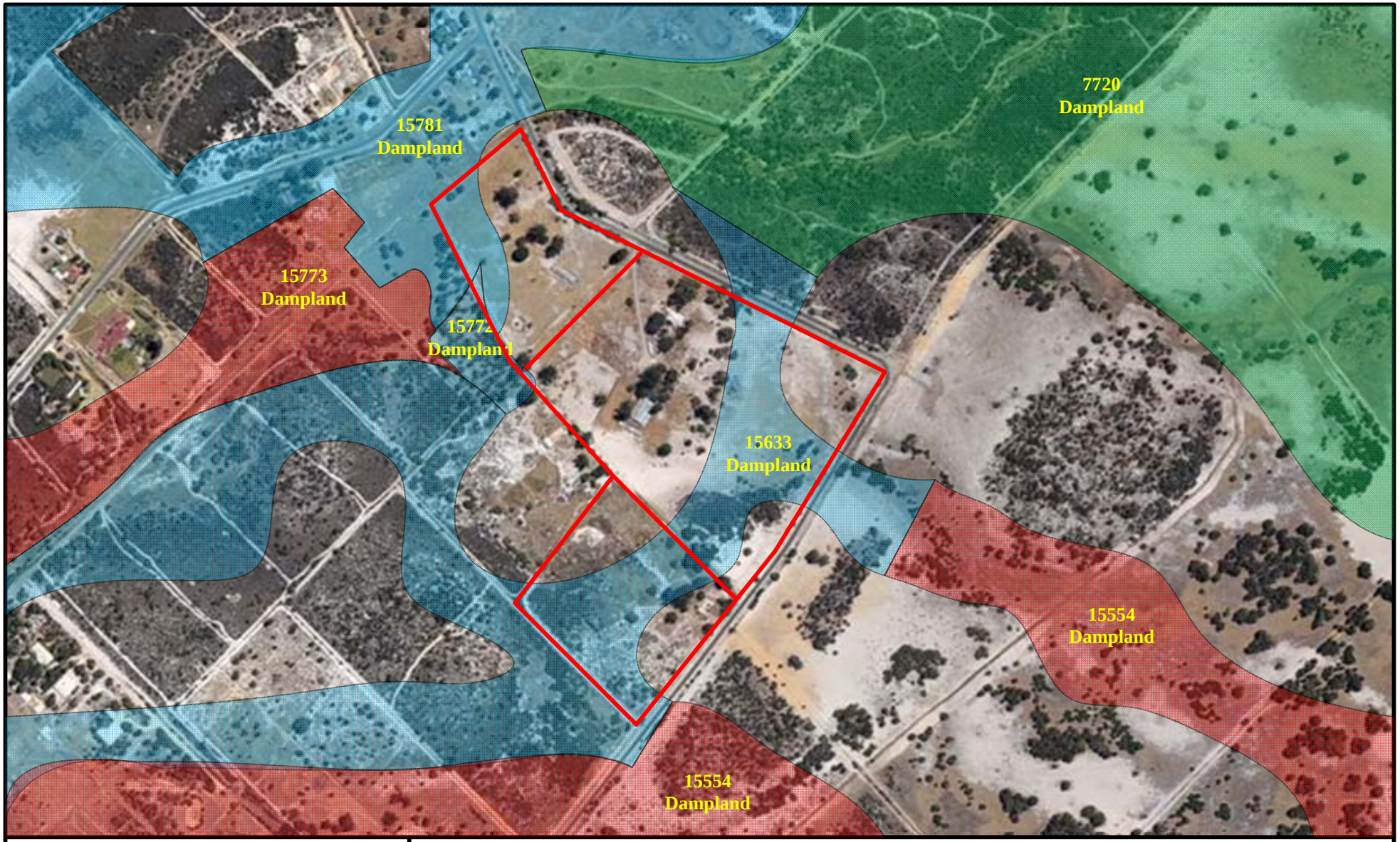


Figure 4: Soil Geology



N

Bioscience

0 200 400m

Figure 5: Geomorphic Wetland Dataset

- Multiple Use Wetland (MUW)
- Resource Enhancement Wetland (REW)
- Conservation Category Wetland (CCW)

5.0 Geotechnical Investigation

5.1 Objectives

- Determine soil and groundwater (if encountered) conditions to a depth of 2.5 metres below current ground level.
- Provide advice on any need for groundwater control or subsoil drainage
- Determine soil permeability and suitability for stormwater infiltration.
- Determine the site classification according to AS 2870 (1996), and recommend measures to upgrade classification if required.
- Provide advice in relation to excavation control requirements, site preparation earthworks, characteristics of fill requirements and compaction control.

5.2 Field Investigations

Field investigations took place in April 2011 with 10 boreholes were dug using a mechanical hollow tipped auger drill rig that provides core samples of the soil profile as the hole is drilled. From the soils cores, soil profiles were logged and samples taken for laboratory analysis (Figure 6). Piezometers were installed into the drilled boreholes for groundwater investigations.

5.3 Soil Profiles

The site has a typical soil profile of sand over sandy clays, with a layer of weakly cemented iron rich silty sand (coffee rock) commonly found between the sand and clays.

The common soil profile was found at all boring locations except for D3, which was loamy and clayey sands all the way through the profile. The depth of sand at each location varied between 4200mm at D4 and 2250mm at D5, the sand was generally grey and white medium textured Bassendean sand. Coffee rock was intersected at all except two of the locations, D3 and D 6, and occurred at variable locations within the soil profile, most commonly at the interface between sands and clayey sands. Clayey sands are of the Guilford formation and varied from grey to brown in colour. Soil profile logs and photos can be seen in Appendix 1

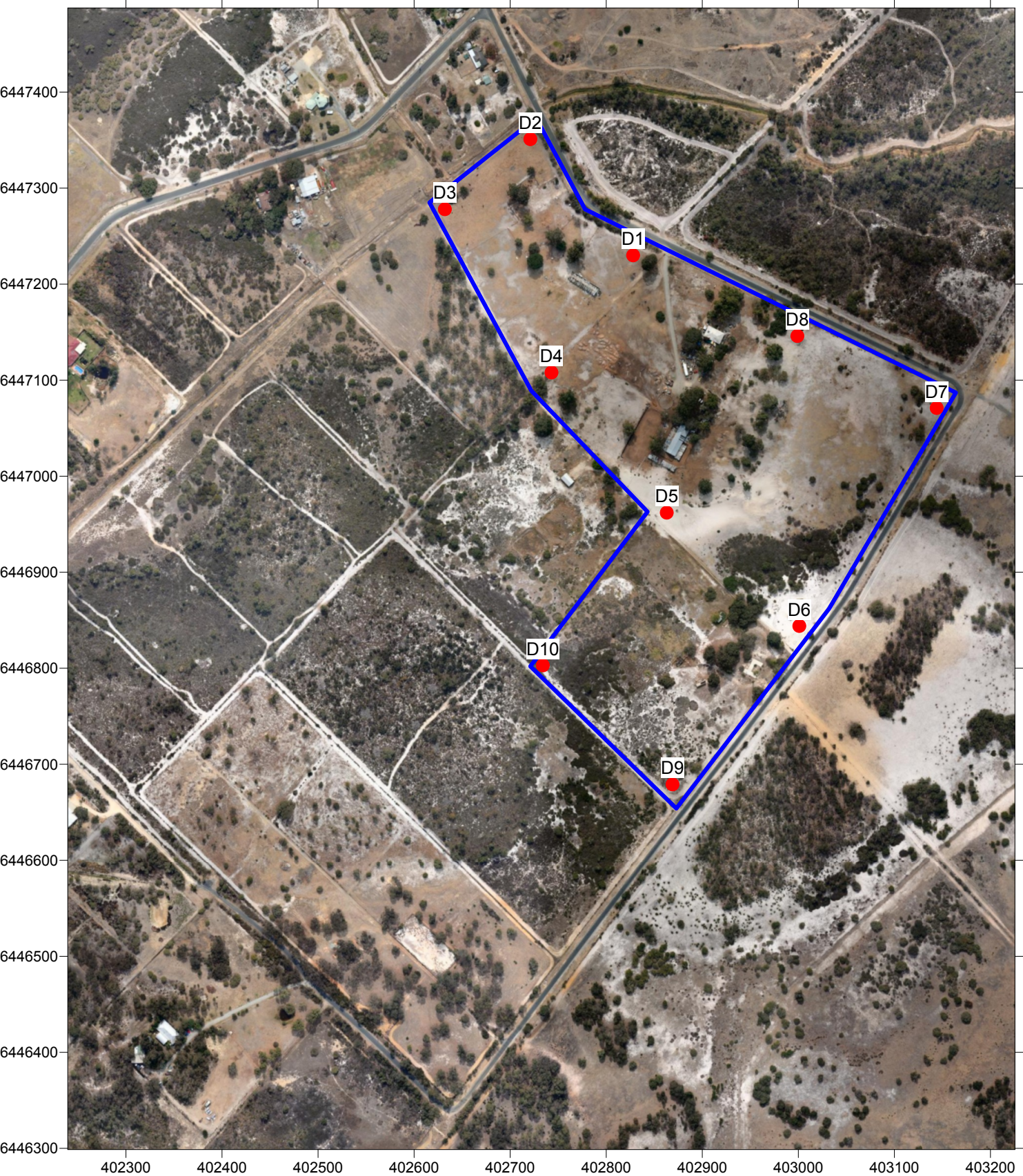


Figure 6: Geotechnical Investigation Locations

N

0m 100m 200m 300m 400m 500m

Bioscience

5.4 Groundwater

Groundwater conditions at the site have been assessed through the use of piezometers installed during drilling and collection of soil cores. Groundwater has since been monitored on a regular basis to determine seasonal fluctuations in groundwater levels and how they may impact upon development of the site. Groundwater at the site has occurs between 0.7 and 2.6 metres below ground level and has a seasonal fluctuation of up to 2m. Groundwater levels can be seen in Appendix 2. Given that the Forrestdale Main Drain runs through the site it will have a lowering effect on the groundwater of the site when the groundwater rises and intersects the level of the drain.

5.5 Laboratory Investigations

At the completion of the fieldwork, a program of laboratory tests was performed on selected soil samples. Test results have been used to assist with the classification and determination of engineering properties of the soil for this geotechnical investigation.

- Particle size distribution – AS1289.3.6.1
- Atterberg limit
  - Liquid limit – AS1289.3.1.2
  - Plastic limit - AS1289.3.2.1
  - Plasticity index – AS1289.3.3.1
  - Linear shrinkage – AS1289.3.4.1
- Acid Sulfate Soil DEC field test plus total Carbon and Sulphur

The laboratory tests were carried out in accordance with the requirements specified in AS 1289 by Bioscience's soil laboratory in Forrestdale.

5.5.1 Particle Size Distribution

Particle size distribution (PSD) was determined on soils collected during the field investigation that gave a representative example of the soils present in the soil profiles of the site. The results of the PSD analysis show that the sands on the site are generally a medium textured, poorly to uniformly sorted sand with less than 5 per cent fines (<0.075mm). The clays on the site are actually clayey sands with a fines content between 15 and 30 per cent. Graphs of PSD can be seen in figure 7.

Fours samples contained more than 12 per cent fines and were therefore classified as clayey sands, four of the samples contained less than 5 per cent fines and are classed as clean sands

generally poorly or uniformly sorted. The remaining four samples that underwent PSD are borderline classifications between sands and clayey sands, with three of them being closer to sands with between 5 and 8 per cent fines, and the other closer to clayey sands at 11.57 per cent fines.

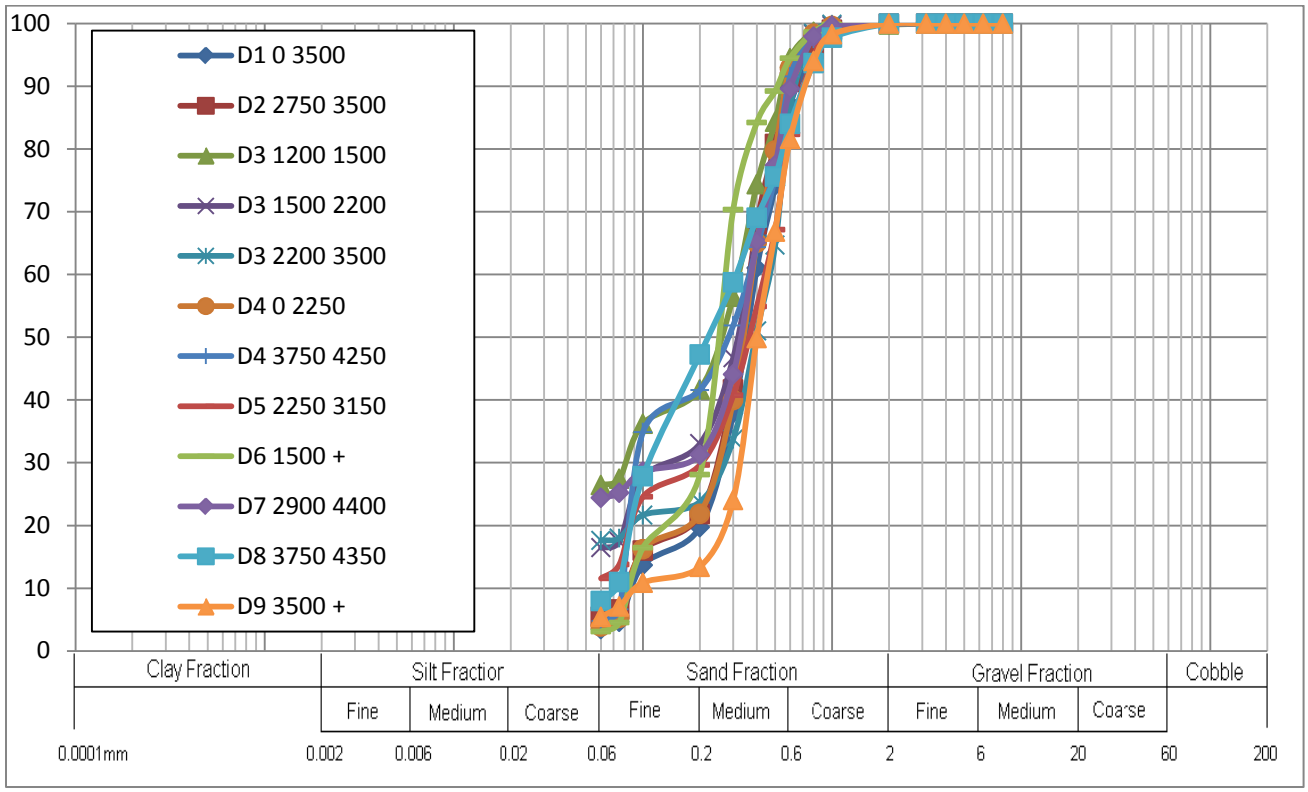


Figure 7: Particle Size Distribution Graph

5.5.2 Attergberg Limit

The Atterberg limits tests are simple standardized tests that were developed to determine the water contents that will induce particular behaviour, and provides a useful measure of potential soil reactivity and ground movements, which are fundamental in foundation design. Samples that contained more than 20% of fines in PSD analysis underwent Atterberg testing.

Both samples plotted above the "A" Line , with sample D7 2900-4400 classified as a clay of low plasticity. Sample D3 1200-1500 classified as a clay of high plasticity, making it a highly reactive clay. The raw results for these tests are summarised in table 1.

Table 1: Atterberg Testing Results

Borehole	Sample Depth (m)		Soil Weight		Liquid Limits			Plastic Limits (PL)	Plastic Index (PI)	Linear Shrinkage (LS)	Atterberg Classification
			Total soil Weight (g)	% fines (<425um)	No Blows (15 to 35)	Water content (%)	Liquid Limits (LL)	Water content (%) OR Plastic Limits (PL)	PI = LL - PL	Linear Shrinkage (LS) (%)	
D3	1200	1500	208.6	89.07	28	92.02	92.91	27.56	65.35	6.67	CH
D7	2900	4400	246.5	147.8	26	31.52	31.57	17.68	13.89	8.00	CL

NOTE: M = Silt, C = Clay, L = Low plasticity, I = Intermediate plasticity, H = High plasticity

These can be seen in Figure 8 where the A - Line separates soils that behave in the way of organics and silts, plotting below the A - Line, to those that are clays and plot above the A - Line. Given the fact that both soils have a high percentage of sand fraction and are classified as clayey sands, the reactivity of the clay will not cause as much ground movement as if they were more pure clays. Also the depth of the sand cover at D7 limits any impact the clay would have on the surface.

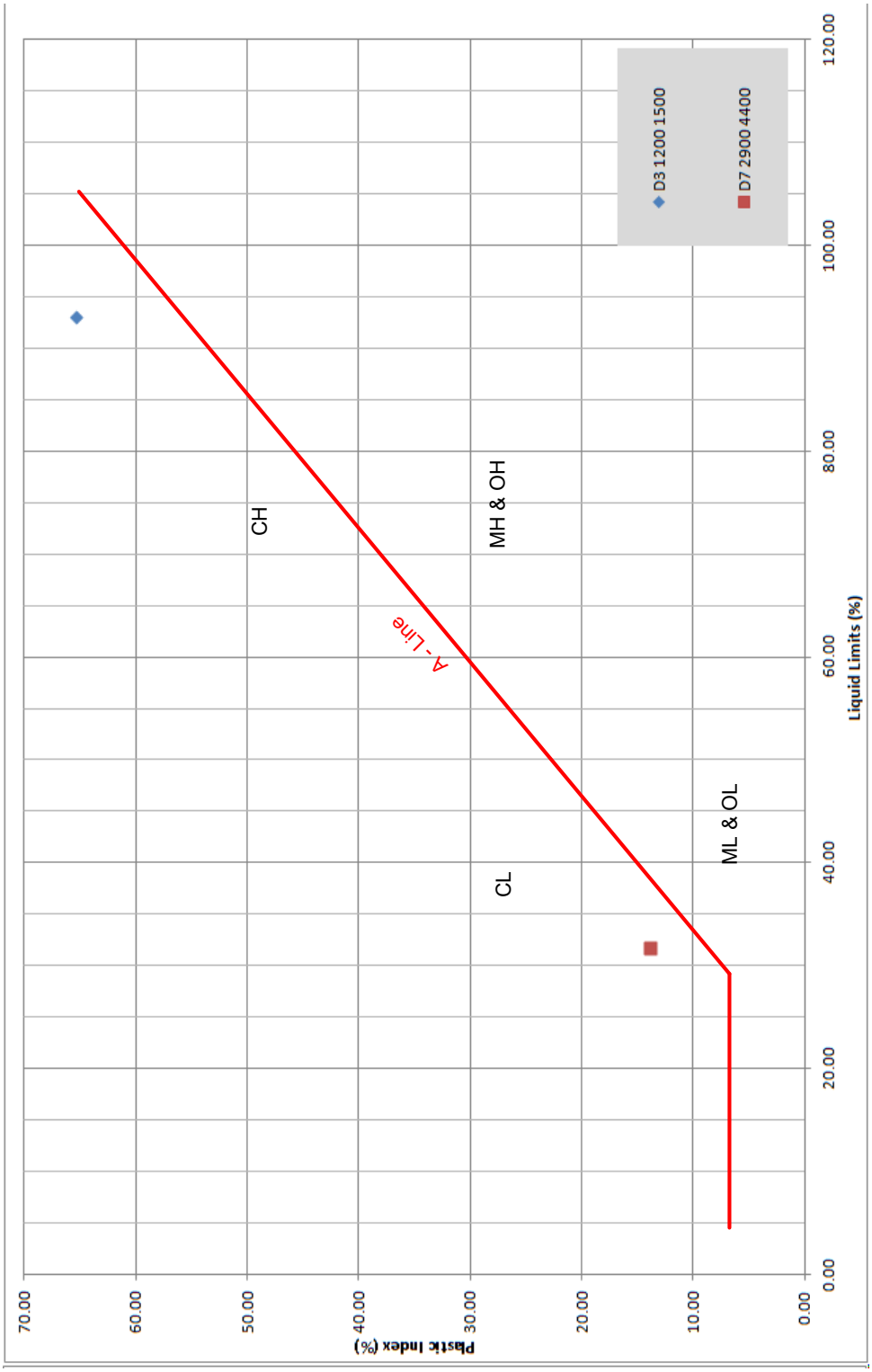


Figure 8: Atterberg Graph

5.5.3 Acid Sulphate Soil Exclusion Tests

The acid sulphate risk maps for the site shows a large area of lot 1792 Holmes street and lot 11 Passmore street to have a high to moderate risk of acid sulphate soils occurring within 3m of the natural soil surface. The rest of the site has a moderate to low risk of acid sulphate soils occurring within 3m of the natural soil surface, but high to moderate risk below 3m. As a result of this, exclusion testing was done on the soils collected during field investigation to determine the acid sulphate potential.

Acid sulphate soils (ASS) exclusion testing involves the use of field testing and determination of total sulphur content.. If the Field test procedure indicated potential or actual acid sulphate soils, determining the total sulphur can confirm or eliminate the result. For a sample to be classified as potential acid sulphate soil the minimum "oxidisable" (S_{POS}) sulphur present must be greater than 0.03% for a sand, or greater than 0.06% for sandy loams and light clay or greater than 0.1% for silts and clays. Therefore if total sulphur is less than the specified levels, then the sample cannot be potential or actual ASS.

The field test procedure involves measuring the field pH of the soil (pH_F) and then using hydrogen peroxide to oxidize the soil and then measure its oxidized pH (pH_{FOX}). A field pH of less than 3 can indicate an actual acid sulphate soil whereas if the field pH was not low and the oxidized pH drops to less than 3, then the soil may be a potential acid sulphate soil. Drops in pH of greater than 2 ph units indicate that a soil has potential to be oxidised and could be a risk of becoming acid sulphate soils. Table 2 summarises the results of the acid sulphate testing.

Selected soil samples collected during geotechnical investigation were analysed using the DEC field test procedure as well as LECO carbon sulphur analyser and redox potential. Overall these give an indication of whether or not soils are actual, potential or non acid sulphate soils. Twenty samples underwent these tests and 3 samples came back as being potential acid sulphate soils. These soils are generally soils deeper than 2.5 metres with higher clay contents, or the presence of coffee rock. 16 samples returned results that indicate they are not acid sulphate soils but have a sulphur content above the 0.03% threshold for treatment of acid sulphate soils..

Any excavations of natural soils on the site will require more detailed investigation of the soils in order to develop an acid sulphate soils management plan specific to the excavations that would take place. If dewatering is to be required as part of any excavations, a dewatering management plan would be required and a groundwater abstraction licence needed before any dewatering can take place.

Table 2: Acid Sulphate Testing Results

Sample ID	Depth	pH_F	pH_{FOX}	ΔpH	Reaction	Sulphur %	Redox
D1	3950-4200	4.44	3.72	0.72	L	0.08451	329.9
D2	2750-3500	4.72	3.52	1.2	L	0.03371	300.2
D2	3500+	4.54	2.1	2.44	L	0.041	401.8
D3	750-1200	7.37	6.27	1.1	L	0.01417	286.9
D3	1200-1500	7.2	6.05	1.15	L	0.02193	315.7
D3	1500-2200	7.88	6.47	1.41	L	0.00993	306.5
D3	2200-3500	7.6	5.62	1.98	L	0.02398	265.3
D4	2250-2500	5.4	3.91	1.49	L	0.2006	392.3
D4	3000-3750	4.42	3.33	1.09	L	0.03832	371.8
D4	4250+	4.95	3.19	1.76	L	0.2666	347.1
D5	2250-2550	5.51	4.49	1.02	L	0.02606	355.9
D5	2550-3150	5.37	3.73	1.64	L	0.07597	305.2
D5	3150+	5.54	3.23	2.31	L	0.07045	339.9
D7	2750-2900	4.53	3.45	1.08	L	0.05975	386.1
D7	4400+	5.24	2.8	2.44	L	0.1041	321.7
D8	3450-3700	4.62	3.22	1.4	L	0.08865	359.3
D8	3700-4350	4.84	3.59	1.25	L	0.03415	319.7
D8	4350+	5.08	3.34	1.74	L	0.1025	340.2
D9	3500+	5.66	4.2	1.46	L	0.06156	333.9
D10	3500+	4.63	3.19	1.44	L	0.03358	364.4

6.0 Site Evaluation and Recommendations

6.1 Site Classification

The “Residential Slab and Footings Australian Standard 2870” provides a site classification system and associated generic foundation design recommendations, for residential development. The site classification system is based on the potential soil reactivity, and associated ground movements, attributable to seasonal soil moisture variations or potential problems sites due to adverse geotechnical conditions.

Where the sand is only a thin layer overlying clay substrate, the depth of sand will have a major impact on the classification and hence the type and consequent cost of the slab and footing construction. This classification is related to the amount of movement that the foundation can accommodate without causing damage to the structure. This movement can be either settlement or seasonal movement due to the swelling and shrinkage of the clayey soils due to the wetting and drying caused by the varying water levels.

The site classification was determined using a combination of field and laboratory investigations. Spatial variation in soils and topography mean caution must be observed when assuming that site classification is continuous between any two investigation sites.

All of the site except the area around D3 is "Class A", as defined in the Residential Slab and Footings (Australian Standard 2870), as these areas have 1.5m or greater sand over loamy/clayey soils. Site D3 is a "Class H" classification as defined in the Residential Slab and Footings (Australian Standard 2870), as there is less than 1.5m of sand cover over the loamy/clayey soils and surface movement may result from the reactive soils due to moisture changes (Figure 9). This can be improved to a class A by the application of engineered fill to the site after the removal of the reactive clays and creation of a separation of 1.5m to the loamy/clayey soils.

6.2 Soil Reactivity

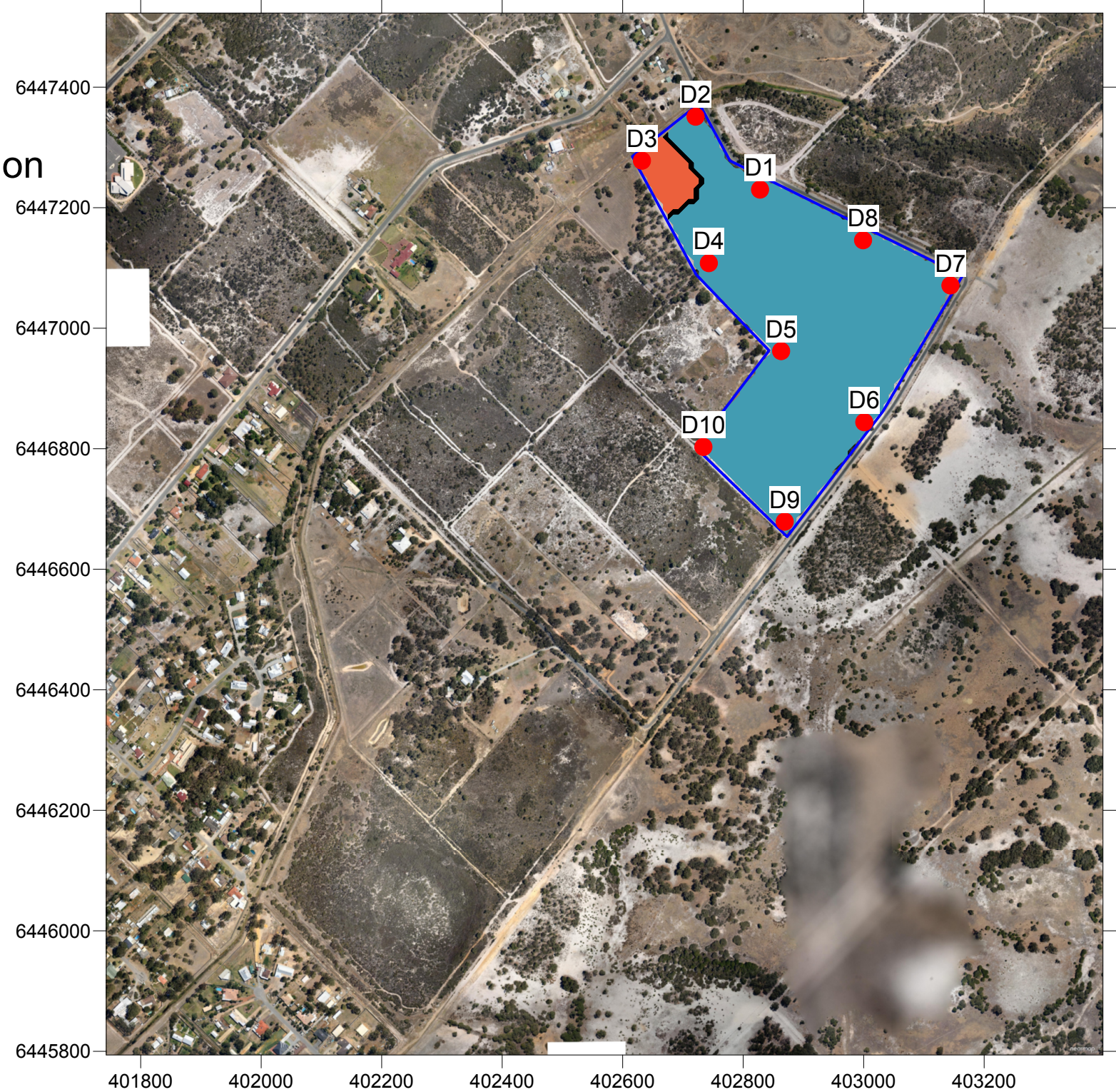
Of the two samples tested for Atterberg limits D7 2900-4400 displayed low reactivity and D3 1200-1500 displayed high reactivity. As a result of this there is likely to be minimal surface movement at D7 as a result of changes in moisture of the subsoil clays. Surface movement at D3 are likely due to the proximity of the reactive clays to the surface and the shallow depth to groundwater. Post development surface levels should be carefully considered to ensure any ground movements from clays do not detrimentally impact upon buildings.

Figure 9:
Geotechnichal Classification

Class A

Class H

Bore	Easting	Northing
D1	402828	6447230
D2	402721	6447351
D3	402632	6447278
D4	402743	6447108
D5	402863	6446962
D6	403001	6446844
D7	403144	6447071
D8	402999	6447146
D9	402869	6446679
D10	402734	6446803
D11	402470	6446506
D12	402309	6446683



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Further investigation of the class H area around D3 is recommended so as to determine the extent of the reactive clays to allow determination of appropriate treatment of that area. Visual inspection of the soil surface of the area surrounding D3 indicated this clay area is isolated and does not extend far from the investigation site. This should be confirmed through the excavation of more test pits in the vicinity.

6.3 Soil Permeability and Drainage

The Bassendean sand surface soils have a permeability in the order of $10^{-3}$and 10^{-5} m/s based on particle size distribution. This is generally suitable for onsite disposal of stormwater, however the underlying low permeability coffee rock and clays, with permeabilities between 10^{-7} and 10^{-9}m/s, mean drainage will have to be carefully considered. Fill material can be used to increase the separation to clays to ensure effective performance of soak wells and infiltration areas.

6.4 Site Preparation

The following site preparation procedure is recommended

- Identification and diversion or protection of any buried services within the work area.
- Removal of topsoil, organics, root, old services and other deleterious material from the site.
- Contouring/shaping of the ground surface to ensure surface runoff drains appropriately form the site.
- Proof compact the exposed surface using a suitable compaction plant. A minimum of 12 tonne static mass vibratory smooth drum roller is preferred to achieve densification of sandy soil at depth. A minimum of eight overlapping passes should be provided.
- Where the surface deforms excessively during compaction or wet and/or weak material is exposed, over-excavation and replacement with compacted free draining sand fill may be required.
- Site works and preparation should be undertaken in summer or autumn, where groundwater levels are near their seasonal lows, as soil will become very difficult to work with in wet conditions.
- Dewatering or drainage may be required to control groundwater levels. Experience indicates that difficulties with compaction may occur when groundwater is present within about 1.0 to 1.5m of the level at which compaction is applied.
- Confirm that adequate compaction is achieved as outlined below.

- Should compaction to satisfactory depth not be achieved by surface compaction it may be necessary to over excavate, compact the base of the excavation and replace the soil in compaction layers.
- Place and compact approved clean free draining fill material in layers of no greater than 0.3m thickness, up to the level required.

6.5 Excavation and Dewatering

Based on the observed soil properties intersected during the fieldwork it is anticipated that excavations across the site should be achieved using standard earthmoving equipment. Excavations in sand areas are prone to instability; consequently care must be exercised in such excavation and appropriate safety measures adapted where necessary.

Where excavations are required to extend into the clayey Guildford formation soils, before building up with sand fill it's will be necessary to re-establish a smooth clay surface to prevent "tanking" of groundwater. Tanking of groundwater has the potential to significantly decrease foundation stability.

Where excavations extend close to groundwater levels, dewatering may be required to draw down the groundwater levels to 1m below the base of the excavation to achieve adequate compaction. If possible, site preparation should occur during dry periods to reduce or cease the dewatering requirements. Should dewatering be required, care must be taken to ensure nearby groundwater dependent ecosystems are not adversely affected.

There remains a small potential of ASS occurring during dewatering and/or excavation, consequently Bioscience recommends that site works attempt to maintain a low project risk and defined by table 3 below. A dewatering licence would need to be obtained from the Department of Water before any such work is undertaken. Any dewatering would require a dewatering management plan and effluent discharge carefully monitored due to the proximity to the Southern River.

Table 3: Acid Sulphate Soils Project Risk Assessment

Project Factors	Project Risk Level		
	Low	Medium	High
Duration of Project	Less than 1 month	1-3 months	Greater than 3 months
Volume of Excavation	< 100m^3	100 - 1000m^3	> 1000m^3
Depth of Excavation	Less than 3m BGL	3-10m BGL	Greater than 10m BGL
Depth of Groundwater	Depth to groundwater > depth of excavation	Depth of excavation <3m below groundwater	Depth of excavation >3m below groundwater
Distance to Sensitive Receptors	> 500m	200 - 500m	< 200m
Sensitivity of Environmental Receptors	Unclassified water body	Multiple use	Conservation
Beneficial Use of Groundwater Resources	Irrigation or lower quality	Priority 3 resource	Priority 1/2 resource

6.6 Compaction

Fill materials, placement and compaction methods and quality control should apply with relevant structure fill requirements according to standard industry practice and AS 3798 "Guidelines on Earthworks for Commercial and Residential Developments". The fill should generally be placed in loose layers not exceeding 300mm thickness and each layer should be compacted with suitable equipment to a minimum of 95% modified maximum density (MMDD) or 70% density index as appropriate.

A Perth Sand Penetrometer in accordance with AS1289.6.3.3 may be used for compaction control in sand provided it is calibrated for each material type on-site. All areas within the building envelopes should be compacted to achieve a minimum blow count of 8 blows per 300 mm penetration to a depth of 1 m below the existing ground level, when tested in accordance with the above test method. If difficulties arise in achieving this blow count, then *in situ* density testing in accordance with AS 1289 should be performed to confirm the correlation between blow counts and density to ensure that a density index of 70% is achieved.

6.7 Fill Material

Fill material will be required on site to ensure that an adequate separation of groundwater is maintained (i.e. greater than 1.5m above AAMGL) on the provision that it contains less than 5% fines (i.e. <0.075mm) and has a maximum particle size of 40mm and is free of any organic or deleterious material.

7.0 References

AS 1289-2000. Methods of Testing Soils for Engineering Purposes. Standards Australia.

AS 1729-1993. Geotechnical Site Investigations. Standards Australia.

Davidson, W.A., 1995, Hydrogeology and Groundwater Resources of the Perth Region, Western Australia. Geological Survey of West. Australia, Bull. 142.

Hillman M, Cocks, G and Ameratunga J. (2003) Guildford Formation, Australian Geomechanics 38: 31-39

JDA., (2002) Main Report: Impact of Existing Drains and Proposed Living Streams on Groundwater Table and Nutrient Export. In Southern River/Forrestdale/Brookdale/Wungong, Structure Plan, Urban Water Management Strategy.

Jordan J.E. (1986), Armadale, part sheets 2033 I and 2133 IV, Perth Metropolitan Region, Environmental Geology Series, Geological Survey of Western Australia.

Perth Groundwater Atlas (2004) - Department of Water.

8.0 Limitations

Bioscience Pty Ltd has prepared this report for Lots 9 & 1792 Holmes Street and Lot 11 Passmore Street, Southern River, WA. The work was carried out under Bioscience's Conditions of Engagement. This report is provided for the exclusive use of the landholders for this project only and for the purposes described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. In preparing this report Bioscience has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of anthropogenic influences. Such changes may occur after Bioscience's field testing has been completed.

Bioscience's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by Bioscience in this report may be limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attached notes and should be kept in its entirety without separation of individual pages or sections. Bioscience cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion given in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by Bioscience. This is because this report has been written as advice and opinion rather than instructions for construction.

Appendix 1: Soil Profile Logs

D1

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	3500	Sand	white grey	uniform	sub rounded	dry	soft/loose	layer
3500	3950	Sand	grey brown	uniform	sub rounded	wet	soft/loose	layer
3950	4200	Sand	brown	uniform	sub rounded	wet	hard	layer

D2

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	1250	Sand	grey	uniform	sub rounded	dry	soft	layer
1250	2250	Sand	white	uniform		dry	soft	layer
2250	2750	Sand	brown	uniform		moist	soft	layer
2750	3500	Sand	brown	fine uniform		wet	hard	layer
3500	+	Clayey Sand	grey brown	well		wet	firm	layer

D3

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	500	loamy sand	light brown	well		dry	firm	layer
500	750	loamy sand	yellow	well		moist	firm	layer
750	1200	clayey sand	grey mottled orange	well		moist	firm	layer
1200	1500	sandy clay	orange mottled grey	well		moist	firm	layer
1500	2200	clayey sand	grey mottled orange	coarse well sorted		moist	firm	layer
2200	3500	sandy clay	grey	well		wet	firm	layer
3500	+	sandy clay	grey	fine well sorted		wet	firm	layer

D4

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	2250	Sand	grey	unifrom		dry	soft/ loose	layer
2250	2500	Sand	brown	fine uniform		moist	soft	layer
2500	3000	Sand	grey brown	unifrom		moist	soft	layer
3000	3750	Sand	brown			wet	soft	layer
3750	4250	Sand	grey brown			wet	soft	layer
4250	+	Sand	brown			wet	firm	layer

D5

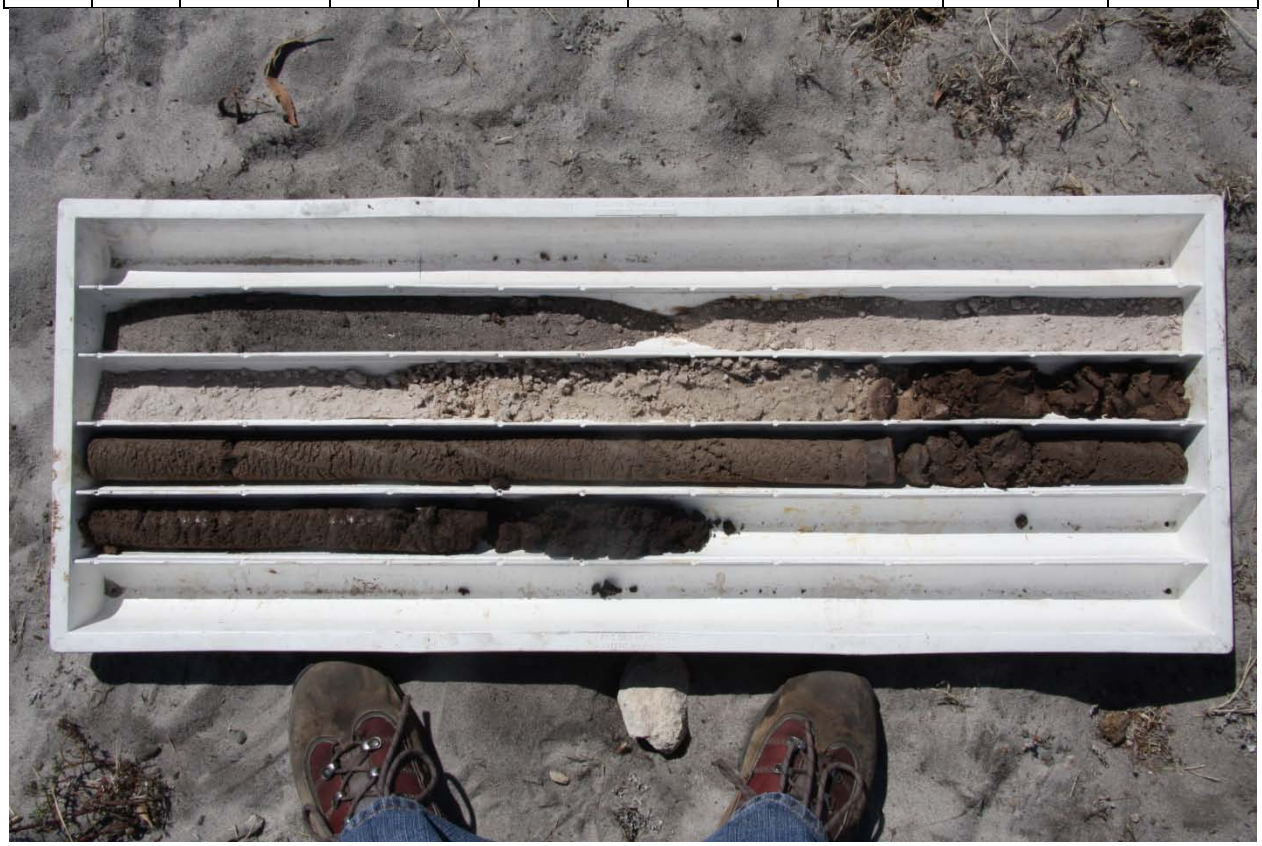
Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	750	Sand	white	uniform meduim texture		dry	soft	layer
750	1500	Sand	grey white	uniform meduim texture		dry	soft	layer
1500	2250	Sand	brown white	uniform meduim texture		dry	soft	layer
2250	2550	silty sand	brown	uniform		wet	soft	layer
2550	3150	silty sand	light brown	fine uniform		wet	soft	layer
3150	+	silty sand	white	poorly sorted		wet	hard	layer

D6

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	1500	Sand	grey white	unifrom	sub rounded	dry	soft/loose	layer
1500	+	Sand	white	unifrom	sub rounded	moist to wet	soft	layer

D7

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	1500	Sand	dark grey	uniform		dry	soft/loose	layer
1500	2750	Sand	off white	uniform		moist	soft/loose	layer
2750	2900	silty sand	brown	poor		moist	firm	layer
2900	4400	sandy clay	brown	well		moist	firm	layer
4400	+	silty sand	brown	poor		wet	firm	layer



D8

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	1500	Sand	grey	uniform		dry	soft/loose	layer
1500	3450	Sand	light yellow brown	uniform		damp	soft/loose	layer
3450	3700	Sand	dark brown	poor		wet	fard	layer
3700	4350	Sandy clay	brown	well		wet	firm	layer
4350	+	silty sand	brown	well		wet	firm	layer

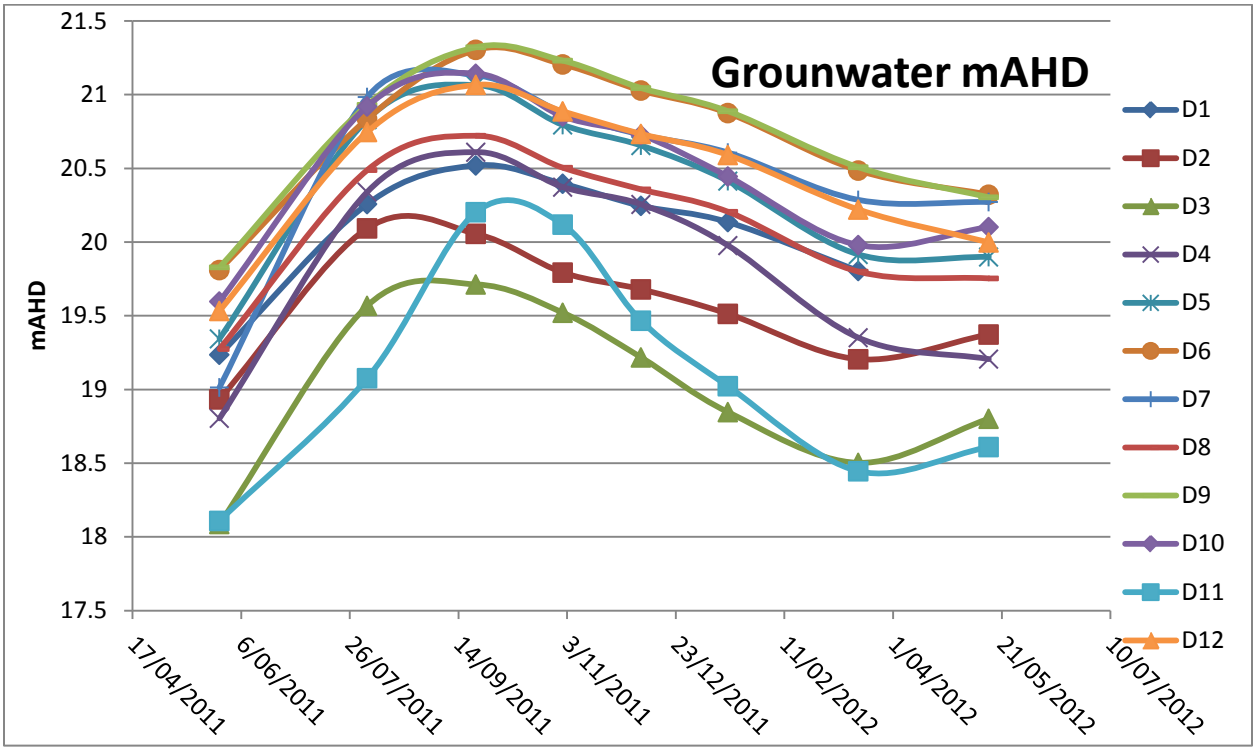
D9

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	2000	Sand	grey white	uniform		dry	soft loose	layer
2000	3500	Sand	white	uniform		moist	soft loose	layer
3500	+	Sand	brown	poorly		wet	hard	layer

D10

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure
From	To							
0	1500	Sand	grey	uniform		dry	soft/loose	layer
1500	2250	Sand	white	uniform		damp	soft/loose	layer
2250	3500	Sand	brown white	uniform		wet	soft/loose	layer
3500	+	Silty Sand	brown	poor		wet	hard	layer

Appendix 2: Groundwater Monitoring Data



Appendix G: Addendum to Previous LWMS (28/07/2014)

ADDENDUM TO SOUTHERN RIVER 3D LWMS	
SUBJECT OF CONCERN	**DEPARTMENT OF WATER COMMENT AND BIOSCIENCE & SHAWMAC COMMENTS AND AMENDMENTS**
	The proposed living stream design is not acceptable to the DoW. The cross-section design is not consistent with the DoW's living stream design guidelines It should be designed as per the advice given in our previous comments (refer to correspondence dated 9 September 2014). *Bioscience comment: The living stream design has been improved by Shawmac. See new drawings (Appendix C).*
	One of the approaches of Water Sensitive Urban Design (WSUD) is that Public Open Space (POS) should be designed in such a way that it works as a POS during small rainfall events (as stormwater for events up to 15mm is contained in specific areas for 'biofiltration') and functions as a flood storage area during larger events. However, the proposed basin in the LWMS don't demonstrate this and it appears that these are solely designed for drainage detention/retention functions. *Bioscience comment: Drainage and basin design has been amended accordingly. See Appendix C for details.*

Appendix G: Addendum to Previous LWMS (28/07/2014)

ADDENDUM TO SOUTHERN RIVER 3D LWMS	
SUBJECT OF CONCERN	**CITY OF GOSNELLS COMMENT AND BIOSCIENCE COMMENT AND AMENDMENTS**

General	The City of Gosnells had identified few major concerns regarding the drainage approach for the proposed development site as document suggest setting of a AAMGL as assessed ground water level without providing a Sub soil drainage system and proposed not to provide soak wells or sumps at lot scale. The City still believes that the calculation of critical ground water levels using AAMGL appears unsuitable for the location with very shallow groundwater levels / perched surface water levels and their observed ~3.5 m seasonal fluctuations. The LWMS should cover the whole the ODP area and this documents covered only the part of the area. The other major concern relates to the methods of deriving and parameters around the finish lot levels which have not been further described. The levels are very important for the assessment in order to determine whether the proposed stormwater management concept is suitable or not. Appropriate stormwater management strategies must be derived and address different rainfall event based on the site characteristics and their application requirement such as Objective (Water quality - 1 year 1 hr event, Water quantity - 5 - 100 year critical duration event, conservation), Scale of application (Lot, Street, Precinct) and Soil condition. Then the levels and setting of a CGL can be decided based on the topography, MGL, AAMGL, free flow condition at the end of the subsoil drainage system such that giving enough clearance to protect constructed infrastructure as well as to ensure ongoing functionality of the stormwater management measures employed on the site. The following comments are mainly based on or relate to the above mentioned two major concerns. Normally, we suggest two possible options that could be used to potentially overcome these issues. Option 1 Provide a comprehensive and functional sub-soil drainage system to maintain the required minimum separation to physical infrastructure, residential footings and to the invert level of the stormwater management measures (base separation of a minimum 0.5 m to CGL). Functionality of any subsoil drainage system should be clearly demonstrated (proof of concept) and it must be outlined how this system will interact with the receiving water body or downstream environment (free flow condition required above maximum predicted winter rest levels) - including mitigation strategies to prevent adverse water quality implications for this environment. Option 2 Maximum Groundwater Levels (MGL) of the last 40 or 50 years are to be considered instead of AAMGL's. This information will then form the basis for the calculation of critical ground water levels, which can be used to provide an agreed minimum separation to physical infrastructure, residential footings and to the invert level of the storm water management measures (0.5 m) without the need for subsoil drainage. *Bioscience comment: Upon City agreement groundwater levels from the last 20 years have been used to set MGLs for the site based on the 3 years monitoring across the precinct. Legacy nutrients across the site have restricted use of subsoil drains. All finished lot levels and drainage infrastructure have inverts*

	set against MGL.
General	Required numbers of hard copies and soft copies are to be submitted in accordance with the checklist provided on the City's web site. This will help minimizing the time required for the assessment (three different departments are being involved in assessment process). *Bioscience comment: Copies provided*
General	Provide a separate sheet attached to the front of the report with responses to the City's comments and reference to the updated sections. This would assist the City to ensure that the previous comments have been addressed or why they have not been addressed. *Bioscience comment: Addendum attached*
General	Most of the figures are not clear and difficult to read. Provide the figures in A3 size. *Bioscience comment: Figures amended*
General	Completed BUWM checklist to be provided with reference to the each section *Bioscience comment: Checklist provided at front of report*
General	There are too many details provided with the drainage concept plan and it is difficult to pick up the correct information. The following plans need to be provided separately with the updated LWMS - Pre- and post- development catchment plans, AAMGL contour plan, Landscape plan, topography contours, finish lot levels plans. *Bioscience comment: Plans amended by Shawmac*
Executive Summary	It is proposed to use AAMGL as the assessed ground water level without proposing a subsoil drainage. As it explain above clearly City would like to follow any of the option 1 and 2. According to the BUWM document, All the rain fall event should be maintained at pre development stage up to 1 in 100 year event not up to 1 in 5 year. As it is given under the surface and stormwater management (section 7) " Pre and Post development flows have been modelled for 1:1 to 1:100 year ARI. The modelling shows that even in extreme rainfall events, stormwater can be retained on site" all the post development flows could be maintained at pre development level easily. The City would like to propose a mixed system for lot drainage with a combination of soak wells and lot connection by providing a enough separation to the assessed ground water level. *Bioscience comment: Drainage philosophy revised to option 2 (no subsoil*

	drains) as legacy nutrients could contaminate the FMD
Previous Studies	The City's advice in its comments on version 1 of the LWMS has not been addressed: The LWMS should list the report to the City of Gosnells *"Results of Floristic Assessment of Lot 1790 Passmore Street, Southern River, 21 September 2011"*, with other relevant previous studies into land and water management in the area *Bioscience comment: Reference listed.*
Proposed Development	The City's advice in its comments on version 1 of the LWMS has not been addressed: Piping of the Balannup Drain in the ODP area must be listed as an aspect of the proposed development. The LWMS is relatively silent on the matter. The FMDADS does not allow for piping of this section and furthermore requires a basin to be constructed at this location. Current LWMS does not comply with FMDADS. *Bioscience comment: The Balannup Drain is to be a living stream in the revised plan.*
Design Criteria	The statements given under 2nd bullet point under the water quality section and the 3rd bullet point given under the section 07 in the page 8 contradict each other. *Bioscience comment: This section has been largely updated to include all of the City comments and is now Section 3: Design Principles and Criteria. Bullet points amended*
Design Criteria	The statements given under the 6th bullet point in the water quality section and the 3rd bullet point given under the section 07 in the page 8 contradict each other. Based on the maintenance issue raised with the use of GPTs City of Gosnells is not going to accept GPTs. *Bioscience comment: Comment as above. Bullet points amended. GPTs will not be used in the development*
Design Criteria	Although it was noted in the responses sheet, the City's advice in its comments on version 1 of the LWMS has not been addressed. It is advised to avoid use of GPT devices in the drainage system unless necessary to treat particular waste streams due to the maintenance issues arising from incorrect design *Bioscience comment: GPTs will not be used in the development. Document amended.*

Design Criteria	The City's advice in its comments on version 1 of the LWMS has not been addressed: Text advises that ecosystem health criterion is to *"protect the existing hydrological and ecological regime of the wetlands by maintaining pre-development peak winter groundwater levels"*. This should be more precisely advised as *"maintaining pre-development hydrology"*, rather than one aspect if this only. *Bioscience comment: Sections in text updated as requested.*
Vegetation & Fauna	This section has not been updated in line with section 3.7.1 of version 2 of the "EIA". *Bioscience comment: Section 4.11 updated with relevant sections of the EIA report as requested.*
Geology and Geomorphology	Due to the shallow ground water condition with high seasonal fluctuations, use AAMGL level may not be suitable to use as assessed ground water level unless providing suitable subsoil drainage system at or above the AAMGL. The infiltration may not be possible at the preferred location of the storage areas unless providing a required clearance by implementing a CGL. Permeability of the insitu soils and ability to infiltrate stormwater at source and within the storage area has yet to be provided. The calculation of infiltration rates based on the particle size distribution (using an Empirical formulas) is not representing the correct value of permeability which can be achieved practically at site especially in shallow ground water condition. it is better to have few onsite permeability tests at least 1m depth and that may gives the indication of a proper subsoil system. *Bioscience comment: Section added: 4.5.4. Bioscience performed a constant head permeameter test at the location of the proposed POS basin and found the unsaturated infiltration rate to be 423mm/hr. The recorded rate would be highly suited for infiltration as a means of stormwater disposal.*
Groundwater Hydrology	The City's advice in its comments on version 1 of the LWMS has not been addressed. It is very important to get an idea about the finished lot levels which has to be finalized at this stage including all the critical drainage points specially invert levels of inflows and outflows to the basin, sub soil inverts if any. The AAMGL level calculated for this site still appears only to be based on a relatively short term pre-development observation period (one year) & limited bore monitoring data. This introduces a high risk for inaccuracy of conclusions and unless increased safety factors are introduced, this analysis needs to be revised and be based on both current and long term bore monitoring data available from DoW or other credible sources. In order to propose a suitable concept plan for stormwater management, a substantiated AAMGL base contour plan has to be in place that stands the test of time. This contour plan can then be refined as more monitoring data is collected, with appropriate contingency measures in place. *Bioscience comment: The groundwater monitoring for 3 years has now been used to calculate both AAMGL and MGL from the last 20 years data from DoW long term bore; as agreed with the City. The MGL has been used to set the fill requirements, inverts and finished floor levels. Supporting plans and figures are*

	included in this version along with the calculation methodology.
Groundwater Monitoring	According to the given short term monitoring data, even in the 2012 which is a dry year compare to 2011, the Peak ground water level was 1.31m higher than the AAMGL. The ground water level variation only for the year 2011 and 2012 shows about 3.5m and the peak levels also very much higher than the proposed AAMGL of 20m AHD. This AAMGL has to be revised with more data available. *Bioscience comment: Comment as above.*
Average Annual Maximum Groundwater Level(AAMGL)	The AAMGL level calculated for this site still appears only to be based on a relatively short term pre-development observation period (one year) & limited bore monitoring data. It is advised to follow the above comments and redefined the AAMGL that suit to the current environment *Bioscience comment: Comment as above.*
1 in 100 Year Average Recurrence Interval	The both 1 in 10 year and 1 in 100 year event are considered as flood events and ground water level for those events are not important. The surface inundation areas, volumes, pre and post development flows, top surface water levels and to the clearance to the FFL are more important than 1 in 100 year ground water levels. Based on the given ground water monitoring data from June 2011 to October 2012, the basin 1, 2 going to be under water most of the time throughout year even for 1in 1 year event. *Bioscience comment: Comments as above. Section 5.6.4.1 has been removed from the report and MGL set using long term data.*
Table 3	It is required to provide details like sampling collected date at least month of the year specially with the ground water levels and water quality data as they are highly variable with the time of the year. *Bioscience comment:* Details on monitoring have been included in the revised version.
Regional Drainage Strategy	According to the Forrestdale Main Drain Arterial Drainage Study(DoW, 2009), the main drain should be widened to provide online storage area (1.5ha , 14228m3 for 1 in 100 year event) within this development area. This information should be provided and inundation areas should be clearly shown in 1 in 100 year event plan.

	Bioscience comment: All plans have been revised. Inclusion of comment in section 4.7.1 to confirm widening is incorporated in development.
Stie Characteristics Summary	This section has to be updated based on all comments provided above. *Bioscience comment: The summary has been removed and Executive Summary will now cover these points.*
Groundwater Use	Para 1 advises that "*groundwater bores will not be available to households*". How is this proposed to be achieved? *Bioscience comment: Comment removed and section revised.*
Groundwater Use / Waterwise Landscaping	The Concept Plan provided at Figure 16 appears to only be for one small area of POS. The ODP document advises that there is potential for various areas of highly functional recreational POS areas however this needs to be shown (concept plan for all POS in ODP area). As advised in the BUWM document a LWMS should include irrigation areas (which requires a concept plan and calculations for all POS). *Bioscience comment: Concept planned required for irrigation*
Agreed Action of Implementation	Revisit the statement given as" Reducing the size of lots within the development to reduce external(garden) water use" Increasing Runoff ? Less Recharge ? No Soakwells ? *Bioscience comment: Section removed and comments added into Water Use and Sustainability Initiatives section*
Development Water Balance	Figures are given for irrigation requirements, however this needs to be supported by concept plans for all the POS areas and land areas proposed for irrigation. The document states that the irrigation requirement exceeds the DoW irrigation allowance, without advising how this will be addressed and if this has been raised / resolved with the DoW. *Bioscience comment: Will require updating at subdivision stage. The Shawmac plan has been revised to include total POS areas and the area requirements for drainage. It is still unclear as to the final POS arrangements but some irrigation requirements have been added to the section assuming that maximum irrigation is required for the POS. Until a landscaping plan is finalised an accurate irrigation amount cannot be calculated.*
Figure 16 - Public Open Space Concept Plan	This needs to include all areas of POS. It should have dimensions and clearly show areas (on the plan and numbers) for the different functions of POS - *Bioscience comment: Concept Landscape Plan required*

Forrestdale Main Drain Widening	The discussion provided here focuses only on that portion of the FMD associated with Lot 6 Matison Street and Lots 8 and 9 Holmes Street - approximately 15% of the MD passing through the ODP area. The LWMS must provide guidance to the ODP on the treatment of the MD for the entire ODP area. *Bioscience comment: Section 7.1: FMD Widening has been updated to include the whole area. The Shawmac drainage plans provide the areas required to achieve the compensation basin volumes.*
Forrestdale Main Drain Widening	Piping of the Balannup Drain in the ODP area must be listed as an aspect of the proposed development. The LWMS is relatively silent on the matter. The FMDADS does not allow for piping of this section and furthermore requires a basin to be constructed at this location. Current LWMS does not comply with FMDADS. *Bioscience comment: The Balannup Drain will be a living stream and an online compensation basin is to be located along the FMD. This concept is shown on the revised drainage plans.*
Lot drainage	Is it possible to compensate peak flows by providing piped connection to street drainage? *Bioscience comment: Street drainage is to flow into compensation basins and be released slowly into the FMD at predevelopment peak flows or be directly infiltrated. The substantial fill imported to site will allow lots to utilise soakwells*
Street Drainage	As it explains in section 7.2, Soakwells on lots are not suitable but the infiltration in road is proposed. This contradicts each other. The City prefers to have a 1:6 side slope in Swales instead of 1:4. The sentence given as " Minimum separation required between the invert of the swales is 500mm" is incomplete and that need to be corrected. *Bioscience comment: Fill levels onsite have now been set by long term MGL values and all swales are to have 500mm clearance over MGL.*
Public Open Space Basins	Again the infiltration is considered in the basin but not at the lot scale. Most of the times, lots FFL are sitting about 300mm above the road finish levels and much more higher than base of the basin levels. *Bioscience comment: The drainage plans have been revised as per the above comments. All finished levels set to long term MGLs.*
Public Open Space Basins	The City's advice in its comments on version 1 of the LWMS has not been addressed: Basins 1 and 2 appear to be located largely on Lot 5 Matison Street, in the heavily vegetated REW buffer. The location of the basins is considered inappropriate; they should take advantage of existing cleared land elsewhere. The clearing of native vegetation is at odds with statements made in section 5.10, and the "EIA". New text in 7.4 advises that the basins will consist of entirely native planting, but this does not compensate for unnecessary clearing. If the basin locations are immovable, the LWMS should

	provide such discussion. *Bioscience comment: The basin locations have been revised. After discussion with the DoW and City (24/06/2014) it was advised that locating naturally landscaped swales and overflow compensation basins within the buffer on Lot 5 would be acceptable provided the basins are "naturalistic" and vegetated in native plant species.*
Public Open Space Basins	The revised LWMS advises in para 2, with regard to Basins 1 and 2 in wetland buffer areas, that "*the revegetation of these areas and directing water to them will improve the condition and hydrology of the wetland by ensuring they have a sustained water supply through the infiltration of stormwater*". The City advised, in its comments on version 1 of the LWMS (8.0 Groundwater Management Strategy), that the LWMS should address matters including localised groundwater mounding through stormwater infiltration in the zone of influence of the proposed basins due to proximity of infiltration basins to natural assets. The proposal in para 2 requires exactly this type of consideration. A "*sustained water supply*" does not equate to a maintained hydrology. *Bioscience comment: Section and Shawmac drainage summary amended. Predevelopment flow conditions are to be maintained and subsoil drainage will not be implemented.*
Public Open Space Basins	"Basin 3 will be a turfed areas with the side slopes mulched and planted with native species (figure 16)" - is this entire POS meant to be flooded / a drainage basin in winter? What are the requirements for the different storm events? It is not appropriate for the entire POS to be unusable throughout winter (POS credits - restricted / unrestricted POS %). If a section of the POS will be used for drainage this needs to be clearly shown on the plan (and it is suggested that a different treatment - not turf - will be needed for the more frequent rainfall events). *Bioscience comment: The Shawmac drainage plan has been updated and POS areas have been revised. The plans show required areas for drainage function in each rainfall event.*
1 In 1 Year ARI event	The Catchment plan has to be provided for covering total ODP area. It seems that there are only 3 catchments which covers only the part of the total ODP. However the figures given in table 6 and 7 are not clear enough. Catchment area should be same for all the rain fall event. *Bioscience comment: The Shawmac drainage plan has been expanded and included as an appendix to the report. The predevelopment flow rates will be maintained for most of the site by virtue of it not being developed.*
Typical Rain Garden Design	For maintenance purposes a hard edge defining the rain gardens is required, rather than the 1:4 side slopes shown. *Bioscience comment: Shawmac drainage plan assumes hard edges on rain gardens in revised plans.*

Groundwater Management Strategy	It is advice to follow the two options and select one of the best option in order to manage the groundwater levels. If the subsoil going to interact with the groundwater which contain legacy nutrient, the best option would be the option 2 as it does not require a subsoil. However the option 1 requires to go for the MGL instead of AAMGL and this requires some additional fill. *Bioscience comment: The option to not export any groundwater through subsoil drains has been selected and imported fill will be used to gain the required separation to both AAMGL and MGL that have been calculated against long term DoW bore data.*
Protection of Infrastructure and Assests	Is it possible to maintain the proposed separation without proposing a sub soils? The City still believes that the calculation of critical ground water levels using AAMGL appears unsuitable for the location with very shallow groundwater levels / perched surface water levels and their observed ~3.5 m seasonal fluctuations. *Bioscience comment: See comment above. Three years of monitoring data has now been used to calculate groundwater levels.*
Protection of Infrastructure and Assests	According to the last paragraph, Soakwells are not proposed at lot scale. However the design detail from SHAWMAC shows that "Storage in lot pits included". *Bioscience comment: Drainage philosophy has been revised under CoG advice and will maintain a separation to MGL of 1.7m to facilitate the use of soakwells of 1.2m deep across the development.*
Protection of Groundwater Dependent Ecosystems	New dot point 5 "*Infiltration basins to be located close to the boundary of wetlands to allow infiltrated water to replenish water in wetlands"* presents a maximisation of groundwater mounding potential, not minimisation. The wetlands in the ODP area rarely exhibit surface water, and are reliant on proximity to groundwater for ecosystem health. Potential groundwater mounding in the zone of influence of the proposed basins is a threat to ecosystem health that must be evaluated and addressed. *Bioscience comment: The drainage strategy has been revised and section amended.*
Groundwater Quality	New references to Barr and Baron (2009) fail to highlight the fact that "legacy nutrients" are, in the main, the result of long-term accumulation of organic matter in wetland areas, from which little has been exported over time due to long groundwater travel times to receiving bodies, including Balannup BD, Forrestdale MD and Southern River. Legacy nutrients are predominantly organic, and cannot be "treated" by traditional techniques such as nutrient stripping vegetation. Until and unless a novel method for removing organic nitrogen and phosphorous can be proven, a key objective of the LWMS must

	be to neither intercept nor export superficial groundwater from the site. *Bioscience comment: The drainage philosophy has been revised to remove all use of subsoil drainage as to not export the legacy nutrients.*
Dewatering	Reference to legacy nutrients and their treatment should be included here. All dewatering product should be recharged as near as possible to its source, and should not be exported. *Bioscience comment: Comments added to section as requested.*
Future Works - Subdivision and UWMP	"Landscape plans for drainage and public open spaces areas" - although detailed landscape designs are to be provided at the subdivision stage, it is required for concept plans to be provided for all POS areas now (BUWM LWMS requirements states - Landscape Plan is a deliverable - with information to be provided - "Landscape - proposed POS areas, POS credits, water source, bore(s), lake details (if applicable), irrigation areas" *Bioscience comment: Comment added to Future Works section and concept landscape plan required*

ADDENDUM TO SOUTHERN RIVER 3D LWMS	
SUBJECT OF CONCERN	**CITY OF GOSNELLS COMMENT AND BIOSCIENCE COMMENT AND AMENDMENTS**
General	There are too many details provided with the drainage concept plan and it is difficult to pick up the correct information. The following plans need to be provided separately with the updated LWMS -(AAMGL, MGL contour plan, topography contours) *Bioscience comment: Shawmac have revised the plans and separated details for clarity*
Table 2 - Water Quantity	Fifth bullet point - the word Detain should replace with the word Retain *Bioscience comment: Amended*
Soil Permeability	The permeability test results (report) needs to be attached to the report *Bioscience comment: Amended and Attached*
General	Most of the figures are not clear and difficult to read. Provide the figures in A3 size. *Bioscience comment: Figures amended*
Groundwater	The previous comment made under the section 5.6.1 has been addressed. However

Hydrology 5.6.1	the LWMS should cover the whole area but not only the residential sites. What are the proposed likely finished surface levels for School site and the Playing field ? what are the storage volumes required ? What is clearance that maintain above the proposed MGL level at both sites? Where is the updated section 5.6.1 ? Where is section 5.3 - 5.6 ? *Bioscience comment: Shawmac have revised plans to the entire area including the school and playing field with details as requested. Bioscience have amended the error in section numbering. Groundwater is now covered in Section 4.6*
AAMGL 5.6.3	The AAMGL level has been calculated for this site based on the City's previous comment. However the given AAMGL contour plan is not clear to read the levels. Although it is decided to used the MGL as the assessed ground water level for the drainage design, the MGL contour plan hasn't been provided. *Bioscience comment: Shawmac have revised plans for MGL across the entire area*
Groundwater Monitoring 4.6.2	Where is the MGL contour plan ? As MGL is the datum of this development, a clear MGL contour plan needs to be provided with the document. Even the given AAMGL contour plan is not clear enough to read the numbers. *Bioscience comment: Shawmac have revised plans for MGL across the entire area*
Regional Drainage Strategy 4.7.1	The event plans should be covered the total area that covers by the LWMS. But not only the residential sites. a *Bioscience comment: Shawmac have revised plans for MGL across the entire area*
Regional Drainage Strategy 4.7.1	Based on the City's previous comment, some important information have been provided with the updated document. However, there are some important details have been missed and those need to be provided with a new submission. What is total storage that provided due to widening of FDMD ? Provide the critical dimensions of the widened FDMD? A cross-sectional detail of the Balannup Lake Drain (before it meets FDMD) needs to be provided with the proposed width for the drain widening. The inundation areas should clearly shown in 1 in 100 year event plan and that should be covered the full ODP area but not on *Bioscience comment: Shawmac have revised plans to included the requested information*
Groundwater Use/ Water Wise Landscaping 5.1.4	The Concept Plans provided at Figure 10a - 10c are not in context - there should be a landscape concept plan for all the "Green areas" - and they do not adequately address the unrestricted POS (recreational areas). 10% POS provision should contain 8% urestricted. As advised in the BUWM document a LWMS should include irrigation areas (which requires a concept plan and calculations for all POS). *Bioscience comment: Figures 10a-10c are concepts of POS in the eastern portion of the entire 3D area. Shawmac identify that the restricted portion (5yr Storage) of Basin CA is 7.6% and Basin CB is 12.3%. The 8ha playing fields are also unrestricted POS.*
Irrigation Requirement 5.3	Text states 34, 540m2 of POS with only 2, 820m2 being irrigated … this doesn't seem to be a sufficient amount of unrestricted / usable POS being provided. Sufficient detail has not been provided. *Bioscience comment: Amended*

Stormwater Management Strategy 6	The use of word "detention" is not appropriate in this development and this need to be corrected. *Bioscience comment: Amended*
POS and Basins 6.4	The drainage function (& environmental) in the POS cannot impact greater than 20% of the POS area - 80% POS is to be unrestricted. The drainage information provided by Shawmac needs to inform the landscape concept plans, however the POS is not solely for drainage purposes. *Bioscience comment: Shawmac identify that the restricted portion (5yr Storage) of Basin CA is 7.6% and Basin CB is 12.3%. The 8ha playing fields are also unrestricted POS and make up over 80% of the total development land.*
Vegetation & Fauna	This section has not been updated in line with section 3.7.1 of version 2 of the "EIA". *Bioscience comment: Section 4.11 updated with relevant sections of the EIA report as requested.*
Table - Groundwater Monitoring Data (Appendix)	Correct the table heading *Bioscience comment: Amended*
Appendix C	Catchment B is named as C and this needs to be corrected. The given topographic contours have covered only the north part of the site and haven't show any in southern part of the site. *Bioscience comment: Amended* What are the pre-development runoff coefficients used for the calculation? *Bioscience comment: Coefficient used is 0.4 which is in accordance with FMD study. Drainage summary text has been amended to clarify*
Future Works - Subdivision and UWMP	More information required at this stage. *Bioscience comment: Amended*

ADDENDUM TO SOUTHERN RIVER 3D LWMS	
SUBJECT OF CONCERN	**DEPARTMENT OF WATER COMMENT AND BIOSCIENCE & SHAWMAC COMMENTS AND AMENDMENTS**

Executive Summary	In a meeting held on 23 June 2014 (with representatives from Bioscience, Shawmac, City of Gosnells and DoW) it was agreed that subsoil drainage and treatment would be used near the drains, however the LWMS proposes not to use subsoil drainage for managing shallow groundwater level. If this is the case, then the amended LWMS should demonstrate that there will be no extended waterlogging conditions at low lying areas, including treatment and POS areas. These areas should have gradual draining provisions. *Bioscience comment: Legacy nutrients in groundwater in some areas of Precinct 3D restrict the use of subsoil drains to remove risk of nutrient export to the FMD. This approach is a preferred option of the City. The locations of basin storage are areas of sand with a high infiltration rate. All basins to maintain a clear separation above MGL as stated in report.*
Executive Summary and BUWM Checklist (pg 20)	Small event management criteria: 1. Retain or detain and treat stormwater runoff from constructed impervious surfaces generated by up to the 1-year, t-hour ARI (or at least 15mm) event at its source, preferably in lots and road reserves. 2. Maintain pre-development peak flow rates and total volumes runoff from the whole sub-catchment at outlets from the site at the critical 1-year ARI event. *Bioscience comment: Wording to be changed in accordance with DoW comment*
	Please remove the dot point- "Reducing the size of lots within the development to reduce external (garden) water use" from Table 1. Remove the dot point "Use of major minor approach to stormwater management" from Table 1. The WSUD approach encourages implementing stormwater systems that have disconnection or no pipes used. Remove the dot point that refers to pipe design for the 5 year event in Table 1. *Bioscience comment: Removed*
	Amend the last dot point in Table 1 Surface and Stormwater Management to "Forrestdale Main Drain (FMD) to be rehabilitated into a living stream which can provide multiple benefits including online compensation. Flood protection criterion should also be listed under the Surface and Stormwater Management section in Table 1. Appropriate wording for the 'base of the development' is the 'finished floor level'. The finished floor level should be at least 0.3m higher than the 100 year ARI flood level on the road reserve. Flood protection criterion to be stated as "Provide adequate clearance from 100 year ARI flooding to protect people and property from flooding. Building habitable floor levels will be at least 0.3m above the 100 year ARI flood height of the urban drainage system and at least 0.5m above the 100 year ARI flood height of waterways to protect people and property from flooding" *Bioscience comment: Amended* It has been stated that "All runoff from catchment to receive treatment prior to discharge to receiving environment". It may not be practical to treat the 100 year ARI

	flood volume, so remove this dot point from Table 2. The statement "A relative comparison between pre and post-development for discharge volume" (Table 2 - Water Quantity) is not clear. Please include the statement "Post development peak flow rates from 100 year ARI event will be equal or .less than 100 year ARI pre-development peak flow rates" End of pipe solution is not considered to be a good WSUD approach. Please remove this dot point in Table 2 - Water Quality Modify the flood protection design criteria in Table 2 - Protection of Property, as previously advised above for Table 1. *Bioscience comment: Amended all*
Geotechnical Investigation (Section 4.5)	The LWMS should include a copy of the geotechnical survey/investigation report conducted in May 2011 in the Appendices. *Bioscience comment: Included as Appendix*
Groundwater (Section 4.6)	The LWMS has used the terminology "AAMGL" throughout the document. It is to be noted that the DoW no longer supports use of the term (AAMGL) as there is no policy or guideline that specifies the data range (i.e. the number of years of data to use for the calculation - e.g. a 10-year, 50-year or 100-year dataset could have been used to calculate the average value) and how often during one year the data should be collected (e.g. the groundwater level might have only been recorded once in a calendar year, or it might have been recorded monthly, etc.). Therefore, the calculated value could vary, depending on the dataset that is used. Additionally, the average value may not account for factors such as magnitude of variation in seasonal peaks, short-term impacts (e.g. groundwater abstraction), longer term trends (such as changing climate), potential rises post development due to loss of evapotranspiration and importation of new water (e.g. scheme water used to irrigate gardens), and the ecological water requirements of groundwater-dependent ecosystems. The LWMS has used the DoW T85 bore's maximum recorded groundwater level from the last 20 years (i.e. the data from 1993) for calculating maximum groundwater level (MGL) for the site, although data is available since 1975 (refer to Appendix A in the LWMS). The DoW recommends that the maximum recorded data from the full dataset is used (i.e. the data from 1975). Clarify whether the approach used will address potential risks to urban form due to groundwater rise and waterlogging, given that just a single bore has been used as reference for the calculation. *Bioscience comment: Reference to AAMGL removed accordingly. Shawmac have amended plans. The dataset used i.e. 20 years, was confirmed with CoG prior to establishing the MGL calculations as the regional groundwater levels are declining.* Please include a hydrograph of the DoW's long-term data. *Bioscience comment: Included within Appendix A with long term data.* The LWMS should also confirm that management of shallow groundwater has been conducted in accordance with the DoW's guideline Water resource considerations when controlling groundwater levels in urban development (DoW, April 2013). *Bioscience comment: Subsoil drains are not proposed and groundwater levels will be*

	maintained by infiltration of surface water close to source with adequate separation to MGL maintained with imported sand fill. Include the date range of pre-development groundwater quality sampling in Table 5 - Groundwater Quality Results. Pre-development groundwater quality results indicate that the groundwater is acidic (e.g. pH readings as low as 3.57, 3.86, 4.28 - refer to Appendix A) and nutrient levels are elevated at some locations. These water quality results should be compared with the ANZECC guidelines and/or available local Water Quality Improvement Plan targets and the implications/relevance to the development should be discussed. The text currently in this section is generic and is not specific to the development area. *Bioscience comment: All monitoring data is provided in Appendix A. The report text has been updated and the proposal for any subsoil drainage has been removed in favour of maintaining separation to groundwater using imported fill. This removes risk of groundwater nutrient export into receiving waters as per the City of Gosnells' request.* In regards to the two current groundwater licences within the development area, has the water quality of these bores been tested and is it suitable for irrigation purposes (as monitoring results show that water quality is variable across the development area)? In regards to additional water available for irrigation, please note that groundwater availability information from the DoW is only current for the time it was produced, as this information changes constantly. This should be acknowledged in the text. *Bioscience comment: Text amended. Bioscience have been unable to gather water samples from the existing bores but will endeavour to complete sampling before UWMP stage.*
Surface Water Quantity 4.7.4	It appears that only one surface water sample from the FMD has been taken and analysed to date. Pre-development monitoring of surface water should continue (6 months of monthly water quality sampling is recommended to get background water quality levels) to inform the LWMS and Urban Water Management Plan (UWMP) and to determine appropriate trigger values I improvement targets for the site. *Bioscience comment: Bioscience will continue to collect water samples from the FMD when possible to gain an understanding of quality trends, however, the water within the drain within the site boundaries is flowing and is likely generated upstream of the site boundaries.*
Wetlands 4.8	The EPP lake figure that was in the previous version of the LWMS (dated 18 December 2012) appears to be missing from the current LWMS *Bioscience comment: Since 2010, Bioscience has been liaising with the Department of Environment and Conservation (DEC) and City of Gosnells in regards to the incorrect demarcation of the EPP Lake classification. The reason for the anomaly is firstly, because the area is not a Lake as defined within the policy, and secondly it has low environmental values due to extensive grazing by horses.* *It is noted that there is no mechanism for correcting anomalies in the mapping of EPP Lakes, however the Minister for Environment has the discretionary power to cast aside the classification in the event that a development application is received. In this instance, the development application would take the form of the proposed ODP and therefore the formal lodgement of the ODP will enable to Minister to exercise such discretion.*

Water Use and Sustainability (Section 5)	This section lists options for water conservation, but not what will or won't be used in the development and why. Please discuss which options/initiatives are preferred and their relevance to development area. *Bioscience comment: Section updated and grey water references removed.* Amend 'Water Landscaping' to 'Waterwise Landscaping'. (Amended) Please note that 7,500 kl/ha/yr is an average irrigation rate for POS, not a target. As you may be aware, in the North West Corridor (City of Wanneroo) this average rate is being reduced to 6,750 kl/ha/yr as a water efficiency measure. (Amended) The LWMS provides typical concept plans for POS and runoff attenuation areas, however the conceptual design should show all design elements such as design dimensions, flow rates, runoff volume, runoff directions, provision of flush kerbs or break in kerbs, and locations of all POS areas on the plan etc. *Bioscience comment: Information contained within the Shawmac drainage plans for Precinct 3D. The concept plans for the LWMS have also been reviewed.* A 300mm high vertical stone wall has been proposed for the rain gardens in Figures 1 Oa - 1 Oc. Please clarify whether the rain gardens can have gentle side slopes where all banks are blended with the adjacent landscape to reduce any safety risks. *Shawmac comment: "City of Gosnells prefer a hard edge around raingardens rather than gently slopes for maintenance purposes. 300mm high limestone blocks are not considered a significant safety risk"* Concept landscape plans (as mentioned above) and irrigation requirements have been included for two drainage basin POS and the FMD widening (refer to Figures 10a - 10c). However, no plans have been provided for the District Open Space and High School playing fields and the estimated irrigation requirements currently assume that 100% of the DOS is irrigated. The DoW's preference is for these plans and refined irrigation requirements to be provided at this stage, however it will be acceptable for the LWMS to clearly commit to undertake these further investigations at the next stage of planning *Bioscience comment: Irrigation requirements in Section 5.3 have been revised to include an approximate 60% irrigation rate for the DOS. A statement confirming further investigations at UWMP stage is also included.* Please indicate at what stage an application for a Groundwater Licence will be submitted to the DoW? *Bioscience comment: Water licences to be applied for prior to commencement of UWMP (Section 11)*
Stormwater Management Strategy (Section 6)	The provided conceptual cross-section design for the FMD widening and Balannup Drain living stream is not consistent with the DoW living stream design criteria. Please refer to the living stream advice below and modify the cross-section (refer to Appendix C, SD-DP-17) and conceptual design (refer to Figure 10c) for the living stream. *Bioscience comment: Shawmac have amended all plans* *The living stream should be designed in such a way that the design reflects the*

	attributes of a natural stream including; *Cross-sections:* *- Base flow/low flow channel: channel size just enough to convey the flows resulted from typical winter groundwater table rise and seepage flow,* *- Bank-full flow channel: channel size just enough to convey a typical winter flood flows (e.g. 1.5 year ARI flow),* *- Floodplain channel: channel (overland flow capacity) size sufficient to convey major flood flows (e.g. 100 year ARI flows or higher).* *Shawmac comment: The 1.5 year ARI flow rates have been included within the Shawmac Drainage Summary* Long-sections: - Mimic slope of the channel invert as close to the slope of general topography of the area *Shawmac comment: "Channel invert does follow general topogragpy, long section is as per the FMD study. Additional drawing provided"* *Vegetation:* *- All cross-sections should be covered, with range of vegetation in taking consideration of hydraulic requirements (e.g. sedges and rushes that can bend in high flows can be planted on base flow and bank-full flow channel and taller species on floodplain channel)* *Shawmac comment: "Drawings show sedges/rushes on base/bankfull cross section and grass on floodplain"* *Provide the design details of the Living Stream including cross-sections and long sections.* *Shawmac comment: "Cross sections and long sections are provided and updated"* The 1.5 year ARI flow rates should be provided to design the living stream on Forrestdale Main Drain *Shawmac comment: The 1.5 year ARI flow rates have been included within the Shawmac Drainage Summary and included on basin drawings.* Please include information on total connected impervious area and runoff volume generated from this area by 1 year 1 hour ARI or 15mm rainfall event. Compare the runoff volume with the total design volume of rain gardens and confirm that the design volume of rain gardens is equal or greater than the runoff volume (refer to Appendix C, Section 2) *Shawmac comment: "This data is provided in report. Design Volumes are equal to runoff volumes"* There is no catchment "B" but there are two catchments "C" (refer to Appendix C, SD DP-11) *Shawmac comment: "Amended"* The 1, 5 and 100 year ARI event plans should cover the whole development area rather than a portion of the area (refer to Appendix C)

	Shawmac comment: "Plans have been expanded to cover entire area" Overland flow from the adjacent road (of the FMD) is parallel to the FMD. Clarify whether the roads adjacent to the FMD have flush or breaks in kerb and one way cross-fall to FMD so that runoff is allowed to flow into FMD rather than parallel directions (refer to Appendix C, SD-DP-14 to 16) *Shawmac comment: " FMD study requires flows from new developments to be compensated prior to entering FMD. As such roads will have oneway crossfall to raingarden adjacent to FMD then directed to basin B to compensate."* Pipes can be seen just below the rain gardens. Clarify whether these are sub-soil drainage for the rain gardens or pipe designed for 5 year ARI event (refer to Appendix C, SD-DP-14 to 16). Remove the pipes where not required *Shawmac comment: "These are stormwater pipes, not subsoil. Legend on drawings has been amended"* The legend shows inundated areas on the plan. Confirm whether all inundated areas are rain gardens? (refer to Appendix C, SD-DP-14). Provide a complete legend *Shawmac comment: " The inundated areas are raingardens. The legend has been updated"* It has been stated that for the High School "all stormwater to be retained on site". Please note that during the 100 year ARI event, overland flow through road reserve can occur, provided that pre-development flow rates and direction area is maintained (refer to Appendix C, SD-DP-16) *Shawmac comment: "It is intended that the highschool retain all stormwater inc. 100 yr flow on site. The high school is currently situated within a catchment low point and it will be unfeasible to direct this stormwater elsewhere"* Move rain gardens as high as possible from the attenuation area so that it is separated from bigger events, can provide effective treatment to small events and can drain runoff downstream once treated. Blend rain gardens with the adjacent landscape rather than a sudden vertical drop. Include a flush kerb or break in kerbs on adjacent roads. It is not clear whether these areas will function as POS in addition to stormwater management. If so, clarify how the proposed design will function for both. The POS/basin base is flat. Please provide gradual longitudinal slope along the centre so that water is drained to a corner of the area and when water is exposed it has less surface area (refer to Appendix C, SD-DP-17, Section A-A). *Shawmac comment: "CoG prefers raingardens to be as low as possible so that large events will drain to raingardens once capacity is freed up, leaving POS areas dryer for longer periods. Section A-A shows basin is not flat and will grade to raingardends"* Provide overland flow rather than weir control flow from stormwater attenuation area to the FMD. No sudden vertical drop on rain gardens. Blend with adjacent landscape (refer to Appendix C, SD-DP-17, Section B-B) *Shawmac comment: "City of Gosnells prefer a hard edge around raingardens rather than gently slopes for maintenance purposes. 300mm high limestone blocks are not considered a significant safety risk. Overland flow is not feasible due to significant level differences"*

Monitoring (Section 9)	The DoW advises to conduct an appropriate pre and post development monitoring program consistent with the Water monitoring guidelines for better urban water management strategies and plans (DoW, 2012) Please refer to previous advice regarding continual pre-development monitoring to inform the LWMS and the next stage of planning and to develop suitable trigger/target values. This particularly relates to surface water quality, as only one sample has been taken previously in May 2014. Monthly samples when the FMD is flowing (e.g. June to October) is required pre-development as well as post-development (refer to Table 12). *Bioscience comment: Bioscience have been undertaking monitoring for 3 winters and are committed to continue post development. The surface water quality sampling will be continued to establish baseline levels for establishing post development targets within the FMD.*
Future Work (Section 11)	Amend the first dot point to also include surface water quality monitoring. Amend the third dot point to include detailed landscape management plans and. irrigation requirements for drainage and public open space areas. Also include a dot point for the development of a dewatering management plan (which was committed to in Section 8.2). *Bioscience comment: Amended*