Technical Appendix D - LWMS

Forrestfield North Residential Precinct LWMS

Local Water Management Strategy

Prepared for
Element
by Strategen-JBS&G

December 2020

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Forrestfield North Residential Precinct LWMS

Local Water Management Strategy

Strategen-JBS&G is a trading name of
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December 2020

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The advice herein relates only to this project and all results conclusions and recommendations made should be reviewed by a competent person with experience in environmental investigations, before being used for any other purpose.

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Sampling and chemical analysis of environmental media is based on appropriate guidance documents made and approved by the relevant regulatory authorities. Conclusions arising from the review and assessment of environmental data are based on the sampling and analysis considered appropriate based on the regulatory requirements.

Limited sampling and laboratory analyses were undertaken as part of the investigations undertaken, as described herein. Ground conditions between sampling locations and media may vary, and this should be considered when extrapolating between sampling points. Chemical analytes are based on the information detailed in the site history. Further chemicals or categories of chemicals may exist at the site, which were not identified in the site history and which may not be expected at the site.

Changes to the subsurface conditions may occur subsequent to the investigations described herein, through natural processes or through the intentional or accidental addition of contaminants. The conclusions and recommendations reached in this report are based on the information obtained at the time of the investigations.

This report does not provide a complete assessment of the environmental status of the site, and it is limited to the scope defined herein. Should information become available regarding conditions at the site including previously unknown sources of contamination, Strategen-JBS&G reserves the right to review the report in the context of the additional information.

Client: Element

Report Version	Revision No.	Purpose	Strategen-JBS&G author/reviewer	Submitted to Client	
				Form	Date
Preliminary Draft Report	A	Client review	M Dunlop/ D Newsome	Electronic	13/04/18
Draft Report	1	Public Review	M Dunlop/ D Newsome	Electronic	20/04/18
Final Report	2	Final for advertising	M Dunlop/ D Newsome	Electronic	24/04/18
Revised final	C	Client endorsement	M Dunlop/ D Newsome	Electronic	01/04/19
Revised final	3	Final	J Hunt/ D Newsome	Electronic	26/06/20
Revised final	4	Final	J Hunt/ D Newsome	Electronic	24/09/20
Revised final	5	Final	J Hunt/ D Newsome	Electronic	10/12/20

Document originally prepared by Strategen Environmental Pty Ltd (now Strategen-JBS&G).

Filename: R02 57806-128960 LWMS (Rev 5)

Executive Summary

In response to the State Government's Forrestfield-Airport Link Project, the City of Kalamunda (the City) is facilitating the design and subsequent implementation of the development of the Forrestfield North Area. To coordinate the development, an Activity Centre Plan (ACP) and a Local Structure Plan (LSP) are being developed for two designated precincts:

- ACP for the TOD Precinct (TODP) (55 ha)
- LSP for the Residential Precinct (RP) (123 ha) (Figure 1).

The TODP is a METRONET project whereas the RP is not a METRONET Project. These areas combined are referred to as the LSP Precinct Areas.

This document provides the Local Water Management Strategy (LWMS) for the RP and has been developed to inform and support the lodgement of the LSP for the Forrestfield North RP (the site) prepared by the City. A copy of the LSP is presented in Figure 2.The principal objective of this LWMS is to achieve better urban water management outcomes by guiding development within the precinct which incorporates and manages the total water cycle in a sustainable manner and meets objectives for water sensitive urban design. This includes consideration of:

- water conservation and efficiency (water use)
- water quantity management (groundwater levels and surface water flows)
- water quality management (groundwater and surface water quality).

Potential water sustainability measures have been assessed against the sustainability principles outlined in the *Water Resources Statement of Planning Policy 2.9* (WAPC 2004). This requires that an integrated approach is needed to address these issues and achieve sustainable outcomes and an acceptable 'prioritisation and balance' between competing interests (WAPC 2004) with consideration of the District Water Management Strategy prepared for the Forrestfield North Area (Strategen 2014). This requires that sustainability is pursued through integration of:

- environmental protection (including protection of water resources)
- social advancement
- economic prosperity (WAPC 2004).

Table ES 1 below summarises how the water management principles and objectives for the site will be met.

Table ES 1: Compliance with water management principles and objectives

Category	Principles	Objectives	Methods for achievement
Water use	• consider all potential water sources in water supply planning • integration of water and land use planning • sustainable and equitable use of all water sources having consideration for the needs of all users, including community, industry and the environment.	• minimise the use of potable water where drinking water quality is not essential • achieve a significant reduction in water use below the 100 kL/person/year State Water Plan (Government of Western Australia 2007) target • mandate Water Efficiency Labelling and Standards rated water efficient products, water efficient irrigation, waterwise landscaping and rainwater storage tanks for individual green title lots.	• potable water use estimated at 66 kL/day through mandating water efficient fittings and appliances and reduced garden areas • irrigation volumes for POS and schools will be kept within the current City of Kalamunda licenced allocation volume • POS design will maximise retention of native bushland, include extensive rehabilitation and minimise the use of turf in POS where not required • trials of soil amendments and/or irrigation measures to reduce turf water and fertiliser use will be undertaken in the first two POS areas containing turf and result used to inform POS design.
Groundwater and surface water quantity	• to retain natural drainage systems and protect ecosystem health • to protect from flooding and waterlogging • to implement economically viable stormwater systems • post development annual discharge volume and peak flow rates to remain at pre-development levels or defined environmental water requirements.	• where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles • for flood management, manage up to the 1% AEP event within the development area to pre-development flows and the requirements of Water Corporation (Water Corporation 2010). • adopt ‘at source’ stormwater management approach and consider reducing pit and pipe drainage system significantly. Treat polluted runoff by installing appropriate treatment systems where required. • Consider managing stormwater runoff by providing overland flow paths and opportunities for infiltration of runoff on lots, road reserves and public open space where site conditions permit • Pre-development flow rates will be maintained for events up to the 1% AEP event at discharges from the site, including Poison Gully • Design stormwater management systems to provide serviceability, amenity and road safety during minor rainfall events.	• control of groundwater levels on the site is not proposed and thus impacts on groundwater regimes will be limited • maintain pre-development flows off the site through detention and retention on site, while minimising land take for drainage to improve public amenity.

Category	Principles	Objectives	Methods for achievement
Groundwater and surface water quality	• to maintain or improve groundwater and surface water quality • where waterways/open drains intersect the water table, minimise the discharge of pollutants from groundwater • where development is associated with an ecosystem dependent upon a particular hydrologic regime, minimise discharge or pollutants to shallow groundwater and receiving waterways and maintain water quality in the specified environment.	• maintain surface water and groundwater quality • retain and/or detain and treat (if required) — stormwater runoff from constructed impervious surfaces generated by the first 15 mm of rainfall at-source as much as practical.	• use of raingardens, including roadside raingardens to retain and treat the 1-year, 1-hour event through use of raingardens and tree pits • minimisation of turf areas and POS fertiliser use to reduce nutrient discharge to the environment • investigation and redevelopment of Brand Road landfill to manage and mitigate potential impacts to groundwater.

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1. Introduction

In response to the State Government's Forrestfield-Airport Link Project, the City of Kalamunda (the City) is facilitating the design and subsequent implementation of the development of the Forrestfield North Area. To coordinate the development, an Activity Centre Plan (ACP) and a Local Structure Plan (LSP) are being developed for two designated precincts:

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This document provides the Local Water Management Strategy (LWMS) for the RP and has been developed to inform and support the lodgement of the LSP for the Forrestfield North RP (the site) prepared by the City as presented in Figure 2. The principal objective of this LWMS is to achieve better urban water management outcomes by guiding development within the precinct which incorporates and manages the total water cycle in a sustainable manner and meets objectives for water sensitive urban design. This includes consideration of:

- water conservation and efficiency (water use)
- water quantity management (groundwater levels and surface water flows)
- water quality management (groundwater and surface water quality).

This LWMS is presented in support of the LSP to fulfil the requirements of *Planning Bulletin 92: Better Urban Water Management* (WAPC 2008).

1.1 Proposed development

The LSP proposes a medium to high density residential precinct (R40 to R100) with an estimated yield of approximately 3500 dwellings. The precinct also includes:

- Primary School
- Approximately 22 ha of public open space, approximately 10 ha reserved for conservation purposes, and approximately 1 hectare of bush forever (Figure 2)

1.2 Statutory framework

This LWMS has been prepared in accordance with *Better Urban Water Management* guidelines (WAPC 2008) on advice from Department of Water and Environment Regulation (DWER). The document is consistent with regional and district scale urban water management planning, including the *State Water Plan* (DPC 2007) as well as *State Planning Policy 2.9 Water Resources* (WAPC 2006). The document aims to meet the principles and objectives of stormwater management in Western Australia, as detailed in the *Decision Making Process for Stormwater in Western Australia* (DWER 2017) and *Decision Making Process for Stormwater in Western Australia* (DWER 2017). Section 2 provides more information on the key policies. The LWMS is consistent with the District Water Management Strategy (DWMS) prepared for the Forrestfield North Area. A completed copy of the LWMS checklist is presented in Appendix 1.

1.3 District Water Management Strategy

A DWMS was prepared by Strategen (now Strategen-JBS&G) (2015) for the broader Forrestfield North area and approved by the then Department of Water (DoW, now DWER) and the then Shire of Kalamunda (now the City of Kalamunda).

The LWMS addresses the RP and provides a refinement of surface water and groundwater management presented in the DWMS. The LWMS has been developed with regard to the water management needs of the TODP, with consideration given to stormwater flows in the broader Forrestfield North Area.

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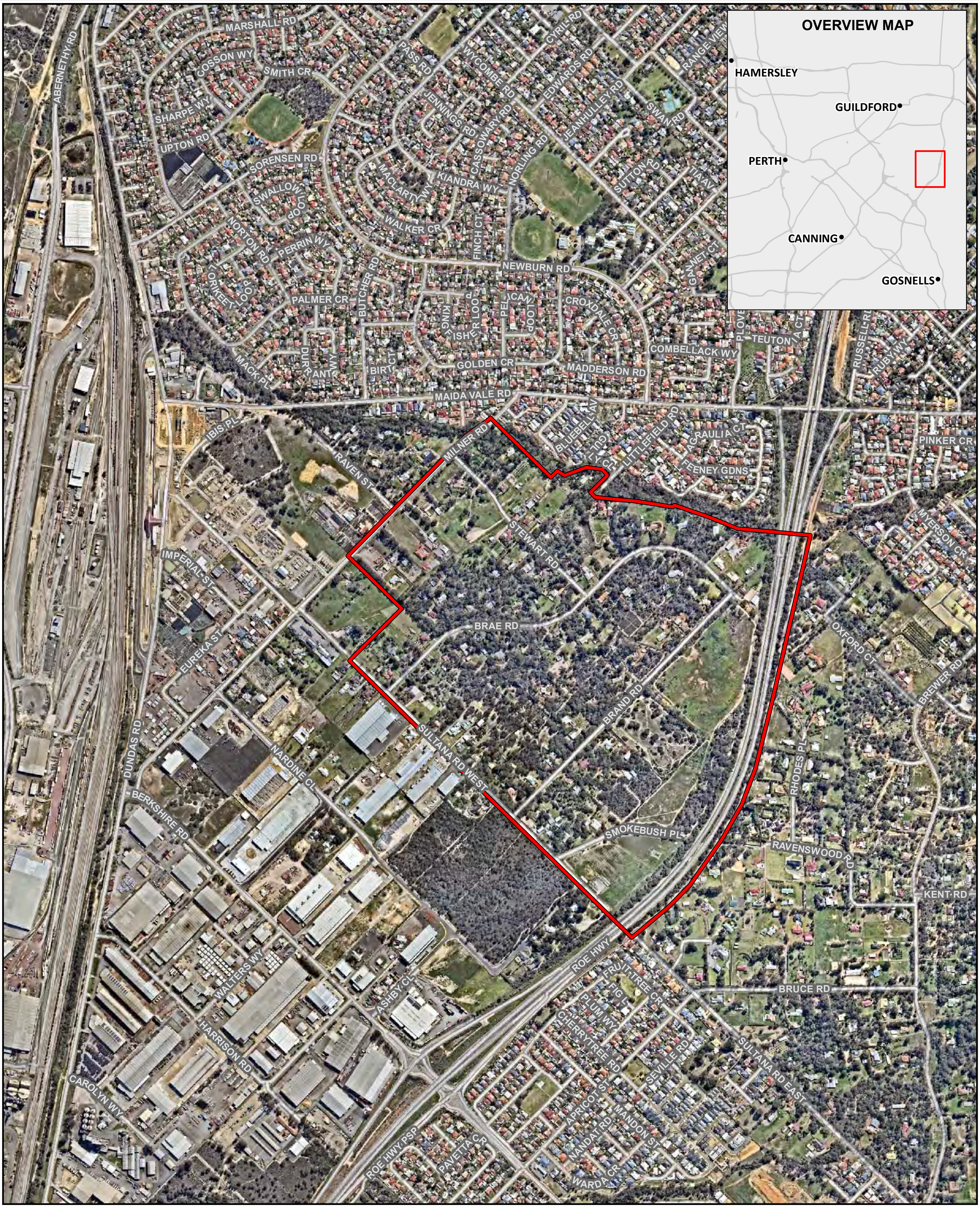

Legend:

▭ Residential precinct

═ Roads (MRWA)

Scale 1:15,000 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 23-Sep-2020

Drawn By: cthatcher

Checked By: JH

Forrestfield North Residential Precinct, WA

SITE LOCATION

FIGURE 1

File Name: W:\Projects\1)Open\Element (TPG)\57806 - FF North TOD & Res LWMS\GIS\Maps\R02_Rev_A\57806_01_SiteLocation.mxd
Image Reference: www.nearmap.com© - Imagery Date: 30 August 2020

Job No: 57806

Client: Element

Version: A	Date 16/04/2020
Drawn By: hsullivan	Checked By: CT

Image reference: Element, 2020

Forrestfied North Residential Precinct, WA

STRUCTURE PLAN

FIGURE 2

File Name: \\008pmpmr004v001.jbsg.aust\JBS Perth\Projects\1)Open\Element (TPG)\57806 - FF North TOD LWMS\GIS\Maps\R01 Rev A\57806_02_StructurePlan.mxd

2. Key principles and objectives

The LWMS uses the following documents to define its key principles and objectives for sustainable water management:

- *Liveable Neighbourhoods Edition 4* (WAPC 2009)
- *Water Resources Statement of Planning Policy 2.9* (WAPC 2004)
- *Stormwater Management Manual for WA* (Department of Water 2007)
- *Decision Making Process for Stormwater in Western Australia* (Decision Process, DWER 2017)
- *Better Urban Water Management* (WAPC 2008)
- *Interim: Developing a Local Water Management Strategy* (DoW 2008)
- *Forrestfield North District Water Management Strategy* (Strategen 2015).

The sections below outline the application of key policies in relating to this LWMS. The key points of these policies are discussed below. A summary of the key design principles and objectives from these documents is provided in Table 2 1.

Table 1: Water management principles and objectives

Category	Principles	Objectives
Water use	• consider all potential water sources in water supply planning • integration of water and land use planning • sustainable and equitable use of all water sources having consideration for the needs of all users, including community, industry and the environment.	• minimise the use of potable water where drinking water quality is not essential • achieve a significant reduction in water use below the 100 kL/person/year State Water Plan (Government of Western Australia 2007) target • mandate Water Efficiency Labelling and Standards rated water efficient products, water efficient irrigation, waterwise landscaping and rainwater storage tanks for individual green title lots.
Groundwater and surface water quantity	• to retain natural drainage systems and protect ecosystem health • to protect from flooding and waterlogging • to implement economically viable stormwater systems • post development annual discharge volume and peak flow rates to remain at pre-development levels or defined environmental water requirements.	• where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles • for flood management, manage up to the 1% AEP event within the development area to pre-development flows and the requirements of Water Corporation (Water Corporation 2010) • adopt 'at source' stormwater management approach and consider reducing pit and pipe drainage system significantly. Treat polluted runoff by installing appropriate treatment systems where required • consider managing stormwater runoff by providing overland flow paths and opportunities for infiltration of runoff on lots, road reserves and public open space where site conditions permit • pre-development flow rates will be maintained for events up to the 1% AEP event at discharges from the site, including Poison Gully • design stormwater management systems to provide serviceability, amenity and road safety during minor rainfall events.

Category	Principles	Objectives
Groundwater and surface water quality	• to maintain or improve groundwater and surface water quality • where waterways/open drains intersect the water table, minimise the discharge of pollutants from groundwater • where development is associated with an ecosystem dependent upon a particular hydrologic regime, minimise discharge or pollutants to shallow groundwater and receiving waterways and maintain water quality in the specified environment.	• maintain surface water and groundwater quality • retain and/or detain and treat (if required) — stormwater runoff from constructed impervious surfaces generated by the first 15 mm of rainfall at-source as much as practical.

2.1 Water Resources Statement of Planning Policy 2.9 and Liveable Neighbourhoods

The LWMS has been developed in accordance with regional and local principles and objectives of Integrated Urban Water, including promotion of water conservation measures, reuse and recycling of water and best practice in stormwater management (WAPC 2004). These objectives are consistent with Liveable Neighbourhoods (WAPC and DPI 2007).

2.2 Stormwater Management Manual and Decision Process

The DoW position on Urban Stormwater Management in Western Australia is outlined in Chapter 2: *Understanding the Context of the Stormwater Management Manual for Western Australia* (DoW 2004-2007), which details the management objectives, principles, and a stormwater delivery approach for WA. Principal objectives for managing urban water in WA are stated as:

- Water Quality: to maintain or improve the surface and groundwater quality within development areas relative to pre-development conditions
- Water Quantity: to maintain the total water cycle balance within development areas relative to the pre-development conditions
- Water Conservation: to maximise the reuse of stormwater
- Ecosystem Health: to retain natural drainage systems and protect ecosystem health
- Economic Viability: to implement stormwater systems that are economically viable in the long term
- Public Health: to minimise the public risk, including risk of injury or loss of life to the community
- Protection of Property: to protect the built environment from flooding and waterlogging
- Social Values: to ensure that social aesthetic and cultural values are recognised and maintained when managing stormwater
- Development: to ensure the delivery of best practice stormwater management through planning and development of high-quality developed areas in accordance with sustainability and precautionary principles Australia (DoW 2004-2007).

DWER revised the *Decision Process for Stormwater Management in WA* in 2017 to provide a decision framework for the planning and design of stormwater management systems and assist in meeting the objectives specified above. The Decision Process is a component of Chapter 4 of the Stormwater Management Manual for WA and focuses on achieving desired stormwater outcomes by:

- designing urban stormwater management systems that reduce risk to people and property from flooding to within acceptable levels
- designing urban stormwater management systems that mimic natural hydrological processes for that catchment
- retaining natural water bodies as the receiving environments for runoff of suitable quality from minor and major rainfall events

- retaining and planting vegetation (preferably local native species) wherever possible to reduce stormwater runoff volumes and peak flow rates, reduce urban temperatures, improve water quality, increase urban biodiversity, and improve aesthetics and urban amenity
- implementing stormwater management systems and site management, maintenance and other practices to prevent, reduce and treat pollutants
- designing urban stormwater management systems that achieve good urban amenity and provide multiple functions (DWER 2017).

2.3 Better Urban Water Management

The guideline Better Urban Water Management (WAPC 2008) focuses on the process of integration between land use and water planning and specifying the level of investigations and documentations required at various decision points in the planning process, rather than the provision of any specific design objectives and criteria for urban water management. This LWMS complies with the Better Urban Water Management process.

2.4 City of Kalamunda drainage guidelines

The City has prepared the Stormwater Design Guidelines for Subdivisional and Property Development (City of Kalamunda, 2018) to assist “developers, builders and consulting engineers to produce consistent designs for Stormwater Management Systems for residential, commercial, and industrial developments within the City of Kalamunda. This guideline should also be referenced when preparing an Urban Water Management Plan or Stormwater Management Strategy” (City of Kalamunda, 2018).

This document was provided after the stormwater modelling was completed for the LWMS and therefore some requirements in the document have not been included in the LWMS. However, the approach taken in the LWMS is more conservative in terms of sizing the drainage infrastructure than in the drainage guidelines, and as such provides a worst case scenario to provide proof on concept The drainage infrastructure sizing will be refined at subdivision stage and will take into consideration the requirements outlined in the guidelines.

2.5 Agency consultation

Consultation was undertaken with DWER (meeting held 29 September 2017) and Water Corporation (meeting held 6 December 2017) confirming the adequacy of the Water Corporation (2007 and 2010) documents to provide information on the regional drainage network and provide advice on modelling parameters to be used and stormwater volumes to be considered. Copies of these meeting minutes are provided in Appendix 5.

Ongoing consultation has been undertaken with DWER and the City as the proponent of the project.

3. Pre-development environment

This section provides a summary of information presented in the DWMS approved by DoW in June 2015 and additional studies where relevant. In accordance with the DWMS, this LWMS is informed by data from provided in the DWMS, including on groundwater and surface water monitoring was undertaken by Strategen over 2011/12 (Strategen 2015) which was considered to adequately cover the LSP area. The DWMS did not identify the need for further studies or monitoring prior to the preparation of the LWMS.

3.1 Climate

The RP area exhibits a Mediterranean climate, characterised by hot dry summers and mild wet winters, similar to that of other coastal areas in the Perth Metropolitan region.

The closest Bureau of Meteorology (BoM) monitoring station to the RP area is situated at Perth Airport, approximately 4 km away (BoM 2015). Temperature and rainfall data from this station are summarised in Table 2.

Summer months extend from October to April, with maximum daily temperatures of between 22 and 32°C. The winter months extend from May to September, with mean minimum temperatures of approximately 18°C.

Rainfall at Perth Airport mainly occurs during winter with a mean monthly rainfall of 155.9 mm in June and 10 mm in January. The mean annual rainfall for the area is 766.1 mm.

Table 2: Climate statistics for Perth Airport (1944 to 2017) (BoM Station 9021) (BoM 2018)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean Max Temp (°C)	31.8	32.0	29.7	25.5	21.8	19.0	17.9	18.6	20.2	22.7	26.0	29.0	24.5
Mean Min Temp (°C)	17.1	17.5	15.9	13.0	10.4	9.0	8.0	8.1	8.9	10.3	12.8	14.9	12.2
Mean Rainfall (mm)	10.0	15.3	16.4	40.5	98.9	155.9	155.7	118.2	73.2	43.3	25.9	11.2	766.1

3.2 Land use

The RP predominantly consists of semi-rural /residential and horticultural uses.

3.3 Topography

The topography of the precinct ranges from approximately 46 m Australian Height Datum (AHD) in the north-eastern section to approximately 35 m AHD in the south-western corner. Topographic contours for the precinct are shown in Figure 3.

Geology 1:50,000		
🟨	Mgs2	*Mgs2: GRAVELLY SILT - strong brown, tough with common pebbles of fine to coarse-grained, sub-rounded granite, some dolerite and rare sandstone (SS) variable sand content*
▨	S10	*SAND over PEBBLY SILT: very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted of eolian origin over pebbly silt as per MGS1*
☐	Mgs1	*Mgs1: PEBBLY SILT - strong brown silt with common, fine to occasionally coarse-grained, sub-rounded laterite quartz, heavily weathered granite pebble, some fine to medium-grained quartz sand, of alluvial origin*
☐	S12	*S12: SAND - yellow, fine to medium-grained, sub-angular to rounded quartz, with some feldspar, well sorted, variable silt content, of colluvial origin*

Figure 3: Topography and soils

Scale 1:6,000 at A3

0 60 120 180 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 9/04/2018

Author: vd

Source: Nearmap: Aerial imagery - 04/06/2017.

Legend

⌖ Monitoring bore location (Strategen 2012)

— Contour (mAHD)

▭ Residential Precinct

strategen JBS&G

Path: Q:\Consult\2017\QPG\QPG17388\01_GIS_documents\ArcMap_documents\TPG16528_G045_RevB.mxd

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3.4 Geology and soils

Regional Mapping indicates that the geology of the RP consists of a mixture of Bassendean Sands over Guildford Formation (S10) and sands of the Yoganup Formation (S12) (Gozzard 1986) (Figure 3). The Yoganup Formation predominantly occurs in the east of the precinct and consists of yellow, fine to medium grained quartz sand with some feldspar and variable silt content of colluvial origin (Gozzard 1986). EMRC (2013) reports that the eastern portion of the RP is underlain by superficial deposits of Bassendean Sand and Guildford Formation which comprise approximately 25-30 metres of saturated thickness of the superficial aquifer.

Geological soil unit mapping indicates that the site is characterised by sand at the surface, consisting of:

- S10: Thin layer of SAND – very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted, of eolian origin over alluvial silts and sands of the Guildford formation
- S12: SAND – yellow, fine to medium grained, sub-angular to rounded quartz, with some feldspar, well sorted, variable silt content, of colluvial origin (Gozzard 1986).

3.4.1 Depth to low permeability material

As discussed in the DWMS, several bores were drilled across the precinct by Strategen in September 2011. The lithology of the bores within the RP were:

- MB02: predominantly sand with clayey sand at 6.5 m depth
- MB04: gravelly sand at surface with sand at depth
- MB05: predominantly sand (coarse to medium grained)
- MB06: sand with clayey sand at 13.5 m depth
- MB07: sand with clayey sand at 2.5 m depth (Strategen 2012a).

Depths to the interpolated low permeability material varied from 2.5 m to greater than 5 m, with the shallowest depths in the east of the site (Figure 4). Low permeability material is not anticipated to be of concern over the majority of the RP Area. The presence of low permeability material should be confirmed through geotechnical investigations at the subdivision stage.

3.4.2 Hydraulic conductivity

Hydraulic conductivity testing was undertaken at proposed basin and storage tank locations on 23 October 2018 based on Australian Standard methodology (AS 1547:2012). Further details of the testing are presented in Appendix 7. These values were used to derive hydraulic conductivities to be used in stormwater modelling (Table 3).

Table 3: Hydraulic conductivity test results

Basin	Soil type	Conductivity measured(m/day)	Recommended conductivity for model (m/day)
AS1	Clayey Sand	1.2	0.6
AS1B	Clayey Sand	0.7	0.3
AS3	Clayey Sand	0.8	0.4
MV5	Fine to medium SAND	2.7	1.3
PG4	Fine to medium SAND	6.3	3.1
PG5	Clayey gravelly SAND	0.9	0.4
PG6	Clayey gravelly SAND	0.8	0.4
PG6B	Fine to medium SAND	>10	3.0

3.4.3 Acid sulfate soils

Acid Sulfate Soils (ASS) are naturally occurring, iron-sulphide rich soils, sediments or organic substrates, formed under waterlogged conditions. If exposed to air, these sulphides can oxidise and release sulphuric acid and heavy metals. This process can potentially occur due to a change in drainage conditions, lowering of the water table (dewatering) and/ or excavation.

Review of regional mapping indicates that the precinct has a low to moderate risk of ASS occurring within 3 m of natural soil surface (Class 2) (DER 2015). The nearest area of high to moderate risk of ASS occurring within 3 m of natural soil surface is approximately 400 m south east of the precinct (Figure 5).

During bore installation in 2011, samples were collected at 25 cm intervals from the surface to a depth of 4 m and results analysed. Results indicate relatively neutral pH and pHf_{ox} results, with minimal difference between these indicators. ASS are not considered likely to be a significant risk in the RP.

3.4.4 Contaminated sites

The DWER (2017) Contaminated Site Database was searched and there are currently no registered contaminated sites within the precinct. The closest registered contaminated site is associated with the Marshalling Yards located approximately 0.8km south west of the RP.

Previous land uses

Brand Road Landfill

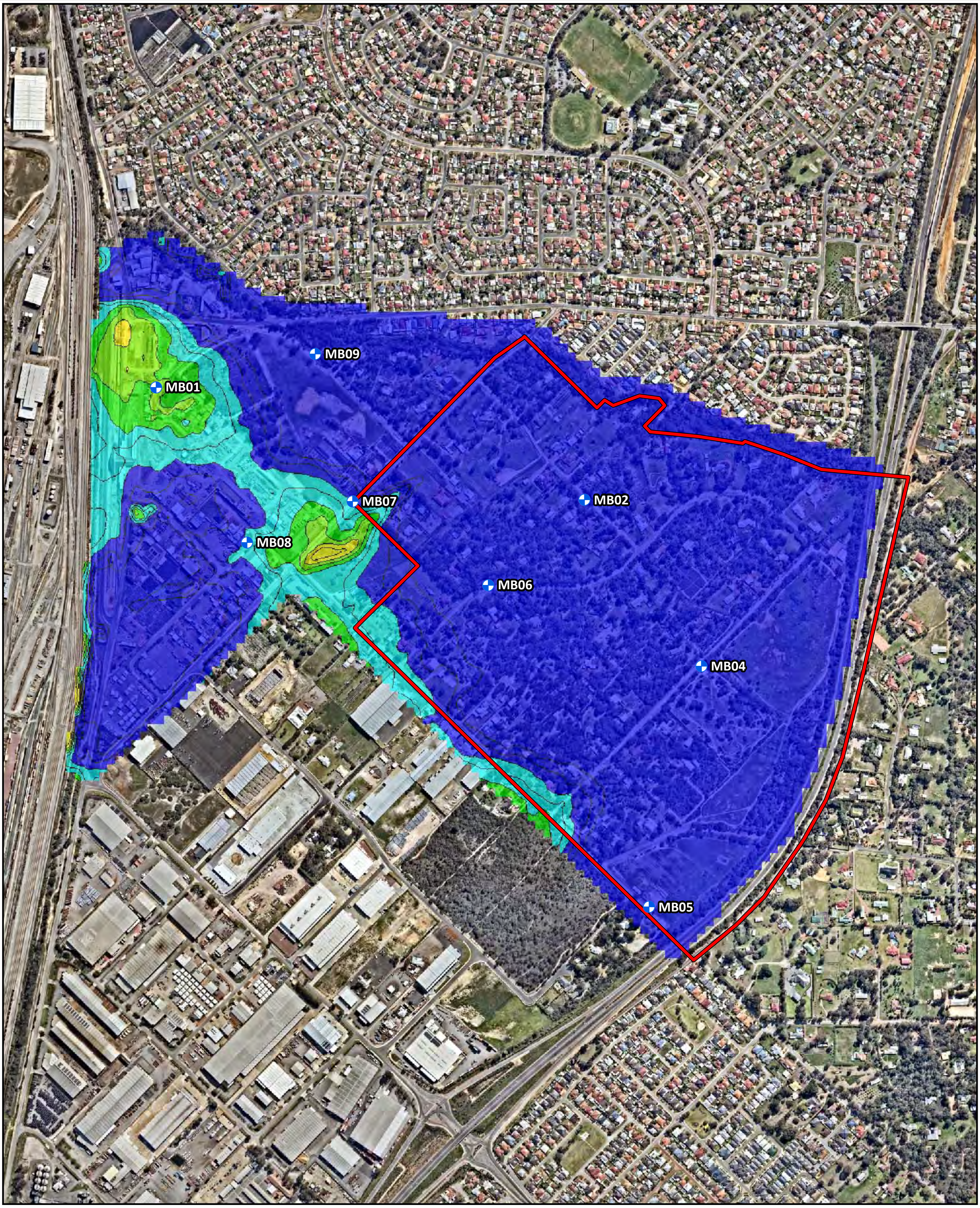
Brand Road landfill operations (Lot 13, 14 and 18 on Plan 24292) commenced in approximately 1978. It was operated by Western Excavating from the beginning of the sand mining activities until 1989. The sanitary landfill operations started in 1989.

The former Brand Road landfill is located on the eastern boundary of the Precinct (Figure 5). A Preliminary Site Investigation (PSI) for the former landfill was completed in 2010 (GHD 2010). This site is considered '*Possibly Contaminated – Investigation Required*' under the *Contaminated Sites Act 2003* (Reference: DEC10015). A series of site investigations and reporting has been completed for the former landfill. Land use planning for the RP has incorporated the landfill within the design of the LSP.

Orchards

Based on historical aerial photography, there have been several hobby farms and/or orchards within Lots 94 and 98 Brae Road and Lots 100, 101, 102 and 103 Smokebush Place High Wycombe (Figure 5). These land uses and their associated activities are potentially contaminating due to the use of metals, organochlorine pesticides, organophosphate pesticides, carbamate and fuels (DoE 2004).

Investigations consistent with the requirements of the *Contaminated Sites Act 2003* are anticipated to be required prior to the redevelopment of these areas.



Legend:

- 🟥 Residential precinct
- ● Monitoring bore location (2012)

Depth to low permeability material

5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

Scale 1:12,500 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 23-Sep-2020

Drawn By: cthatcher

Checked By: JH

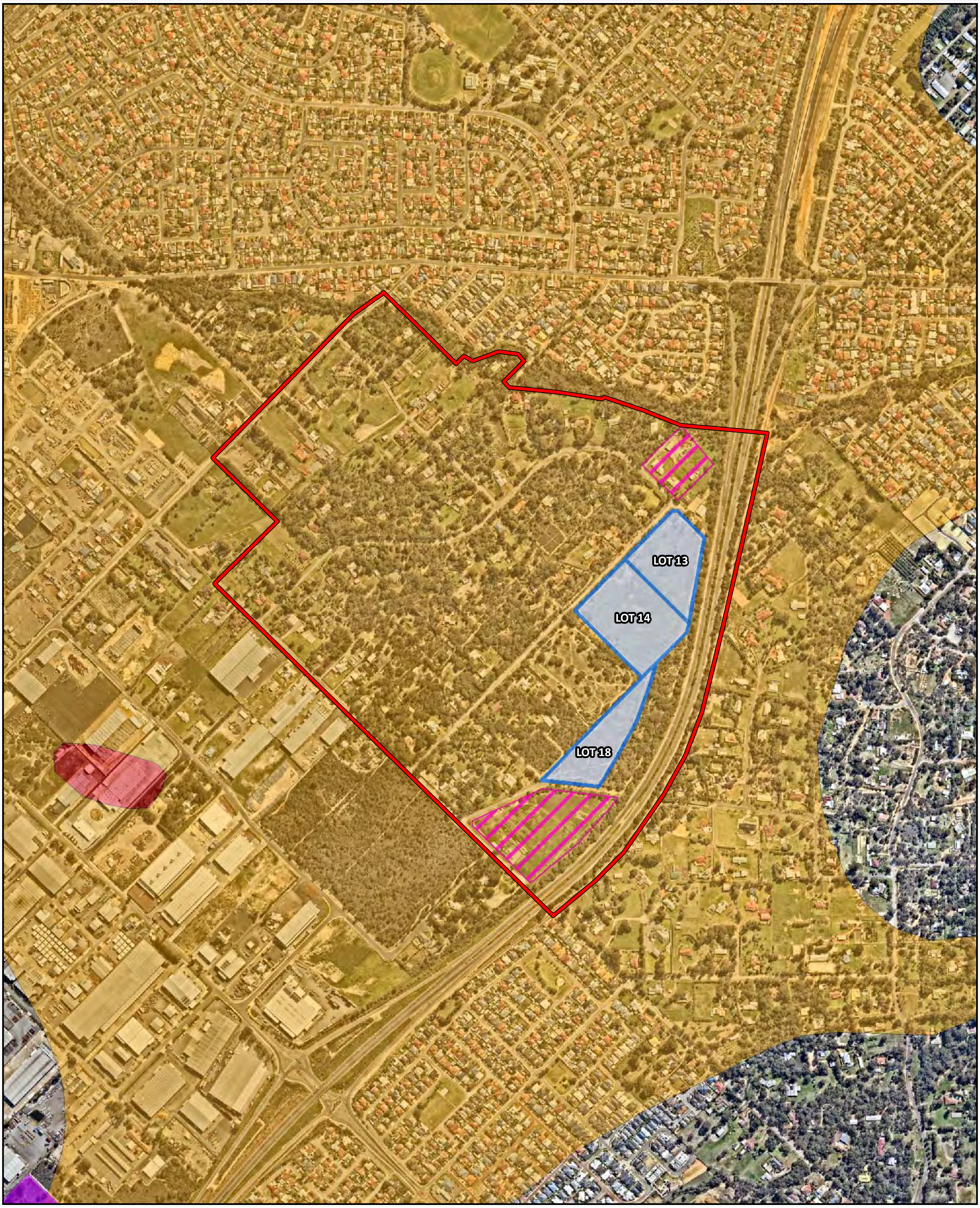
Forrestfield North Residential Precinct, WA

DEPTH TO LOW PERMEABILITY MATERIAL

FIGURE 4

strategen JBS&G

File Name: W:\Projects\1)Open\Element (TPG)\57806 - FF North TOD & Res LWMS\GIS\Maps\R02_Rev_A\57806_04_Permeability.mxd
Image Reference: www.nearmap.com© - Imagery Date: 30 August 2020



Legend:

▭ Residential precinct
▭ Indicative landfill (source: GHD 2010)
▨ Historical orchard activity

Acid sulfate soil (DWER)
🟥 High to moderate risk
🟨 Moderate to low risk

DWER registered contaminated sites
🟪 Contaminated - remediation required

Scale 1:12,500 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 23-Sep-2020

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Checked By: JH

Forrestfield North Residential Precinct, WA

ACID SULPHATE SOILS AND POTENTIALLY CONTAMINATED SITES

FIGURE 5

File Name: W:\Projects\1)Open\Element (TPG)\57806 - FF North TOD & Res LWMS\GIS\Maps\R02_Rev_A\57806_05_ASS.mxd
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3.5 Groundwater

3.5.1 Groundwater monitoring

Strategen installed bores in the LSP precinct areas in September 2011 as part of the preparation of a DWMS (Figure 2). Bore details are presented in Table 4 and Appendix 2. Groundwater levels were monitored for water level monthly between September 2011 and December 2012 (Appendix 3). The highest groundwater levels to date were recorded in October 2011 (Table 4).

Groundwater appeared to flow in a generally south easterly direction. This is consistent with the work of ENV (2012) for the area to the south of Sultana Road West and monitoring in the TODP by Strategen for a confidential client which indicates that Poison Gully is a losing stream (i.e. discharges surface water to groundwater) in the TODP area.

3.5.2 Maximum groundwater levels

Available groundwater level data was reviewed for October 2011, April 2012 and October 2012 for monitoring bores MB01 to MB09. Comparisons were made to historic groundwater levels from the nearest DWER bore 61610508 and other available historical groundwater level data to provide an estimate of short-term perched MGL following high rainfall periods. The estimated maximum groundwater levels for each bore location is provided in Table 4. The maximum groundwater level contours are presented in Figure 6. The depth to maximum groundwater levels is presented in Figure 7.

The groundwater levels for 2011 and 2012 were compared along with the DoW bore (61610508) to allow an assessment of the perching that occurs where the clay layer is known to be present west of Milner Rd (Table 5). Groundwater monitoring results obtained by PTA between 2014 and 2016 (Appendix 8) were also considered as part of the review process.

Table 4: Groundwater levels

Bore	Easting	Northing	Ground level (mAHD)	Screened depth (mbgl)	October 2011 (mbgl)	Oct 2011 (mAHD)	Oct 2012 (mAHD)	Difference	Max groundwater level (mAHD)
MB01	404861	6464332	30.04	6 - 9	3.79	26.427	24.690	1.737	30.027
MB02	405922	6464054	38.45	14 - 18	14.22	24.235	23.990	0.245	31.235
MB04	406211	6463643	39.73	15 - 19	15.73	23.876	23.800	0.076	30.876
MB05	406081	6463047	40.77	15 - 19	16.99	23.776	23.570	0.206	30.776
MB06	405683	6463843	36.24	13 - 16	11.92	24.319	23.970	0.349	31.319
MB07	405347	6464050	34.49	9 - 13	9.61	24.876	24.230	0.646	31.876
MB08	405086	6463948	31.84	6 - 9	3.97	27.873	25.750	2.123	30.873
MB09	405255	6464415	33.36	2 - 5.5	0.95	32.411	28.350	4.061	33.411

Table 5: Rainfall, DWER Bore (61610508) and groundwater levels data summary

	2011	2012	Difference (m)	Comment
DoW bore (61610508)	~ 14.5 mAHD	~ 14 mAHD	~ 0.5	2017 (Oct) levels ~15.2 mAHD (0.7 m higher than 2011, 1.2 m higher than 2012).
Rainfall (Jan-Sept)	666.4 mm	526 mm	0.14	Higher rainfall for Jan-Sept 2011.
Rainfall (Oct)	63.4 mm	13.8 mm	0.496	High Oct 2011 rainfall periods immediately prior to groundwater level measurement.
Oct groundwater levels East of Milner Rd	23.776 - 24.319 mAHD	23.570 - 23.990 mAHD	0.076 - 0.349 m	no significant perching is evident east of Milner Rd (absence of clay layer).
Oct groundwater levels West of Milner Rd	26.427 - 32.411 mAHD	24.690 - 28.350 mAHD	1.737 - 4.061 m	Significant perching to the northwest near MB09 due to clay layer west of Milner Rd.

Perching of groundwater was not observed in the RP.

3.5.3 Groundwater quality

Groundwater and surface water quality monitoring was undertaken by Strategen on six occasions between October 2011 and November 2012.

Water quality monitoring results for the RP and TODP are summarised below with all results provided in Appendix 3.

Monitoring data for pH ranged from 4.62 (MB4) to 7.21 (MB9) with a median across all bores of 5.84 (Appendix 4). This indicates that groundwater is generally neutral to acidic. Groundwater is fresh with a median electrical conductivity (EC) level of 0.438 mS/cm (Appendix 4). EC levels were less than 1.1 mS/cm for all bores (Appendix 4).

Total nitrogen (TN) levels varied from 0.31 mg/L to 25 mg/L throughout the monitoring period with a median of 2.1 mg/L (Table 6). This median exceeds the Swan Canning Water Quality Improvement Plan's (SCWQIP) long-term and short-term target for TN (1 mg/L and 2 mg/L respectively) (Swan River Trust 2009). The Australian Drinking Water Guidelines for nitrate of 30 mg/L nitrate as nitrogen were exceeded in MB07 and MB08 on two occasions each. Groundwater within the RP may require treatment if mobilised due to installation of subsoil drainage.

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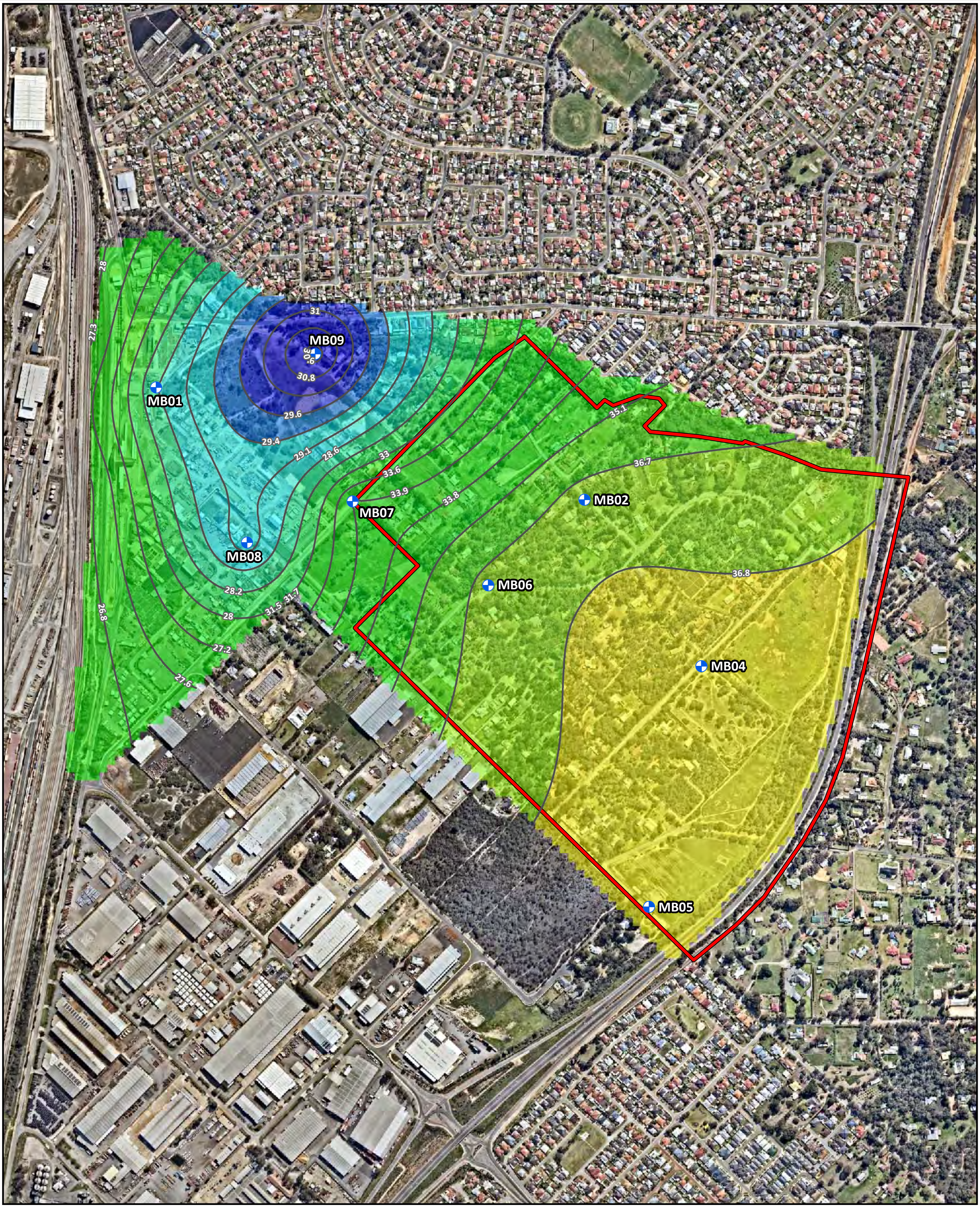

Legend:

🟥 Residential precinct

— Groundwater contour (mAHD)

● Monitoring bore location (2012)

Maximum groundwater level (mAHD)

33.0
32.0
31.0
30.0
29.0
28.0
27.0
26.0
25.0
24.0
23.0

Scale 1:12,500 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 23-Sep-2020

Drawn By: cthatcher

Checked By: JH

Forrestfield North Residential Precinct, WA

GROUNDWATER LEVELS

FIGURE 6

strategen JBS&G

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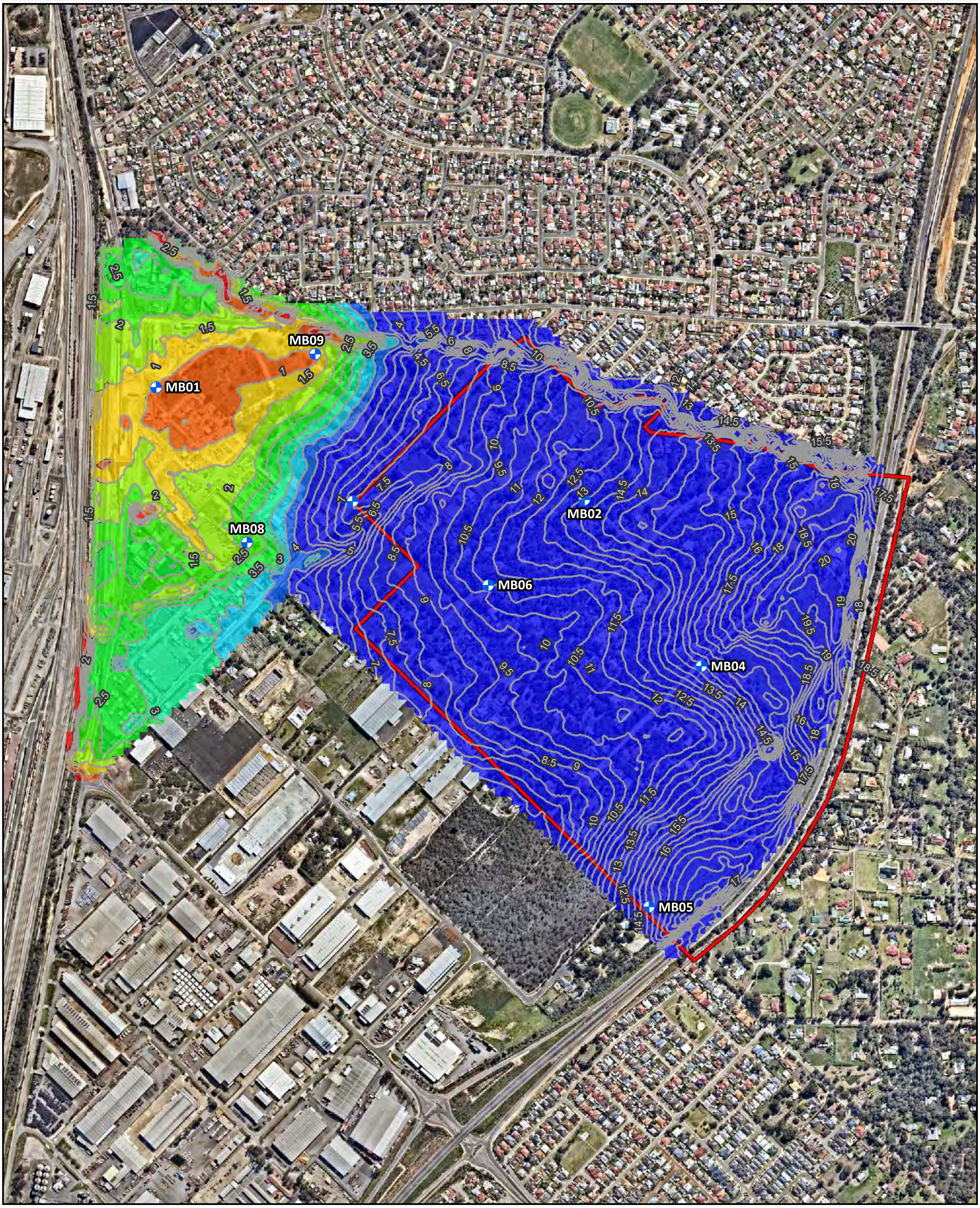

Legend:

☐ Residential precinct

— Topography

● Monitoring bore location (2012)

Depth to maximum groundwater level (mAHD)

🟦	5.0
🟦	4.5
🟦	4.0
🟦	3.5
🟩	3.0
🟩	2.5
🟩	2.0
🟩	1.5
🟨	1.0
🟧	0.5
🟥	0.0

Scale 1:12,500 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 23-Sep-2020

Drawn By: cthatcher

Checked By: JH

Forrestfield North Residential Precinct, WA

DEPTH TO GROUNDWATER

FIGURE 7

strategen JBS&G

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Table 6: Groundwater nutrient summary

Bore	Statistic	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
MB01	Min	0.93	0.21
	Max	5.90	1.70
	Average	2.43	0.72
MB02	Min	0.55	0.12
	Max	1.20	0.82
	Average	0.82	0.37
MB04	Min	0.62	0.84
	Max	2.30	2.40
	Average	1.24	1.33
MB05	Min	5.10	2.30
	Max	6.90	5.70
	Average	5.76	4.14
MB06	Min	0.31	0.12
	Max	5.30	1.90
	Average	2.38	0.90
MB07	Min	7.10	0.20
	Max	10.00	1.60
	Average	8.08	0.81
MB08	Min	18.00	0.18
	Max	25.00	1.20
	Average	21.50	0.66
MB09	Min	-	-
	Max	-	-
	Average	1.30	0.08

Total phosphorus (TP) results varied from 0.12 to 5.76 mg/L, with an average of 0.72 mg/L (Table 6). These levels are above the SCWQIP long-term and short-term target for TP (0.1 mg/L and 0.2 mg/L respectively).

3.5.4 Groundwater availability

The RP area is located in the 'Shire of Kalamunda' subregion of the Perth Groundwater Area. The superficial, Leederville and Yarragadee Aquifers in this area are identified by the DWER Water Register as being fully allocated, with groundwater not being available for new licences (accessed 2 October 2017).

A total of 137.4 ML is allocated for private use within the TODP and RP areas (Table 7). The timing of development of these areas will depend on the landowners, who may choose to retain their allocations for other purposes rather than providing these to the City. As such these allocations have not been relied on for the future irrigation of Public Open Space (POS) and landscaping.

Table 7: Groundwater licences within the TOD and RP areas

Licence Number	Licence Allocation (kL)	Licence Address
63807	89390	Lot 22 On Diagram 71134 Volume/Folio 1791/535 Lot 22 Dundas Rd High Wycombe; Lot 23 On Diagram 71134 Volume/Folio 1791/536 Lot 23 Milner Rd High Wycombe; Lot 551 On Plan 4684 Volume/Folio 365/181a Lot 551 Dundas Rd High Wycombe
152091	3500	Lot 89 on Plan 13420; Certificate of Title Volume 1581 Folio 996 Lot 89 on Stewart Road High Wycombe
152215	23120	Lot 1 on Diagram 17430; Certificate of Title Volume 1324 folio 130 Lot 1 Milner Road High Wycombe
154669	3500	Lot 4 on Diagram 69590; Certificate of Title 1723, Folio 473 Lot 4 Brand Road High Wycombe
155694	7625	Lot 3 On Diagram 69590 Volume/Folio 1723/472 Lot 3 Brand Rd High Wycombe
167016	7280	Lot 92 On Plan 13420 Volume/Folio 1581/969 Lot 92 Milner Rd High Wycombe
167785	3000	Lot 220 On Plan 31169 Volume/Folio 2526/471 Lot 220 Nardine Cl Forrestfield
Total	**137415**	

The City currently operates a managed aquifer recharge (MAR) scheme at Hartfield Park for irrigation of POS. MAR is the intentional recharge of water to suitable aquifers for subsequent recovery. The MAR scheme at Hartfield Park pumps water from an adjacent drain into the Leederville Aquifer during the winter months. During the summer months, this water is abstracted from the aquifer for irrigation of POS.

A preliminary ‘entry-level’ assessment of potentially incorporating a MAR to supply irrigation water for LSP area based on the *Australian Guidelines for Water Recycling* (AGWR) (NRMMC, EPHC and NHMRC 2006) has been undertaken to inform decision making on this issue. The MAR option would have involved injection of stormwater into the Leederville Aquifer during the winter wet season and abstraction during the summer dry season for irrigation. As previously discussed, the City currently operates a MAR scheme for irrigation at Hartfield Park, approximately 4 km south of the site. The findings of the review and subsequent discussions with DWER and hydrogeologists indicated:

1. Volumes of stormwater within the two LSP precinct areas (RP and TODP) may not be adequate to support a MAR scheme. MAR using wastewater or greywater would require the installation of complex treatment units.
2. Uncertainty regarding the depth and presence of the Leederville Aquifer – estimated to be greater than 80 m in the LSP precinct areas, compared to approximately 40 m at Hartfield Park. This would increase the cost of investigations and installation of any MAR bores.
3. Uncertainty regarding water quality in the Leederville Aquifer in the area as limited information is available.
4. A bore has been installed by PTA into the Leederville Aquifer near Forrestfield North Train Station as a temporary source of construction water with a temporary, non-transferrable groundwater allocation. Subject to further investigation, this bore may be suitable in the longer term to be used as a Leederville Aquifer MAR injection bore.
5. Water quality in the Leederville Aquifer under the site may not be suitable for irrigation of turf.

The review identified that, based on the above, the LSP precinct area conditions were not favourable for a MAR scheme compared to other locations within the City. The City is strategically considering opportunities to install MAR schemes within the City, pending more detailed future assessment.

The City currently has an allocation for irrigation of POS in the superficial aquifer which covers the POS currently irrigated by the City. Review of groundwater use by the City indicates that this allocation is not being fully utilised. The City has identified that 100,000 kL/year from the existing allocation can be made available for irrigation within the LSP precinct areas (Varelis P [City of Kalamunda] 2017, pers. comm. 12 October). As the RP is the larger precinct with more residential development and contains playing fields, the school and extensive POS, a total of 48,000 kL/yr has been allocated to this precinct, and 30,000 kL/yr to the TODP.

3.6 Surface water

The site is located within two drainage catchments, referred to as ‘Poison Gully’ (PG, northern portion of the site) and ‘Airport South’ (AS, southern portion of the site) (Figure 8). Poison Gully drains into the Perth Airport Northern Main Drain. The Airport South catchment drains into the Peth Airport Southern Main Drain.

Within the RP, drainage infrastructure is limited to open drains within road reserves where required.

The majority of the RP has:

- sandy soils
- significant depth to groundwater
- limited areas of hardstand.

Consequently, runoff is currently infiltrated on site in smaller events, with flows offsite occurring in larger events.

The Main Drains are currently operated by Water Corporation. Both Main Drains drain into the Swan River. Arterial drainage planning for these drainage systems are documented in:

- *Limestone Creek (Perth Airport Northern Main Drain) Stage 1 Capacity Review 2010* (Water Corporation 2010)
- *Perth Airport Southern Main Drain Scheme Review (2006),* Water Corporation 2007.

3.6.1 Poison Gully

Poison Gully, which collects water from elevated areas to the east of the LSP precinct areas and flows in a westerly direction via the Perth Airport Northern Main Drain and Limestone Creek into the Swan River (Figure 9). Poison Gully is an ephemeral creek that flows during the winter months. Water monitoring in Poison Gully commenced in September 2011, with water only present in September and October 2011. Poison Gully is located largely to the north of the RP boundary (Figure 9). Poison Gully also has Aboriginal Heritage significance as it is a water source and a historical birthplace (Ethnosciences 2018).

Water Corporation has undertaken hydraulic and hydrological modelling of Poison Gully as part of the *Limestone Creek (Perth Airport Northern Main Drain) Capacity Review* (2010). Flood levels and extent of flooding were interpolated from the Water Corporation (2010) modelling (Appendix 4). Extents of flooding and levels shown have been estimated for a previous foreshore assessment based on this modelling (Appendix 4). Development within the Poison Gully floodplain is not proposed.

The width of the mapped 1% Annual Exceedance Probability (AEP, equivalent to 100-year Average Return Interval) flood plain is variable, ranging from less than 10 m to approximately 40 m at the widest point. The Water Corporation (2010) modelling does not identify a separate floodway (area of fast flow) and flood fringe (area of slower water movement).

Road culverts for Poison Gully are as follows:

- Roe Highway – four 1500 mm diameter culverts
- Littlefield Road – 2000 x 3000 mm box culvert
- Milner Road – one 1350 mm diameter culvert
- Maida Vale Road – two 1350 mm diameter culverts (Water Corporation 2010).

Water Corporation (2010) considered that these culverts were adequate for the current flows in Poison Gully, based on the level of development. Should overtopping of surface water at Milner Road be considered unacceptable from a serviceability perspective, the current design of the road and culverts may need to be reviewed.

The Water Corporation monitored surface water quality in Poison Gulley at Littlefield Rd from 1981 to 2011. Strategen Environmental performed surface water monitoring downstream of the Site near Dundas Rd in 2015 (Appendix 8). The Water Corporation surface water quality results for 2011 and the are provided in Table 8.

Table 8: Predevelopment surface water quality results

Analyte	TN (mg/L)	TP (mg/L)	TKN (mg/L)	NH4 (mg/L)	NOX (mg/L)	pH	EC (mS/cm)
Dundas Rd (3-6-2015)	0.8	2.2	0.5	>0.02	0.25	7.2	-
Littlefield Rd 2011 average	1.0	0.05	0.4	0.04	0.6	7.1	-

Foreshore assessment and management

A foreshore assessment and boundary delineation for Poison Gully was included in the approved DWMS (Strategen 2012, Appendix 4). The foreshore boundary has been delineated based on consideration of bank steepness, presence of native vegetation and the 1% AEP floodway (Appendix 4). The most important factor has generally been the floodway and the presence of native vegetation that stabilises the banks and strips nutrients.

The Poison Gully foreshore area consists largely of retained vegetation. The management of foreshore areas and other retained vegetation which extends into the site will be addressed through preparation of a POS Revegetation Management Plan as identified in the *Forrestfield North Residential Precinct Environmental Assessment Report and Management Strategy* (Strategen 2018).

3.6.2 Airport South catchment

The Airport South catchment includes approximately 114 ha of land to the west of Roe Highway in Maida Vale (MV1 and MV2) (Figure 8). Historically, any water not infiltrated in MV1, MV2 or the RP would have run through the AS4/AS5 and Nardine Catchments and discharged to the west of Dundas Road as shown in Figure 8. Recent industrial development in the Nardine Catchment has impeded the flow path from AS3 to the Dundas Road area, where filling of low-lying areas identified as flow paths in the 1% AEP event by Water Corporation (2007) has occurred.

Catchments MV1 and MV2 which drains into an approximately 2400 m^3 basin (Bartlett D [CoK] 2017, pers. comm. 3 November) on the site via one 600 mm diameter Main Roads culvert (Figure 8). Because of industrial development in the Nardine Catchment, the basin no longer has a clear discharge pathway (i.e. no drain or delineated creek line) and is located on the former Brand Road Landfill.

The LWMS has reviewed the current situation with respect to these catchments and catchment Forrest2, which is similarly affected by development in the Nardine Catchment.

Flows into the Nardine Catchment are anticipated to occur in larger events only (e.g. 5205 AEP event and larger). As the southern portion of the Nardine Catchment has not been developed, it is possible that localised flooding has occurred but has not been in a location or of a scale to cause concern.

3.7 Wetlands and groundwater dependent ecosystems

A search of the Geomorphic Wetlands of the Swan Coastal Plain Database shows that the western section of the precinct is mapped as a Multiple Use Wetland (MUW), and a portion of Poison Gully Creek and an area to the south, both outside of the RP boundary, are classified as a Palusplain Resource Enhancement Wetland (REW) (UFI 13997) (DWER 2017, Figure 9).

REW's are considered as priority wetlands where they have been partially modified but still support substantial ecological attributes and function. The ultimate objective is to manage, restore and protect towards improving their conservation value. No unauthorised development is permitted within a REW. A generic wetland buffer to protect the wetlands ecosystem is usually associated with REW, site buffer assessment can be undertaken to determine the buffer widths (EPA 2008). The existing buffer (generic 30m) associated with REW (UFI 15880) (Poison Gully) is semi developed (i.e. residential properties, cleared footprints and sheds).

MUW's are the lowest management category assigned to wetlands by the DWER, and are generally considered appropriate for development, provided the hydrological regime is not disturbed (EPA 2008).

Based on the depth to groundwater, the wetlands in the RP are not considered to be dependent on groundwater.

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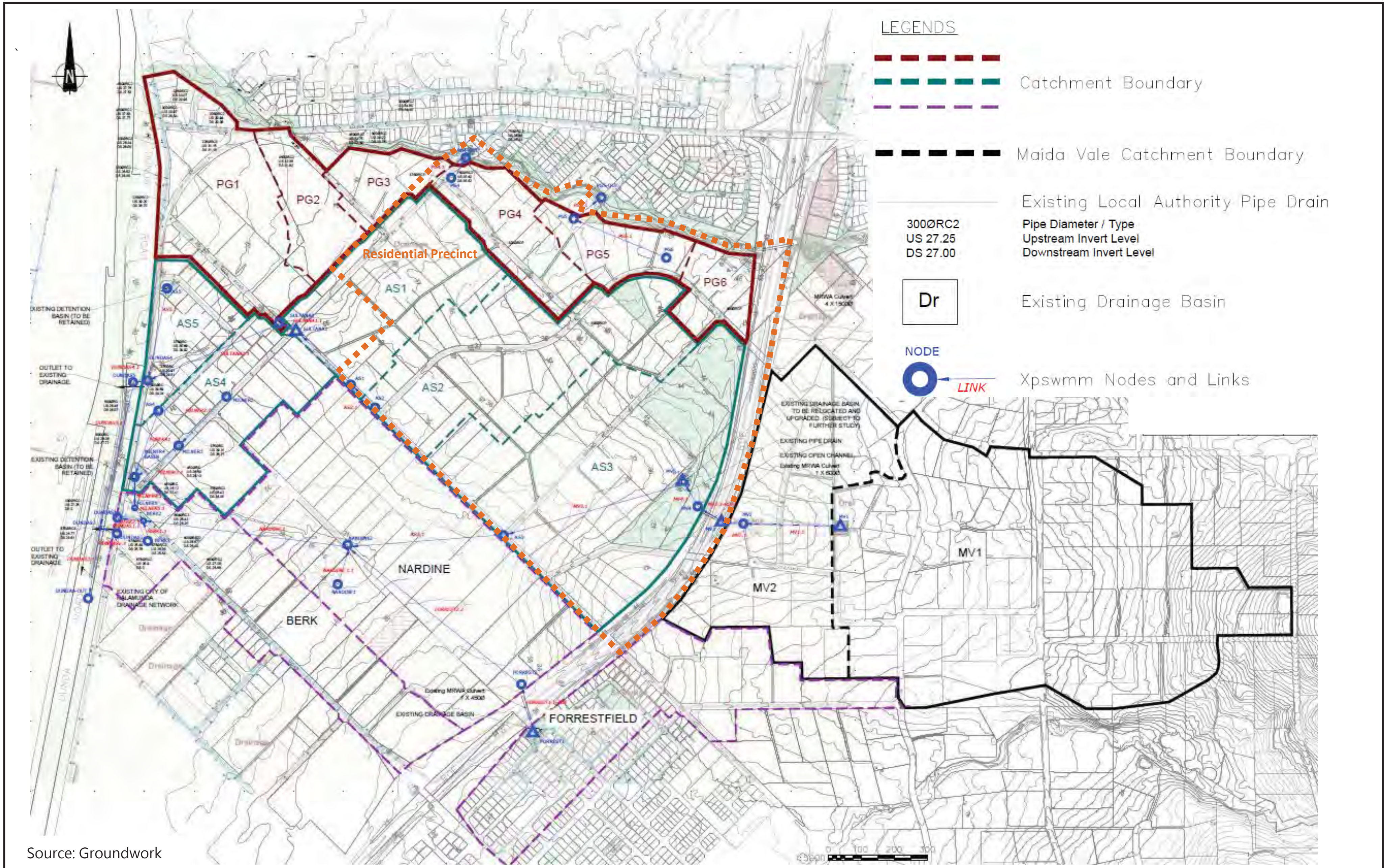
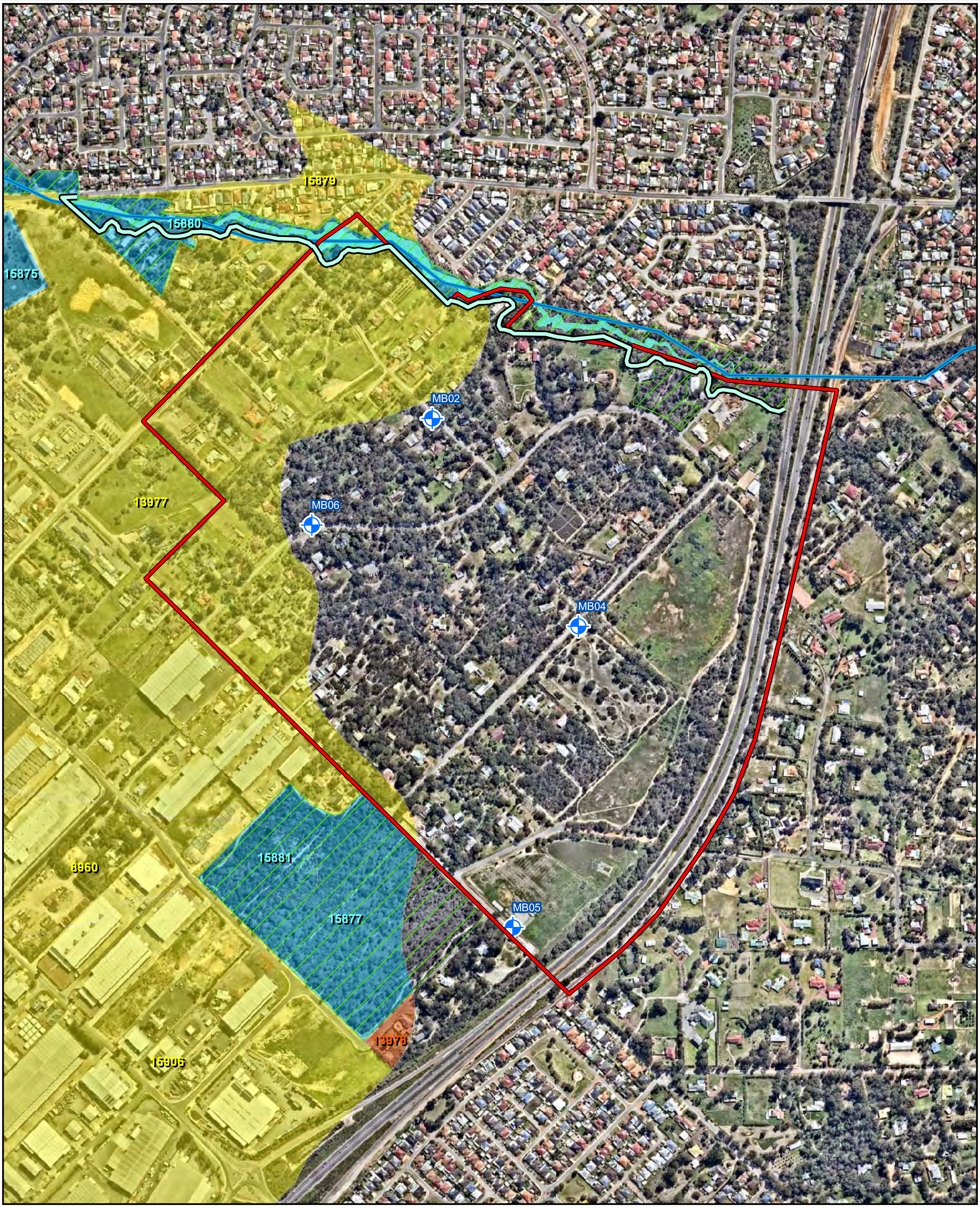


Source: Groundwork

Figure 8: Surface Water Catchments



Legend:

- 🟥 Residential precinct
- 🟩 Estimated 100 year flood area
- ▨ Bush Forever site

Geomorphic Wetlands (DBCA)

- 🟦 Resource Enhancement
- 🟨 Multiple Use
- 🟧 Not Applicable

- ═ Foreshore boundary
- ─ Poison Gully Creek
- ⊕ Groundwater monitoring bore

Scale 1:10,000 at A4	0 100 200 metres
Coord. Sys. GDA 1994 MGA Zone 50	
Job No: 57806	
Client: Element	
Version: A	Date: 24-Sep-2020
Drawn By: cthatcher	Checked By: JH

Forrestfield North Residential Precinct, WA

WETLANDS AND SURFACE WATER

FIGURE 9

strategen JBS&G

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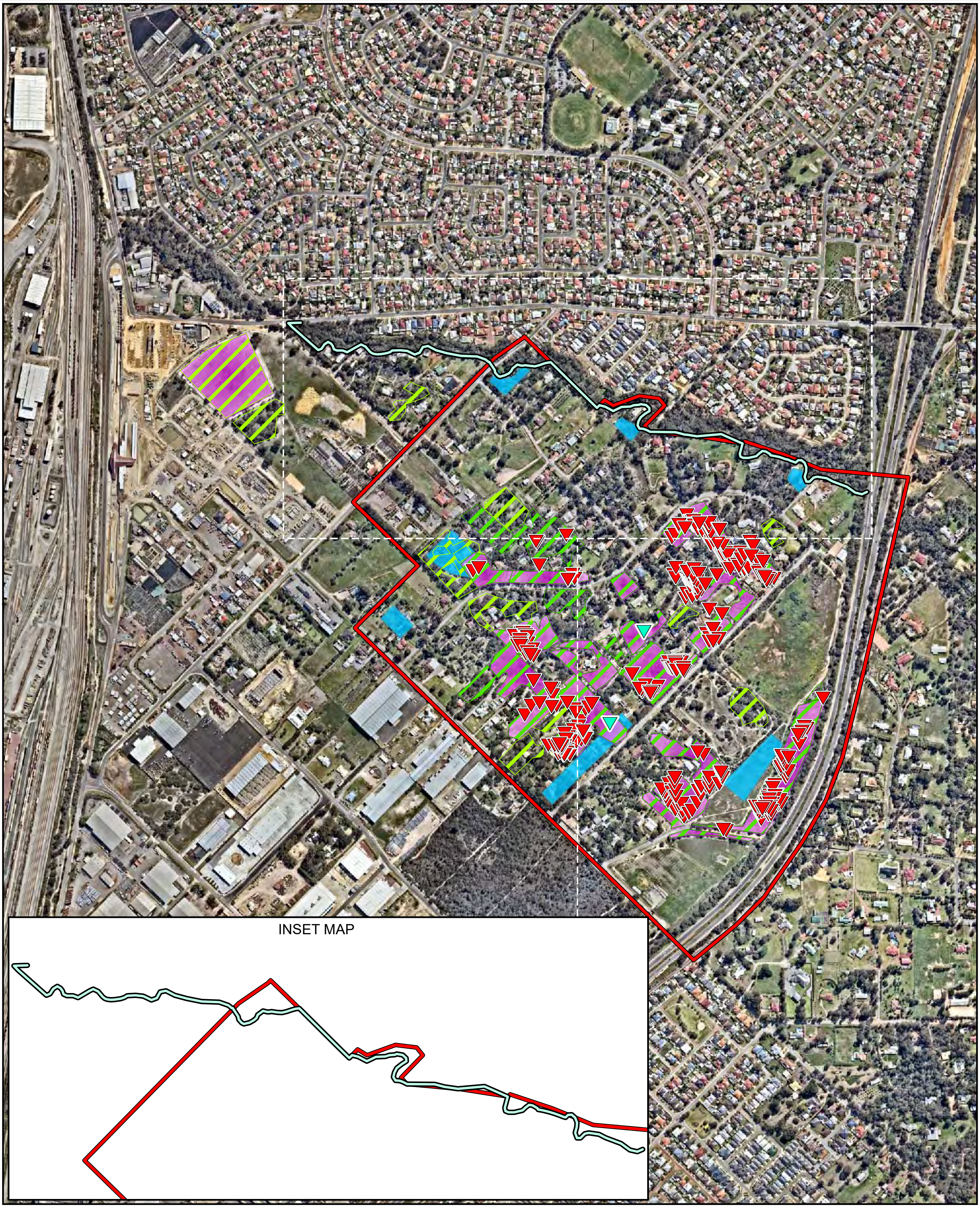

Legend:

▭ Residential precinct

🟦 1% AEP drainage basin

🟪 TEC extent / Banksia woodland TEC

Black cockatoo habitat

▨ High quality habitat

▨ Valued quality habitat

— Foreshore boundary

▼ *Isopogon drummondii* (P3)

▼ *Conospermum undulatum* (T)

Scale 1:12,500 at A4

0 100 200
metres

Coord. Sys. GDA 1994 MGA Zone 50

Job No: 57806

Client: Element

Version: A

Date: 24-Sep-2020

Drawn By: cthatcher

Checked By: JH

Forrestfield North Residential Precinct, WA

ENVIRONMENTAL PLAN

FIGURE 10

strategen JBS&G

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3.8 Biodiversity and natural assets

A detailed discussion of the vegetation, flora and fauna of the RP is provided in the *Residential Precinct Environmental Assessment and Management Strategy* (EAMS, Strategen 2018). The EAMS discussed that remnant vegetation on site has been fragmented through semi-rural land development and clearing for building footprints. The key environmental assets for the site include the:

- Banksia Woodlands of the Swan Coastal Plain Threatened Ecological Community
- *Conospermum undulatum* (Wavy-leaved Smokebush) – threatened species
- Black Cockatoo foraging and habitat trees (Figure 10).

A Strategic Conservation Management Plan (SCMP) (Emerge, 2020) was prepared in order to “provide an overarching framework that will support the implementation of the LSP and ensure the long-term preservation of biodiversity values through:

- Specifying and guiding the required impact avoidance and conservation gain outcomes for identified biodiversity values in the LSP area.
- Providing greater certainty regarding conservation outcomes and management requirements for Kal (the City), government departments (state and commonwealth), the local community and future developers of land within the LSP area.”

The above documents have informed the design of the site such that it aims to:

- consolidate existing fragmented environmental areas and to retain and conserve viable significant flora, threatened ecological communities and fauna habitat
- create a planning outcome which will ensure the long-term protection and management of the ‘ecology retention area’ (new Bush forever /conservation area).

To achieve these objectives, the land take for drainage has been minimised and extensive areas of bushland have been maintained, with a focus on retaining and rehabilitating key environmental assets and providing biological linkages. This includes commitments to the retention and rehabilitation of bushland in new environmental conservation areas as shown in Figure 2.

4. Water sustainability initiatives

The scope of works for the RP involved the assessment of potential water sustainability initiatives for use at a precinct and lot level. Because of the relatively high density of development proposed (R40 to R100), the development is anticipated to consist of a mixture of small individual lots and groups of apartments and/or townhouses constructed and operated by a strata body. The water sustainability measures proposed are cognisant of the type of development proposed in the RP.

4.1 Principles

Potential water sustainability measures have been assessed against the sustainability principles outlined in the *Water Resources Statement of Planning Policy 2.9* (WAPC 2004). This requires that an integrated approach is needed to address these issues and achieve sustainable outcomes and an acceptable 'prioritisation and balance' between competing interests (WAPC 2004). This requires that sustainability is pursued through integration of:

- environmental protection (including protection of water resources)
- social advancement
- economic prosperity (WAPC 2004).

Initiative options have consequently been evaluated against environmental, social and economic criteria.

4.2 Initiative options

The RP development is anticipated to consist of a mixture of single dwellings and strata developments in the form of apartments and townhouses. Consideration was given to both precinct and lot/strata scale options.

Precinct scale options considered were:

1. Stormwater Managed Aquifer Recharge (MAR).
1. Wastewater recycling.
2. Improved water and fertiliser efficiency in POS irrigation through installation of soil amendments or water efficient irrigation systems at construction.
3. Use of pervious pavements to increase infiltration in paved areas of POS, car parks and pedestrian pavements.

Lot/strata options considered were:

1. Water efficient gardens at a lot/strata scale.
2. Installation of water efficient fixtures.
3. Rainwater tanks for in-house water use.
4. Rainwater tanks for ex-house water use.
5. On-lot greywater/wastewater recycling.
6. Roof gardens.

Initiative options have consequently been evaluated against environmental, social and economic criteria consistent with the principles outlined in SPP 2.9 (WAPC 2004) with consideration given to practicability (Table 9). Where initiatives show benefits but may have significant costs or logistical issues (such as pervious pavements), trials have been recommended to assess the suitability of these initiatives for use in the RP.

4.3 Evaluation of options

The evaluation of options is presented in Table 9.

Table 9: Sustainability option evaluation

Option	Economic	Social	Environmental	Recommendation
Precinct scale options				
Stormwater Managed Aquifer Recharge (MAR).	1. High capital cost. 2. High operating cost. 3. Cost per kilolitre anticipated to be higher than scheme water and groundwater.	1. May allow for increased irrigation of POS.	1. Benefit to water dependent ecosystems because of reduced groundwater abstraction for POS irrigation.	Not a preferred option. Investigation identified likely high cost and significant uncertainties around site suitability for MAR (Section 3.5.4). The City undertaking identification and evaluation of potential MAR sites within the City.
Wastewater/greywater recycling (with or without MAR).	1. High capital cost. 2. High operating cost. 3. Cost per kilolitre anticipated to be higher than scheme water and groundwater.	1. May allow for increased irrigation of POS. 2. Challenges in finding a suitable long-term manager for the scheme if it is not economically viable.	1. Treated wastewater/greywater contains high concentrations of nutrients which can impact on groundwater and surface water quality. These nutrients must either be removed as part of the treatment process or the wastewater used in locations where this is not of concern (i.e. away from creeks and wetlands).	Not a preferred option.
Improved water and fertiliser efficiency in POS irrigation through soil amendment or installation of extremely water efficient below ground irrigation at construction.	1. Low to moderate capital cost compared to MAR, but higher than a conventional POS. 2. Operational cost similar to or higher than standard POS. The use of soil amendments are not anticipated to result in any additional operating costs. 3. May lower operating costs if less water is required.	1. Neutral – not anticipated to result in a perceptible difference to standard POS.	1. Benefits in reduction in nutrient loads to groundwater/surface water and groundwater abstraction.	All POS landscaping will be water efficient. Trial recommended for soil amendment and below ground irrigation. Preferred methods to be trialled on the first two POS areas containing turf to be developed with consideration given to expanding use after the trial (Section 7.2.1).

Option	Economic	Social	Environmental	Recommendation
Use of pervious pavements to increase infiltration in paved areas of POS, car parks and pedestrian pavements.	1. Typically, higher capital cost than traditional paving. 2. Typically, higher maintenance requirements and costs than conventional paving because of need to prevent clogging (Section 5.1.4).	1. Potential reduction in POS land take for drainage will increase the useability of POS. 2. Limited benefit in urban heat island effect. Permeable pavements can be cooler than other pavements when wet but little or no benefit during the drier (summer) months (USEPA 2008).	1. Potential to infiltrate water on site may reduce requirements for drainage areas. 2. Removal of sediment and nutrients from stormwater compared to conventional pavement (DPLG 2010).	Trial proposed for future potential adoption. To be included in design guideline. Pervious paving to be trialled by the City at either the Community Purpose (Community Hub) site or District Open Space for use in car parks and/or low traffic areas (e.g. laneways) (Section 5.1.4).
Large scale community storage rainwater in underground tanks for reuse in irrigation	1. High capital cost. 2. High operating cost. 3. Cost per kilolitre anticipated to be higher than scheme water, groundwater and MAR (because of need to install large tanks).	1. May allow for increased irrigation of POS.	2. Benefit to water dependent ecosystems because of reduced groundwater abstraction for POS irrigation.	Not a preferred option. Investigation identified likely high cost and significant uncertainties. The City undertaking identification and evaluation of potential MAR sites within the City.
Lot/strata scale options				
Water efficient gardens at a lot/strata scale (i.e. low water use landscaping and water efficient irrigation).	1. Low capital cost. 2. No significant difference in operating (maintenance) costs to householders anticipated. 3. Limited operating cost benefits. The higher density housing proposed in the RP results in small garden areas, so irrigation is anticipated to be only 11% of household water use (Section 7.1). Operating costs for household irrigation will be low regardless of whether development areas are low.	1. Additional agency approvals for dwelling construction not required.	1. Limited water use reduction as irrigation is only a small portion of potable water demand. Reducing potable water demand reduces groundwater abstraction from the environment and greenhouse emissions from pumping and desalination. 2. Water efficient gardens are more likely to include local species that benefit native birds and wildlife.	Encouraged. To be included in design guideline. Use of water efficient landscaping at a household level is encouraged as best practice.
Installation of water efficient fixtures (e.g. taps, toilets).	1. Small increase in capital cost compared to standard fixtures (perhaps $200-$300 per house). 2. Reduction in household water bills with limited operating costs (maintenance cost).	1. Additional agency approvals for dwelling construction not required.	1. The use of water efficient fixtures in all buildings for toilets, showers and taps could reduce potable water demand by approximately 12%.	Preferred option. To be included in design guideline. The use of water efficient fixtures will be mandated for all new buildings.

Option	Economic	Social	Environmental	Recommendation
Rainwater tanks for in-house water use (e.g. toilets, washing machines).	1. Capital cost estimated at $3000 for an individual house. 2. Householder operating costs higher than scheme water because of need for pumping to maintain water pressure and maintenance of tank. 3. Overall cost per kilolitre higher than scheme water (Section 7.1).	1. Feel good factor. 2. Requires additional householder or strata company maintenance to keep tank clean and pump operational. 3. Additional agency approvals for dwelling construction not required.	1. Potential benefit in reduction in scheme water use by 17%, reducing water abstraction from the environment and greenhouse gas emissions.	Preferred option. To be included in design guideline. Installation of rainwater tanks for in-house water use is supported for individual green title lots. The use of rainwater tanks for multi-dwelling strata lots will require additional management considerations by the corporate body management such as the legal and compliance issues to ensure the tanks provide acceptable quality water and equitable distribution of costs.
Rainwater tanks for ex-house water use.	1. Capital cost estimated at $1500 for a 1000L tank for individual house. 2. Overall cost per kilolitre higher than scheme water (Section 7.1). 3. Larger tanks for strata scale may be more viable.	1. Feel good factor. 2. Requires additional householder or strata company maintenance to keep tank clean and pump operational. 3. Additional agency approvals for dwelling construction not required.	1. Limited benefit if used only for irrigation, unless very large tanks are provided. Reasonably sized rainwater tanks in Perth cannot provide water over the dry summer months when irrigation is required. 2. Scheme water may be replaced/augmented if there is a non-potable, wet season water demand.	Not recommended in isolation. Advantages are at best marginal unless coupled with in-house rainwater water use.
On-lot greywater/wastewater recycling.	1. Requires each house to install a treatment system. High capital cost. 2. As external (irrigation) water use is anticipated to be low, benefits can only be realised if systems are plumbed into internal water uses (e.g. toilets, washing machines), a high level of treatment is required. 3. Operating costs higher than scheme water because of need for treatment, pumping and maintenance. 4. Overall cost per kilolitre typically higher than scheme water.	1. Feel good factor. 2. Regulatory complexity. Requirement for approval from Department of Health for individual households and/or strata companies for each building with a greywater or wastewater recycling system. 3. Requires additional householder or strata company maintenance to keep treatment and pump operational. 4. Potential for health risks if system is not properly installed and maintained.	1. Potential benefit in reduction in scheme water use similar to or greater than rainwater tanks, reducing water abstraction from the environment and greenhouse gas emissions.	Not recommended. Installation of domestic greywater or rainwater recycling systems are encouraged but not mandated because of the regulatory complexities, potential health risks and high capital and operating costs.

Option	Economic	Social	Environmental	Recommendation
Roof gardens.	1. Requires strong rooves designed to: • manage the weight of the soil and plants, which may be 0.1 - 1 tonne/m^2 • provide effective drainage for the above garden bed, including drainage layers and waterproof membranes to protect the house residents below (City of Sydney, undated). 2. Designing to these standards is anticipated to result in significant additional construction costs, particularly for single dwellings which typically have lightweight, lower strength metal or tile roofs. 3. Higher maintenance costs and requirements than a typical roof (e.g. weeding, inspection of membranes and drainage layers).	1. Feel good factor. 2. Reduces urban heat island effect by absorbing heat and providing roof insulation (and consequently energy costs). 3. May provide additional green space and amenity to residents within their lots where gardens can be made accessible. 4. Requires regular maintenance by strata or lot owner.	1. Provides stormwater treatment. 2. Roof gardens are similar to pot plants with respect to soil depth and will require regular irrigation over the summer months. Systems with thinner soil layers (‘extensive’ green rooves) may also require irrigation during periods of infrequent rain. This may increase potable water demand.	For developer consideration at UWMP stage. Trial recommended on public building if appropriate site available. To be included in design guideline. Roof gardens can have a significant benefit in terms of water treatment, reducing urban heat island effects. Where buildings are designed to have heavier roof loads (e.g. apartment blocks which typically have air-conditioning and water tanks on rooves), roof gardens may be able to be constructed with limited additional cost. For single storey residential dwellings, the cost of installing a roof garden may be prohibitive.

5. Surface water management strategy

5.1 Surface water management system

The stormwater drainage system has been designed using a major/minor approach. The major drainage system includes the use of roads, swales, detention storages and open spaces to provide safe passage of stormwater runoff from major storm events greater than 18% AEP and up to the 1% AEP. The minor system will focus on treatment of the 63% AEP, 1 hour event and involves the use of raingardens within some road reserves and areas of POS identified for drainage purposes, outside of the areas of POS identified for Environmental Conservation purposes (Figure 2).

5.1.1 Minor drainage system

The minor drainage system is defined as the series of raingardens, kerbs (flush or no kerb), pipes and gutters designed to convey runoff generated by minor storms up to and including the 1 hour duration, 63% AEP storm event. The minor drainage system incorporates best management practice (BMP) water quality structural controls such as vegetated raingardens and bioretention storages that provide water quality treatment in the RP area. Proposed locations of POS storages for the 63% AEP event are shown on Figure 11. Storage details are presented in Table 10.

Key points of the minor drainage system strategy are as follows:

1. Treatment of stormwater from roads in vegetated storages within detention storages sized to treat the first 16 mm of rainfall from the roads. Storages will be located in car parks, streets and POS. This is approximately the 1 hour duration, 63% AEP storm event, which comprises 99% of the total annual runoff volume (DoW 2011).
2. Lots and laneways will be required to retain the first 16 mm, approximately equivalent to the 1 hour duration, 63% AEP storm event at source using methods as described in Section 5.1.3.
3. The following major streets have been designed to include roadside swales, with additional raingarden volume provided in drainage storage areas (DSAs), areas of public open space identified for drainage purposes (Figure 15):
    - New Main Connecting Road
    - Milner Road
    - Stewart Road
    - Brae Road
    - Brand Road
    - Sultana Road West.

    The use of raingardens/swales and tree pits on all roads to manage stormwater will be employed for minor roads adjacent to the Poison Gully POS and encouraged for all other roads with a preference for median swales where possible. Finalised swale/raingarden designs and locations will be presented in the Urban Water Management Plans. Minimum design guidelines for raingardens are presented in Section 5.3.

    Opportunities for overland flow paths will be considered at a Subdivision stage where these are consistent with structure plan requirements (e.g. Bush Forever, land ownership).
4. Kerb breaks and flush kerbing to be utilised around POS and raingardens to encourage overland flow.
5. An outlet pipe of 600mm diameter is required from the corner of Sultana and Milner Rd (AS1) through to the basin at the corner of Milner and Berkshire Roads. This pipe is required along Sultana Rd, Milner Rd and across Dundas Rd to the existing outlet channel.

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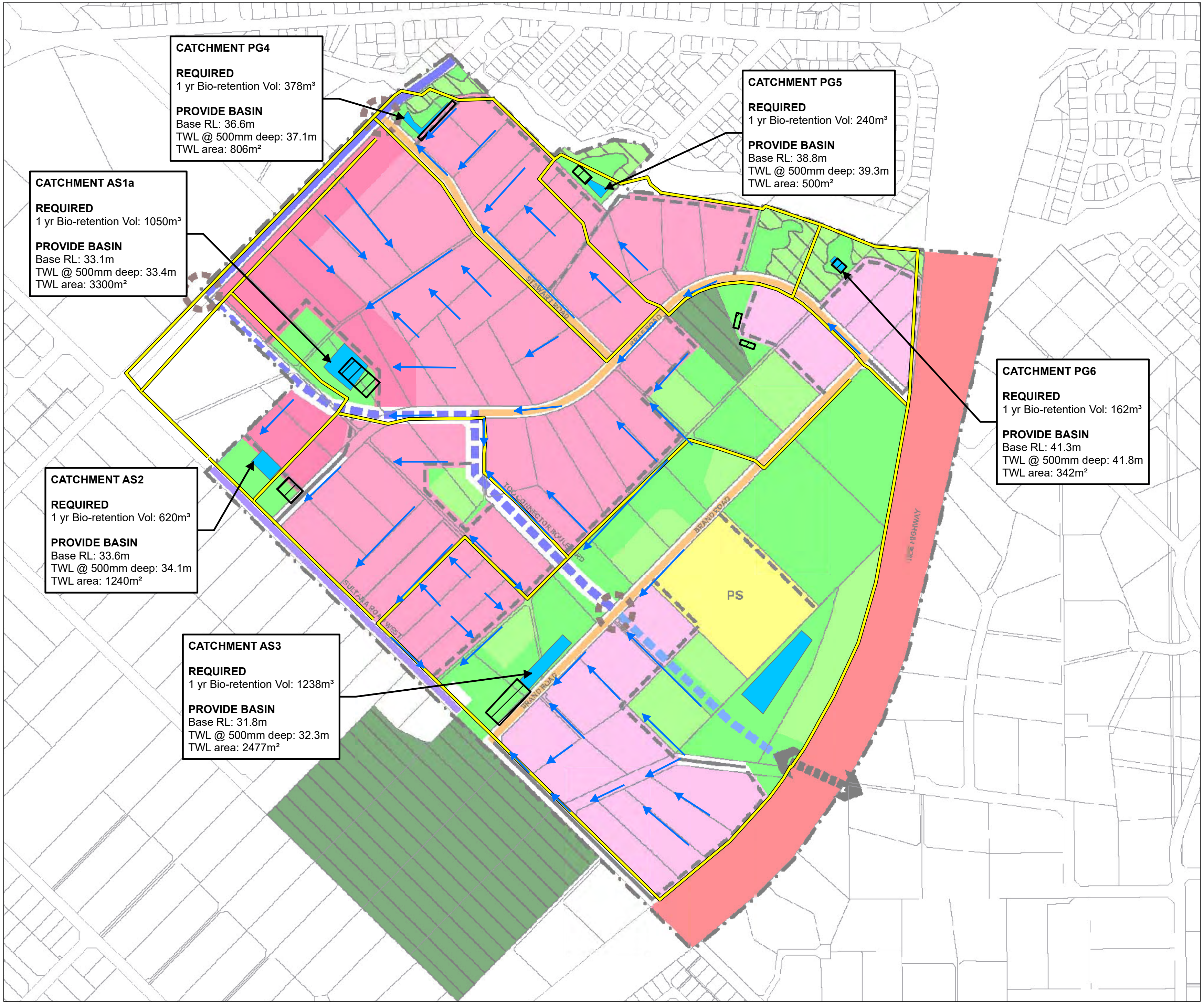

CATCHMENT PG4

REQUIRED
1 yr Bio-retention Vol: 378m³

PROVIDE BASIN
Base RL: 36.6m
TWL @ 500mm deep: 37.1m
TWL area: 806m²

CATCHMENT PG5

REQUIRED
1 yr Bio-retention Vol: 240m³

PROVIDE BASIN
Base RL: 38.8m
TWL @ 500mm deep: 39.3m
TWL area: 500m²

CATCHMENT AS1a

REQUIRED
1 yr Bio-retention Vol: 1050m³

PROVIDE BASIN
Base RL: 33.1m
TWL @ 500mm deep: 33.4m
TWL area: 3300m²

CATCHMENT PG6

REQUIRED
1 yr Bio-retention Vol: 162m³

PROVIDE BASIN
Base RL: 41.3m
TWL @ 500mm deep: 41.8m
TWL area: 342m²

CATCHMENT AS2

REQUIRED
1 yr Bio-retention Vol: 620m³

PROVIDE BASIN
Base RL: 33.6m
TWL @ 500mm deep: 34.1m
TWL area: 1240m²

CATCHMENT AS3

REQUIRED
1 yr Bio-retention Vol: 1238m³

PROVIDE BASIN
Base RL: 31.8m
TWL @ 500mm deep: 32.3m
TWL area: 2477m²

Legend:

- ▨ 18% AEP (5yr ARI) (below ground) Storage tank conceptul shape stormtech MC3500 or similar
- 🟦 63% AEP (1yr ARI) TWL conceptual shape; 63% AEP (1yr ARI) TWL conceptual shape
- — Catchment boundary
- → Flow direction

strategen JBS&G

Job No: 57806	
Client: Element	
Version: A	Date 16/04/2020
Drawn By: hsullivan	Checked By: CT
Scale 1:9,000	

0 100 200
metres

Forrestfield North Residential Precinct, WA

63% AEP EVENT PLAN

FIGURE 11

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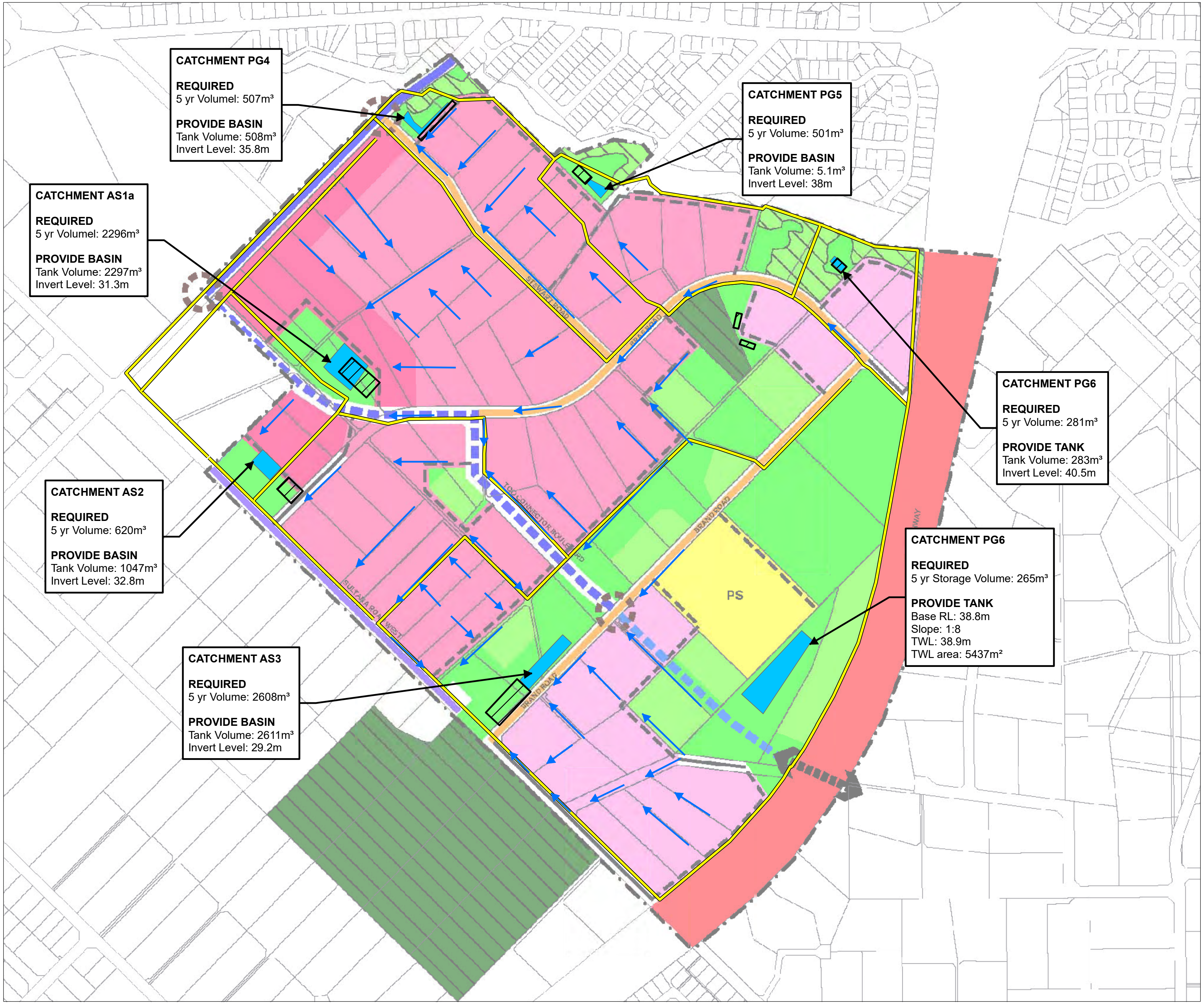
Image Reference: www.nearmap.com© - Imagery Date: January 2020. SLIP Public Services Locate 2020.



CATCHMENT PG4

REQUIRED
5 yr Volumel: 507m³

PROVIDE BASIN
Tank Volume: 508m³
Invert Level: 35.8m

CATCHMENT PG5

REQUIRED
5 yr Volume: 501m³

PROVIDE BASIN
Tank Volume: 5.1m³
Invert Level: 38m

CATCHMENT AS1a

REQUIRED
5 yr Volumel: 2296m³

PROVIDE BASIN
Tank Volume: 2297m³
Invert Level: 31.3m

CATCHMENT PG6

REQUIRED
5 yr Volume: 281m³

PROVIDE TANK
Tank Volume: 283m³
Invert Level: 40.5m

CATCHMENT AS2

REQUIRED
5 yr Volume: 620m³

PROVIDE BASIN
Tank Volume: 1047m³
Invert Level: 32.8m

CATCHMENT PG6

REQUIRED
5 yr Storage Volume: 265m³

PROVIDE TANK
Base RL: 38.8m
Slope: 1:8
TWL: 38.9m
TWL area: 5437m²

CATCHMENT AS3

REQUIRED
5 yr Volume: 2608m³

PROVIDE BASIN
Tank Volume: 2611m³
Invert Level: 29.2m

Legend:

- ▨ 18% AEP (5yr ARI) (below ground) Storage tank conceptul shape stormtech MC3500 or similar
- 🟦 63% AEP (1yr ARI) TWL conceptual shape; 63% AEP (1yr ARI) TWL conceptual shape
- — Catchment boundary
- → Flow direction

Job No: 57806

Client: Element

Version: A | Date 16/04/2020

Drawn By: hsullivan | Checked By: CT

Scale 1:9,000

0 100 200
metres

Forrestfield North Residential Precinct, WA

18% AEP EVENT PLAN

FIGURE 12

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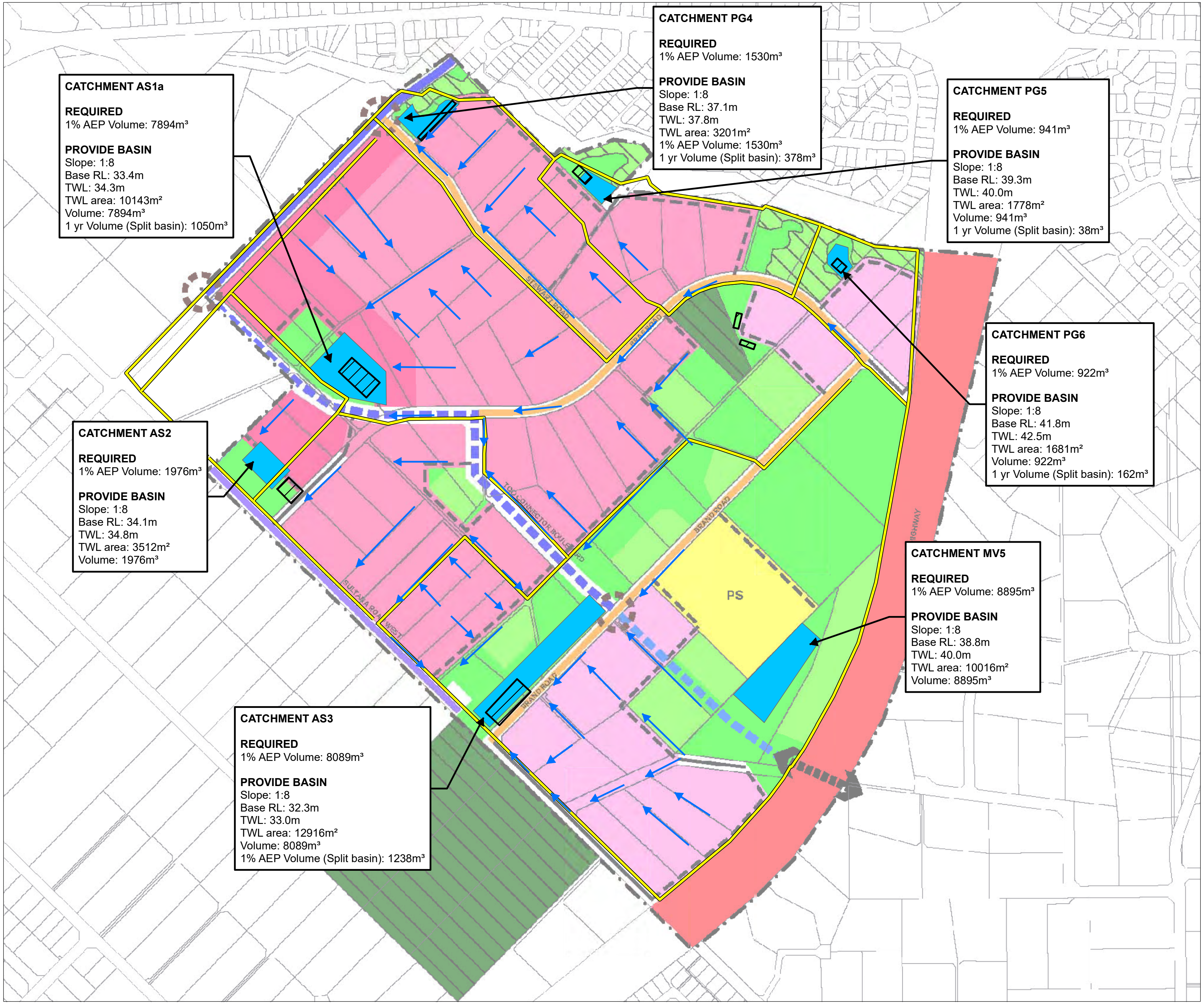
Image Reference: www.nearmap.com© - Imagery Date: January 2020. SLIP Public Services Locate 2020.



CATCHMENT PG4

REQUIRED
1% AEP Volume: 1530m³

PROVIDE BASIN
Slope: 1:8
Base RL: 37.1m
TWL: 37.8m
TWL area: 3201m²
1% AEP Volume: 1530m³
1 yr Volume (Split basin): 378m³

CATCHMENT AS1a

REQUIRED
1% AEP Volume: 7894m³

PROVIDE BASIN
Slope: 1:8
Base RL: 33.4m
TWL: 34.3m
TWL area: 10143m²
Volume: 7894m³
1 yr Volume (Split basin): 1050m³

CATCHMENT PG5

REQUIRED
1% AEP Volume: 941m³

PROVIDE BASIN
Slope: 1:8
Base RL: 39.3m
TWL: 40.0m
TWL area: 1778m²
Volume: 941m³
1 yr Volume (Split basin): 38m³

CATCHMENT PG6

REQUIRED
1% AEP Volume: 922m³

PROVIDE BASIN
Slope: 1:8
Base RL: 41.8m
TWL: 42.5m
TWL area: 1681m²
Volume: 922m³
1 yr Volume (Split basin): 162m³

CATCHMENT AS2

REQUIRED
1% AEP Volume: 1976m³

PROVIDE BASIN
Slope: 1:8
Base RL: 34.1m
TWL: 34.8m
TWL area: 3512m²
Volume: 1976m³

CATCHMENT MV5

REQUIRED
1% AEP Volume: 8895m³

PROVIDE BASIN
Slope: 1:8
Base RL: 38.8m
TWL: 40.0m
TWL area: 10016m²
Volume: 8895m³

CATCHMENT AS3

REQUIRED
1% AEP Volume: 8089m³

PROVIDE BASIN
Slope: 1:8
Base RL: 32.3m
TWL: 33.0m
TWL area: 12916m²
Volume: 8089m³
1% AEP Volume (Split basin): 1238m³

Legend:

- ▨ 18% AEP (5yr ARI) (below ground) Storage tank conceptual shape stormtech MC3500 or similar
- 🟦 1% AEP (100 yr ARI) TWL conceptual shape
- ═ Catchment boundary
- → Flow direction

strategen JBS&G

Job No: 57806	
Client: Element	
Version: A	Date 16/04/2020
Drawn By: hsullivan	Checked By: CT
Scale 1:9,000	

0 100 200
metres

Forrestfield North Residential Precinct, WA

1% AEP EVENT PLAN

FIGURE 13

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Table 10: Storage details - 63% AEP, 1 hour event*

Catchment	Above ground storage provided (m^3)	Above ground storage TWL area (m^2)	Above ground storage invert (mAHD)	Above ground storage TWL (mAHD)	Above ground storage depth (m)	Outflow (m^3/s)
PG4	378	806	37.1	37.6	0.5	0
PG5	240	500	38.8	39.3	0.5	0
PG6	162	342	41.3	41.8	0.5	0
MV5	-	0	38.8	-	-	0
AS1a	1,050	3300	33.1	33.4	0.3	0
AS2	620	1240	33.6	34.1	0.5	0
AS3	1,238	2477	31.8	32.3	0.5	0

*All values are indicative and must be reviewed at subdivision stage

Table 11: Total storage for 1% AEP*

Catchment	Modelled hydraulic conductivity (m/day)	Below ground storage provided (m^3)	Above ground storage provided (m^3)	Total storage provided (m^3)	100 year storage base area (m^2)	Above ground storage TWL area (m^2)	Below ground storage invert (mAHD)	Above ground storage invert (mAHD)	Above ground storage TWL (mAHD)	Total above ground storage depth (m)	Outflow (m^3/s)	Outlet diameter (mm)	Side Slopes 1 in x
PG4	3.1	507	1,908	2,415	1,799	3201	35.8	36.6	37.8	1.2	0.076	225	8
PG5	0.4	501	1,181	1,682	915	1778	38	38.8	40.0	1.2	0.059	225	8
PG6	0.4	281	1,084	1,365	874	1681	40.5	41.3	42.5	1.2	0.037	225	8
MV5	1.3	0	8,895	8,895	5,437	10,016	-	38.8	40.0	1.2	0	N/A	8
AS1a	0.3	2296	8,944	11,240	1,681	10,143	31.3	33.1	34.3	1.2	0.081	300	8
AS2	0.6	1049	2,596	3,645	10,143	3,512	32.8	33.6	34.8	1.2	0.055	300	8
AS3	0.4	2,608	9,327	11,935	9,269	12,916	29.2	31.8	33.0	1.2	0	N/A	8

*All values are indicative and must be reviewed at subdivision stage

Table 12: Storage details– 5% AEP event*

Catchment	Below ground storage provided (m^3)	Above ground storage provided (m^3)	Total storage capacity (m^3)	Above ground storage TWL area (m^2)	Above ground storage invert (mAHD)	Above ground storage TWL (mAHD)	Above ground storage depth (m)	Outflow (m^3/s)	Outlet diameter (mm)	Side Slopes 1 in x	POS Area	% of POS area inundated
PG4	507	378	885	806	37.6	37.1	0.5	0.053	225	8	7,751	10
PG5	501	240	741	500	39.3	38.8	0.5	0.052	225	8	3,669	14
PG6	281	162	443	342	41.8	41.3	0.5	0.037	225	8	7,725	4
MV5	0	-	265	5437	38.9	38.8	0.1	0	N/A	8	105,072	5
AS1a	2296	1050	3,346	3300	33.4	33.1	0.3	0.068	300	8	10,522	31
AS2	1049	620	1,669	1240	34.1	33.6	0.5	0.045	300	8	6,917	18
AS3	2,608	1238	3,846	2477	32.3	31.8	0.5	0	N/A	8	23,021	11

*All values are indicative and must be reviewed at subdivision stage

5.1.2 Major drainage system

The major drainage system has been designed to maintain the pre-development flow off the site in events up to the 1% AEP, 48-hour event as requested by Water Corporation (Kanagaratnam K, 2017, pers. comm. 12 December). In most catchments, the critical storm duration is the 6-hour event and larger storages are required for this event.

Key points of the major drainage system strategy are as follows:

1. Minor roads will be graded to direct flow overland to the lowest point in each catchment. The ultimate road low point will be adjacent to POS, with overflow flood storage provided within the drainage storage area, an area of POS being prioritised for drainage, rather than conservation or recreation, purposes. The POS design will aim to create flood storage in an informal manner, minimising formal drainage storage areas. Major event storages are anticipated to be turfed to form useable POS areas.
2. To maximise POS amenity and minimise the impact of inundation on POS areas, a mixture of below and above ground storage is proposed.
3. All lot finished levels will have a minimum 0.3 m clearance above the estimated 1% AEP flood level in the road and POS.
4. All lot finished levels will have a minimum 0.5 m clearance above the estimated 1% AEP flood level of the detention storages and Poison Gully.
5. Overland flow pathways are proposed to Poison Gully in consultation with appropriate stakeholders, including Aboriginal communities.
6. Top water levels in a major event will be no greater than 1.2 m for safety and amenity reasons. Major event basins have been designed with a batter of 1 in 8.
7. The Storage layout and locations shown are conceptual and will be reviewed at the UWMP stage based on the detailed earthworks and civil designs.
8. To prevent building and critical infrastructure, commercial and industrial building habitable floor levels with the following minimum clearances above the 1% annual exceedance probability (AEP) flood level:
    - road drainage systems: 0.3 m
    - terminal retention or detention areas with no overflow relief: 0.5 m
    - major drainage system and waterways: 0.5 m.

    These clearances will be demonstrated through detailed design at the UWMP stage.

Details of storages are presented in Figure 12, Figure 13, Table 11 and Table 12. Figure 14 provides a conceptual cross section of the proposed major event storage.

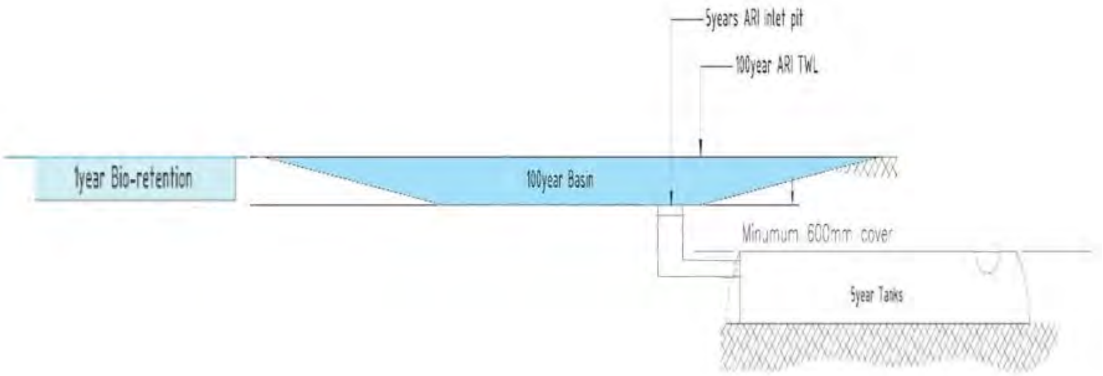

Figure 14: Conceptual storage design

5.1.3 Lot scale water management

Lots (including strata developments) and laneways will be required to retain and infiltrate the first 16 mm of rainfall within the lot or strata development (equivalent to the 1 hour, 63% AEP event) prior to the water entering the road drainage system.

Lot scale water management systems should aim to include a treatment element in the form of a lot scale bioretention system (Plate 1), biofiltration tree pits or a planted roof garden to clean stormwater prior to infiltration. The use of pervious pavements for outdoor spaces and driveways is encouraged to reduce stormwater volumes, consistent with *Decision Process for Stormwater Management in Western Australia,* November 2017. Water may be infiltrated through soak wells and subsurface soakage tanks and cells if required. Pervious pavements may also be used for driveways and outdoor paving to reduce the amount of runoff produced on the lot (Section 5.1.4).

Plate 1: Lot scale bioretention systems

Source: newwaterways.org.au

5.1.4 Pervious pavement

Pervious pavement (otherwise known as permeable and porous pavement) is a load bearing pavement structure that is permeable to water.

Pervious pavements fall into two broad categories:

1. Permeable pavements, which comprise a layer of paving blocks typically impervious, specially shaped to allow the ingress of water by way of vertical 'slots' or gravel-filled 'tubes'. There are generally large gaps between impervious paved areas for infiltration (Plate 2).
2. Porous pavements, which comprise a layer of highly porous material (DPLG 2010).

Plate 2: Permeable pavement with tree pits

Source: Place Lab

Pervious pavements can potentially be used in:

- private paved areas such as courtyards
- areas with low traffic volumes and light traffic weight (e.g. laneways, driveways)
- car parks
- pedestrian pavements
- public open space (DPLG 2010).

Pervious pavements can have advantages compared to traditional pavements because of:

- increased infiltration of stormwater and reduced runoff
- reductions in sediment and nutrient loads (DPLG 2010).

Pervious pavements can be cooler than other pavements when wet due to evaporation but offer little or no benefit when dry (USEPA 2008). Pervious pavements are unlikely to reduce the urban heat island effect in the dry summer months when this effect is most needed.

The disadvantages of pervious pavements are:

- pervious pavements can become clogged with oil and sediment over time
- to remove or prevent clogging, maintenance is required in terms of:
    - high pressure hosing, sweeping or vacuuming to remove sediments and maintain infiltration rates
    - periodic replacement of aggregate layers (approximately every 20 years) and replacement of geotextile fabric
    - maintenance of surface vegetation (if present, permeable pavements only).

Such maintenance is higher and potentially more costly than that which is required for a conventional pavement. For these reasons, pervious pavements are not commonly installed in Western Australia.

The largest areas for potential use of pervious pavements in the RP are laneways, and car parks associated with the District Open Space (DOS) (Figure 15). Primary School and Community Purpose (CP) site. Laneways and car parks constructed by the City such as the CP site and DOS, offer an opportunity to trial the use of permeable pavement in the RP. As part of the construction of the CP site and the DOS, the City should undertake a trial of the use of permeable paving for low traffic areas and/or car parks.

Design of the lot scale bioretention systems, pervious paving and soak wells will be mandated through the Design Guidelines that form part of the Structure Plan.

5.2 Surface water modelling

The pre-development XP-SWMM model was used based on the land uses presented in Table 13 and the modelling parameters and assumptions presented in Table 14. Modelling assumptions and critical durations were developed in consultation with Water Corporation. Pre-development catchment boundaries and land uses are presented in Table 13 and Figure 8. Hydraulic conductivities are presented in Table 11.

Table 13: Pre-and post-development land use*

Catchment	Land use	Pre-development area (m^2)	Post-development area (m^2)	Catchment
PG4	Lots	82,074	59,558	PG4
	Road	12,884	30,097	
	POS	-	5,118	
PG5	Lots	62,010	32,043	PG5
	Road	4,906	18,904	
	POS	-	15,969	
PG6	Lots	45,120	20,059	PG6
	Road	7,509	12,738	
	POS	-	12,047	
AS1a	Lots	167,430	180,769	AS1a
	Road	17,480	78,058	
	POS	-	61,462	
AS1b	Lots	22,356	34,555	AS1b
	Road	2,334	8,211	
	POS	-	-	
AS2	Lots	265,045	72,677	AS2
	Road	29,173	45,994	
	POS	-	12,870	
AS3	Lots	419,893	159,595	AS3
	Road	36,036	93,610	
	POS	-	182,117	
MV1	Lots	749,294	749,294	MV1
	Road	63,770	63,770	
MV2	Lots	319,889	319,889	MV2
	Road	12,222	12,222	

*All values are indicative and must be reviewed at subdivision stage

Table 14: Catchment runoff parameters

Land use	Impervious fraction	Surface roughness (Manning's n)		Initial loss (mm)	Continuous loss (mm/hr)
		Impervious	Pervious		
Rural lots	0.1	0.014	0.025	Horton's equation, Medium well drained, AMC3	
Rural roads	0.5	0.014	0.025	16	6
Urban lots	0.9	0.014	0.025	26	6
Urban roads	0.9	0.014	0.025	1.5	0
Urban roads with biofilter	0	0.014	0.025	26	6
POS - bush	0	0.014	0.4	26	7
Commercial /industrial (existing)	0.9	0.014	0.025	Horton's equation, Medium well drained, AMC3, assumed to contain 1% AEP event onsite.	

5.2.1 Pre-development flows

Pre-development flows for key locations in critical events are presented in Table 15.

Table 15: Pre-development flows for critical events*

Catchment	Peak flow (m^3/s)				
	63% AEP, 1 hour	18% AEP, 6 hours	10% AEP, 6 hours	1% AEP, 6 hours	1% AEP, 48 hours
PG4	0	0.316	0.073	0.24	0.058
PG5	0	0.043	0.297	0.287	0.061
PG6	0	0.025	0.038	0.142	0.033
MV5	0	0	0	0.507	0.028
AS1	0	0.064	0.109	0.318	0.157
AS2	0	0.174	0.144	0.817	0.165
AS3	0	0.108	0.032	0.835	0.159
AS - Dundas Road Outlet (DUNDAS-OUT)	0	0.247	0.382	2.547	0.565

*All values are indicative and must be reviewed at subdivision stage

5.2.2 Post-development flows

Post-development flows for key locations in critical events are presented in Table 16.

Table 16: Post-development flows for critical events*

Catchment	Peak flow (m^3/s)				
	63% AEP, 1 hour	18% AEP, 6 hours	10% AEP, 6 hours	1% AEP, 6 hours	1% AEP, 48 hours
PG4	0	0.056	0.062	0.076	0.067
PG5	0	0.052	0.056	0.063	0.059
PG6	0	0.037	0.037	0.037	0.037
MV5	0	0	0	0	0
AS1a	0	0.068	0.074	0.238	0.081
AS2	0	0.045	0.05	0.388	0.055
AS3	0	0	0	0	0
AS - Dundas Road Outlet (DUNDAS-OUT)	0	0.224	0.299	0.46	0.154

*All values are indicative and must be reviewed at subdivision stage

5.2.3 Flows from outside the Precinct

Maida Vale

The Airport South catchment includes approximately 114 ha of land to the west of Roe Highway in Maida Vale which drains into a basin on the site via a Main Roads culvert, referred to as MV1 and MV2 (Figure 11). Prior to development, any water not infiltrated in MV1 and MV2 or the small basin located on the site would have run through the Nardine Catchment to the south of Sultana Road West in larger events (anticipated greater than the 63% AEP event) (Figure 11). The development of the Forrestfield-High Wycombe Industrial Area south of Sultana Road West has removed this historic flow path. This matter was discussed with the City who advised that their preferred option to manage this was installation of an infiltration basin within the RP to infiltrate stormwater from MV1 and MV2 until the infrastructure can be rectified (Bartlett D [CoK] 2017, pers. comm. 3 November).

Surface water modelling undertaken as part of this project has identified that the current storage at MV5 is not adequately sized. A total volume of 10,0012 m^3 of storage is required for the 1% AEP event compared to the 2400 m^3 currently available. With the current basin, a 1% AEP event in the MV area would result in flooding of the RP. Storage will be retained at this location until the school and associated sporting facilities are constructed.

The current storage is not considered suitable for long term infiltration because of its' location. The storage is located at a topographic low point and there is no obvious location within RP for relocation without construction of considerable additional pipework. Relocating this basin to an area east of Roe Hwy will be required.

Stormwater modelling for the Maida Vale area shall be undertaken as part of future structure planning for the Maida Vale South Area. This modelling should allow for the relocation of the basin at MV5.

The Nardine St catchment is assumed to retain the 1% AEP event (all durations).

East Forrestfield

The discharge pathway for East Forrestfield Catchment (referred to as “Forrest1”) is via a Main Roads culvert and has likewise been affected by the development of the Forrestfield/High Wycombe Industrial Area. A 1% AEP event in this area would result in flooding of the Industrial Area. This matter was not addressed in the LWMS for the Industrial Area (ENV 2012). To address this matter and ensure pre-development flows are maintained, stormwater storage is required to be constructed. A suggested basin location and sizing is 3561 m^3. This design and location are indicative and should be subject to more detailed investigation by the City.

Works for the East Forrestfield and Maida Vale South areas will be excluded from the Developer Contribution Scheme is there is no nexus with the development of the precinct.

5.3 Surface water quality management

The effective implementation of the structural and non-structural controls as part of the urban development will enhance water quality from the RP area as a result of the land use change. Non-structural source controls to reduce nutrient export from the RP area will focus on reducing the need for nutrient inputs into the landscape. The following non-structural strategies are proposed:

- species will be selected for drought tolerance and low fertiliser requirements
- street sweeping.

The UWMPs will outline the schedule and cleaning requirements for street sweeping, which will be co-ordinated with the City.

Structural source controls are proposed to compliment the non-structural source controls and provide a complete treatment train for stormwater movement through the RP area. The following structural controls are considered appropriate for the RP area:

- the use of bio-retention storages and raingardens to treat road runoff in events up to and including the 63% AEP, 1-hour event
- a trash rack installed downstream of each vegetated treatment area or at the upstream end of the storage overflow to manage gross pollutants.

The minimum specifications for all bio-retention systems (raingardens and storages, including on lot bioretention systems) are presented in Table 17.

Table 17: Minimum specifications for bio-retention systems

Item	specifications
Amended soil media	• minimum 300 mm thickness • saturated hydraulic conductivity of 3 m/day • PRI ≥10 • light compaction only • infiltration testing prior to installation and again following completion of construction. Ongoing testing to be undertaken as required by monitoring program.
Species selection and planting density	• species to be in accordance with *Vegetation Guidelines for Stormwater Biofilters in the South-West of Western Australia* (Monash University 2014) • densities to be in accordance with *Adoption Guidelines for Stormwater Biofiltration Systems* (CRC for Water Sensitive Cities 2015) • planting density appropriate to species selection.

The bio-retention systems should be sized to function correctly with a saturated hydraulic conductivity, ksat, of 3 m/day. The *Adoption Guidelines for Stormwater Biofiltration Systems* (CRC for Water Sensitive Cities 2015) indicate that the desired ksat is in the range of 2.5 to 7 m/day, to fulfil the drainage requirements as well as retain sufficient moisture to support the vegetation. The CRC for Water Sensitive Cities (2015) also identifies that for vegetated systems some clogging will occur in the first few years until the vegetation is established. Once the plants are established, the roots and associated biological activity maintain the conductivity of the soil media over time.

It should be recognised that data currently guiding the design of bio-retention systems is recent and largely based on laboratory testing. The specifications provided in this document should be considered as the best available information at the time. Some flexibility in the specifications will be required as the knowledge base increases.

6. Groundwater management strategy

6.1 Groundwater level management

Based on the depth to MGL within the precinct it is not anticipated that control of groundwater will be required in the RP. Should control be determined to be required at the UWMP stage, then this shall be discussed with DWER and groundwater monitoring and/or modelling undertaken if required. Any subsoil drainage modelling shall consider the potential impact of subsoil drainage on any Environmentally Sensitive Areas (ESAs) and the need for treatment to remove nutrients from mobilised groundwater.

6.2 Groundwater quality management

Groundwater quality will be managed through:

- effective treatment of stormwater to reduce nutrient loads (Section 5.2.1)
- sustainable landscaping practice, including use of soil amendments and minimisation of fertiliser use in POS (Section 7.2).
- post development monitoring (Section 8.4).

7. Water conservation and efficiency

7.1 Potable water consumption

A water balance was undertaken for the RP to estimate potable water consumption at Forrestfield North based on the Water Corporation Water Use Calculator and the Alternative Technology Association (2010) rainwater tank calculator for individual, household scale rainwater tanks. In summary:

1. The total water use is 518,986 kL/yr or 85.4 kL/yr without water conservation measures. Of this, 12% or 10.6 kL/person/year is groundwater for irrigation of POS. The remaining 74.8 kL/person/year is potable water use. This volume is 25% below the State Water Plan potable use target of 100 kL/person/year. This is considered a favourable outcome and reflects the comparatively high density of the development, with limited external water use.
2. Of the 74.8 kL/person/year potable use, approximately 73.5 kL/yr is for domestic use.
3. An estimated 11% of potable use is for residential irrigation (approx. 8.5 kL/person/year) compared to perhaps 40% in a lower density development. Consequently, in-house water use (e.g. showers, toilets) reductions need to be targeted to reduce water use.
4. Water efficient fixtures are generally the most cost-effective way of reducing water use as there is a small upfront cost difference and there is unlikely to be a difference in maintenance costs when compared to traditional fixtures. The use of water efficient fixtures in all buildings for toilets, showers and taps could reduce potable water demand by approximately 12% to approximately 66 kL/yr.
5. Providing rainwater tanks and plumbing these in for in-house use (toilet flushing and washing machines) alone would reduce potable water demand by approximately 17% to 62.3 kL/year. It is recommended that rainwater tanks should provide a minimum of 1000 L of storage capacity connected to a minimum roof area of 55 m^2 per dwelling. If rainwater tanks are provided, these should be plumbed in for internal use as:
    - ex-house water use is a small component of the domestic demand (11%)
    - rainwater is available over the winter months (April to October) and domestic irrigation occurs predominantly over the summer months (October to March).

Installation of internally plumbed rainwater tanks is proposed for individual green title lots. The use of rainwater tanks for multi-dwelling strata lots is not considered feasible because of the legal and compliance issues with maintenance required to ensure tanks provide acceptable quality water.

On the basis of these findings:

1. It is proposed that the use of water efficient fixtures will be mandated for new developments in the RP to minimise water use in a sustainable manner. This will include the use of water efficient fixtures to the following standards in all buildings:
    - showerheads and taps that use ≤6 L/min in kitchens, bathrooms and laundries
    - dishwashers, where installed, that use ≤14 L per use
    - toilets that use ≤4.7 L per full flush.
2. The use of rainwater tanks for in-building water use is recommended, however not mandated. Where provided, rainwater tanks shall be plumbed in for in-building water use and provide a minimum of 1000 L of storage capacity and connected to a minimum roof area of 55 m^2 per dwelling.
3. Use of water efficient residential landscaping incorporating local species is encouraged as best practice.

With these measures, it is estimated that potable water demand will be approximately 66 kL/person/year, approximately one third less than the State Water Plan target of 100 kL/person/year. This is considered to be a sustainable outcome.

7.2 Public open space water efficiency

POS design will be undertaken to ensure that sustainable outcomes which reduce water and fertiliser use, are implemented through the following principles:

- improvement of the existing soil with 50 mm of soil conditioner certified to Australian Standard (AS) 4454 mixed into the native soil or fill to a depth of 100 mm in turf and 250 mm in garden beds
- landscape plantings primarily based on native Waterwise plant species with a focus on native species
- planting design based on watering requirements to allow for hydrozoning
- garden beds to be mulched to 75 mm or in accordance with Bushfire Management Plan requirements
- turf areas to be focussed around facilities such as play spaces and picnic facilities, to ensure turf is located where it will be best utilised
- implementation of an appropriate management and maintenance program for POS that reduces irrigation rates and fertiliser use over the long term to promote future water savings.

For all areas, efficiencies will be sought during landscaping design at the subdivision stage to target a reduction in fertiliser and irrigation water use while maintaining a high standard of POS, including:

- retaining natural bushland where feasible
- reduce irrigated areas by minimising turf through prioritising turf in active areas
- utilise low water use vegetation and hard surfaces where feasible to reduce irrigation demand
- utilise efficient irrigation systems to reduce water use
- utilising establishment only irrigation for streetscapes and landscaping.

7.2.1 Water and fertiliser use reduction trials

The first two areas of POS that contain turf to be developed will be used as trial areas for soil improvements or irrigation systems that can significantly reduce irrigation water use without affecting the quality of turf and thus provide a more sustainable POS outcome without impacting upon amenity.

The sandy soils, such are present in the surface of the Residential Precinct, have poor water retention and high infiltration rates. Loam and sandy loam textured soils are more suitable for turf growth because these contain a higher portion of clays, silts and organic matter that retain soil water and nutrients much more efficiently than sand. Soil amendments that add silt and clay to soil, such as Eclipse Aquamor Soil Improver and Soil Solver can be mixed into sands to achieve a sandy loam or loam soil classification. Other options for trials may include subsoil irrigation systems which reduce irrigation losses through evaporation, but these are less likely to reduce fertiliser use than soil amendments.

As technologies will develop over time, the methods to be trialled in each POS will be identified by COK at the time of subdivision, identifying the preferred methods. The trial construction, monitoring and reporting methods will be developed at the UWMP stage through consultation between the City and the developer. Findings of these studies will inform the future stages of POS development within the precinct.

7.2.2 Water use requirements

Water for the POS will be sourced from the existing City groundwater allocation (Section 3.5.4).

POS irrigation water use has been based on the following assumptions:

- permanent irrigation of turf with an average irrigation rate of 6,750 kL/ha/yr
- establishment irrigation of planted areas (POS and landscaped verges) at an average rate of 6,750 kL/ha/yr for two years.

The projected long-term irrigation demand is 38,652 kL/yr excluding the school. With allowance of 9,678 kL/yr for the school, this brings the total volume to 48,330 kL/yr. This volume is within the 100,000 kL/year allocated by the City from their existing superficial irrigation allocation (Section 3.5.4). The temporary establishment irrigation rate will vary depending on the development cycle, but an estimated total of 299,000 kL will be required for all establishment irrigation (based on a two-year establishment period). Estimated water use volumes for each POS and the street plantings are provided in Appendix 6.

Projected irrigation volumes include allowances for irrigation of the school and community purpose sites. The City has confirmation from the Department of Education that the allocated volume is sufficient for their requirements. This volume will be provided by the City to the Department of Education on construction of the school site.

7.2.3 Landscaping concept

The landscape plan (Figure 15 and Figure 16) is based on the ambition to create a ‘Forest Neighbourhood’, a medium density area with a bush character. This would provide Forrestfield North with a competitive difference in regard to other medium density developments around the Perth Metropolitan Area.

To realise the forest neighbourhood, the landscape plan works on two main ingredients:

- spaces for people - creating an attractive public realm for people of all demographics, with a comfortable microclimate, safe paths and an abundance of elements that support activation
- forest character - creating a continuous urban forest that supports the bush character, provides a suitable microclimate for people, connects to nature and contributes to the biodiversity.

The landscape plan translates the framework of the Local Structure Plan to the public realm design guide, incorporating the technical demands of the Local Water Management Strategy, the Bushfire Management Plan, the Transport Impact Assessment and the Community Infrastructure Strategy.

Job No: 57806

Client: Element

Version: A

Date 23/09/2020

Drawn By: cthatcher

Checked By: JH

Image reference: Place Laboratory, 2020

Forrestfied North Residential Precinct, WA

LANDSCAPE PLAN

FIGURE 15

File Name: W:\Projects\1)Open\Element (TPG)\57806 - FF North TOD & Res LWMS\GIS\Maps\R02_Rev_A\57806_15_LandscapePlan.mxd

Job No: 57806

Client: Element

Version: A
Date 24/09/2020

Drawn By: cthatcher
Checked By: JH

Image reference: Place Laboratory, 2020

Forrestfied North Residential Precinct, WA

TOWN PARK PLAN

FIGURE 16

File Name: W:\Projects\1)Open\Element (TPG)\57806 - FF North TOD & Res LWMS\GIS\Maps\R02_Rev_A\57806_16_TownParkPlan.mxd

8. Implementation

Responsibility for the development of the RP will be divided between the City and individual developers. The City will be responsible for development of:

- POS (including drainage structures in POS)
- District Integrator and Neighbourhood Connector Roads, including drainage structures and any upgrades required to these roads and associated drainage infrastructure (Figure 2).

These works will be funded through a Developer Contribution Plan (DCP) and are referred to as ‘DCP infrastructure’.

Construction of all other roads and drainage structures will be the responsibility of the developer and will be developed through a subdivision or development application process. These are referred to as ‘Subdivision infrastructure’.

8.1 Urban Water Management Plans

Processes defined in Better Urban Water Management (WAPC, 2008) require an Urban Water Management Plan (UWMP) at subdivision stage. With an approved LWMS, a UWMP is required to be prepared by the developer or proponent:

- as a condition of subdivision
- for any strata development or a Development Application for a site greater than 2000 m^2.

Further work that is identified for inclusion in the UWMP:

- results of geotechnical investigations, including measurement of hydraulic conductivity at locations where underground storages are proposed as part of the subdivision infrastructure
- present design of treatment structures, including tree pits, biofilters, median vegetated swales and vegetated swales at public car parks, streets and public open spaces
- present design stormwater management systems that provide serviceability, amenity and road safety during minor rainfall events with consideration of the City of Kalamunda’s Stormwater Design Guidelines for Subdivisional and Property Development (City of Kalamunda, 2018)
- consideration of art within stormwater management structures
- refinement of the final configuration (storage side slopes, type and invert level of underground storages etc) and exact location of the flood detention storage areas dependent on final earthworks, drainage and road design levels for the RP area
- construction details inverts and diameters of stormwater pipes
- confirmation of groundwater design levels
- confirmation of subsoil location and levels (if any)
- confirmation of finished levels and demonstration of adequate clearance to the 1% AEP flood levels to residential, commercial and industrial building habitable floor levels
- landscaping design and POS water use
- Foreshore Management Plan will be a required condition of subdivision approval for all development areas adjacent to Poison Gully
- identify any eroded areas within the Poison Gulley foreshore reserve and commit to upgrading or repairing as required
- identify any direct discharge piped into Poison Gulley and commit to replacing with overland flow paths where practical
- review surface water quality trigger levels in consideration of any additional pre-development monitoring results.

8.2 Construction management

8.2.1 Dewatering

Dewatering may be required for some elements of subdivision construction, including servicing infrastructure. Given the depth of construction, dewatering is anticipated to occur in the Superficial Aquifer only.

Prior to the commencement of any dewatering, the developer must apply for and obtain a "Licence to Take Water" from DWER. All dewatering should be carried out in accordance with the conditions of this licence. Where possible, construction should be timed to minimise impacts on groundwater and any dewatering requirement.

Dewatering will be managed through re-infiltration on site where feasible.

8.2.2 Acid sulphate soils and contaminated sites

Management of ASS and contaminated sites will be addressed as a separate process to the urban water management document approvals process.

ASS and potentially contaminated sites will be investigated and managed in accordance with the applicable DWER guidance and requirements of dewatering licences as they arise. Investigations and mapping indicate a low risk of ASS within the site (Section 3.4.3).

8.2.3 Stormwater outlets to Poison Gully

Poison Gully is not within a proclaimed Surface Water Area under the Rights in Water and Irrigation Act 1914 and therefore a bed and banks permit from the DWER will not be required for works within Poison Gully.

8.3 Stormwater system operation and maintenance

The operation and maintenance of DCP Infrastructure will be the responsibility of the City.

The operation and maintenance of Subdivision Infrastructure installed in roads will initially be the responsibility of the developer, ultimately reverting to the local authority, being the City.

The drainage system will require regular maintenance to ensure its efficient operation. It is considered the following operating and maintenance practices will be required periodically:

- removal of debris to prevent blockages
- street sweeping to reduce particulate build up on road surfaces and gutters.
- maintenance of vegetation in bio-retention systems/ storages
- cleaning of sediment build-up and litter layer on the bottom of storages
- undertake education campaigns regarding source control practices to minimise pollution runoff into stormwater drainage system
- checking and maintenance of subsoil drainage function.

8.4 Monitoring and contingency planning

The objective of this section is to provide guidance on the future post-development monitoring based on the pre-development monitoring for the RP area. The monitoring will focus on comparing post-development conditions to baseline conditions, as well as monitoring the BMPs to assess their effectiveness and that these structures are fulfilling their function. Prior to handover to the City, any BMPs constructed by developers must be assessed to confirm that these are in satisfactory condition and functioning appropriately.

8.4.1 Hydraulic performance monitoring

Hydraulic performance monitoring aims to determine if stormwater infiltration through basins and swales is consistent with the intended design.

Where amended soils profiles have been installed, infiltration testing will be completed to test the hydraulic conductivity of the media. Testing will be completed annually during the monitoring period.

Infiltration testing will be completed using a permeameter. Permeameter tests will be completed once per year in each basin.

8.4.2 Water quality and level monitoring

Post development monitoring will be undertaken by the City on the basis of the monitoring schedule outlined in Table 18 at monitoring bores to be installed during POS construction. Water quality assessment criteria and contingency actions will be undertaken as outlined in Table 18. Monitoring will be undertaken at the time of construction of the BMPs by the developer associated with the construction of each BMP.

Table 18: Monitoring schedule

Monitoring type	Location	Method	Frequency and timing	Parameters
Groundwater level	Four locations (one adjacent to each main basin for AS1/2, AS3, PG4 and PG5)	Electrical depth probe or similar	Monthly for two years (February, May, August, October)	Water level (m AHD).
Surface water quantity	Outlets of basins for AS1/2, PG4 and PG5	Continuous logger	Downloaded three times per year for two years	Stage (flow inferred).
Groundwater quality	Four locations (one adjacent to each main basin for AS1/2, AS3, PG4 and PG5)	Pumped bore samples	Quarterly for two years (February, May, August, October)	In situ: pH, EC, temperature Laboratory: TN, Kjeldahl nitrogen, ammonia, nitrate, nitrite, TP, filterable reactive phosphorus, total dissolved salts, selected heavy metals
Surface water quality	Outlets of basins for AS1/2, PG4 and PG5	Collected via grab sampler	Three times per year while flowing for two years	

Annual monitoring reports will be prepared by the City for review by DWER a period of two years following construction of the relevant storages. At the end of the two-year period, the monitoring results will be reviewed against the criteria identified in Table 19. If performance is not considered satisfactory and the criteria are not met, remedial actions may be required, and additional two years’ monitoring may be required.

Table 19: Criteria for assessment and contingencies

Monitoring type	Criteria for assessment	Criteria assessment frequency	Contingency action
Groundwater levels	Water levels not to increase above predevelopment MGL	Monthly review of water levels against MGLs	1. Assess if depth to groundwater is reaching levels of concern for natural assets or infrastructure 2. Investigate subsoil drainage
Surface water quantity	Flow discharging from storage basins to be within peak flows established in LWMS.	Annual review of water quantity targets	1. Review design and operation of stormwater drainage system. 2. Perform maintenance as required.

Monitoring type	Criteria for assessment	Criteria assessment frequency	Contingency action
Groundwater quality	Nutrient levels within the RP area should not exceed the maximum recorded pre-development level.	Annual review	1. Identify and remove any point sources. 2. Review operational and maintenance measures. 3. Consider modifications to stormwater system. 4. Consider reinforcement of community education/awareness programs. 5. Consider initiation of community-based projects.
Surface water quality	Assess performance of vegetated storages in nutrient reduction. Water quality discharging from the RP area should not exceed the maximum recorded pre-development level.	Annual review	1. Review design and operation of stormwater drainage system. 2. Perform maintenance as required.

Proposed water quality trigger values for the site have been determined considering existing concentrations recorded on site and trigger values recommended in the National Water Quality Management Strategy (NWQMS) (ANZECC 2000). Site specific trigger values are provided in Table 20 and are suitable for both surface and ground water. The NWQMS guideline default trigger values (ANZECC 2000) are intended to be for slightly disturbed ecosystems, not highly modified environments such as the site, and are designed to be used when no pre-development monitoring has been carried out to inform site specific trigger values. As such, trigger values should be reviewed at UWMP stage in consideration of any additional pre-development monitoring results available for the site and should be reviewed post-construction as water quality across the site changes to reflect the new land use.

Table 20: Post-development surface and groundwater trigger values

Analyte	TN (mg/L)	TP (mg/L)	TKN (mg/L)	NH4 (mg/L)	NOX (mg/L)	pH	EC (mS/cm)
Dundas Rd (3-6-2015)	0.8	2.2	0.5	>0.02	0.25	7.2	-
Littlefield Rd 2011 average	1.0	0.05	0.4	0.04	0.6	7.1	-
ANZECC Guideline Trigger Value[1]	1.2	0.065	-	0.8	0.15	6.5-8	0.12-0.3
Site trigger values	5	0.3	3	0.08	4	5.0-8.0	0.8

1. Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) - Trigger values for freshwater for a 95% level of protection (slightly to moderately disturbed ecosystem), values adopted for Lowland River, South West Australia.

8.4.3 Contingency action plan

If results from the initial monitoring occasion indicate that nutrient concentrations exceed the nominated trigger values, a number of contingency measures will be employed. The first action that will be undertaken is to repeat the monitoring to remove the potential for sampling error. If the repeat monitoring still shows results which breach the trigger value, the next action will be to compare the upstream (incoming) nutrient concentrations with the outgoing (downstream) nutrient concentrations.

If the downstream nutrient concentrations are >40% higher than the upstream nutrient concentrations, the following actions will be undertaken:

1. Review POS nutrient application practices to identify source if possible.
2. Conduct surveillance of subdivision area to determine any other potential and obvious nutrient inputs.

3. Remove source of nutrients if possible (e.g. fertiliser input, etc.).
4. Manual removal of excess plant material to facilitate further nutrient uptake.

In the case of total phosphorus in Poison Gulley, this approach is not suitable given the high level of downstream TP. In this situation the monitoring results should be compared with predevelopment results to initiate the above actions.

8.5 Responsibilities and funding

Responsibilities for funding, construction and maintenance are presented in Table 21.

Table 21: Table of responsibilities

Management Issue	Responsibility and funding	
	Developer	The City
DCP Infrastructure		
Construction and management of irrigation system.		✓
Construction of planted raingardens, street drainage and detention storages.		✓
Detention storages and planted raingardens.		✓
Management of stormwater storage landscaping.		✓
Post-development monitoring		
• Monitoring over a two-year period, commencing immediately after the Practical Completion of the storage.		✓
Street sweeping		✓
Installation of low water use fixtures and fittings and rainwater tanks (where required)		
• selection of fittings and tanks	✓	
• demonstration of compliance	✓	
• review of compliance (as required).		✓
POS water and fertiliser use reduction trials (first two POS areas developed that contain turf)		
• selection of methods to be trialled		✓
• trial design and materials funding (in consultation with developer)		✓
• POS construction implementing trial methods		✓
• trial monitoring (two years) and reporting		✓
• implementation of findings (as required).		✓
Pervious paving trial by the City at either the Community Purpose site or District Open Space for use in car parks and/or low traffic areas		
• selection of methods to be trialled		✓
• trial design and materials funding (in consultation with developer)		✓
• POS construction implementing trial methods		✓
• trial monitoring (two years) and reporting		✓
• implementation of findings (as required).		✓
Subdivision infrastructure		
Construction of planted raingardens, street drainage and any detention storages.	✓	
Street drainage maintenance	✓	
• between successful Practical Completion Inspection and written confirmation of the City's acceptance (12 month defects liability period)		
• after the City's acceptance.		✓
Detention storages and planted raingardens	✓	
• between successful Practical Completion Inspection and written confirmation of the City's acceptance (12-month defects liability period)		
• after the City's acceptance.		✓

Management Issue	Responsibility and funding	
	Developer	The City
Street sweeping • up to the successful Practical completion of civil works • after the City’s acceptance.	✓	 ✓
Installation of low water use fixtures and fittings • selection of fittings • demonstration of compliance • review of compliance (as required).	 ✓ ✓	 ✓

9. Summary of compliance

Table 22 below summarises how the water management principles and objectives for the site will be met.

Table 22: Compliance with water management principles and objectives

Category	Principles	Objectives	Methods for achievement
Water use	• consider all potential water sources in water supply planning • integration of water and land use planning • sustainable and equitable use of all water sources having consideration for the needs of all users, including community, industry and the environment.	• minimise the use of potable water where drinking water quality is not essential • achieve a significant reduction in water use below the 100 kL/person/year State Water Plan (Government of Western Australia 2007) target • mandate Water Efficiency Labelling and Standards rated water efficient products, water efficient irrigation, waterwise landscaping and rainwater storage tanks for individual green title lots.	• Potable water use estimated at 66 kL/day through mandating water efficient fittings and appliances, mandating rainwater tanks for green title development and reduced garden areas • Irrigation volumes for POS and schools will be kept within the current City of Kalamunda licenced allocation volume • POS design will maximise retention of native bushland, include extensive rehabilitation and minimise the use of turf in POS where not required • Trials of soil amendments and/or below ground irrigation measures to reduce turf water and fertiliser use will be undertaken in the first two POS areas containing turf and result used to inform POS design.
Groundwater and surface water quantity	• to retain natural drainage systems and protect ecosystem health • to protect from flooding and waterlogging • to implement economically viable stormwater systems • post development annual discharge volume and peak flow rates to remain at pre-development levels or defined environmental water requirements.	• where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles • for flood management, manage up to the 1% AEP event within the development area to pre-development flows and the requirements of Water Corporation (Water Corporation 2010). • adopt 'at source' stormwater management approach and consider reducing pit and pipe drainage system significantly. Treat polluted runoff by installing appropriate treatment systems where required • consider managing stormwater runoff by providing overland flow paths and opportunities for infiltration of runoff on lots, road reserves and public open space where site conditions permit • pre-development flow rates will be maintained for events up to the 1% AEP event at discharges from the site, including Poison Gully • design stormwater management systems to provide serviceability, amenity and road safety during minor rainfall events.	• control of groundwater levels on the site is not proposed and thus impacts on groundwater regimes will be limited • maintain pre-development flows off the site through detention and retention on site, while minimising land take for drainage to improve public amenity • at source stormwater management will be adopted through retention of the first 26mm of water on lots and use of biofilters and tree pits within road reserves where feasible • the 63% AEP event (including the first 15 mm) will be treated through vegetated structures prior to discharge to receiving water bodies • pre-development flow rates will be maintained for events up to the 1% AEP event at discharges from the site, including Poison Gully • design stormwater management systems to provide serviceability, amenity and road safety during minor rainfall events.

Category	Principles	Objectives	Methods for achievement
Groundwater and surface water quality	• to maintain or improve groundwater and surface water quality • where waterways/open drains intersect the water table, minimise the discharge of pollutants from groundwater • where development is associated with an ecosystem dependent upon a particular hydrologic regime, minimise discharge or pollutants to shallow groundwater and receiving waterways and maintain water quality in the specified environment.	• maintain surface water and groundwater quality • retain and/or detain and treat (if required) — stormwater runoff from constructed impervious surfaces generated by the first 15 mm of rainfall at-source as much as practical.	• use of raingardens, including roadside raingardens to retain and treat the 1-year, 1-hour event through use of raingardens and tree pits • minimisation of turf areas and POS fertiliser use to reduce nutrient discharge to the environment • investigation and redevelopment of Brand Road landfill to manage and mitigate potential impacts to groundwater. • the 63% AEP event (including the first 15 mm) will be treated through vegetated structures prior to discharge to receiving water bodies.

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Appendix 1
LWMS checklist

Checklist for assessment of local structure plan or local planning scheme amendment

1. Tick the status column for items for which information is provided.
2. Enter N/A in the status column if the item is not appropriate and enter the reason in the comments column.
3. Provide brief comments on any relevant issues.
4. Provide a brief description of any proposed best management practices, e.g. multi-use corridors, community based-social marketing, water re-use proposals.

LWMS item	Deliverable	Included?	Location in text
Executive summary			
Summary of the development design strategy, outlining how the design objectives are proposed to be met	Table 1: Design elements and requirements for BMPs and critical control points	✓	Table ES-1
Introduction			
Total water cycle management – principles & objectives Planning background Previous studies		✓	Sections 1 and 2
Proposed development			
Structure plan, zoning and land use. Key landscape features Previous land use	Site context plan Structure plan	✓ ✓	Section 1.1 and 3.2 Figures 2 and 3
Landscape - proposed POS areas, water source, bore(s), lake details, irrigation areas (if applicable)	Landscape Plan	✓	Section 7.2.3 Appendices 7 and 8
Design criteria			
Agreed design objectives and source of objectives		✓	Section 2
Pre-development environment			
Existing information and more detailed assessments (monitoring). How do the site characteristics affect the design?		✓	Section 3
Site Conditions - existing topography/ contours, aerial photo underlay, major physical features	Site condition plan	✓	Section 3.3 Figures 1, 3
Geotechnical - topography, soils including acid sulfate soils and infiltration capacity, test pit locations	Geotechnical plan	✓	Section 3.4, Figures 3 to 5.
Environmental - areas of significant flora and fauna, wetlands and buffers, waterways and buffers, contaminated sites	Environmental Plan plus supporting data where appropriate	✓	Sections 3.7 and 3.8 Figures 9 and 10
Surface Water – topography, 100 year floodways and flood fringe areas, water quality of flows entering and leaving (if applicable)	Surface Water Plan	✓	Section 3.6, Figures 8 and 9
Groundwater – topography, pre development groundwater levels and water quality, test bore locations	Groundwater Plan plus site investigation	✓	Section 3.6, Figures 6 and 7
Water sustainability initiatives			
Water efficiency measures – private and public open spaces including method of enforcement		✓	Section 7
Water supply (fit-for-purpose), agreed actions and implementation		✓	Section 7
Wastewater management		✓	Section 7

LWMS item	Deliverable	Included?	Location in text
Stormwater management strategy			
Flood protection - peak flow rates, volumes and top water levels at control points,100 year flow paths and 100 year detention storage areas	100yr event plan Long section of critical points	✓ ✓	Section 5.1.2 Figure 11
Manage serviceability - storage and retention required for the critical 5 year ARI storm events Minor roads should be passable in the 5 year ARI event	5 yr event plan	✓	Section 5.1.2 Figure 11
Protect ecology – detention areas for the 1 yr 1 hr ARI event, areas for water quality treatment and types of agreed structural and non-structural best management practices and treatment trains (including indicative locations). Protection of waterways, wetlands (and their buffers), remnant vegetation and ecological linkages	1yr event plan Typical cross sections	✓ ✓	Section 5.1.1 Figure 11
Groundwater management strategy			
Post development groundwater levels, existing and likely final surface levels, outlet controls, and subsoils areas/exclusion zones	Groundwater/subsoil plan	✓	Section 6
Actions to address acid sulfate soils or contamination		✓	Section 3.4, 8.2.2
The next stage – subdivision and urban water management plans			
Content and coverage of future urban water management plans to be completed at subdivision. Include areas where further investigations are required before to detailed design.		✓	Section 8.1
Monitoring			
Recommended future monitoring plan including timing, frequency, locations and parameters, together with arrangements for ongoing actions		✓	Section 8.4
Implementation			
Developer commitments		✓	Section 8.5
Roles, responsibilities, funding for implementation		✓	Section 8.5
Review		✓	Section 8.5

Appendix 2
Bore logs

Soil Log

Page No:	**1 of 3**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**11 m bgl**
Borehoe ID:	**MB01**	**GPS:**	**E 404861.05**
Logged by:	**CJ**		**N 6464332.42**

Depth (m)	Graphic log	Description of soil type	Additional observations
0	▨	Sandy GRAVEL/ Gravelly SAND, brown/grey, fine to coarse sand	no smell
0.1			
0.2			
0.3			
0.4			
0.5			
0.6			
0.7			
0.8			
0.9			
1			
1.1			
1.2			
1.3			
1.4			
1.5			
1.6			
1.7			
1.8			
1.9			
2			
2.1			
2.2			
2.3			
2.4			
2.5			
2.6			
2.7			
2.8			
2.9			
3			

Soil Log

Page No:	**2 of 3**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**11 m bgl**
Borehoe ID:	**MB01**	**GPS:**	**E 404861.05**
Logged by:	**CJ**		**N 6464332.42**

Depth (m)	Graphic log	Description of soil type	Additional observations
3	▥	Clayey SAND, orange-brown to orange, medium to coarse sand	no smell
3.2			
3.4			
3.6			
3.8			
4			
4.2			
4.4			
4.6			
4.8			
5			
5.2			
5.4			
5.6			
5.8			
6			bore slotted 6 m to 9 m
6.2			
6.4			
6.6			
6.8			
7			
7.2			
7.4			
7.6			
7.8			
8			
8.2			
8.4			
8.6			
8.8			
9			

Soil Log

Page No:	**3 of 3**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**11 m bgl**
Borehoe ID:	**MB01**	**GPS:**	**E 404861.05**
Logged by:	**CJ**		**N 6464332.42**

Depth (m)	Graphic log	Description of soil type	Additional observations
9.2	▥	Clayey SAND, orange-brown to orange, medium to coarse sand	no smell
9.4	▥		
9.6	▥		
9.8	▥		
10	▥		
10.2	▥		
10.4	▥		
10.6	▥		
10.8	▥		
11	▥	**EOH - 11 m BGL**	
11.2			
11.4			
11.6			
11.8			
12			
12.2			
12.4			
12.6			
12.8			
13			
13.2			
13.4			
13.6			
13.8			
14			
14.2			
14.4			
14.6			
14.8			
15			
15.2			

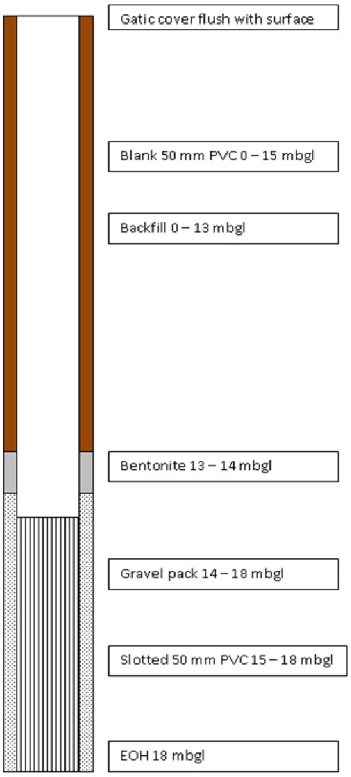
Soil Log

Page No:	**1 of 2**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**18 m bgl**
Borehoe ID:	**MB02**	**GPS:**	**E 405921.6**
Logged by:	**CJ**		**N 6464053.81**

Depth (m)	Graphic log	Description of soil type	Additional observations
0 0.5	░	SAND, medium grained, subrounded, grey-black. Becoming grey below 0.5 m	no smell
1 1.5 2 2.5 3 3.5	░	SAND, grey, medium grained, becoming orange below 1m	
4 4.5 5 5.5 6	▓	Gravelly SAND orange, medium sand, low to no plasticity	
6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15	░	clayey SAND, red, medium sand, moderate plasticity, becoming grey below 14.5 m	no smell, slow drilling

Soil Log

Page No:	**2 of 2**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**18 m bgl**
Borehoe ID:	**MB02**	**GPS:**	**E 405921.6**
Logged by:	**CJ**		**N 6464053.81**

Depth (m)	Graphic log	Description of soil type	Additional observations
15	▨	clayey SAND, grey, medium sand, moderate plasticity **Water at 15.5 - 16 m**	no smell, slotted from 15 m.
15.5	▨		
16	▨	SAND, medium, subrounded, orange/red, moist	
16.5	▨		
17	▨		
17.5	▨		
18	▨	EOH - 18 m	
18.5			
19			
19.5			
20			
20.5			
21			
21.5			
22			
22.5			
23			
23.5			
24			
24.5			
25			
25.5			
26			
26.5			
27			
27.5			
28			
28.5			
29			
29.5			
30			

Soil Log

Page No:	**1 of 1**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	**not encountered, not installed as bore**
Date of works:	**9/09/2011**	**End of hole:**	**19.8 m BGL**
Borehoe ID:	**MB03**	**GPS:**	**corner Brae Rd and Brand Rd**
Logged by:	**CJ**		**Not surveyed as bore not installed**

Depth (m)	**Graphic log**	**Description of soil type**	**Additional observations**
0 1	░	0 - 0.25 m gravelly SAND, medium to coarse material, black to grey topsoil, then 0.25 -2.5 m SAND, grey to yellow/orange, medium grained	no smell
2 3 4 5 6	░	2.5 m - 7 m, SAND, yellow/orange, medium to coarse grained, subrounded, darker than above	
7 8 9 10 11 12	▥	Clayey SAND, fine to medium sand, grey-orange, moderately sorted	
13 14 15 16 17 18 19	░	SAND, fine to medium, orange- grey, moderately sorted becoming grey EOH 19.8 m	
20 21 22 23 24 25 26 27 28 29 30			

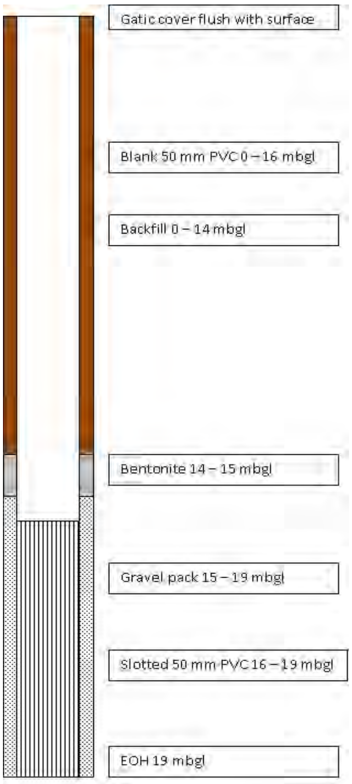
Soil Log

Page No:	**1 of 2**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**19 m bgl**
Borehoe ID:	**MB04**	**GPS:**	**E 406211.14**
Logged by:	**CJ**		**N 6463642.55**

Depth (m)	Graphic log	Description of soil type	Additional observations
0	▨	Gravelly SAND, medium to coars, subangular, black/orange, moderately sorted	
0.5	░	SAND, medium grained, subrounded, orange, moderately sorted	
1	░		
1.5	░		
2	░		
2.5	░		
3	░		
3.5	░		
4	░		
4.5	░		
5	░		
5.5	░		
6	░		
6.5	░		
7	░	SAND, medium/coarse grained, brown/orange, subangular, moderately sorted	
7.5	░		
8	░		
8.5	░		
9	░		
9.5	░		
10	░	SAND, coarse, yellow, subangular, moderately sorted	
10.5	░		
11	░		
11.5	░		
12	░		
12.5	░		
13	░		
13.5	░		
14	░		
14.5	░		
15	░		

Soil Log

Page No:	**1 of 2**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**19 m bgl**
Borehoe ID:	**MB04**	**GPS:**	**E 406211.14**
Logged by:	**CJ**		**N 6463642.55**

Depth (m)	Graphic log	Description of soil type	Additional observations
15.5		SAND, coarse, yellow, subangular, moderately sorted	
16			
16.5			
17			
17.5			
18		SAND, medium to coarse, yellow/grey, subrounded, moderately sorted	
18.5		EOH at 19 m	
19			
19.5		 	
20			
20.5			
21			
21.5			
22			
22.5			
23			
23.5			
24			
24.5			
25			
25.5			
26			
26.5			
27			
27.5			
28			
28.5			
29			
29.5			
30			
30.5			

Soil Log

Page No:	**1 of 2**	**Drill method:**	**Auger - Strataprobe**
Job Number:	**SKA11193.02**	**Hole diameter:**	**50 mm**
Project:	**Forrestdale**	**Groundwater at:**	
Date of works:	**9/09/2011**	**End of hole:**	**19 m BGL**
Borehoe ID:	**MB05**	**GPS:**	**E 406081.39**
Logged by:	**CJ**		**N 6463046.74**

Depth (m)	**Graphic log**	**Description of soil type**	**Additional observations**
0	▨	SAND, medium to fine grained, subangular, grey, poorly sorted	
0.5			
1			
1.5			
2			
2.5			
3			
3.5			
4	▨	Sand, medium grained, orange, subangular, moderately sorted	
4.5			
5			
5.5			
6			
6.5			
7			
7.5			
8			
8.5			
9	▨	SAND, coarse, yellow, subrounded, poorly sorted,	
9.5			
10	▨	SAND, coarse, grey, subrounded moderately sorted	
10.5			
11	▨	SAND, medium grained, brown'grey, subrounded, moderately sorted	
11.5			
12			
12.5			
13			
13.5			
14			
14.5			
15			

Soil Log

Page No:	2 of 2	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	
Date of works:	9/09/2011	**End of hole:**	19 m BGL
Borehoe ID:	MB05	**GPS:**	E 406081.39
Logged by:	CJ		N 6463046.74

Depth (m)	Graphic log	Description of soil type	Additional observations
15.5	▨	SAND, medium grained, brown-grey, subrounded, moderately sorted	
16	▨		
16.5	▨		
17	▨		
17.5	▨		
18	▨		
18.5	▨	EOH	
19	▨		
19.5			
20			
20.5			
21			
21.5			
22			
22.5			
23			
23.5			
24			
24.5			
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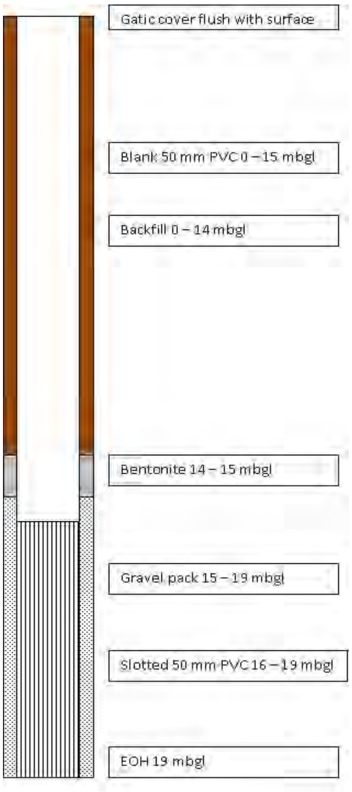
27.5			
28			
28.5			
29			
29.5			
30			
30.5			



Soil Log

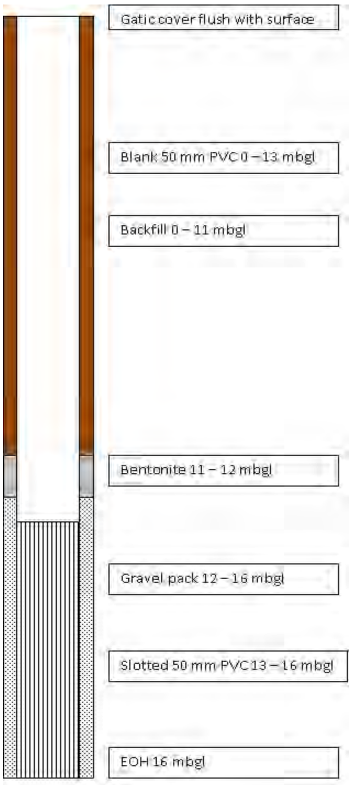
Page No:	1 of 2	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	13.9 m BGL
Date of works:	9/09/2011	**End of hole:**	16 m bgl
Borehoe ID:		**GPS:**	E 405683.24
Logged by:	CJ		N 6463843.04

Depth (m)	Graphic log	Description of soil type	Additional observations
0 0.5	░	SAND, medium grained, subrounded, brown, moderately sorted becoming yellow from 0.75 m	
1 1.5 2 2.5 3 3.5 4 4.5	░	SAND, fine to medium grained, subrounded, orange, moderately sorted	
5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10 10.5 11 11.5 12 12.5 13	░	SAND, fine to medium grained, orange, subrounded, moderately sorted	
13.5 14 14.5	▥	clayey SAND medium grained, subrounded, orange/grey, moderately sorted Groundwater at 13.9 m BGL	
15	▥	clayey SAND, medium grained, subrounded, grey, moderately sorted, moist	

Soil Log

Page No:	2 of 2	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	13.9 m BGL
Date of works:	9/09/2011	**End of hole:**	16 m bgl
Borehoe ID:		**GPS:**	E 405683.24
Logged by:	CJ		N 6463843.04

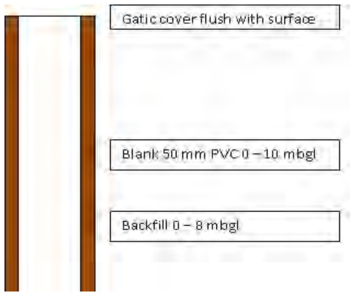
Depth (m)	Graphic log	Description of soil type	Additional observations
15.5		clayey SAND, medium grained, subrounded, grey, moderately sorted, moist	
16			
16.5			
17			
17.5			
18			
18.5		EOH 19 m	
19			
19.5			
20			
20.5			
21			
21.5			
22			
22.5			
23			
23.5			
24			
24.5			
25			
25.5			
26			
26.5			
27			
27.5			
28			
28.5			
29			
29.5			
30			
30.5			



Soil Log

Page No:	1 of 1	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	
Date of works:	9/09/2011	**End of hole:**	13 m BGL
Borehoe ID:	MB07	**GPS:**	E 405347.43
Logged by:	CJ		N 6464050.07

Depth (m)	Graphic log	Description of soil type	Additional observations
0 0.5	■	Gravelly SAND, medium to coarse, subangular, grey, moderately sorted	
1 1.5 2 2.5	░	SAND, medium grained, subrounded, orange/yellow, moderately sorted	
3 3.5 4 4.5 5 5.5 6 6.5 7 7.5	▥	Clayey SAND, orange, subrounded, moderately sorted	
8 8.5 9 9.5	▥	Clayey SAND, brown/grey, subrounded, moderately sorted	
10 10.5 11 11.5 12 12.5	▥	Clayey SAND, medium grained, grey, subrounded, moderately sorted EOH - 13 m	
13 13.5 14 14.5 15			



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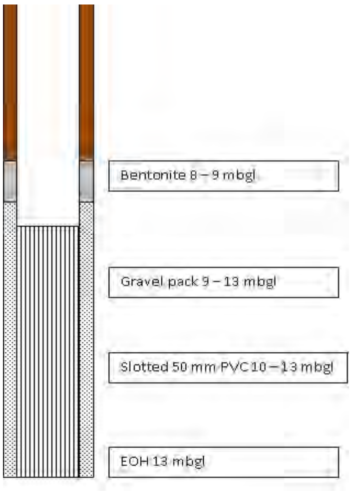

Bentonite 8 – 9 mbgl
Gravel pack 9 – 13 mbgl
Slotted 50 mm PVC 10 – 13 mbgl
EOH 13 mbgl

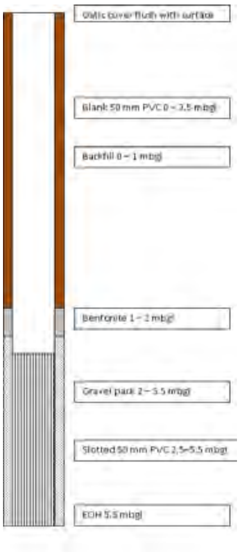
Soil Log

Page No:	1 of 1	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	
Date of works:	9/09/2011	**End of hole:**	9 m
Borehoe ID:	MB08	**GPS:**	E 405086.11
Logged by:	CJ		N 6463948.16

Depth (m)	Graphic log	Description of soil type	Additional observations
0 0.5 1	░	SAND, medium grained, subrounded, black/grey, moderately sorted	
1.5 2 2.5	░	SAND, medium grained, subrounded, brown-orange, moderately sorted	
3 3.5	░	SAND, medium to coarse grained, subrounded, orange-brown, moderately sorted	
4 4.5 5 5.5 6 6.5 7 7.5 8 8.5	▥	Clayey SAND, medium grained, subrounded, light brown/orange	
9	▥	Clayey SAND, fine-medium grained, subrounded, grey, well sorted	
9.5 10 10.5 11 11.5 12 12.5 13 13.5 14 14.5 15		Bore screened 6 m to 9m BGL	

Soil Log

Page No:	1 of 1	**Drill method:**	Auger - Strataprobe
Job Number:	SKA11193.02	**Hole diameter:**	50 mm
Project:	Forrestdale	**Groundwater at:**	
Date of works:	9/09/2011	**End of hole:**	7 m
Borehoe ID:	MB09	**GPS:**	E 405255.15
Logged by:	CJ		N 6464414.64

Depth (m)	Graphic log	Description of soil type	Additional observations
0		Sand, medium grained, subrounded black to 0.1 m and then grey	
0.5			
1			
1.5		1.5 -2.25 m, SAND, medium grained, subrounded, grey, moist	
2			
2.5		2.25 m on, clayey SAND, meidum grained, subrounded, orange, poorly sorted	
3			
3.5			
4			
4.5			
5			
5.5			
6			
6.5		EOH, slotted to 5.5 m	
7			
7.5			
8			
8.5			
9			
9.5			
10			
10.5			
11			
11.5			
12			
12.5			
13			
13.5			
14			
14.5			
15			

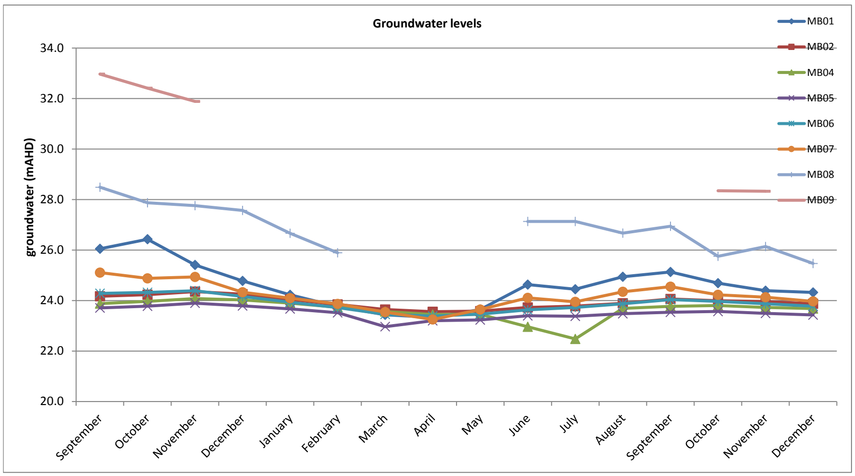
Appendix 3

Water monitoring summary

GROUNDWATER FIELD OBSERVATIONS

					These may not always be required							
Sample Identification Number	Sample Date	Depth to groundwater (mbtoc)	Groundwater level (m AHD)	Depth from ground level	pH	Change in pH	Electrical Conductivity	Temp	Dissolved Oxygen	Dissolved Oxygen	Redox	Comments
Units					pH Unit	pH Unit	mS/cm	oC	mg/L	%	mV	
MB01 - TD = 9.028 mbtoc, RL = 30.64 mAHD												
September	28/09/2011 12:25	4.590	26.050		6.61		0.311	21.3	3.420	39.10	187.6	bailed 30 L, bore still not dry
October	19/10/2011 11:40	4.213	26.427		6.62	0.01	0.452	21.5	2.760	31.40	188.0	bailed 10 L, bore still not dry, samples taken
November	14/11/2011 8:45	5.228	25.412									
December	22/12/2011 9:25	5.863	24.777									
January	16/01/12	6.412	24.228		5.87	-0.75	0.319	23.2	2.780	87.30	133.0	Bailed 15L, Bore still not dry, samples taken
February	22/02/12	6.874	23.766									
March	27/03/12	7.202	23.438									
April	23/04/12	7.306	23.334		5.68	-0.19	0.246	22.2	2.720	32.10	67.0	Bailed 10L,Bore still not dry, samples taken
May	24/05/12	6.998	23.642									
June	27/06/12	6.010	24.630									
July	26/07/12	6.190	24.450		5.84	0.16	0.239	22.2	2.240	25.70	113.8	Bailed 10L,Bore still not dry, samples taken
August	29/08/12	5.700	24.940									
September	26/09/12	5.510	25.130									
October	24/10/12	5.950	24.690									
November	21/11/12	6.250	24.390		6.07	-0.23	0.230	22.3	3.100	31.60	145.3	Bailed 10L,Bore still not dry, samples taken
December	20/12/12	6.320	24.320									
MB02 - TD = 16.835 mbtoc, RL = 39.05 mAHD												
September	28/09/11	14.878	24.172		5.03		0.150	20.20	3.390	38.10	261.8	bailed 20 L, bore still not dry
October	19/10/11	14.815	24.235		4.84	-0.19	0.253	20.60	4.100	46.60	260.2	bailed 10 L, bore still not dry, samples taken
November	14/11/11	14.696	24.354									
December	22/12/11	14.795	24.255									
January	16/01/12	15.004	24.046		4.85	0.01	0.336	21.50	13.750	158.20	270.0	bailed 15 L, bore still not dry, samples taken
February	22/02/12	15.201	23.849									
March	27/03/12	15.407	23.643									
April	23/04/12	15.491	23.559		4.63	-0.22	0.286	20.40	3.870	43.20	197.0	Bailed 10L, bore still not dry, samples taken (red colour)
May	24/05/12	15.467	23.583									
June	27/06/12	15.325	23.725									
July	26/07/12	15.270	23.780		4.91	0.28	0.253	20.40	4.440	49.20	178.5	bailed 15 L, bore still not dry, samples taken
August	29/08/12	15.160	23.890									
September	26/09/12	14.990	24.060									
October	24/10/12	15.060	23.990									
November	21/11/12	15.090	23.960		4.85	0.06	0.156	22.80	4.030	47.30	221.5	Bailed 10L, bore still not dry, samples taken (red colour)
December	20/12/12	15.180	23.870									
MB04 - TD = 18.1 mbtoc, RL = 40.33 mAHD												
September	28/09/11	16.454	23.876		5.03		0.530	22.30	2.600	30.10	234.9	bailed 10 L, bore still not dry
October	19/10/11	16.364	23.966		4.82	-0.21	0.650	21.80	3.040	37.30	246.2	bailed 10 L, bore still not dry, samples taken
November	14/11/11	16.251	24.079									
December	22/12/11	16.305	24.025									
January	16/12/11	16.434	23.896		4.62	-0.20	0.608	22.89	6.430	68.20	240.0	bailed 15 L, bore still not dry, samples taken
February	22/02/12	16.597	23.733									
March	27/03/12	16.765	23.565									
April	23/04/12	16.881	23.449		4.28	-0.34	0.820	21.50	1.850	20.40	-12.6	Bailed 10L, bore still not dry, samples taken. Sulphur smell and metal smell - ant nest also in bore
May	24/05/12	16.876	23.454									
June	27/06/12	17.371	22.959									
July	26/07/12	17.850	22.480		4.57	0.29	0.840	21.40	24.900	2.18	157.8	Bailed 10L, bore still not dry, samples taken. Sulphurous smell - ant nest also in bore
August	29/08/12	16.640	23.690									
September	26/09/12	16.560	23.770									
October	24/10/12	16.530	23.800									
November	21/11/12	16.600	23.730		4.38	0.19	0.830	22.80	4.350	52.10	154.7	bailed 15 L, bore still not dry, samples taken
December	20/12/12	16.650	23.680									
MB05 - TD = 18.776 mbtoc, RL = 41.37 mAHD												
September	28/09/11	17.663	23.707		5.73		0.345	20.90	5.800	65.31	176.8	bailed 15 L, bore still not dry
October	19/10/11	17.594	23.776		6.06	0.33	0.267	20.80	6.450	71.50	176.2	bailed 10L, bore still not dry, samples taken
November	14/11/11	17.475	23.895									
December	22/12/11	17.581	23.789									
January	16/01/11	17.697	23.673		5.03	-1.03	0.268	21.95	18.640	195.20	258.0	bailed 15 L, bore still not dry, samples taken
February	22/02/12	17.851	23.519									
March	27/03/12	18.405	22.965									
April	23/04/12	18.166	23.204		5.42	0.39	0.354	20.50	6.360	70.30	221.8	8L, bore dry and recharged in 20 minutes, samples taken.
May	24/05/12	18.139	23.231									
June	27/06/12	17.975	23.395									
July	26/07/12	17.990	23.380		5.75	0.33	0.346	20.40	7.560	84.00	203.5	bailed 15 L, bore still not dry, samples taken
August	29/08/12	17.890	23.480									
September	26/09/12	17.830	23.540									
October	24/10/12	17.800	23.570									
November	21/11/12	17.880	23.490		5.32	0.43	0.306	22.10	7.060	81.60	176.9	bailed 10L, bore still not dry, samples taken
December	20/12/12	17.940	23.430									
MB06 - TD = 15.72 mbtoc, RL = 36.84 mAHD												
September	28/09/11	12.559	24.281		5.18		0.910	20.20	1.460	16.30	-1.7	bailed 25 L, bore still not dry. Sulfur smell
October	19/10/11	12.521	24.319		4.94	-0.24	1.070	19.80	1.780	19.80	-7.5	bailed 10 L, bore still not dry, sulfur smell, samples taken
November	14/11/11	12.451	24.389									
December	22/12/11	12.678	24.162									
January	16/01/11	12.902	23.938		4.84	-0.10	1.002	21.26	8.430	129.30	-38.0	bailed 10 L, bore still not dry, sulfur smell, samples taken
February	22/02/12	13.120	23.720									
March	27/03/12	13.386	23.454									
April	23/04/12	13.456	23.384		4.55	-0.29	1.150	20.10	1.910	21.00	-38.6	Bailed 10L, bore still not dry, sulfur smell, samples taken
May	24/05/12	13.376	23.464									
June	27/06/12	13.210	23.630									
July	26/07/12	13.110	23.730		4.93	0.38	1.130	19.50	2.000	21.80	85.8	bailed 10 L, bore still not dry, sulfur smell, samples taken
August	29/08/12	12.970	23.870									
September	26/09/12	12.800	24.040									
October	24/10/12	12.870	23.970									
November	21/11/12	12.970	23.870		5.15	-0.22	1.260	21.60	4.200	49.00	90.6	Bailed 10L, bore still not dry, sulfur smell, samples taken
December	20/12/12	13.060	23.780									
MB07 - TD = 13.407 mbtoc, RL = 35.09 mAHD												
September	28/09/11	9.982	25.108		6.20		0.256	21.20	5.660	63.20	235.1	bailed 30 L, bore still not dry
October	19/10/11	10.214	24.876		6.15	-0.05	0.293	21.00	6.690	75.80	183.5	bailed 10 L, bore still not dry, samples taken
November	14/11/11	10.151	24.939									
December	22/12/11	10.763	24.327									
January	16/01/11	10.998	24.092		5.84	-0.31	0.245	21.75	15.180	134.10	188.0	bailed 15 L, bore still not dry, samples taken
February	22/02/11	11.226	23.864									
March	27/03/12	11.545	23.545			0.00						
April	23/04/12	11.841	23.249		6.05	0.21	0.310	21.90	6.600	74.80	158.8	Bailed 8L, slow recharge, samples taken
May	24/05/12	11.446	23.644									
June	27/06/12	10.985	24.105									

					These may not always be required							
Sample Identification Number	Sample Date	Depth to groundwater (mbtoc)	Groundwater level (m AHD)	Depth from ground level	pH	Change in pH	Electrical Conductivity	Temp	Dissolved Oxygen	Dissolved Oxygen	Redox	Comments
Units					pH Unit	pH Unit	mS/cm	oC	mg/L	%	mV	
July	26/07/12	11.140	23.950		6.34	0.29	0.137	20.80	4.520	49.90	164.2	bailed 15 L, bore still not dry, samples taken
August	29/08/12	10.740	24.350									
September	26/09/12	10.540	24.550									
October	24/10/12	10.860	24.230									
November	21/11/12	10.960	24.130		6.25	0.09	0.195	21.40	4.530	48.50	155.6	bailed 10 L, bore still not dry, samples taken
December	20/12/12	11.120	23.970									
MB08 - TD = 7.47 mbtoc, RL = 32.44 mAHD												
September	28/09/11	3.950	28.490		6.15		0.690	20.40	6.880	76.60	228.9	bailed 30 L, bore still not dry
October	19/10/11	4.567	27.873		6.03	-0.12	0.920	20.10	6.650	76.00	201.7	bailed 10 L, bore still not dry, samples taken
November	14/11/11	4.681	27.759									
December	22/12/11	4.872	27.568									
January	16/01/11	5.775	26.665		5.83	-0.20	0.710	22.81	24.730	270.60	204.0	Bailed 6 L and bore ran dry, replenished in 15-20 minutes, sample taken
February	22/02/12	6.549	25.891									
March	27/03/12	dry										dry
April	23/04/12	dry										dry
May	24/05/12	dry										dry
June	27/06/12	5.310	27.130									
July	26/07/12	5.310	27.130		Not enough sample for Physio-Chem analysis							Bailed 1 L and bore ran dry, replenished in 25 mins, samples taken
August	29/08/12	5.770	26.670									
September	26/09/12	5.500	26.940									
October	24/10/12	6.690	25.750									
November	21/11/12	6.300	26.140		6.58	-0.75	0.014	23.00	6.230	73.30	115.3	bailed 10 L, bore still not dry, samples taken
December	20/12/12	6.970	25.470									
MB09 - TD = 5.64 mbtoc, RL = 33.96 mAHD												
September	28/09/11	0.990	32.970		6.02		0.174	16.80	4.180	43.90	232.3	bailed 30 L, bore still not dry
October	19/10/11	1.549	32.411		6.68	0.66	0.191	17.30	5.890	62.30	204.8	bailed 10 L, bore still not dry, samples taken
November	14/11/11	2.075	31.885									
December	22/12/11	dry										dipper muddy ?may just be moisture at bottom of bore
January	16/12/11	dry										Bore was dry, water level obtained by moist mud level, no sample taken
February	22/02/12	dry										Bore was dry, water level obtained by moist mud level
March	27/03/12	dry										dry
April	23/04/12	dry										dry
May	24/05/12	dry										dry
June	27/06/12	dry										dry
July	26/07/12	dry										dry
August	29/08/12	dry										dry
September	26/09/12	dry										Bore was dry, water level obtained by moist mud level, no sample taken
October	24/10/12	5.610	28.350									water level obtained by moist mud level, no sample taken
November	21/11/12	5.630	28.330									water level obtained by moist mud level, no sample taken
Poison Gully Creek (at Milner Road)												
September	28/09/11				7.21		0.640	14.80	9.030	87.30	181.4	
October	19/10/11	<0.20cm			6.75	-0.46	0.700	16.60	8.700	89.10	208.9	Less flow than September
November	14/11/11	<0.20cm										Similar flow to October
December	22/12/11											Creek is dry
January	16/01/12											Creek is dry
February	22/02/12											Creek is dry
March	27/03/12											dry
April	23/04/12											dry
May	24/05/12											dry
June	27/06/12	50 cm										no samples taken
July	26/07/12	25 cm										no samples taken
August	29/08/12	50 cm										no samples taken
September	26/09/12	50 cm										no samples taken
October	24/10/12	45 cm										Samples taken
November	21/11/12	Dry										Creek is dry
December	20/12/12											
Water Corporation Bore off Noble street (near railway tracks in bushland area)												
May	24/05/12	3.041										Depth to Ground: 5.570
June	27/06/12	2.970										
July	26/07/12	2.910										
August	29/08/12	2.870										
September	26/09/12	2.750										
October	24/10/12	2.450										
November	21/11/12	2.330										
December	20/12/12	2.590										



GROUNDWATER LABORATORY
ANALYTICAL RESULTS

		Physio-chem	Metals and Metaloids							Nutrients							
Sample Identification Number	Sample Date	pH	Arsenic	Cadmium	Copper	Chromium	Nickel	Lead	Zinc	Ammonia as N	Nitrite as N	Nitrate as N	Nitrite + Nitrate as N	Total Kjeldahl Nitrogen as N	Total N	Total Phosphorus (Kjeldahl Digestion)	Reactive Phosphorus as P
Units		pH Unit	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
The Swan Canning Water Quality Improvement Plan (short term limits)															2	0.2	
The Swan Canning Water Quality Improvement Plan (Long term limits)															0.5	0.05	
ANZECC & ARMCANZ (2000) guidelines for slightly disturbed ecosystems in South West Australia		6.5 - 8.5															
ANZECC & ARMCANZ (2000) guidelines for fresh and marine water quality - 95% trigger value (Freshwater)			24	0.2	1.4	1	11	3.4	8								
Australian Drinking Water Guideline (2000)												11.3					
MB01	28/09/2011	6.61															
	19/10/2011	6.62	9	<0.1	24	2	11	62	170	0.65	0.27	1.2	1.47	1	2.4	0.61	0.003
	16/01/2012	5.87	7	<0.1	44	7	22	100	520	1.9	0.029	0.97	0.999	4.9	5.9	1.7	<0.002
	23/04/2012	5.68								0.066	<0.05	1.12	5.25	0.66	1.8	0.41	<0.002
	26/07/2012	5.84								0.09	<0.05	0.63	0.66	0.45	1.1	0.21	0.008
	21/11/2012	6.07								0.0464	0.2	0.25	0.45	0.66	0.93	0.68	<0.005
MB02	28/09/2011	5.03															
	19/10/2011	4.84	<1	<0.1	<1	<1	<1	3	19	0.046	<0.005	0.13	0.1325	0.42	0.55	0.22	<0.002
	16/01/2012	4.85	<1	<0.1	7	5	2	10	31	0.14	<0.05	0.2	1.125	0.92	1.2	0.46	<0.002
	23/04/2012	4.63								0.047	<0.05	0.22	1.005	0.43	0.65	0.82	<0.002
	26/07/2012	4.91								0.05	0.006	0.22	0.23	0.51	0.74	0.23	0.008
	21/11/2012	4.85								0.175	<0.005	0.018	0.018	0.96	0.98	0.12	<0.005
MB04	28/09/2011	5.03															
	19/10/2011	4.82	<1	<0.1	<1	1	3	4	46	0.15	0.012	0.11	0.122	0.92	1	2.4	<0.002
	16/01/2012	4.62	<1	<0.1	9	3	1	9	18	0.20	<0.05	0.02	0.115	1.1	1.1	1.1	<0.002
	23/04/2012	4.28								<0.005	<0.05	<0.05	0.05	0.62	0.62	1	<0.002
	26/07/2012	4.57								0.12	<0.05	<0.005	NR	1.2	1.2	1.3	0.006
	21/11/2012	4.38								0.035	<0.005	0.069	0.069	2.3	2.3	0.84	<0.005
MB05	28/09/2011	5.73															
	19/10/2011	6.06	<1	<0.1	1	2	3	50	20	0.120	0.014	4.5	4.514	0.88	5.4	5.7	<0.002
	16/01/2012	5.03	<1	<0.1	5	7	2	48	30	0.026	<0.05	4.74	21.025	0.041	5.1	2.3	0.003
	23/04/2012	5.42								0.037	<0.05	5.41	24.025	0.62	6	4.8	<0.002
	26/07/2012	5.75								0.06	<0.05	4.5	4.5	0.91	5.4	3.4	0.002
	21/11/2012	5.32								0.065	<0.005	4.8	4.8	2.1	6.9	4.5	<0.005
MB06	28/09/2011	5.18															
	19/10/2011	4.94	<1	<0.1	16	1	4	89	56	0.047	<0.005	0.13	0.1325	1.5	1.7	0.69	<0.002
	16/01/2012	4.84	2	<0.1	36	12	4	270	75	0.27	<0.05	0.022	0.1025	2.8	2.8	1.9	<0.002
	23/04/2012	4.55								0.038	<0.05	<0.05	0.05	0.31	0.31	0.12	<0.002
	26/07/2012	4.93								0.13	<0.05	0.012	0.037	1.8	1.8	0.58	0.005
	21/11/2012	5.15								0.052	<0.005	0.058	0.058	5.2	5.3	1.2	<0.005
MB07	28/09/2011	6.20															
	19/10/2011	6.15	<1	<0.1	13	2	4	6	66	0.037	<0.005	7.5	7.5025	0.43	8	0.38	<0.002
	16/01/2012	5.84	<1	<0.1	18	8	3	7	58	0.10	<0.05	6.32	28.0025	0.91	7.3	0.77	<0.002
	23/04/2012	6.05								0.098	<0.05	7.67	34.025	0.25	8	0.2	<0.002
	26/07/2012	6.34								0.08	<0.05	1.6	1.6	5.5	7.1	1.6	0.003
	21/11/2012	6.25								<0.005	<0.005	6.1	6.1	4.1	10	1.1	<0.005
MB08	28/09/2011	6.15															
	19/10/2011	6.03	<1	<0.1	6	<1	<1	8	14	0.023	<0.005	22	22.0025	0.81	23	0.18	<0.002
	16/01/2012	5.83	2	<0.1	47	10	5	240	170	0.19	<0.005	20.32	90.0025	4.3	25	0.72	<0.002
	23/04/2012	IS								IS	IS	IS	IS	IS	IS	IS	IS
	26/07/2012	IS								0.03	<0.05	18	18	2.5	20	0.52	0.017
	21/11/2012	6.58								0.15	<0.005	13	13	5.7	18	1.2	0.013
MB09	28/09/2011	6.02															
	19/10/2011	6.68	<1	<0.1	4	<1	<1	3	20	0.03	<0.005	0.54	0.5425	0.76	1.3	0.08	<0.002
	16/01/2012	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS
	23/04/2012	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS
	26/07/2012	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS
	21/11/2012	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS	IS
Posion Gully	28/09/2011	7.21															
	19/10/2011	6.75	<1	<0.1	<1	<1	<1	<1	22	0.024	<0.005	0.15	0.1525	0.28	0.42	<0.01	<0.002
	16/01/2012	IS								IS	IS	IS	IS	IS	IS	IS	IS
	23/04/2012	IS								IS	IS	IS	IS	IS	IS	IS	IS
	24/10/2012	IS								<0.005	<0.005	<0.005	<0.005	0.36	0.36	0.01	<0.02
Groundwater statistics	max	7.21												max	25	5.7	
	min	4.28												min	0.31	0.08	
	median	5.71												median	2.35	0.77	

nr - not recorded
NA - Not analysed
IS -Insufficient sample

Shire of Kalamunda – Mapping

MB03 – not cased. Do not include in monitoring

FORRESTFIELD/HIGH WYCOMBE PROPOSED INDUSTRIAL AREA – STAGE 3

N

Appendix 4

Foreshore assessment

STRATEGEN
environmental consultants

Mr Andrew Fowler-Tutt
Manager Development Services
Shire of Kalamunda
PO Box 42
KALAMUNDA WA 6926

Reference: SKA11210.02

Dear Mr Fowler-Tutt

POISON GULLY CREEK FORESHORE ASSESSMENT

A foreshore assessment of Poison Gully Creek has undertaken by Strategen to support an Environmental Review of the proposed rezoning of the Forrestfield Industrial Area (FIA) Stage 3 (the Project) from ‘Rural’ to ‘Light Industrial’, under the Metropolitan Region Scheme. The foreshore assessment is intended to inform the establishment of an appropriate foreshore reserve on the northern boundary of the Project.

A foreshore is the land that adjoins or directly influences a waterway (WRC 2001). More specifically, it is the area of transition between the edge of the waterway and the furthest extent of riparian vegetation, flood prone land, and riverine landform or simply the adjacent upland (WRC 2001). Where human activities have affected the waterway, the foreshore area may be the land between the waterway and the area actively being used (WRC 1999, *Statewide Foreshore Policy – Policy Update No. 2*).

The FIA Stage 3 will be located to the south of Poison Gully (the creek) between Roe Highway and Maida Vale Road (Figure 1). Discussions with the Department of Water (Mackintosh J [Department of Water] 2011, pers. comm. 22 November) indicated that assessment of the southern boundary of the Poison Gully foreshore between Roe Highway in the east and Maida Vale Road in the west would be adequate to support development of FIA Stage 3.

The foreshore assessment involved a desktop review of existing information and a site visit. The site visit was completed on 28 May 2012 by Strategen. The creek was predominantly dry at the time of the site visit, with pools of standing water present at Littlefield Road and areas to the west of this. The assessment considered the following biophysical criteria; vegetation, hydrology, soil type, geology, topography, habitat, land use and heritage, based on the guidelines in *Determining Foreshore Reserves* (WRC 2001).

The channel of the creek is predominantly located within an existing foreshore reserve that is zoned for ‘public recreation and drainage’ (ID&A 2001). The creek runs though private property at locations near Maida Vale Road and immediately to the east of Milner Road. The boundary of private property is shown as the ‘Project boundary’ on the figures.

Topography

The creek is deeply incised along its length adjacent to FIA Stage 3, with the steepest gradient occurring on the eastern extent of the creek. The level of the base of the creek varies from approximately 41 meters Australian Height Datum (mAHD) at Roe Highway in the east to approximately 32 mAHD at Maida Vale Road (Figure 2). The creek flows in a westerly direction. Figure 2 illustrates 0.2 m topographical contours of the creek.

The form of the creek changes from east to west. East of Littlefield Road, the creek comprises a 1-2 m deep low flow channel with a top width of approximately 2 m, contained within a larger 3-6 m deep incised channel with a 20 to 30 m top width (ID&A 2001). In some isolated points, the low flow channel abuts the sides of the larger incised channel, resulting in a vertical exposed bank of 3 to 5 m in height(Plate 1). Further west (downstream), the creek becomes less incised and shallower, with an approximately 0.5 m deep low flow channel with a width of approximately 1-2 m, with the outer incised channel reducing to a depth of 2 to 3 m and becoming less steep at the far western end, near Maida Vale Road.

Plate 1 Photograph taken from low flow channel of Gully, showing steep banks of approximately 4 m in height (photo taken between Roe Highway and Littlefield Road)

Plate 2 Exposed tree roots on bank of low flow channel, east of Milner Road

The steeper banks of the stream are often vertical or close to vertical and are potentially quite dangerous to persons who may access the area. At many locations, these banks are very close to property boundaries or are within the properties themselves (Figure 2). Where steep banks abut property boundaries, the removal of trees and other vegetation and the construction of large structures may increase the risk of erosion, with impacts on both Poison Gully and the structures involved.

Soil type and geology

The geology of Poison Gully in this area is described in the regional mapping as Bassendean Sands (light grey fine to medium grained quartz sands of eolian origin) over the sands and silts of the Guildford Formation soils (Gozzard 1986). This geological unit extends over Poison Gully and the surrounding Forrestfield area (Gozzard 1986). The soils of the creek were predominantly sand to sandy clay in the west of the site, becoming more consolidated, cemented and clayey to the east.

A small patch (less than 0.5 m by 0.5 m) of rock was observed at the bottom of the creek at one location to the east of Littlefield Road. This rock appeared to be limestone-like in nature.

Hydrology

1 in 100 year Average Return Interval (ARI) flood level modelling for Poison Gully was undertaken by Water Corporation (2010). This flood modelling indicates a 1 in 100 year ARI flood level ranging between 39.81 mAHD at Roe Highway and 32.36 mAHD at Maida Vale Road (Figure 3). The flood height at Roe Highway is considered likely to be underestimated, as the invert level of the creek at this point is greater than 40 mAHD, above the Water Corporation Flood level (Figure 3). Based on the Water Corporation modelling, Poison Gully will overtop the road at Milner Road in the 1 in 100-year ARI event (Figure 3).

Flood levels and extent of flooding were interpolated from the Water Corporation modelling by Strategen along Poison Gully (Figure 3). Extents of flooding and levels shown have been estimated for the purpose of the foreshore assessment based on this modelling. The accuracy and results of this modelling have not been checked by Strategen. The mapping is therefore considered indicative and persons undertaking construction or other works adjacent to Poison Gully should make their own assessments of the flooding risks involved.

The width of flooding is variable, ranging from less than 10 m to approximately 40 m at the widest point. The Water Corporation modelling does not identify a separate floodway (area of fast flow) and flood fringe (area of slower water movement). For the purposes of this study, it has been assumed that the whole width of the inundated area is floodway.

Erosion

Evidence of erosion was observed to varying degrees along the length of Poison Gully Creek at the time of the site visit. The outer vertical banks are comprised of a consolidated and lightly cemented alluvium. These banks appear relatively stable and the rates of erosion are anticipated to be very low (ID&A 2001). However, other vertical eroding banks were evident in the low flow channel, as identified by IDA (2001). ID&A (2001) considered that the erosion was consistent with a stream in 'good to high physical condition'.

Vegetation

Vegetation mapping of lots, but not the existing foreshore reserve, was undertaken by Shire of Kalamunda as part of the works for the Project. Vegetation within the lots is predominantly cleared, but some patches of Marri woodland and Jarrah/Banksia woodland in good condition occur near Maida Vale Road and at one location between Roe Highway and Littlefield Road (Figure 4, Maps 1 and 4).

Formal mapping of vegetation within the existing foreshore reserve was not undertaken as part of this study. Because of the steepness of the banks and narrow nature of the main flow channel, there is little classical wetland vegetation such as sedges or rushes present.

Vegetation condition within the Foreshore Reserve varied between completely degraded and good to very good. The best vegetation within the Foreshore Reserve was located adjacent to and within the good vegetation mapped on lots near Maida Vale Road and between Littlefield Road and Roe Highway. A variety of introduced plant species are present along the creek, including watsonia (*Watsonia bulbillifera*) and Spanish bamboo (*Arundo donax*). The area immediately to the east of Milner Road is heavily infested with morning glory (*Ipomoea indica*) (Plate 3). Native and introduced vegetation plays an important role in terms of bank stabilisation.

Plate 3 Morning glory infestation of Poison Gully on private land at Milner Road.

This section of Poison Gully, including most of the foreshore reserve and some surrounding bush is recognised as a Bush Forever site, because of its regional significance (Figure 4, Maps 1-5). Poison Gully and the surrounding areas west of Littlefield Road are also identified as a Resource Enhancement Category Wetland (REW) (Figure 3, Maps 1-3).

The upland vegetation is considered important for the maintenance of the health of Poison Gully as the root systems assist in bank stabilisation, and also for nutrient stripping and habitat purposes. The Bush Forever site is considered to represent the minimum area of vegetation requiring protection. Where areas of good vegetation extend beyond this, the extent of this bushland has been taken into account in delineating the vegetation boundary (Figure 4, Maps 1 and 4). Mapping of native vegetation has been undertaken based on aerial photography.

Habitat

Waterways are important for conservation as they can provide important breeding and feeding sites for fauna. Poison Gully Creek is an ephemeral waterway. At the time of the site visit, a small pool of standing water was present near Littlefield Road and a few other minor pools were observed to the east of Littlefield Road. Rain had not occurred for more than a week prior to the survey.

The vegetation in the foreshore area may provide habitat for species including Quenda and black cockatoo (Bamford 2012).

Land use

The proposed FIA Stage 3 lies to the south of Poison Gully Creek. This area is currently zoned 'Rural' and is predominantly rural residential. To the north of the creek lies residential development.

Protecting existing residential and future proposed Light Industrial land uses from inundation and erosion must be considered in establishing a foreshore reserve.

Heritage

Poison Gully Creek is a registered Aboriginal heritage site (Site 25023) and is considered a birthplace and water source.

Rationale for foreshore boundary

The foreshore boundary has been delineated based on consideration of bank steepness, presence of native vegetation and the extent of the 1 in 100 year flood (Figure 5). These factors have been considered through:

- bank steepness- assessment of topographic mapping provided in Figure 2, to determine where steep banks occur and ensure that these are protected
- 1 in 100 year flood mapping based on interpolation of Water Corporation modelling (Figure 3)
- presence of quality native vegetation based on retention of vegetation identified as being in good condition from Bush Forever, Shire mapping of quality vegetation within the Project Area and observations of vegetation undertaken during the site inspection, as identified by the vegetation boundary in Figure 4.

The foreshore boundary represents the outer limits of these three boundaries. Where good quality vegetation identified by the Shire mapping extends well beyond the foreshore into Stage 3, a compromise has been made to ensure a practical boundary.

The most important factor has generally been the floodway and the presence of native vegetation that stabilises the banks and strips nutrients. The steep banks that may require stabilisation are generally within this area, as these banks are difficult to clear and generally avoided. The 1 in 100 year floodway rarely extends beyond the vegetation boundary at few locations, most notably to the east of Milner Road (Figure 5). The recommended foreshore boundary for the site is presented in Figure 5.

Buffers

The lower sections of Poison Gully are categorised as a Resource Enhancement Category wetland. The use of a 30-50 m buffer is recommended to areas of REW.

The area within the foreshore boundary is anticipated to remain as a REW. The foreshore to the east of this area is considered to be of a similar or better quality to the foreshore within the REW area. The foreshore should therefore be afforded a similar buffer to that applied to a REW. This buffer should be assessed at the LSP stage.

Yours sincerely

Darren Walsh
SENIOR PRINCIPAL

19 October 2012

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Figure 1 Location plan

Figure 2 Aerial and detailed topography

Figure 3 1 in 100 year flood mapping

Figure 4 Vegetation

Figure 5 Foreshore boundary

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Scale

0 50 100

metres

N

Figure 1 Location plan

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:4,500 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

🟥 Project Boundary
🟨 Map pages

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Figure 2 Map 1

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Scale
0 10 20
metres

N

Legend
- Elevation 1 m (mAHD)
- Elevation 20cm (mAHD)
- 🟥 Project Boundary

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Scale

0 10 20

metres

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Figure 2 Map 2

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

—	Elevation 1 m (mAHD)
—	Elevation 20cm (mAHD)
▭	Project Boundary

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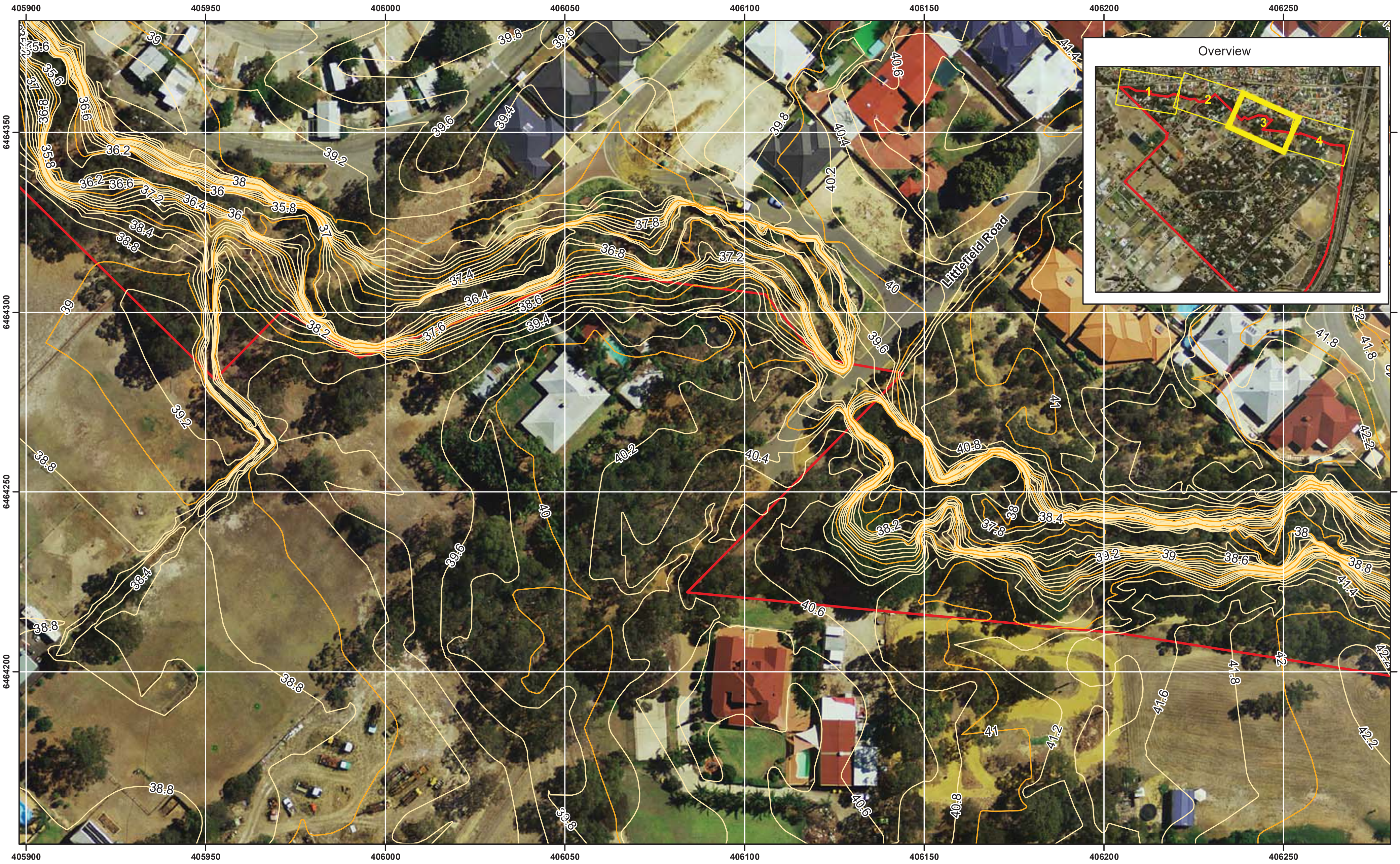

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Scale

0 10 20

metres

N

Figure 2 Map 3

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- Elevation 1 m (mAHD)
- Elevation 20cm (mAHD)
- 🟥 Project Boundary

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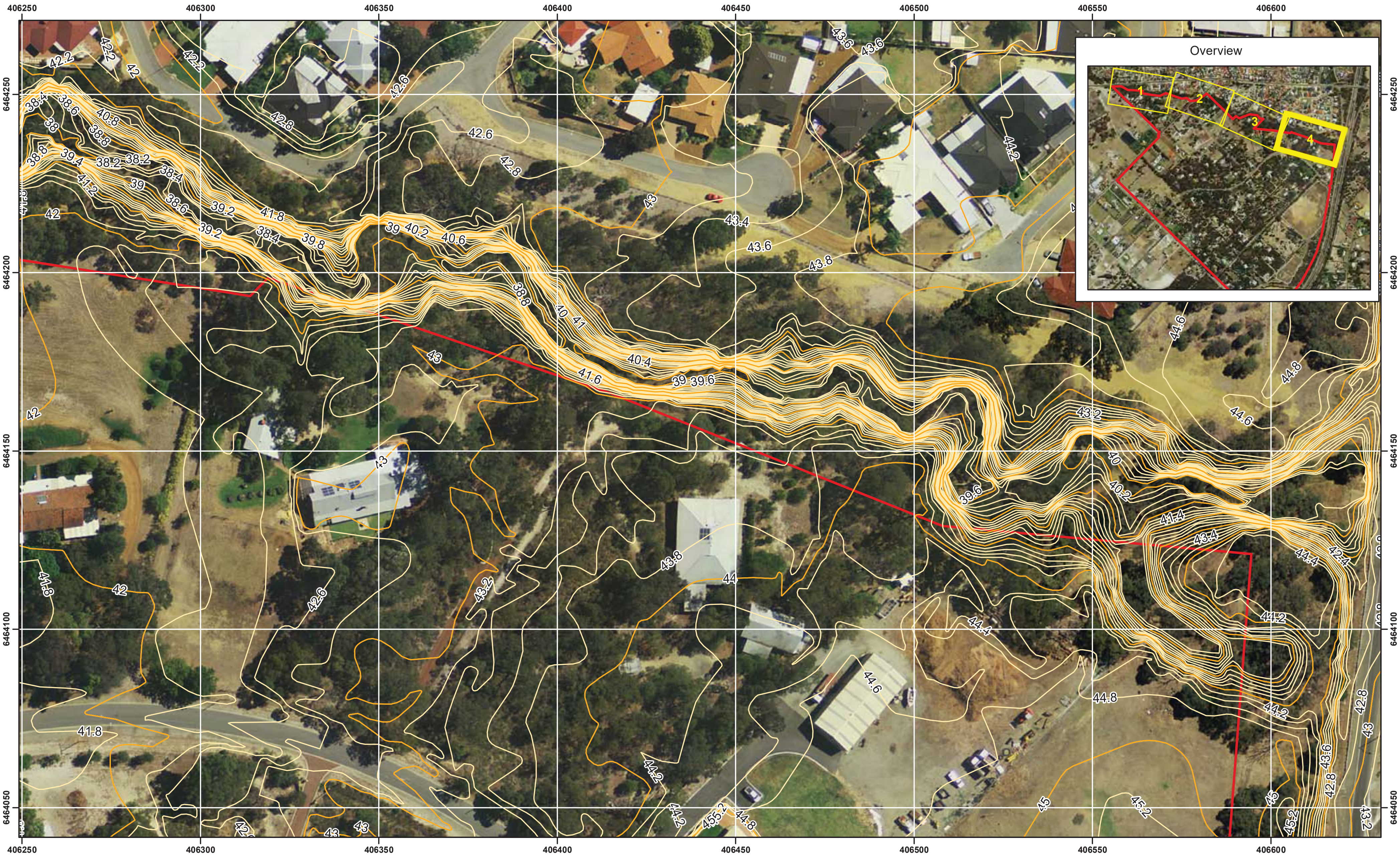

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Scale

0 10 20

metres

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Figure 2 Map 4

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

—	Elevation 1 m (mAHD)
—	Elevation 20cm (mAHD)
▭	Project Boundary

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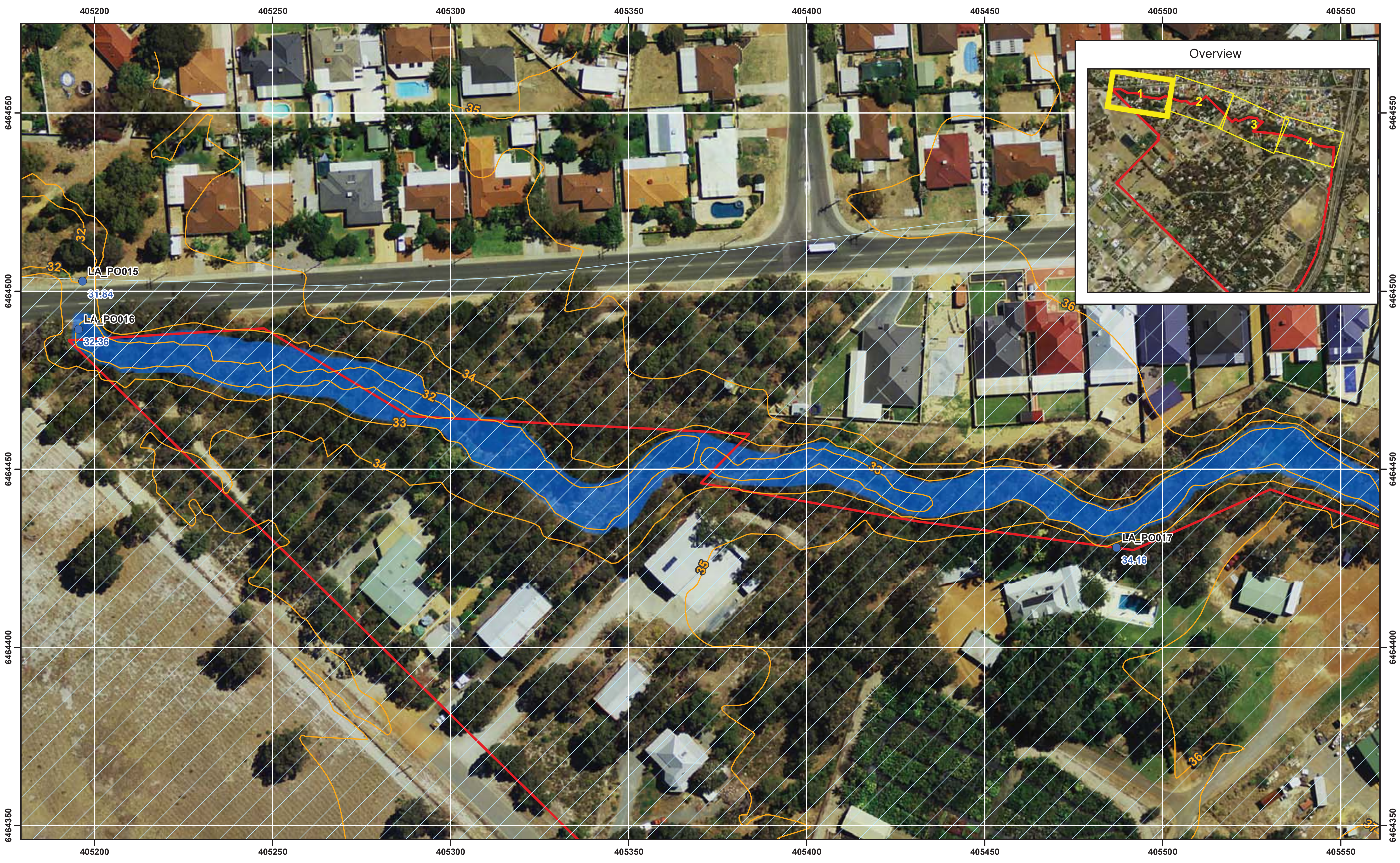

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Scale

0 10 20
metres

N

Figure 3 Map 1

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

●	100 year Flood Modelling Points (Water Corporation)
—	Elevation (mAHD)
▨	Resource Enhancement Wetland
🟥	Project Boundary
🟦	Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

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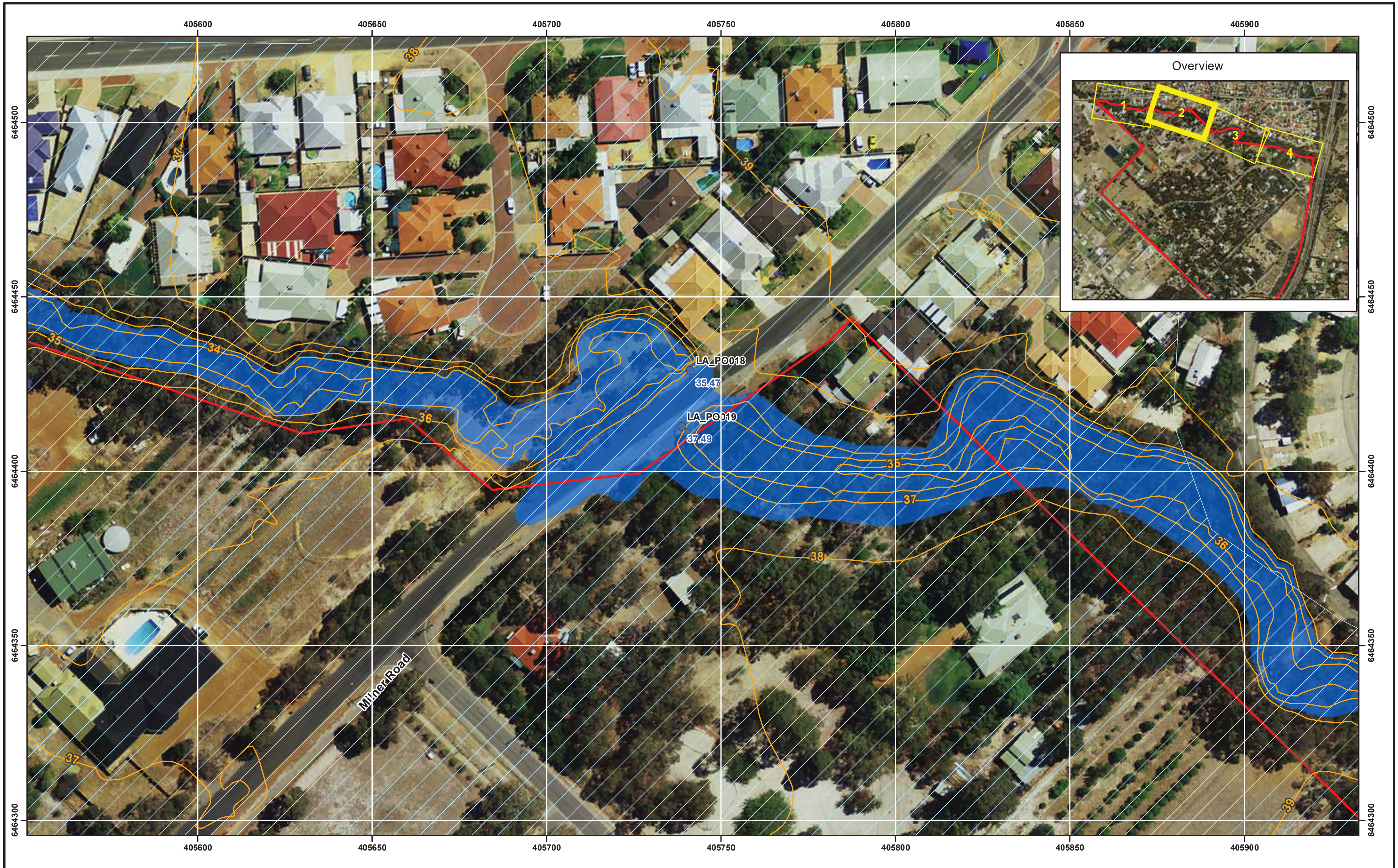

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Scale

0 10 20

metres

N

Figure 3 Map 2

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- ● 100 year Flood Modelling Points (Water Corporation)
- — Elevation (mAHD)
- ▨ Resource Enhancement Wetland
- ☐ Project Boundary
- ■ Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

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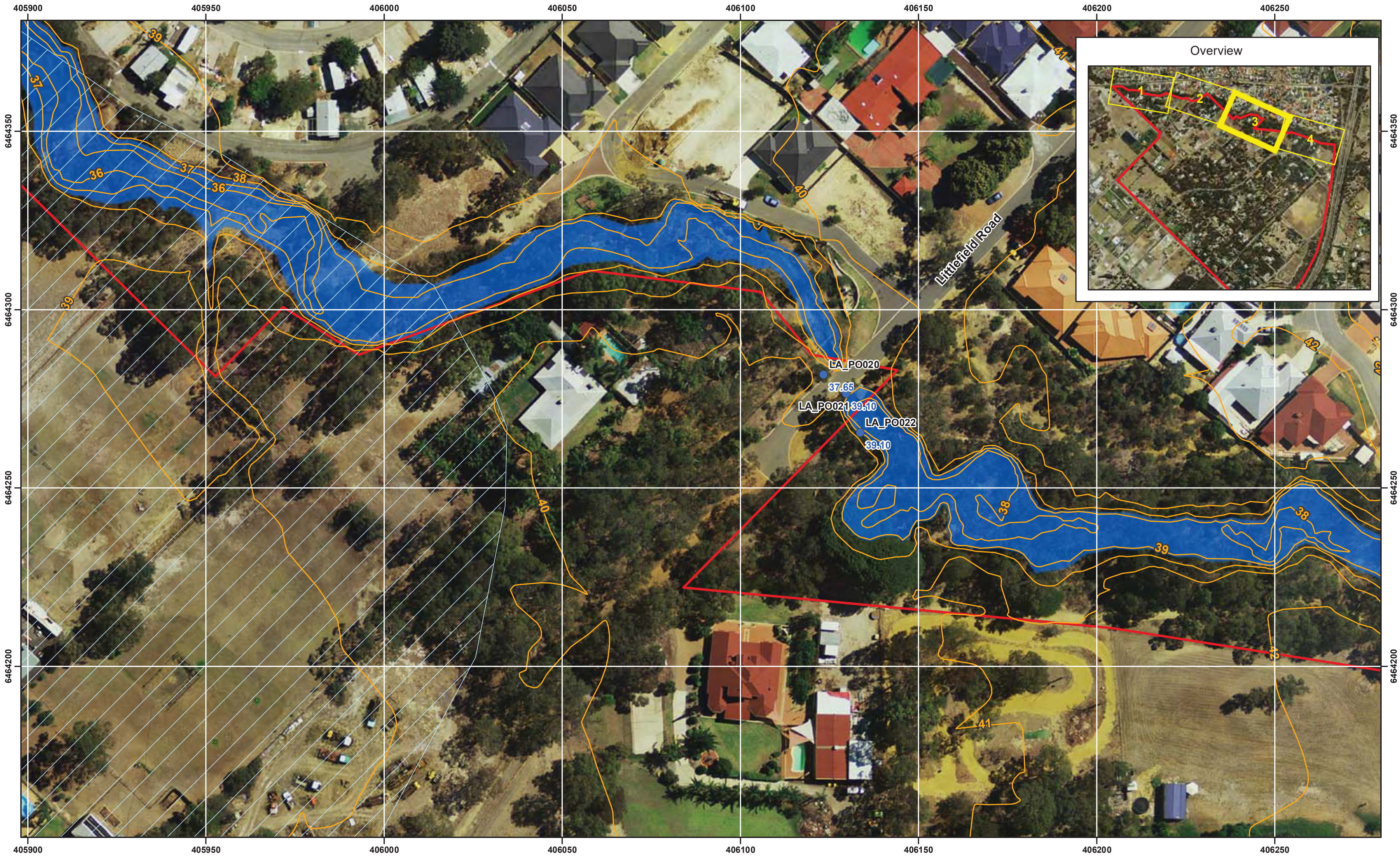

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Scale

Figure 3 Map 3

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- ● 100 year Flood Modelling Points (Water Corporation)
- — Elevation (mAHD)
- ☐ Resource Enhancement Wetland
- 🟥 Project Boundary
- 🟦 Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

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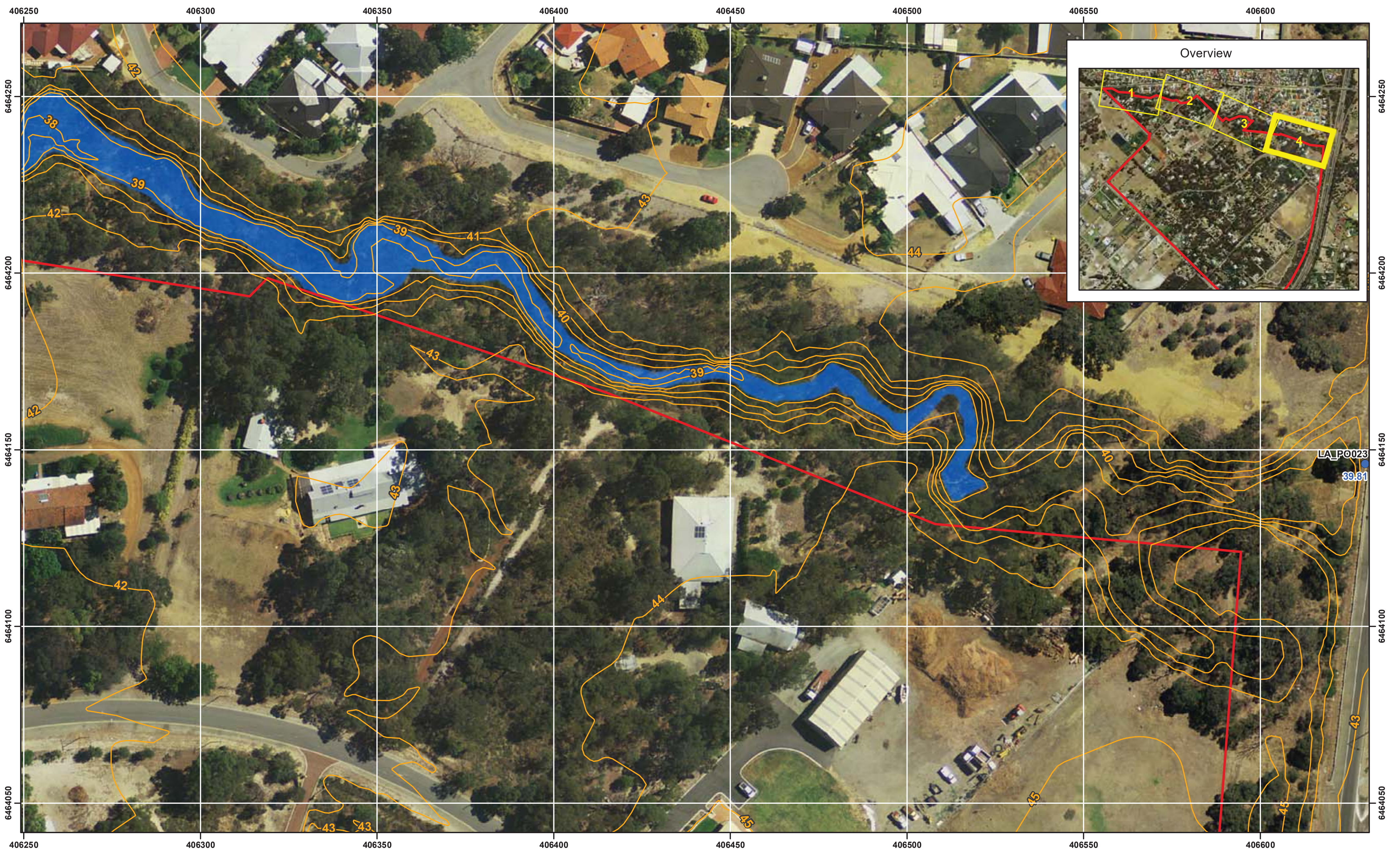

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Scale
0 10 20
metres

N

Figure 3 Map 4

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- ● 100 year Flood Modelling Points (Water Corporation)
- — Elevation (mAHD)
- ☐ Resource Enhancement Wetland
- ☐ Project Boundary
- ■ Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F003_A3.mxd

Figure 4 Map 1

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Scale
0 10 20
metres

N

Legend

- Vegetation boundary
- Elevation (mAHD)
- ▨ Bush Forever site
- 🟥 Project Boundary
- ▨ Jarrah/Banksia Woodland
- ▨ Jarrah/Sheoak Woodland
- ▨ Marri Woodland

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Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F004_A3.mxd

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Scale

0 10 20

metres

N

Figure 4 Map 2

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- Vegetation boundary
- Elevation (mAHD)
- Bush Forever site
- Project Boundary
- Jarrah/Banksia Woodland
- Jarrah/Sheoak Woodland
- Marri Woodland

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F004_A3.mxd

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Scale

0 10 20

metres

N

Figure 4 Map 3

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

🟩 Vegetation boundary	▨ Jarrah/Banksia Woodland
— Elevation (mAHD)	▨ Jarrah/Sheoak Woodland
▨ Bush Forever site	▨ Marri Woodland
🟥 Project Boundary	

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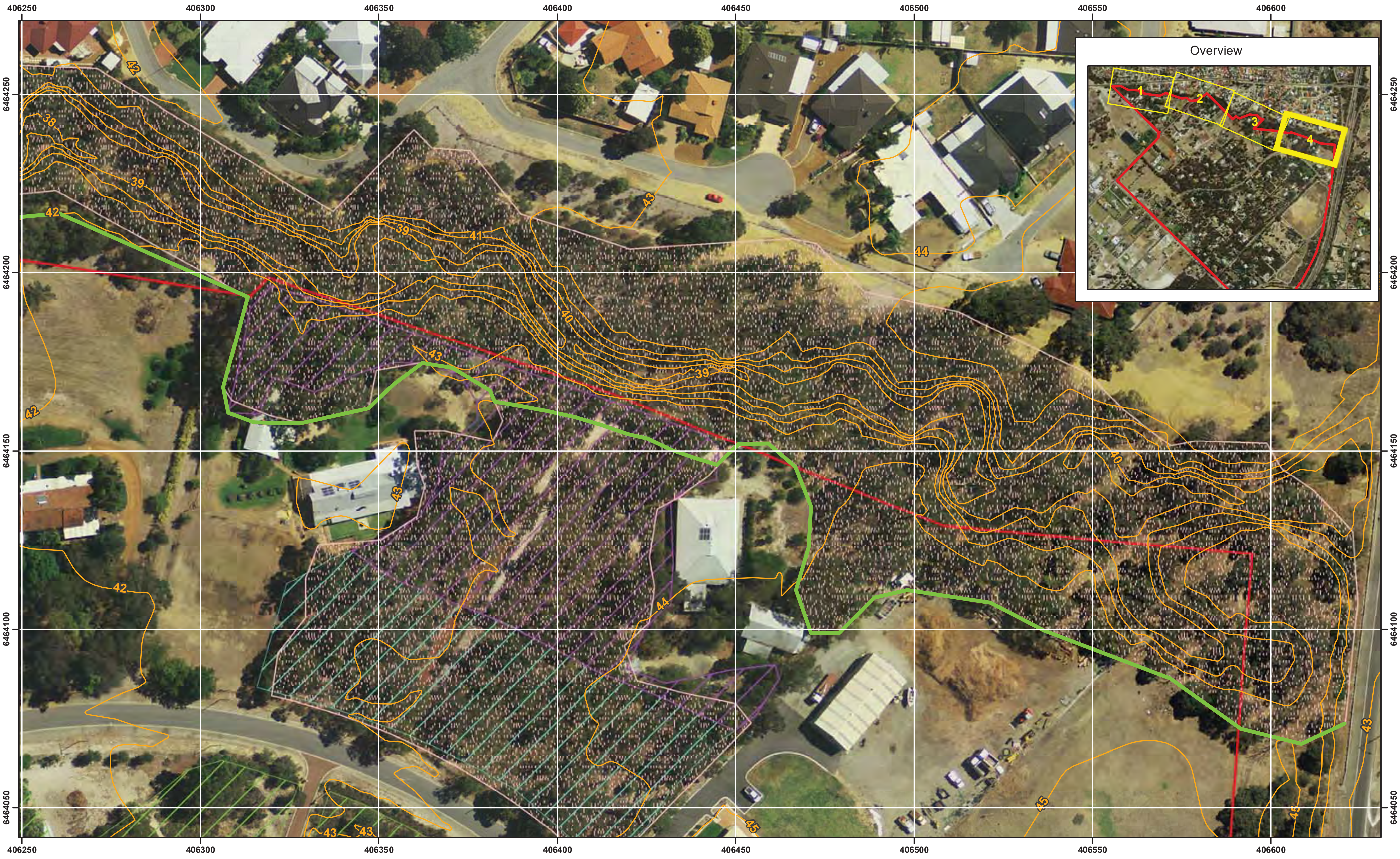

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Scale
0 10 20
metres

N

Figure 4 Map 4

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend
- Vegetation boundary
- Elevation (mAHD)
- Bush Forever site
- Project Boundary
- ▨ Jarrah/Banksia Woodland
- ▨ Jarrah/Sheoak Woodland
- ▨ Marri Woodland

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F004_A3.mxd

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Scale

0 10 20

metres

N

Figure 5 Map 1

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

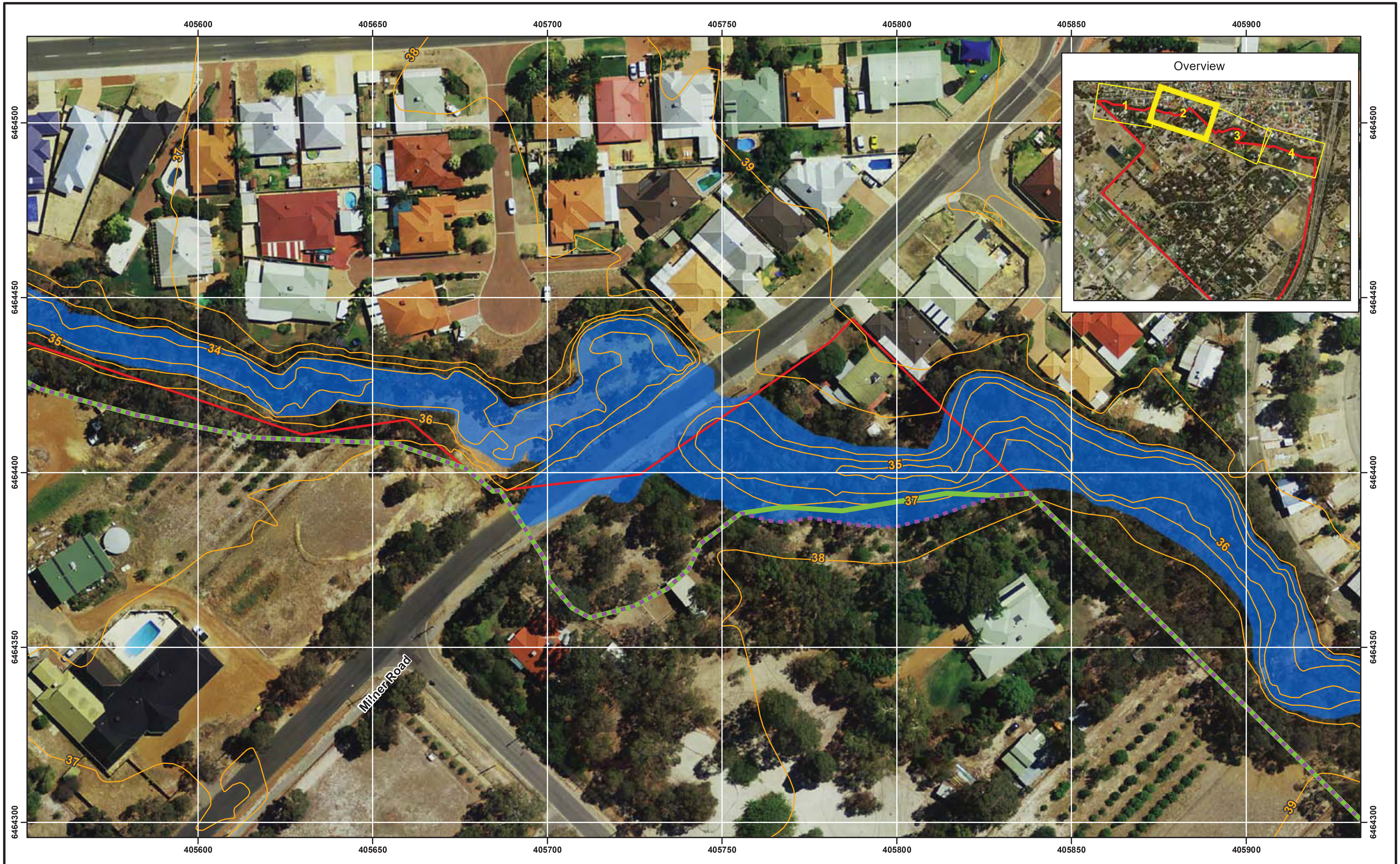
Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- ▪▪ Foreshore boundary
- ▬ Vegetation boundary
- — Elevation (mAHD)
- ☐ Project Boundary
- 🟦 Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F005_A3.mxd



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Scale

0 10 20
metres

N

Figure 5 Map 2

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

- ▪ ▪ Foreshore boundary
- ▬ Vegetation boundary
- — Elevation (mAHD)
- ☐ Project Boundary
- ■ Estimated 100 year flood area*

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F005_A3.mxd

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Scale

0 10 20

metres

N

Figure 5 Map 3

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

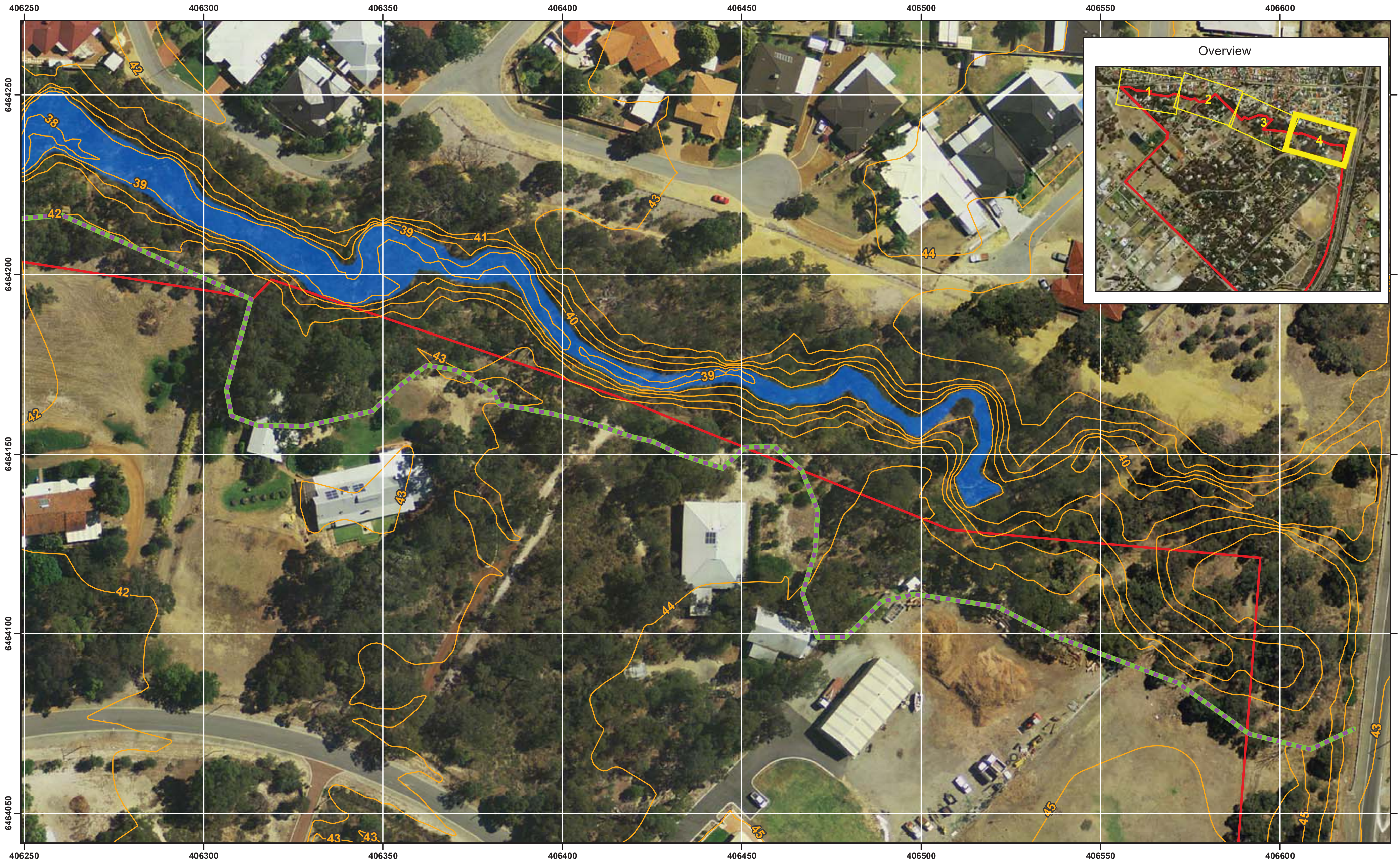
Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

▪▪ Foreshore boundary	🟥 Project Boundary
▬ Vegetation boundary	🟦 Estimated 100 year flood area*
— Elevation (mAHD)	

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F005_A3.mxd



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Scale

0 10 20

metres

N

Figure 5 Map 4

Coordinate System: GDA 1994 MGA Zone 50
Date: 13/09/2012
Author: JCrute
Note that positional errors may occur in some areas

Scale: 1:1,000 at A3
Source: Aerial image, Topography,
Project boundary: Client 2012.
Vegetation: Shire of Kalamunda 2012

Legend

▪▪ Foreshore boundary	🟥 Project Boundary
▬ Vegetation boundary	🟦 Estimated 100 year flood area*
— Elevation (mAHD)	

*1 in 100 year ARI flood levels have been projected based on Water Corporation modelling.

Path: Q:\GIS\Consult\2011\SKA\SKA11210\ArcMap_Documents\L001\SKA11210_02_L001_F005_A3.mxd

Appendix 5
Agency meeting minutes

Level 1, 50 Subiaco Square Road Subiaco WA 6008 PO Box 243 Subiaco WA 6904
Phone (08) 9380 3100 Fax (08) 9380 4606
177 Spencer Street Bunbury WA 6230 PO Box 287 Bunbury WA 6231
Phone (08) 9792 4797 Fax (08) 9792 4708

Forrestfield North – meeting with Department of Environment and Water Regarding MAR

Time	1:30 pm	Job code	TPG16528.01
Date of meeting	29/09/17	**Client**	City of Kalamunda
		Scribe	M. Dunlop
Purpose of meeting	Discussion of the potential for MAR and drainage design at Forrestfield North		

Attendees

Name	Organisation	Name	Organisation
Peter Varelis	City of Kalamunda	Steve O'Brien	DWER
Doug Bartlett	City of Kalamunda	Chris O'Boy	DWER
Murray Casselton	TPG	Matt Viskovich	DWER
Dale Newsome	Strategen	Carlie Slodecki	DWER
Margaret Dunlop	Strategen	Steve Watson	DWER

Minutes / Notes

1. Strategen advised the project team is investigating MAR as one option for water supply for POS at Forrestfield North. This will be put into the two LWMSes for Forrestfield North (TOD Precinct and Residential Precinct). Other options include water trading with other users within the sub-area or reallocation of water within existing City of Kalamunda (COK) water licences to allow for flexibility. Forrestfield North is anticipated to be a joint COK/Metronet project.
2. TPG advised Forrestfield North will be a high density development (approx. 6,700 dwellings) with a focus on innovation and sustainability. There is also a high percentage POS (approx. 20%) with 10% being retained natural spaces. District Playing Fields are proposed on top of the former Brand Road Landfill to meet the shortfall of Playing Fields in the broader COK. The City is planning to undertake a Detailed Site Investigation and Geotechnical Investigation to confirm the suitability of the former landfill for this use.
3. DWER advised that PTA had installed a Leederville Aquifer abstraction bore to provide water for the Forrestfield Airport Link project near the future Forrestfield Station. The bore is approximately 100 m deep and has a temporary allocation for dewatering (i.e. allocation cannot be transferred for POS use). A H2 level hydrogeological report for the Leederville abstraction licence was prepared by PTA, which includes pump test and geological results. This would be useful to better assess the feasibility of MAR. The bore may be suitable for future MAR use but is not located in the vicinity of proposed POS. Resolving this issue is not likely to be in the timeframe required for the Structure Plan and consequently LWMS. **Action:** COK to request hydrogeological reporting for the bore.
4. DWER accepts that the LWMSes may present a Plan A/Plan B approach as the funding for MAR is uncertain (would require financial support from outside COK) provided that the non-MAR option could be demonstrated to work. A MAR Pre-feasiblity report is not required for the LWMSes provided that there is another feasible option for POS water supply.
5. DWER advised that the use of MAR based on stormwater should not prevent Water Sensitive Urban Design criteria being met – i.e. treat first 15 mm of rainfall, maintain pre-development flows off the site.
6. COK advised that because this was a Metronet project, there is an emphasis on showcasing WSUD including structures such as tree pits and roadside swales. **Action:** TPG/Creative Direction to provide conceptual cross sections for roads showing WSUD structuresin consultation with Strategen

7. DWER suggested rechecking the Water Register for potential licence transfers from other users within the superficial, as this was last checked for the DWMS and there were large licences within the Structure Plan area. **Action:** Strategen to review Water Register.
8. DWER requested a landscape concept plan and irrigation breakdown to be provided with the LWMSes, in a similar matter to what is required for the North West Corridor (i.e. includes areas and volumes for establishment and ongoing irrigation in each POS). The use of reduced irrigation areas is supported. It was noted by Strategen that (a) a high standard of POS is expected given the high density nature of the area, (b) turf or low fuel landscaping areas will be required for separation of buildings from high fire risk retained bush. **Action:** Strategen to include breakdown tables in LWMSes, with assistance from Creative Direction (landscaper).
9. DWER advised that a draft MAR policy was out for public consultation.
10. DWER (Steve Watson) asked whether there was adequate regional information regarding the drainage system to develop a drainage strategy for the LWMS. Strategen advised that regional drainage planning for the area had been undertaken by Water Corporation in the form of the Perth Airport North and Perth Airport South Arterial Drainage Scheme Reviews. **Action:** DWER to review the ADS reports and advise whether additional regional level work is required. COK would request this information within two weeks of provision of draft meeting minutes.

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Forrestfield North – meeting with Water Corporation regarding Forrestfield North drainage

Time	10:30 am	Job code	TPG16528.01
Date of meeting	06/12/17	**Client**	City of Kalamunda
		Scribe	M. Dunlop
Purpose of meeting	Discussion of the drainage design and allowable discharges for Forrestfield North project		

Attendees

Name	**Organisation**	**Name**	**Organisation**
Katrina Cooper	Strategen	Brett Coombes	Water Corporation
Margaret Dunlop	Strategen	Kanex Kanagaratnam	Water Corporation
Peter Golder	Groundwork	Martin Daniels	Water Corporation

Minutes / Notes

1. Strategen advised the project team is undertaking drainage planning for Forrestfield North. This will be put into the two LWMSes for Forrestfield North (western TOD Precinct and eastern Residential Precinct). Other options include water trading with other users within the sub-area or reallocation of water within existing City of Kalamunda (COK) water licences to allow for flexibility. Forrestfield North will be a high density residential and commercial development. There is also a high percentage POS, which is predominantly being retained for conservation or as playing fields. As a consequence, stormwater storage is proposed to be largely underground.
2. The site covers parts of the Airport North (AN) and Airport South (AS) catchments. The main drainage systems for AN and AS are managed by Water Corporation (WC).
3. Department of Water and Environmental Regulation (DWER) have advised that WC is the main advising body regarding drainage design for Forrestfield North because of the AN and AS drainage. The purpose of this meeting is to seek advice from WC regarding the allowable discharge rates and any other EC requirements with respect to drainage on the sites.
4. WC emphasised the requirement for post-development flows to be the same as or less than pre-development flows for the critical duration, partially due to commitments made to Perth Airport.
   Action: WC to confirm critical duration for AN and AS. Likely to be the 24 or 36 hour event.
   Timeframe: TBC by WC
5. WC advised that a pre-development loss model would need to be developed for the site and endorsed by WC. This comment notes that:
   - Historic modelling has not used a consistent loss model for AN and AS.
   - The 6 L/s/ha quoted in the WC AN report is an average over the catchment rather than a prescriptive value as pre-development flow rates depend on factors such as soil type and land use
   - The pre-development model should consider the extent of any pre-development storages on the site – e.g. significant natural low points that hold stormwater after rainfall events.
   - The pre-development loss model and the critical duration will determine the pre-development flows from the project area.
   - **Action:** Addendum 1 provided subsequent to meeting showing proposed parameters and loss model **Timeframe:** WC advises a likely 3 week period to review the model.
6. The project team advised that flows will be balanced across the two LWMS areas – i.e. flows may be lower from the eastern sandy area and higher from the western clayey, higher density area – but predevelopment flows will be maintained. WC advised that this approach was acceptable

provided the catchment divides were largely maintained. Some flexibility is allowed to match the proposed road layout.

7. The project team is aiming to avoid new outlets to Poison Gully but it is possible these will be required. In terms of invert levels for new outlets into Poison Gully, WC advised that they do not have a policy on this matter. Invert levels in Poison Gully are consequently at the discretion of the City of Kalamunda as owners. Any new outflows should be designed in the context of the WC Main Drain manual. **Action:** Project team to confirm with the City regarding invert levels of any new outlets to Poison Gully if required.
8. WC were advised of the presence of the basin adjacent to Roe Hwy which compensates flows from the east of Roe Hwy and that the overland flow path for this basin has been blocked by industrial development. The City's preferred approach has been to enlarge the basin to contain the total volume of flow from this area. WC advised that the area to the east is identified for urban development and that the basin will need to accommodate the flows from this basin as an urbanised catchment. The flow out of this basin in the pre-development scenario can be used to offset increases in flows in other areas. **Action**: Project team to confer with City regarding post-development flow volumes from the catchment to the east of Roe Hwy.
9. Project team advised that stormwater based Managed Aquifer Recharge was being considered by City of Kalamunda at a whole of local government level. This includes consideration of the Forrestfield North and other sites identified by the City. Superficial groundwater from existing City allocations is being proposed for POS irrigation at this stage.

Addendum 1: Proposed parameters and loss model (information subsequent to meeting)

Land Use	% Impervious	Manning n	
		Pervious	Impervious
Urban Roads	80%	0.04	0.025
R5-R12 Lots	10%	0.05	0.025
R60/80 Lots	90%	0.04	0.025

Retain flows on site or detain initial 16mm – depending on soil/groundwater conditions

Rural Lots	5%	0.04	0.025
Industrial	90%	0.04	0.025
POS	0%	0.04	0.025

Soil Type	Initial	Continuing
Impervious	1.5mm	0mm/hr
BoM - Forrestfield	26mm	6mm/hr (orange sandy surface soils)
Rural Road imp	16mm	6mm/hr
Silty Sand	16mm	6mm/hr
Guildford with some vegetation	10mm	3mm/hr

In the pre-development scenario the assumptions are

- Silty sand within the Perth Airport North catchment
- Forrestfield soil conditions within the Airport South catchment
- Allowance will be made for rural roads and pre-development storage.

Appendix 6
Irrigation schedule

Forrestfield North - Residential Area

Note: Park pavement & turf areas: based on high-level assumptions on path length + play / seating areas

Blocks with irrigation requirements

	Community Use (m2)	Existing Bush Forever (m2)	Environmental Conservation (m2)	POS (m2)	Drainage (m2)	TOTAL (m2)	Pavement / Built Up (m2)	# Trees in pavement (establishment)	Planting (irrigation for establishment (m2)	Turf (permanent irrigation) (m2)	TOTAL (m2)	Temporary irrigation (kL/a)	Permanent irrigation (kL/a)
POS-01				70,222		70,222	8,693	60	13,167	48,363	70,222	8,887	32,645
POS-02				34,942		34,942	550		33,592	800	34,942	22,675	540
POS-03				19,646		19,646	1,251		17,595	800	19,646	11,877	540
POS-04				40,884		40,884	1,920		37,764	1,200	40,884	25,491	810
POS-05				4,699		4,699	690		3,209	800	4,699	2,166	540
POS-06				12,150		12,150	100		11,350	700	12,150	7,661	473
POS-07				608		608	0		208	400	608	140	270
POS-08				647		647	0		47	600	647	32	405
POS-09				481		481	0		481	0	481	325	0
EC-01			19,015			19,015					0	0	0
EC-02			7,017			7,017					0	0	0
EC-03			10,495			10,495					0	0	0
EC-04			6,108			6,108					0	0	0
EC-05			8,082			8,082					0	0	0
EC-06			4,610			4,610					0	0	0
EC-07			6,468			6,468					0	0	0
EC-08			10,449			10,449					0	0	0
EC-09			11,908			11,908					0	0	0
EC-10			3,843			3,843					0	0	0
EC-11			4,866			4,866					0	0	0
EC-12			3,991			3,991					0	0	0
EC-13			3,833			3,833					0	0	0
DB-01					8,441	8,441	690		7,751		8,441	5,232	0
DB-02					2,828	2,828	312		2,116	400	2,828	1,428	270
DB-03					4,860	4,860	550		3,910	400	4,860	2,639	270
DB-04					5,620	5,620	550		4,270	800	5,620	2,882	540
DB-05					3,510	3,510	480		2,630	400	3,510	1,775	270
DB-06					3,964	3,964	84		3,080	800	3,964	2,079	540
DB-07					8,886	8,886	700		7,386	800	8,886	4,986	540
BF-01		10,412				10,412					0	0	0
						333,485	16,570	60	148,556	57,263	222,388	100,275	38,652

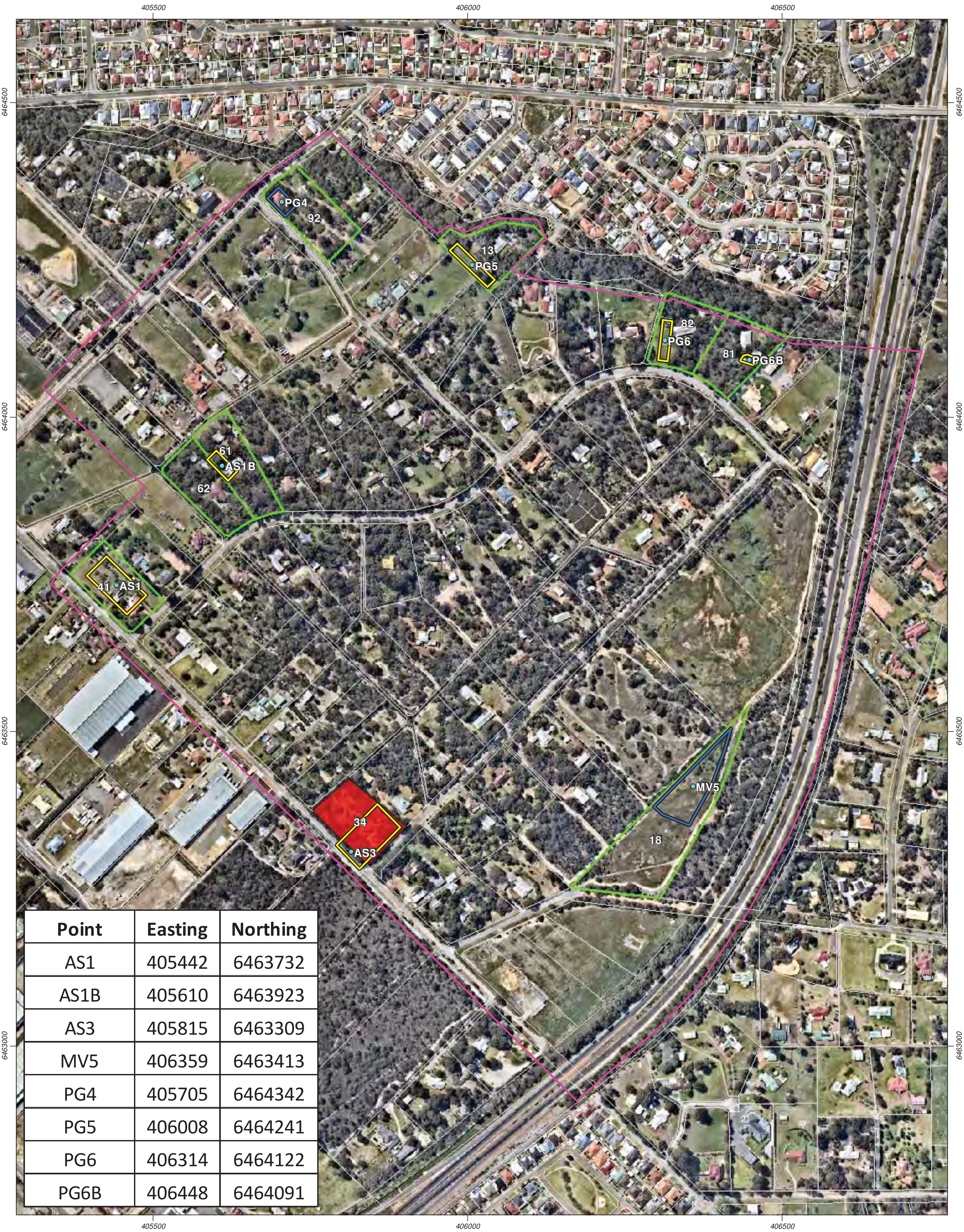
Forrestfield North - Residential Area

Data source: from KC00604.000 E05 Street Trees Rev B.xlsx
Widths from Publ. Realm Guide sections
Tree amounts based on Publ.Realm Guide sections

Structure Plan Streets - DCS

Street	Section	Length	Width	Typology	# Trees in pav.	# Trees in plant.		Tree sizes				Width verges / median (m)	m2 planting (incl. trees)	Temporary tree irrigation demand (kL/a)	Swale width within verges (m)	Swale area (m2)	Temporary swale irrigation demand (kL/a)	Total temporary irrigation demand (kL/a)
								220lt	100lt	45lt								
TOD Connector Boulevard																		
	Milner - Activity Centre	533	30	FF Boulevard	213	187		133	160	107		5.8	3,091	2,087	3	1,524	1,029	3,115
	Activity Centre to Roe Hwy	840	30	FF Boulevard	336	294		210	252	168		5.8	4,872	3,289	3	2,145	1,448	4,736
Milner Road																		
	TOD Connector to Raven	200	30	Urban Boulevard	40	70		50	20	40		5.8	1,160	783	3	525	354	1,137
	Raven to Stewart	235	30	Urban Boulevard	47	82		59	24	47		5.8	1,363	920	3	630	425	1,345
	Stewart to Maide Vale	150			30	53		38	15	30		5.8	870	587	0	0	0	587
Stewart Road																		
	East of Milner to Brea	566	20	Forest Ave		425		28	94	302		9	5,094	3,438	1	416	281	3,719
Connector Road																		
	TOC Connector to Sultana Road West	240	20	Forest Ave		180		24	80	336		18	4,320	2,916	5	825	557	3,473
	(According to Long. Drawing this is only Raven to Poison Gully)																	0
Brea Road																		
	TOD Connector to Roe Hwy	915	20	Forest Ave		686		46	153	488		9	8,235	5,559	1	715	483	6,041
Brand Road																		
	Brea to Sultana Road West	910	20	Forest Ave (bush edge)		516		23	174	319		12.5	11,375	7,678	3	2,655	1,792	9,470
Sultana Road West																		
	Activity Centre Frontage	760	25	Industrial Boulevard		228			228			9.7	7,372	4,976	3	2,205	1,488	6,464
	Brand Road to Roe Hwy	412	20	Industrial Boulevard		124			124			9.7	3,996	2,698	3	1,011	682	3,380
			(in Civil drawings this seems 25m)															
	Turn Around	45				14			14			9.7	437	295	3	60	41	335
TOTAL					**666**								**52,185**	**35,225**		**12,711**	**8,580**	**43,805**

Appendix 7
Hydraulic conductivity testing



Point	Easting	Northing
AS1	405442	6463732
AS1B	405610	6463923
AS3	405815	6463309
MV5	406359	6463413
PG4	405705	6464342
PG5	406008	6464241
PG6	406314	6464122
PG6B	406448	6464091

Figure X: Field map

N

Scale 1:5,500 at A3

0 100 200 m

Coordinate System: GDA 1994 MGA Zone 50

Date: 19/10/2018

Legend

- 🟪 Precinct boundary
- 🟩 Lots with permitted access
- 🟥 Lot 34 - No access
- ☐ Surrounding lot boundaries
- 1 in 100 year Storage basin
- 1 in 5 year (below ground) Storage tank

strategen ENVIRONMENTAL

Q:\Consult\2016\TPG\TPG16528\ArcMap_documents\TPG16528_G056_RevA.mxd

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Data source: Nearmap: Aerial image, flown 09/2018. Landgate: Cadastre, 11/2017. Client: Element Advisory Pty Ltd. Development layout, 08/2018. Created by: c.thatcher

Basin	Easting	Northing	Soil type	Ksat measured(m/day)	Recommended Ksat for model (m/day)
AS2	405442	6463732	Clayey Sand	1.2	0.6
AS1B	405610	6463923	Clayey Sand	0.7	0.3
AS3	405815	6463309	Clayey Sand	0.8	0.4
MV5	406359	6463413	Fine to medium SAND	2.7	1.3
PG4	405705	6464342	Fine to medium SAND	6.3	3.1
PG5	406008	6464241	Clayey gravelly SAND	0.9	0.4
PG6	406314	6464122	Clayey gravelly SAND	0.8	0.4
PG6B	406448	6464091	Fine to medium SAND	>10	3.0

DEPTH FALLEN IN 1 min METHOD

LOCATION: AS2

Taslma-Hallam Method
Date: 22/10/2018
Soil type: Clayey Sand (fine to medium)

Instrument parameters					**Test parameters**				
Area of infiltration	A	17.72002	cm2		Depth of auger hole	D	50	cm	
Volume for 10 cm	V10	177.2002	cm3		Depth of water in hole	H	25	cm	
					Average radius of hole	r	3.5	cm	
					Depth to any impermeable layer	S	N/A	cm	Should be greater than 2H
Depth fallen in 1 min	Z1	6.5	cm						last measurement
	Z2	7	cm	last measurement					previous measurement
	Q1	115.1802	cm3/min	previous measurement					
	Q2	124.0402	cm3/min						

Use equation from AS1547:2012

$$Ksat = \frac{4.4*Q*(0.5sinh^{-1}((H/2r)-SQRT((r/h^2)+0.25))+r/H)}{2*pi*H^2}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	310.841308	**Top line**	334.7521779

Ksat, Q1	**0.079**	**cm/min**	**Ksat**	**0.085**	**cm/min**
	1.140	**m/day**		**1.228**	**m/day**

Test Ks 1.2 m/day

DEPTH FALLEN IN 1 min METHOD

LOCATION: AS1B

Taslma-Hallam Method

Date: 22/10/2018

Soil type: Clayey Sand (fine to medium)

Instrument parameters				
Area of infiltration	A	17.72002	cm2	
Volume for 10 cm	V10	177.2002	cm3	
Depth fallen in 10s	Z1	5	cm	
	Z2	3.5	cm	last measurement
	Q1	88.60012	cm3/min	previous measurement
	Q2	62.02008	cm3/min	

Test parameters					
Depth of auger hole	D		50	cm	
Depth of water in hole	H		25	cm	
Average radius of hole	r		3.5	cm	
Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
					last measurement
					previous measurement

Use equation from AS1547:2012

Ksat = 4.4*Q*(0.5sinh^-1((H/2r)-SQRT((r/h^2)+0.25))+r/H)
2*pi*H^2

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	239.1086985	**Top line**	167.3760889

Ksat, Q1	**0.061**	**cm/min**
	0.877	**m/day**

Ksat	**0.043**	**cm/min**
	0.614	**m/day**

Test Ks 0.7 m/day

DEPTH FALLEN IN 1 min METHOD

LOCATION: AS3

Taslma-Hallam Method

Date: 22/10/2018

Soil type: Clayey Sand (fine to medium)

Instrument parameters					**Test parameters**					
Area of infiltration	A	17.72002	cm2		Depth of auger hole	D		50	cm	
Volume for 10 cm	V10	177.2002	cm3		Depth of water in hole	H		25	cm	
					Average radius of hole	r		3.5	cm	
					Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
Depth fallen in 10s	Z1	6	cm							last measurement
	Z2	3	cm	last measurement						previous measurement
	Q1	106.3201	cm3/min	previous measurement						
	Q2	53.16007	cm3/min							

Use equation from AS1547:2012

$$\text{Ksat} = \frac{\text{4.4*Q*(0.5sinh^-1((H/2r)-SQRT((r/h^2)+0.25))+r/H)}}{\text{2*pi*H^2}}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	286.9304382	**Top line**	143.4652191

Ksat, Q1	**0.073**	**cm/min**	**Ksat**	**0.037**	**cm/min**
	1.052	**m/day**		**0.526**	**m/day**

Test Ks 0.8 m/day

DEPTH FALLEN IN 1MIN METHOD
LOCATION: MV5
Taslma-Hallam Method
Date: 9/12/16
Soil type: Fine to med sand

Instrument parameters					**Test parameters**					
Area of infiltration	A	17.72002	cm2		Depth of auger hole	D		50	cm	
Volume for 10 cm	V10	177.2002	cm3		Depth of water in hole	H		25	cm	
					Average radius of hole	r		3.5	cm	
					Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
Depth fallen in 1min	Z1	15	cm							last measurement
	Z2	16	cm	last measurement						previous measurement
	Q1	265.8004	cm3/min	previous measurement						
	Q2	283.5204	cm3/min							

Use equation from AS1547:2012

$$K_{sat} = \frac{4.4*Q*(0.5sinh^{-1}((H/2r)-SQRT((r/h^2)+0.25))+r/H)}{2*pi*H^2}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	717.3260954	**Top line**	765.1478351

Ksat, Q1	**0.183 cm/min**		**Ksat**	**0.195 cm/min**
	2.630 m/day			**2.806 m/day**

Test Ks 2.7 m/day

DEPTH FALLEN IN 10 SEC METHOD

LOCATION: PG6b

Taslma-Hallam Method >15L infiltrates in <5s

Date: 9/12/16

Soil type: Fine to med sand

Instrument parameters					**Test parameters**					
Area of infiltration	A	17.72002344	cm2		Depth of auger hole	D		50	cm	
Volume for 10 cm	V10	177.2002344	cm3		Depth of water in hole	H		25	cm	
					Average radius of hole	r		3.5	cm	
					Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
Depth fallen in 1min	Z1		cm							last measurement
	Z2		cm	last measurement						previous measurement
	Q1	0	cm3/min	previous measurement						
	Q2	0	cm3/min							

Use equation from AS1547:2012

$$\text{Ksat} = \frac{4.4*Q*(0.5\sinh\text{^-}1((H/2r)-\text{SQRT}((r/h\text{^}2)+0.25))+r/H)}{2*\pi*H\text{^}2}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	0	**Top line**	0

Ksat, Q1	**0.000**	**cm/min**	**Ksat**	**0.000**	**cm/min**
	0.000	**m/day**		**0.000**	**m/day**

Test Ks >10 m/day

DEPTH FALLEN IN 10 SEC METHOD

LOCATION: PG4

Taslma-Hallam Method

Date: 9/12/16

Soil type:

Instrument parameters					**Test parameters**					
Area of infiltration	A	17.72002	cm2		Depth of auger hole	D		50	cm	
Volume for 10 cm	V10	177.2002	cm3		Depth of water in hole	H		25	cm	
					Average radius of hole	r		3.5	cm	
					Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
Depth fallen in 10s	Z1	6	cm							last measurement
	Z2	6	cm	last measurement						previous measurement
	Q1	637.9208	cm3/min	previous measurement						
	Q2	637.9208	cm3/min							

Use equation from AS1547:2012

$$\text{Ksat} = \frac{\text{4.4*Q*(0.5sinh\^{}-1((H/2r)-SQRT((r/h\^{}2)+0.25))+r/H)}}{\text{2*pi*H\^{}2}}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	1721.582629	**Top line**	1721.582629

Ksat, Q1	**0.438**	**cm/min**	**Ksat**	**0.438**	**cm/min**
	6.313	**m/day**		**6.313**	**m/day**

Test Ks 6.3 m/day

DEPTH FALLEN IN 1 min METHOD

LOCATION: PG5

Taslma-Hallam Method

Date: 9/12/16

Soil type: Clayey gravelly SAND, Coarse sand, lateritic gravels with some clay content

Instrument parameters				
Area of infiltration	A	17.72002	cm2	
Volume for 10 cm	V10	177.2002	cm3	
Depth fallen in 1min	Z1	6	cm	
	Z2	4	cm	last measurement
	Q1	106.3201	cm3/min	previous measurement
	Q2	70.88009	cm3/min	

Test parameters					
Depth of auger hole	D		50	cm	
Depth of water in hole	H		25	cm	
Average radius of hole	r		3.5	cm	
Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
					last measurement
					previous measurement

Use equation from AS1547:2012

$$\text{Ksat} = \frac{4.4*Q*(0.5\sinh^{-1}((H/2r)-\text{SQRT}((r/h^2)+0.25))+r/H)}{2*\pi*H^2}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	286.9304382	**Top line**	191.2869588

Ksat, Q1	**0.073**	**cm/min**	**Ksat**	**0.049**	**cm/min**
	1.052	**m/day**		**0.701**	**m/day**

Test Ks 0.9 m/day

DEPTH FALLEN IN 1 min METHOD

LOCATION: PG6

Taslma-Hallam Method

Date: 9/12/16

Soil type: Clayey Gravelly SAND, Coarse sand, lateritic gravels with some clay content

Instrument parameters					**Test parameters**					
Area of infiltration	A	17.72002	cm2		Depth of auger hole	D		50	cm	
Volume for 10 cm	V10	177.2002	cm3		Depth of water in hole	H		25	cm	
					Average radius of hole	r		3.5	cm	
					Depth to any impermeable layer	S	N/A		cm	Should be greater than 2H
Depth fallen in 1min	Z1	5	cm							last measurement
	Z2	3.7	cm	last measurement						previous measurement
	Q1	88.60012	cm3/min	previous measurement						
	Q2	65.56409	cm3/min							

Use equation from AS1547:2012

$$\text{Ksat} = \frac{4.4 \cdot Q \cdot (0.5\sinh^{-1}((H/2r) - \text{SQRT}((r/h^2)+0.25)) + r/H)}{2 \cdot \pi \cdot H^2}$$

Q1		**Q2**	
Bottom line		**Bottom line**	
2*pi*H^2	3926.990817	2*pi*H^2	3926.990817
Top line		**Top line**	
Sinh-1 bit	0.992580246	**Sinh-1 bit**	0.992580246
square root term	0.519230199	**square root term**	0.519230199
r/H	0.14	**r/H**	0.14
Top line	239.1086985	**Top line**	176.9404369

Ksat, Q1	**0.061**	**cm/min**	**Ksat**	**0.045**	**cm/min**
	0.877	**m/day**		**0.649**	**m/day**

Test Ks 0.8 m/day

Appendix 8

Forrestfield Groundwater Level Monitoring – Forrestfield Airport Link

Forrestfield Groundwater Level Monitoring - Forrestfield -Airport Link

Desktop Review

Prepared for
Public Transport Authority
by Strategen

May 2016

Forrestfield Groundwater Level Monitoring - Forrestfield -Airport Link

Desktop Review

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ACN: 056 190 419

May 2016

Limitations

Scope of services

This report ("the report") has been prepared by Strategen Environmental Consultants Pty Ltd (Strategen) in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Strategen. In some circumstances, a range of factors such as time, budget, access and/or site disturbance constraints may have limited the scope of services. This report is strictly limited to the matters stated in it and is not to be read as extending, by implication, to any other matter in connection with the matters addressed in it.

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In preparing the report, Strategen has relied upon data and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise expressly stated in the report, Strategen has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. Strategen has also not attempted to determine whether any material matter has been omitted from the data. Strategen will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to Strategen. The making of any assumption does not imply that Strategen has made any enquiry to verify the correctness of that assumption.

The report is based on conditions encountered and information received at the time of preparation of this report or the time that site investigations were carried out. Strategen disclaims responsibility for any changes that may have occurred after this time. This report and any legal issues arising from it are governed by and construed in accordance with the law of Western Australia as at the date of this report.

Environmental conclusions

Within the limitations imposed by the scope of services, the preparation of this report has been undertaken and performed in a professional manner, in accordance with generally accepted environmental consulting practices. No other warranty, whether express or implied, is made.

Client: Public Transport Authority

Report Version	Revision No.	Purpose	Strategen author/reviewer	Submitted to Client	
				Form	Date
Preliminary Draft Report	A	Client review	M Dunlop, D Jarvis/ P Bourgault	Electronic	3/3/2016
Draft Report	B	Client submission	M Dunlop, D Jarvis/ P Bourgault	Electronic	4/4/2016
Final Report	C	Client submission	M Dunlop, D Jarvis/ P Bourgault	Electronic	7/4/2016
Final for agency submission	0	Agency submission	M Dunlop, D Jarvis/ P Bourgault	Electronic	5/5/2016
Revised final for agency submission	1	Agency submission	M Dunlop, D Jarvis/ P Bourgault	Electronic	9/5/2016

Filename: PTA16057_01 R001 Rev 2 - 9 May 2016

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1. Introduction

The Forrestfield-Airport Link Project (the Project) is a new rail line to the eastern suburbs of Perth. The project will be delivered by a lead contractor who will be appointed in early to mid-2016.

Preliminary groundwater modelling of the Forrestfield Development Envelope (FDE) identified that the cone of depression from dewatering activities at the FDE (Dive Structure) potentially extends into surrounding Threatened Ecological Community (TEC) vegetation within Poison Gully and Lot 12 Ibis Place (Figure 1-1, Figure 1-2). The drawdown shown on Figure 1-2 is considered to represent the current worst case scenario (Golder 2015b). The more likely scenario is shown in Figure 1-3.

Advice from Department of Parks and Wildlife (DPaW) suggests that a shallow perched water table is present within Ibis Place and potentially the Poison Gully TEC.

Following the Environmental Protection Authority (EPA) assessing and recommending approval of the Project, the Minster for Environment approved the project on 13 November 2015 with the issue of Ministerial Statement 1022.

Condition 6-2 of Ministerial Statement 1022 requires that a Flora and Vegetation Monitoring Plan be prepared that “shall…

- detail baseline groundwater levels as close as practicable to Poison Gully and Lot 12 Ibis Place
- attach the results of the groundwater level baseline survey, include a report on the extent of perched groundwater levels at Poison Gully Creek and Lot 12 Ibis Place…”

Groundwater level monitoring is recommended to determine the level of connectivity between the regional aquifer, which will be subject to temporary construction dewatering, and any perched groundwater in the immediate surrounds of the dive structure at Forrestfield. The objective of this report is to review the existing geological and hydrogeological information and develop a baseline groundwater level monitoring program. This report forms Phase 1 of the Scope of Services set out in RFQ160300.

1.1 Scope

This report presents a desktop review of the existing bore network and site investigation data for the FDE and surrounds, specifically surrounding the proposed dive structure (site of dewatering works) and the neighbouring TECs at Poison Gully and Ibis Place.

Based on the Scope of Services, this desktop review:

- assesses the existing information, including available geotechnical and hydrogeological data, to determine the existence or potential presence of perched groundwater within the Forrestfield Development Envelope and adjacent areas of TEC
- assess the suitability of the monitor bore network with regard to well distribution and depth
- where perched groundwater is identified, determine whether sufficient information is currently available to determine connectivity between the regional groundwater table and perched groundwater, and assess the potential for the dewatering to draw down the perched groundwater
- where insufficient information is available, develop a monitoring program to identify the existence/absence of shallow perched groundwater in the zone of influence of dewatering.

The Scope of Services requires that the proposed monitoring program includes:

- location of existing wells and access constraints
- location of new wells to ensure adequacy of data
- the specifications required for the installation of the wells
- post installation survey of the wells
- frequency and type of monitoring, e.g. bore loggers or frequency of dipping.

Figure 1-1: Site location and Threatened Ecological Communities

Scale 1:6,500 at A4

0 100 200 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 26/02/2016

Author: DWhite

Source: Aerial image: ESRI online , approx. 2010.

All other data: Client 2015.

Legend

— Poison Gully Creekline

☐ Development Envelope

🟦 Stations

🟨 Surface disturbance

Threatened Ecological Community

🟧 Poison Gully TEC

🟩 Ibis Place TEC

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Figure 1-2: Predicted worst case groundwater drawdown contours

Scale 1:8,000 at A4

0 50 100 150 200 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 2/03/2016

Author: JCrute

Source: Aerial image: ESRI online approx. 2010. All other data: Client 2015.

Legend

- Poison Gully Creekline
- Groundwater drawdown contour (m)
- Forrestfield-Airport Link
- Development Envelope
- Stations
- Poison Gully TEC
- Ibis Place TEC

Note: The area of the Project within Commonwealth zoning does not form part of the Proposal which is subject to assessment by the EPA.

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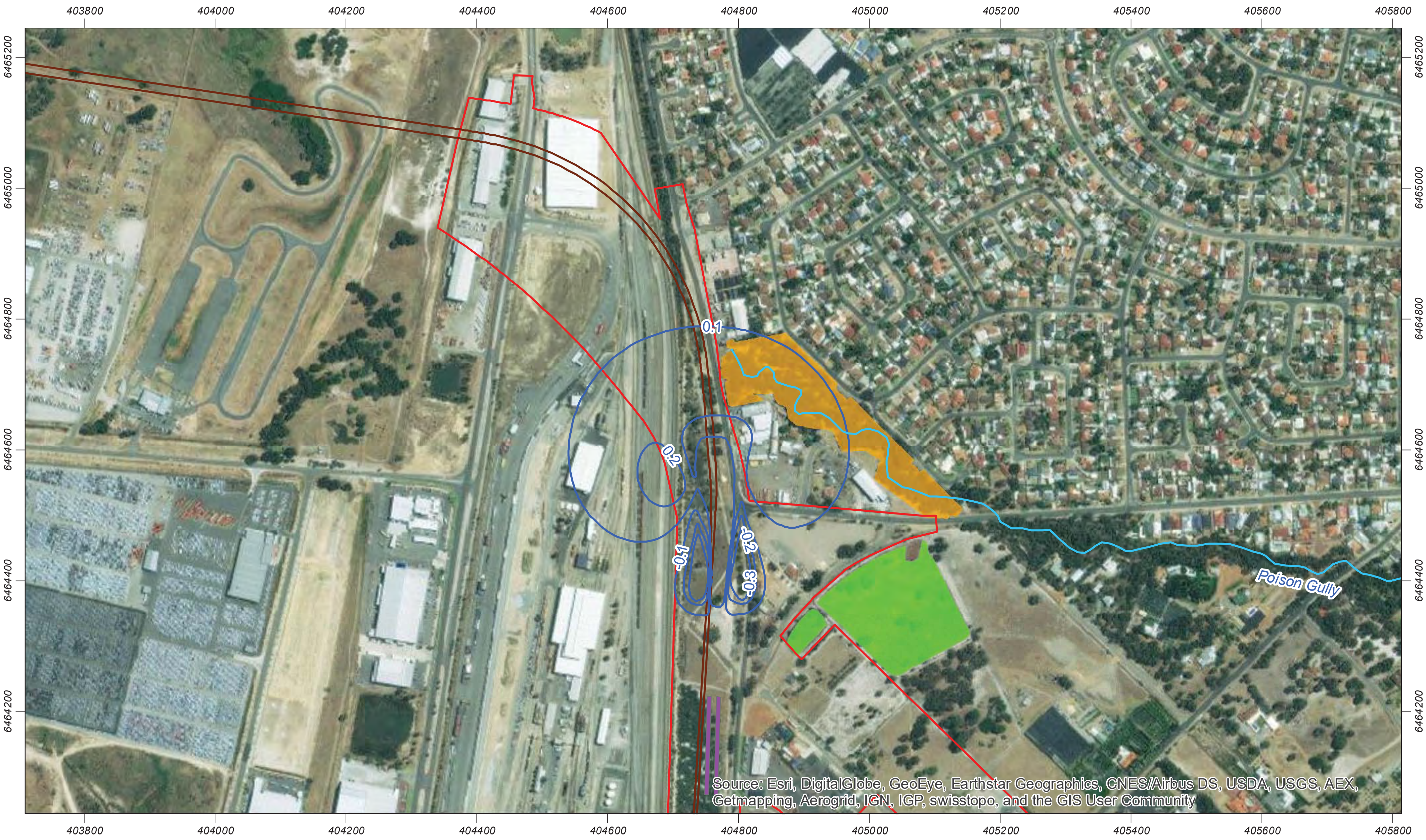

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 1-3: Predicted likely groundwater contours

Scale 1:8,000 at A4

0 50 100 150 200 m

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 28/04/2016

Author: JCrute

Source: Aerial image: ESRI online approx. 2010. All other data: Client 2015.

Legend

- Poison Gully Creekline
- Groundwater drawdown contour (m)
- Forrestfield-Airport Link
- Development Envelope
- Stations
- Poison Gully TEC
- Ibis Place TEC

Note: The area of the Project within Commonwealth zoning does not form part of the Proposal which is subject to assessment by the EPA.

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1.2 Documents reviewed

Documents reviewed for this report include:

- *Contamination and Acid Sulphate Soils Investigation* (Golder 2015a)
- *Groundwater Conditions Report* (Golder 2015b)
- *Geotechnical Baseline Report* (PTA 2015)
- *Stage 2 Geotechnical Investigations - Factual Geotechnical Report* (Golder 2015c)
- *Stage 2 Geotechnical Investigations - Factual Geological and Hydrogeological Model Report* (Golder 2015d)
- *Stage 3 Geotechnical Investigation - Monthly Vibrating Wire Piezometer Monitoring Report no. 06* (Worley Parsons 2016)
- *FAL Project: Forrestfield Station Groundwater Levels Investigation* (Western 2015)
- *Summary of advice from other agencies* 25 February 2015 (OEPA 2015)
- *Forrestfield Airport Link Assessment on Proponent Information - Environmental Review Document* (Strategen 2015a)
- *Forrestfield Airport Link Surface Water Monitoring Report* (Strategen 2016)
- *Forrestfield North District Structure Plan – District Water Management Strategy* (Strategen 2015b).

DPaW has raised questions about the presence of perched groundwater at Ibis Place and in the surrounding areas to the Office of the Environmental Protection Authority (OEPA 2015). The evidence of perched groundwater is based on a report by Ecoscape (2010) titled *Threatened Ecological Community (TEC) Assessment of Lot 12 Ibis Place, High Wycombe.* This report included information obtained from installing five piezometers in the Ibis Place TEC. DPaW has provided PTA with a one page extract of this report but this does not include information regarding piezometer installation and geology.

2. Desktop review

2.1 Conditions required for perched groundwater

Rainfall infiltrating into a soil profile will percolate downwards with gravity at a rate governed by the permeability of the surface soils. In circumstances where the percolating rainfall encounters a soil layer of lower permeability, the downward movement of water is impeded and it is possible the soil above the layer of lower permeability becomes saturated. If a borehole or equivalent is placed into this zone of saturation, free water will flow into the void made by the hole. In many instances this free water is referred to as perched groundwater. Figure 2.1 illustrates this concept.

Perched groundwater can occur at any point in the soil profile where an impeding layer occurs above the permanent superficial aquifer. When present the perched groundwater reflects a localised zone of saturation within the vadose (unsaturated) zone above the permanent watertable. In some circumstances where there is sufficient recharge and sufficient thickness of permeable soils over less permeable soils the presence of perched groundwater can be semi-permanent to permanent. Soils beneath the impeding layer remain unsaturated and are not directly hydraulically connected to the underlying permanent superficial aquifer.

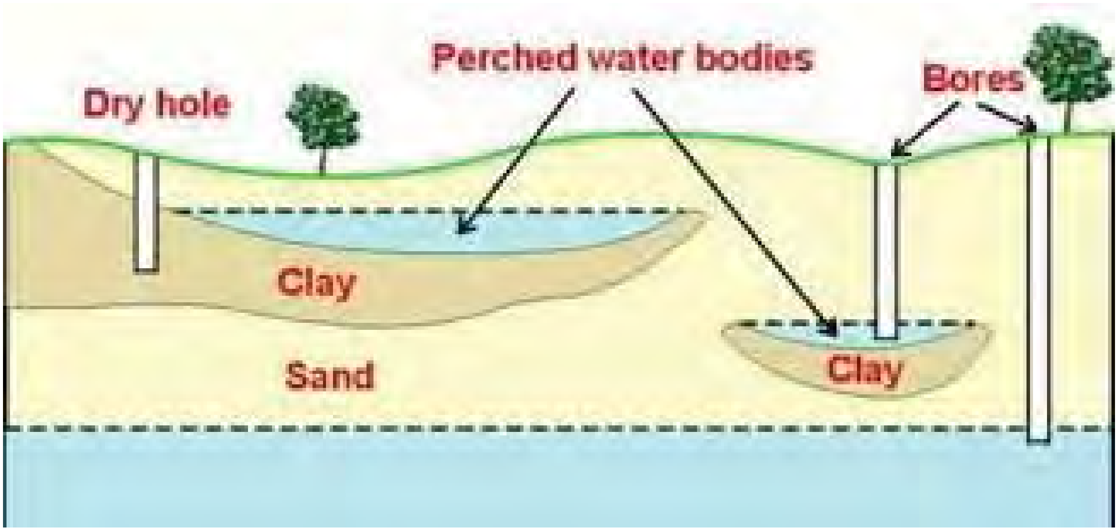


Figure 2-1: Conceptual cross section of perched water body

The presence of perched water can be seasonal. In this case, perched water may be present during the wetter months but dried out during summer as a result of evapotranspiration by vegetation and slow percolation of water through the impeding layer into the regional aquifer.

Understanding the potential for perched water requires an understanding of the soil type, soil texture, underlying geology and hydrology of a site. For the purposes of this report, the term 'impeding layer' has been used to describe less permeable layers in the soil profile above which perched groundwater may occur. Until information regarding the relative hydraulic conductivities of soil strata has been gathered, it is difficult to determine if any soil layers are sufficiently impermeable to impede the vertical percolation of infiltrating rainwater to allow saturation above the impeding layer to occur and perched groundwater to be present.

2.2 Soil investigations

2.2.1 Surface environmental geology mapping

Surface environmental geology mapping for the Perth Metropolitan Region (Gozzard 1986) indicates that the soils at the site are from the S_{10} soil unit, being thin Bassendean Sand over Guildford Formation (Qpb/Qpa) (Figure 2-2). Bassendean Sand is defined as the S_8 soil unit, very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted of eolian origin.

The upper profile of soils from the S_{10} soil unit are typically layers of Bassendean Sand with interbedded lenses of clay derived from the Guildford Formation. The sands from the Guildford Formation may also be expressed at the top surface of the soil profile. Seasonal perched groundwater is common in this soil type.

2.2.2 Soil investigations

Geological investigations have been undertaken within the area of surface disturbance and have included test pitting and the construction of bores at the locations shown on Figure 2-3. The following represents a summary of the geological conditions based on the bore logs provided to Strategen for the MW 3 series of bores shown in Figure 2-3 and test pits as presented in Appendix 2. Information was available for 22 bores installed between 20 October 2014 and 11 May 2015. Bore logs are presented in Appendix 1.

Surficial fill

At MW3-001, MW3-009, MW3-034 and MW3-038 a layer of sand to sandy gravel fill has been placed on the site. The Golder logs identify that the fill depth ranges from 0.8 m at MW3-034 to 4 m at MW3-009. On review of the logs following observations of soils in the TEC, Strategen considers that the brown orange and yellow orange sands to sandy gravel in the Golder logs are natural soils and represent the surficial layer of the Guildford Formation. On this basis, Strategen considers the actual fill depth at these bores to be more likely 0.2 m (MW 3-001) to 0.9 m (MW 3-009) with the possibility that some of the grey sands above these layers being misidentified Bassendean Sand.

Bassendean Sand

A layer of sand is present at the top of the profile at most locations. This sand was confirmed as being from the S_{10} Formation, being “light grey, yellow, dark brown, fine to medium grained sand, loose to dense” (Golder 2015d). Some of this sand layer contains gravel or had orange to red colouring, indicating that these gravels may actually be derived from the reworked Guildford Formation that occurs below the sand. For the purposes of this report, this sand layer with intermittent gravels is referred to as Bassendean Sand. Where present, the material ranges from 0.3 to 3.5 m in thickness, with base levels between 24.18 mAHD (MW 3-001) and 29.67 mAHD (MW 1-01 A).

This top layer of sand was not present at MW 3-013, MW3 -038, MW 3-044, MW 3-051, MW 3-052 or MW 3-055 (Table 2-1). Apart from MW 3-013, these are all located in the north of the Site near Poison Gully (Figure 2-3). MW 3-013 is located near Milner Road, to the south of Ibis Place.

Guildford Formation

The gravelly and clayey soils of the Site are primarily associated with the Guildford Formation. Golder 2015 (d) described the Guildford Formation in the Forrestfield portion of the Project as consisting of “pale grey and brown, fine to coarse grained, rounded to sub-angular, medium dense to very dense sand, silty sand and clayey sand with trace quartz gravel generally less than 5 mm of size. The Guildford Formation also contains a sequence of mottled orange, low plasticity, stiff to hard clays in the Forrestfield area that are generally present within 10 m of ground surface and being up to 6 m thick”.

Table 2-1: Summary of geology and potential for perched groundwater

Name	Ground level (mAHD)	Bottom of sand and fill (mbgl)	Bottom of sand (mAHD)	Top of potentially impeding layer (mbgl)	Top of potentially impeding layer (mAHD)	Type of impeding material	Moisture present over dry soil?	Top of screen (mbgl)
MW 3-001	27.78	3.60	24.18	Not present	Not present	Not present, clayey sand only	No	3.00
MW 3-004	30.00	2.10	27.90	Not present	Not present	Not present, silty clayey sand only	No	5.00
MW 3-009	30.20	5.50	24.70	5.50	24.70	sandy clay	No	3.90
MW 3-012	29.24	0.30	28.94	0.30	28.94	silt then silty clay at 4.8 mbgl	No	7.50
MW 3-013	34.68	Not present	Not present	2.00	32.68	clayey silt	No	16.30
MW 3-019	30.61	1.00	29.61	Not present	Not present	Not present, clayey sand only	No	3.50
MW 3-026	28.39	0.60	27.79	3.00	25.39	sandy gravelly clay, then sandy clay	No	5.00
MW 3-034	31.23	2.20	29.03	2.20	29.03	clayey silt	No	4.00
MW 3-038	29.33	1.50	27.83	1.50	27.83	sandy clay	No	4.50
MW 3-044 D	29.54	Not present	Not present	1.40	28.14	clayey silt	No	11.00
MW 3-044 S	29.50	Not present	Not present	1.40	28.14	clayey silt	No	3.30
MW 3-047	30.36	1.50	28.86	1.50	28.86	clayey silt	No	9.00
MW 3-051 D	29.41	Not present	Not present	2.40	27.01	clayey silt	No	15.50
MW 3-051 S	29.39	Not present	Not present	2.40	28.19	clayey silt	No	4.00
MW 3-052	28.35	Not present	Not present	2.00	26.35	clayey silt	No	7.00
MW 3-055	28.81	Not present	Not present	1.50	27.31	silty clay	No	4.00
MW 1-01 A	30.47	3.50	26.97	5.30	25.17	Clay	Moisture not logged	8.00
MW 1-01B	29.33	1.00	28.33	Not present	Not present	Not present	Moisture not logged	8.50
MW 1-01 C	30.47	2.15	28.32	Not present above 0 mAHD (i.e. above sea level)	Not present above 0 mAHD	Not present above 0 mAHD	Moisture not logged	7.00
MW 1-01 D	30.19	5.00	25.19	Not present above 0 mAHD (i.e. above sea level)	Not present above 0 mAHD	Not present above 0 mAHD	Moisture not logged	7.00
MW 1-05	28.42	1.00	27.42	Not present	Not present	Not present	Moisture not logged	7.00
PW 1-01	30.32	2.00	28.32	Not present	Not present	Not present	Moisture not logged	7.00

The geology of the Guildford Formation as present in the bore logs is highly variable and includes units from sandy gravel to clays. From a perched groundwater perspective, the key factors are the presence of fine grained layers which may impede downward percolation of water. Where the majority component of a soil unit is described as silt or clay and the material above is predominantly sand, the difference in permeability may be sufficient for seasonal perched groundwater to occur. A silty or clayey sand was not considered to offer adequate difference in permeability to significantly impede the downwards movement of water and thus cause perched groundwater on top of the layer.

Test pits

The test pits along the south-western edge of the Ibis Place TEC indicate:

- TP 1-46: sand then sandy clayey gravel 'weakly to very weakly iron cemented mass' at 0.4 m then refusal at 1.3 m (no groundwater encountered, excavated on 2/12/14)
- TP1-49: sand over moist gravelly clayey sand 'weakly to well cemented' at 0.7 m then refusal at 2.4 m (no groundwater encountered, excavated on 2/12/14)
- TP1-20: sand then moist interbedded sand and clayey sand 'weakly to well cemented lateritic gravel at 1.3m, no refusal (no groundwater encountered, excavated on 12/12/14) (Appendix 2).

The material causing refusal at TP1-46 and TP1-49 could possibly be a cemented perching layer, but there no evidence of actual perching (i.e. no saturation was encountered).

TP1-28 and TP1-29 are located in the vicinity of Poison Gully

- TP1-28: gravelly sand, then sand over clayey sand and then sandy clay at 1.5 mbgl. No evidence of groundwater to 2.1 mbgl during excavation on 15/10/14. Base of hole at approximately 27.15 mAHD
- TP1-29: sandy clay over sandy gravel then clayey sand to 2.6 m. No evidence of groundwater to this depth during excavation on 27/10/14. Base of hole at approximately 26.62 mAHD (Appendix 2).

The bases of the holes appear to be above the invert of the creek at this location. As such, this does not provide any indication of whether the creek is intersecting perched groundwater, which could be present below the base of the holes.

Data gaps for the assessment of perched groundwater

Based on the observed soil profiles, layers with the potential to impede flow were considered to occur in 14 of the 22 bores. Where impeding layers were present, the top of the impeding layer varied from 0.3 m (MW 3-012) to 5.5 mbgl (MW 3-009), with the majority being less than 2.5 m below the surface. The elevation (in mAHD) of these impeding layers varied from 24.7mAHD (MW 3-009) to 32.68 mAHD (MW 3-013). In all cases, the bores were only screened below the impeding layer (Table 2-1).

Logs from four bores installed by Strategen in September 2011 for the Shire of Kalamunda (SoK) in the broader Forrestfield area (MB01, MB07, MB08 and MB09) did not record any potential impeding layers, with sand or gravelly sand/sandy gravel at the surface and then clayey sand at depths between 2.25 and 3.5 mbgl to the end of the hole (Strategen 2015b). Locations of these bores are shown on Figure 2-3.

The geology quoted by DPaW for Ibis Place is consistent with very shallow Bassendean Sand over the Guildford Formation, however the bore logs for these bores have not been provided to Strategen.

The bores and test pits are focussed on investigating the upper soil profile of the regional superficial aquifer along the proposed alignment. One bore (MW 3-034) has been located adjacent to Ibis Place and one on Milner Road (MW 3-013) (Figure 2-3). Only MW 3-055 is located to the north of Poison Gully. Given the complex geology of the subject area, the current geological information is considered limited within and surrounding the TECs. Information in bore logs is variable and determining the presence or otherwise of impeding layers is difficult. Additional geological information would be beneficial.

2.3 Hydrogeology

Ecoscape (2010) report

Ecoscape (2010) reported a depth to groundwater in August 2008 of less than 0.4 m in five piezometers installed within the Ibis Place TEC. The soil samples taken from the installation of the bores showed a "shallow layer of wet sand approximately 10 cm thick over a wet clayey sand, to wet sandy clay, with dry mottled clay at a depth of approximately 1 m" (Ecoscape 2010, quoted in DPaW undated). These readings were taken in winter and it is possible that the perched water was ephemeral and resulted from a period of rain that occurred leading up to the monitoring event. The exact date of the monitoring event has not been provided to allow comparison to rainfall records.

These water levels are in contrast to the groundwater levels at the adjacent PTA bore MW 3-034, which was dry during monitoring by Western Environmental in July and October 2015 (Western 2015). MW 3-034 was installed to a depth of 6.3 metres below ground level (mbgl) and was screened between 3.3 and 6.3 mbgl. Water may have been present as a perched layer above this screened depth.

Evidence from bore installation and test pits

If perched groundwater was present during bore installation or test pitting, a layer of wet soil would have been found over a dry impeding layer. Such perched groundwater conditions were not encountered during drilling or test pitting, indicating that permanent perched groundwater is unlikely to be present. Bore logs were available to Strategen for the bores listed in Table 2-1 and four bores installed for SoK by Strategen (Figure 2-3). Test pit logs were available for locations in the vicinity of both the Ibis Place TEC and Poison Gully (Appendix 2).

These bore logs show that perched groundwater was not present during bore or test pit installation. Groundwater levels on the Swan Coastal Plain generally peaks in October, and as such perched groundwater would be more likely to be present at this time of year. In terms of timing of installation:

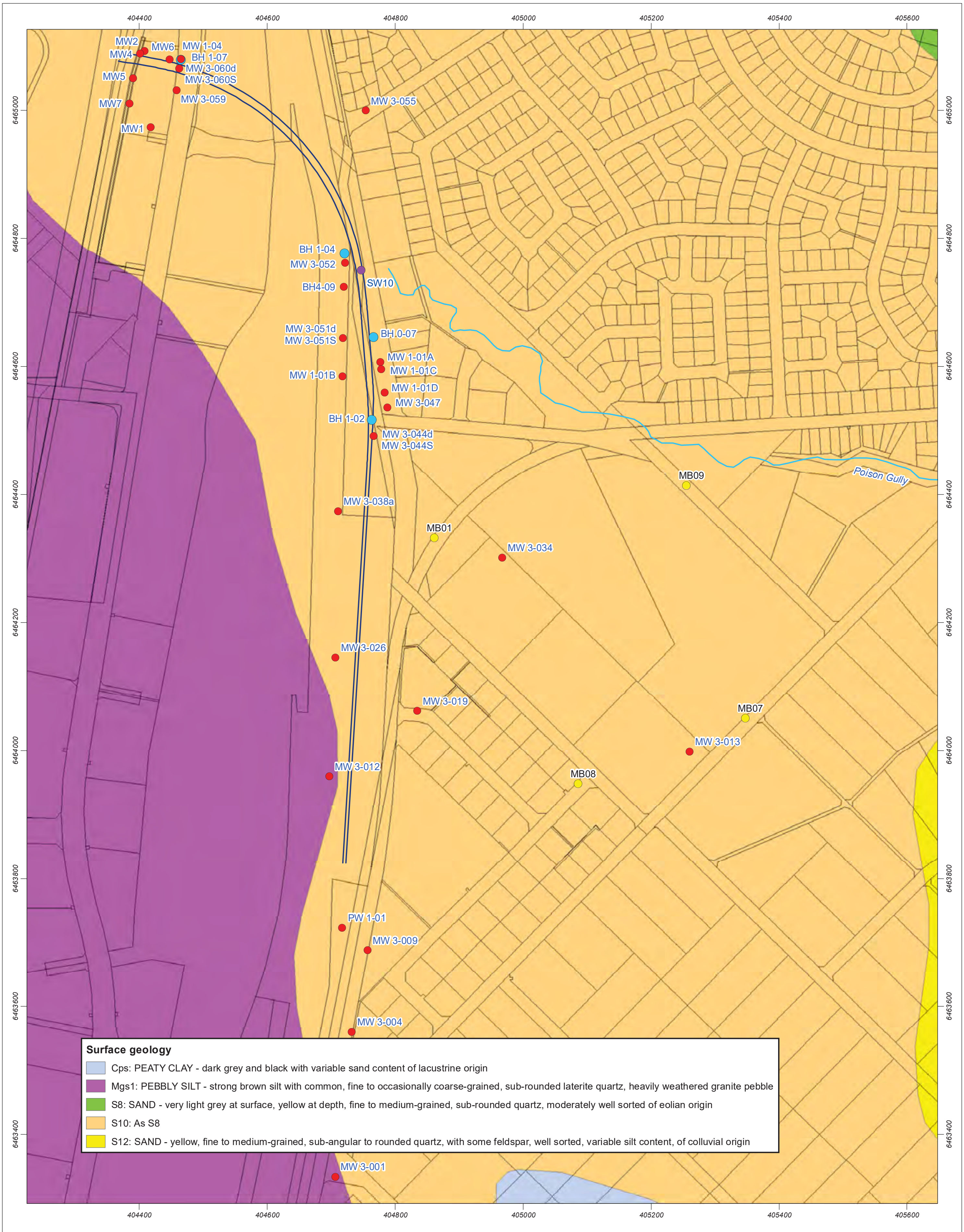
1. Installation of the Golder bores for which soil moisture was logged occurred during January and February 2015, when ephemeral perching would be unlikely to be present.
2. Strategen bores were installed in September 2011, close to peak groundwater when ephemeral perching would be more likely to be expressed.
3. Of the Golder test pits, two were installed in October 2014 (around peak groundwater) and three in December 2014. Perched groundwater is likely to be found if present during October but is less likely to be present in December.

The lack of perching in the pits and bores constructed in September and October indicates that perching is not present at these locations.

Screened depth

Of the bores installed to date, none have been screened in the top 3 m of the profile. Top of screen levels vary from 3.0 mbgl at MW 3-001 to 16.3 mbgl at MW 3-013 with bottoms of screens located from 5.9 to 32.5 mbgl. All of the bores that had intersected impeding layers were screened below the top of the impeding material.

Groundwater levels encountered during the summer installation period were below this level and thus the shallowest bores were screened across the groundwater table, as is standard practice. A minimum of 0.5 m of bentonite was placed above the screens to ensure that water from aquifers above the aquifer being monitored did not affect water levels in the bore. Assuming this process was effective and the top of all screens are located below the top of potentially impeding layers, groundwater levels in these bores will not accurately reflect water levels occurring above the impeding layer.



Surface geology

- ▭ Cps: PEATY CLAY - dark grey and black with variable sand content of lacustrine origin
- ■ Mgs1: PEBBLY SILT - strong brown silt with common, fine to occasionally coarse-grained, sub-rounded laterite quartz, heavily weathered granite pebble
- 🟩 S8: SAND - very light grey at surface, yellow at depth, fine to medium-grained, sub-rounded quartz, moderately well sorted of eolian origin
- ■ S10: As S8
- 🟨 S12: SAND - yellow, fine to medium-grained, sub-angular to rounded quartz, with some feldspar, well sorted, variable silt content, of colluvial origin

Figure 2-2: Regional geology

Scale 1:5,414 at A3

0 50 100 150 200 250 m

Coordinate System: GDA 1994 MGA Zone 50
Note that positional errors may occur in some areas
Date: 1/03/2016
Author: JCrute
Source: Aerial image: ESRI online , approx. 2010. Bores: Client 2015/2016. Geology: Map sheet Perth, 1:50,000, DMP 2012.

Legend

- ● Monitoring Bore (Shire of Kalamunda)
- ● Surface Water Monitoring Location
- ● Vibrating Wire Piezometer
- ● Monitoring Bore (PTA)
- — Poison Gully Creekline
- — Forrestfield-Airport Link
- ☐ Development Envelope

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Figure 2-3: Groundwater and surface water monitoring locations

Scale 1:5,414 at A3

0 50 100 150 200 250 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 31/03/2016

Author: JCrute

Source: Aerial image: ESRI online , approx. 2010. All other data: Client 2015/2016.

Legend

- ● Monitoring Bore (Shire of Kalamunda)
- ● Surface Water Monitoring Location
- ● Vibrating Wire Piezometer
- ● Monitoring Bore (PTA)
- ▲ Open Pit Observations
- — Poison Gully Creekline
- — Forrestfield-Airport Link
- ☐ Development Envelope
- 🟧 Poison Gully TEC
- 🟩 Ibis Place TEC

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Vibrating wire piezometers

Vibrating wire piezometers (VWPs) have been installed at three locations to monitor groundwater pressure/levels at depth (Figure 2-3). The VWPs record water levels on a minimum of daily frequency. VWPs are located at:

- BH0-07 contains at 12.5 mbgl, monitored since April 2014
- BH1-02 at 12.5 mbgl and 24.5 mbgl, monitored since October 2014
- BH1-04 at 9.8 mbgl and 13.7 mbgl, monitored since October 2014.

Strategen understands that the VWP monitoring program will continue until May/June 2016. The VWPs have been installed too deep to represent any perched groundwater but will provide useful historical water level data.

Groundwater levels

The PTA bores were monitored for groundwater levels on:

- 10 March 2015 by Golder
- 23 July 2015 by Western Environmental
- 20 October 2015 by Western Environmental
- 26 February 2016 by Strategen.

The SoK bores were monitored on 12 October 2015 by Gecko Environmental. The only SoK bore located by Gecko (MB09) was dry. Strategen attempted to locate the SoK bores on 26 February 2016, but only MB09 could be located. The SoK bores were installed in the road reserve, so it is likely that these have been either destroyed or covered over with material (e.g. concrete) where flush covers were used.

The only bore showing water levels clearly above an impeding layer is MW 3-009. The water level on 20 October 2015 was 24.86 mAHD, with an impeding layer logged as being present at 24.70 mAHD. Groundwater levels at this bore varied from 24.54 mAHD to 24.86 mAHD during the monitoring events, and thus has been both above and below the top of the impeding layer. This is consequently not considered to be evidence of consistent perching.

Data gaps for assessment of perched groundwater

The bores installed by Golder have been designed to monitor the deeper parts of the superficial aquifer that will be directly affected by dewatering, close to the proposed alignment. Additional monitoring is recommended in the vicinity of the TECs to better understand the hydrology of these areas.

2.4 Surface water

Poison Gully (Plate 1 to Plate 3) is an ephemeral creek which collects water from elevated areas to the east of the Site including parts of Kalamunda and flows in a westerly direction via the Perth Airport Northern Main Drain and Limestone Creek into the Swan River. Between Maida Vale Road and the location to the west of Dundas Road, where Poison Gully becomes a piped drain, the creek is incised up to approximately 2 m below the normal ground surface. No surface water was observed in this section of Poison Gully during a site visit on 26 February 2016. During 2015, the creek was dry at SW10 in the vicinity of the Site during two of four surface water monitoring events (March and December) (Strategen 2016). The location of SW10 is shown on Figure 2-3.

Groundwater monitoring undertaken by Strategen for Shire of Kalamunda in the Forrestfield area indicated a southerly regional groundwater flow direction in the area to the south of Poison Gully in October 2011 (Strategen 2014). The study area and bores for this project were predominantly located to the east of FDE, with the easternmost bore located in Ibis Place. The implication of this flow direction is that Poison Gully may be a losing stream (i.e. one that recharges groundwater) during the period over which it flows. In saying this, the study was undertaken at a regional level and the majority of the project area was located to the east of the area of interest for this study, within soils mapped as deep Yoganup Sands rather than the Guildford Formation.

Plate 1: Poison Gully, February 2016

Plate 2: Poison Gully, February 2016

Plate 3: Poison Gully, February 2016 showing erosion

Surface water levels recorded by Strategen (2016) at SW10 were approximately 26.5 mAHD on 3 June and 3 September 2015. The maximum groundwater level recorded by Western Environmental during their July and October 2015 groundwater monitoring events was 25.31 mAHD in MW 1-01A on 23 June. This implies that the water level in Poison Gully when flowing is generally above the regional groundwater level. This implies that the general direction of water flow when Poison Gully is flowing would be from Poison Gully to the regional groundwater (i.e. this section of Poison Gully is a losing stream).

Poison Gully has previously been surveyed by Water Corporation (2010) as part of a drainage study of the area. Strategen has been provided with this information for another job under the condition that it is used for that purpose. Permission to use this information should be obtained by PTA to assist in determining the interaction between Poison Gully and any perched groundwater.

2.5 Observation of open pits

On the 24 March, Strategen inspected several open pits ranging in depth from 1-2.5m to assess the textural differences within the soil profile. Two pits to approximately one metre depth where inspected along Raven Road on the north-eastern side of the Ibis Road TEC (Plate 4). Another large excavation along the alignment of the gas pipeline running parallel with Dundas Road on the western side was inspected (Plate 5). This excavation was close to the culvert on Dundas Road, through which Poison Gully flows. The approximate locations of the observation pits are shown on Figure 2-3.

The soil profile along Raven Road was found to be grey fine-medium sand to about 0.3m depth over yellow to orange clayey sand (~5% clay) with weathered coffee rock. This soil, which also contains a large percentage of gravel, is unlikely to retard downward percolation of rainwater sufficient to result in perching during normal flows. High intensity rainfall may be sufficiently retarded above the clayey sand for short periods to cause isolated pockets of water saturation, but this would be of very short duration.

The soil profile along the gas pipeline alignment had three distinct horizons. The surface 0.3-0.4m is grey fine-medium sand, typical of Bassendean sand. The underlying 0.4-1.0m of soil profile textured as a clayey sand and was similar to the soil encountered in Raven Road. At a depth of ~0.8m there is a distinct textural change from the clayey sand to sandy clay. The sandy clay is quite plastic but the sand grains are obvious. Based on the bolus formed by wetting some of the sandy clay material and manipulating it in the hand and forming a ribbon by squeezing between the thumb and forefinger (The National Committee on Soil and Terrain, 2009), it is estimated there is about 25% clay. During normal rainfall events, this textural difference at about 1m is possibly sufficient to retard downward percolation of rainfall for long enough to result in minor amounts of water saturation within the soil profile (perched groundwater). However it was noticed there were regular macropores (cracks and old root channels greater than 2 mm in diameter) that would conduct any perched groundwater deeper into the soil profile (Plate 6). Macropores can rapidly convey water through the unsaturated zone of the soil profile, draining areas of temporary saturation (Beven and Germann 1982; Bourgault Du Coudray 1996).

At all inspected locations, the soil profile was dry and showed no evidence of perching. It is highly unlikely there is any connectivity between potential perched groundwater layers and the regional superficial groundwater table.

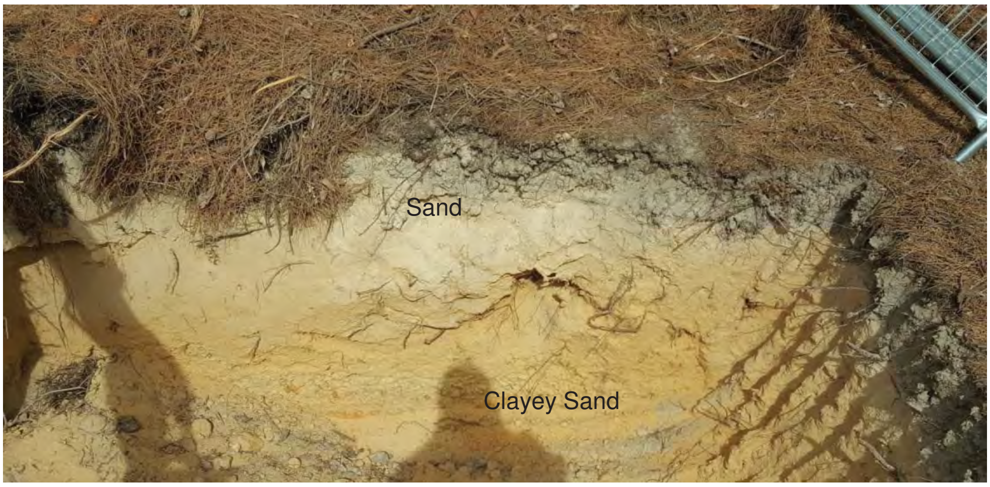

Plate 4: Soil profile at OP2

Plate 5: Soil observations at OP1

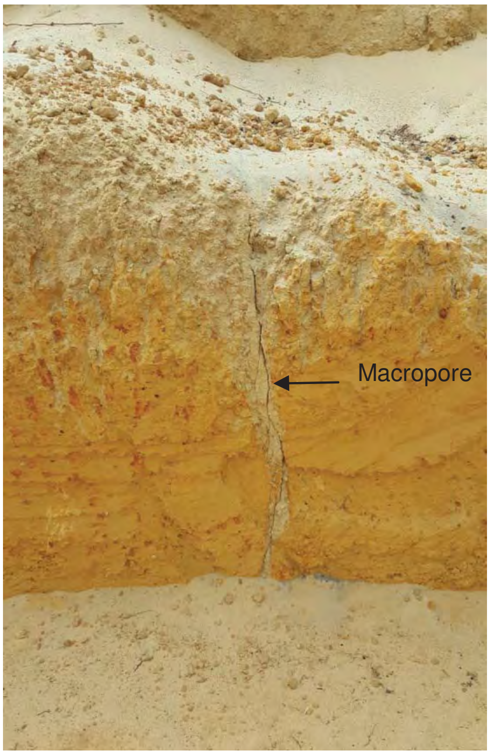

Plate 6: Macropore through sandy clay layer at OP1 and natural gravel within the profile

2.6 Potential for perched groundwater

Apart from the Ecoscape (2010) report, there is no conclusive evidence that perched water occurs near the proposed Forrestfield area. It is possible that the perched groundwater seen by Ecoscape is temporary perched groundwater following the retardation of percolating rainfall by a impeding soil layer of lower hydraulic conductivity, following a short period of relatively high intensity rainfall. Based on the inspection of the soil profile near Raven Road and adjacent to Dundas Road, there is sufficient textural difference between overlying sands and underlying sandy clay to give rise to the possibility of localised temporary perched groundwater following rainfall. The refusal in test pits adjacent to Ibis Place TEC is also indicative of a cemented layer that may cause perching.

Soil logs show potential impeding layers that may cause perched groundwater after rainfall are present at 13 out of 16 Golder bores and at TP 1-46 and TP 1-49 on the southwestern boundary of the Ibis Place TEC. However, perched water was not encountered during bore installation in January/February 2015 or test pitting. This suggests that if there is any perched groundwater, it is not permanent. A potentially impeding layer was noted at a depth of 2.2 mbgl at the bore closest to Ibis Place and in the form of refusal during test pitting at 1.3 m and 2.4 mbgl at TP1-46 and TP 1-49 respectively. There is no evidence of hydraulic connection between the perching layers and the underlying superficial aquifer.

Where potential impeding layers were found, they were of variable texture, depth and thickness. This implies that temporary perched groundwater may exist in some areas but not others.

If permanent perched groundwater occurred and was above the level of Poison Gully, springs or seeps where lateral flow of the perched water intercepted the creek would be expected. If significant volumes of perched water were present and seeping into Poison Gully permanent to semi-permanent pools would be expected along the creek line. There is no evidence of subsurface seepage into Poison Gully from perched groundwater, even in areas where the creek is deeply incised.

2.7 Conclusions

The groundwater level monitoring to date has been focussed on the regional superficial aquifer. While more information regarding the hydrology of the TECs would be beneficial, the evidence available indicates that any perched groundwater that may occur is likely to be ephemeral and limited to isolated areas. Hence temporary lowering of the regional groundwater table is unlikely to impact the TECs adjacent to the FDE.

3. Proposed future works program

3.1 Groundwater monitoring

3.1.1 Bore specifications

The proposed additional monitoring bore locations are shown in Figure 3-1. Bore depth will depend on the geology and presence of groundwater at the drilling location.

Monitoring bores will be installed as a pair or shallow bore only on the following basis:

1. As a pair of monitoring bores, typically 2 to 5 metres apart, where a deep bore is not currently present and a better understanding of the interaction between the shallower and regional (deeper) superficial aquifer is required. The shallow bore will be screened so that it is above the first impeding layer that is encountered in the profile (typically from 0 to 3 mbgl) to intersect any seasonal perched groundwater that may occur in that location. The deepest of the pair will be screened below any confining layer (typically at depths of more than 4 mbgl, but not more than 8 mbgl) so as to intersect the regional groundwater table. If no impeding layer is identified, the shallow bore will still be installed to a depth of 2mbgl.
2. As a shallow bore on top of the impeding layer at a location where a deeper bore already exists or as a supplementary shallow bore located adjacent to the TEC. Where this is not located adjacent to a deeper bore, the hole will extend a minimum of 300 mm into the potential impeding layer to confirm that perched groundwater is likely to be present and then the hole refilled to the top of the impeding layer. If no impeding layer is identified, then the bore will be installed to depth of 2mbgl.

Bores will be constructed in accordance with the requirements outlined in the Land and Water Biodiversity Committee (2003) guidance document *Minimum Construction Requirements for Water Bores in Australia.* Minimum bore internal diameter shall be 50 mm based on this guidance and to allow installation of 41 mm diameter data loggers in any bore.

The screening intervals for all bores will be carefully selected based on the soil profiles encountered at each location. A screened interval of 2-3 m will be installed either completely above (shallow bores) or completely below (deep bores) any impeding layer that is identified.

The soil lithology will be logged for all new bores proposed for installation at the locations shown in Figure 3-1 and Table 3-1 by a suitably qualified environmental scientist. Where bores are paired as a deep and shallow set, logging is required for both bores. The deep bore shall be installed first and this geological information will be used to determine the depth of the shallow well. This will include logging of soil type, texture and moisture status at a minimum of every 20 cm down the hole. Bores will be installed using a push core drilling rig to ensure a clean core is obtained for accurate geological logging.

The proposed locations for the additional bores are provided in Table 3-1. A deep bore screened below the perching layer to access the regional groundwater table will be paired with MW3-009 as a potential control bore set (Figure 3-1). This location has been selected as a control bore as:

- a perched groundwater layer is known to occur in this area
- the bores are located outside the drawdown area shown on Figure 1-2.

Table 3-1: Additional monitoring bore locations

Label	Type	E (MGA94z50)	N (MGA94z50)
MW 8-001	A, D, K	404846.2	6464670
MW 8-002	B	404918.1	6464733.1
MW 8-003	A	404929.3	6464604.2
MW 8-004	B, K	405114.4	6464477.6
MW 8-005	A	405021.3	6464444.5
MW 8-006	A, D, K	404874.8	6464295.5
MW 8-007	A, D	405144.3	6464305.7
MW 3-009 (D)	R	404846.2	6464670

A: New Bore Pair
B: Shallow Bore Only
D: Data Logger Pair
K: Permeability Test
R: Deeper bore to Access Regional Groundwater Table

All new monitoring bores will be surveyed for Easting, Northing and Elevation (surface and top of casing in mAHD) to allow accurate assessment of the groundwater at the site.

3.1.2 Proposed monitoring program

Groundwater water levels will be measured on a monthly basis for all bores shown on Figure 3-1. It is anticipated that monitoring will commence in May 2016 and be ongoing. The amount of data collected should be maximised.

In addition to the monthly measurements, opportunistic monitoring immediately following daily rainfall greater than 10 mm, or following high-intensity rainfall, such as following a thunderstorm, even though the duration and total amount of rainfall is relatively modest. It may be necessary to visit the shallow bores several times following a rain event to ensure any temporary perched groundwater is captured.

The period from March to July is associated with seasonal low groundwater levels (typically March/April) followed by the subsequent rise of the watertable as the winter months approach. Heavy falls are likely to occur in the proposed monitor period, and the monthly and opportunistic monitoring of the shallow bores during these periods should provide sufficient data to help assess any potential impact to the TECs from drawdown in the regional water table.

Data loggers

Data loggers will be installed in three paired sets (i.e. six loggers in total) at the locations shown on Figure 3-1 (two associated with the Ibis Place TEC and one with the Poison Gully TEC). If possible, a data logger should be placed in one of the Ecoscape piezometers. These data loggers will log water levels on an hourly basis to observe the behaviour of water levels following rain. At this logging frequency, a battery life of at least four months is anticipated.

Ecoscape bores

Access to the Ibis Place piezometers installed by Ecoscape should be obtained if possible for monitoring purposes. These piezometers would need to be assessed prior to use to determine that they are still present and in a suitable condition for monitoring. If these bores are accessible and suitable, they should be included in the monitoring program and a data logger placed in one of the bores.

Vibrating wire piezometers

Strategen understands that the VWPs are intended to be monitored until May/June 2016. If possible, this program should be continued as long as practical up until the period of maximum groundwater levels (typically September). Data from the data loggers and dipping program should be compared to data from the VWPs to assist in investigating interactions between any perched and deeper superficial groundwater.

3.2 Soil investigations

3.2.1 Permeability testing

Permeability testing will be undertaken adjacent in hand augered holes adjacent to bores where impeding layers are identified using a falling head (Talsma-Hallam) permeameter based on methodology described in Appendix G of Australian Standard AS/NZS 1547:2012. The permeability tests will be undertaken in hand augered holes:

- within the permeable layer
- within the potentially impeding layer.

3.2.2 Poison Gully creekline

Obtaining soil logs from the Poison Gully creekline could be useful to determine the interaction between surface water in Poison Gully and groundwater. The creek is highly incised (approximately 2 m) and provides a useful geological cross section. During high flow periods, the sides of the creek are covered in clayey sediment, which sticks to the soil and can make such observations difficult. This section of Poison Gully is a significant site to Aboriginal people, and as such the sides of the creek should not be altered or damaged. Visual inspection should be undertaken and logging undertaken where it is considered that this will provide useful data (e.g. freshly eroded areas). This should ideally be done at a minimum of six locations between where the creek becomes a drain to the west of Dundas Road and Maida Vale Road, with the locations recorded by GPS and surveyed.

For safety reasons, any work in Poison Gully creek line should be done when the creek is dry.

3.3 Surface water

Monitoring of surface water levels in Poison Gully should continue at SW10 on the same frequency as the groundwater monitoring (Section 3.1.2). Data loggers are not proposed for Poison Gully.

As discussed in Section 2.4, survey information for Poison Gully should be obtained from Water Corporation to assist in determining the interaction between Poison Gully and any perched groundwater.

3.4 Potential ethnographic constraints

Investigations should be undertaken at the locations shown on Figure 3-1. Strategen notes that cultural reasons may prevent ground disturbing activities within vegetation areas adjacent to Poison Gully as well as the creek line itself. The cultural sensitivity of these areas should be confirmed with PTA prior to work commencing.

Should this be the case, locations shall be moved to a nearby location without such sensitivities. The movement of locations may impact on the relevance of the data obtained to the Poison Gully TEC. Where such movement of locations is required, this shall be identified within subsequent reporting and the reason for such movements identified.

Figure 3-1: Proposed monitoring locations

Scale 1:5,500 at A3

0 50 100 150 200 250 m

N

Coordinate System: GDA 1994 MGA Zone 50

Note that positional errors may occur in some areas

Date: 6/05/2016

Author: JCrute

Source: Aerial image: ESRI online , approx. 2010.
All other data: Client 2015/2016.

Legend

- ● New Monitoring Location
- ● Monitoring Bore (Shire of Kalamunda)
- ● Existing Surface Water Monitoring Location
- ● Vibrating Wire Piezometer monitored by Worley Parsons
- ● Existing Monitoring Bore (PTA) to be monitored
- — Poison Gully Creekline
- — Forrestfield-Airport Link
- ☐ Development Envelope
- 🟧 Poison Gully TEC
- 🟩 Ibis Place TEC

A: New Bore Pair
B: Shallow Bore Only
D: Data Logger Pair
K: Hydraulic Conductivity Testing
R: Deeper Bore to Access Regional Groundwater Table

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4. Conclusion

The groundwater level monitoring to date has been focussed on the regional superficial aquifer. While more information regarding the hydrology of the TECs would be beneficial, the evidence available indicates that any perched groundwater that may occur is likely to be ephemeral and limited to isolated areas. Hence temporary lowering of the regional groundwater table is unlikely to impact the TECs adjacent to the FDE.

The data gathered from the additional groundwater level monitoring program outlined in this report will form the basis of further assessment of the seasonal behaviour of the Superficial Aquifer and localised areas of perched groundwater. This assessment will assist in the investigation of potential impacts to TECs in the area due to temporary drawdown of the regional watertable due to dewatering.

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Appendix 1
Bore logs

REPORT OF BOREHOLE: MW 1-01A

Golder Associates

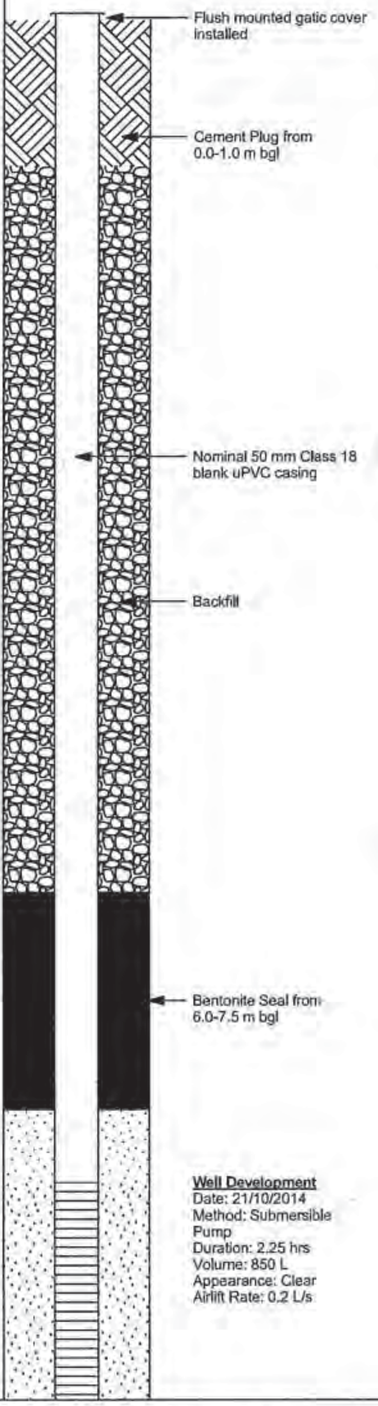
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66617.36 m E 263625.12 m N PCG
SURFACE RL: 30.473 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 46.15 m

SHEET: 1 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 18/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	30.47				**TOPSOIL: SAND** fine to medium grained, quartz, grey, with trace organics and rootlets loose		BS
EPT			0.30 30.17				**SAND** fine to medium grained, quartz, pale orange, with trace roots and rootlets up to 10 mm thick loose to medium dense		
RMF		1							
SPT				SPT 1.50-1.95 m 1, 2, 3 N=5 Rec = 450/450 mm					GF
EPT		2							
SPT		3		SPT 3.00-3.45 m 4, 4, 7 N=11 Rec = 450/450 mm					
EPT			3.50 26.97				**Clayey SAND** fine to medium grained, orange, approximately 10-20% low plasticity clay clay, with some fine to coarse grained sub-rounded to rounded, ferricrete gravel medium dense		
SPT		4		SPT 4.50-4.95 m 4, 7, 12 N=19 Rec = 450/450 mm					
EPT		5	5.00 25.47				**Sandy GRAVEL** fine to medium grained, rounded to sub-angular, ferricrete, quartz, granite, dolerite, grey brown, approximately 30%, coarse grained sand medium dense		
RMF			5.30 25.17				**CLAY** low plasticity, pale grey mottled orange, trace fine to medium grained sand, trace fine to coarse grained sub-rounded, ferricrete gravel, some lenses of clay medium dense to hard		
SPT		6		SPT 6.00-6.45 m 9, 16, 24 N=40 Rec = 450/450 mm					
EPT		7	6.85 23.62				pale grey, gravel absent		
SPT			7.50 22.97	SPT 7.50-7.95 m 10, 12, 15 N=27 Rec = 450/450 mm			**Clayey SAND** fine to medium grained, pale grey, approximately 15-20% low plasticity clay medium dense to very dense		
EPT		8							
SPT		9		SPT 9.00-9.45 m 11, 21, 30 N=51 Rec = 450/450 mm					

CONSTRUCTION



Well Development
Date: 21/10/2014
Method: Submersible Pump
Duration: 2.25 hrs
Volume: 850 L
Appearance: Clear
Airlift Rate: 0.2 L/s

REPORT OF BOREHOLE: MW 1-01A

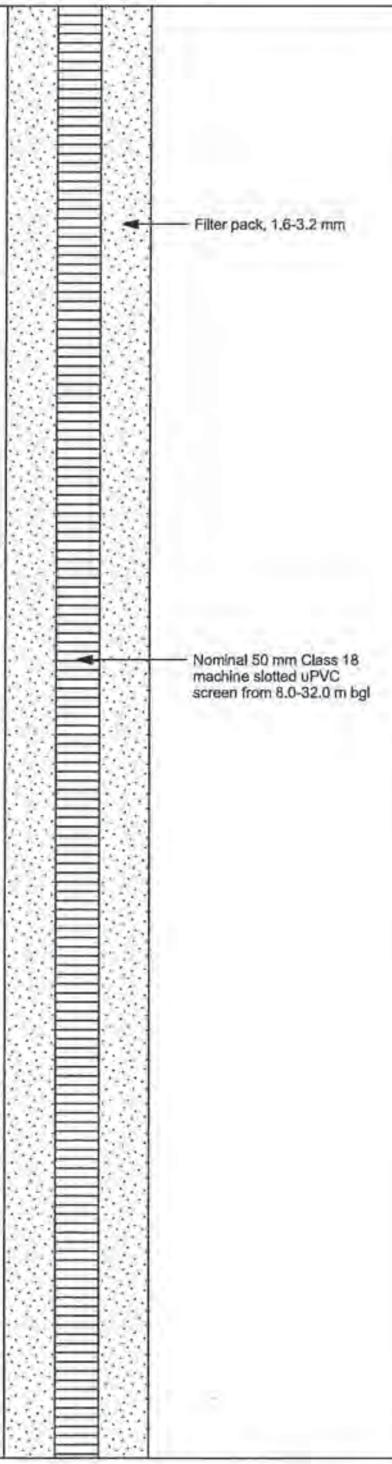
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66617.36 m E 263625.12 m N PCG
SURFACE RL: 30.473 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 46.15 m

SHEET: 2 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 18/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation		
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
EPT		10				Clayey SAND fine to medium grained, pale grey, approximately 15-20% low plasticity clay medium dense to very dense		
SPT				SPT 10.50-10.95 m 4, 12, 24 N=36 Rec = 450/450 mm				
EPT		11						
SPT		12		SPT 12.00-12.45 m 19, 27, 31 N=58 Rec = 450/450 mm				
EPT		13						
SPT				SPT 13.50-13.95 m 9, 15, 19 N=34 Rec = 450/450 mm				
EPT		14						GF
SPT		15		SPT 15.00-15.45 m 11, 15, 23 N=38 Rec = 450/450 mm				
EPT		16						
SPT			16.65 13.82	SPT 16.50-16.95 m 5, 11, 22 N=33 Rec = 450/450 mm		SAND fine to coarse grained, pale grey, with some fines dense to very dense		
EPT		17						
SPT		18		SPT 18.00-18.45 m 16, 25, 33 N=58 Rec = 450/450 mm				
EPT		19						

CONSTRUCTION



REPORT OF BOREHOLE: MW 1-01A

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

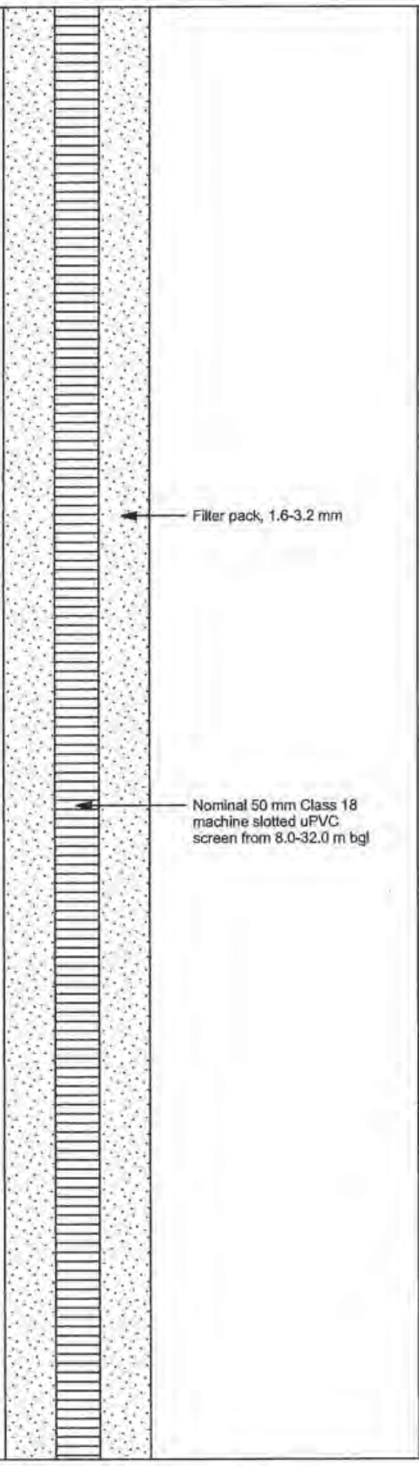
POSITION: TBM Launch Box
COORDS: 66617.36 m E 263625.12 m N PCG
SURFACE RL: 30.473 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 46.15 m

SHEET: 3 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 18/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
SPT			19.85 10.62	SPT 19.50-19.95 m 20, 27, 31 N=58 Rec = 450/450 mm	SAND fine to coarse grained, pale grey, with some fines dense to very dense fine to medium grained	GF
EPT		20				
SPT		21		SPT 21.00-21.45 m 14, 31, 40 N=71 Rec = 450/450 mm		
EPT		22	21.85 8.62		fine to coarse grained, quartz, pale brown grey with some pale orange zones	
SPT				SPT 22.50-22.95 m 8, 24, 36 N=60 Rec = 450/450 mm		
EPT		23				
SPT		24		SPT 24.00-24.45 m 10, 29, 42 N=71 Rec = 450/450 mm		
EPT		25				
SPT			25.90 4.57	SPT 25.50-25.95 m 10, 19, 24 N=43 Rec = 450/450 mm	pale grey, trace fine grained, sub-rounded to rounded, quartz gravel, fines absent, predominately coarse grained sand	
EPT		26				
SPT		27	27.05 3.42	SPT 27.00-27.45 m 10, 22, 35 N=57 Rec = 450/450 mm	trace silt, predominately fine to medium grained sand, laminated, trace iron stained bands	GF
EPT		28	27.80 28.00 2.47		fine to coarse grained, quartz, pale brown grey with some pale orange zones, trace fine grained, sub-rounded to rounded, quartz gravel, fines absent, predominately coarse grained sand Silty SAND fine to medium grained, pale grey mottled orange, approximately 15-20% low plasticity silt, laminated/very thinly bedded medium dense to dense	
SPT				SPT 28.50-28.95 m 11, 15, 20 N=35 Rec = 450/450 mm		
EPT		29				

AIRLIFT YIELD (L/s)

CONSTRUCTION



Filter pack, 1.6-3.2 mm

Nominal 50 mm Class 18 machine slotted uPVC screen from 8.0-32.0 m bgl

GAP 8_09.0 LIB.GLB Log GAP WELL 147642129 MASTER.GPJ <<DrawingFile>> 11/05/2015 17:32 8.30.004 Datgel Tools

Golder Associates

REPORT OF BOREHOLE: MW 1-01A

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66617.36 m E 263625.12 m N PCG
SURFACE RL: 30.473 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 46.15 m

SHEET: 4 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 18/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
EPT					Silty SAND fine to medium grained, pale grey mottled orange, approximately 15-20% low plasticity silt, laminated/very thinly bedded medium dense to dense	GF
SPT		30	30.05 0.42	SPT 30.00-30.45 m 13, 17, 25 N=42 Rec = 450/450 mm	orange	
EPT		31	30.70 -0.23		SAND fine to coarse grained, quartz, orange, trace clay, locally with some clay dense	
SPT				SPT 31.50-31.95 m 16, 27, 19 N=46 Rec = 450/450 mm		
EPT		32	32.00			
			32.15 -1.68		Silty SAND fine grained, orange dense	
			32.40 -1.93		SAND fine to coarse grained, quartz, orange, trace clay, trace fine to coarse grained sub-rounded to rounded gravel dense	OF
			32.60 -2.13		SANDY MUDSTONE-SILTSTONE orange-brown, weathered material of underlying unit highly weathered to moderately weathered, very low to low strength	
PQ3		33		C 33.00-34.60 m Rec = 1600/1600 mm	SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, very low to low strength	
		34		C 34.60-36.00 m Rec = 1300/1400 mm		
		35	34.90 -4.43		CLAYEY SANDSTONE/SANDY MUDSTONE-SILTSTONE grey-black, up to approximately 50% fine to coarse grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic slightly weathered to fresh, extremely low to very low strength	
		36	35.90 -5.43	C 36.00-37.50 m Rec = 1300/1500 mm	CORE LOSS inferred clayey sandstone	
			36.20 -5.73		CLAYEY SANDSTONE/SANDY MUDSTONE-SILTSTONE slightly weathered to fresh, extremely low to very low strength	
		37	36.60 -6.13		SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, very low to low strength	
		38		C 37.50-38.50 m Rec = 1000/1000 mm		
		39		C 38.50-40.15 m Rec = 1650/1650 mm		

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Golder Associates

REPORT OF BOREHOLE: MW 1-01A

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66617.36 m E 263625.12 m N PCG
SURFACE RL: 30.473 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 46.15 m

SHEET: 5 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 18/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
PQ3		40 41 42 43 44		C 38.50-40.15 m Rec = 1650/1650 mm C 40.15-41.60 m Rec = 1450/1450 mm C 41.60-41.70 m Rec = 100/100 mm C 41.70-43.35 m Rec = 1650/1650 mm C 43.35-44.40 m Rec = 1050/1050 mm	■	▤	SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, very low to low strength		Backfill	OF
		45	44.50 -14.03	C 44.40-46.00 m Rec = 1600/1600 mm	■	⁘	SAND fine to coarse grained, quartz, grey, with some clay			
SPT		46	46.15 -15.68	SPT 46.00-46.15 m 72/150mm N=R Rec = 150/150 mm			END OF BOREHOLE @ 46.15 m TARGET DEPTH GROUNDWATER NOT OBSERVED GROUNDWATER MONITORING WELL INSTALLED, SCREENED FROM 8 TO 32 m BELOW GROUND LEVEL			
		47 48 49								

Golder Associates

REPORT OF BOREHOLE: MW 1-01B

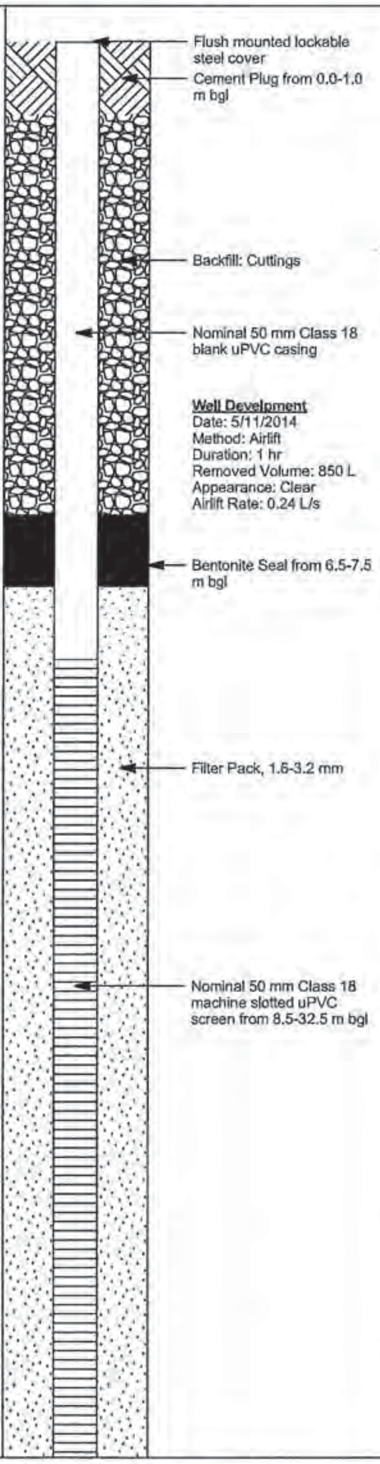
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

COORDS: 66558.46 m E 263603.72 m N PCG
SURFACE RL: 29.326 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 32.50 m

SHEET: 1 OF 2
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 3/11/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation		
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)
WB		0	29.33				SAND fine to medium grained	
			1.00 28.33				Clayey SAND fine to medium grained	
			4.50 24.83				Sandy CLAY low plasticity, fine to medium grained sand	
			7.00 22.33				SAND fine to medium grained	
			7.50 21.83				Silty SAND fine to medium grained	
			13.50 15.83				SAND fine to coarse grained	

CONSTRUCTION



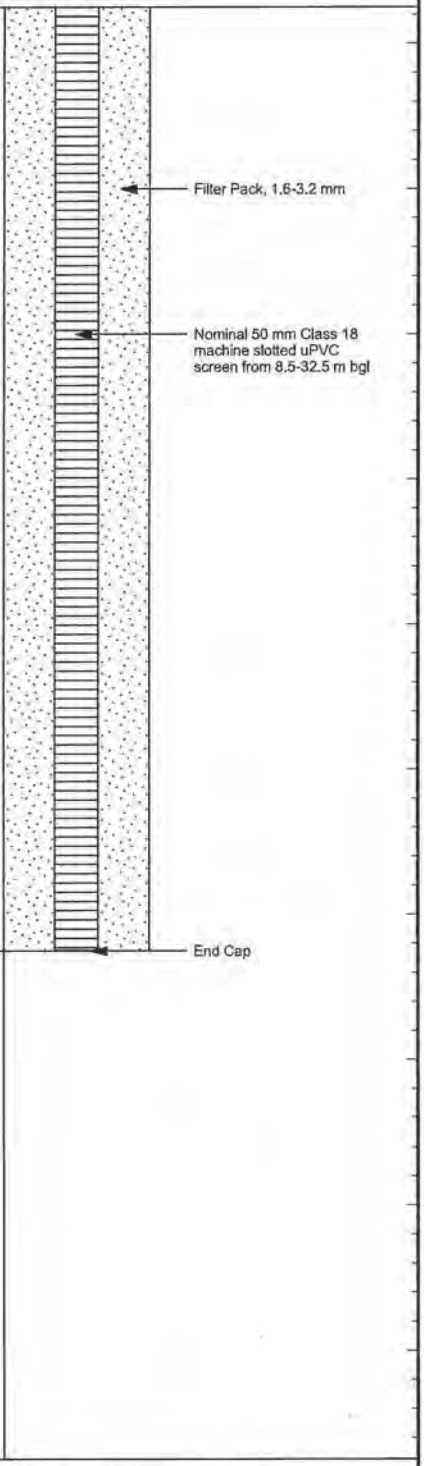
Well Develpment
Date: 5/11/2014
Method: Airlift
Duration: 1 hr
Removed Volume: 850 L
Appearance: Clear
Airlift Rate: 0.24 L/s

Golder Associates

REPORT OF BOREHOLE: MW 1-01B

CLIENT: Public Transport Authority	COORDS: 66558.46 m E 263603.72 m N PCG	SHEET: 2 OF 2	
PROJECT: Stage 2 GI Forrestfield-Airport Link Project	SURFACE RL: 29.326 m DATUM: AHD	DRILL RIG: GDR650	
LOCATION: Bayswater to Forrestfield	INCLINATION: -90°	CONTRACTOR: Hagstrom Drilling Pty Ltd	
JOB NO: 147642129	HOLE DEPTH: 32.50 m	LOGGED: TW	DATE: 3/11/14
		CHECKED: DB	DATE: 11/5/15

Drilling				Sampling	Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION
WB		20					SAND fine to coarse grained		
			22.50 6.83				Silty SAND fine to medium grained		
			25.50 3.83				SAND fine to coarse grained		
			27.50 1.83				Clayey SAND fine to medium grained		
			31.50 -2.17				Silty Sandy CLAY low plasticity, fine to medium grained sand		
			32.50 -3.17				END OF BOREHOLE @ 32.50 m TARGET DEPTH GROUNDWATER NOT OBSERVED GROUNDWATER MONITORING WELL INSTALLED, SCREENED FROM 8.5 m TO 32.5 m DEPTH		



This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

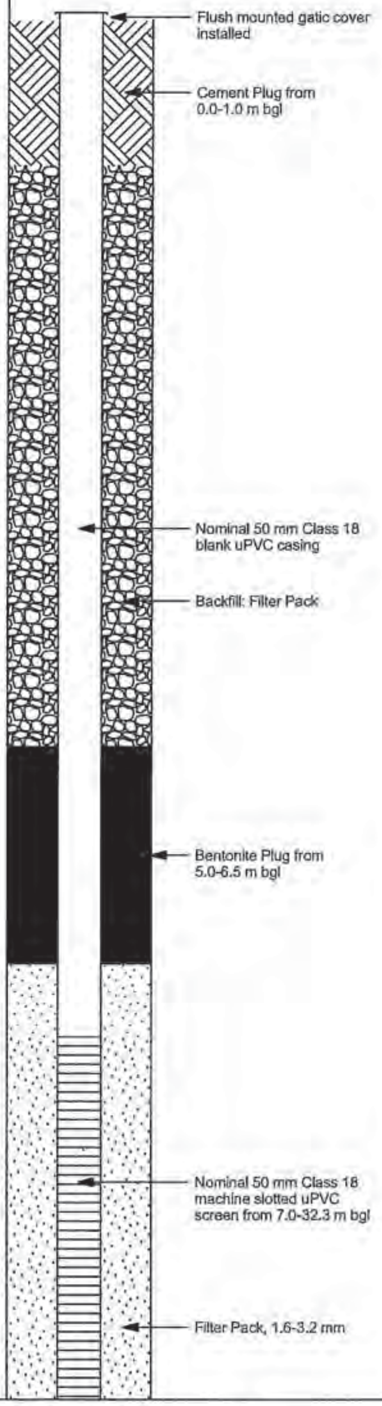
Golder Associates

REPORT OF BOREHOLE: MW 1-01C

CLIENT: Public Transport Authority	POSITION: TBM Launch Box	SHEET: 1 OF 5
PROJECT: Stage 2 GI Forrestfield-Airport Link Project	COORDS: 66618.67 m E 263614.55 m N PCG	DRILL RIG: GDR650
LOCATION: Bayswater to Forrestfield	SURFACE RL: 30.47 m DATUM: AHD	CONTRACTOR: Hagstrom Drilling Pty Ltd
JOB NO: 147642129	INCLINATION: -90°	LOGGED: TW DATE: 20/10/14
	HOLE DEPTH: 45.00 m	CHECKED: DB DATE: 11/5/15

Drilling				Sampling	Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
EPT		0	30.47				TOPSOIL: SAND fine to medium grained, pale grey, with trace organic material and trace rootlets. loose		BS
			0.40 30.07				SAND fine to medium grained, pale brown loose		
SPT		1	*1.00* 29.47	SPT 1.00-1.45 m 1, 2, 2 N=4 Rec = 450/450 mm			orange, with some clay		
EPT			*1.50* 28.97				fine to coarse grained, pale orange, with some fine to coarse grained, angular to rounded granite and ferricrete gravel, possible fill		
		2	*2.15* 28.32				Clayey SAND fine to medium grained, orange, approximately 20% low plasticity clay loose		GF
SPT			*2.50* 27.97	SPT 2.50-2.95 m 6, 9, 9 N=18 Rec = 450/450 mm			Sandy GRAVEL fine to medium grained, rounded to sub-angular, ferricrete, quartz, granite and dolerite, grey brown, coarse grained sand medium dense		
EPT		3	*3.35*				Clayey SAND fine to medium grained, pale grey mottled orange, trace gravel medium dense		
		4	*3.50* 26.97				Sandy GRAVEL fine to medium grained, rounded to sub-angular, ferricrete, quartz, granite and dolerite, grey brown, coarse grained sand medium dense to very dense		
SPT		5	*4.55* 25.92	SPT 4.50-4.95 m 20, 30, 42 N=72 Rec = 450/450 mm			Clayey SAND fine to medium grained, pale grey mottled orange, trace fine gravel dense to very dense		
EPT			*5.20* 25.27				with some layers of gravelly sand to 5.7 m depth		
SPT		6	*5.90* 24.57	SPT 6.00-6.45 m 17, 18, 20 N=38 Rec = 450/450 mm			trace rootlets, no gravel, with some interbeds of sandy clay		
U				U63 6.50-7.00 m Rec = 500/500 mm					
EPT		7							
SPT				SPT 7.50-7.95 m 7, 22, 32 N=54 Rec = 450/450 mm					
EPT		8							
SPT		9	*9.45*	SPT 9.00-9.45 m 13, 18, 20 N=38 Rec = 450/450 mm					

CONSTRUCTION



Golder Associates

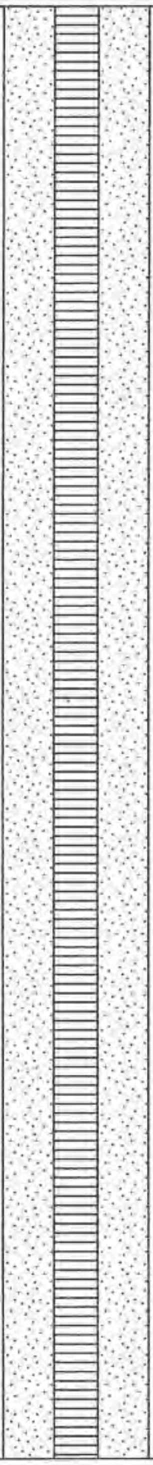
REPORT OF BOREHOLE: MW 1-01C

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66618.67 m E 263614.55 m N PCG
SURFACE RL: 30.47 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 45.00 m

SHEET: 2 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 20/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
EPT		10	21.02				with some interbeds of sand with clay content < 10% Clayey SAND fine to medium grained, pale grey mottled orange, trace fine gravel dense to very dense			GF
SPT			10.65 19.82	SPT 10.50-10.95 m 19, 30, 37 N=67 Rec = 450/450 mm			Clayey Silty SAND fine to medium grained, ~15-20% low plasticity fines, interbeds of sand dense to very dense		**Well Development** Date: 24/10/14 Method: Submersible pump Duration: 2.5 hours Volume: 1000 L Appearance: Clear Airlift Rate: 0.11 L/s	
EPT		11								
SPT		12		SPT 12.00-12.45 m 14, 20, 22 N=42 Rec = 450/450 mm						
EPT		13								
SPT				SPT 13.50-13.95 m 9, 19, 22 N=41 Rec = 450/450 mm						
EPT		14								
SPT		15		SPT 15.00-15.45 m 10, 17, 22 N=39 Rec = 450/450 mm						
EPT		16								
SPT			16.80 13.67	SPT 16.50-16.95 m 8, 12, 27 N=39 Rec = 450/450 mm			SAND fine to coarse grained, mostly quartz, pale grey, with some fines dense to very dense			
EPT		17								
SPT		18	18.50 11.97	SPT 18.00-18.45 m 11, 25, 25 N=50 Rec = 450/450 mm			fine to medium grained			
EPT		19								



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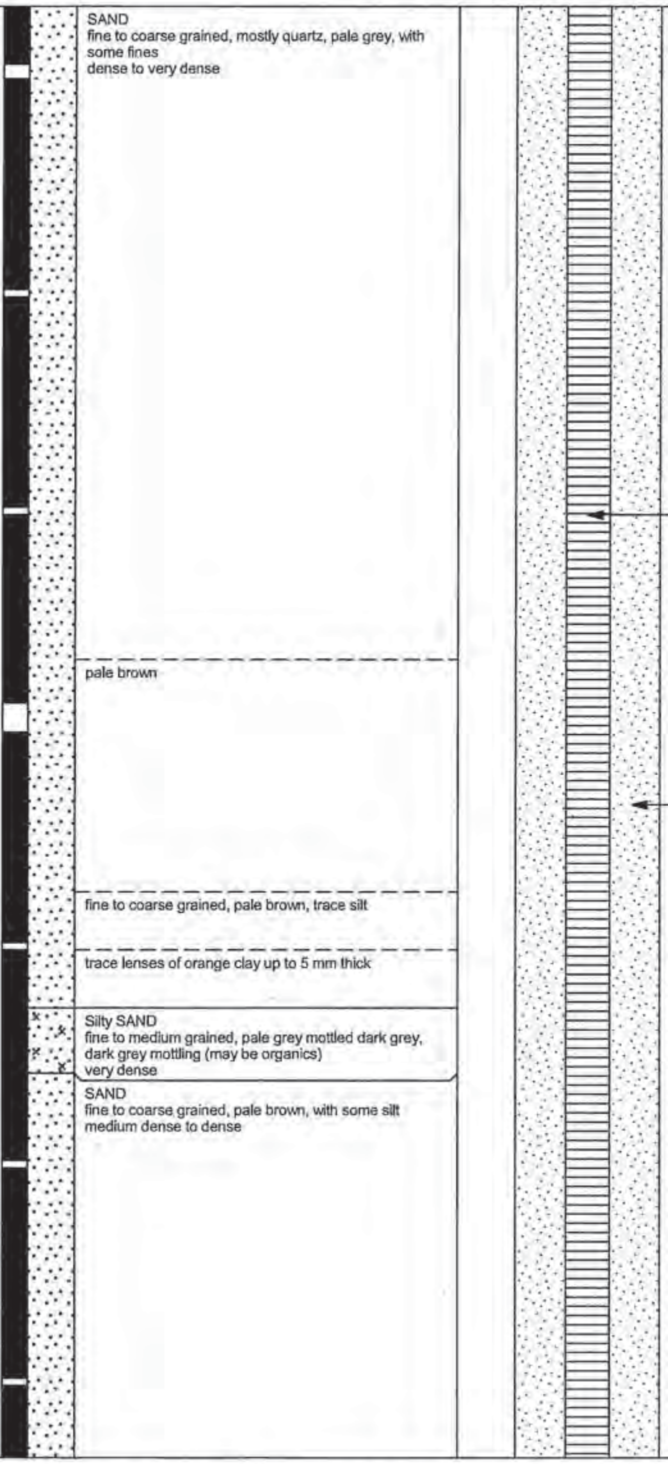
Golder Associates

REPORT OF BOREHOLE: MW 1-01C

CLIENT: Public Transport Authority	POSITION: TBM Launch Box	SHEET: 3 OF 5	
PROJECT: Stage 2 GI Forrestfield-Airport Link Project	COORDS: 66618.67 m E 263614.55 m N PCG	DRILL RIG: GDR650	
LOCATION: Bayswater to Forrestfield	SURFACE RL: 30.47 m DATUM: AHD	CONTRACTOR: Hagstrom Drilling Pty Ltd	
JOB NO: 147642129	INCLINATION: -90°	LOGGED: TW	DATE: 20/10/14
	HOLE DEPTH: 45.00 m	CHECKED: DB	DATE: 11/5/15



Drilling				Sampling	Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
SPT				SPT 19.50-19.90 m 7, 25, 32/100mm HB N>57 Rec = 400/400 mm	SAND fine to coarse grained, mostly quartz, pale grey, with some fines dense to very dense			
EPT		20						
SPT		21		SPT 21.00-21.45 m 18, 25, 31 N=56 Rec = 450/450 mm				
EPT		22						
SPT				SPT 22.50-22.95 m 8, 20, 39 N=59 Rec = 450/450 mm				
EPT		23					Nominal 50 mm Class 18 machine slotted uPVC screen from 7.0-32.3 m bgl	GF
SPT		24	24.00 6.47	SPT 24.00-24.30 m 23, 50/150mm N>50 Rec = 300/300 mm	pale brown			
RMF								
EPT		25					Filter Pack, 1.6-3.2 mm	
SPT			25.60 4.87	SPT 25.50-25.95 m 15, 31, 31 N=62 Rec = 450/450 mm	fine to coarse grained, pale brown, trace silt			
EPT		26	26.00 4.47		trace lenses of orange clay up to 5 mm thick			
			26.40 4.07		Silty SAND fine to medium grained, pale grey mottled dark grey, dark grey mottling (may be organics) very dense			
			26.85 3.62		SAND fine to coarse grained, pale brown, with some silt medium dense to dense			
SPT		27		SPT 27.00-27.45 m 6, 16, 20 N=36 Rec = 450/450 mm				
EPT		28						GF
SPT				SPT 28.50-28.95 m 15, 20, 24 N=44 Rec = 450/450 mm				
EPT		29						

Golder Associates

REPORT OF BOREHOLE: MW 1-01C

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66618.67 m E 263614.55 m N PCG
SURFACE RL: 30.47 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 45.00 m

SHEET: 4 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 20/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
EPT SPT EPT SPT		30 31		SPT 30.00-30.45 m 9, 11, 13 N=24 Rec = 450/450 mm	SAND fine to coarse grained, pale brown, with some silt medium dense to dense	GF
		32	31.60 -1.13	SPT 31.50-31.95 m 7, 10, 11 N=21 Rec = 450/450 mm C 32.00-33.00 m Rec = 850/1000 mm	Sandy SILT low plasticity, orange, fine grained sand, with some silt pockets up to 15 mm thick and some fine to coarse grained sand lenses up to 50 mm thick, likely weathered material of the underlying unit very stiff	
PQ3		33 34	32.30 -1.83	C 33.00-34.40 m Rec = 1400/1400 mm C 34.40-35.40 m Rec = 1000/1000 mm	SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, very low to low strength	OF
		35 36	34.60 -4.13	C 35.40-36.00 m Rec = 600/600 mm C 36.00-37.60 m Rec = 1600/1600 mm	CLAYEY SANDSTONE/SANDY MUDSTONE-SILTSTONE grey-black, up to approximately 50% fine to coarse grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic slightly weathered to fresh, extremely low to very low strength	
		37 38 39	36.25 -5.78	C 37.60-38.80 m Rec = 1200/1200 mm C 38.80-40.00 m Rec = 1200/1200 mm	SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, extremely low to low strength	

AIRLIFT YIELD (L/s)

CONSTRUCTION

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Golder Associates

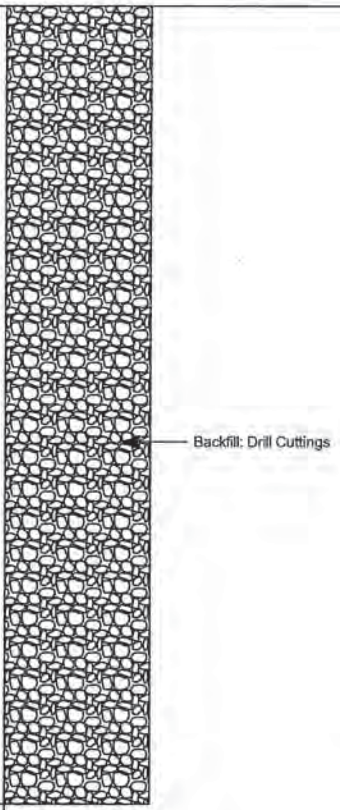
REPORT OF BOREHOLE: MW 1-01C

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: TBM Launch Box
COORDS: 66618.67 m E 263614.55 m N PCG
SURFACE RL: 30.47 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 45.00 m

SHEET: 5 OF 5
DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 20/10/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
PQ3		40 41 42 43 44	44.25 -13.78	C 38.80-40.00 m Rec = 1200/1200 mm C 40.00-40.20 m Rec = 200/200 mm C 40.20-41.90 m Rec = 1700/1700 mm C 41.90-43.40 m Rec = 1500/1500 mm C 43.40-45.00 m Rec = 1050/1600 mm			SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, extremely low to low strength			OF
			44.80 -14.33				Clayey fine to coarse grained, dark grey-green very dense			
		45	45.00 -14.53				SANDY MUDSTONE-SILTSTONE grey-black, approximately 30-40% fine to medium grained sand in a matrix of low to medium plasticity silt and clay, not distinctly layered, some fine laminae and trough stratification present, glauconitic, fine grained disseminated pyrite slightly weathered to fresh, very low to low strength			
		46 47 48 49					END OF BOREHOLE @ 45.00 m TARGET DEPTH GROUNDWATER NOT OBSERVED GROUNDWATER MONITORING WELL INSTALLED, SCREENED FROM 7.0 m TO 32.3 m DEPTH			

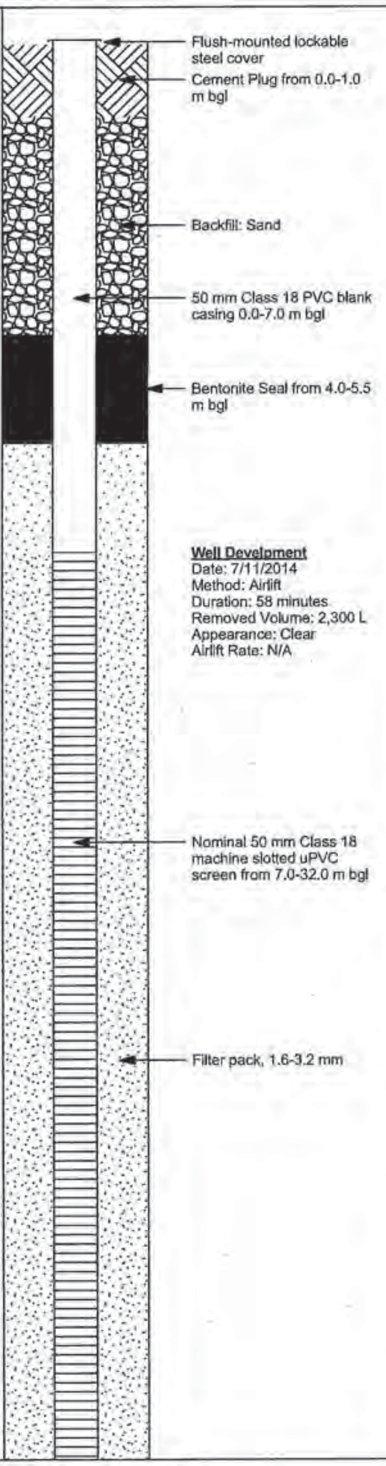


Golder Associates

REPORT OF BOREHOLE: MW 1-01D

CLIENT: Public Transport Authority	COORDS: 66623.68 m E 263577.81 m N PCG	SHEET: 1 OF 2	
PROJECT: Stage 2 GI Forrestfield-Airport Link Project	SURFACE RL: 30.190 m DATUM: AHD	DRILL RIG: DR005	
LOCATION: Bayswater to Forrestfield	INCLINATION: -90°	CONTRACTOR: J&S	
JOB NO: 147642129	HOLE DEPTH: 33.00 m	LOGGED: NA	DATE: 6/11/14
		CHECKED: DB	DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION
WB	29/11/14 12:04, Water Level - mb galic cover	0	30.19				SAND fine to coarse grained, brown, sub-rounded to sub-angular		
		3.00	27.19				Gravelly SAND fine to coarse grained, pale brown, sub-rounded to sub-angular		
		5.00	25.19				Clayey SAND fine to medium grained, pale grey, sub-rounded to sub-angular,		
		9.00	21.19				Clayey Gravelly SAND fine grained, pale grey, sub-rounded to sub-angular		
		12.00	18.19				Clayey SAND fine to medium grained, pale grey, sub-rounded to sub-angular		
		18.00	12.19				No recovery, fines too small for sieve		



Well Develpment
Date: 7/11/2014
Method: Airlift
Duration: 58 minutes
Removed Volume: 2,300 L
Appearance: Clear
Airlift Rate: N/A

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Golder Associates

REPORT OF BOREHOLE: MW 1-01D

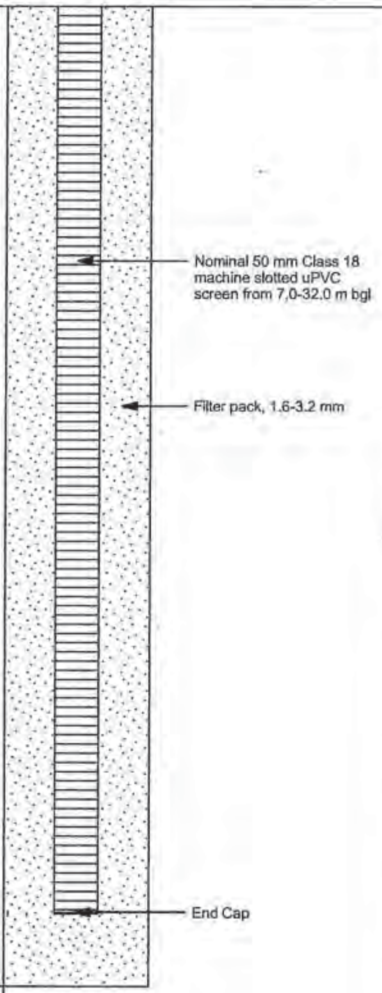
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

COORDS: 66623.68 m E 263577.81 m N PCG
SURFACE RL: 30.190 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 33.00 m

SHEET: 2 OF 2
DRILL RIG: DR005
CONTRACTOR: J&S
LOGGED: NA DATE: 6/11/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION
WB		20					No recovery, fines too small for sieve		
		21, 22	21.00 9.19				SAND fine to medium grained, yellow-brown, sub-rounded to sub-angular		
		24	24.00 6.19				Clayey SAND fine to coarse grained, grey, sub-rounded to sub-angular		
		25, 26	25.00 5.19				SAND fine to coarse grained, grey, sub-rounded to sub-angular		
		28, 30	28.00 2.19				Clayey SAND fine to medium grained, red-brown, with pockets of grey clayey fine grained sand	1.5	
		32	32.00 -1.81				Sandy CLAY dark grey and green, medium plasticity		
		33, 34, 36, 38	33.00 -2.81				END OF BOREHOLE @ 33.00 m TARGET DEPTH GROUNDWATER NOT OBSERVED GROUNDWATER MONITORING WELL INSTALLED, SCREENED FROM 7.0 m TO 32.0 m DEPTH		

CONSTRUCTION



Golder Associates

REPORT OF BOREHOLE: MW 1-05

SHEET: 1 OF 1

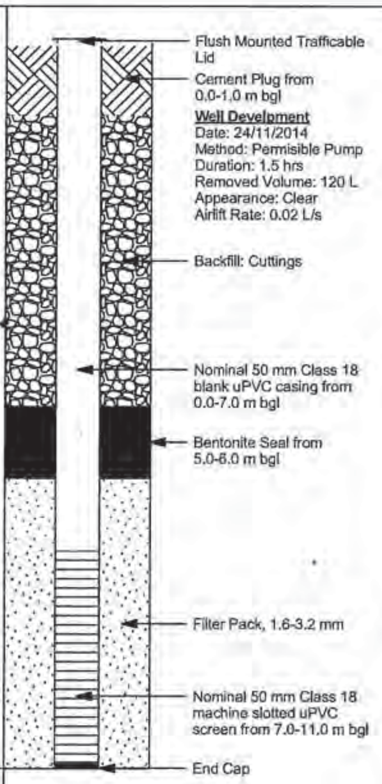
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

COORDS: 66547.98 m E 262741.88 m N PCG
SURFACE RL: 28.416 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 10.00 m

DRILL RIG: GDR650
CONTRACTOR: Hagstrom Drilling Pty Ltd
LOGGED: TW DATE: 21/11/14
CHECKED: DB DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation		
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)
WB		0	28.42				SAND fine to medium grained	
		1.00	27.42				Clayey SAND fine to medium grained	
		7.50	20.92				SAND fine to medium grained	
		10.00	18.42				END OF BOREHOLE @ 10.00 m TARGET DEPTH GROUNDWATER NOT OBSERVED GROUNDWATER MONITORING WELL INSTALLED, SCREENED FROM 7.0 m TO 10.0 m DEPTH	

CONSTRUCTION



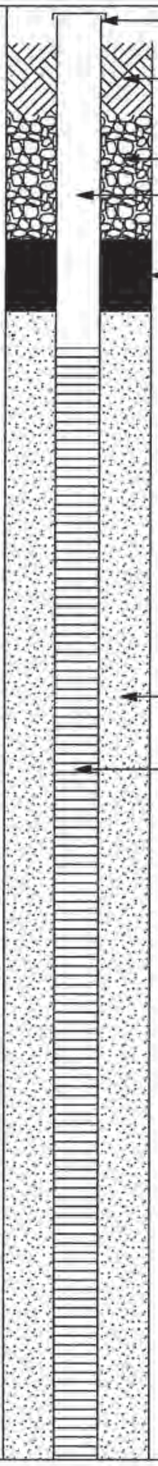
Well Develpment
Date: 24/11/2014
Method: Permisible Pump
Duration: 1.5 hrs
Removed Volume: 120 L
Appearance: Clear
Airlift Rate: 0.02 L/s

Golder Associates

REVISION A REPORT OF BOREHOLE: PW 1-01

CLIENT: Public Transport Authority	COORDS: 66618.950 m E 263607.530 m N PCG	SHEET: 1 OF 2
PROJECT: Stage 2 GI Forrestfield-Airport Link Project	SURFACE RL: 30.320 m DATUM: AHD	DRILL RIG: KL 100 Heli
LOCATION: Bayswater to Forrestfield	INCLINATION: -90°	CONTRACTOR: J&S
JOB NO: 147642129	HOLE DEPTH: 33.00 m	LOGGED: NA DATE: 7/11/14
		CHECKED: SWG DATE: 11/5/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION
WB		0	30.32				SAND fine to coarse grained, grey and red-brown, sub-rounded to sub-angular		
		2	2.00 28.32				Clayey SAND fine to medium grained, red-brown, sub-rounded to sub-angular		
		4	4.00 26.32				grey and pale brown		
		6							
		8							
		10	10.00 20.32				pale grey, fine to coarse grained, trace clay		
		12							
		14							
		16							
		18							



Lockable Steel Riser, 0.4 m agl

Cement Plug from 0.0-1.0 m bgl

Backfill: Sand from 1.0-2.7 m bgl

203 mm Class 18 PVC blank casing from 0.0-4.2 m bgl

Bentonite Seal from 2.7-3.7 m bgl

Well Development
Date: 7/11/2014
Method: Submersible Pump
Duration: 10 hrs
Removed Volume: 6500 L
Appearance: Clear
Airlift Rate: 7 L/s

Filter Pack, size 1.6-3.2 mm from 3.7-31.2 m bgl

203 mm Class 18 PVC machine slotted screen from 4.2-31.2 m bgl

Golder Associates

REPORT OF BOREHOLE: MW 3-001

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66533.36 m E 262352.94 m N MGA94 56
SURFACE RL: 27.78 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 6.00 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: KC DATE: 9/1/15
CHECKED: LK DATE: 14/4/15

Drilling | **Sampling** | **Field Material Description and Instrumentation**

METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
HA		0	27.78 0.20 27.58	Q11812-01 0.10-0.30 m PID = 0.0 ppm	FILL: TOPSOIL fine to medium grained, rounded to sub-rounded, dark brown, 0A dry to moist, loose	MG
				Q11812-02 0.50-0.70 m PID = 0.5 ppm	FILL: Gravelly SAND medium grained, rounded to sub-rounded, brown orange to brown, up to 30 mm gravel, trace blue metal and asphalt, 0A moist, loose	
		1	1.00 26.78	1.00-1.30 m PID = 0.9 ppm	FILL: Sandy GRAVEL fine to medium grained, to 30 mm, rounded to sub-rounded, brown orange, 0A dry to moist, very loose	
			1.30 26.48	1.50-1.70 m PID = 0.5 ppm		
PT			1.70 1.85		FILL: Gravelly SAND fine grained, sub-rounded, up to 20 mm gravel, 0A dry to moist, loose	BS
		2	2.05 25.73		SAND fine to medium grained, rounded, brown, 0A dry, loose	
				2.40-2.60 m PID = 0.5 ppm	brown orange, 0A dry to moist, loose	
			2.85 24.93		medium grained, pale brown, 0A dry, loose	
		3			fine to medium grained, sub-rounded, brown orange, 0A dry, loose	
					medium grained, sub-rounded, orange, 0A dry, loose	
			3.60 24.18	3.50-3.70 m PID = 2.7 ppm	fine grained, rounded, pale grey, 0A dry to moist, loose	GF
	▽	4		Q11812-07 3.80-4.20 m PID = 1.7 ppm Q11812-08 3.80-4.20 m DUPLICATE	Clayey SAND fine to medium grained, rounded to sub-rounded, low plasticity, pale grey, low plasticity clay, rotten egg odour, 0B moist to wet, medium dense	
				4.50-4.70 m PID = 1.0 ppm		
		5		5.50-5.70 m PID = 2.2 ppm		
		6	6.00 21.78	5.80-6.00 m PID = 2.6 ppm	END OF BOREHOLE @ 6.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.00 m DEPTH STANDPIPE INSTALLED	
		7				
		8				
		9				
		10				

AIRLIFT YIELD (L/s)

CONSTRUCTION

Gatic Cover
0.0 - 0.3 m Cement
0.3 - 2.3 m Bentonite/Cement
0.0 - 3.0 m 50 mm Class 18 PVC
2.3 - 2.8 m Bentonite Seal
2.8 - 6.0 m Gravel Filter Pack
3.0 - 6.0 m 50 mm Class 18 PVC Slotted Screen

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Golder Associates

REPORT OF BOREHOLE: MW 3-004

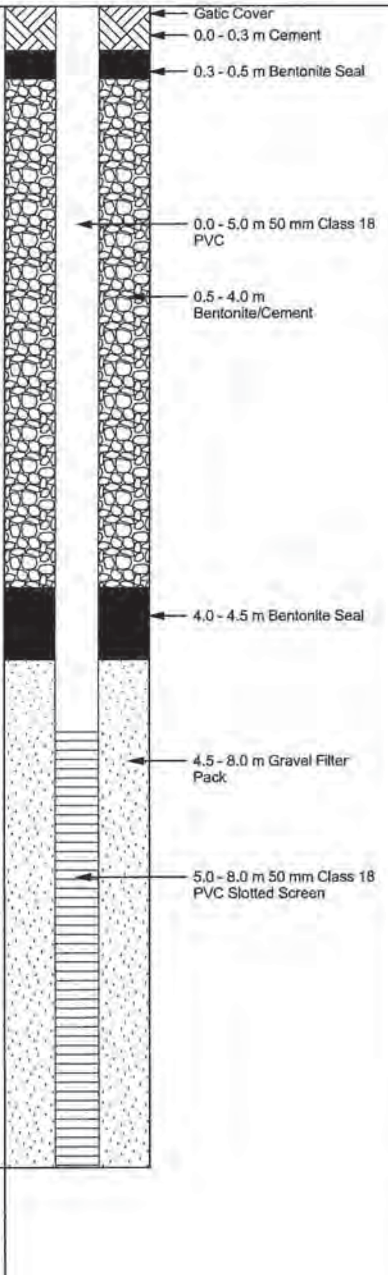
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66561.46 m E 262578.99 m N MGA94 56
SURFACE RL: 30.00 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 8.00 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 7822DT
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 16/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	30.00	Q12023-01 0.00-0.20 m PID = 0.0 ppm			SAND fine to medium grained, well graded, rounded to sub-rounded, yellow brown, trace silt, trace coarse grained sand, 0A dry, loose		BS
			0.20 29.80	Q12023-02 0.40-0.60 m PID = 0.0 ppm			dark grey, with some silt, with some sub-rounded to sub-angular, up to 30 mm gravel, 0A dry, loose		
		1	0.50 29.50	1.00 m PID = 0.0 ppm			dark white, 0A dry, loose		
			1.20				pale yellow, 0A dry, loose		
			1.30 28.70				yellow, 0A dry, loose		
PT		2	1.50 28.50	1.50 m PID = 0.0 ppm 2.00 m PID = 0.0 ppm			orange, 0A dry to moist, loose		
		3	2.10 27.90	3.00 m PID = 0.0 ppm			Silty SAND fine grained, sub-rounded to sub-angular, mottled brown orange, with some up to 10 mm gravel between 2.8-3.0 m, trace clay, 0A moist, loose to dense		GF
		4	4.00 26.00	4.00 m PID = 0.0 ppm			pale grey with mottled orange, increased clay content, 0A moist, dense		
			4.50 25.50				with some low plasticity clay, 0A moist, dense		
		5	5.00 25.00	5.00 m PID = 0.0 ppm			Silty Clayey SAND fine grained, sub-rounded to sub-angular, pale grey, low to medium plasticity clay, 0A moist, firm		
	▽	6	6.00 24.00	Q12023-11 6.00-6.20 m PID = 0.0 ppm 6.20 m PID = 0.0 ppm			mottled pale orange, medium plasticity, 0A wet		
		7	6.80 23.20	7.00 m PID = 0.0 ppm			high plasticity, 0A wet, stiff		
			7.20 22.80				some mottled pale red, 0A wet		
			7.50 22.50				low to medium plasticity, 0A wet		
		8	8.00 22.00	8.00 m PID = 0.0 ppm			END OF BOREHOLE @ 8.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 6.00 m DEPTH STANDPIPE INSTALLED		
		9							
		10							

CONSTRUCTION



Golder Associates

REPORT OF BOREHOLE: MW 3-009

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

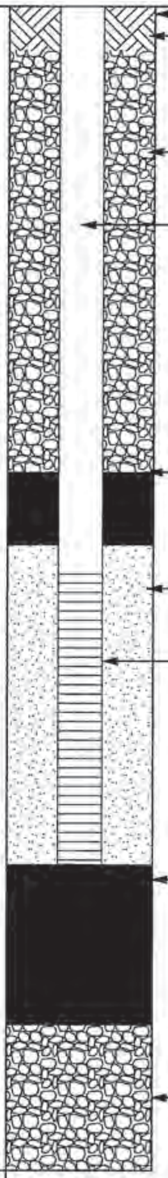
POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66587.32 m E 262706.25 m N MGA94 56
SURFACE RL: 30.20 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 8.00 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: KC DATE: 12/1/15
CHECKED: LK DATE: 14/4/15

Drilling			Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH / RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
HA		0.00 30.20	Q11814-01 0.10-0.20 m PID = 0.0 ppm	FILL: Gravelly SAND fine grained, sub-rounded to sub-angular, dark brown, medium grained, up to 30 mm gravel, 0A dry, loose	MG
		0.40 29.80	Q11814-02 0.40-0.60 m PID = 0.0 ppm	FILL: SAND fine to medium grained, rounded to sub-rounded, pale grey, 0A dry to moist, loose	
		0.90 29.30	Q11814-06 0.40-0.60 m DUPLICATE Q11815-01 0.40-0.60 m TRIPLICATE 1.00-1.10 m PID = 0.0 ppm	sub-rounded to sub-angular, yellow brown, 0A dry to moist, loose	
		1.70 28.50	1.50-1.60 m PID = 0.0 ppm 1.80-2.00 m PID = 0.0 ppm	brown orange, 0A dry to moist, loose	
PT		2.50 27.70	2.50-2.70 m PID = 0.0 ppm	FILL: Gravelly SAND fine to medium grained, sub-rounded to sub-angular, brown orange, medium, red brown, up to 20 mm gravel, 0A dry, medium dense	
		3.00 27.20	3.50-3.70 m PID = 0.1 ppm	brown yellow, 0A dry, medium dense	
		4.00 26.20	4.50-4.70 m PID = 0.0 ppm	SAND fine to medium grained, sub-rounded to sub-angular, pale brown, with some red brown gravel, 0A dry, medium dense	BS
		5.00 25.20		Sandy GRAVEL medium grained, to 20 mm, sub-angular to angular, red brown, sub-angular, pale brown sand, 0A dry, medium dense	
	▽	5.50 24.70	Q11814-10 5.50-5.70 m PID = 0.0 ppm 6.50-6.70 m PID = 0.0 ppm	Sandy CLAY low to medium plasticity, pale grey, fine to coarse, sub-angular to sub-rounded sand, possible iron staining, 0A wet, firm	GF
		7.50 22.70	7.50-7.70 m PID = 0.3 ppm	minor pale red staining, 0A wet, firm	
		8.00 22.20		END OF BOREHOLE @ 8.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 5.50 m DEPTH STANDPIPE INSTALLED	

AIRLIFT YIELD (L/s)

CONSTRUCTION



Gatic Cover
0.0 - 0.3 m Cement
0.3 - 3.2 m Bentonite/Cement
0.0 - 3.9 m 50 mm Class 18 PVC
3.2 - 3.7 m Bentonite Seal
3.7 - 5.9 m Gravel Filter Pack
3.9 - 5.9 m 50 mm Class 18 PVC Slotted Screen
5.9 - 7.0 m Bentonite Plug
7.0 - 8.0 m Bentonite/Cement Backfill

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Golder Associates

REPORT OF BOREHOLE: MW 3-012

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66530.76 m E 262978.68 m N MGA94 56
SURFACE RL: 29.24 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 10.50 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 15/1/15
CHECKED: DATE:

Drilling | **Sampling** | **Field Material Description and Instrumentation**

METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
		-1				
HA		0	29.24	Q10979-02 0.00-0.20 m PID = 0.0 ppm	SAND fine to medium grained, sub-rounded to sub-angular, yellow grey, with some silt, 0A loose	BS
			0.30 28.94	Q10979-03 0.40-0.60 m PID = 0.0 ppm	SILT pale yellow grey, with some fine to coarse grained sand, with some soft, low plasticity clay, 0A dry, loose	
		1	0.80 28.44	0.90-1.10 m PID = 0.0 ppm	yellow, 0A dry, loose	
			1.20 28.04	1.40-1.60 m PID = 0.0 ppm	orange, 0A dry, loose	
PT		2	2.00 27.24	1.90-2.10 m PID = 0.0 ppm 2.90-3.10 m PID = 0.0 ppm	with some up to 15 mm gravel, 0A dry, loose	
		3	3.20 26.04	Q10979-08 3.90-4.10 m PID = 0.0 ppm	Clayey Gravelly SILT grey and orange brown, up to 10 mm gravel, soft, low plasticity clay, trace fine to medium grained sand, 0A dry, loose	GF
	▽	4	4.20 25.04		Silty SAND fine to medium grained, sub-rounded, low plasticity, grey, mottled pale red and orange brown, with some up to 12 mm gravel, 0A wet, dense	
			4.80 24.44	4.90-5.10 m PID = 0.0 ppm	Silty CLAY high plasticity, grey, mottled orange brown, 0A wet, firm	
		5	5.70 23.54	5.90-6.10 m PID = 0.0 ppm	Sandy Clayey SILT grey, mottled orange brown, medium plasticity clay, fine grained sand, 0A wet, firm	
		6	6.20 23.04	6.90-7.20 m PID = 0.0 ppm	low plasticity, 0A wet, hard	
		7	7.30 21.94	7.90-8.10 m PID = 0.0 ppm 9.00 m PID = 0.0 ppm	Silty Clayey SAND fine grained, grey, low to medium plasticity clay, increased clay content between 9.2 - 9.5 m bgl, 0A wet, firm to hard	
		8				
		9				
		10				

CONSTRUCTION

This report of borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for environmental purposes only, without attempt to consider geotechnical properties or the geotechnical significance of the materials encountered. As such it should not be relied upon for geotechnical purposes.

GAP gINT FN. F05
RL3

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REPORT OF BOREHOLE: MW 3-012

Golder Associates

CLIENT: PTA	POSITION: Forrestfield Dive Structure and Launch Box	SHEET: 2 OF 2
PROJECT: FAL Contamination/ASS Investigation	COORDS: 66530.76 m E 262978.68 m N MGA94 56	DRILL RIG: Geoprobe 66200DT
LOCATION: Forrestfield to Bayswater	SURFACE RL: 29.24 m DATUM: AHD	CONTRACTOR: Direct Push Probing
JOB NO: 147643093	INCLINATION: -90°	LOGGED: JG DATE: 15/1/15
	HOLE DEPTH: 10.50 m	CHECKED: DATE:

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
PT		10	10.50	10.00 m PID = 0.5 ppm						GF
			18.74				END OF BOREHOLE @ 10.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.20 m DEPTH STANDPIPE INSTALLED			
		11								
		12								
		13								
		14								
		15								
		16								
		17								
		18								
		19								
		20								
		21								

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Golder Associates

REPORT OF BOREHOLE: MW 3-013

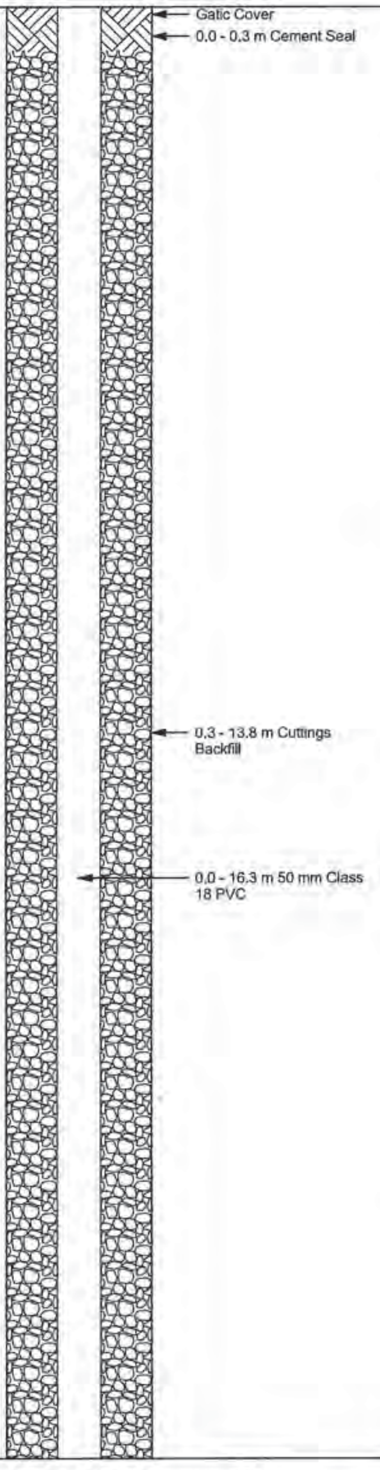
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 67094.62 m E 263011.38 m N MGA94 56
SURFACE RL: 34.68 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.50 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 6/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation		
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	34.68 0.20 34.48	Q12021-01 0.00-0.20 m PID = 0.0 ppm	Silty SAND fine to medium grained, grey, 0A dry, loose		BS
				Q12021-02 0.40-0.60 m PID = 0.0 ppm	dark grey, 0A dry, loose		
		1	1.00 33.68	1.00 m PID = 0.0 ppm	fine grained, pale yellow becoming yellow, 0A dry, loose		
PT				1.50 m PID = 0.0 ppm			
			1.80 32.88		grey, 0A moist, loose		
		2	2.00 32.68	2.00 m PID = 0.0 ppm	Clayey SILT orange with some mottled red, medium plasticity clay, with some fine grained, rounded to sub-rounded sand, with some up to 20 mm gravel, 0A moist, loose to dense		GF
		3		3.00 m PID = 0.0 ppm			
		4		4.00 m PID = 0.0 ppm			
			4.50 30.18		pale yellow grey with mottled orange, 0A moist, dense		
		5		5.00 m PID = 0.0 ppm			
		6		6.00 m PID = 0.0 ppm			
			6.40 28.28		pale grey, 0A moist, soft		
		7	7.00 27.68	7.00 m PID = 0.0 ppm	Clayey SILT grey with mottled orange and red, low to medium plasticity clay, trace fine grained sand, 0A moist, very dense		
			7.80 26.88		pale grey, 0A moist, hard		
		8		8.00 m PID = 0.0 ppm			
		9	9.00 25.68	9.00 m PID = 0.0 ppm	increasing clay content, 0A moist, stiff to hard		
ADH			9.50 25.18		CORE LOSS moist		
		10					

CONSTRUCTION



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Golder Associates

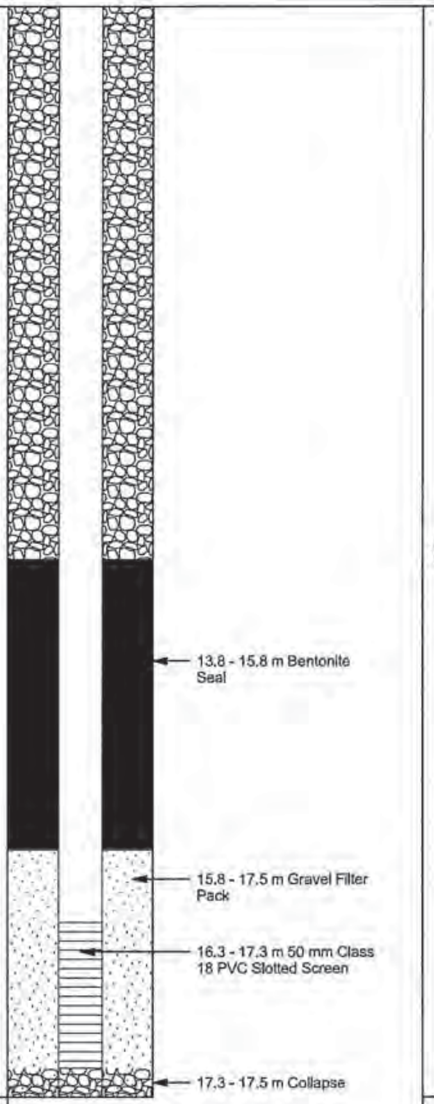
REPORT OF BOREHOLE: MW 3-013

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 67094.62 m E 263011.38 m N MGA94 56
SURFACE RL: 34.68 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.50 m

SHEET: 2 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 6/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
ADH		10			■		CORE LOSS moist			GF
			10.50 24.18		■	× ×	SILT pale yellow grey, with some clay, with some sand, 0A moist, very dense			
	▷	11			■	× ×				
		12	12.00 22.68		■	× ×	trace fine grained sand, 0A moist, very dense			
		15		Q12022-01 14.80-15.00 m PID = 0.0 ppm	■	× ×			13.8 - 15.8 m Bentonite Seal	
		16			■	× ×			15.8 - 17.5 m Gravel Filter Pack 16.3 - 17.3 m 50 mm Class 18 PVC Slotted Screen	
		17	17.00 17.68		■	× ×	mottled grey and red, 0A moist to wet, very dense		17.3 - 17.5 m Collapse	
			17.50 17.18	17.50 m PID = 0.4 ppm			END OF BOREHOLE @ 17.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 11.00 m DEPTH STANDPIPE INSTALLED			
		18								
		19								
		20								


13.8 - 15.8 m Bentonite Seal
15.8 - 17.5 m Gravel Filter Pack
16.3 - 17.3 m 50 mm Class 18 PVC Slotted Screen
17.3 - 17.5 m Collapse

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Golder Associates

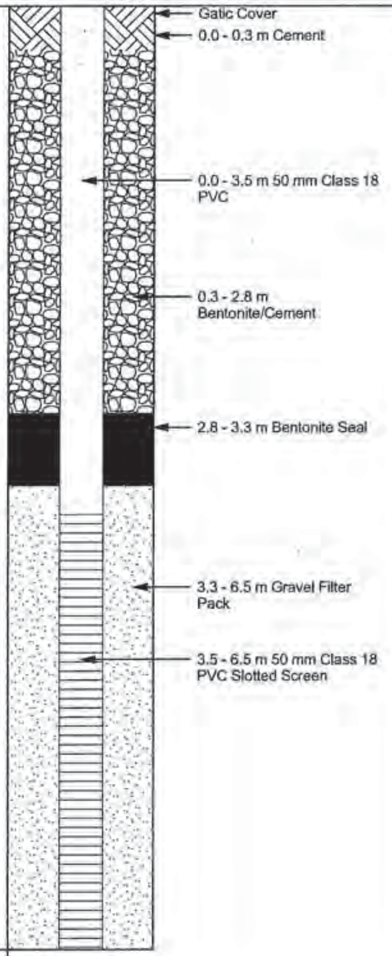
REPORT OF BOREHOLE: MW 3-019

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66669.58 m E 263079.54 m N MGA94 56
SURFACE RL: 30.61 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 6.50 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: KC DATE: 28/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
HA		0	30.61	Q11847-04 0.05-0.30 m PID = 0.2 ppm			TOPSOIL: SAND fine to medium grained, rounded to sub-rounded, brown, with roots, 0A dry, loose			BS
			0.30 30.31	Q11847-05 0.50-0.70 m PID = 0.0 ppm			pale brown, 0A dry, loose			
			0.70 29.91				fine to medium grained, rounded to sub-rounded, pale brown to grey, 0A dry, loose			
		1	1.00 29.61	1.00-1.20 m PID = 0.0 ppm			Silty SAND fine to medium grained, sub-rounded, brown/orange, low cohesive silt, 0A dry, loose			GF
PT				1.50-1.70 m PID = 0.1 ppm						
		2		2.50-2.70 m PID = 0.5 ppm						
		3	3.50 27.11	3.50-3.70 m PID = 0.0 ppm			Gravelly SAND medium to coarse grained, sub-rounded, pale brown/orange, up to 15 mm gravel, with some silt, 0A moist, loose			
		4		Q11847-11 3.80-4.50 m PID = 0.0 ppm						
	▽		4.50 26.11				Clayey SAND fine grained, sub-rounded, pale grey with brown/orange, medium plasticity clay, with some up to 10 mm gravel, trace silt, 0A wet, medium dense			
		5	5.00 25.61				brown/pale red, no gravel, 0A wet, medium dense			
				5.50-5.70 m PID = 1.4 ppm						
		6		6.30-6.50 m PID = 0.2 ppm						
			6.50 24.11				END OF BOREHOLE @ 6.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.50 m DEPTH STANDPIPE INSTALLED			
		7								
		8								
		9								
		10								



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GAP gINT FN. F05
RL3

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Golder Associates

REPORT OF BOREHOLE: MW 3-026

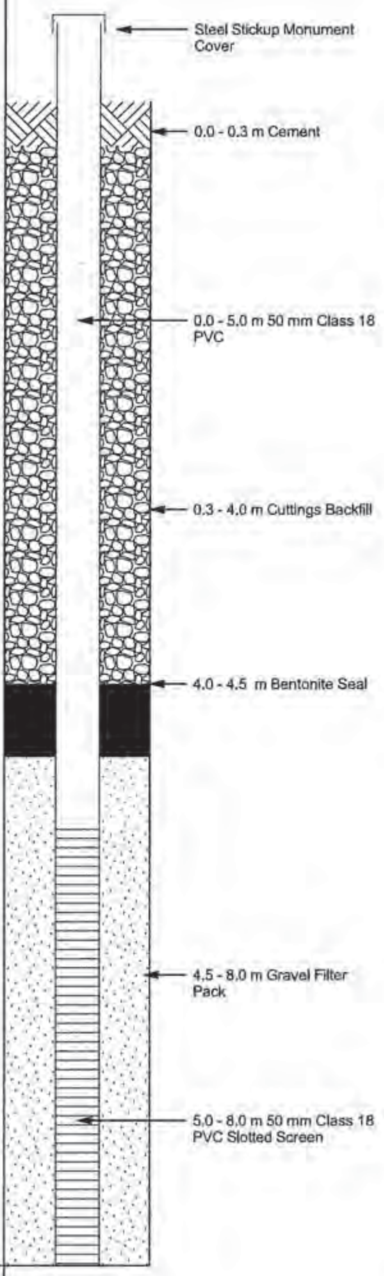
CLIENT: PTA	POSITION: Forrestfield Dive Structure and Launch Box	SHEET: 1 OF 1
PROJECT: FAL Contamination/ASS Investigation	COORDS: 66542.44 m E 263164.43 m N MGA94 56	DRILL RIG: Geoprobe 66200DT
LOCATION: Forrestfield to Bayswater	SURFACE RL: 28.39 m DATUM: AHD	CONTRACTOR: Direct Push Probing
JOB NO: 147643093	INCLINATION: -90°	LOGGED: CS DATE: 12/1/15
	HOLE DEPTH: 8.00 m	CHECKED: LK DATE: 14/4/15

Drilling | **Sampling** | **Field Material Description and Instrumentation**

METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	28.39	Q11853-01 0.00-0.10 m PID = 1.2 ppm Q11853-02 0.40-0.60 m PID = 0.3 ppm	SAND fine to medium grained, sub-rounded to sub-angular, pale brown grey, 0A dry, loose		BS
		0.60	27.79		Clayey SAND fine to medium grained, sub-rounded to sub-angular, pale brown to orange, low plasticity clay, 0A dry, loose		GF
		0.80	27.59	Q11853-03 0.40-0.60 m 0.90-1.10 m PID = 0.4 ppm 1.30-1.50 m PID = 0.3 ppm 2.40-2.60 m PID = 1.1 ppm	grey to orange, with some medium to coarse grained gravel, 0A dry, medium dense to hard		
PT		3.00	25.39	3.40-3.60 m PID = 0.8 ppm	Sandy Gravelly CLAY high plasticity, grey to brown to red, fine to medium, sub-angular to angular gravel, fine to medium grained sand, 0A dry to moist, medium dense		
		4.20	24.19	4.40-4.60 m PID = 1.0 ppm	Sandy CLAY medium to high plasticity, grey, fine to medium, sub-rounded to sub-angular sand, 0A moist, medium dense to hard		
	▽	5.00	23.39	5.40-5.60 m PID = 1.6 ppm Q11853-10 5.70-5.80 m	grey and red, 0A moist to wet, medium dense to hard		
		6.70	21.69	6.40-6.60 m PID = 0.3 ppm 7.40-7.60 m PID = 1.4 ppm 7.80-8.00 m PID = 0.6 ppm	low to medium plasticity, grey, 0A wet, medium dense to hard		
		8.00	20.39		END OF BOREHOLE @ 8.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 5.70 m DEPTH STANDPIPE INSTALLED		

RECOVERED / GRAPHIC LOG

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-034

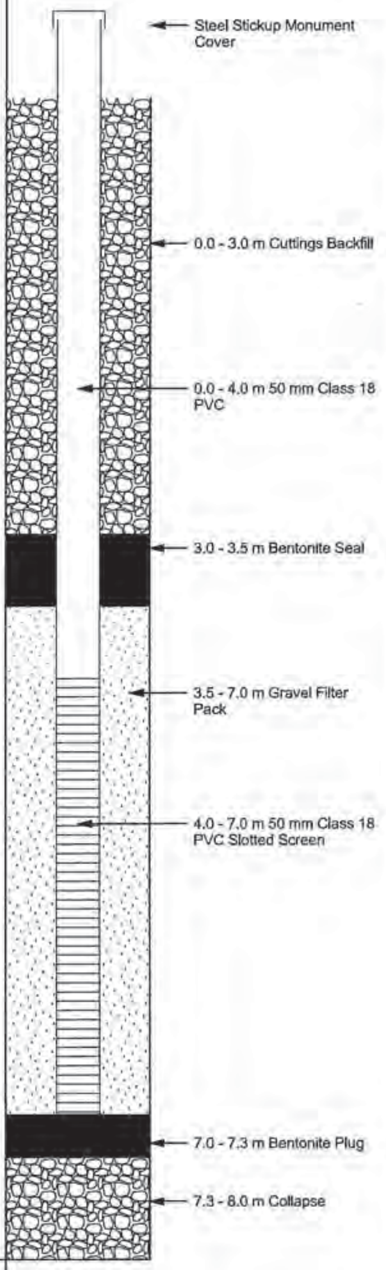
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66804.69 m E 263317.90 m N MGA94 56
SURFACE RL: 31.23 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 8.00 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 15/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
HA		0	31.23	Q10978-01 0.00-0.20 m PID = 0.6 ppm	FILL: SAND fine to medium grained, sub-rounded to sub-angular, grey, trace rootlets, 0A dry	MG
			0.30 30.93	Q10978-02 0.30-0.60 m PID = 0.4 ppm	fine grained, white, 0A dry	
			0.50 30.73	Q10980-01 0.30-0.60 m TRIPLICATE	fine to medium grained, grey, 0A dry	
		1	0.80 30.43	0.80-1.10 m PID = 0.1 ppm 1.30-1.50 m PID = 0.7 ppm	SAND fine to medium grained, red/orange, with some up to 15 mm gravel, with some silt, 0A dry	BS
PT			1.50 29.73		Silty SAND fine to medium grained, pale grey with mottled orange and dark grey, 0A dry, dense	
			1.70 29.53	1.90-2.10 m PID = 0.0 ppm	SAND orange brown and grey, with some sub-rounded, up to 10 mm gravel, 0A dry, dense	
		2	2.00 29.23		trace low plasticity clay, 0A dry, dense	
			2.20 29.03	2.90-3.10 m PID = 0.1 ppm	Clayey SILT orange brown with mottled red, with some up to 10 mm gravel, trace fine grained sand, low plasticity clay, 0A dry, soft	GF
	▽	4	4.00 27.23	3.90-4.10 m PID = 0.4 ppm Q10978-10 4.50-4.90 m PID = 0.0 ppm Q10978-11 4.50-4.90 m DUPLICATE 4.90-5.00 m PID = 0.1 ppm	becoming firm dry to wet	
		5	5.00 26.23		high plasticity, 0A wet, firm	
			5.60		with some sand, 0A wet, firm	
			5.70 25.53		Silty Clayey SAND fine grained, pale grey, medium plasticity clay, 0A wet, dense	
AS		6	6.00 25.23	Q10978-09 5.90-6.20 m PID = 0.1 ppm	Silty SAND fine to medium grained, sub-rounded to sub-angular, grey, with some clay, 0A wet, dense	
			6.50 24.73	6.80-7.20 m PID = 0.2 ppm	Sandy Clayey SILT grey and red/brown, with some gravel, up to 10 mm, medium to high plasticity, 0A wet, soft	
			7.20 24.03	7.80-8.00 m PID = 0.2 ppm	Silty SAND fine grained, sub-rounded to sub-angular, grey and red/brown, with some medium plasticity clay, 0A wet, dense	
		8	8.00 23.23		END OF BOREHOLE @ 8.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.70 m DEPTH STANDPIPE INSTALLED	

CONSTRUCTION



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Golder Associates

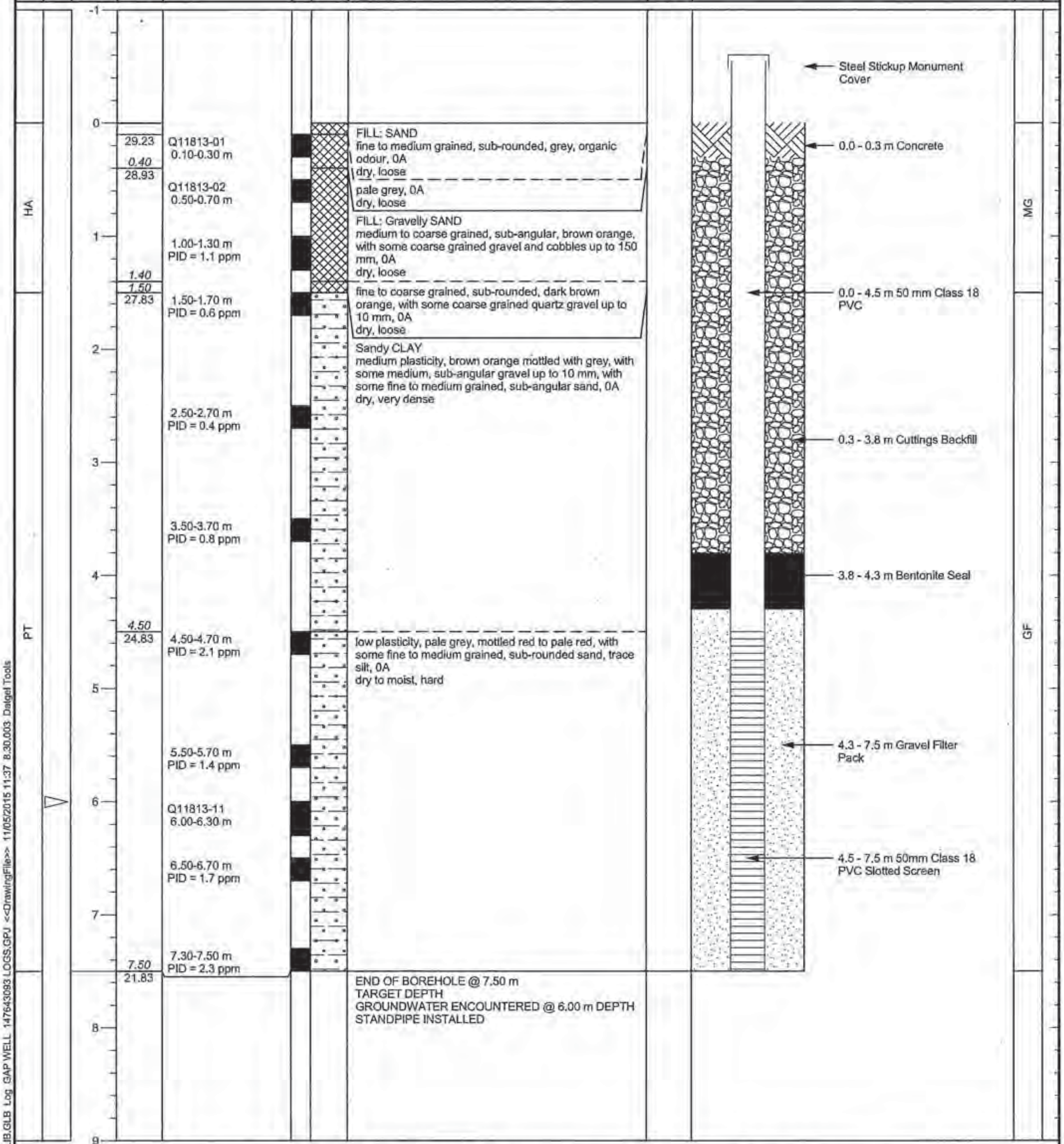
REPORT OF BOREHOLE: MW 3-038

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66549.27 m E 263393.16 m N MGA94 56
SURFACE RL: 29.33 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 7.50 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: KC DATE: 9/1/15
CHECKED: LK DATE: 14/4/15

Drilling | **Sampling** | **Field Material Description and Instrumentation**



METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
HA		0	29.23	Q11813-01 0.10-0.30 m	FILL: SAND fine to medium grained, sub-rounded, grey, organic odour, 0A dry, loose	MG
			0.40 28.93	Q11813-02 0.50-0.70 m	pale grey, 0A dry, loose	
		1		1.00-1.30 m PID = 1.1 ppm	FILL: Gravelly SAND medium to coarse grained, sub-angular, brown orange, with some coarse grained gravel and cobbles up to 150 mm, 0A dry, loose	
PT			1.40 1.50 27.83	1.50-1.70 m PID = 0.6 ppm	fine to coarse grained, sub-rounded, dark brown orange, with some coarse grained quartz gravel up to 10 mm, 0A dry, loose	GF
		2		2.50-2.70 m PID = 0.4 ppm	Sandy CLAY medium plasticity, brown orange mottled with grey, with some medium, sub-angular gravel up to 10 mm, with some fine to medium grained, sub-angular sand, 0A dry, very dense	
		3		3.50-3.70 m PID = 0.8 ppm		
		4	4.50 24.83	4.50-4.70 m PID = 2.1 ppm	low plasticity, pale grey, mottled red to pale red, with some fine to medium grained, sub-rounded sand, trace silt, 0A dry to moist, hard	
		5		5.50-5.70 m PID = 1.4 ppm		
	▽	6		Q11813-11 6.00-6.30 m		
				6.50-6.70 m PID = 1.7 ppm		
		7	7.50 21.83	7.30-7.50 m PID = 2.3 ppm		
		8			END OF BOREHOLE @ 7.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 6.00 m DEPTH STANDPIPE INSTALLED	

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Golder Associates

REPORT OF BOREHOLE: MW 3-044(d)

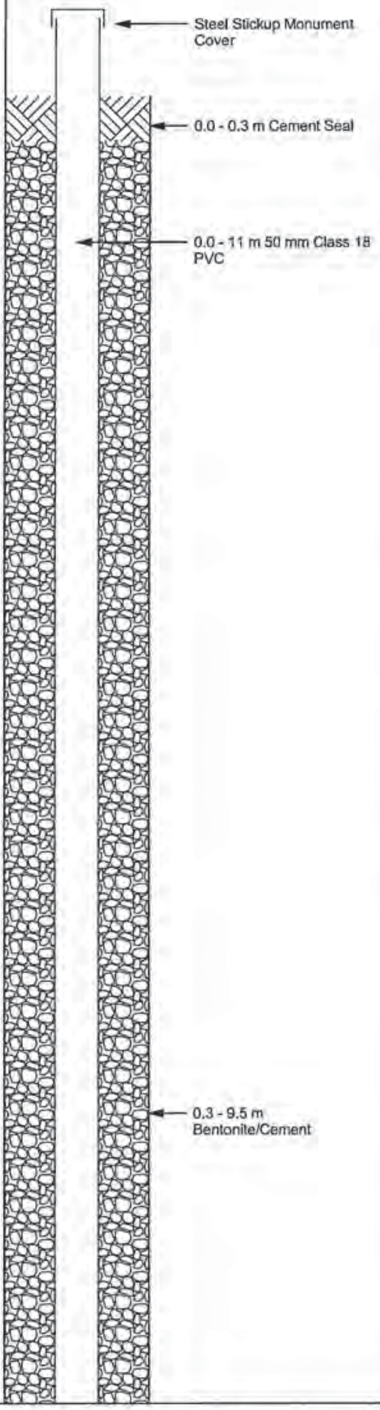
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66605.86 m E 263508.61 m N MGA94 56
SURFACE RL: 29.54 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 14.00 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 28/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
		-1							
HA		0	29.54	0.00 m PID = 0.0 PPM			Silty SAND fine to medium grained, rounded to sub-rounded, dark grey, 0A dry, loose		BS
				0.50 m PID = 0.0 PPM					
		1		1.00 m PID = 0.0 PPM					
		1.20	28.34				yellow, 0A dry, loose		
		1.40	28.14				Clayey SILT brown/orange, medium plasticity clay, with some up to 30 mm gravel, 0A dry to moist, soft to firm		GF
PT				1.50 m PID = 0.1 PPM					
		2		2.00 m PID = 0.0 PPM					
		3		3.00 m PID = 0.0 PPM					
		4		4.00 m PID = 0.0 PPM					
	▽	4.20	25.34				with some fine grained sand, 0A moist to wet, hard		
		5		5.00 m PID = 0.0 PPM					
		5.80	23.74				trace fine grained sand, 0A wet, hard		
		6.00	23.54	6.00 m PID = 0.0 PPM			grey mottled brown becoming grey, 0A wet, hard		
		6.40	23.14				Clayey SAND fine grained, rounded to sub-rounded, pale grey, low plasticity clay, 0A wet, soft		
		7		7.00 m PID = 0.0 PPM					
		8.00		8.00 m PID = 0.0 PPM			with some medium grained sand, 0A wet, dense		
		8.20	21.34				orange, 0A wet, dense		
		9.00							

CONSTRUCTION



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Golder Associates

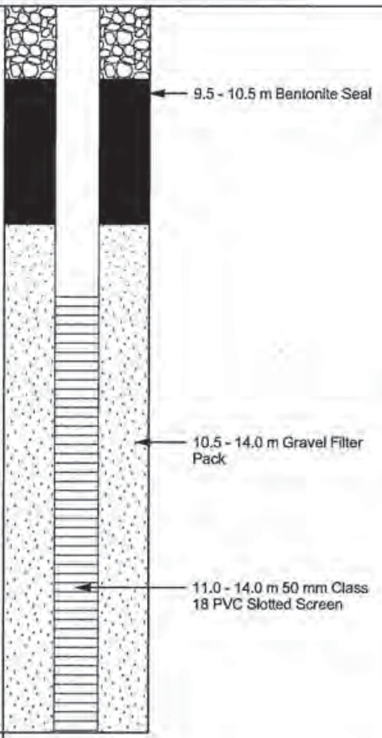
REPORT OF BOREHOLE: MW 3-044(d)

CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66605.86 m E 263508.61 m N MGA94 56
SURFACE RL: 29.54 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 14.00 m

SHEET: 2 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 28/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation				
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	CONSTRUCTION	UNIT
PT		9	20.54	9.00 m PID = 0.1 PPM			with some silt, 0A wet, dense			GF
			9.40 20.14				Clayey SILT pale grey, medium plasticity clay, 0A wet, soft			
		10	10.00 19.54	10.00 m PID = 0.0 PPM			Silty SAND fine grained, sub-rounded to sub-angular, pale grey, with some clay, 0A wet, dense			
		11		11.00 m PID = 0.0 PPM						
		12	12.00 17.54	12.00 m PID = 0.0 PPM			Silty Clayey SAND fine grained, sub-rounded to sub-angular, pale grey, low to medium plasticity clay, 0A wet, dense			
		13		13.00 m PID = 0.1 PPM						
		14	14.00 15.54	14.00 m PID = 0.0 PPM			END OF BOREHOLE @ 14.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.20 m DEPTH STANDPIPE INSTALLED			
		15								
		16								
		17								
		18								
		19								



Golder Associates

REPORT OF BOREHOLE: MW 3-044(s)

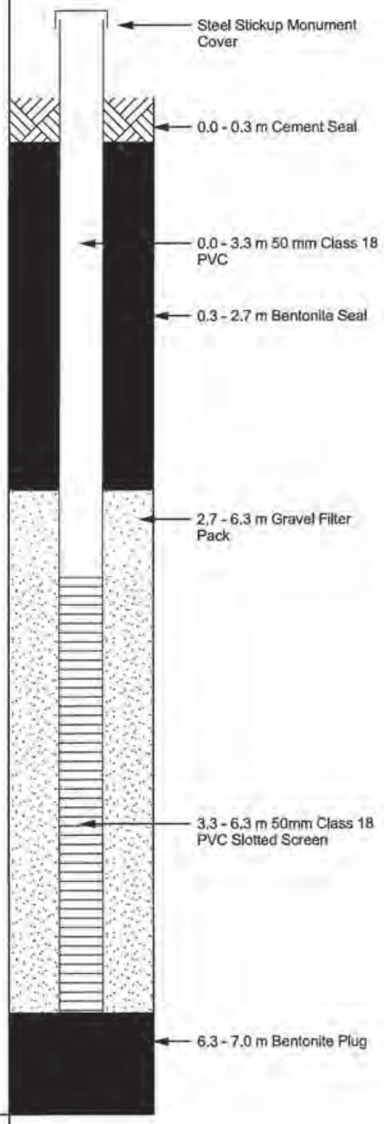
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66606.38 m E 263510.08 m N MGA94 56
SURFACE RL: 29.50 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 7.00 m

SHEET: 1 OF 1
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 27/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	29.50	0.00 m PID = 0.0 PPM 0.50 m PID = 0.0 PPM			Silty SAND fine to medium grained, rounded to sub-rounded, dark grey, 0A dry, loose		BS
		1	1.00 28.50	1.00 m PID = 0.0 PPM			yellow, 0A dry, loose		
PT			1.40 28.10	1.50 m PID = 0.1 PPM 2.00 m PID = 0.0 PPM 3.00 m PID = 0.0 PPM 4.00 m PID = 0.0 PPM			Clayey SILT brown/orange, medium plasticity clay, with some up to 30 mm gravel, 0A dry to moist, soft to firm		GF
	▽		4.20 25.30	5.00 m PID = 0.0 PPM			with some fine grained sand, 0A moist to wet, soft to hard		
			5.80 23.70				trace fine grained sand, 0A wet, hard		
		6	6.00 23.50	6.00 m PID = 0.0 PPM			grey mottled brown becoming grey, 0A wet, hard		
			6.40 23.10				Clayey SAND fine grained, rounded to sub-rounded, pale grey, low plasticity clay, 0A wet, very dense		
		7	7.00 22.50	7.00 m PID = 0.0 PPM			END OF BOREHOLE @ 7.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 4.30 m DEPTH STANDPIPE INSTALLED		

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-047

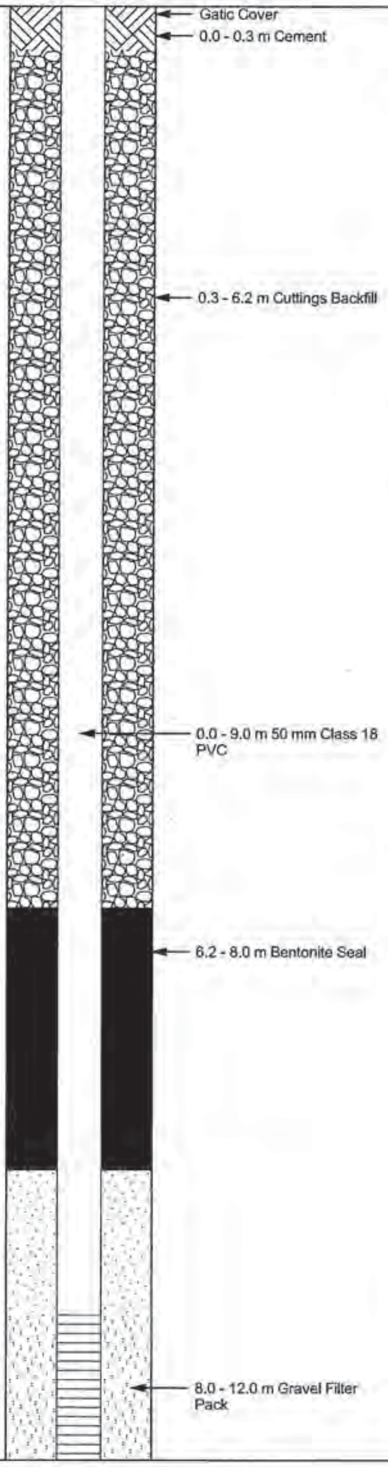
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66628.09 m E 263554.53 m N MGA94 56
SURFACE RL: 30.36 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.00 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 20/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling		Field Material Description and Instrumentation			
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	30.36	Q12033-01 0.00-0.30 m PID = 0.0 ppm			FILL: Silty SAND fine grained, rounded to sub-rounded, dark brown, trace clay, with some wood chips, 0A dry, firm		BS
			0.20 30.16				grey brown, with some sub-angular, up to 10 mm gravel, trace clay, 0A dry, firm		
			0.40	Q12033-02 0.40-0.60 m PID = 0.0 ppm			orange brown, 0A dry, firm		
			0.50 29.86				grey, no gravel, 0A dry, firm		
			0.80 29.56				white grey, 0A dry, firm		
		1	1.00 29.36	Q12033-03 0.90-1.10 m PID = 0.1 ppm			SAND fine grained, grey and orange, with some up to 15 mm gravel, 0A dry, medium dense		
				Q12033-04 1.30-1.50 m PID = 0.0 ppm					
PT			1.50 28.86				Clayey SILT grey mottled orange and red, medium plasticity clay, with some fine grained sand, 0A dry, firm		GF
		2		Q12033-05 1.90-2.10 m					
				Q12033-06 2.40-2.60 m					
			2.70 27.66				Silty CLAY high plasticity, grey mottled red and orange, with some fine to medium grained sand, 0A dry, hard		
		3	3.00 27.36	Q12033-07 2.90-3.10 m			with some fine to coarse grained sand, 0A dry to moist, hard		
				Q12033-08 3.40-3.60 m					
		4	4.00 26.36	Q12033-09 3.90-4.10 m			with some fine grained sand, 0A moist, hard		
				Q12033-10 4.40-4.60 m					
		5	5.00 25.36	Q12033-11 4.90-5.10 m			Silty Sandy CLAY medium to high plasticity, grey mottled orange brown and red, fine grained sand, 0A moist, hard		
				Q12033-12 5.40-5.60 m					
		6		Q12034-01 5.80-6.00 m					
ADH	▽		6.30 24.06	Q12034-02 6.30-6.60 m			CLAY high plasticity, grey with mottled orange and dark grey, trace silt, 0A moist to wet, stiff to hard		
			6.75 23.61				Silty SAND fine to medium grained, gap graded, sub-rounded, white grey, trace clay, 0A wet, dense		
		7		Q12034-03 6.80-7.20 m					
				Q12034-04 7.20-7.50 m					
		8		Q12034-05 7.80-8.25 m					
				Q12034-06 8.25-8.60 m					
				Q12034-07 8.70-9.00 m					
		9		Q12034-09 9.00-9.50 m					
				Q12034-08 9.75-10.00 m					
		10							

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-047

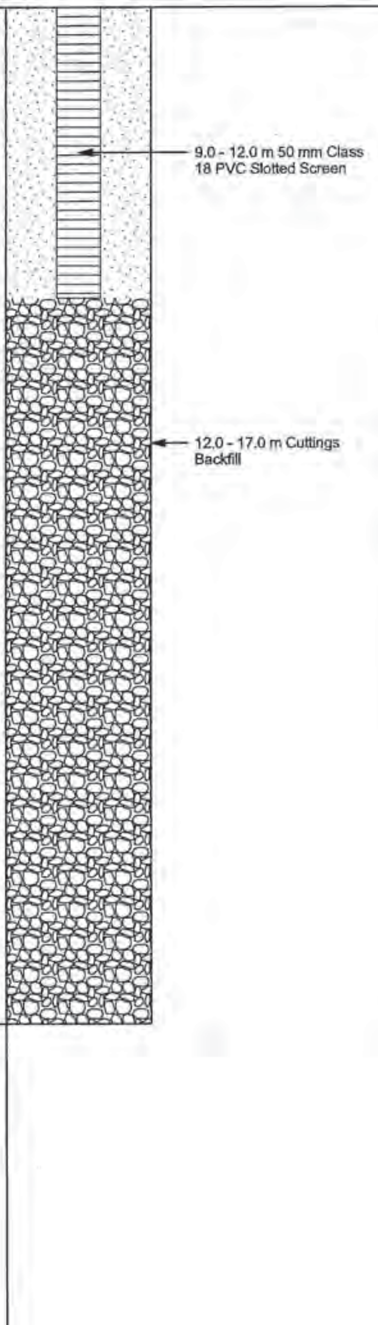
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66628.09 m E 263554.53 m N MGA94 56
SURFACE RL: 30.36 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.00 m

SHEET: 2 OF 2
DRILL RIG: Geoprobe 66200DT
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 20/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation		
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
ADH		10		Q12034-10 10.30-10.60 m	Silty SAND fine to medium grained, gap graded, sub-rounded, white grey, trace clay, 0A wet, dense		GF
			10.60 19.76	Q12034-11 10.70-11.00 m Q12034-12 11.30-11.60 m Q12035-01 11.70-12.00 m Q12035-02 12.30-12.60 m Q12035-03 12.70-13.00 m	pale red, 0A wet, dense		
			13.00 17.36	Q12035-04 13.30-13.60 m Q12035-05 13.70-14.00 m Q12035-06 14.40-14.75 m Q12035-07 14.75-15.20 m Q12035-08 15.30-15.50 m	SILT pale grey, with some medium plasticity clay, 0A wet, firm		
			15.80 14.56	Q12035-09 15.80-16.25 m	Clayey SILT grey green, medium to high plasticity clay, 0A wet, dense to firm		
			16.20 14.16	Q12035-10 16.25-16.40 m Q12035-11 16.60-17.00 m	Silty SAND fine to coarse grained, sub-angular, grey, 0A wet, dense		
		17	17.00 13.36		END OF BOREHOLE @ 17.00 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 6.70 m DEPTH STANDPIPE INSTALLED COLLAPSE FROM 17-20 m bgl		

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-051(d)

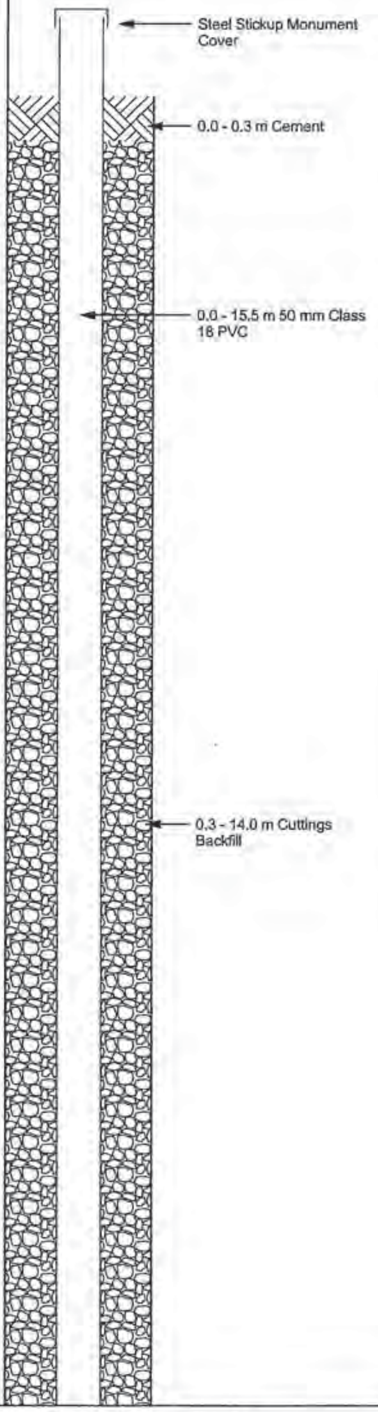
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66559.82 m E 263663.84 m N MGA94 56
SURFACE RL: 29.41 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.50 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: CS DATE: 9/1/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
		-1				
HA		0	29.41	0.00 m PID = 0.4 ppm	Silty SAND fine to medium grained, well graded, sub-angular, brown grey, 0A dry, medium dense	BS
			0.60 28.81	0.50 m PID = 0.3 ppm	SAND fine to medium grained, sub-angular, grey becoming pale yellow, with some silt, 0A dry, medium dense	
		1	*1.20* 28.21	1.00 m PID = 0.4 ppm	Silty SAND fine grained, sub-rounded to sub-angular, pale yellow becoming yellow, 0A dry, medium dense to dense	
PT			*1.50* 27.91	1.50 m PID = 0.0 ppm	orange yellow, with some sub-rounded, up to 10 mm gravel, 0A dry, dense	
		2	*1.80* 27.61		Silty Clayey SAND fine grained, pale yellow and orange, low plasticity, hard clay, with some up to 20 mm gravel, 0A dry, dense	GF
	▷	3	*2.40* 27.01		Clayey SILT pale yellow grey and orange, medium plasticity, soft clay, 0A moist to wet, very dense	
		4	*3.20* 26.21		Silty CLAY high plasticity, pale yellow grey mottled orange and red, with some up to 5 mm gravel-sized fragments of hard clay, 0A wet, stiff	
		5 6	*4.50* 24.91		trace medium to coarse sand, 0A wet, stiff to very stiff	
			6.30 23.11		CLAY high plasticity, pale grey yellow, with some silt, trace sub-rounded, fine grained sand, 0A wet, hard	
		7	*6.50* 22.91		with some fine to medium grained sand, 0A wet, hard	
		8	*7.50* 21.91		SAND fine to medium grained, sub-rounded to sub-angular, pale grey, trace silt, 0A wet, loose	
			8.30 21.11		trace clay, 0A wet, loose	
			8.60 20.81		mottled red, 0A wet, loose	
		9	*9.00*			

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-051(d)

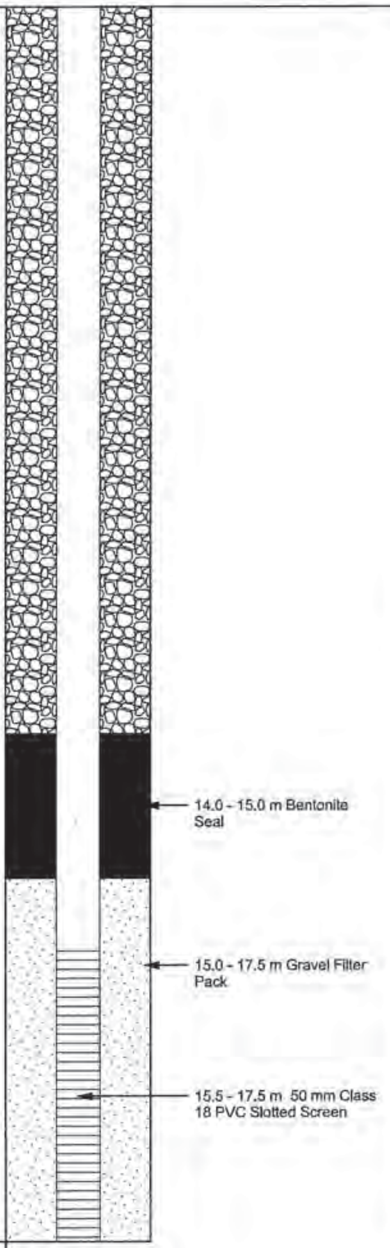
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66559.82 m E 263663.84 m N MGA94 56
SURFACE RL: 29.41 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.50 m

SHEET: 2 OF 2
DRILL RIG: Geoprobe 2000
CONTRACTOR: Direct Push Probing
LOGGED: CS DATE: 9/1/15
CHECKED: LK DATE: 14/4/15

METHOD	WATER	DEPTH (metres)	DEPTH / RL	SAMPLE OR FIELD TEST	RECOVERED	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
PT		9	20.41			trace pale white to grey clay, 0A wet, loose		GF
			11.30 18.11			SILT pale grey, with some hard, low to medium plasticity clay, trace fine grained sand, 0A wet, loose		
			13.00 16.41			with some fine grained sand, 0A wet, loose		
			15.40 14.01			SILT grey, with some fine grained, sub-rounded to sub-angular sand, 0A wet, loose		
			15.70 13.71			SAND fine to medium grained, sub-rounded to angular, grey, with silt, 0A wet, loose		
			16.20 13.21			trace silt, 0A wet, loose		
			16.60 12.81			CORE LOSS		
			17.00 12.41			SAND fine to medium grained, sub-rounded to angular, grey, trace silt, 0A wet, loose		
			17.50 11.91			END OF BOREHOLE @ 17.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 3.00 m DEPTH STANDPIPE INSTALLED		

CONSTRUCTION



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Golder Associates

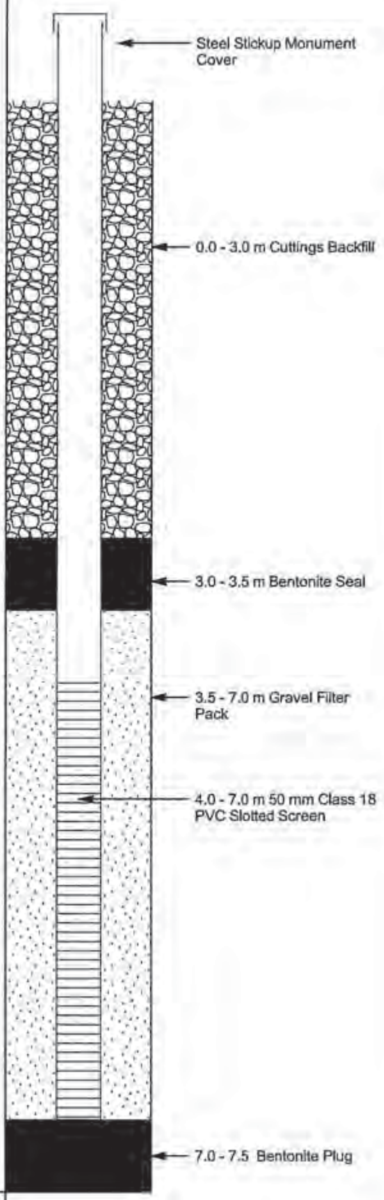
REPORT OF BOREHOLE: MW 3-051(s)

CLIENT: PTA	POSITION: Forrestfield Dive Structure and Launch Box	SHEET: 1 OF 1	
PROJECT: FAL Contamination/ASS Investigation	COORDS: 66559.85 m E 263662.06 m N MGA94 56	DRILL RIG: Geoprobe 2000	
LOCATION: Forrestfield to Bayswater	SURFACE RL: 29.39 m DATUM: AHD	CONTRACTOR: Direct Push Probing	
JOB NO: 147643093	INCLINATION: -90°	LOGGED: CS/JG	DATE: 12/1/15
	HOLE DEPTH: 7.50 m	CHECKED: LK	DATE: 14/4/15

Drilling | **Sampling** | **Field Material Description and Instrumentation**

METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	SOIL/ROCK MATERIAL DESCRIPTION	AIRLIFT YIELD (L/s)	UNIT
HA		0	29.39			Silty SAND fine to medium grained, well graded, sub-angular, brown grey, 0A wet, medium dense		BS
			0.60 28.79	1.00 m REFER TO WELL MW3-051D		SAND fine to medium grained, sub-angular, grey becoming pale yellow, with some silt, 0A dry to wet, medium dense		
			1.20 28.19			Silty SAND fine grained, sub-rounded to sub-angular, pale yellow becoming yellow, 0A dry, medium dense to dense		
			1.50 27.89			orange yellow, with some sub-rounded, up to 10 mm gravel, 0A dry, dense		
			1.80 27.59			Silty Clayey SAND fine grained, pale yellow and orange, low plasticity, hard clay, with some up to 20 mm gravel, 0A dry, dense		GF
	▷ 3		2.40 26.99			Clayey SILT pale yellow grey and orange, medium plasticity, soft clay, 0A dry, very dense		
			3.20 26.19			Silty CLAY high plasticity, pale yellow grey mottled orange and red, with some up to 5 mm gravel-sized fragments of hard clay, 0A moist to wet, stiff		
ADH			4.50 24.89			trace medium to coarse sand, 0A wet, stiff to very stiff		
			6.30 23.09			CLAY high plasticity, pale grey yellow, with some silt, trace sub-rounded, fine grained sand, 0A wet, hard		
			6.50 22.89			with some fine to medium grained sand, 0A wet, hard		
			7.50 21.89			END OF BOREHOLE @ 7.50 m TARGET DEPTH GROUNDWATER ENCOUNTERED @ 3.00 m DEPTH STANDPIPE INSTALLED		

CONSTRUCTION



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Golder Associates

REPORT OF BOREHOLE: MW 3-052

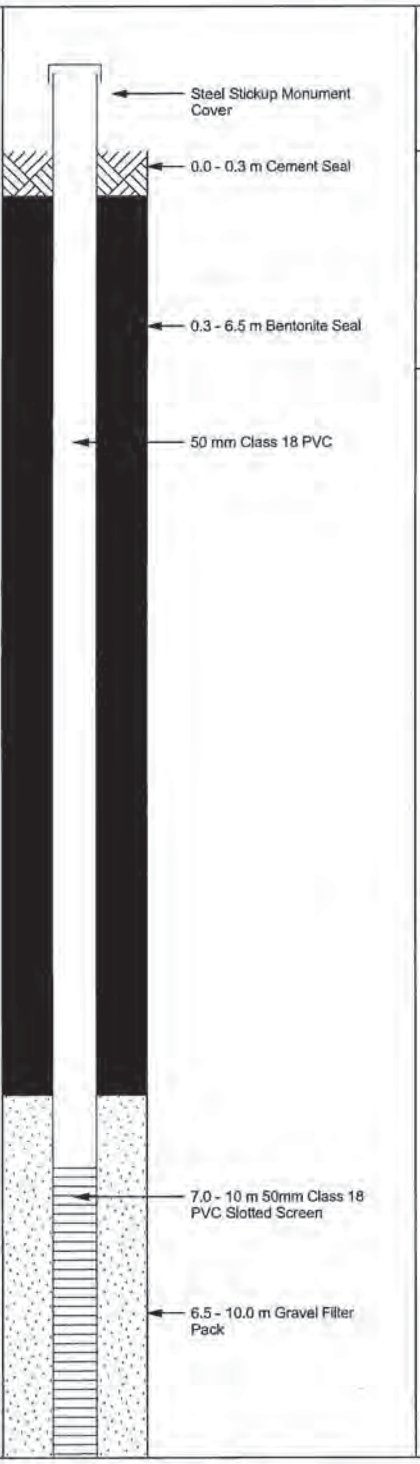
CLIENT: PTA
PROJECT: FAL Contamination/ASS Investigation
LOCATION: Forrestfield to Bayswater
JOB NO: 147643093

POSITION: Forrestfield Dive Structure and Launch Box
COORDS: 66564.11 m E 263781.27 m N MGA94 56
SURFACE RL: 28.35 m DATUM: AHD
INCLINATION: -90°
HOLE DEPTH: 17.00 m

SHEET: 1 OF 2
DRILL RIG: Geoprobe 7822DT
CONTRACTOR: Direct Push Probing
LOGGED: JG DATE: 18/2/15
CHECKED: LK DATE: 14/4/15

Drilling				Sampling	Field Material Description and Instrumentation	
METHOD	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	SOIL/ROCK MATERIAL DESCRIPTION	UNIT
HA		0	28.35	Q12026-01 0.00-0.30 m PID = 0.0 ppm	Silty SAND fine grained, well graded, rounded to sub-rounded, grey brown, 0A dry, dense	BS
			0.40 27.95	Q12026-02 0.40-0.70 m PID = 0.1 ppm	fine to medium grained, grey, 0A dry, dense	
			0.60 27.75		brown grey, with some up to 10 mm gravel, 0A dry, dense to very dense	
		1	1.20 27.15	1.00-1.10 m PID = 0.0 ppm	grey, no gravel, 0A dry, very dense	
PT			1.50 26.85	1.50-1.60 m PID = 0.1 ppm	Sandy Clayey SILT orange with mottled dark red and grey, low plasticity clay, fine grained, sub-angular to sub-rounded sand, with some up to 5 mm gravel, 0A dry, hard	GF
		2	2.00 26.35	2.00-2.10 m PID = 0.0 ppm 3.00-3.10 m PID = 0.0 ppm Q12026-09 3.80-4.10 m PID = 0.0 ppm	Clayey SILT orange mottled dark red/grey, high plasticity clay, with some fine grained sand, 0A dry, stiff	
			4.50 23.85	Q12026-10 4.40-4.60 m Q12026-11 4.80-5.10 m PID = 0.0 ppm	Clayey SILT grey with mottled brown, high plasticity clay, with some sand, 0A dry, stiff	
			5.25 23.10	Q12026-12 5.40-5.60 m Q12027-01 5.80-6.00 m	mottled pale brown, 0A dry, stiff	
		6	6.00 22.35	Q12028-10 6.00-6.20 m PID = 0.0 ppm 6.20-6.30 m PID = 0.0 ppm (CAPILLARY) Q12027-02 6.40-6.60 m	mottled pale red, 0A moist, stiff	
		7	7.00 21.35	Q12027-03 6.90-7.10 m PID = 0.0 ppm Q12027-04 7.40-7.60 m	Silty SAND fine grained, grey with pale red, with some clay, 0A moist to wet, very dense to stiff	
	▽	8		Q12027-05 7.90-8.10 m PID = 0.0 ppm Q12027-06 8.40-8.60 m Q12027-07 8.70-9.00 m		

CONSTRUCTION



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GAP 8_08.06 LIB.GLB Log GAP WELL 147643093 LOGS.GPJ <<DrawingFile>> 11/05/2015 11:38 8.30.003 Datgel Tools

Appendix 2
Test pit locations and logs

LEGEND

STAGE 2 INVESTIGATIONS
- GEOTECHNICAL BOREHOLE
- GEOTECHNICAL BOREHOLE AND VWP
- GEOTECHNICAL BOREHOLE AND MONITORING WELL
- GEOTECHNICAL SONIC BOREHOLE
- CPT
- CPT SEISMIC
- VANE SHEAR
- PLATE DILATOMETER
- PUMPING WELL
- MONITORING WELL
- TEST PIT
- HAND AUGER
- INFILTRATION TEST

STAGE 1 INVESTIGATIONS / HISTORICAL TEST LOCATIONS
- GEOTECHNICAL BOREHOLE
- PIEZOCONE PENETRATION TEST
- TEST PIT
- PROPOSED RAIL ALIGNMENT
- A-F05 SECTION A, REFER FIGURE 5

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

0 20 40 60 80 100 m
1:2,000

CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.18
PREPARED	MS/JRP
DESIGN	PM
REVIEW	DPS
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK,
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
SITE INVESTIGATION PLAN
SHEET 14 OF 16

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	075 R	0	2

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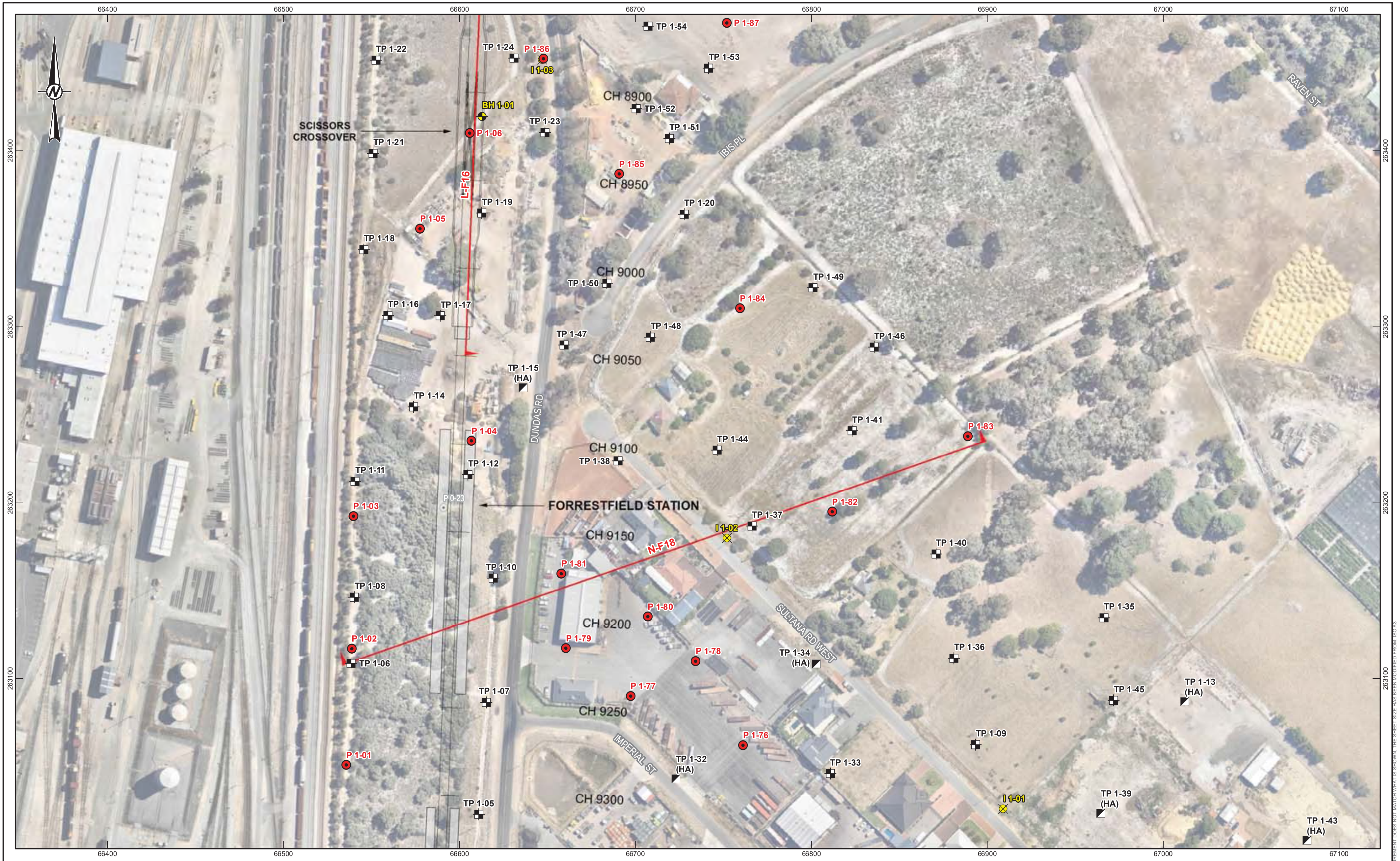
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
0
25mm



LEGEND

STAGE 2 INVESTIGATIONS
- GEOTECHNICAL BOREHOLE
- GEOTECHNICAL BOREHOLE AND VWP
- GEOTECHNICAL BOREHOLE AND MONITORING WELL
- GEOTECHNICAL SONIC BOREHOLE
- CPT
- CPT SEISMIC
- VANE SHEAR
- PLATE DILATOMETER
- PUMPING WELL
- MONITORING WELL
- TEST PIT
- HAND AUGER
- INFILTRATION TEST

STAGE 1 INVESTIGATIONS / HISTORICAL TEST LOCATIONS
- GEOTECHNICAL BOREHOLE
- PIEZOCONE PENETRATION TEST
- TEST PIT
- PROPOSED RAIL ALIGNMENT
- A-F05 SECTION A, REFER FIGURE 5

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

0 20 40 60 80 100 m

1:2,000

CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.18
PREPARED	MS/JRP
DESIGN	PM
REVIEW	DPS
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK,
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
SITE INVESTIGATION PLAN
SHEET 15 OF 16

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	075 R	0	**2**

0 25mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

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Golder Associates

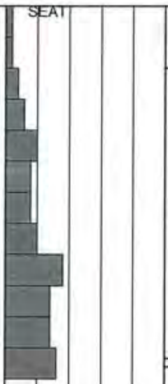
REPORT OF TEST PIT: TP 1-20

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: Forrestfield Carpark
COORDS: 66727.67 m E 263364.08 m N PCG (dGPS)
SURFACE RL: 30.64 m DATUM: AHD (dGPS)
PIT DEPTH: 2.50 m
BUCKET TYPE: 300 mm toothed

SHEET: 1 OF 1
MACHINE: 4-6t Excavator
CONTRACTOR: Universal Diggers
LOGGED: ALH DATE: 12/12/14
CHECKED: DB DATE: 25/4/15

Excavation					Sampling		Field Material Description							
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	PERTH PENETROMETER TEST (AS1289.6.3.3) Blows per 150 mm 0 5 10 15 20 25	UNIT
BH	L		0.0	30.64 0.30				SP	FILL: SAND fine to medium grained, sub-rounded, siliceous, grey-brown, approximately 10-15% non-plastic silt, trace rootlets, trace gravel and brick fragments to fine gravel size	D - M	L - MD		SEAT	MG
			0.5 1.0	30.34 1.30				SP	SAND fine to medium grained, sub-rounded, siliceous, grey, trace silt		MD			BS
	L-M		1.5 2.0	29.34	TP 1-20-1 BDS 1.80-2.50 m			SP / SC	Interbedded SAND & Clayey SAND fine to medium grained, mottled orange-brown and grey, approximately 15% low plasticity clay, with interfingered pockets of sand up to approximately 40% of volume, with some fine to medium, irregular, weakly to well cemented lateritic gravel	M	MD - St	Material is friable and breaks up during excavation PP = 2-2.5 kg/cm²		GF
			2.5 3.0 3.5	28.14					TEST PIT DISCONTINUED @ 2.50 m TARGET DEPTH GROUNDWATER NOT ENCOUNTERED BACKFILLED					



Sketch & Other Observations

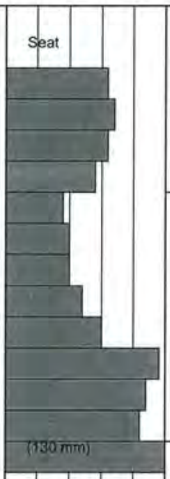
REPORT OF HAND AUGERED BOREHOLE: TP 1-28 (HA)

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: Bored Tunnels
COORDS: 66590.37 m E 263758.29 m N PCG (dGPS)
SURFACE RL: 29.25 m DATUM: AHD (dGPS)
INCLINATION: -90°
HOLE DEPTH: 2.10 m

SHEET: 1 OF 1
LOGGED: AT DATE: 15/10/14
CHECKED: DB DATE: 25/4/15

Drilling					Sampling		Field Material Description							
METHOD	PENETRATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	PERTH PENETROMETER TEST (AS1289.6.3.3) Blows per 150 mm 0 5 10 15 20 25	UNIT
HA	H		0.0					SP	TOPSOIL: Gravelly SAND fine to coarse grained, dark grey, fine to medium grained, rounded to sub-angular gravel	D			Seat	BS
	M-H		0.5	*0.10* 29.15 *0.30* 28.95	TP 1-28(HA)-01 DS 0.50-0.70 m			SP	SAND fine to coarse grained, sub-rounded, grey-brown, with some low plasticity clay dark grey		VD			
			1.0	*0.90* 28.35	TP 1-28(HA)-02 DS 1.10-1.50 m			SC	Clayey SAND fine to medium grained, orange-brown and yellow-brown, low plasticity clay	D - M	D			GF
			1.5	*1.50* 27.75	TP 1-28(HA)-03 DS 1.50-2.00 m			CL-CI	Sandy CLAY low to medium plasticity, orange-brown and yellow-brown, fine to medium grained sand		H			
	H-R		2.0	*2.00* 27.25					with some fine to medium grained, sub-rounded to rounded gravel				(130 mm)	
			2.5 3.0 3.5	27.15					END OF HAND AUGER @ 2.10 m REFUSAL GROUNDWATER NOT OBSERVED BACKFILLED					



Sketch & Other Observations

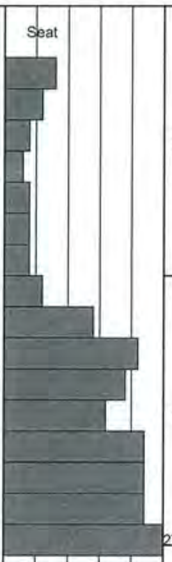
This report of hand augered borehole must be read in conjunction with accompanying notes and abbreviations. It has been prepared for geotechnical purposes only, without attempt to assess possible contamination. Any references to potential contamination are for information only and do not necessarily indicate the presence or absence of soil or groundwater contamination.

Golder Associates

REPORT OF TEST PIT: TP 1-29

CLIENT:	Public Transport Authority	POSITION: Bored Tunnels	SHEET: 1 OF 1
PROJECT:	Stage 2 GI Forrestfield-Airport Link Project	COORDS: 66565.11 m E 263815.87 m N PCG (dGPS)	MACHINE: 4-6t Excavator
LOCATION:	Bayswater to Forrestfield	SURFACE RL: 29.22 m DATUM: AHD (dGPS)	CONTRACTOR: Universal Diggers
JOB NO:	147642129	PIT DEPTH: 2.60 m	LOGGED: AT DATE: 27/10/14
		BUCKET TYPE: 600 mm Bladed	CHECKED: DB DATE: 25/4/15

Excavation					Sampling		Field Material Description							
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	PERTH PENETROMETER TEST (AS1289.6.3.3) Blows per 150 mm	UNIT
EX	H		0.0	*0.10* 29.12			▨	CL-CI	FILL: Sandy CLAY low to medium plasticity, mottled orange-brown and red-brown, fine to coarse grained sand, with some fine to medium grained gravel	D	H	Inferred road base material.	Seat	BS
	L		0.5 1.0		TP 1-29-01 BDS 0.50 m			SP	SAND fine to coarse grained, grey, becoming yellow-brown, with some low plasticity fines		MD			
				1.30 27.92				GP	Sandy GRAVEL fine to medium grained, sub-rounded, yellow-brown and orange-brown, fine to coarse grained sand	D - M		Clay content increasing with depth		GF
			1.5 2.0 2.5	*1.60* 27.62	TP 1-29-02 BDS 1.70 m			SC	Clayey SAND fine to coarse grained, yellow-brown and orange-brown, approximately 20% low plasticity clay, with some fine to medium grained, sub-rounded gravel		VD		27	
			3.0 3.5	26.62					TEST PIT DISCONTINUED @ 2.60 m TARGET DEPTH GROUNDWATER NOT ENCOUNTERED BACKFILLED					



Sketch & Other Observations

Golder Associates

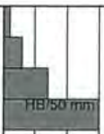
REPORT OF TEST PIT: TP 1-46

CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: Forrestfield Carpark
COORDS: 66835.63 m E 263288.46 m N PCG (dGPS)
SURFACE RL: 31.22 m DATUM: AHD (dGPS)

PIT DEPTH: 1.30 m
BUCKET TYPE: 300 mm toothed

SHEET: 1 OF 1
MACHINE: 4-6t Excavator
CONTRACTOR: Universal Diggers
LOGGED: ALH DATE: 2/12/14
CHECKED: DB DATE: 25/4/15

Excavation					Sampling		Field Material Description							
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	*DEPTH* RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	DCP TEST (AS1289.6.3.2) Blows per 150 mm 0 5 10 15 20 25	UNIT
EX	L		0.0	*0.10* 31.12				SP	TOPSOIL: SAND fine to medium grained, sub-rounded, siliceous, grey, trace silt, trace organics and rootlets	D	L		 HB/50 mm	BS
				0.30				SP	SAND fine to medium grained, sub-rounded, siliceous, grey, trace silt, with some roots and rootlets up to 50 mm in diameter becoming yellow-white, isolated roots	D - M	L - MD	50 mm diameter root at 0.2m depth.		
	H-R		0.5 1.0	*0.40* 30.82	BDS 0.40-0.80 m			GC	Sandy Clayey GRAVEL fine to coarse grained, rounded to sub-rounded, well cemented, lateritic, orange-brown and grey, approximately 15-20% low plasticity clay, fine to coarse grained sand, very weakly to weakly iron cemented mass, with interfingered pockets of grey, very weakly cemented sand		D	Hard excavation, ripping with excavator teeth to penetrate.		GF
	R		1.5 2.0 2.5 3.0 3.5	29.92					TEST PIT DISCONTINUED @ 1.30 m REFUSAL GROUNDWATER NOT ENCOUNTERED BACKFILLED					

Sketch & Other Observations

REPORT OF TEST PIT: TP 1-49

Golder Associates

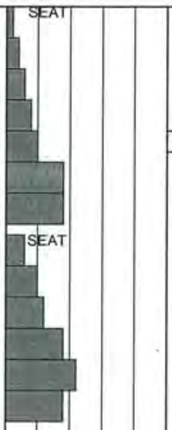
CLIENT: Public Transport Authority
PROJECT: Stage 2 GI Forrestfield-Airport Link Project
LOCATION: Bayswater to Forrestfield
JOB NO: 147642129

POSITION: Forrestfield Carpark
COORDS: 66800.91 m E 263322.18 m N PCG (dGPS)
SURFACE RL: 31.11 m DATUM: AHD (dGPS)

PIT DEPTH: 2.40 m
BUCKET TYPE: 300 mm toothed

SHEET: 1 OF 1
MACHINE: 4-6t Excavator
CONTRACTOR: Universal Diggers
LOGGED: ALH DATE: 2/12/14
CHECKED: DB DATE: 25/4/15

Excavation					Sampling		Field Material Description							
METHOD	EXCAVATION RESISTANCE	WATER	DEPTH (metres)	DEPTH RL	SAMPLE OR FIELD TEST	RECOVERED	GRAPHIC LOG	USCS SYMBOL	SOIL/ROCK MATERIAL DESCRIPTION	MOISTURE CONDITION	CONSISTENCY DENSITY	STRUCTURE AND ADDITIONAL OBSERVATIONS	DCP TEST (AS1289.6.3.2) Blows per 150 mm 0 5 10 15 20 25	UNIT
EX	L		0.0	31.11				SP	TOPSOIL: SAND fine to medium grained, sub-rounded, siliceous, grey, with some non-plastic silt, trace rootlets and organics	D	L		SEAT	BS
				0.20 30.91	TP 1-49-01 BDS 0.20-0.40 m			SP	SAND fine to medium grained, sub-rounded, siliceous, grey, trace silt	D - M	L - MD			
			0.5	0.40 30.71	TP 1-49-02 BDS 0.40-0.60 m				white					
	M		1.0 1.5	0.70 30.41	TP 1-49-03 BDS 1.00-1.50 m			SC	Gravelly Clayey SAND fine to coarse grained, sub-rounded to sub-angular, orange-brown, variable fines content between 20-40% low to medium plasticity clay, fine to medium grained, weakly to well cemented, lateritic gravel	M	MD - D	DCP reseated at 1.1 m depth.	SEAT	GF
	M-H		2.0	1.80 29.31					with some grey mottles, isolated sandy lenses					
			2.5 3.0 3.5	28.71					TEST PIT DISCONTINUED @ 2.40 m REFUSAL GROUNDWATER NOT ENCOUNTERED BACKFILLED					



Sketch & Other Observations

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