Bioscience

District Water Management Strategy

South Forrestdale Industrial Area

Lots 9, 7 & 5 Oxley Road,
5066 Kargotich Road, 10 & 12 Rowley Road

August 2017

District Water Management Strategy
South Forrestdale Industrial Area
Lots 9, 7 & 5 Oxley Road, 5066 Kargotich Road, 10 & 12 Rowley Road

Prepared for:
The owners of Lots 9, 7 & 5 Oxley Road, Lot 5066 Kargotich Road, and Lots 10 & 12 Rowley Road

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Document Control

Issue	Date	Author	Reviewer	Approved	Comments
1	26/03/2015	J. Cousins	N. Benker	P. Keating	
2	01/07/2015	J. Cousins	N. Benker	P. Keating	
3	20/08/2015	J. Cousins	N. Benker	P. Keating	
4	11/09/2015	J. Cousins	P. Keating	P. Keating	
5	17/10/2016	T. Lynn	P. Keating	P. Keating	Draft - Project Review JDA
6	19/12/2016	T. Lynn	P. Keating	P. Keating	Final - Submission
7	24/08/2017	T. Lynn	D. Alanoix	P. Keating	Addresses DoW comments dated 31/01/2017

ADDENDUM TO SOUTH FORRESTDALE (ISSUE 6) IN RESPONSE TO DOW'S COMMENTS DATED 31 JANUARY 2017 (RF PA011709)

Section	**Reference Section**	**Comments**	**Bioscience Response**	**DWMS Issue 7 PDF Page**
n/a	n/a	The District Water Management Strategy (DWMS) must be referred to the Department of Parks and Wildlife (DPaW) for assessment and comment, as the proposal is in proximity to a RAMSAR wetland.	Issue 7 of the DWMS will be submitted to the Department of Biodiversity Conservation and Attractions (former DPaW).	n/a
1.3	Principles and Objectives	Flood criteria should be consistent with the Decision process for stormwater management in WA: *Draft for consultation* (DoW, July 2016). In addition Local Government requirements should be sought and clearly identified if different from the Decision process or the IPWEA *Subdivision Guidelines* (2011).	To be consistent with the Decision process for stormwater management in WA: *Draft for consultation* (DoW, July 2016), the 100-year ARI rainfall event was replaced with the 1% AEP to reflect the new methodology and terminology proposed for this rainfall event size in the review of *Australian rainfall and runoff*. The 1% AEP event is equivalent to the 100-year ARI rainfall event. The report was amended accordingly to reflect this change. In regards to Principle 2 "Manage flooding and inundation risks to hum life and property" (Table 1 of DWMS) the City of Armadale's *Stormwater Management Handbook* does not provide additional flood criteria that would need to be taken into consideration.	19
1.3	Principles and Objectives	The management authority for the Birriga Drain should be clearly identified and discharge criteria dictated by that authority should be clearly identified.	Water Corporation was mentioned as the management authority for the Birriga Drain in Table 1. Water Corporation was contacted on 25 August 2017 in regards to their discharge criteria. Kevin Purcher's response (Senior Development Planner at Water Corp.) was as follows: " Hi Didier The Water Corporation can confirm that the discharge and storage criterion for the portion of land that drains to the Birrega Main Drain is set and assessed by the Department of Water and Regulations. The Water Corporation seeks the Department of Water and Regulations endorsement of the proposal before it can be approved. Any area that is currently draining to the Bush Forever site should be referred to the Department of Biodiversity, Conservation and Attractions, and the Water	21

			Corporation would require the evidence of support from the Department of Biodiversity, Conservation and Attractions for the area to continue to drain there. The area that currently drains to the Forrestdale Main Drain will be assessed by Water Corporation. Any discharge to the Forrestdale Main Drain will be should be in accordance with the Forrestdale Main Drain Arterial Drainage Scheme (published by the Department of Water in 2009). If you have any queries please contact me as per below. Regards **Kevin Purcher** Senior Development Planner Development Services **E:** Kevin.Purcher@watercorporation.com.au **T:** (08) 9420 2385 "	
	Figure 15	Pre-development flow paths for each sub-catchment should be provided on this figure.	Pre-development flow paths were added to the figure.	52
2.7.3	Wetlands	The buffer requirements for all wetlands in proximity to this development should be identified and discussed, in consultation with DPaW. Will buffers to Forrestdale Lake and other adjacent Conservation Category Wetlands be required? Indicative buffers should be provided.	The buffers have been set at 50 m, consistent with EPA Guidance 33 section B4-3. We note however, that at further planning stage buffers can be reviewed based on further assessment. Figure 19 was amended to reflect this comment.	61
3.1.2	Grey Water Recycling	While the DoW encourages alternatives water sources and fit-for-purpose water use, the feasibility of grey water reuse in this area needs to be considered, discussed and justified, given the site has high groundwater levels, a perched groundwater system and is in proximity to sensitive wetland systems. If a commitment is made to provide a third pipe system the viability of this future system should be addressed.	Feasibility of grey water reuse will be considered at designed stage. Response to this comment will be provided in the subsequent LWMS.	n/a
3.3	Water Supply and Wastewater	This section should state if the subject site will be serviced with reticulated sewer and water supply and any constraints to their installation, rather than referring to an appendix.	The following will be added to the section: "*The site will be serviced with water supply and sewer.* *Currently there is no service network or formal water scheme future planning for the subject land. The Water Corporation has advised the area could be served through the Armadale-Kelmscott scheme subject to supply being via 5.8km extension from*	103

			the DN760 on Armadale Road. The size of supply mains or route has not been considered in any detail. Preliminary advice indicated that a DN300 main would be required as a minimum, though it is likely a greater size would be needed to in order to achieve flows sufficient for fire fighting. *Similarly to the water supply there is no formal wastewater scheme for the subject land, however WC suggests the land could be serviced for sewerage via a temporary pump station located at a suitable low point within the industrial area, with discharge to the east to the Armadale Pump Station 2, Hilbert Rd. The temporary pump station, pressure main and related works would be undertaken at the developers' cost.* *Indicative potential alignments are provided in Appendix L*."	
4.1.1	Conceptual Management Strategy	a) Bioretention - additional information should be provided on likely and/or required locations for bioretention areas (e.g. within road reserves, local parks, on individual lots and the planning requirements that need to be considered at the Structure Plan Stage, such as road reserve widths. b) Drainage network for 10 year ARI - Please provide further details on the piped or overland flowpath network requirements such as road reserve widths necessary and general discharge locations. c) Flood management - provide flood storage area size requirements and appropriate locations. Further information on how the flood event is managed/transported should be provided (e.g. via road reserves). If multiple use corridors are proposed then approximate locations should be provided. d) Finished floor levels - incorrect criteria has been used. See the Decision process for stormwater management in WA: Draft for consultation (DoW, July 2016).	a) Bioretention areas will be located within road reserves. Road reserves will be 20m wide. This comment was added to the relevant section of the report. b) As per a) c) Predevelopment floodplain storage for catchments SE and SW is 59ML. This is for an area of 190ha and equates to 310KL/ha. The total flood storage requirement for the South Forrestdale Industrial Area will be clarified at LWMS stage. Flood event will be managed via the road reserves. d) This section has been amended as per the following: "*Finished floor levels to have a clearance of at least 0.3 m above the 1% annual exceedance probability (AEP) flood level of the urban drainage system and at least 0.5 m above the 1% annual exceedance probability (AEP) flood level of waterways(*(DoW, July 2016)*. This is to ensure protection to the built environment as well as human safety."*	105 - 107
	Proposed	Further information should be provided on the	Only light industry Is proposed to be developed within the site. In accordance with	15

	development	potential types of industry that will be developed and the likely pollution issues associated with these industries.	TPS4, light industry means an industry: a) in which the processes carried on, the machinery used, and the good and commodities carried to and from the premises do not cause any injury to or adversely affect the amenity of the locality. b) The establishment or conduct of which does not, or will not, impose an undue load on any existing or proposed service for the supply or provision of essential services. The following was added to the report.	

Executive Summary

This report has been prepared to support an application to amend the Metropolitan Region Scheme (MRS) for Lots 9, 7 & 5 Oxley Road, Lot 5066 Kargotich Road, and Lots 10 & 12 Rowley Road (Study Area), changing the current rural zoning of the Study Area to non-heavy industrial. The application is in response to land requirements highlighted in the Economic and Employment Lands Strategy (EELS) report (WAPC, 2012). It presents a sustainable approach to total water cycle management within the development area consistent with the best practice principles supported by the City of Armadale and Department of Water.

The Study Area is approximately 190ha of land currently zoned rural and used for grazing. The EELS report highlighted approximately 340ha of land with potential for land use amendment. 110ha has already been rezoned to industrial land use under the MRS. This reports takes into consideration effects of the land use change on the surrounding environment and landholders as well as the previously zoned industrial land covered by the EELS report.

The Study Area is relatively flat and drains to four locations; north west along Bush Forever Site No. 345, north east under Oxley Road and towards Forrestdale Main Drain, south east overland through Lot 8 Rowley Road, and south west overland through Lot 8 Rowley Road. The two latter catchments discharge points ultimately discharge through culverts under Rowley Road and into Birriga Drain. The condition of these flow paths are generally good but some vegetative blockages coupled with poor grading, connectivity and sizing issues lead to local inundation. The Study Area also receives minor surface flows from the adjacent Bush Forever site to the west.

The geology of the Study Area has layers of sand and sandy clay of varying depths occasionally over clay of the Guildford formation. Geotechnical investigations exposed clay to be at or near the surface in some locations and sand to total bore depth in others. The clay layer offers little potential for infiltration although subsoil drainage will be considered to limit the importation of fill material. The Study Area is identified as having some areas with potential acid sulfate soils. These locations are typically around wetland and seasonally inundated zones.

The development is within close proximity to Forrestdale Lake, a Ramsar wetland of ecological importance. Early investigations suggest that the system is a groundwater flow-through lake based on regional data. As more investigations proceeded, it is suggested that it is driven by local groundwater; while detailed groundwater-surface water modelling identified the system as rainfall driven with a localised connection to groundwater via the surrounding dunal system. While further investigations are warranted to determine the actual surface water – groundwater interaction of Forrestdale Lake, the majority of groundwater flow (and surface water flow) from within the South Forrestdale Industrial Area heads south, away from Forrestdale Lake, and therefore has no interaction. The small area of interaction in the north of the development can be carefully managed via engineered solutions and strict design criteria to ensure that suitable water quality outcomes are achieved.

The pre-development drainage network was modelled using XP SWMM simulation software. The model encapsulates the surrounding drainage catchments contributing to the 190ha Study Area to assess the integration of the development into the wider region.

To comply with better urban water management (BUWM) planning, the Study Area is to maintain these flows post development. Total volume stored in floodplain storage is 55,900m^3 and shall be maintained post development. The Department of Water's MIKE SHE modelling indicates that the allowable discharge rate from the South Forrestdale Industrial Area into the Birriga Main Drain in the 1% AEP event is 2.85m^3/s (the Study Area contributing 1.8m^3/s).

The proposed development includes general and light industrial lots with associated local roads and drainage infrastructure. The development is to limit water use where possible and reduce pressure on water supply by implementing sustainable water management including use of water efficient fixtures and fittings, rainwater harvesting, water reuse schemes and water wise landscaping. Communications with service providers indicate a good potential for future connection with local infrastructure.

Water quality is to be maintained, and, in accordance with best practice improved where possible. This is achievable with implementation of both structural and non-structural best management practices (BMPs). Where viable, swales and other biofiltration systems shall be incorporated at source into the design to complete the treatment train approach. Vegetated swales and basins will be used to promote particulate settlement and nutrient stripping. Groundwater quality is variable across the site and is generally affected by the soil type, vegetation cover and agricultural practices. Groundwater quality will be maintained, and, if possible, improved by incorporating nutrient stripping in infiltration systems and by an established monitoring program.

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1 Introduction

Bioscience has been commissioned on behalf of the owners of Lots 9, 7 & 5 Oxley Road, Lot 5066 Kargotich Road, and Lots 10 & 12 Rowley Road (Study Area), to develop a District Water Management Strategy (DWMS) for the combined lots herein referred to the South Forrestdale Industrial Area and reported as the Study Area (**Figure 1**).

The Study Area is part of a larger body of land identified in the Economic and Employment Lands Strategy (EELS) report as potential industrial zoned land. This report has been prepared to support an application of amendment to the Metropolitan Region Scheme (MRS), changing the rural zoning of the Study Area to non-heavy industrial. It presents a sustainable approach to total water cycle management within the redevelopment area consistent with the best practice principles supported by the City of Armadale (CoA), the Department of Water (DoW), and the Department of Parks and Wildlife (DPAW; formerly Department of Environment and Conservation).

Note that only light industry is proposed to be developed within the site. In accordance with TPS4, light industry means an industry:

a) in which the processes carried on, the machinery used, and the good and commodities carried to and from the premises do not cause any injury to or adversely affect the amenity of the locality.
b) The establishment or conduct of which does not, or will not, impose an undue load on any existing or proposed service for the supply or provision of essential services.

Supporting information for the DWMS has been gathered from a range of sources including the DoW, DPaW, Department of Planning and Infrastructure (DPI), the Water Corporation (Water Corp), CoA, various engineering consultants, and Friends of Forrestdale. Bioscience previously produced the DWMS to successfully rezone the neighbouring Lots 6, 8 & 200 Rowley Road from rural to non-heavy industrial land use. The areas share many characteristics and are heavily interconnected by environmental and hydrogeological features by virtue of the shared boundaries. Where ever possible this document will refer to this area in order to put the environmental and hydrological features into perspective.

1.1 Previous Studies

The driving key principles and design objectives for this DWMS are derived from the following studies:

- *Liveable Neighbourhoods* (WAPC, 2007)
- *State Planning Policy 2.9: Water Resources* (WAPC 2007)
- *State Planning Policy 4.1: State Industrial Buffer Policy (WAPC, 2004)*
- *Stormwater Management Manual for WA* (DoW 2004-2007)
- *Better Urban Water Management* (WAPC 2008)
- *A State Water Strategy for WA* (2003a)
- *Economic and Employment Lands Strategy: non-heavy industrial* (WAPC, 2012)
- *Guidelines for District Water Management Strategies (DoW, 2013)*

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

- *The Southern River/ Forrestdale/ Brookdale/ Wungong District Structure Plan* (WAPC, 2001)
- *Southern River/ Forrestdale/ Brookdale/ Wungong District Structure Plan: Urban Water Management Strategy* (JDA, 2002)
- *Forrestdale Main Drain Arterial Drainage Strategy (ADS)* (Water Corporation, 2007)
- *Wungong Urban Water Master Plan: District Water Management Strategy* (JDA, 2006)

- *The Southern River Integrated Land and Water Management Plan* (DoW, 2009)
- *Economic Employment and Lands Strategy (EELS) (WAPC, 2012)*
- *The Forrestdale Main Drain Arterial Drainage Strategy* (Water Corporation, 2009)
- *Surface Water Quality Investigation Using High Resolution Water Quality Analysers* (CSIRO, 2010)
- *Environmental Impact Assessment:* (Bioscience, 2014)
- *Geotechnical Investigations: Lots 6, 8 and 200 Rowley Road Forrestdale in 2010 and the rest of the Study Area in 2012* (Bioscience, 2010 & 2012)
- *South Forrestdale DWMS for Lots 6, 8 and 200 Rowley Road (Bioscience, 2013)*
- *Geomorphic Wetlands Swan Coastal Plain Dataset Request for Modification. Lot 8 Rowley Road Forrestdale* (Bioscience, 2010)
- *Forrestdale Lake Nature Reserve Management Plan (CCWA, 2005), Management Plan No. 53*
- *Birriga and Oaklands Flood Modelling and Drainage Study, Department of Water (Hall, 2015)*
- Lower Serpentine Hydrological Studies, Department of Water (Marillier et al. 2012a, Marillier et al. 2012b, Marillier et al. 2015)

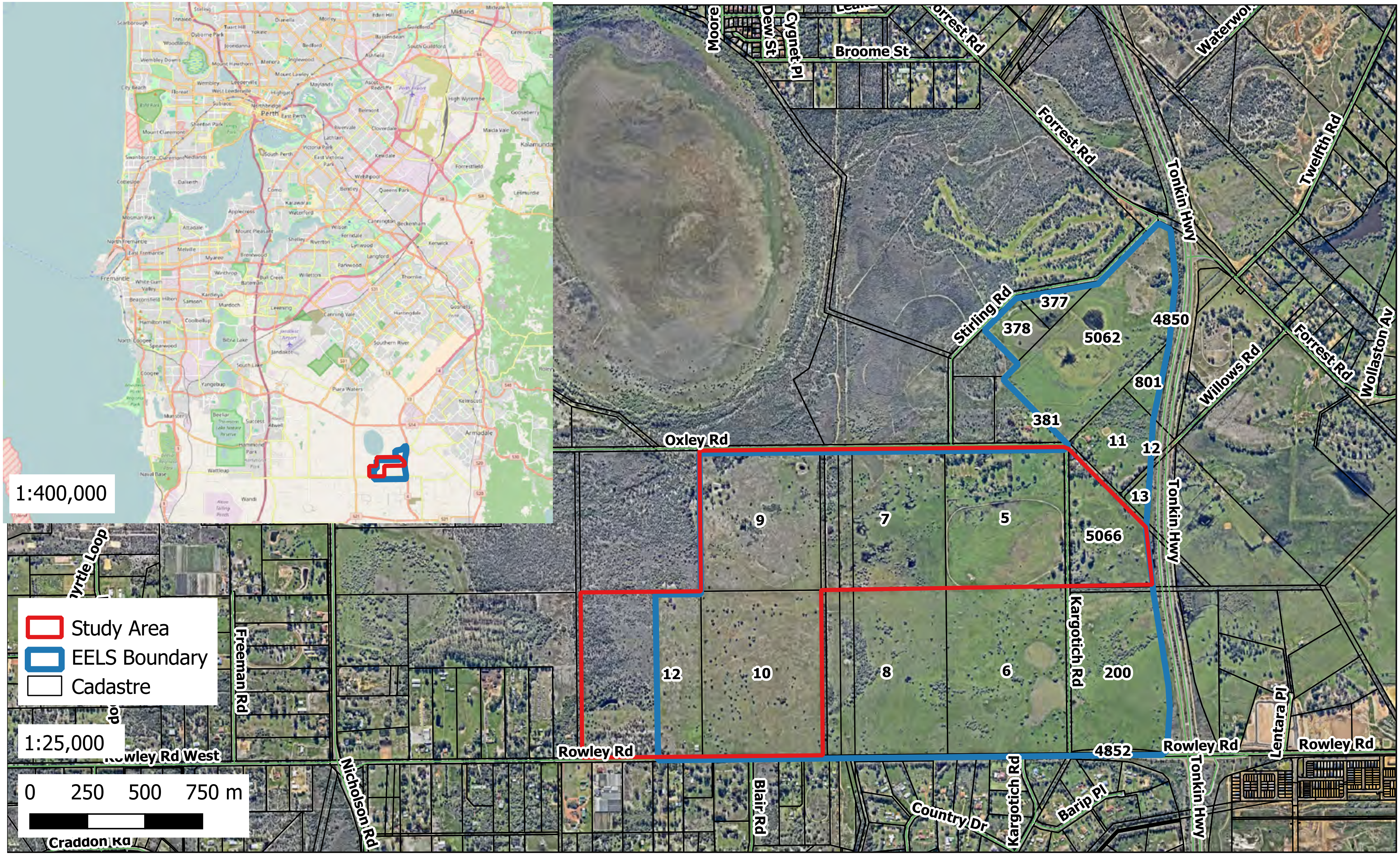
1.2 Drivers for Land Use Amendment

The EELS - Non-Heavy Industrial (WAPC, 2012) has been prepared as part of the state governments response to a recognised deficit in Perth’s industrial land supply. The aims of the strategy include:

- Identify the areas, type and locations of industrial land required over the next 20 years.
- Review the existing industrial land development program and identify possible extension opportunities.
- Identify and evaluate the suitability of locations for new general and light industrial estates.
- Develop a strategy to facilitate the delivery of general and light industrial land and assist in the restoration of the Government’s long-term general and light industrial landbank.

Thirty-seven sites, totalling around 13 000ha have been identified as potential gross developable land for future use (20 year outlook). South Forrestdale has been identified as a potential medium term non-heavy industrial site comprising of eight main landowners and covering an area of 354ha (**Figure 1**). Within this area, the Study Area is approximately 190 ha totalling around 54% of the South Forrestdale potential industrial site. The aforementioned MRS amendment for Lots 6,8 and 200 meant 106 ha (30% of the EELS area) has already been rezoned. The area offers a large expanse of land that meets initial criteria for non-heavy industrial practices. These include established electricity supply, potable water supply, flat topography, acceptable drainage potential, proximity to key infrastructure including road and rail, proximity to local workforce and public transport links.

Lots North of Oxley Road (remaining 58ha) were excluded for initially progressing within the EELS South Forrestdale Industrial Area due environmental constraints thus not suitable for development. Further investigations within this area may identify land suitable for development, though is not included within this Study Area or report.



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Project Title: South Forrestdale Industrial DWMS
Client:
Date: 11/10/2016
Drawn: TL
Checked:
Revision: A

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FIGURE 1: Location

South Forrestdale Industrial Area

Source: Aerial - Nearmaps (11/10/2016); Streetview - Bing (11/10/2016); Cadastre - Landgate (21/07/2016)

1.3 Principles and Objectives

The DWMS encapsulates the key principles of total water cycle management, integrated urban water management and water sensitive urban design (WSUD) as shown in **Table 1**.

Table 1: Key Design Principles

Principle 1: Manage catchments to maintain or improve water resources	
Principle	**Key DWMS Element**
1. Manage runoff from all rainfall events as high in the catchment as possible.	• Provide at-source treatment for first flush events (1 year 1 hour ARI) • Provide drainage network for critical 10 year ARI and flow paths for 1% AEP
2. Manage post development hydrology to maintain and/or improve hydrological, hydrogeological and ecological functions.	• Subsoil exclusion zones to be developed around sensitive environments
3. Maintain or improve water quality of surface water and groundwater.	• Ensure water quality treatment of first flush events (Bioretention Areas) • Lot level storage to provide treatment in line with Bioretention Areas • Pre-development and post development monitoring programs and reviews
4. Manage, protect and restore waterways and wetlands.	• Utilise wetland buffer for retention storage prior to overflow into natural flow channel and discharge at Rowley Road
5. Minimise pollutant inputs through implementation of appropriate structural and non-structural controls.	• Ensure suitable information supplied to lot purchasers (to include understanding of multiple use corridor, lot drainage requirements, treatment, non-potable water use)
6. Retain native vegetation and natural landform.	• Protect existing hydrological and ecological regime of the wetlands by maintaining pre-development peak winter groundwater levels

Principle 2: Manage flooding and inundation risks to human life and property	
Principle	**Key DWMS Element**
1. Provide adequate clearance from the 1% AEP flood level and surface water or groundwater inundation and waterlogging.	• Maintain predevelopment peak flow rates for the critical 10 year ARI and 1% AEP • Major roads to remain passable during the 1% AEP storm event • Provide a minimum of 1.2m separation above groundwater levels

2. Prevent increased flooding or inundation of upstream, downstream or adjacent developed areas.	- Finished floor levels to have a clearance of 0.5m from the 1% AEP flood water level - Sub-soils drains to be installed at or above AAMGL, where required
3. Manage surface water flows to prevent damage to downstream infrastructure and assets.	- Provide a minimum of predevelopment flood storage requirements on site (Peel Catchment only – Birriga Drain) - Prevent ponding of stormwater for greater than 96hours
4. Manage risk to public health from disease vector and nuisance insects.	- Minimum clearance of 0.3m from base of infiltration areas to controlled groundwater level
Principle 3: Ensure the efficient use and reuse of water resources	
Principle	**Key DWMS Element**
1. Minimise water use within developments.	- Consumption target for water of 100 kL/person/yr, (State Water Plan target) including not more than 40-60 kL/person/yr scheme water - No irrigation requirements within drainage areas and planted areas
2. Maximise water reuse, including using wastewater and harvested stormwater.	- If useable grassed areas proposed, utilise a drought tolerant species and reduce irrigation requirements to less than 6,250kL/ha - Water efficient fixtures and fittings within buildings, in line with BCA guidelines
3. Achieve highest value use of fit-for-purpose water, considering all available sources of water for their potential as a resource.	- All lot purchasers to provide rainwater harvesting systems - Consideration of grey water system - Provide non-potable (third pipe) network throughout development
Principle 4: Recognise and maintain economic, social and cultural values associated with water	
Principle	**Key DWMS Element**
1. Improve social amenity by having multiple use corridors and by integrating water management measures into the street and lot landscape to increase visual, recreational, cultural, public health and ecological values.	- Consider MUC associated with High Voltage powerlines and RE wetland - Drainage areas to provide suitable foraging habitat for the critically endangered native bee, Neopasiphae simplicior (include *Goodenia filiformis*, *Lobelia tenuior*, *Angianthus preissianus*, and *Velleia sp.* where possible)

Note that Water Corporation is the management authority of the Birriga Drain. The discharge criteria dictated by this authority is set and assessed by the Department of Water and Regulations. Criteria are further discussed in Section 2.7.1.

2 Pre Development Environment

2.1 Site Location

The Study Area is located 25km south of Perth CBD within the City of Armadale. The south western side of Lots 10 & 12 Rowley Road directly abuts the Serpentine-Jarrahdale Shire boundary. The Study Area is bound along part of the east and northern perimeter by Bush Forever Site No. 345 and Oxley Road, Tonkin Highway to the east, the recently rezoned industrial Lots 6, 8 & 200 Rowley Road, and Rowley Road along the southern side of Lot 10 & 12 Rowley Road (**Figure 1**). The Study Area is approximately 190ha.

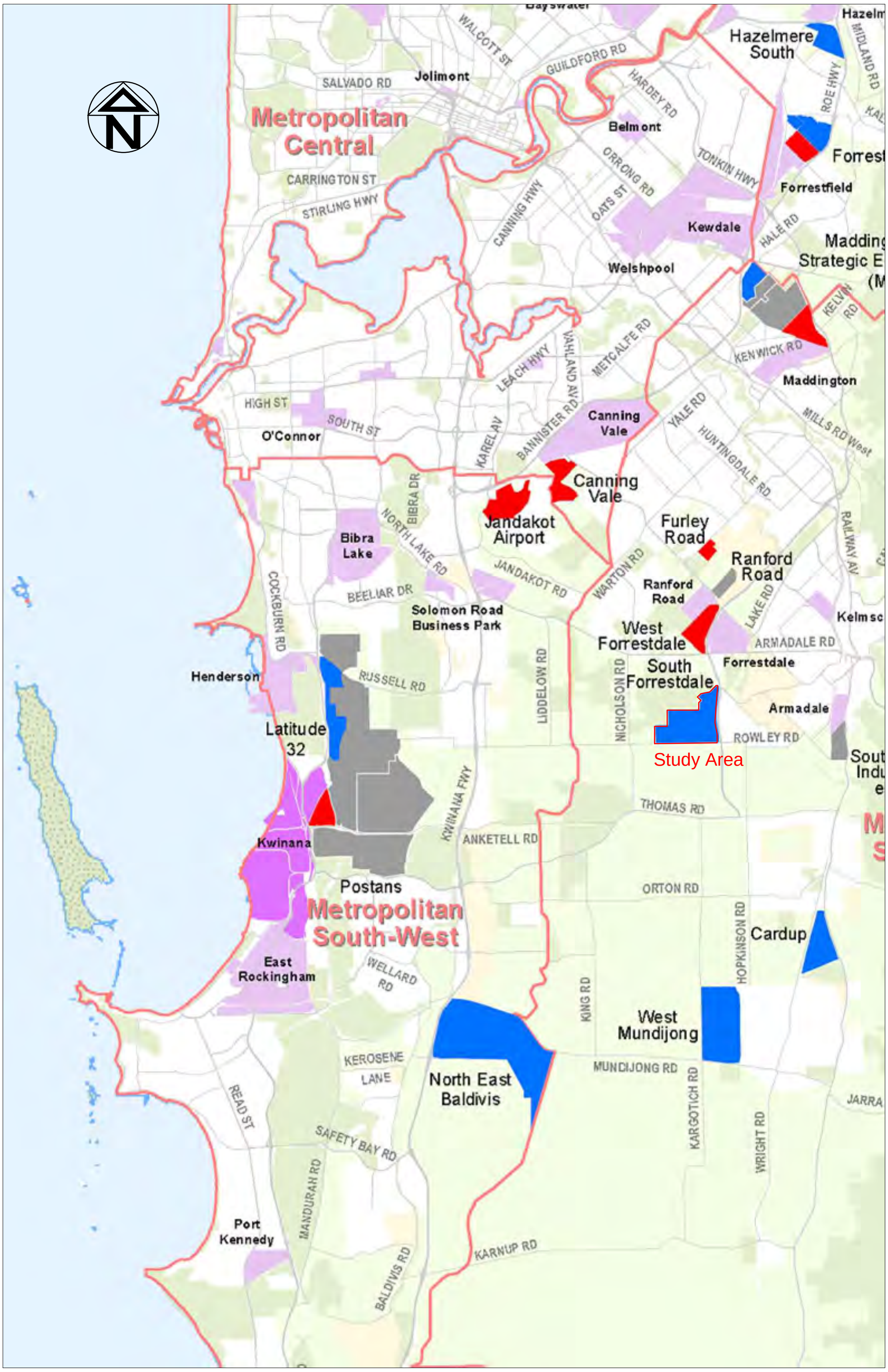
The EELS report identified an area of approximately 340ha of land with potential to amend land use classification in the MRS from rural to industrial. This report is in support of an amendment to the 190ha of land within Lots 9, 7 & 5 Oxley Road, 5066 Kargotich Road, 10 & 12 Rowley Road that form part of the South Forrestdale Industrial Area (**Figure 1 & 2)**.

2.2 Climate

The south west of Western Australia is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. According to the Bureau of Meteorology (BoM) the mean annual rainfall is 875mm (Armadale Station, BoM, average since 1903). The 90th percentile is 1,094mm (**Table 2**). Perth also experiences frequent periods of strong winds. Potential evapotranspiration of the region is in excess of 1,000 mm/yr.

Table 2: Rainfall at Armadale Station (1903-2014)

Statistic	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Mean	8.4	11.6	17.9	41.5	120.0	178.3	177.6	133.1	84.0	51.8	24.2	11.7	875.2
Lowest	0.0	0.0	0.0	0.0	19.8	2.2	26.2	17.5	6.1	0.0	0.0	0.0	499.2
Median	2.5	3.3	9.0	33.9	117.7	178.4	175.0	128.0	79.9	47.6	18.8	7.0	879.1
90th %ile	24.7	28.2	50.6	83.3	203.0	289.3	268.1	207.4	137.0	90.6	56.7	25.6	1094.0
Highest	114.0	166.0	76.7	154.8	300.9	452.1	359.6	363.7	205.9	137.2	89.1	77.2	1369.3



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Employment lands
- 🟪 Industrial Area (existing)
- 🟪 Industrial Area Heavy (existing)

Potential Non-heavy Industrial Areas
- 🟥 Short-term (0-4 yr planning frame)
- 🟦 Medium-term (4-10 yr planning frame)
- ⬛ Long-term (10+ yr planning frame)

Data Source: Western Australia Planning Commission

Bioscience Pty Ltd

South Forrestdale Industrial Area ,Perth, WA

District Water Management Strategy
09/09/2015

Figure 2: EELS: Non-heavy Industry, Perth metropolitan & Peel Regions

2.3 Topography

Topography of the Study Area has been provided by LiDAR survey from the DoW (**Figure 3**). Contours on **Figure 4** indicate a relatively flat surface with minor elevations and depressions (noted by the lack of 1m isopotentials relative to outside the Study Area). The Study Area is approximately 25mAHD with some minor depressions at 24mAHD. Sand dunes surrounding Lake Forrestdale rise to 30mAHD locally, disconnecting it from surface water sheet flows.

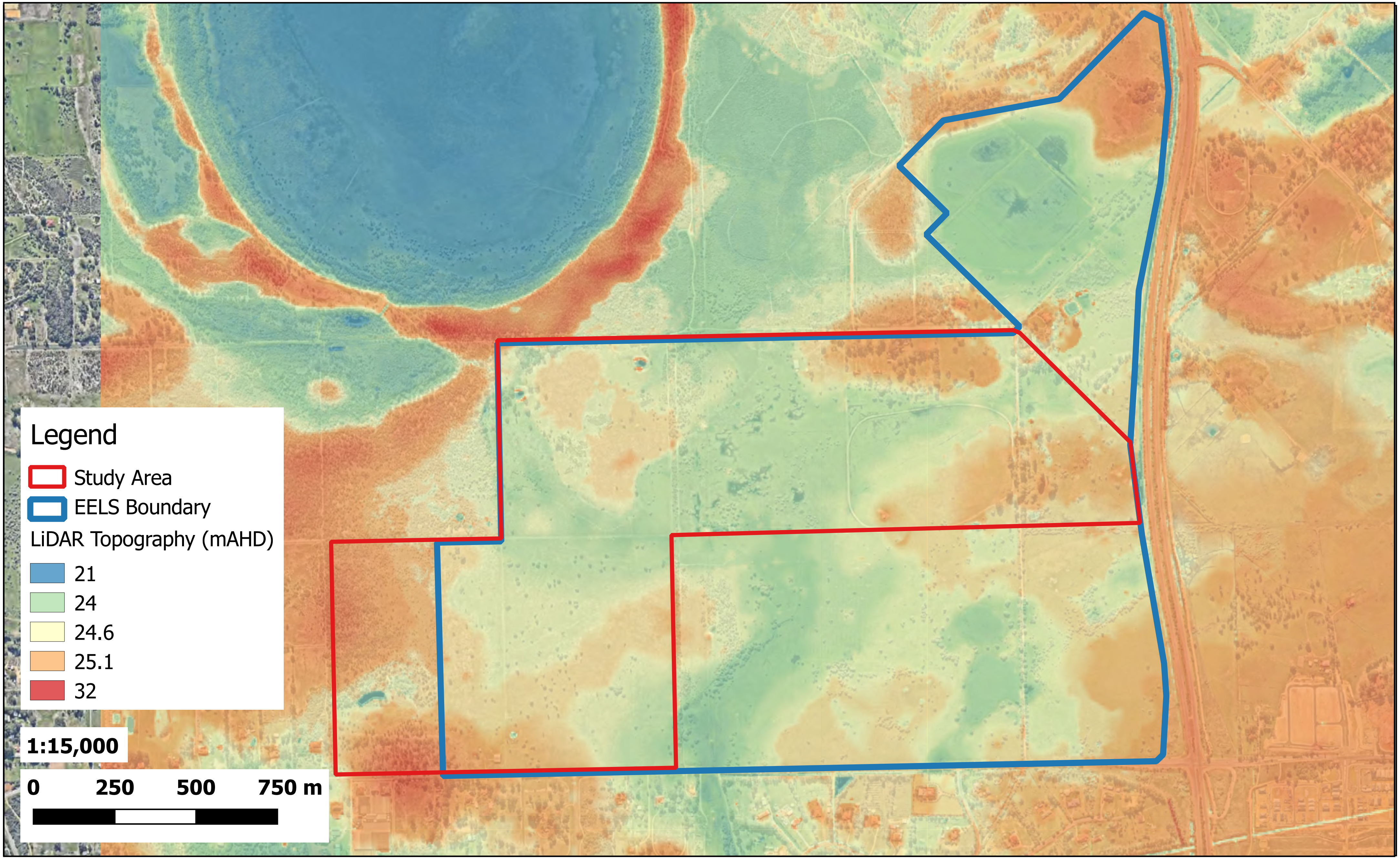
2.4 Historical Land Use

2.4.1 Aboriginal Heritage

A search on the Aboriginal Heritage Inquiry System (AHIS) on the Department of Indigenous Affairs (DIA) website, indicated that no registered sites are within South Forrestdale Industrial Estate. Forrestdale Lake is a registered site (number 3713) and is identified as a registered, unrestricted site (**Appendix A**). It is a mythical site where camping and hunting grounds also existed. Additional archaeological sites related to Brookdale were also noted. These sites are some 1.5km from the northern boundary of the Study Area.

The CALM Forrestdale Lake Management Plan (number 53), 2005, describes the Aboriginal heritage of Forrestdale Lake as follows:

> *"According to Nyungar tradition, wetlands, waterways and lakes, including Forrestdale Lake, are said to be the home of the powerful water serpent figure, the Waugal. The Waugal is spiritually and mythologically important to Aboriginal people who believe that it created rivers and lakes, and maintains the flow of waters that feed its resting places. According to Nyungar beliefs, these places are described as winnatch (an area that is avoided, usually for reasons of cultural or religious significance) and consequently require the highest respect and reverence in the way they are considered, used and valued.*
>
> *As well as its mythological status, the lake was a source of tortoise for people from Pinjarra, Mandurah and Armadale. Seasonal camps were usually established under the shelter of surrounding melaleuca scrub in the lake's north-western edge, and some groups set up semipermanent camps for extended periods on their way from the Darling Plateau to the coast. (O'Conner et al. 1989; Gray 1994). Thus, the lake has significance both as a tortoise hunting site, and for these campsites at the lake."*



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Project Title: South Forrestdale Industrial DWMS
Client:
Date: 30/09/2016
Drawn: TL
Checked:
Revision: A

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FIGURE 3: Topography (LiDAR)

South Forrestdale Industrial Area

Source: Aerial - Nearmap (30/09/2014); LiDAR - DoW (17/05/2010)

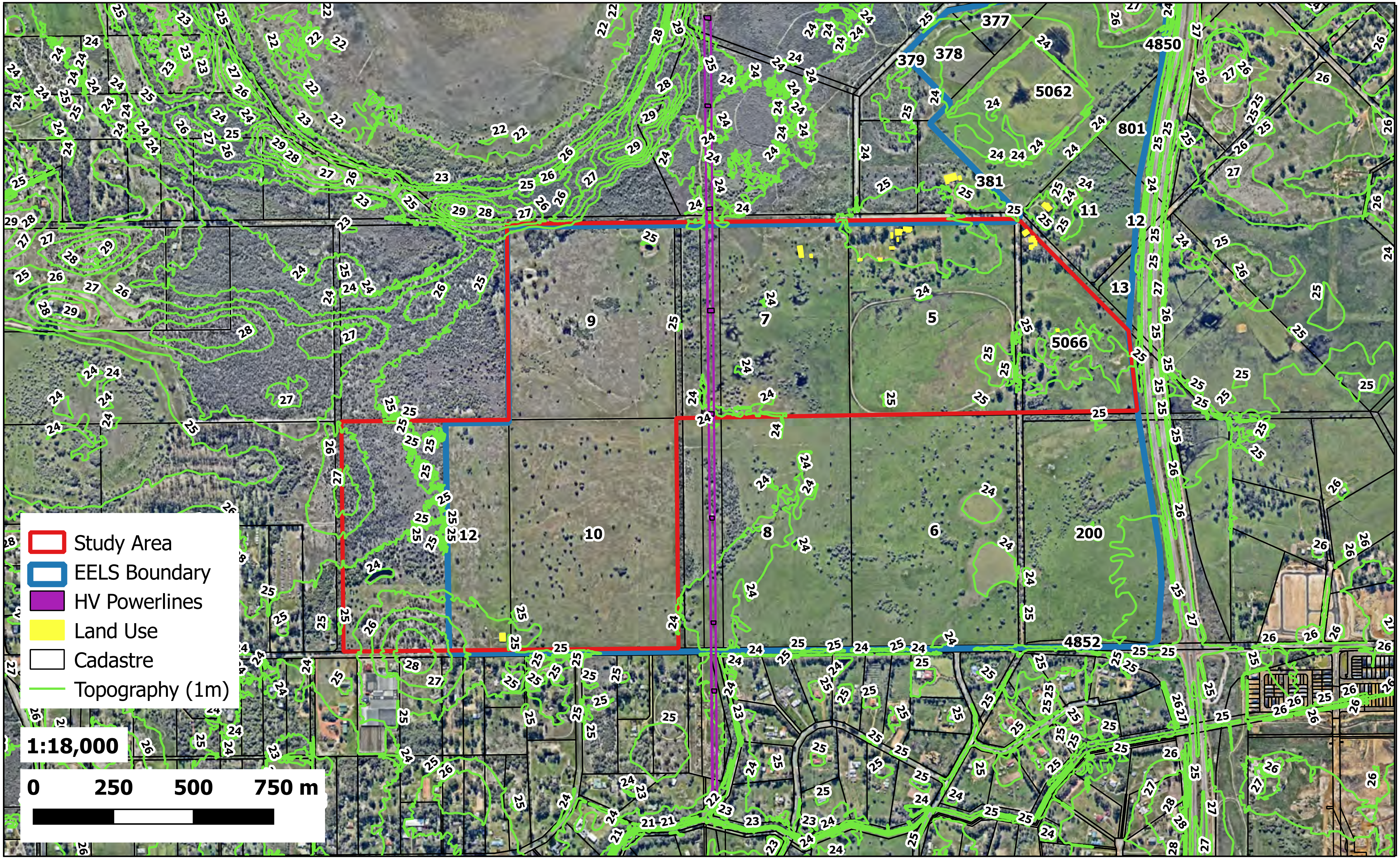

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FIGURE 4: Topography & Landuse

South Forrestdale Industrial Area

Source: Aerial - Nearmap (30/09/2014); Cadastre - Landgate (21/07/2016); Topography LiDAR - DoW (2012)

2.4.2 European Land Use

The CALM Forrestdale Lake Management Plan (number 53), 2005, describes the historical European land use within the vicinity of Forrestdale Lake as follows:

> *"The first non-Aboriginal settlement at Forrestdale Lake (then known as Lake Jandakot) occurred in 1885, when William and Alfred Skeet were granted a 'Special Occupation' licence for 100 acres adjoining the Lake, as well as licences to cut and sell timber. The area at this time has been described by Popham (1980) as:*
>
> > *'... rich swamplands ... closely covered by huge paperbark trees, many thirty feet high with a diameter of some three feet, the undergrowth beneath them dense with rough scrub and tanglewood creepers'.*
>
> *Early settlers in the Forrestdale Lake area commenced farming in 1893 on the edge of Commercial Road. Large areas of land were soon utilised for farming around Taylor Road, where the water table is close to the surface. Other settlers soon followed and the Lake Jandakot settlers cleared their land, experimented with crops and ran dairy cattle and poultry as viable commercial ventures (Popham 1980).*
>
> *By 1898, the area surrounding the Lake had been set aside as a Townsite Reserve and recommendations made regarding subdivision. The Jandakot region soon became a thriving community, producing vegetables, apiary products and in later years, dairy produce for the Fremantle markets. The prosperity of the region encouraged the construction of a railway between Fremantle and Jandakot, which in July 1907 was extended to Armadale for the purpose of transporting goods to the Fremantle Markets (CALM 1987).*
>
> *From the 1920s intensive agriculture gave way to sheep and cattle grazing, which continued over the next 50 years. During the 1940s the west side of Forrestdale Lake was heavily grazed by sheep and cattle, particularly during the drier summers when land owners used the fringing vegetation to supplement feed from their paddocks (Atkinson, 1984).*
>
> *The population in the Forrestdale area rapidly increased in the latter half of the 1960s as the townsite blocks to the northwest of the Lake were taken up. Since that time, the population has slowly increased to its current figure of approximately 1350."*

Aerial mapping is shown in **Figure 4**. The following land uses have been summarised for the study area:

- Lots 10 Rowley Road and 9 Oxley Road has no buildings
- Lot 7 Oxley Road has 2 agricultural sheds
- Lot 5 Oxley is used to rear horses and has associated buildings and a residential property
- Lot 5066 Kargotich Road has a residential building and various sheds

- Lot 12 Rowley Road is half Bush Forever site and half open rural grazing land with a single shed.
- All lots are fenced and have been used predominantly for rural activities associated with grazing and livestock
- A Western Power easement runs north to south along the western side of Lot 7 Oxley Road.

2.5 Regional Geology, Geomorphology and Soils

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

Underlying the Bassendean formation is the Guildford formation. The soils of the Guildford formation are complex, and comprise a successive layering formed from erosion of material from the scarp to the east. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium.

The Guildford formation is characterised by poor drainage due to the low permeability of sub-soil clays which prevent the downward infiltration of rainfall, consequently during winter months' water logging and surface inundation can occur. In addition, the clay fraction of the Guildford formation is known to have highly variable Plasticity Indices (Hillman *et al.,* 2003). Soil Organic content varies between 1-3% of volume in the surface layers, dropping to between 0.2-1% in subsoils *(ASRIS).* There are also Swampy or Lacustrine (Vertosols) soils in the locality, which consist of peaty waterlogged soils.

The geology at the site as per the Geological Survey of Western Australia 1:50000 Environmental Geological Series Armadale Map part of sheets 2033 I and 2133 IV (**Figure 5**) is composed of:

- S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately to well sorted, minor heavy minerals, of eolian origin
- S10 – SAND- as S8 over sandy clay to clayey sand of the Guildford Formation of Aeolian origin (Bassendean Sand over Guildford Formation).
- Sc – SANDY CLAY – Silty in part, pale grey to brown, medium to coarse grained, poorly sorted, subangular to rounded, frequent heavy minerals, rare feldspar, of alluvial origin
- Sp1 – PEATY SAND- Grey to black, fine to medium-grained, moderately sorted quartz sand, slightly peaty, of lacustrine origin
- *Cs – SANDY CLAY* – White-grey to brown, fine to coarse-grained, sub-angular to round sand, clay of moderate plasticity gravel and silt layers near scarp

Geotechnical investigations to support the DWMS have confirmed the Geological Survey mapping, and have found that the western side of the subject site has sand to depths of 3.5 - 5m over Guildford clay, but the depth of sand over clay declines in an easterly and southerly direction such that most of Lot 5066, and the south east corner of Lot 9 have clay very close to the surface of organic silty loam.

The majority of the site is identified as S10 sand over clay from the Guildford Formation. Graphic Logs from GSWA 1:50000 Environmental Series are also available. SE238 is identified within the northern boundary of Lot 3 Oxley Road (**Figure 5**). It identified the following approximate soil geology for the site:

0-1.5m sand
1.5m-15m clayey sand
15-21m sandstone
21-23m clayey sand
23-26m sand
26-27.4m siltstone

The approximate extent of clayey faces associated with the Guildford Formation is identified as running through the Study Area from the southern border of Lot 8 Rowley Road, through the south west corner of Lot 5 Oxley Road and continuing through the northern boundary of Lot 5 Oxley Road (**Figure 5**).

2.5.1 Geotechnical Investigations

Preliminary geotechnical investigations have been completed for the Study Area and EELS development area. These provide confirmation to the regional soil lithology described above. It is noted that these reports are preliminary and limited in scope and therefore additional, more detailed, geotechnical investigations will be required at subsequent planning stages. Copies of the reports are included in **Appendix B** and **C** respectively.

2.5.1.1 Lot 6, 8 and 200 Rowley Road Geotechnical Investigation (Bioscience, 2010)

A Geotechnical Investigation Report (Bioscience, 2010) was completed as part of the previous MRS amendment for this area. The following conclusions were noted within this report:

- Site is physically capable of being developed into an industrial development
- Site soil lithology can be summarised as Bassendean sands over Guildford Formation
- Guildford soils have low permeabilities, therefore limited opportunities to infiltrate stormwater
- Fill likely required due to depth to groundwater and high plasticity of Guildford soils.

2.5.1.2 2012 Report

During installation of groundwater monitoring bores Bioscience completed a preliminary geotechnical investigation covering Lots 9, 7, 5 Oxley Road and Lot 10 Rowley Road (Bioscience, 2012). The following conclusions were noted within this report:

- The Bassendean sand surface soils have a permeability in the order of 10^{-3} and 10^{-5} m/s based on particle size distribution. This is generally suitable for onsite disposal of stormwater, however the underlying low permeability clays, with permeabilities between 10^{-7} and 10^{-9} m/s, mean drainage will have to be carefully considered.
- Dewatering possible during site preparation for compaction requirements
- Controlled groundwater levels likely as groundwater within 1-1.5m below ground level (BGL)
- Actual and Potential Acid Sulphate Soils present sporadically below 1.6m

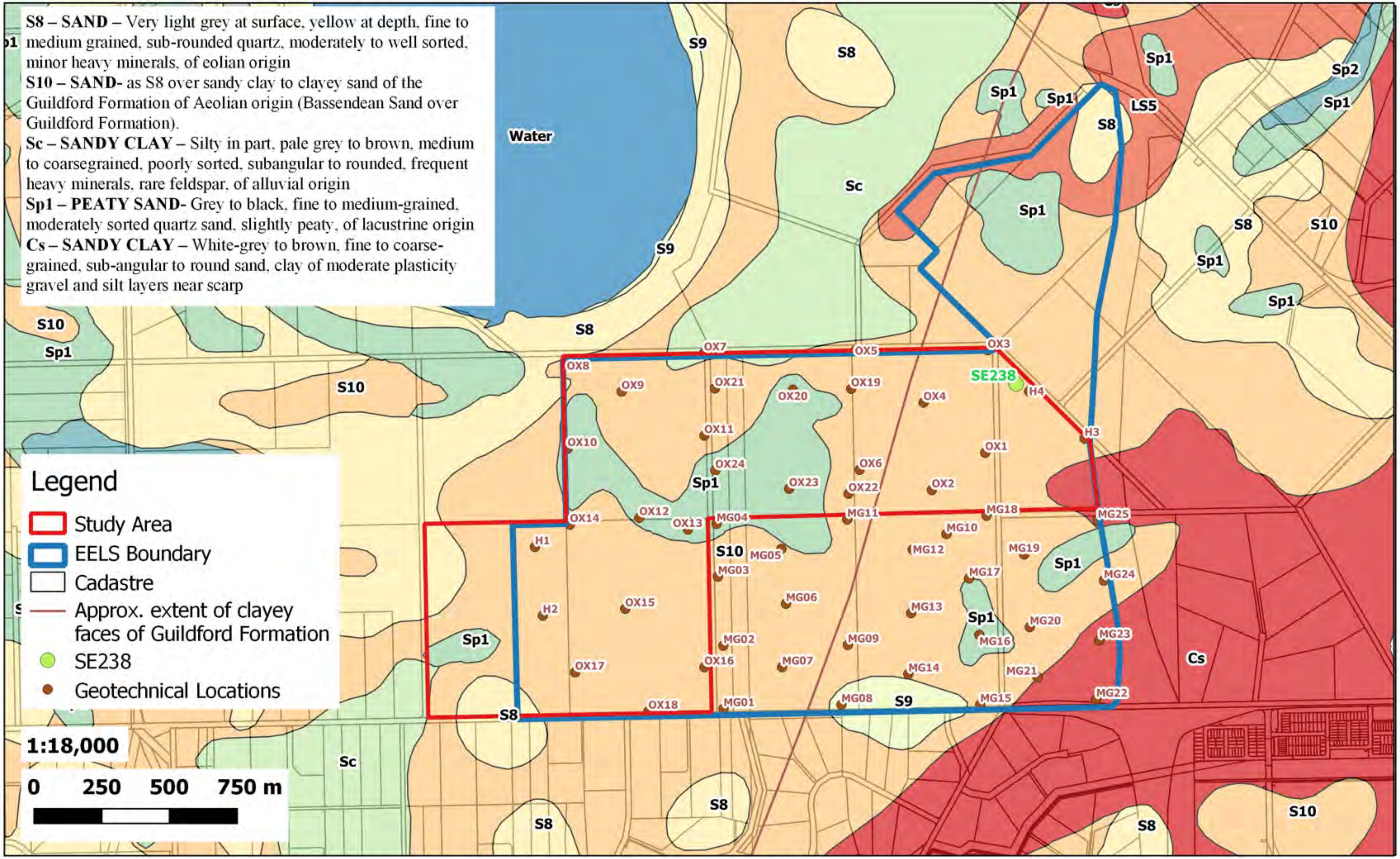
S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately to well sorted, minor heavy minerals, of eolian origin

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FIGURE 5: Surface Geology

South Forrestdale Industrial Area

Source: Cadastre - Landgate (21/07/2016); Geology - Geological Survey of Western Australia, Environmenta Series - Armadalel

2.5.2 Acid Sulfate Soils

The acid sulfate risk maps for the site (**Figure 6**) shows a subject area to have a large area of potentially high risk of acid sulfate soils occurring within 3m of the natural soil surface. This area generally coincides with clay layers being close to surface as indicated in **Figure 5**. The rest of the site has a moderate to low risk of acid sulfate soils occurring within 3m of the natural soil surface, but high to moderate risk below 3m. As a result of this, exclusion testing was done on the soils collected during field investigation to determine the acid sulphate potential.

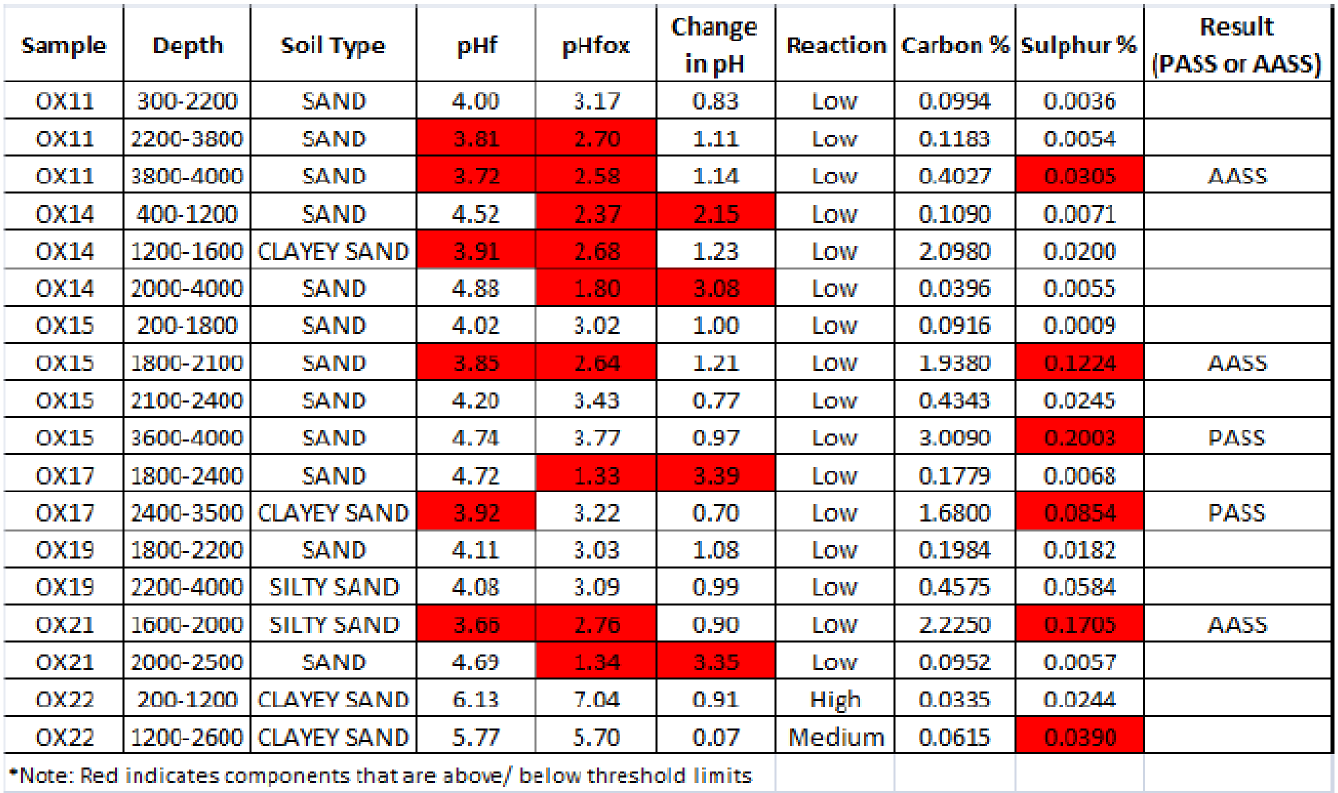
Acid sulfate soils (ASS) exclusion testing involves the use of field testing and determination of total sulphur content. If the Field test procedure indicated potential or actual acid sulfate soils, determining the total sulphur can confirm or eliminate the result. For a sample to be classified as potential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

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

Selected soil samples collected during geotechnical investigation were analysed using the DEC field test procedure as well as LECO carbon sulphur analyser and redox potential. Overall these give an indication of whether or not soils are actual, potential or non-acid sulfate soils. **Table 3** summarises the results of the acid sulfate testing.

Eighteen samples underwent these tests and 3 samples came back as being actual acid sulfate soil (AASS) and two were potential acid sulfate soils (PASS). The AASS soils are all found deeper than 1600 mm in sand or silty sand. PASS occurs at depths greater than 2400mm in sands and clayey sands. The strong reactions of samples from bore OX22 is possibly caused by the presence of manganese in the soil sample. There is no AASS and an unlikely PASS in OX22. Sample locations are shown on **Figure 6**.

Table 3: Summary of Acid Sulfate Testing (Bioscience, 2012)



Sample	Depth	Soil Type	pHf	pHfox	Change in pH	Reaction	Carbon %	Sulphur %	Result (PASS or AASS)
OX11	300-2200	SAND	4.00	3.17	0.83	Low	0.0994	0.0036	
OX11	2200-3800	SAND	3.81	2.70	1.11	Low	0.1183	0.0054	
OX11	3800-4000	SAND	3.72	2.58	1.14	Low	0.4027	0.0305	AASS
OX14	400-1200	SAND	4.52	2.37	2.15	Low	0.1090	0.0071	
OX14	1200-1600	CLAYEY SAND	3.91	2.68	1.23	Low	2.0980	0.0200	
OX14	2000-4000	SAND	4.88	1.80	3.08	Low	0.0396	0.0055	
OX15	200-1800	SAND	4.02	3.02	1.00	Low	0.0916	0.0009	
OX15	1800-2100	SAND	3.85	2.64	1.21	Low	1.9380	0.1224	AASS
OX15	2100-2400	SAND	4.20	3.43	0.77	Low	0.4343	0.0245	
OX15	3600-4000	SAND	4.74	3.77	0.97	Low	3.0090	0.2003	PASS
OX17	1800-2400	SAND	4.72	1.33	3.39	Low	0.1779	0.0068	
OX17	2400-3500	CLAYEY SAND	3.92	3.22	0.70	Low	1.6800	0.0854	PASS
OX19	1800-2200	SAND	4.11	3.03	1.08	Low	0.1984	0.0182	
OX19	2200-4000	SILTY SAND	4.08	3.09	0.99	Low	0.4575	0.0584	
OX21	1600-2000	SILTY SAND	3.66	2.76	0.90	Low	2.2250	0.1705	AASS
OX21	2000-2500	SAND	4.69	1.34	3.35	Low	0.0952	0.0057	
OX22	200-1200	CLAYEY SAND	6.13	7.04	0.91	High	0.0335	0.0244	
OX22	1200-2600	CLAYEY SAND	5.77	5.70	0.07	Medium	0.0615	0.0390	

*Note: Red indicates components that are above/ below threshold limits

Given that preliminary ASS investigations did not provide any correlation between regional mapping and sample results, it is recommended that additional, more detailed, ASS investigations are completed at subsequent structure planning stages. These can be designed to reflect areas of likely impact such as areas of deep excavation for deep sewer or locations where dewatering may occur.

Any development activities involving deep excavation and major infrastructure earth works such as the installation of sewers, and lowering of the ground water can disturb and accentuate ASS risk. An ASS investigation will have to be carried out in accordance with DER guidelines. Should the proposed investigations indicate actual and/or potential ASS are present within the vicinity of the specific construction activities, then an ASS Management Plan will be developed.

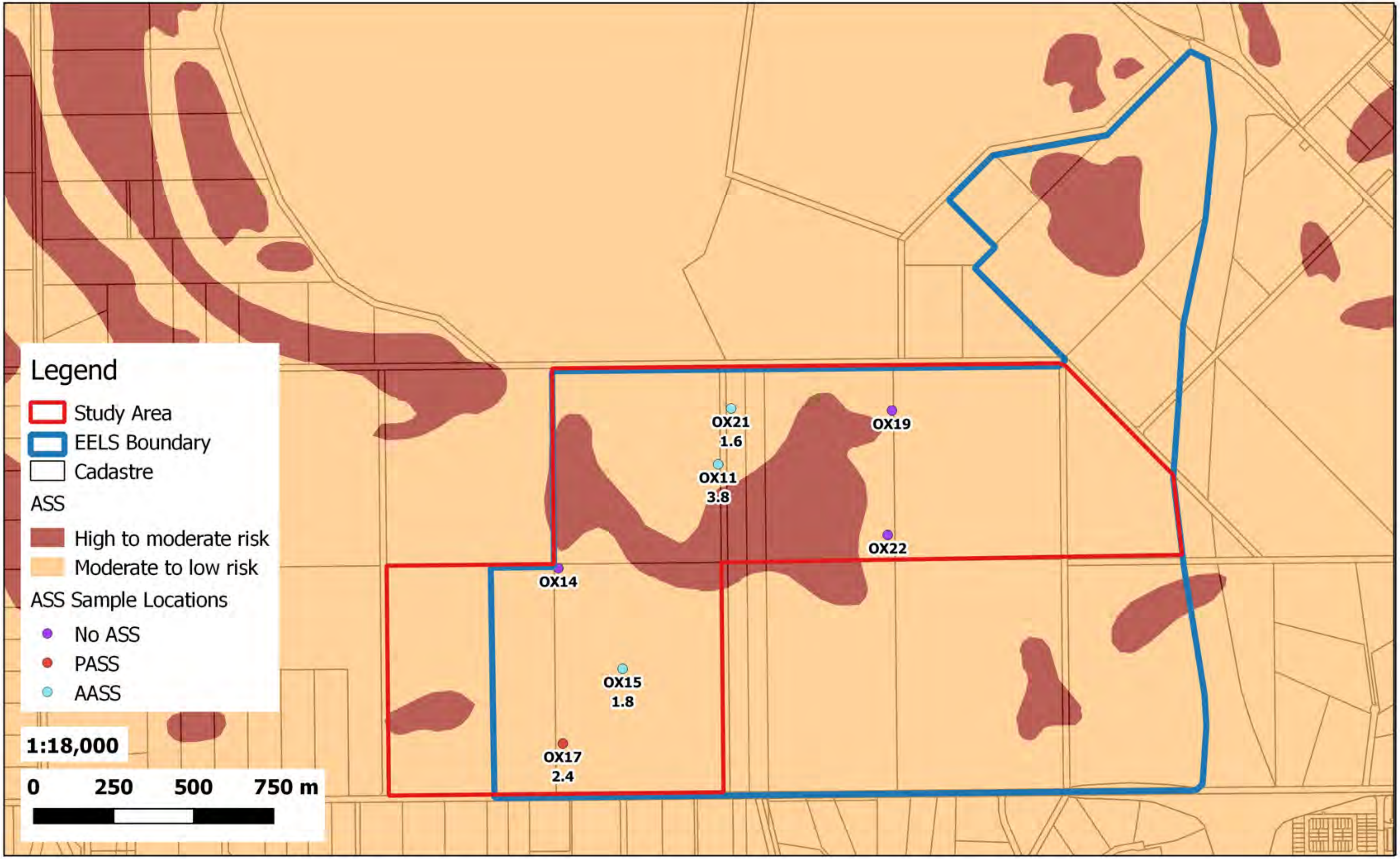


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FIGURE 6: Acid Sulfate Soils

South Forrestdale Industrial Area

Source: Cadastre - Landgate (21/07/2016); ASS - DPaW (21/07/2016)

2.6 Hydrogeology

2.6.1 Regional Hydrogeology

The youngest sediments in the Perth Basin are collectively termed the ‘superficial formations’ and include (from oldest to youngest) the Ascot Formation, Yoganup Formation, Guildford Formation, Bassendean Sand, Tamala Limestone, Becher Sand and Safety Bay Sand (Davidson 1995). The superficial formations near the Study Area are 35m thick, consisting of Bassendean Sand that inter-fingers with Guildford Formation eastwards towards the Darling Scarp (Davidson 1995).

The Study Area, sits on a groundwater divide with regional contours suggesting inflow from the east and west and outflow to the north and south, as defined by Davidson (1995). The area is identified as a groundwater col on **Figure 7**.

According to the Department of Water’s (DoW) Perth Groundwater Atlas the groundwater divide is also evident (**Figure 8**). The Perth Groundwater Atlas metadata notes:

> *“The groundwater contours were hand drawn interpolations from 1:2,000 map sheets. Original data was supplied from whatever available source could supply the maximum/ minimum ground water levels. Borehole readings and the gauging of casings provided over weekly, fortnightly or monthly periods were all used for interpolation. Records accessed were from the early 1950’s through to the 1970’s.*
>
> *Because of the large scale (1:2,000) of data capture and the comprehensive use of archival records, the interpolated contours have proven to be very accurate. Constant verification is supplied by any new records of recently drilled boreholes. Updating or modification of the contours is done whenever an obvious anomaly occurs.”*

The estimated maximum water table ranges from 24-25mAHD within the Study Area (**Figure 8**). Likewise, the topography of the site varies from 24-25mAHD. Therefore, this regional mapping suggests that large portions of the site may become inundated during winter months.

Additional regional investigations were completed by the DoW as part of the Lower Serpentine Hydrological Studies (various reports), of which the Study Area is on the northern bounds of this investigation. As such the groundwater divide is not clear, however, the change in groundwater flow direction south of Forrestdale Lake is still evident and generally aligns with the previous regional groundwater mapping. Mapping provided in Lower Serpentine Hydrological Studies – Water Science Technical Series number 48, Marillier (2015), identifies the AAMGL for a base-case (current conditions) reported for a period from 1981-2010 (**Figure 9**). Groundwater inundation based on this AAMGL relative to topography was also calculated and mapped (**Figure 10**).

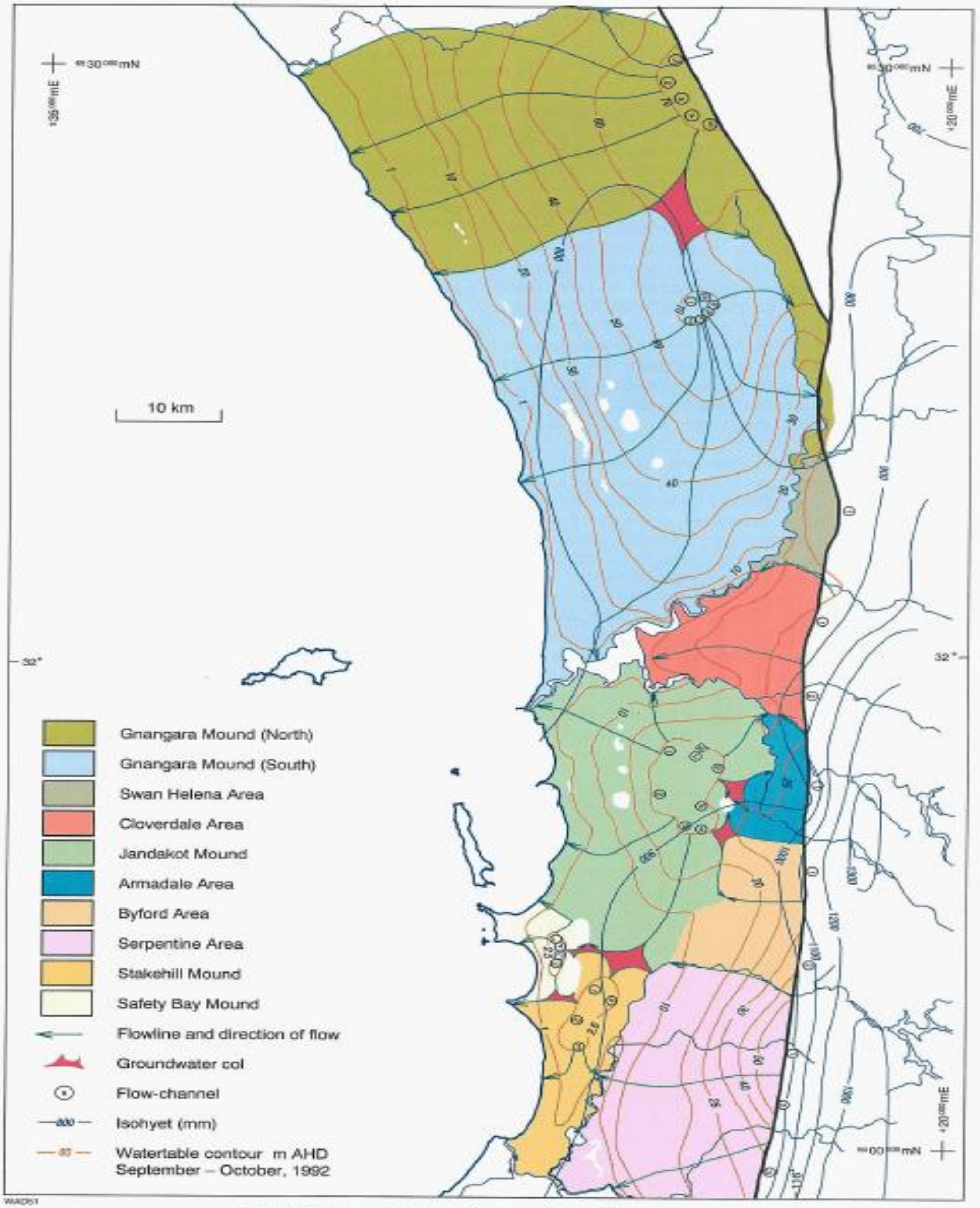

Figure 27. Superficial aquifer groundwater flownet

Figure 7: Superficial Aquifer Groundwater Flownet (Davidson, 1995)

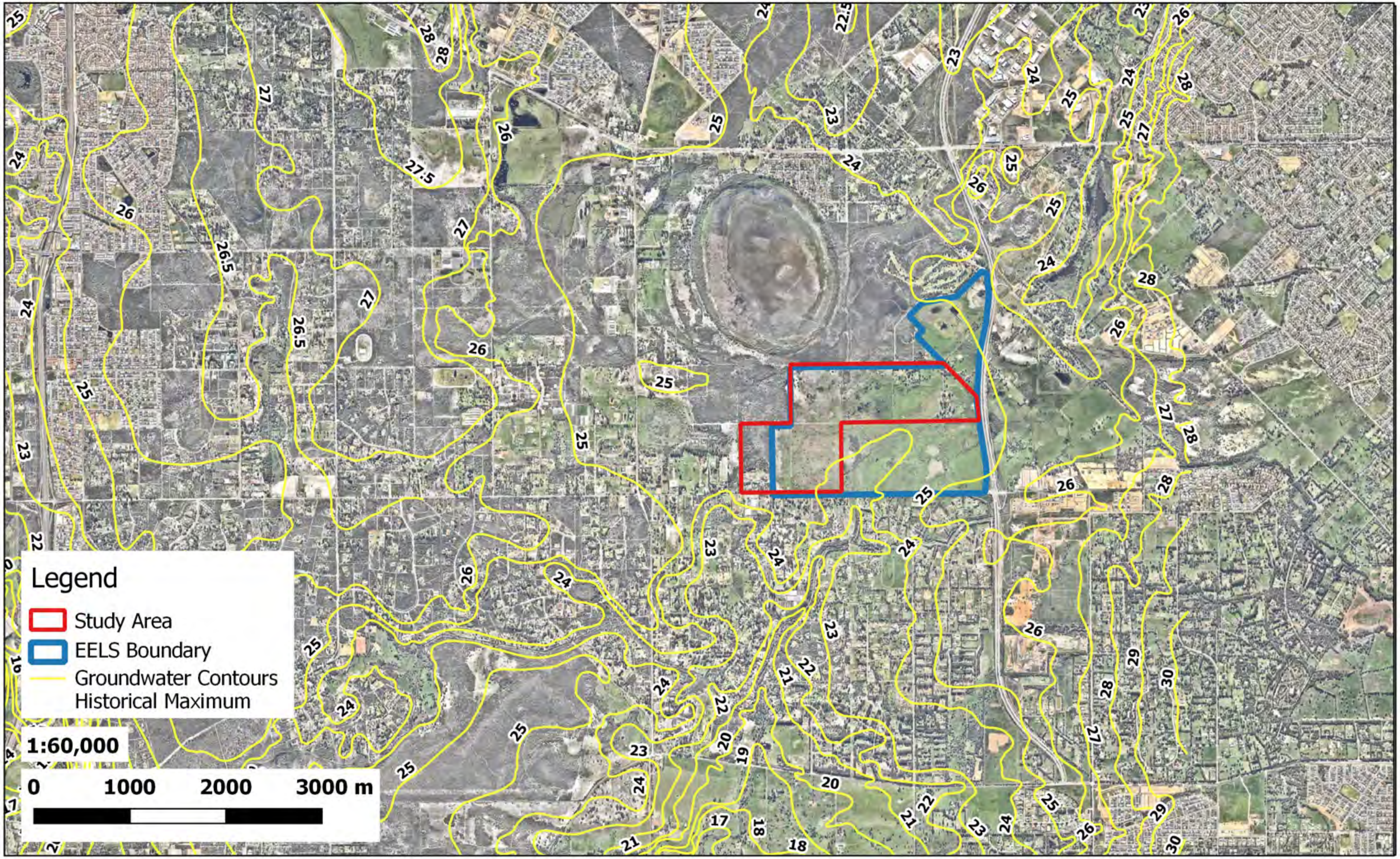

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FIGURE 8: Historical Maximum Groundwater Contours

South Forrestdale Industrial Area

Source: Aerial - Nearmaps (30/09/2016); GW Contours - DoW Perth Groundwater Atlas (2004)

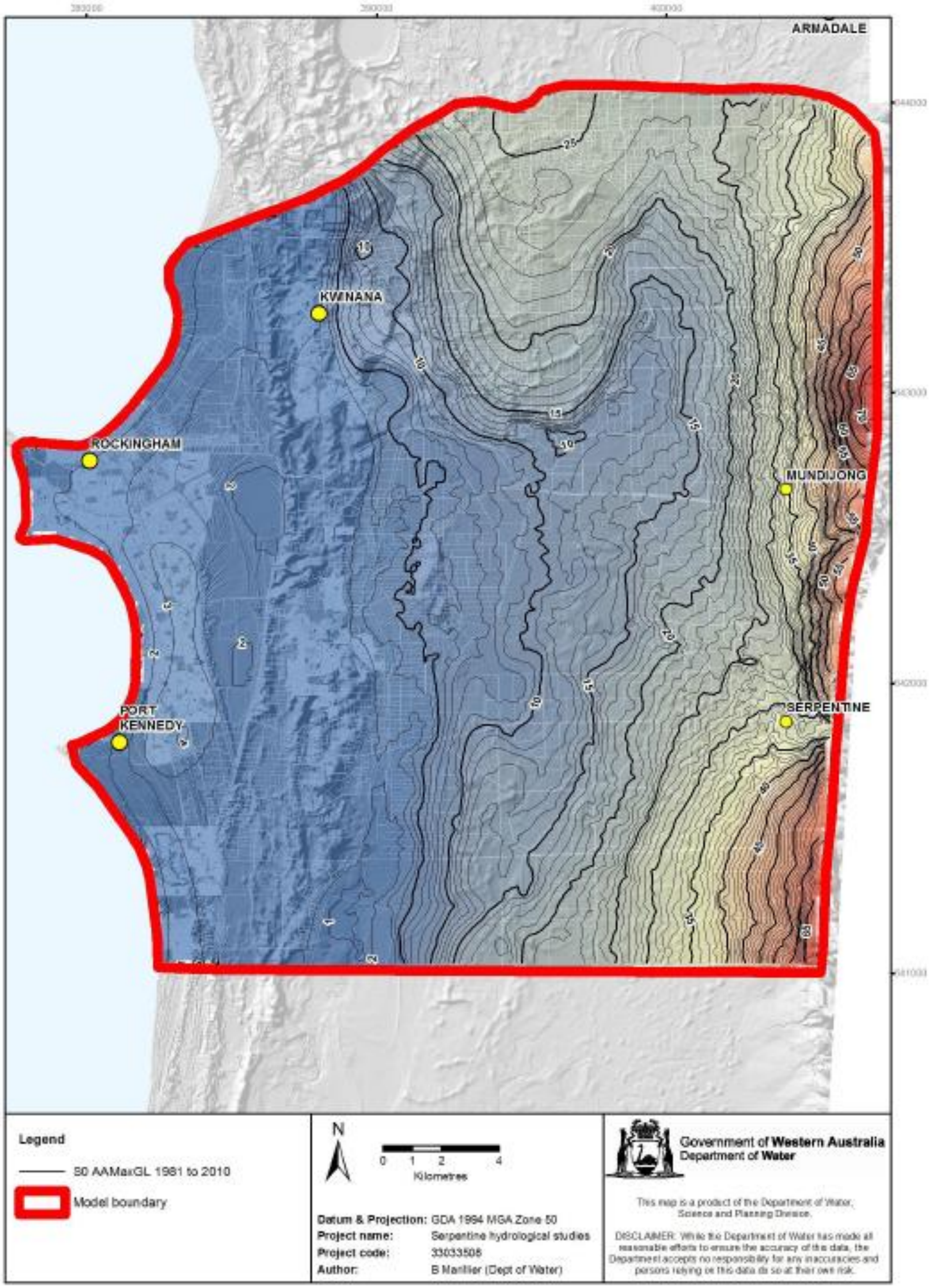

Figure 3-1 AAMaxGL (mAHD) for the base-case (S0) scenario for 1981-2010

Figure 9: AAMGL for Base-Case Scenario 1981-2010 (Marillier, 2015)

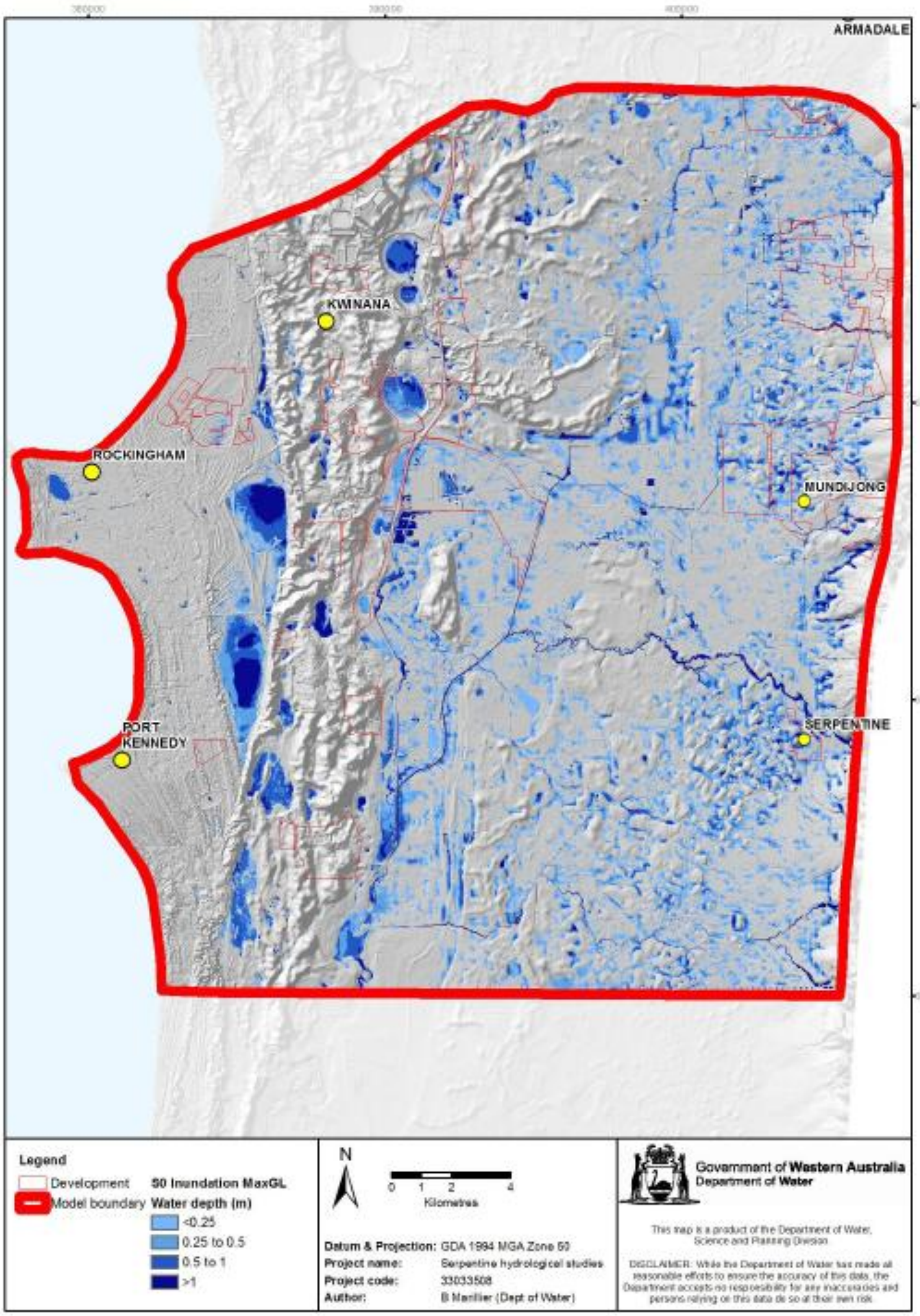

Figure 3-2 Groundwater inundation (m above surface) for the base-case (S0) scenario for 1981-2010, calculated from surface topography and MaxGL surface

Figure 10: Groundwater Inundation for Base-Case Scenario 1981-2010 (Marillier, 2015)

A review of regional groundwater levels was conducted to confirm that the current available data still suggests that the groundwater divide exists. Annual Average Maximum Groundwater Levels (AAMGL) were collected for all nearby DoW monitoring bores. It was assumed that the data obtained was accurate and no further refinement of the data was required (i.e. verification of impacts of nearby pumping or ensuring time periods were the same). Our mapping has excluded Forrestdale Lake as its interaction with groundwater is not fully understood and therefore any surface water levels associated with Forrestdale Lake may skew actual groundwater contouring. Bores utilised are shown in **Table 4**.

It was noted that a similar exercise was completed by Barron et al. (2007) as part of CSIRO work within the Southern River catchment and excluded bores with a potential impact from groundwater extraction. This report was not available and therefore could not be compared to our mapping and was only referred to within Barr et al. (2009). The following bores were used for regional AAMGL mapping:

Table 4: Regional Bores Utilised for AAMGL mapping

WIN Site	Easting	Northing	Time Period	AAMGL
3103	397898	6437450	1975-2015	23.46
3104	397847	6439081	1975-2015	24.52
3115	403197	6436042	1975-2015	25.22
3117	403669	6439093	1976-2015	25.15
4343	398401	6439411	1976-2015	23.04
4674	396886	6440903	1975-2015	25.65
4675	396862	6442071	1975-2015	26.24
4781	398491	6440451	1975-2015	24.51
4782	398352	6442020	1975-2015	24.60
4910	402761	6442759	1975-2004	23.96
12781400	399919	6442341	1996-2015	23.19
23023904*	400945	6440811	2007 -2008	23.35
4676	396909	6443397	1975-2016	25.3318
4678	397523	6444745	1975-2010	26.19324
4783	398114	6444096	1979-2015	25.97243
4785	398736	6445295	1975-2015	25.17037
4879	402225	6445829	1975-2013	21.53041
3083	395320	6437658	1975-2015	23.5285
3086	395292	6439057	1984-2015	25.64181
3209	394609	6440409	1973-1994	24.55855
3210	395209	6442416	1973-1983	25.94644
3212	395209	6442439	1984-2015	26.02969
4575	396059	6440580	1982-2015	25.95985
4586	395200	6443765	1975-2015	26.9778

*DoW Bore used as Max. value due to limited data east of Forrestdale Lake

Figure 11 identifies the regional AAMGL mapping. The mapping clearly shows an interpretation of groundwater flowing east from the Jandakot mound, with additional flow heading west from the edge of the darling scarp coinciding with a groundwater divide in the vicinity of the Study Area. With the major aquifer to the west and the isopotentials grading sharper to the north east, this would suggest that the majority of groundwater flow comes from west and heads in a north east direction, as identified in Bourke (2010) and ERM (2000). AAMGL calculation and bore logs are included in **Appendix D.**

Various mapping identifies this groundwater divide differently. It is likely that the location of this divide changes between seasons as well as annually depending on various localised factors (such as rainfall and evaporation) that determine the actual location of the divide. However, it is apparent that within the vicinity of the Study Area groundwater flows on a regional basis come from several direction and therefore the movement of groundwater is likely to vary within the vicinity of the groundwater divide.

It should be noted that the regional water table in this area is also identified as relatively flat with zones of stagnation north-east and south of the lake. This was suggested by Davidson (1995) and refined by ERM (2000) and Bourke (2010).

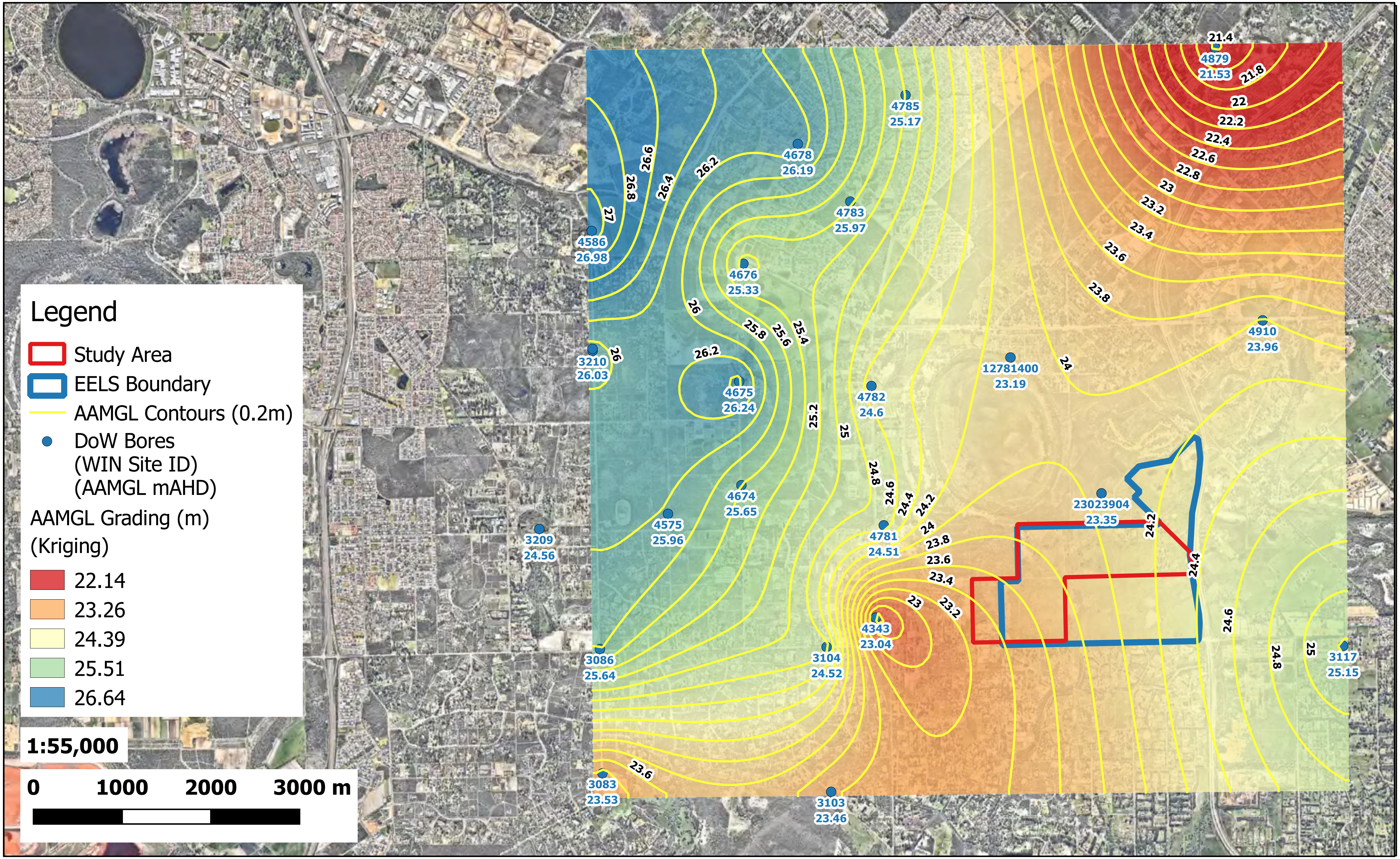

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FIGURE 11: Regional AAMGL Mapping

South Forrestdale Industrial Area

Source: Cadastre - Landgate (21/07/2016); Geology - Geological Survey of Western Australia, Environmenta Series - Armadalel

2.6.2 Local Hydrogeology

Bioscience has been undertaking groundwater investigations across the Study Area since the initial installation of 25 monitoring bores (piezometers) in May 2010 on Lots 6, 8 and 200 Rowley Road. An additional three piezometers were installed in May 2011 in the wetland area on Lot 8 Rowley Road. A further 24 piezometers were installed in 2012 to monitor groundwater across Lot 10 Rowley Road, Lots 9, 7 & 5 Oxley Road (**Figure 12**). Bore logs are included in **Appendix E**.

The number of bores and length of monitoring included within this DWMS is greater than would be expected for a development of this size and at this planning stage. However, as this Study Area was deemed complex in relation to groundwater and hydrogeology, this levels of detail has been provided to verify the regional data available. The work completed thus far would be considered sufficient for a subsequent Local Water Management Strategy, with at least four groundwater peak water levels being obtained. However, due to the regional significance of land adjacent to the Study Area, it is recommended that additional predevelopment monitoring is completed to verify the monitoring already conducted. Additional monitoring should also be developed in such a way that also provides further information in areas where this monitoring regime is lacking.

2.6.2.1 Groundwater Levels

Groundwater levels measured within the South Forrestdale Industrial Estate are included in **Figure 13** (m below ground level, mBGL) and **Figure 14** (m Australian Height Datum, mAHD). Generally, a consistent seasonal cyclical pattern can be seen between all monitoring bores with a change of between 1 and 2m between their peaks and trough. Raw monitoring data is included in **Appendix F**.

Due to the complexity associated with the desktop assessment of the groundwater hydrology, it was decided that no correlation to regional groundwater would be completed at this stage of the investigations. Rather, contour mapping identified within Figure 12 is based on observed onsite data only. To ensure that a consistency in mapping was completed, it was also decided that a single sample event would be mapped, namely 14/10/2013. This sample event represents the peak measured groundwater levels for 2013. It is also the maximum recorded level for many samples sites, as well as being a sample event that intersected the two monitoring programs associated with Lots 6, 8 and 200 Rowley Road (MG Bores) and the Study Area (OX Bores). This therefore had the most number of samples within one sampling event and is most likely to represent groundwater distribution at winter peaks. Interestingly though, as a review of its accuracy a comparison to maximum recorded groundwater levels was completed and found only slight changes to the contouring occurred.

Additional predevelopment monitoring will be conducted to provide a detailed understanding of groundwater hydrology for use in determining the final development layout and requirements. Additional detail is included in Section 5.2.

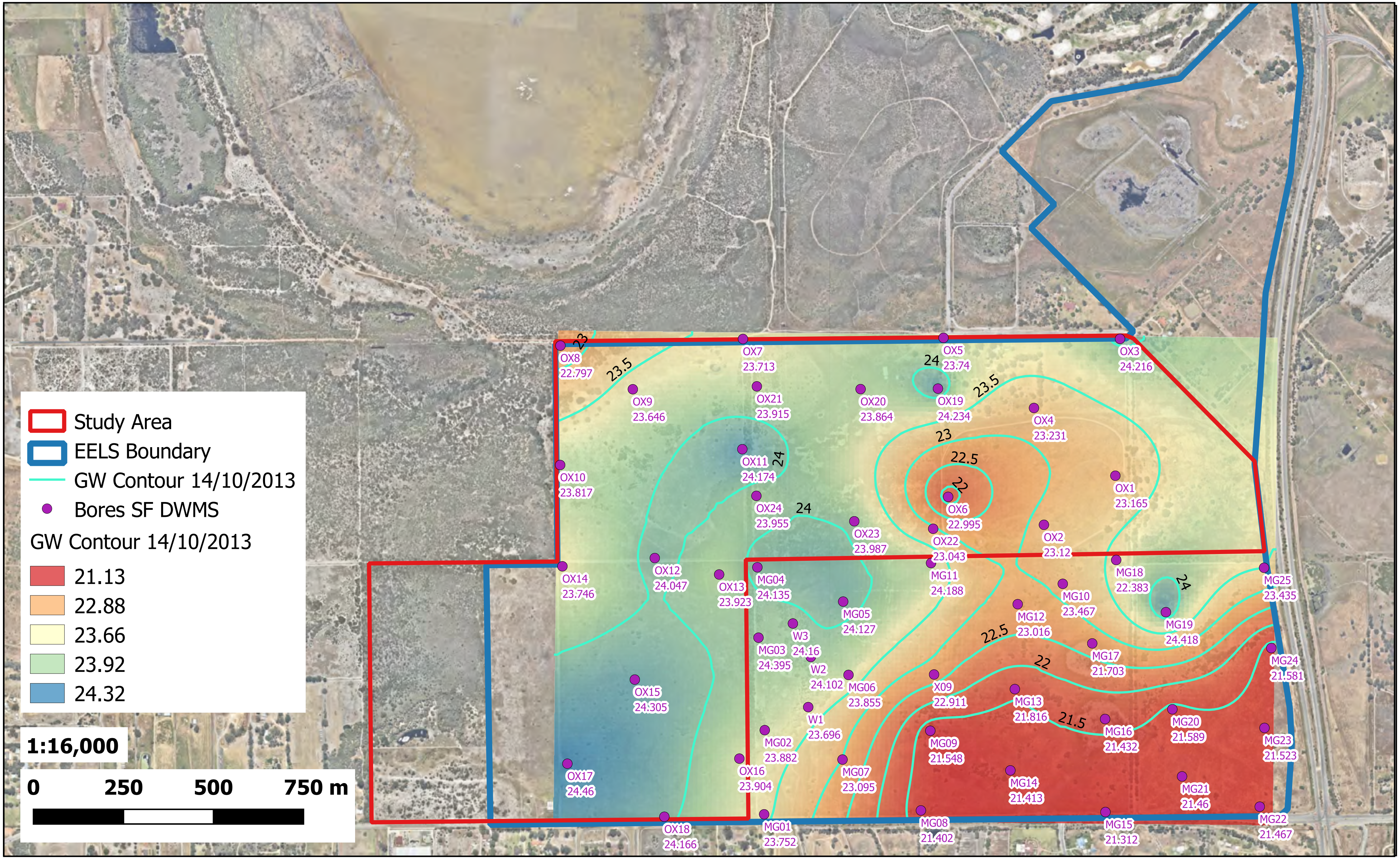

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FIGURE 12: Local GWL (14/10/2013)

South Forrestdale Industrial Area

Source: Aerial - Nearmap (12/10/2016)

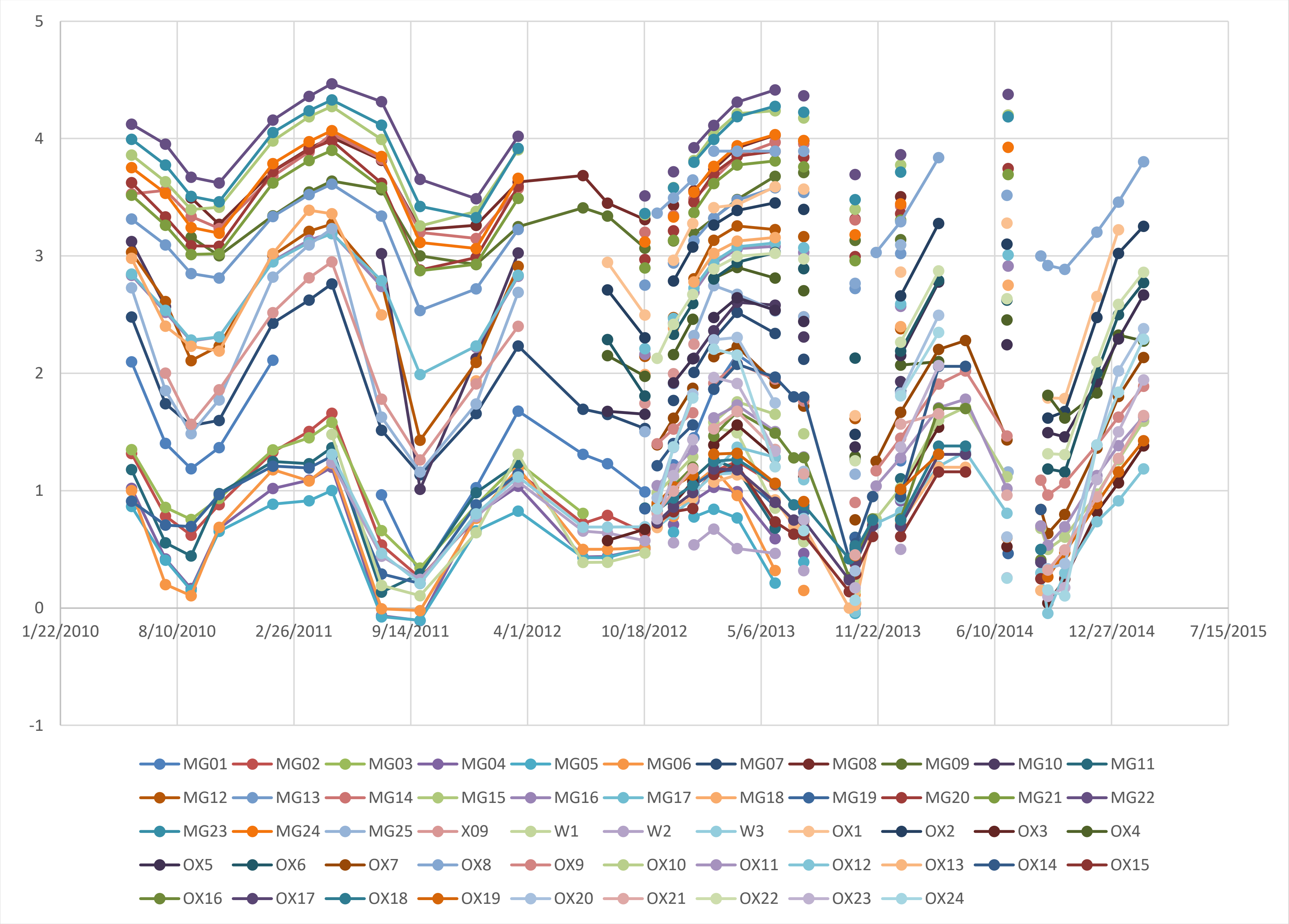


Figure 13: South Forrestdale Industrial Area Groundwater Levels (mBGL)

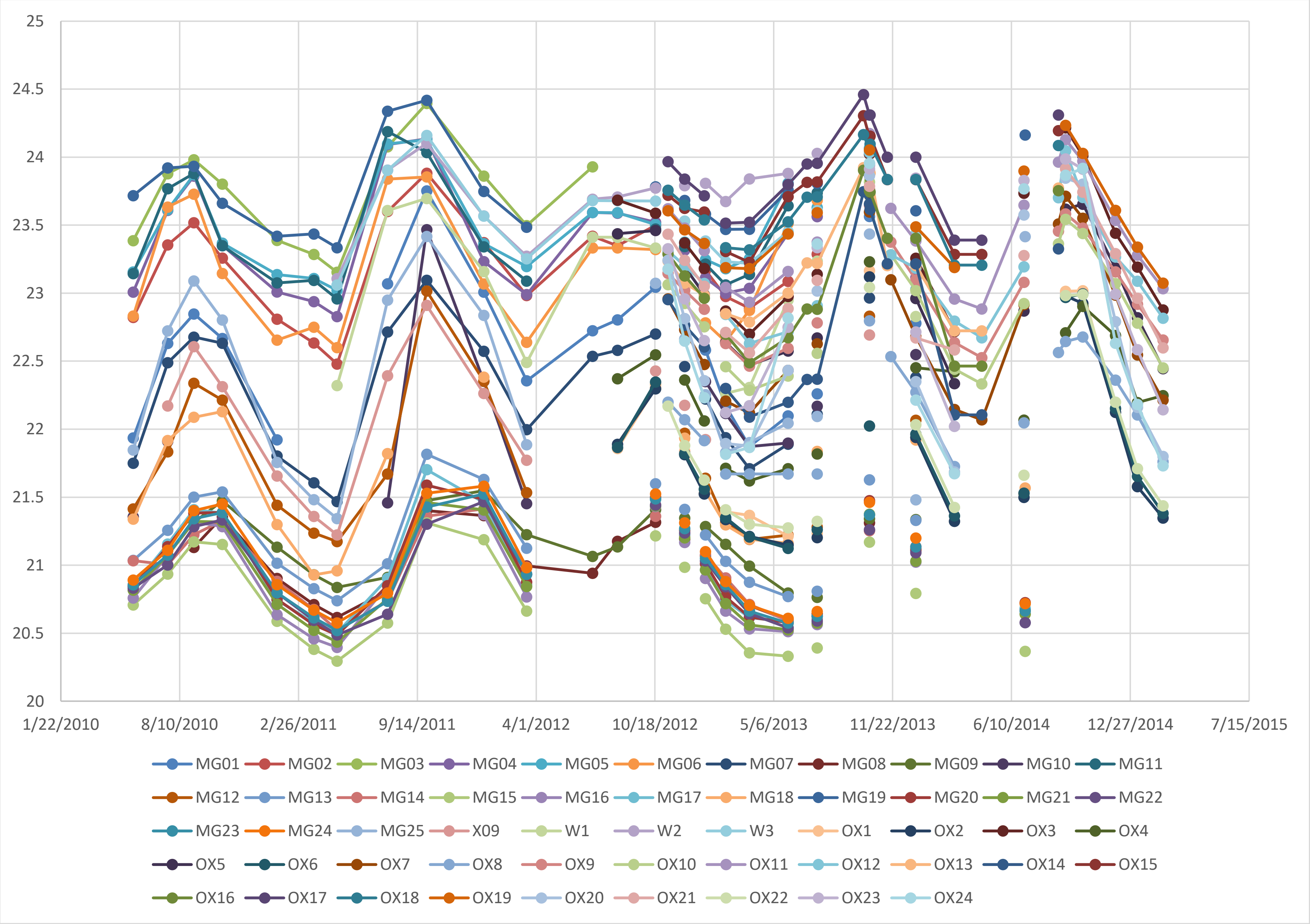


Figure 14: South Forrestdale Industrial Area Groundwater Levels (mAHD)

2.6.2.2 Groundwater Quality

Groundwater quality characteristics are variable across Lot 10 & 12 Rowley Road, Lots 9, 7 & 5 Oxley Road, and Lot 5066 Kargotich Road in regards to pH, salinity and nutrient concentrations. **Table 5** gives a summary of the groundwater quality results. The Guideline Values are referenced from ANZECC ARMCANZ (former Ministerial Councils Australian and New Zealand Environment and Conservation Council & Agriculture and Resources Management Council of Australia and New Zealand), The Department of Health and the Swan River Trust. The Guideline Values are target values for groundwater quality for both short and long term in healthy environments. However, these values can fluctuate due to naturally occurring factors.

Table 5: Groundwater Monitoring Quality Results

Quality Parameter	Guideline Values (Guideline Reference)	Mean	Max	Min	No. Samples
Electrical Conductivity ($mS.cm^{-1}$)	0.3 - 1.5 (2)	4.52	59.2	0.10	173
pH	6.5-8.5 (1) 6.0-8.5 (3)	5.82	7.69	3.59	176
Total P (mg/L)	0.2mg/L (1) 0.1mg/L (6)	0.86	12.12	<0.01	113
PO_4-P	0.03 (2)	0.93	12.36	<0.01	162
Total N (mg/L)	2.0mg/L (1) 1.0mg/L (6)	0.92	7.70	<0.01	114
NH4-N (mg/L)	0.04mg/L (2)	0.53	4.12	<0.01	111
NO3-N (mg/L)	0.1mg/L (2)	0.36	6.8	<0.01	122
Fe (mg/L)	0.3mg/L (1) 0.2mg/L (3) 3mg/L (5) 10mg/L (4)	2.11	23.38	0.004	123
SO4 (mg/L)	5000mg/L (5)	330.26	4384.70	0.20	147
Cl (mg/L)	2500mg/L (5)	2.28	24.55	<0.001	136

ANZECC ARMCANZ (2000)	1. Fresh water ecosystems 2. Wetlands 3. Long term irrigation 4. Short term irrigation
Department of Health (2006)	5. Domestic non potable groundwater use
Swan River Trust	6. Swan canning clean up targets

Groundwater pH varied from neutral to very acidic with ranges from 3.59 to 7.69. The pH tends to fluctuate seasonally and with groundwater levels. pH affects the amount of nutrients that are soluble in soil water i.e. nutrients for plant growth. Many wetlands have near-neutral pH (approximately 7), but considerable variation occurs naturally and in annual cycles. Rainwater is naturally slightly acidic (as low as pH 5.5), due to dissolved atmospheric carbon dioxide, but the pH may be rapidly modified by chemical and biological processes once the water enters the wetland (e.g. carbonate buffering, photosynthesis) (DEC, 2013). In wetlands with little biological activity and few reactive minerals, the pH may remain mildly acidic.

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

Salinity, or electrical conductivity (EC) ranged from fresh to saline, with the highest recorded EC being 59.2mS.cm^{-1} and the lowest 0.1mS.cm^{-1}. These bores are typically in clayey soils in low lying areas where water seasonally inundates the surface. EC values estimate soluble salt content and can be elevated by fertiliser use. The availability and concentration of salt in a wetland helps to shape its ecological character (DEC, 2013). The type and concentration of salts in a wetland has a very strong bearing on the wetland, and particularly on the life forms which will inhabit it. Wetland species are adapted to particular ranges and types of salts in their environment. Rapid changes to EC can cause a decline in health or species mortality. Areas experiencing wetting and drying, especially in clay lined subsoil depressions, through evaporation will see an increased concentration of salts in the soil. This is a natural process but should be monitored. Excessive drying by future drainage shall be avoided.

Nutrients in groundwater are substances that provide nourishment for the promotion of life. Generally, in regards to wetlands, the two main nutrients of interest are phosphorus and nitrogen. These nutrients influence the type and abundance of living things contained within the Study Area. Nutrients are carried into the Study Area by water movements i.e. surface and groundwater flows. Concentrations of dissolved nutrients are elevated by uptake from soils and rocks which is influenced by water volumes leading to requirement for a treatment train approach in water management. Nutrient export is regulated by structural control systems to reduce discharge flow rates and water level fluctuations.

Total phosphorus (TP) values range from 0 – 12.12mg/L (W2). High phosphorus levels can be indications of past human or animal activity i.e. surface water runoff from developed areas, application of fertilisers and animal grazing.

Total Nitrogen (TN) values range from 0 – 7.7 mg/L (OX3). TN values are mostly low and fall below the fresh water ecosystems target of 2.0mg/L. Although nitrogen occurs naturally in plants, levels can become elevated if plants are affected by drought before decomposing and leaching with runoff. Often higher levels are expected with application of fertilisers (ammonia based) and animal grazing.

High variability was observed between sample locations based on the limited datasets currently obtained. **Table 6** provides the average concentrations for each sample location and major analyte. All results are included within **Appendix F**. The following locations observed high concentrations at a specific sample location:

EC (mS/cm): OX6, OX22, OX23, OX24, MG12
SO4 (mg/L): OX6, OX22, OX23, OX24
TN (mg/L): OX3, OX17, MG05, W2, W3
NO3 (mg/L): MG03, MG04, MG10, MG18
NH4 (mg/L): OX15, OX17, MG01, MG19, W2, W3
TP (mg/L): OX5, MG02, MG05, W2, W3
FRP (mg/L): OX5, MG02, MG03, W2
Fe (mg/L): OX4, MG11, MG19, W2
Cl (mg/L): OX6, OX24

Table 6: Average Groundwater Concentrations South Forrestdale Industrial

	pH	EC (mS/cm)	SO4 (mg/L)	TN (mg/L)	NO3 (mg/L)	NH4 (mg/L)	TP (mg/L)	FRP (mg/L)	Fe (mg/L)	Cl (µg/L)
OX1	7.07	1.05	32.43	0.18	0.04	0.00	0.22	0.27	0.04	71.11
OX2	7.38	1.54	101.21	0.16	0.00	0.04	0.08	0.13	0.18	232.66
OX3	6.42	1.10	56.83	2.05	0.58	0.15	0.56	0.83	6.40	97.32
OX4	6.31	5.33	73.16	0.54	0.47	0.17	1.64	2.03	17.00	61.09
OX5	4.80	2.14	76.40	1.23	0.01	0.98	4.47	4.99	0.52	249.78
OX6	6.58	21.75	1905.88	0.04	0.00	0.03	0.15	0.10	0.17	8727.19
OX7	5.92	1.14	24.61	1.26	0.01	0.95	1.06	0.86	7.15	279.67
OX8	3.92	0.15	43.10	0.53	0.14	0.07	0.49	0.49	1.03	3.00
OX9	4.27	0.12	13.30	0.53	0.01	0.38	0.23	0.42	0.23	15.48
OX10	5.77	0.17	10.08	0.76	0.14	0.36	0.08	0.05	0.30	20.15
OX11	4.21	0.23	16.59	0.90	0.06	0.60	0.20	0.51	0.55	29.02
OX12	5.60	0.23	12.49	1.42	0.06	0.67	0.05	0.08	1.44	24.00
OX13	5.93	0.52	5.44	0.81	0.08	0.39	0.01	0.12	0.99	8.75
OX14	4.56	0.33	46.29	1.05	0.00	0.79	0.54	0.92	0.59	1.16
OX15	4.32	0.51	63.22	1.78	0.32	1.30	1.30	1.74	0.31	19.73
OX16	4.82	0.25	18.73	0.78	0.03	0.35	0.41	0.69	1.45	20.98
OX17	4.60	0.70	44.43	2.27	0.00	1.71	1.41	1.63	1.29	85.85
OX18	4.81	0.26	19.33	1.00	0.01	0.36	0.13	0.29	0.22	31.77
OX19	4.59	0.38	17.57	0.81	0.00	0.21	0.33	0.54	0.31	60.00
OX20	6.50	10.75	455.86	0.74	0.00	0.38	0.04	0.01	0.21	4669.63
OX21	4.24	0.29	41.08	0.75	0.00	0.23	0.24	0.44	1.64	1328.80
OX22	6.12	16.52	1068.64	0.15	0.02	0.02	0.03	0.01	1.64	5194.60
OX23	6.95	19.10	898.17	0.44	0.01	0.39	0.12	0.01	0.10	7306.42
OX24	6.90	36.83	2582.95	0.54	0.16	0.14	0.04	0.01	0.42	20922.32
MG01	4.60	0.18	12.19	0.62	0.66	1.03	0.91	1.77	0.78	45.75
MG02	4.14	0.24	8.795	1.33	1.11	0.81	2.16	4.55	4.72	624.19
MG03	4.90	0.17	0.01		5.20	0.20		3.35		
MG04	6.77	6.55	359.6	0.84	2.44	0.16	0.13	1.78	1.17	1928.60
MG05	6.17	0.75	70.455	2.06	0.48	1.04	3.57	2.67	5.28	120.27
MG06	6.55	2.44	51.355	0.32	0.07	0.01	0.26	0.12	2.33	647.95
MG07	6.55	3.74	302.54	0.15	0.24	0.07	0.28	0.06	0.13	920.70
MG08										
MG09										
MG10	7.37	1.88	180.61	0.01	1.88	0.01	0.80	0.66	1.55	192.89
MG11	6.58	0.66	9		0.00	0.04		0.41	15.29	10.00
MG12	6.41	17.48	206		0.34	0.60		0.17	0.17	6746.00
MG13	6.58	2.80	176.865	0.01	0.01	0.11	0.02	0.01	5.87	757.97
MG14	6.48	2.14	261.855	0.16	0.01	0.01	0.33	0.19	1.09	326.44
MG15	6.30	1.35	125.2866667	0.02	0.02	0.01	0.07	0.05	6.65	136.14
MG16	6.56	3.76	306.8733333	0.25	0.01	0.41	0.01	0.02	2.03	801.75
MG17	6.83	4.62	199.3	0.01	0.02	0.10	0.01	0.03	4.16	1577.77
MG18	6.19	7.28	373.115	0.16	0.01	0.30	0.05	0.01	1.92	3575.96
MG19	6.51	1.06	0.01		6.20	1.17		2.91	11.27	
MG20	6.67	2.37	87		0.01	0.01		0.01	0.09	
MG21	6.93	3.05	220		0.01	0.01		0.01	0.11	
MG22	6.53	2.31	232		0.04	0.06		0.06	0.16	
MG23	6.41	2.97	103		0.00	0.02		0.03	0.09	
MG24	4.53	10.50	232		0.01	0.67		0.03	2.09	
MG25	6.58	0.70	52		0.02	0.14		0.17	7.17	
W1										
W2	4.15	1.01	105.05	3.66	0.53	3.13	11.82	12.24	10.28	210.95
W3	4.46	0.58	30.42	2.11	0.01	2.07	2.80	2.78	0.63	251.26

2.7 Hydrology

The Study Area is situated on the boundary of the Peel-Harvey catchment and Swan River catchment management areas, two major regional catchment divides (**Figure 15**). These catchment divides are not clearly defined due to the reasonable flat landscape and topography in the Study Area. Catchment delineation techniques were used to accurately delineate the sub catchments within Hall, 2015; however, this main catchment divide may have been delineated earlier as it is noted to be in a similar location within DoW's Inland Waters – Hydrographic Catchments datasets (last updated November 2008).

Surface water generally flows to one of three discharge points from the Study Area (**Figure 15**):

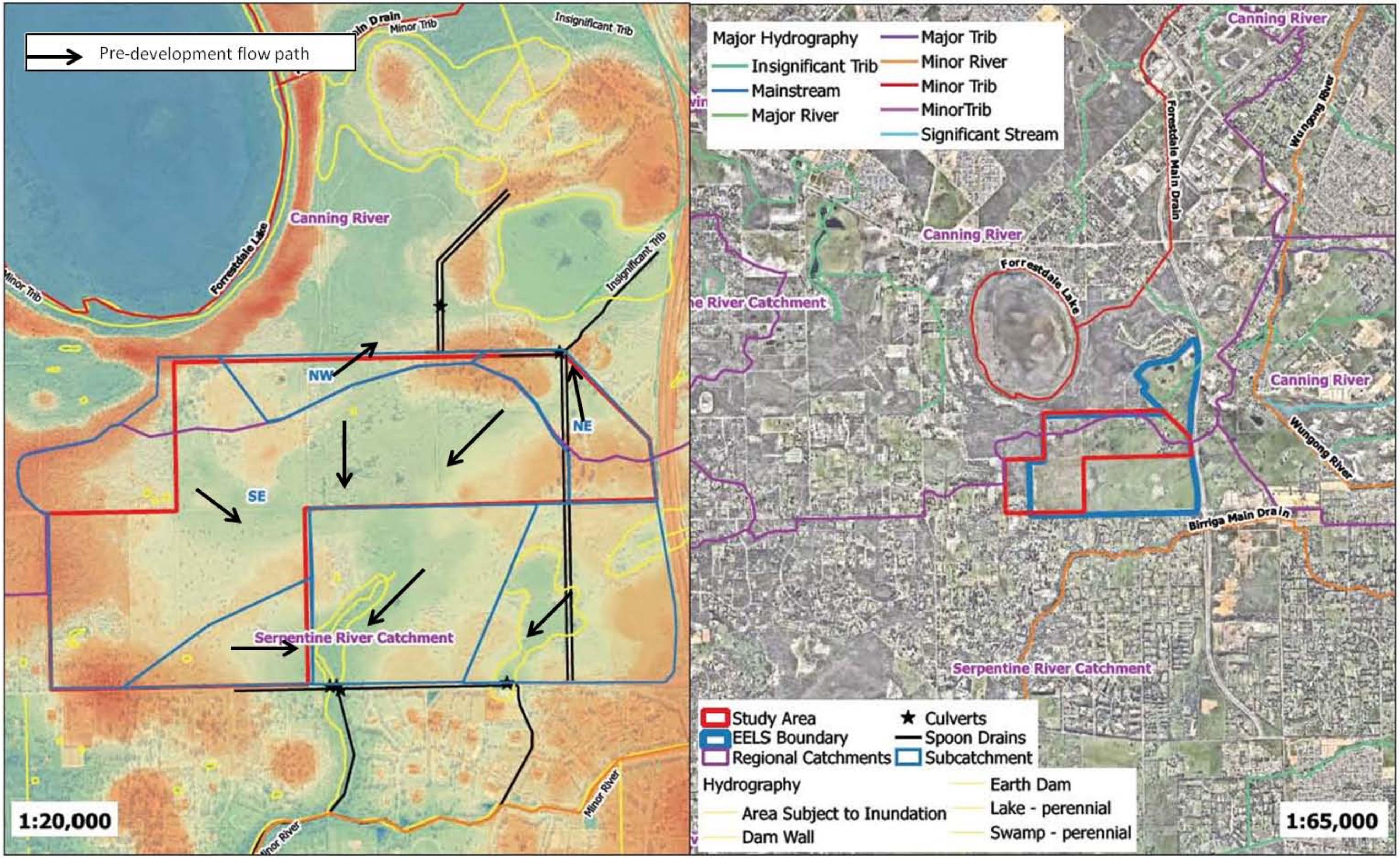
- South east (SE) across Lot 8 Rowley Road culverts and into the Birriga Main Drain
- South west (SW) heads easterly to Lot 8 Rowley Road culverts and into the Birriga Main Drain
- North west (NW) to Stirling Road spoon drain via sheet flow
- North east (NE) to Resource Enhancement Wetland (7537) through a series of open channel drains and culverts under Oxley Road

The majority of the Study Area (sub catchments SE and SW) heads south towards seven Ø500mm culverts under Rowley Road south of Lot 8. Lot 5066 Kargotich Road has a single Ø900mm culvert under Rowley Road. Lot 5066 suffers inundation as a direct result of the poor hydraulic design and maintenance of open channel drains within the Study Area. Water from SE and SW sub catchments is directed to Water Corporation's Birriga Drain, a major tributary to the Serpentine River and Peel-Harvey catchment. Flows south from the Study Area have been investigated in the Birriga and Oaklands Flood Modelling and Drainage Study (Hall, 2015)

The area in the north is split into two small catchments. The northwest sub catchment drains via sheet flow into City of Armadale spoon drains along Stirling Road heading in a northerly direction towards Forrestdale Townsite. Due to the unmade road, the relatively flat topography and the spoon drain not being formed until the corner of Oxley Road and Stirling Road, it is likely that some sheet flow within sub catchment NW will head into Bush Forever Site 345. The northeast sub catchment heads towards Oxley Road and Kargotich Road spoon drains before heading towards REW 7537.

The connection of the spoon drains between Oxley Road and Stirling Road is currently poorly defined. It is likely that upgrading some of this infrastructure as part of the proposed development will be required. Further investigations into the open drains should be completed as part of structure planning work, with subsequent results included in the Local Water Management Strategy. Consultation with the CoA, DoW, and DPaW would be required to ensure that no impact to the surrounding environment occurs with any changes to the hydrology. The open drain network is also shown on **Figure 15**.

Currently no monitoring (flows or quality) has been completed for surface water locations leaving the South Forrestdale Industrial Area. It is proposed that predevelopment monitoring is conducted, with preliminary results included within a subsequent Local Water Management Strategy (LWMS) and Urban Water Management Plans (UWMP's). This is explained further in Section 5.2.



Bioscience
Integrating Resource Management

Project Title: South Forrestdale Industrial DWMS
Client:
Date: 03/10/2016
Drawn: TL
Checked:
Revision: A

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FIGURE 15: Hydrology

South Forrestdale Industrial Area

Source: Hydrographic Subcatchments - (DoW, 03/11/2008); Minor Hydrography (DoW, 29/10/2008); Major Hydrography - Rivers (DoW, 29/10/2008); Aerial (Nearmap, 14/09/2014); LiDAR (DoW, 17/05/2010)

2.7.1 Birriga and Oaklands Flood Study

The Lower Serpentine Drainage Area has come under pressure from urban development in recent years. As such the DoW are in the process of completing a Drainage and Water Management Plan (DWMP) for the Birriga and Oaklands Drain sub catchments. The majority of the Study Area falls within the Birriga Drain sub catchment and therefore is part of this area.

As part of this work the DoW completed a Water Science Technical Series Flood Modelling and Drainage Study (WST 71; Hall, 2015). A MIKE SHE fully integrated surface water-groundwater model was conducted on a 20m grid within the Birriga and Oaklands Drains catchments to determine the critical flow rates and associated storage within the catchment. Hall, 2015 notes that:

> *"Birriga Model is a regional model with a spatial resolution of 20m. Model results interpreted at smaller scales (i.e. subdivision or lot scales) will have some inherent structural limitations that users need to be aware of. These include:*
>
> - *Grid resampling issues: These can result in underestimating road elevations, generally in the order of 0.1–0.3m, and can cause water to overtop roads at modelled elevations lower than what would actually occur. Some major roads were 'stamped' into the grid – that is, the grid was manually modified to reflect the actual level of the road's centreline to avoid this issue though many minor roads within the modelling domain were not modified. Grid resampling can also remove small-scale flow paths. This is generally not a major issue in large flood events (as the small-scale flow paths are generally inundated) but it can result in overestimating floodplain storage, and underestimating the flood recession.*
> - *Road culverts were not explicitly modelled in many locations. This can cause an overestimated flood extent upstream of some roads in some parts of the model. To partially overcome this issue, major bridges and culverts in the Birriga and Oaklands drains were modelled explicitly, and where there were significant culverts or bridges on roads outside the Birriga and Oaklands drain's the DEM was generally modified to allow the transfer of water from one side of a road to another (however, in these cases, conveyances may be over predicted due to the 20m grid). In the Birriga catchment, many of the small culverts (< 400 mm) are blocked, and it is likely that many more will block in a flood event. It is impossible to know which will remain free-flowing during a large flood event. The assumption inherent in the modelling process is that all minor road culverts block at the start of the flood event (a common assumption in many 2-D modelling projects)." and*
>
> *"The floodplain mapping is suitable to be viewed at a scale of 1:5000. If a higher resolution is required, a more detailed flood study is recommended. As a result of the structural limitations of the Birriga flood model, the results are likely to be unsuitable for calculating:*
>
> - *detailed flood extent, depth and storage at a lot scale*
> - *detailed flows through roads (culverts) at a lot scale.*
>
> *If lot-scale results are required by development proponents or other stakeholders, it is recommended that the Birriga model be used to assist finer grid-scale modelling where development is planned."*

Hall, 2015 also noted that additional limitations to development may apply:

> *"It is recommended that any development or drainage design on the western side of the Oaklands Main Drain within the study area considers the following:*
>
> - *The potential for failure of the levee banks on the Birriga and Serpentine Main Drains: This study indicates that levee overtopping is possible in large (>50 year ARI events), and with areas of levee failure possible before overtopping (the levee banks are not maintained and so are in poor condition in many locations). Therefore, all developments west of Oaklands Main Drain or adjacent to the Birriga Main Drain downstream of Orton Road should be considered at risk of levee failure during large flood events.*
> - *The capacity of Birriga and Oaklands Main Drains to convey drainage water without influencing downstream landholders: The regular breaks and lateral culverts in the drains mean that additional discharge to the drain upstream could result in increased downstream flooding.*
> - *The importance of floodplain storage: The Birriga and Oaklands catchments contain large areas of floodplain storage which help mitigate peak flood flows and total flood volumes. Consideration of the floodplain storage should be taken into account in the development process – as reducing or eliminating these storage areas will probably result in additional discharge to the main drains, which in turn could result in more extensive downstream flooding or levee bank overtopping.*
>
> *Although none of these considerations prohibit development within the study area, they may require that more land is set aside for storage and retention of flood water compared with areas with more capacity for infiltration, less floodplain storage or steeper hydraulic gradients."*

Figure 16 identifies the detailed 100 year ARI flood plain mapping (1% AEP) and ponded areas derived from the MIKE SHE model (taken from Hall, 2015; Figure 7-1). As alluded to above, more detailed modelling may refine the results and it is likely to reduce the flood storage requirement. Any future work relating to this, if completed, should be completed during structure planning stage to identify the final flood storage requirement pre and post development.

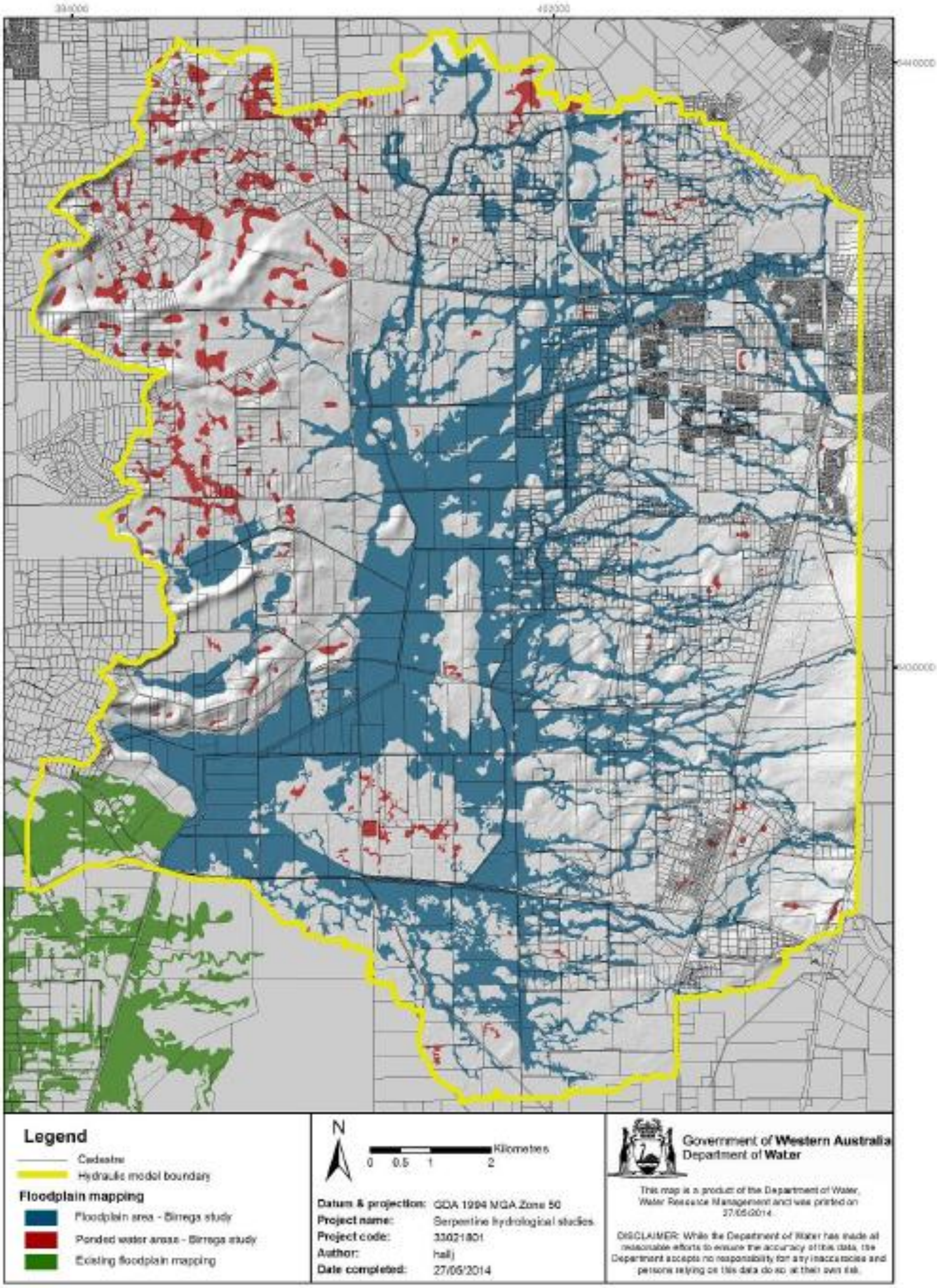
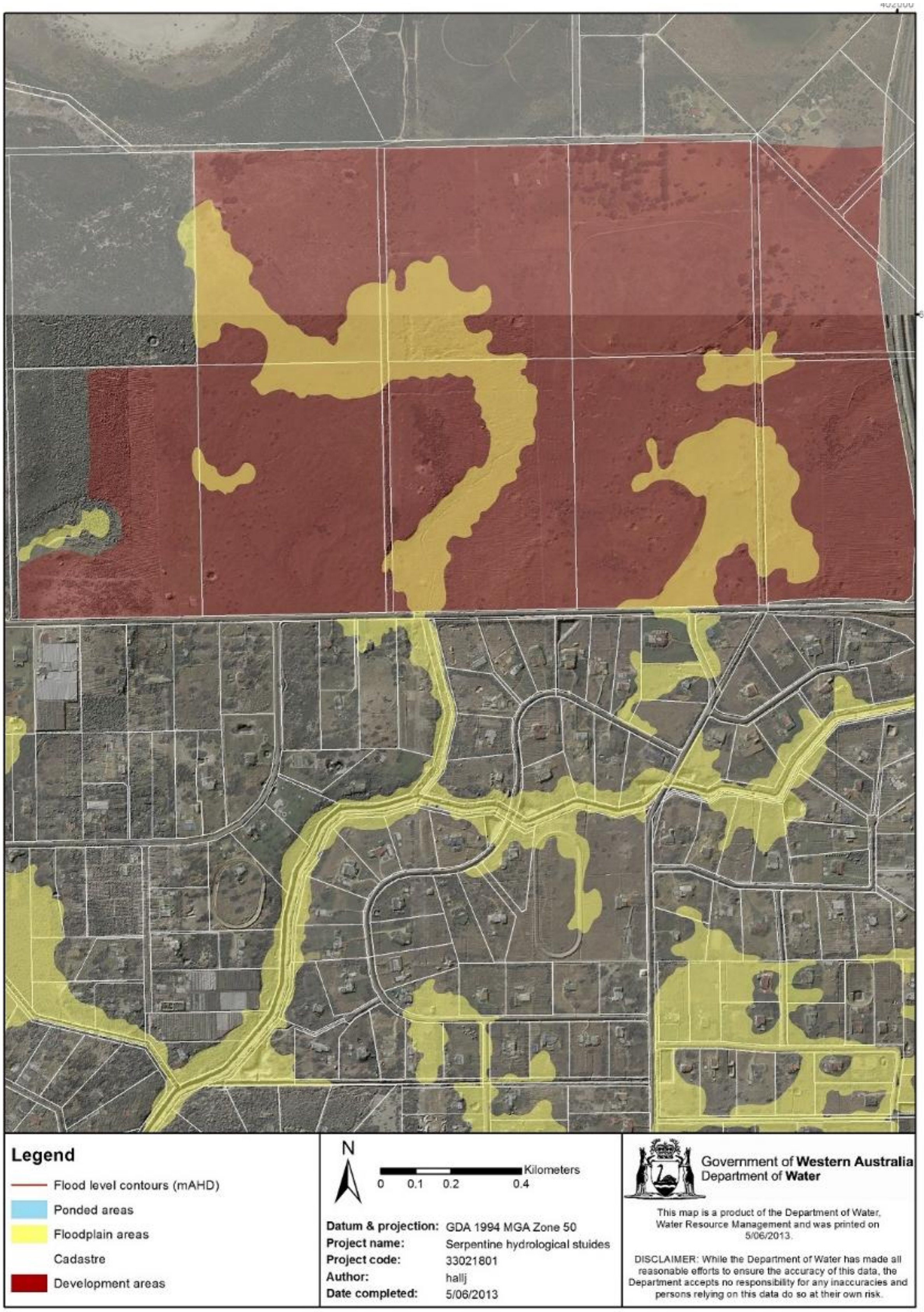


Figure 16: 100 year ARI Floodplain Mapping

Bioscience have been in communication with Joel Hall, DoW, with respects to his model and outputs relating to flood storage for South Forrestdale Industrial Area. Correspondence is provided in **Appendix G**, with the following design constraints being provided:

- The 1% AEP peak maximum flow rate must be maintained. The peak flow rate is identified as 2.85m^3/s through the culverts discharging at Rowley Road (at the main drainage line that drains to Birriga Drain). This allowable outflow is for the entire South Forrestdale Industrial Area that is within the Birriga catchment and not just the Study Area.
- The pre-development floodplain storage must be preserved. Predevelopment floodplain storage for catchments SE and SW is 59ML. This is for an area of 190ha and equates to 310KL/ha. The total flood storage requirement for the South Forrestdale Industrial Area would need to be clarified further.
- Additional storage (additional to pre-development floodplain storage) for post development 100yr flows above the pre-development flows (from the introduction of hard surfaces to the landscape) will be required; and peak flow rates at downstream end of the development are not increased post-development.
- Road reserves and drainage reserves throughout the catchment can be included in the post-development 1% AEP flood storage. Consultant will do this modelling, however DoW will provide inflow and outflow hydrographs for the model as well as pre-development storage estimates (consultants do have the option to refine the pre-development storage estimates, however this will need to be accepted by DoW and supported by transparent modelling and calculations).
- The management of small events (the first 15mm of rainfall) must be stored 'at source' within the development, and will count towards the total storage requirement in the development area.

DoW have provided a more detailed map showing flood detention which has determined the flood storage requirements, **Figure 17**.



Datum & projection: GDA 1994 MGA Zone 50
Project name: Serpentine hydrological stuides
Project code: 33021801
Author: hallj
Date completed: 5/06/2013

This map is a product of the Department of Water, Water Resource Management and was printed on 5/06/2013.

DISCLAIMER: While the Department of Water has made all reasonable efforts to ensure the accuracy of this data, the Department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Figure 17: Local Floodplain Mapping (DoW)

2.7.2 Surface Water Modelling

A computer model was produced by Bioscience using the XP SWMM software package to calculate runoff rates for a range of ARI events between 10 minutes and 72 hours. XPSWMM is a comprehensive package for dynamic modelling of stormwater by developing link-node (1D) and spatially distributed hydraulic models (2D) for analysis and design for water resource management.

The XP model setup utilises LiDAR topographical data to create a digital terrain map (DTM). The drainage network (links and node) details are input manually to represent the real world drainage network observed onsite. Topography divides for the Study Area were divided into runoff sub-catchments with each being designated a landuse runoff coefficient in accordance with advice from the DoW extracted from the MIKE SHE fully integrated model. The equivalent runoff coefficient used for the Study Area in the MIKE SHE model conservatively assume a saturated site (no initial losses) with clay based soil profiles; approximating to a 67% predevelopment runoff.

A 335ha area was modelled to establish the interaction between the site and regional catchment. The model includes existing storage capacity within land drains and culverts. Four discharge nodes were built into the model (**Figure 18**) with a total of 209ha contributing catchments.

The XP model was used to simulate flow dynamics for 1, 10 year ARI and 1% AEP events between 10 minutes and 72 hours to assess the critical storm event. A summary of results is shown in **Table 7** and **Figure 18**.
Total stored in flood plain storage is 55,900m³ for the 1% AEP Storm event.

The volumes in **Table 7** define the predevelopment runoff to discharge points and the flood plain storage. Total stored in the 1% AEP (i.e. equivalent to the 100 yr ARI event) flood plain storage is 55,900m³ and shall be maintained post development. As stated earlier, this will require refinement at future structure planning stages, with the model being provided to DoW to identify the agreed final predevelopment flood storage requirements.

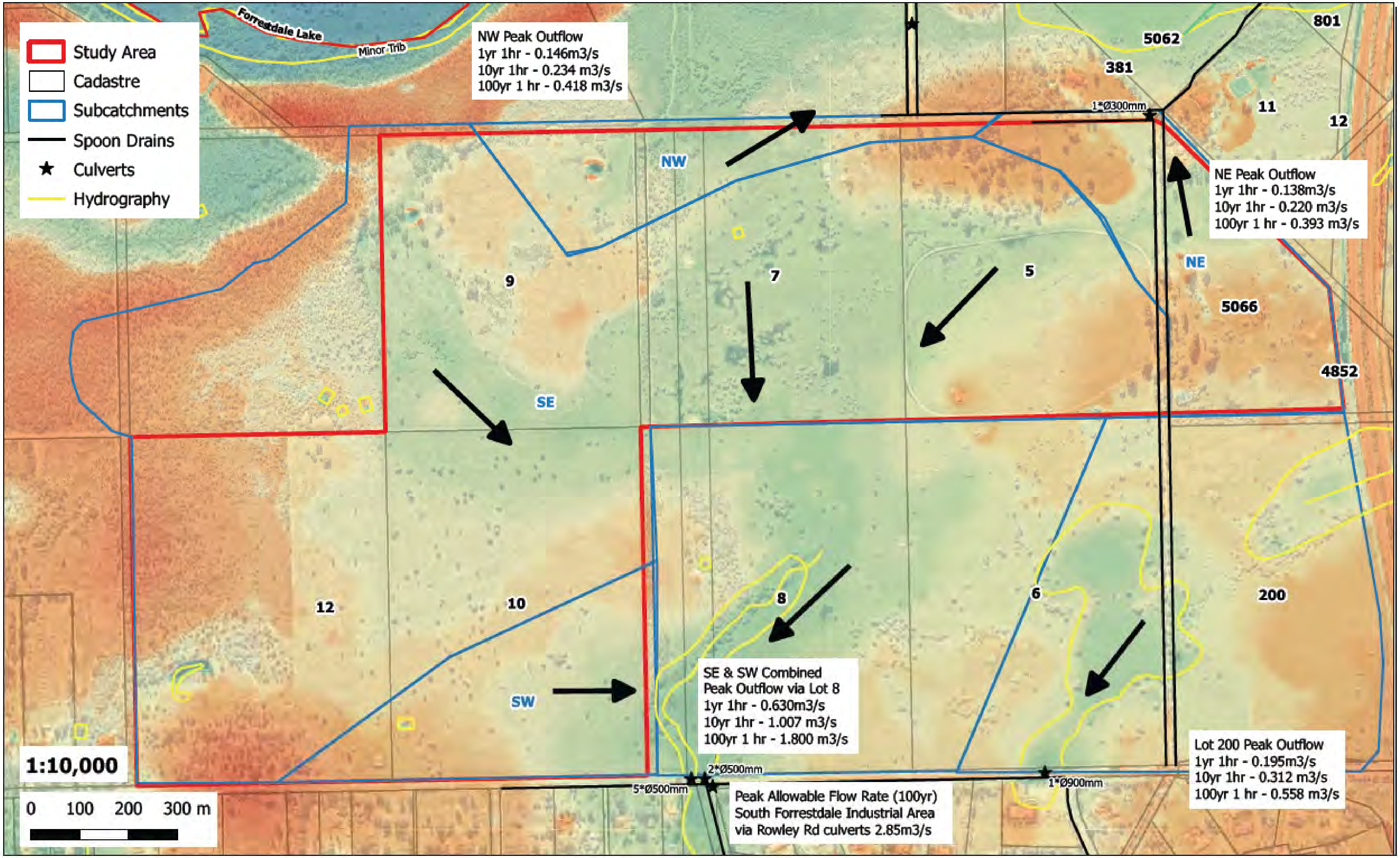
DoW’s MIKE SHE modelling indicates that the allowable discharge rate from the Study Area into the Birriga Main Drain in the 1% AEP event is 2.85m³/s. Of this, it has been determined that the combined SE and SW catchments within the Study Area produce 1.8m^3/s of this peak flow. Discharge from NE and NW was modelled to be 0.393 and 0.418m^3/s respectively.

The results of the XP SWMM model are similar to that from DoW’s MIKE SHE model. These results should be considered preliminary and further investigations/modelling should be conducted with refined information at subsequent planning stages. A suitable 2D model that can accurately determine flood storage within the Study Area should be completed to the satisfaction of DoW.

Table 7: XP STORM Predevelopment Results (190 ha Study Area and Contributing Land)

Discharge Point	Catchment Area (ha)	ARI Event	Total Runoff to Point (m³)	Critical Storm Duration	Flood Plain Storage (m³)	Peak Outflow (m^3/s)
NW	29	1 year	4000	1 hour	2800	0.146
		10 years	5600	1 hour	4400	0.234
		100 years	10000	1 hour	8700	0.418
NE	15	1 year	2000	1 hour	0	0.138
		10 years	3000	1 hour	0	0.220
		100 years	5100	1 hour	1300	0.393
SE	139	1 year	18400	1 hour	12500	*
		10 years	26000	1 hour	20500	*
		100 years	46500	1 hour	40000	*
SW	24	1 year	3200	1 hour	1200	0.630*
		10 years	4500	1 hour	2500	1.007*
		100 years	8000	1 hour	5900	1.800*
TOTAL		**10 years**	**39,100**		**27,400**	
		100 years	**69,600**		**55,900**	

*Combined Peak Outflow for SE and SW via Rowley Road



NW Peak Outflow
1yr 1hr - 0.146m3/s
10yr 1hr - 0.234 m3/s
100yr 1 hr - 0.418 m3/s

NE Peak Outflow
1yr 1hr - 0.138m3/s
10yr 1hr - 0.220 m3/s
100yr 1 hr - 0.393 m3/s

SE & SW Combined
Peak Outflow via Lot 8
1yr 1hr - 0.630m3/s
10yr 1hr - 1.007 m3/s
100yr 1 hr - 1.800 m3/s

Lot 200 Peak Outflow
1yr 1hr - 0.195m3/s
10yr 1hr - 0.312 m3/s
100yr 1 hr - 0.558 m3/s

Peak Allowable Flow Rate (100yr)
South Forrestdale Industrial Area
via Rowley Rd culverts 2.85m3/s

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Integrating Resource Management

Project Title: South Forrestdale Industrial DWMS
Client:
Date: 04/10/2016
Drawn: TL
Checked:
Revision: A

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FIGURE 18: Predevelopment Modelling Results

South Forrestdale Industrial Area

Source: Cadastre - Landgate (21/07/16); Aerial - Nearmaps (30/09/14); LiDAR - DoW (17/05/10); Hydrography - DoW (29/10/08)

2.7.3 Wetlands

According to the DEC geomorphic wetland dataset the entire Study Area lies within two multiple use wetlands (**Figure 19**), namely a sumpland and a palusplain (UFI: 14884 and 15797). The Study Area is also in close proximity to wetlands of conservation significance, the majority of which are associated with Forrestdale Lake.

Multiple Use Wetlands (MUWs) are areas where wetland functions, values and attributes have been seriously degraded such that they no longer serve any substantial ecological role. They are typically cleared of native vegetation and do not support wetland fauna. The management objective is to preserve hydrological functions, but otherwise they can be developed for more beneficial use.

North of the Study Area (Lots 5,7 and 9) is a Conservation Category Palusplain Wetland (UFI 7383). The Ramsar Wetland Boundary is the road reserve north of Lot 9. To the west of Lot 9 in the Bush Forever land is a Conservation Category (CCW) Sumpland (UFI 12992). These are all associated with the Forrestdale Lake nature reserve.

Within Lot 12 are three wetlands, being Palusplain CCW (UFI 15198), Dampland CCW (UFI 12993) and Dampland Resource Enhancement Wetland (REW; UFI 15575). This area has been designated and reserved for Bush Forever.

To the east of Lot 10, in the adjoining road reserve and Lot 8 is a Palusplain REW (15796). This REW is within the South Forrestdale Industrial Area and will require retention and management as part of this development.

Fifty-metre buffers have been set to protect these conservation and resource enhancement wetlands. This is consistent with EPA Guidance 33 section B4-3. We note however, that at further planning stage buffers can be reviewed based on further assessment.

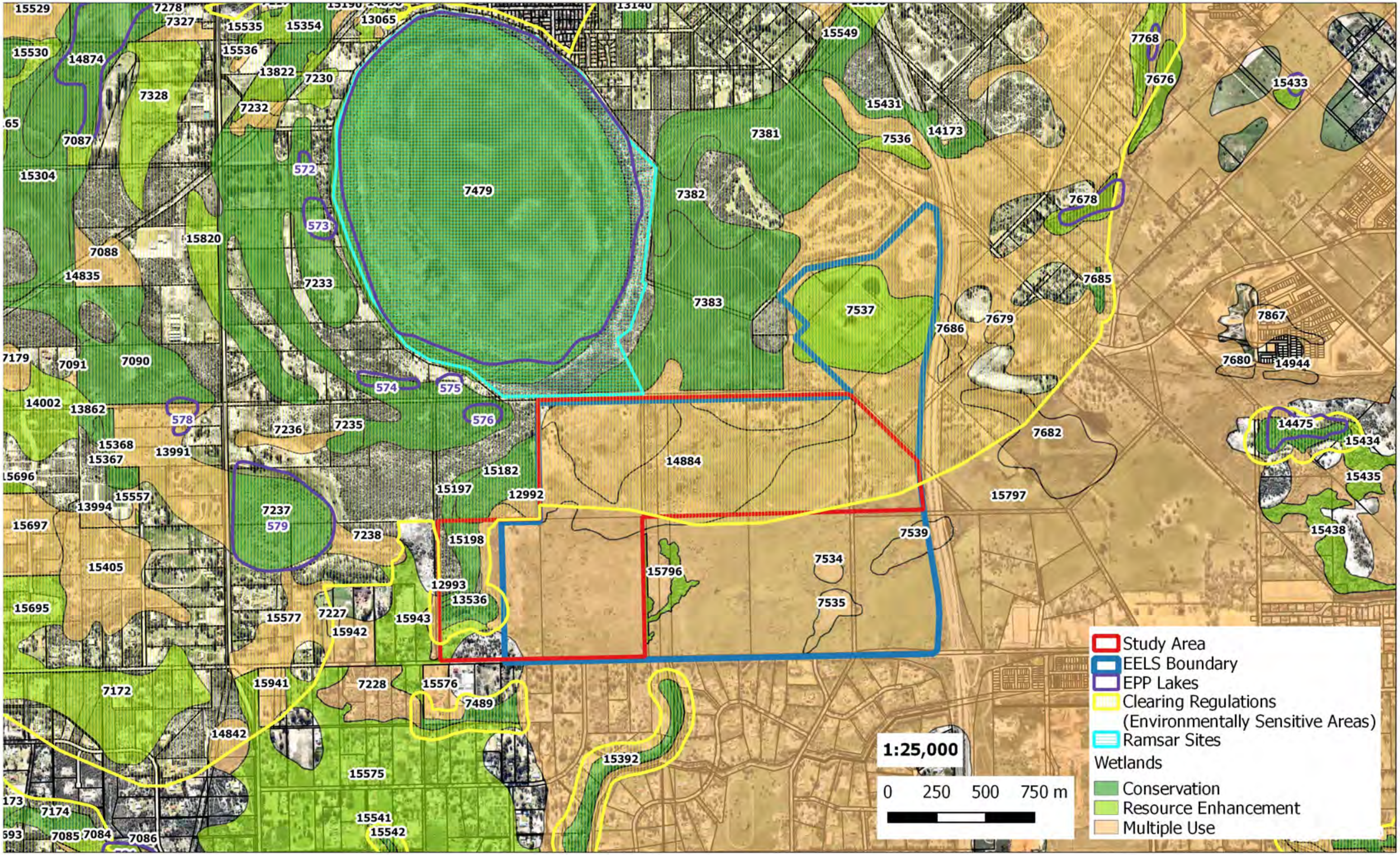

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FIGURE 19: Geomorphic Wetlands & Associated Management Boundaries

South Forrestdale Industrial Area

Source: Cadastre - Landgate (21/07/2016); EPP Lakes (EPA, 1992); Clearing Regulations - DER (21/07/2016); RAMSAR- DPaW (21/07/2016); Geomorphic Wetlands - DPaW (21/07/2016)

2.8 Forrestdale Lake

Forrestdale Lake is a Class A nature reserve of 245ha, gazetted for the Conservation of Flora and Fauna (number 24781). It is internationally important as a habitat and refuge for water birds, and in 1990, together with Thomsons Lake, was designated to the List of Wetlands of International Importance under the Convention on Wetlands (Ramsar, Iran, 1971; Ramsar site 481). Forrestdale Lake is also classified as a Conservation Category Wetland (CCW) and has been given additional protection under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 2004* (**Figure 19**)*.* Furthermore, Forrestdale Lake is also a Bush Forever site, 345.

The presence of migratory birds protected under the Japan-Australia Migratory Bird Agreement (JAMBA) and the China-Australia Migratory Bird Agreement (CAMBA) means that Forrestdale Lake is also given additional protection under the EPBC Act. Any action that has had, will have, or is likely to have a significant impact on a matter of national environmental significance such as Ramsar wetlands and migratory species listed under international treaties, such as the Australian agreements with Japan (JAMBA) and China (CAMBA) and the Bonn Convention, is required to undergo an environmental assessment and approvals process (CALM, 2005).

Needless to say, Forrestdale Lake is considered important for conservation and thus any potential impact to it requires thorough investigation to either absolve, mitigate or manage the risks.

Forrestdale Lake is vested to the Conservation Commission of Western Australia and managed by the Department of Parks and Wildlife (DPaW, formerly CALM). It is managed in line with the Forrestdale Lake Nature Reserve Management Plan 2005 (number 53). In line with the CALM Act, this management plan will be utilised for a period of ten years from gazettal and therefore is due for revision. The CALM Act also notes that where such a revision has not occurred by the end of this period, the plan will stay in force until it is either revoked by the Minister or a new plan is approved. Therefore, the 2005 management plan is the current and most recent plan (CALM, 2005).

The following sections are designed to provide an overview of the management of Forrestdale Lake, identifying the various studies and investigations used to understand the system. Early investigations suggest that the system is a groundwater flow-through lake based on regional data. As more investigations proceeded, it is suggested that it is driven by local groundwater; while detailed groundwater-surface water modelling identified the system as rainfall driven.

2.8.1 Forrestdale Lake Management Plan 2005

Forrestdale Lake is a Class A Nature Reserve (number 24781), gazetted in 1957 for the Conservation of Flora and Fauna. It is vested with the Conservation Commission of Western Australia and managed by DPaW. The adjoining reserve (number 27165) is vested in the City of Armadale for the purpose of Recreation, and is reserved for 'Parks and Recreation' in the Metropolitan Region Scheme (MRS). It contains Declared Rare Flora (DRF) and Priority flora species, as well as two Threatened Ecological Communities (TECs).

The management plan proposes that the vesting of the recreation reserve, excluding the golf course, be transferred to the Conservation Commission and that it be managed by CALM as nature reserve. Negotiations to this effect were underway between the Department and the City of Armadale in 2005. The status of these negotiations are unknown, though in general the management of these areas has no bearing or effect on the South Forrestdale Industrial Area.

Forrestdale Lake is known for its birdlife. It provides an important habitat for large populations of water birds, with more than 20,000 water birds being recorded in January 1986. It is one of the few remaining examples of the lakes and vegetation originally found on the Swan Coastal Plain, and is included in the State Government's *Environmental Protection (Swan Coastal Plain Lakes) Policy (2004)* as a wetland having conservation value. This policy protects the environmental values of Forrestdale Lake and prohibits any unauthorised filling, mining, draining (into and out of the wetland), effluent discharge and alteration of water levels. The policy provides for the protection of the ecosystem health of wetlands on the Swan Coastal Plain, such as Forrestdale Lake, including the protection of the ecological structure, function and processes of the wetland, as well as the protection of the beneficial uses including its use for study, education, recreation, aesthetic enjoyment and the benefit of the public generally (CALM, 2005).

The lake itself is a deflation basin rimmed by low sand ridges up to five metres high, and lakebed sediments that comprise sand to sandy organic mud overlying soft marly limestone and clayey sand, and a sandstone outcrop is present on the north eastern margin of the lake (CALM, 2005). Lake deposits up to 2m thick underlie Forrestdale Lake and include silt, clay, peat, diatomite, marl and freshwater limestone (ERM Mitchell McCotter 2000). The lake is most likely underlain by pyritic peaty sediments, which are also potential acid sulphate soils (CALM, 2005).

Surface water levels were much higher at Forrestdale Lake in the 1970s and 80s, and have been steadily declining since 1992. Groundwater levels have also decreased since records commenced in 1996 (CALM, 2005). Results from Stage 1 of the Section 46 review of the Gnangara and Jandakot Groundwater Mounds indicate that water levels in Forrestdale Lake are currently about 1.5 to 2.5 m below levels observed in the 1970s and 1980s (CALM, 2005). Also, the lake is now drying earlier than in previous wetter years, which has resulted in the encroachment of vegetation (predominantly *Typha orientalis*) onto the lakebed, subsequently decreasing the amount of mudflats available for wading birds, and therefore reducing the habitat value of the lake for waterbirds (CALM, 2005).

In 1992 Environmental Water Provisions (EWPs) were set for a number of wetlands across the Jandakot Mound, including Forrestdale Lake, under Section 46 of the Environmental Protection Act. These EWPs include a preferred minimum water level and an absolute minimum level, and were set to ensure the maintenance of the lake's habitat value for migratory birds and rare, threatened and priority flora and fauna. The ecological values at Forrestdale Lake require a natural cycle of filling and drying to continue, with maintenance of water levels above a preferred summer minimum of 21.6mAHD and an absolute summer minimum of 21.1mAHD. It should be noted that the base of Forrestdale Lake is essentially 21.6mAHD and therefore minimal, if not any, water would be present in summer though the sediment profile would still contain moisture. These levels have been breached a number of times at Forrestdale Lake. There is also a requirement for water depth of at least 0.9m when levels are at their annual maximum. In wet years the lake should be dry by April, by February/ March in medium years and by January in dry years (CALM, 2005).

In 2001, a Section 46 review of the EWPs proposed a revision to environmental conditions on the basis that the 1992 conditions did not take into account a shift to a drier climate. The EPA opposed any changes to the EWPs based on the international importance of the wetland and the lack of understanding of groundwater-surface water interactions (Bourke, 2009).

Wetland ecosystems such as Forrestdale Lake are affected by events that cause variations to the quality and quantity of groundwater supply (CALM, 2005). Examples of these events include rainfall and modified land uses within catchments (such as groundwater extraction and urban development). In order to protect the wetland ecosystem and maintain its ecological character and viability as waterbird habitat, the impacts of climate change, groundwater extraction and existing and proposed land uses within the Forrestdale Lake catchment need to be understood and managed (CALM, 2005).

The management plan identifies Forrestdale Lake as a surface expression of groundwater that has formed where the water table intersects with the ground surface and surface runoff probably had little effect on its depth when it was in an undisturbed condition. Changes in water levels are a significant management issue at Forrestdale Lake due to its significance for many migratory water species (CALM, 2005).

While the management plan notes that Forrestdale Lake is groundwater fed, it has not provided evidence to suggest this to be the case. The management plan refers to ERM McCotter, 2000 report (an unpublished report to CALM) noting the water level of Forrestdale Lake responds to events that cause variations in the quantity of groundwater supply, evidence that the lake is strongly controlled by the local hydrology (ERM McCotter 2000). It goes on further to note a number of factors influence the water quality of Forrestdale Lake, particularly groundwater discharge. During dry years in particular when drain flow is either minimal or non-existent, discharge from groundwater contributes about 99%, or effectively the entire nutrient load into the lake. During periods of rainfall, drain discharges into the lake can also be a source of nutrient input (ERM Mitchell McCotter 2000).

Bioscience believes that the ERM, 2000 report was overly simplistic and inferred too much information from regional data to accurately confirm that Forrestdale Lake is in fact groundwater fed. A review of this report is provided below.

2.8.1.1 Nutrient Study – Forrestdale Lake (ERM, 2000; Unpublished Report)

CALM prepared a management plan for Forrestdale Lake in 1987 which identified the need for a nutrient monitoring and management study on the basis that high nutrients within Forrestdale Lake were promoting increased algal growth and subsequently increasing the midge (chironomid) populations. ERM were commissioned to complete a staged investigation of Forrestdale Lake. The first stage involved a Baseline Nutrient Study, completed in 1999; while the second involved a Nutrient Monitoring Program, completed between June 1999 and May 2000; the final report being a Baseline Nutrient Study and Monitoring Summary – Forrestdale Lake (November 2000, number 299072).

The report very early on concludes that "*flow from the superficial formation includes Forrestdale Lake*" (Section 1.3.1) and "*groundwater discharge occurs at surface water features including Forrestdale Lake*" (Section 1.3.3) at which point no evidence has been provided to conclude this. It is likely that this has been assumed based on regional wetlands present within the Swan Coastal Plains, a majority of which are known to be groundwater flow through systems. This is further suggested as Section 1.3.4 refers to Davidson, 1995 stating that "*lakes are perched above the water table only during periods of exceptionally high rainfall. Following rain, hydraulic connection between lake water and groundwater is rapidly established and lake water levels represent isopotentials of the groundwater systems connected to the lake.*" This is in contrast to **Figure 20**, below, which only shows a reasonable correlation between lake water level and groundwater levels and the conclusion from Davidson, 1995 (above) cannot be drawn. It can only be concluded from the graph below that both the superficial aquifer and Forrestdale Lake are likely to both obtain water from the same source based on the similarity of the hydrographs, most likely direct rainfall. It should be noted that no comment with respect to the head difference of groundwater and Forrestdale Lake can be made from **Figure 20** as the location of the monitoring bore for this graph (and the report) is not defined and therefore a 2m gradient between locations may be appropriate.

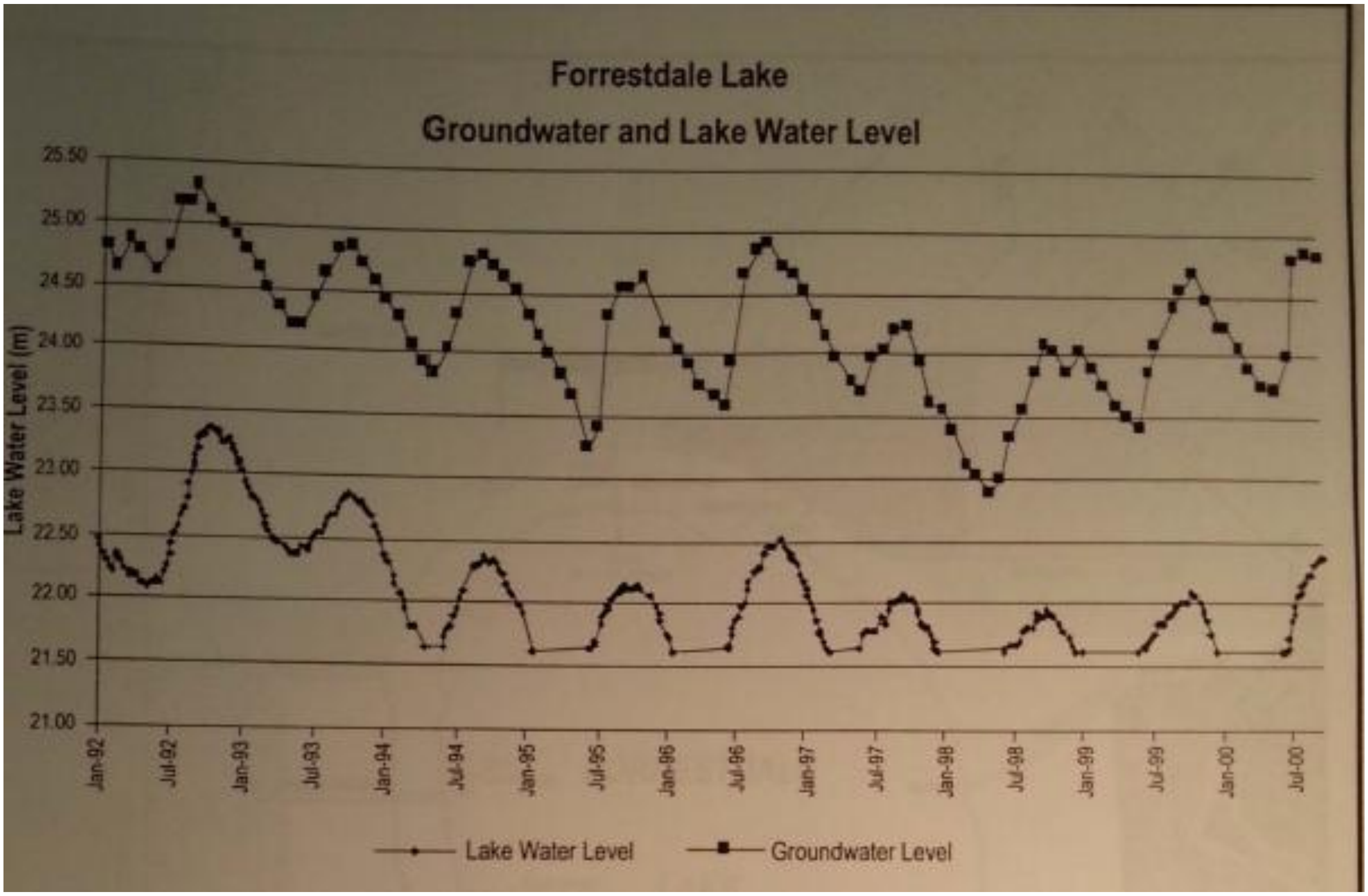

Figure 20: Forrestdale Lake versus Groundwater Levels

Furthermore, if as ERM allude that Forrestdale Lake is mostly groundwater driven, it would be expected that a lag between water levels in Forrestdale Lake and groundwater is evident. **Figure 20**, above, show a close correlation of peaks and troughs between this groundwater location and Forrestdale Lake. This would only be seen in systems where a strong connection and high hydraulic conductivity is present. It is unlikely that this would be the case for Forrestdale Lake based on the description of the lacustrine deposits on the lake bed provided by ERM (and others). It is likely that this stratigraphy would act as a barrier and prevent or delay groundwater from entering Forrestdale Lake and thus a lag being seen between groundwater levels and lake water levels.

ERM also undertook a review of *A Review of the Hydrochemical Study of Lake Forrestdale* by V&C Semnuik Group and included the findings as follows:

- "*Monitoring Wells and Monitoring Program*
    - *Shallow monitoring wells do not intercept a significant portion of the groundwater flow system contributing to the Lake*
    - *Piezometers installed in transects normal to the lake shore were not surveyed and hence local hydraulic gradients or flow directions could not be determined*
- *Report and Findings*
    - *No connection between lake and groundwater system was established as neither vertical nor horizontal hydraulic gradients have been calculated or inferred*

- *Regional groundwater flows or gradients were not considered in placement of additional wells, sampling and analysis nor interpretation of results*";

> "*In reference to determining the groundwater catchments, it is noted that it is not possible within the scope of this study to quantify all factors although a representative groundwater catchment area can be estimated. For example, there are not sufficient data to estimate vertical thickness of the aquifer that discharges to the Lake. However, assumptions have been made based on previous, more detailed hydrogeological investigations of similar lakes in the Swan Coastal Plain.*"; and
>
> *"The winter groundwater catchment has been assessed based on data presented in WRC (1997). Site specific data could not be incorporated into the calculation due to the different aquifer thicknesses penetrated by the monitoring wells. The WRC data are considered to be suitable to determine the groundwater catchment for the scale of this study.*
>
> *Figure 6, Appendix A shows the groundwater flownet for the highest anticipated groundwater levels. The groundwater catchment is also indicated.*
>
> *The major features of the winter groundwater catchment are estimated as follows:*
>
> - *The width is approximately 120% of the lake "width" (the dimension perpendicular to the groundwater flow direction);*
> - *The western extremity of the groundwater catchment would extend towards the Jandakot borefield although the location of the western boundary is not known (a groundwater divide would occur east of the borefield);*
> - *The major groundwater flow is from the west, discharging to the north-east under the township;*
> - *A minor flow cell occurs on the eastern margin of the Lake – negligible groundwater exchange with the lake water occurs; and*
> - *A groundwater stagnation point occurs south-east of the Lake*
>
> *The major input of groundwater to the Lake therefore occurs from the west. Lake water discharges to the north-east under the township, and to a lesser extent to the south-east."*

These statements suggest that generalized understandings of 'similar' systems has been used to define the water balance and groundwater inputs into Forrestdale Lake. While this approach is not unusual, it must be noted that it can be highly inaccurate to use this approach when the system is not understood in enough detail.

ERM calculated groundwater inflows by the "*throughflow past a groundwater elevation contour, within the flow cell that discharges into the Lake*." This was done on a monthly basis and then tabulated to an annual water balance, replicated in **Table 8**.

Table 8: Forrestdale Lake Water Balance (ERM, 2000)

Item	Input (kL/annum)	Output (kL/annum)
Rainfall (R)	2,070,000	
Groundwater Inflow (Gi)	600,000	
Drainage Discharge (D)	500,000	
Evaporation (E)		3,000,000
Groundwater Outflow (Go)		90,000
Total	**3,170,000**	**3,090,000**

> "*An error of approximately 80,000 cubic metres per year (deficit) is noted in the figures presented above. This represents approximately 2% and is considered to be acceptable. Furthermore, it is considered that actual errors are greater than indicated but they negate each other.*
> *It is clear that groundwater inflow is the most significant component in the equation, and it is least susceptible to short-lived seasonal variations. Drain flows in high rainfall (thus high groundwater level) seasons may be significant, although groundwater flows will be higher as well. Drains have been known to be dry all year round during low rainfall seasons.*"

The table and associated text suggesting that the system is dominated by groundwater has not taken into account the overall water balance. The results in **Table 8** still suggest that the system is rainfall dominated. A minimum of 65% of inflow sources comes from direct rainfall (2,070.00/3,170,000), while a maximum of 35% is from a groundwater source (taking the over simplistic assumption that all drainage discharge is from a groundwater source) ((600,000+500,000)/3,170,000). The same can be seen with 97% of outflow being climate driven (evaporation) (3,000,000/3,090,000), while only 3% groundwater dependent (groundwater outflow) (90,000/3,090,000).

> "*Figure 9, Appendix A shows historical Lake water level, rainfall and groundwater level variations historically and since 1992. The relationship between Lake water rainfall and groundwater levels is summarised below:*
>
> - *long term groundwater levels are controlled by long term climatic conditions;*
> - *groundwater levels start to rise approximately two months after the onset of winter rainfall, and rainfall and groundwater peaks are separated by approximately three to four months;*
> - *early season rainfall increases Lake levels by up to 300 millimetres in the absence of a supporting groundwater system;*
> - *Lake water levels respond to rainfall in a subdued manner until the groundwater level supports the Lake water;*
> - *Lake water levels mimic groundwater levels from the time at which groundwater intersects the lake to the end of summer dry period; and*
> - *Lake water disappears when groundwater levels fall below the lake floor.*

> *It is apparent that the Lake is strongly controlled by the local hydrogeology. Thus changes to the groundwater system will impact the Lake. Conversely, management of the groundwater system that interacts with the Lake would provide a mechanism to improve the lake water quality."*

ERM, 2000 have utilised regional groundwater information and have provided little clarification to its suitability for Forrestdale Lake. Inference from regional data to determine the groundwater through-flow and water balance has meant that the results identified within ERM, 2000 may not be accurate and further investigations into groundwater interactions would be required.

2.8.2 Perth Shallow Groundwater Systems – Forrestdale Lake (DoW, 2010)

Between 2007-2010, the DoW commenced investigations on the Perth Shallow Groundwater Systems (SGS), of which Forrestdale Lake was one of up to 30 wetlands to be investigated. This scope of work arose from the findings within (McHugh and Bourke, 2007) that summarised the current management issues and identified the additional information to address these issues. McHugh and Bourke (2007) noted that site specific data should be collected to determine groundwater-surface water connectivity and groundwater quality into and out of Forrestdale Lake.

Site investigations occurred over a 12 month period from May 2007 to May 2008 to obtain this data. Unfortunately, SGS funding concluded prior to the finalisation on the specific report for Forrestdale Lake. Discussions with Sandie McHugh (12/09/2016) revealed that a near complete draft was available and provided for the purpose of providing the information within this DWMS. Section 2.8.3 provides a summary of the investigations and conclusions completed within Draft Forrestdale Lake – Perth Shallow Groundwater Systems Investigations: Hydrogeological Record Series, Report No. 41 (Bourke, 2010). To review this report in its entirety, a request to the DoW (Sandie McHugh) would be required as permission is required to release the draft report.

The specific objectives of the Perth SGS Investigation, as described in Bourke (2010) were to:

1. Redesign and upgrade the existing monitoring infrastructure and install new monitoring networks at ecologically important sites;
2. Investigate the hydrogeology of selected lakes, wetlands and remnant wetlands to determine the interactions and connectivity of surface water bodies and groundwater;
3. Investigate the palaeoclimate of key wetlands to provide an appreciation of how lakes have functioned in the past and to enable us to place the current changes within this long-term context; and
4. Investigate the chemistry of wetlands and wetland sediments to give a detailed understanding of the ability of wetlands to alter lake and groundwater quality

Specific to Forrestdale Lake, the following objectives of this study were determined:

1. Determine groundwater - surface water connectivity;

2. Determine any significance of groundwater abstraction on lake levels;
3. Determine any influence of the lake on water quality in the Superficial aquifer;
4. Identify the risk of acidification; and
5. Identify ecological impacts of groundwater decline and water quality (Bourke, 2010).

Report 41 identified the following from its investigations, with subsequent sections providing further extracts from Bourke (2010) related to these preliminary findings:

1. Forrestdale Lake is not a through-flow lake. Rather, the lake acts as drainage basin that captures local groundwater discharge and drainage.
2. Hydraulic gradients were towards the lake throughout the sampling period and no outflow from the lake was determined during this study.
3. The Kardinya Shale that forms a confining layer between the superficial and Leederville aquifers is absent beneath the lake.
4. Local evapo-concentration has led to the development of a plume of saline groundwater east of the lake basin that is likely to be leaking into the Leederville aquifer.
5. This type of hydrogeological system has not previously been described on the Swan Coastal Plain.
6. The risk of acidification due to oxidation of acid sulfate soils at Forrestdale Lake is minimised by the high buffering capacity of the sediments in the lake basin and high pH of the lake water.
7. Management options for Forrestdale Lake could be refined by further improvement to our hydrogeological understanding of the system and the external factors affecting water quantity and quality in the area.

Anecdotal evidence obtained by Bourke (2010) and according to locals, notes the expansion of the Wungong dam in the late 1970's was largely responsible for reducing water levels in Forrestdale Lake, by reducing overflow from Wungong Brook.

Section 2.8.2 provides an in-depth summary of the work completed by DoW, though not made publicly available due to funding restrictions. This study was the first completed solely on Forrestdale Lake and thus has a large amount of details not previously explored and helps to understand some of the current thinking behind the hydrological cycle related to Forrestdale Lake.

2.8.2.1 Investigation Program

Bourke (2010) summarised the following site investigations as part of the scope, which informed their findings into the groundwater interaction with Forrestdale Lake:

> *"Bore installation sites were selected based on regional groundwater flow paths, the location of the vegetation monitoring transect and suitable access for a drill rig. Bores were installed along two transects perpendicular to groundwater flow, south west-north east and north west-south east. Sampling for water levels and water chemistry was carried out at approximately monthly intervals over a 12 month period between April 2007*

> *and May 2008. A series of 5 hand-auger cores were also collected along an east-west transect through the middle of the lake basin."*

2.8.2.2 Geology

Cretaceous Formations

Bourke (2010) described that superficial geology as follows, which can be inferred to represent a similar formation within the Study Area, with reference to the south of the lake:

> *"Forrestdale Lake overlies a sub-crop boundary with the confining Kardinya Shale Member of the Osborne Formation west of the lake, and the Pinjar member of the Leederville Formation east of the lake. Beneath and immediately west of the lake the Kardinya Shale member is absent and the Henley Sandstone member of the subcrops beneath the Superficial formations. This interpretation is in contrast to Davidson (1995) which suggests that the Henley Sandstone is absent in this area.*
>
> *The Henley Sandstone was only intersected in one drill hole, as a dark green, micaceous, pebbly coarse-grained sand from 34 to 40 m bns in FRD_W. This is interpreted as the Henley Sandstone of the Osborne Formation after the description by Davidson (1995) as 'weakly consolidated to friable, fine to coarse grained, poorly sorted…dark greenish brown and glauconitic'.*
>
> *This sequence suggests that the development of the superficial formations in this area began with the deposition of the Ascot Formation during a time of sea-level high stand. As sea level retreated, the area was a marginal/transitional marine environment with evidence of fluvial deposition and material that was eroded from the scarp. Wind blown dunes on top (Bassendean dune system) developed with sequences of aeolian sand and silty sand, inter-bedded with pebbles deposited by smaller river channels."*

Lake Bed Sediments

The lakebed sediments of Forrestdale Lake are predominantly comprised of clay and clay-marl with variable organic content. Bourke (2010) supported these findings. Bourke (2010) also suggested that Forrestdale Lake has an eastward migration over time based on a sequence of organic sediments underlain by marlstone, similar to the current lakebed lithology, found within FRD_WC between 1.8 and 2.4m depth.

“The survey lines across the lake showed a conductive layer, defined as clay by Geoforce, which appeared to extend from the surface to 4m deep. During installation of FRD_E2C, which is within the lake basin, a layer of clayey sand was intersected less than 1m thick. The clay marl layer intersected at FRD_WC was only 0.3m thick. These layers are much thinner than the 4m interpreted by Geoforce, suggesting that 4m is likely to be an upper bound for the thickness of the clay marl lining the lake basin.” (Bourke, 2010)

Acid Sulfate Soils

Acid sulfate soils are not considered to be an issue for Forrestdale Lake, even with declining water levels, due to the high buffering capacity of the sedimentary soils. Bourke (2010) noted:

> *"Forrestdale Lake is not likely to be at high risk of acidification. While acid sulfate soil testing was not specifically carried out on the lake-bed sediments, they are known to have a high buffering capacity. This is reflected in the high pH range of the lake waters (8 to 10), and provides some protection against acidification of the lake even if the pH of adjacent groundwater declines."*
>
> *"The high buffering capacity of the lakebed sediments is likely to provide some protection against acidification in the future if water levels decline."*

2.8.2.3 Hydrology

As rainfall is the driving factor for increases in water levels, either directly or via recharge to the local groundwater system, an understanding of the rainfall pattern and its influence on Forrestdale Lake is pertinent. Bourke (2010) describes the response of the system to rainfall as:

> *"Although rains began in April 2007, Forrestdale Lake remained dry until July 2007, with the first water levels at the staff gauge recorded on August 7. Over the period from April through July, a total of 425mm of rainfall had fallen, without a measured increase in lake levels. This suggests that direct precipitation on the lake-bed is rapidly evaporated or infiltrates into dry sediments if it is not supported by the watertable. There is no record of the lake holding water after the unseasonal rains that fell in February 2008 (78 mm in 4 days), but this may be because the temporal sampling resolution (1 month) was too large to capture this event."*
>
> *"The lake water level (21.8 m AHD) in August was higher than groundwater levels immediately east (0.1 m higher) and west (0.2 m higher). Given that the measurements aren't on the same day, it's difficult to make a direct comparison. Water levels in the bore screened within the lake basin (FRD_E2c) are higher than the lake level in August, suggesting groundwater does not flow up into the lake from below. Water levels in the shallow and intermediate bores at the north-east and south-east clusters were also higher than the lake during August. This may be related to scheme water usage in*

> *Forrestdale township elevating local groundwater levels, and suggests a seepage face from the aquifer to the lake in the north-east."*

However, the seepage face does not explain the prolonged higher groundwater levels within the vicinity of Forrestdale Lake (seen at all FRD nested bores except FRD_W) after Forrestdale Lake became dry (December 2007). This suggests that other environmental factors, such as evapo-transpiration may play a major role in Forrestdale Lake levels.

> *"By September groundwater levels in all shallow and intermediate bores had risen above the lake water level, with a hydraulic gradient from the top of the aquifer towards the lake. This gradient was maintained throughout the period the lake held water."*

2.8.2.4 GW Flow Paths

Bourke (2010) identified a local groundwater recharge to Forrestdale Lake, an interpretation that differs from previous studies including Davidson (1995).

> *"Maps of the watertable and inferred groundwater flow paths at seasonal maximum and minimum groundwater levels are presented in* ***Figure 21****. These contours suggest that groundwater flows towards the lake within a 2km radius, but outside of this range, groundwater is likely to be diverted to the north east and south west, away from the lake basin. This data suggests that local recharge provides the majority of groundwater to the lake-basin, rather than regional through-flow. This interpretation differs from Davidson (1995) who concluded that the lake sits on a groundwater divide with inflow from the east and west, and outflow from the north and south."*

Local groundwater monitoring and mapping provided in Section 2.6.2 and **Figure 12** identifies the groundwater divide where flow is directed towards Forrestdale Lake as much closer than identified within **Figure 21**, at least in the south where Bourke (2010) has also noted no bores were installed and water levels were not known. The cross sectional flow paths identified by Bourke (2010) are also shown in **Figure 22 - 25.**

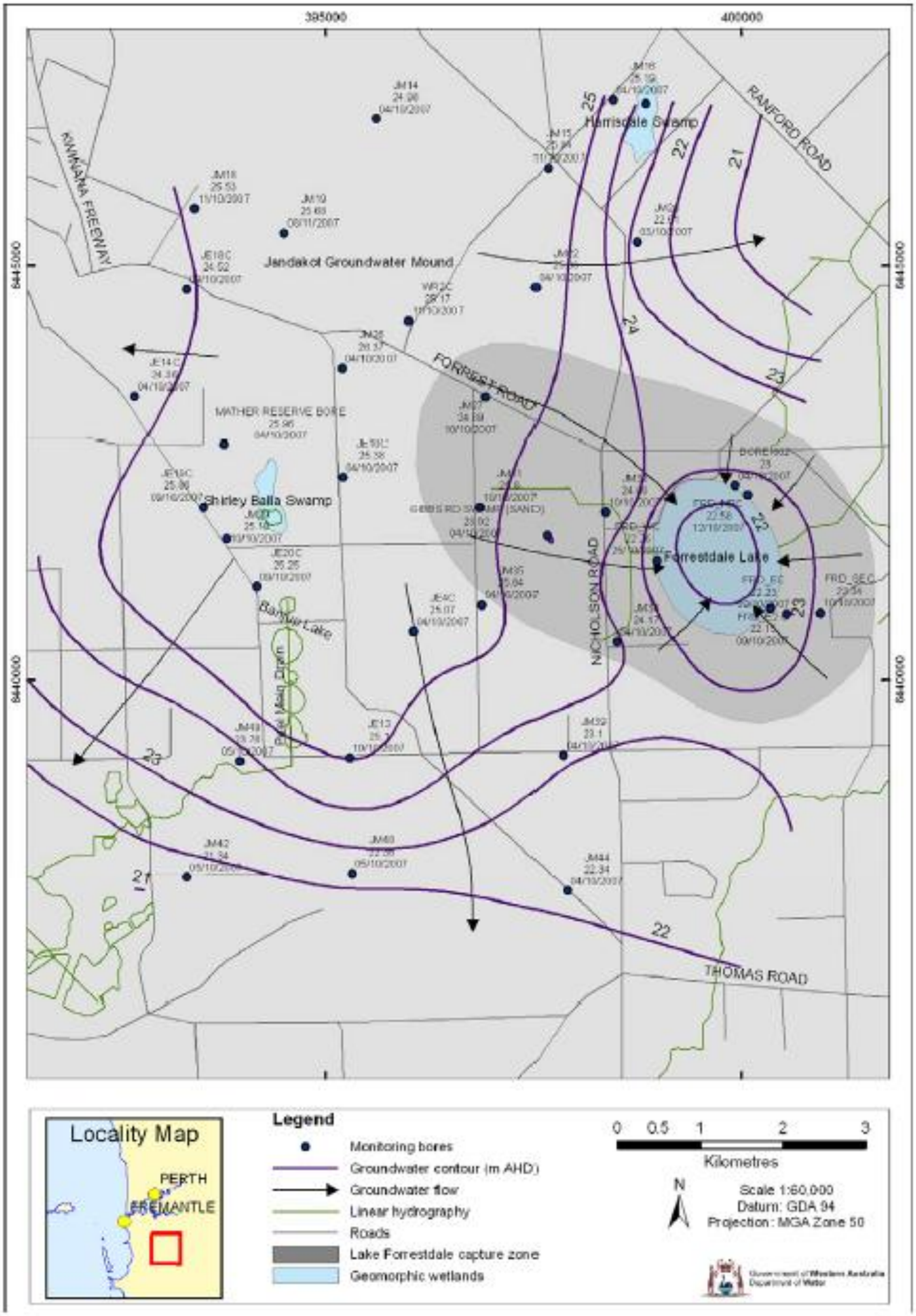

Figure 21: Lake Forrestdale Capture Zone

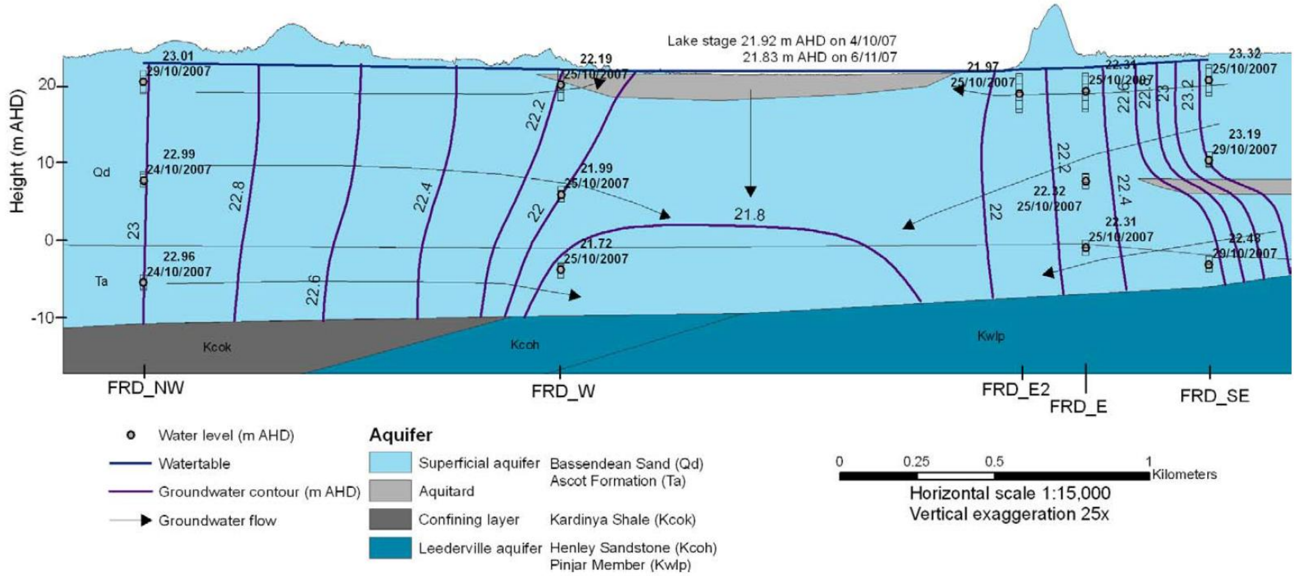

Figure 22: ***Groundwater contours and flow paths along a NW-SE transect at seasonal maximum water levels (October 2007)***

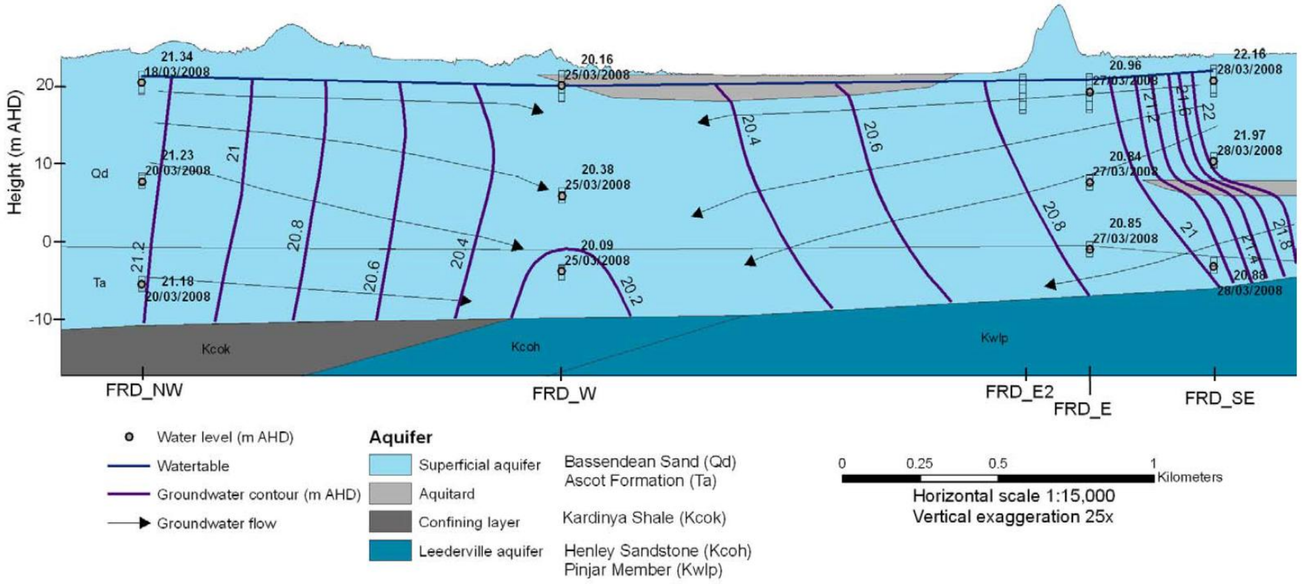

Figure 23: ***Groundwater contours and flow paths along a NW-SE transect at seasonal minimum water levels (March 2008)***

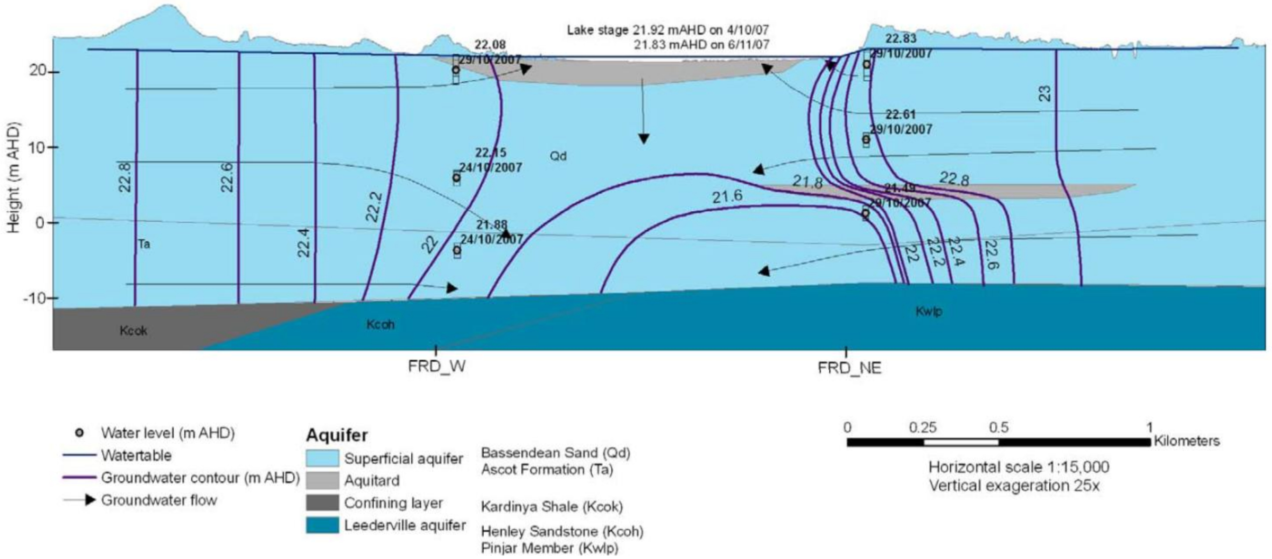

Figure 24: ***Groundwater contours and flow paths along a SW-NE transect at winter maximum water levels (October 2007)***

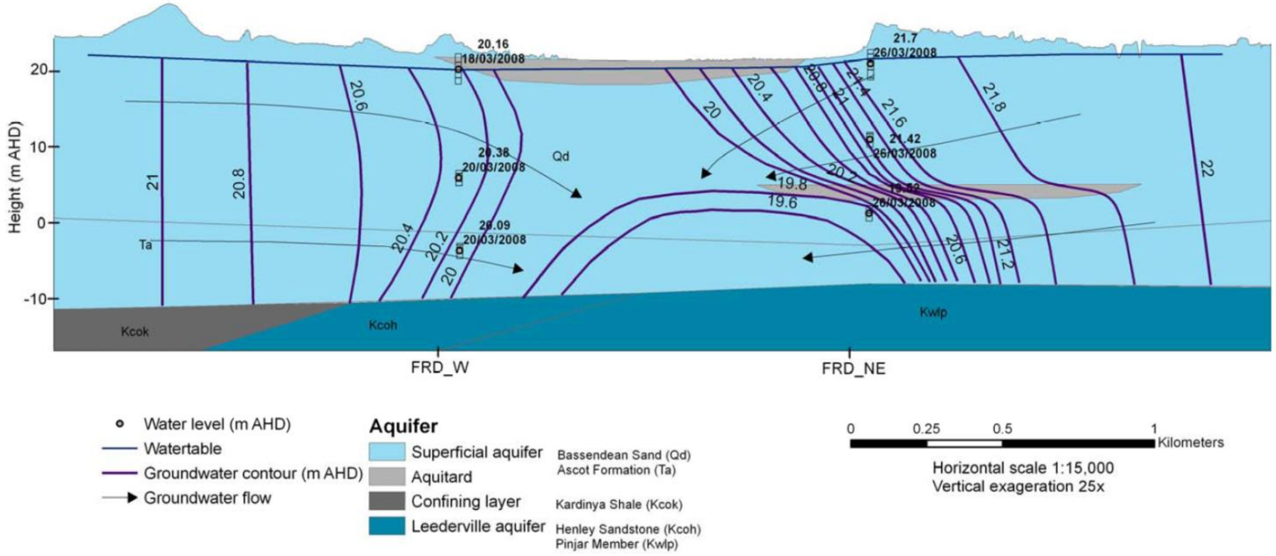

Figure 25: ***Groundwater contours and flow paths along a SW-NE transect at summer minimum water levels (March 2008)***

2.8.2.5 Water Chemistry

Chloride Distribution

Chloride concentrations can be used to help determine the sources of water. Bourke (2010) completed preliminary investigations related to chloride to help with further conclusions on how Forrestdale Lake interacts with groundwater.

> *"There was little seasonal variation in the chloride concentrations in intermediate and deep bores. The largest variation was in the water table bores with decreases in FRD_WC and SEC during the winter recharge period (August to October). The chloride concentration in FRD_SEC fell from 9800 mg/L on 29 June to 70 mg/L on 3 August, 2007, after which time it steadily increased to 1700 mg/L. This suggests a sudden influx of freshwater and may be related to surface drainage and rainfall.*
>
> *An additional one off sampling event was conducted during December 2009 to capture the annual peak chloride concentration in the lake and water table bores east of the lake (FRD_E2C and FRD_EC). The data showed that the chloride concentration in the lake water had reached 4600 mg/L. The bore outside the lake basin, to the east of the dune had similar values with a chloride concentration of 5600 mg/L. This might suggest that the bore to the east is receiving outflow of a saline plume from the lake. However, the bore on eastern edge of the lake basin had lower concentration of 392 mg/L, suggesting that the saline plume from the lake (if it exists) was not intercepted in this bore. Also the chloride concentrations in FRD_EC are higher than the lake, suggesting at minimum, further addition of chloride from another source that is not Forrestdale Lake.*
>
> *There are two possible interpretations: 1) saline water from the lake passes below the bore in the lake basin, under the dune and into the bore FRD_EC, or 2) Forrestdale Lake is not the source of the high salinity in the bore east of the dune.*
>
> *The second interpretation is considered to be more likely, with the high salinities in FRD_E and FRD_SE related to local effects rather than discharge from Forrestdale Lake. The area east of the lake where the bores sites FRD_E and FRD_SE are located experiences ponding of water at the surface during the winter months, with this ponded water disconnected from the water table by up to 2 m. While at the surface this water is exposed to evaporation which will increase the chloride concentration. This ponding may be caused by low permeability sediments; coffee rock with consolidated nodules and*

> *clayey sand layer were present at FRD_E in the top 5 m of the profile. Iron stained sands at FRD_SE were unconsolidated and there was no distinct low-permeability layer within the top 15 m of the profile above the organic silt in this hole."*

Based on the information provided, the source of chloride (and salinity) cannot be categorically determined. It should be noted that in a large shallow open water body, such as Forrestdale Lake, significant variations in salinity can be recorded depending on where samples are taken. With the sample from Forrestdale Lake being within the similar range to that of the FRD_EC and FRD_SEC bores, it is still likely that Forrestdale Lake is the salinity source. Furthermore, Barr et al. (2009) identified extremely high rates of recharge in Bassendean Sands adjacent to lacustrine deposits on the eastern ridge of Forrestdale Lake which may provide discharge of higher saline waters from Forrestdale Lake (while bypassing FRD_E2C). This high permeability area is explained further in Section 2.8.5.

> *"Chloride concentrations are also higher at the base of the Superficial aquifer (average 1600 mg/L), north-east of the lake, this may be related inflow of water from the Leederville aquifer induced by groundwater abstraction. However, it is normal for an unconfined aquifer receiving rainfall recharge to be more saline at the base (Davidson 1995, Yesertener 2009)."*

Metals

Of the metals tested, boron was the only metal to exceed guidelines within Forrestdale Lake. Groundwater identified higher levels of arsenic, chromium, iron, and manganese.

> *"Boron was the only metal or metalloid detected in the lake at concentrations above the ANZECC guideline for freshwater ecosystems (Figure 41). Lake water samples from September and October 2007 had boron concentrations of 0.5 and 0.55 mg/L respectively. Lake water sampled in December 2009 had a higher concentration of 1.5 mg/L, four times the guideline for freshwater ecosystems. The higher concentrations in December are probably related to low water levels and evapo-concentration.*
>
> *Borate minerals are commonly found in internal drainage basins and salt lakes in arid and semi-arid environments (Garrett 1998). The concentration of boron in the lake is above that of the surrounding groundwater, suggesting that boron is being concentrated within the lake basin."*

> *"Groundwater exceeded irrigation guidelines for arsenic and chromium…Iron and manganese are commonly above the ANZECC guidelines for irrigation water but this is unlikely to be of concern."*

Nutrients

Bourke (2010) provides a sound summary of the nutrient concentrations within Forrestdale Lake and a comparison and likely interactions with the surrounding groundwater. This can be summarised as follows:

> *"The highest TN and TP concentrations (up to 9.5 mg/L TN and 0.99 mg/L TP) were in the water table bore closest to Forrestdale township (FRD_NEC). This might be related to leakage from septic tanks, and is evident throughout the Superficial aquifer in the NE bore cluster. FRD_WC also has high nutrient levels in October and November, possibly due to inflows through James drain, or inflow from the marshy area just west of this bore cluster."*

> *"Dissolved organic carbon (DOC) in the lake ranged from 32 to 51 mg/L, and groundwater concentrations ranged from 9 to 91 mg/L (Figure 47). The highest readings were at FRD_NEC and FRD_WC, and may be due to water drainage through James drain (at FRD_WC) and leakage from septic tanks (at FRD_NEC)."*

> *"Total nitrogen, total phosphorous and ammonia concentrations in Forrestdale Lake were above ANZECC trigger levels for lakes and wetlands in South West W.A (ANZECC 2000). Nutrients in the lake may also be produced through internal eutrophication and cation exchange in the presence of elevated sulfate concentrations (Beltman et al. 2000, Smolders et al 2006)."*

Summary Hydrochemical

Bourke (2010) summarised the hydrochemical analysis relating to the SGS program for Forrestdale Lake. It was noted that:

> *"Total nitrogen, total phosphorous and ammonia concentrations in Forrestdale Lake were above ANZECC trigger levels for lakes and wetlands. Nutrients in the lake could be sourced from groundwater inflow, drainage through James and Skeet drains, or produced through internal eutrophication."*

> *"Seasonal variation in salinity was observed in the watertable bores at the west at south-east drill sites. Salinities peaked during winter, reaching a maximum of 23,000 mg/L in June FRD_SEC and 11,000 mg/L in September FRD_WC. The overall trend in FRD_WC is of increasing salinity. Elevated salinity in FRD_SEC is likely to be related to the development of a plume of saline water east of the lake. Salinities in this plume are higher than the salinity of the lake measured at lowest water levels. Hydraulic gradients are into the lake from the eastern side, and this plume is likely to have developed through local evapotranspiration of water that ponds at the surface during winter."*

> *"The only metal that was detected above ANZEECC guidelines in Forrestdale Lake was boron. Borate minerals can form in evaporate basins and elevated concentrations in the lake could be due to dissolution of borate minerals within the lakebed sediments."*

> *"Chromium and arsenic concentrations above the irrigation guideline were in groundwater at the base of superficial aquifer. These concentrations were measured as total concentrations and include the contribution from suspended sediment in the water sample. Further testing of dissolved concentrations of should be carried out to determine if soluble concentrations of these metals are also above irrigation guidelines."*

> *"Forrestdale Lake is alkaline, with pH measured up to 10 in this study. The high alkalinity is probably maintained by the clay marl in the lakebed sediments, which contain significant stores of carbonate."*

2.8.2.6 SW-GW Interaction

One of the main points of the SGS study on Forrestdale Lake was to determine the surface water-groundwater interactions in order to help manage the system into the future. While not conclusive, the results of this study have shown that the system is likely to operate differently to the majority of wetlands on the Swan Coastal Plain (i.e. is not a flow-through groundwater fed lake) with respect to its interaction with groundwater. Further investigations are suggested and would be necessary to confirm the surface water – groundwater interaction.

> *"There is little evidence for perching of surface water above the clay lining the lake basin. Hydrographs suggest that there is a lag of approximately one month where lake water levels are higher than the water table immediately east and west of the lake, but water levels in the north-east are higher than the lake at this time. Finer resolution*

> *water level data of the lake and groundwater as they respond to rainfall would be required to fully resolve this question.*
>
> *The weight of evidence suggests that Forrestdale Lake is predominantly fed by local groundwater inflow. Data from this study shows that groundwater levels start rising with rainfall in April and the lake doesn't begin to fill until approximately two months later when water table is higher than the bottom of the lake basin. Presumably, when the lake sediments become saturated, groundwater seepage occurs from the surrounding dune system to replenish the lake. As regional groundwater contours are fairly flat, the lake appears to act as a local drainage basin, rather than relying on regional groundwater through-flow. Also, the lake bed is a shallow depression and surface water is likely to be subject to significant evaporation. As a result, the Influx of groundwater from the adjacent dune system during winter is likely to be the major contributor to the lake water balance. This is supported by modelling by CSIRO that suggests that only flow from within the immediate dune system contributes to the lake water balance and not through-flow from the broader regional aquifer."*

The CSIRO modelling (Barr *et al.*, 2009) referred to above identifies the Forrestdale Lake system as rainfall driven, not predominantly groundwater inflow; though notes groundwater interaction occurs only on the periphery within the immediate dunal system. This is explained in further detail within Section 2.8.5.

> *"…the lake and rainfall are least similar in ionic composition and the watertable bores generally plot between them. If the lake was predominantly fed by direct precipitation the lake and rainfall would be expected to plot closer together. This supports the interpretation that water in Forrestdale Lake is supplied by groundwater that has been recharged by rainfall."*
>
> *"Watertable contours show local groundwater gradients towards the lake basin during summer and winter. If there is any outflow from the lake at or near the watertable it would be to the south, where no bores have been installed and water levels are not known. High chloride concentrations east of the lake are considered to be the product of local evapo-concentration in that area, and are unlikely to be caused by a plume of saline water flowing out of Forrestdale Lake…The degree of saturation maintained over summer is likely to be important in determining the response of the lake levels to initial winter rains. That is, dryer conditions will mean that more rain will be*

> *required to initiate pooling of water in the lake basin, and thus may influence lake levels."*
>
> *"Water levels in FRD_NE and FRD_SE are above the lake basin in the summer of 2007-2008, even when the lake doesn't hold water. Bore site FRD_SE is outside of the dune system but FRD_NE is on the inside flank of the lake basin so higher groundwater levels here suggest a seepage face on the north-eastern side of the lake. This is supported by aerial photography from 2009 that shows green vegetation in this area even during summer when the lake is dry."*

While this study has revealed a significant amount of detail relating to the groundwater within the vicinity of Forrestdale Lake and identifying the possible groundwater-surface water interaction, most of which contradict the previously held belief that Forrestdale Lake was a through-flow lake; it would be worthwhile developing an overall water balance for Forrestdale Lake that also takes into account further environmental driven processes such as rainfall and evapotranspiration.. Bourke (2010) has also noted that finer resolution monitoring would be required to fully resolve the question of groundwater - surface water interaction.

2.8.2.7 Bioscience Water Level Review

A review of FRD bores hydrographs was completed to determine their suitability for comparison against Forrestdale Lake water levels. The FRD bores are all nested locations with three monitoring bores (shallow, intermediate and deep superficial bores) being located at each site. In general, all monitoring had similar hydrographs with peak winter levels in September and minimum summer water levels in March. Water levels varied between seasons ranging from 1.4m to 2.5m between the minimum and maximum recorded values (**Figures 26-30**). Perching seems evident within the North East and South East bores. These locations closely align with the areas in which ERM (2000) suggest that groundwater catchment outflow occurs.

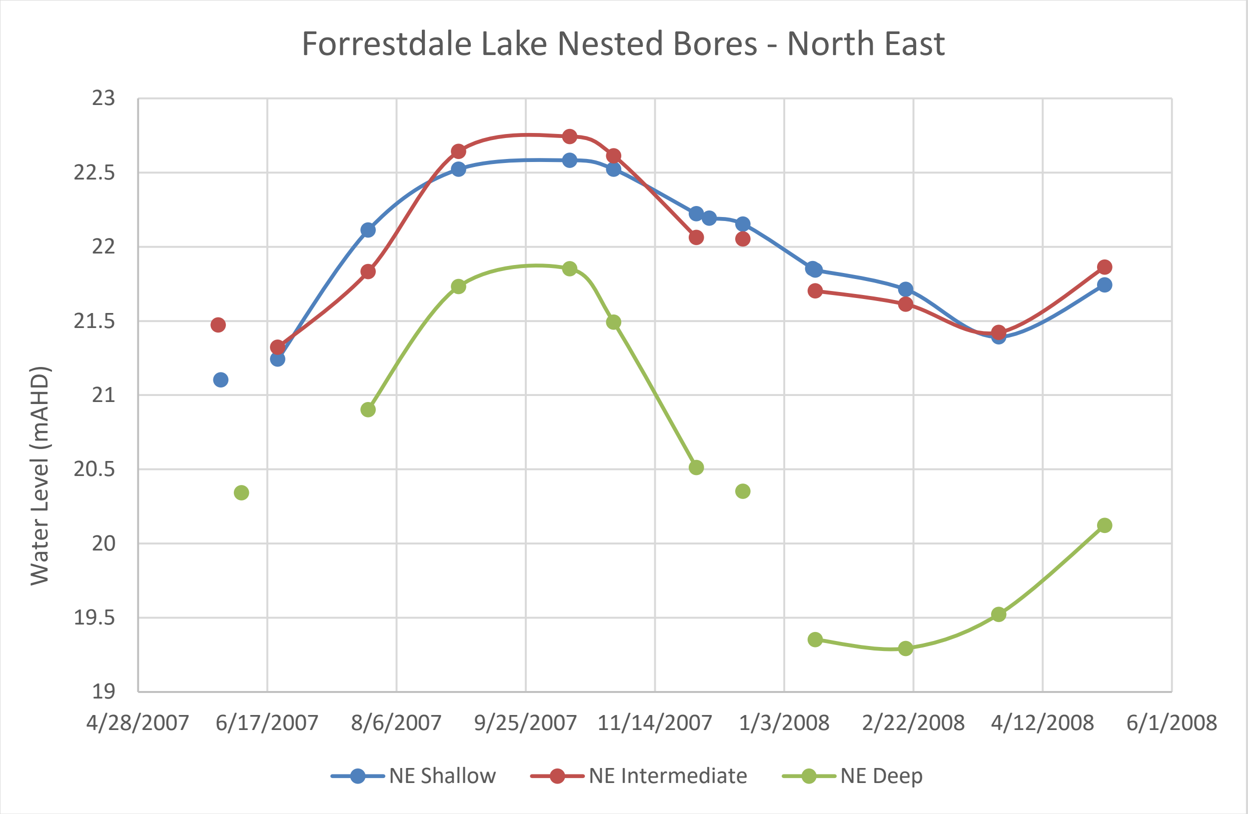

Figure 26: Forrestdale Lake Nest Bores – North East

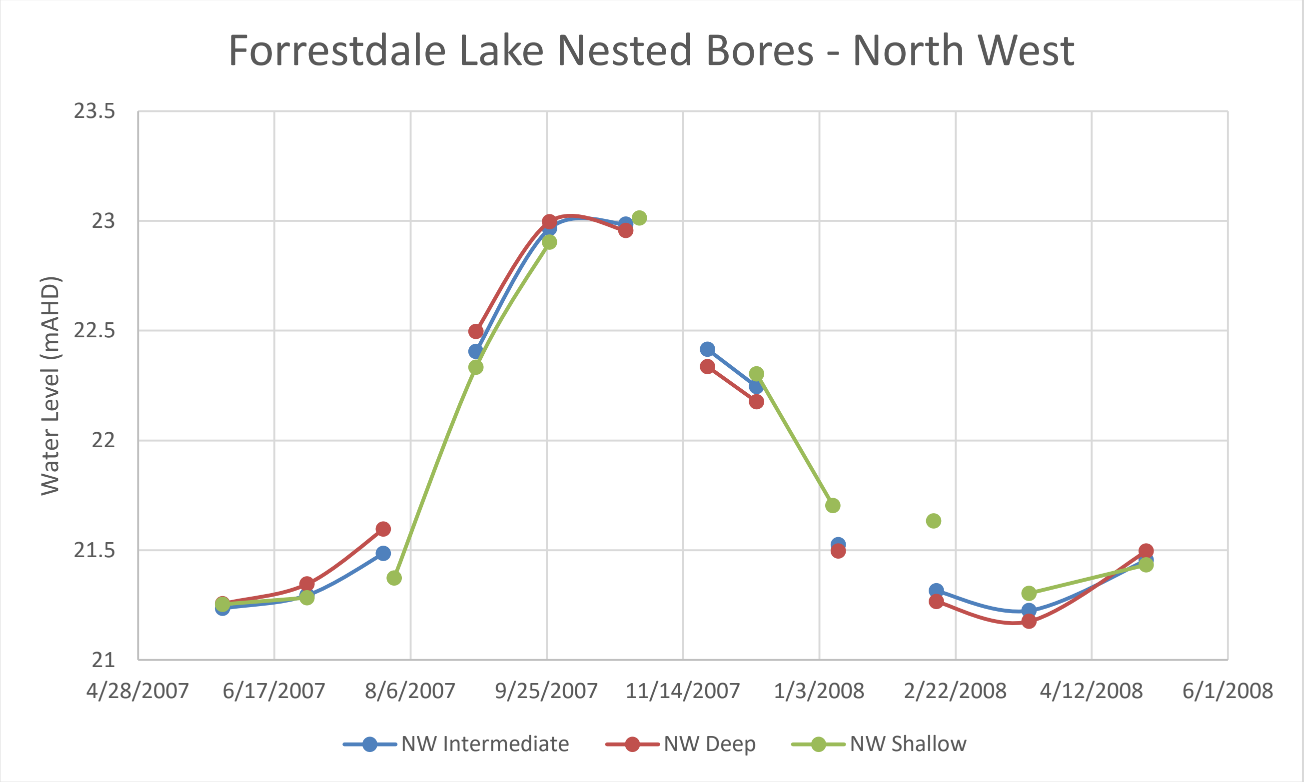

Figure 27: Forrestdale Lake Nest Bores – North West

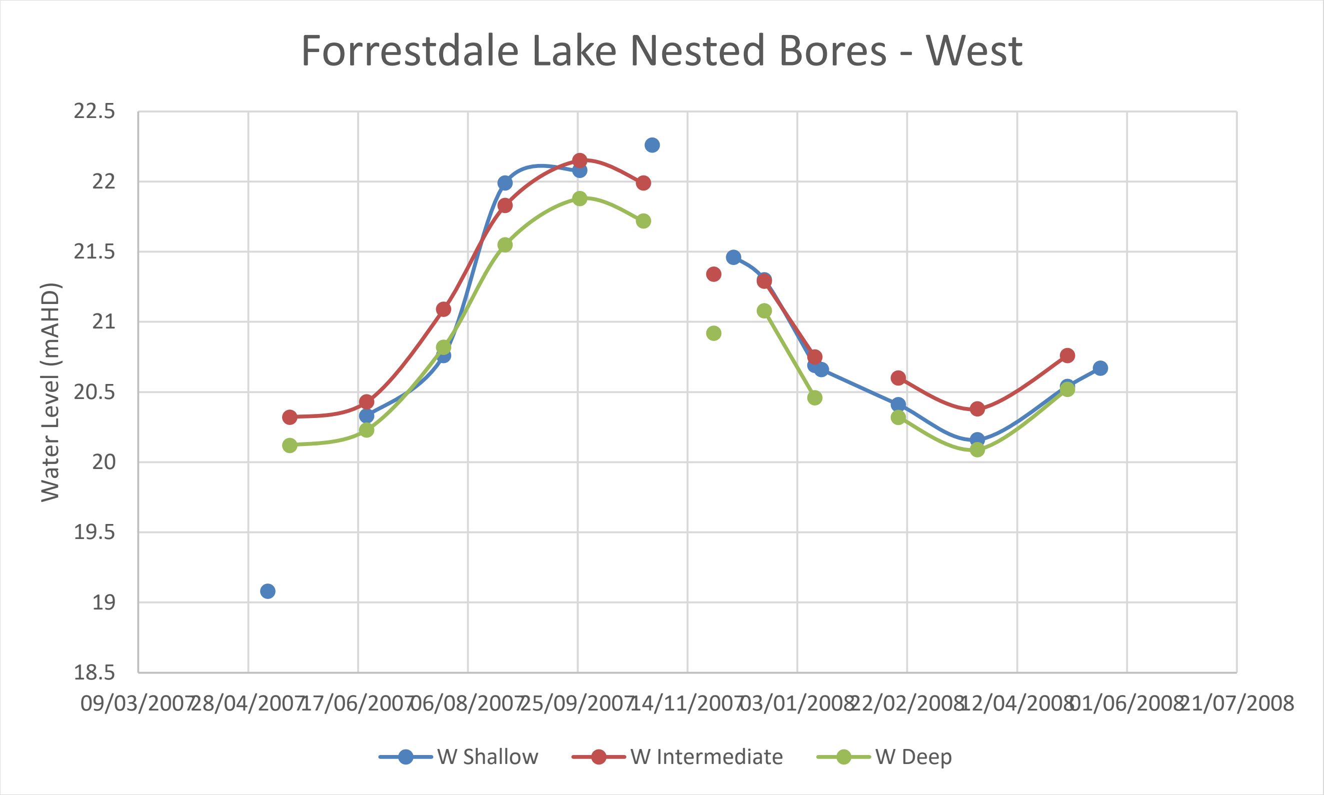

Figure 28: Forrestdale Lake Nest Bores – West

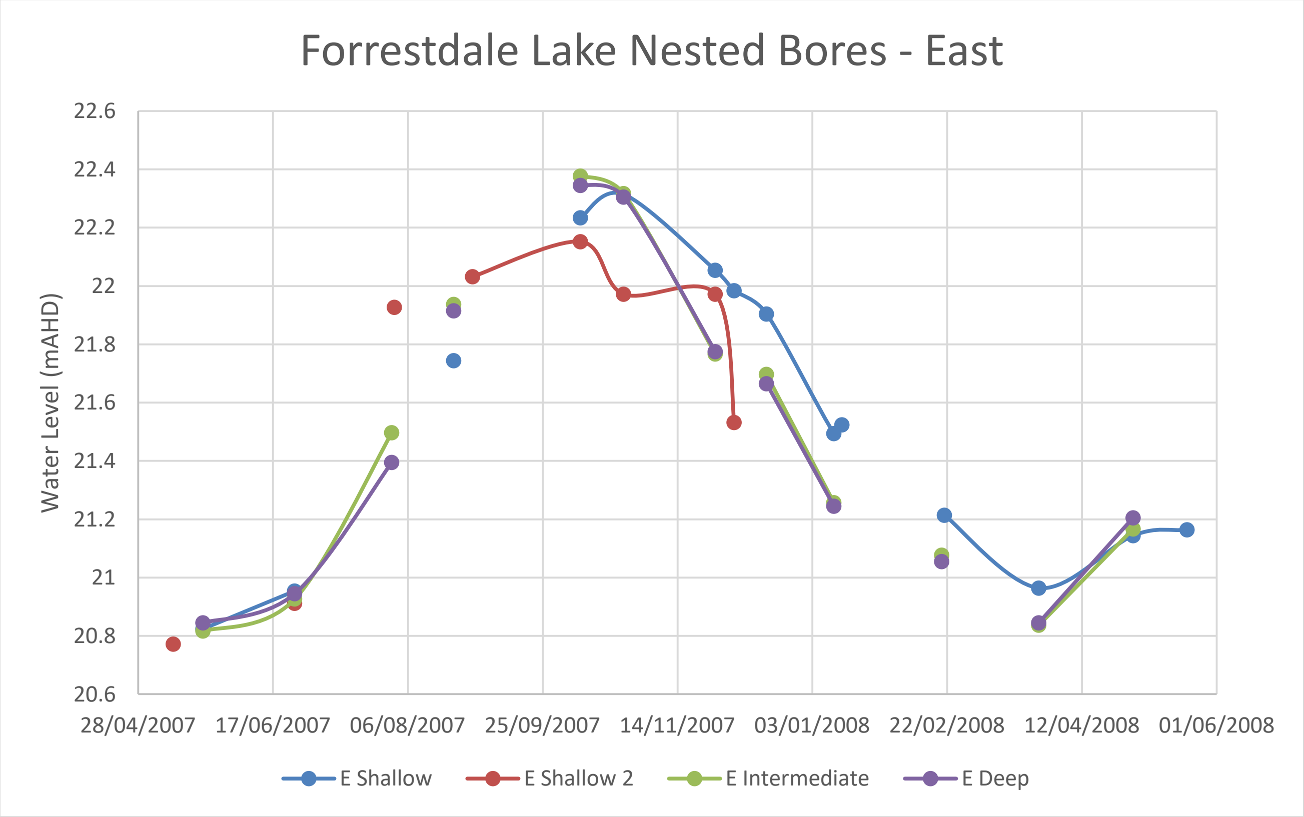

Figure 29: Forrestdale Lake Nest Bores – East

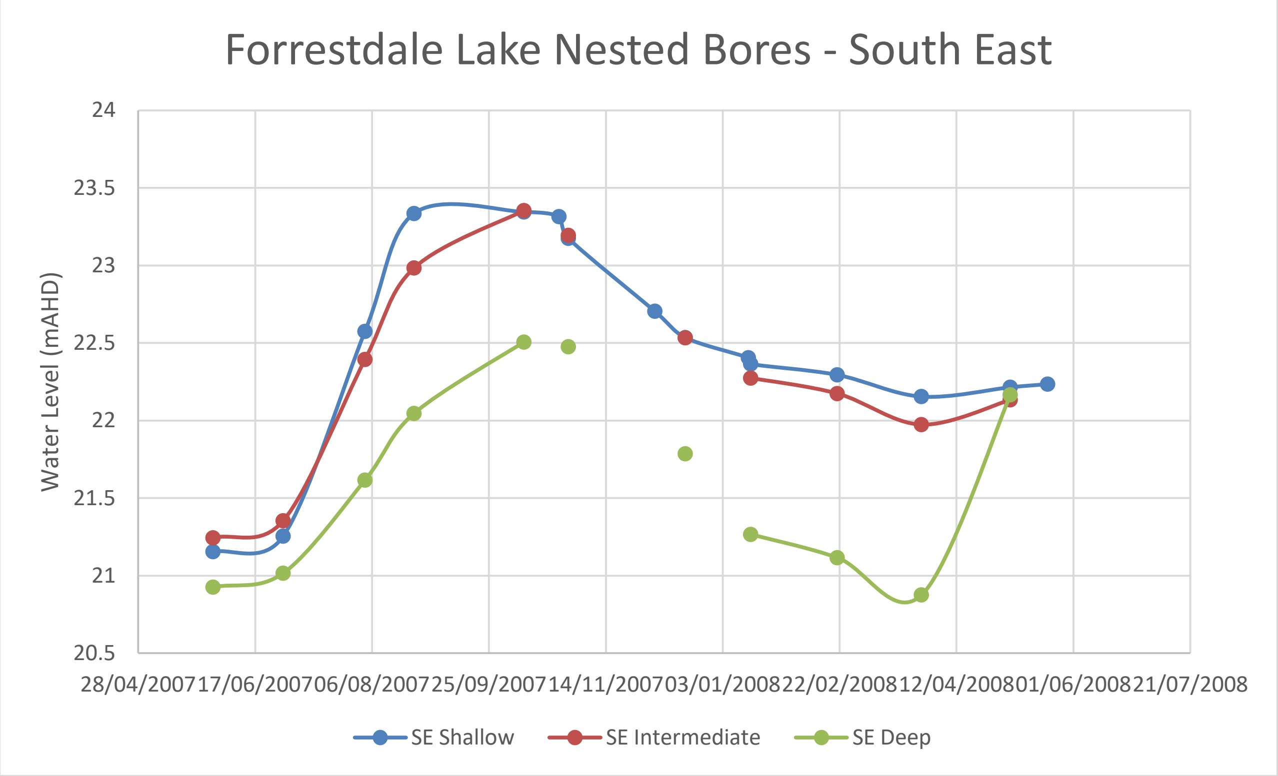

Figure 30: Forrestdale Lake Nest Bores – South East

Figure 31 provides a hydrograph for a single year during the period in which the FRD bores where monitored (22/05/2007 to 21/05/2008) against measurements made in Forrestdale Lake and along with rainfall data. As all nested bores showed similar responses, a single monitoring bore for each location has been provided for the ease of reviewing the results.

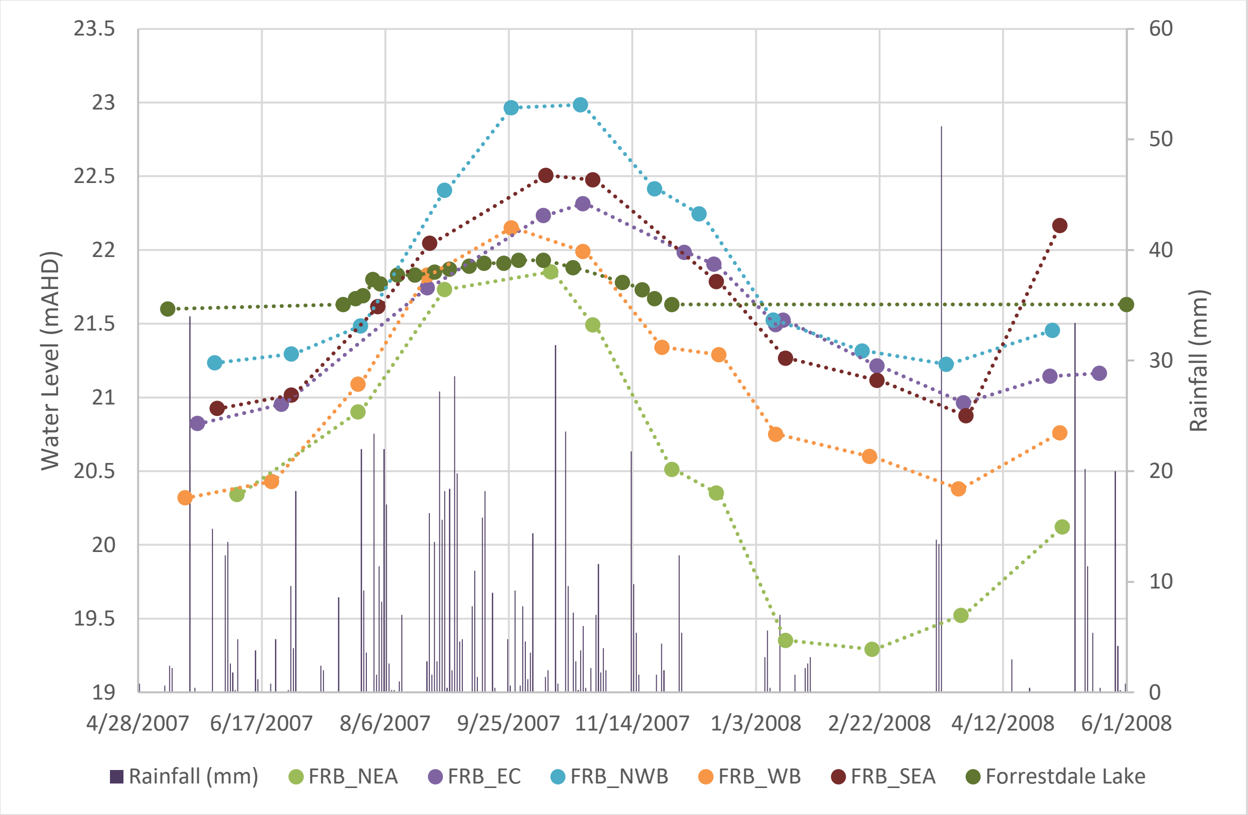

Figure 31: Local Groundwater Levels versus Forrestdale Lake 2007-2008

Initial smaller rainfall events during autumn (April and May) do not seem to have an effect on both groundwater levels nor Forrestdale Lake. While it is widely known that a delay to water level response in the superficial aquifer occurs from rainfall within the Swan Coastal Plain, it could be expected that water levels within Forrestdale Lake would respond quicker. This lag could be associated with the wetting of the catchment prior to runoff occurring. It is also likely that soil/sediment profile of the lake bed has a significant water holding capacity and therefore water levels would not be recorded until such time as this capacity is exceeded. The stratigraphy of finely silty sands (lacustrine deposits) previously identified suggest this is possible and may be the case. Bourke (2009) also noted that 445mm of rainfall occurred in 2008 prior to water levels being observed in Forrestdale Lake, further supporting this theory.

Forrestdale Lake water levels begin to increase after this saturation point, though before groundwater levels rise above lake levels. ERM, 2000 noted that a rise of up to 300mm was rainfall driven prior to the system being groundwater driven, with the system being subdued until groundwater levels support the Lake. If this was the case, the initial catchment area for Forrestdale Lake would be small and once groundwater levels reached a certain level, in this case above 21.7mAHD near the boundary of Forrestdale Lake, the catchment area would take into account the groundwater catchment. This would provide an influx of inflow and thus a response to this would be evident in lake levels. As is clear in **Figure 31**, water levels rise at a relatively consistent rate and conversely decrease at a similar rate in response to increases and decreases in winter rainfall. This response may still be groundwater or rainfall dependant, thought the temporal sampling resolution of one month is too large to determine these affects, as alluded to previously by Bourke (2009).

Water Levels within the FRD bores are shown to have a delayed water level relative to rainfall with up to four months required after winter rainfalls are complete prior to water levels dropping to pre-winter levels. The water levels within Forrestdale Lake start declining through winter as reduced rainfall occurs coming into the spring period. If Forrestdale Lake was groundwater driven, the water levels would continue closer to its peak for this additional three to four months associated with higher groundwater levels. Furthermore, ERM, 2000 noted that groundwater will only discharge to the lake when elevations are above approximately 21.7mAHD. The Forrestdale Bores show most locations with levels well above 21.7mAHD (up to 1.3m above) and that if this connection existed as ERM, 2000 states, Forrestdale Lake water levels would continue longer than measured and would follow the groundwater hydrograph closer.

Bourke (2009) has not explained the slower decline in groundwater levels, while Forrestdale Lake has declined quite markedly. It is acknowledged that evapotranspiration will affect Forrestdale Lake much more than the superficial groundwater. However, if groundwater is connected as alluded to, based on a groundwater gradient, the water levels observed would still provide groundwater input into the lake. It is possible that the groundwater inflow at this point occurs, though at a lower rate than evaporation and therefore static water is not observed. This has not verified as yet and finer resolution monitoring would probably be required to confirm if this is the case.

2.8.3 Surface Water – Groundwater Modelling Report (CSIRO, 2009)

The Southern River catchment, in which Forrestdale Lake is a part of is under significant pressure from urban development. Development is challenged by high groundwater levels, generally 1-2m below ground level, as well as significant wetlands including Forrestdale Lake. CSIRO was granted funding to develop a detailed hydrological model of the Southern River catchment. A coupled MODHMS surface water – groundwater model was developed as part of this scope. This process-based model allowed simultaneous simulation of water interception and evaporation from vegetation, infiltration, runoff, drainage and groundwater flows (Barr *et al*., 2009).

Barr *et al.* (2009) concluded that "*Forrestdale Lake receives very little groundwater inflow and, due to the low conductivity of the bottom sediments in the lake, infiltration to the underlying aquifer is not a large component of the water balance. Forrestdale Lake receives most of its water from rainfall on the lake and the surrounding dunes.*" and "*the lake is currently dry 99 days each year on average. In the model an increase of 10% in the average annual rainfall decreased the number of dry days by 21. A decrease of 10% in the average annual rainfall resulted in an increase of 25 days in the average time the lake was dry.*" These results note that a small change in rainfall makes a reasonably large change to water levels, in particularly the time of inundation.

> "*Figure 26 shows the observed and simulated water levels in Forrestdale Lake for the period 1997-2006. Table 10 contains the statistical measures for model effectiveness in the simulation of the lake*

level. These show excellent results for the scaled mean sum of residuals (SMSR) and coefficient of determination (CD), with acceptable results for the other statistical measures. These statistics give an indication of the closeness of the simulation results to the observations."

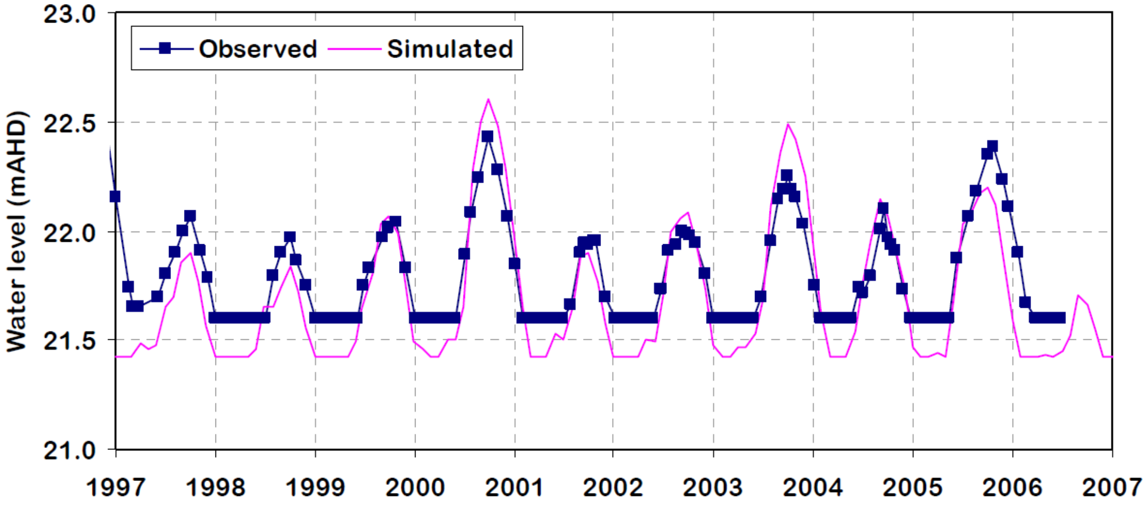

Figure 26 Model validation: observed and simulated water levels in Forrestdale Lake

Figure 32: Model validation: observed and simulated water levels in Forrestdale Lake

"The model reproduces well the seasonal changes in the water level in the lake with some over-prediction in the maximum level in the lake. The agreement between observed and modelled data related to the time of the rise and fall in the water levels allows suggesting that processes which lead to these changes in water levels are also well replicated by the model.

Figure 27 shows the inundation duration curves for Forrestdale Lake for both simulated and observed data over the simulation period (1997-2006). The model results show good agreement with the observed data."

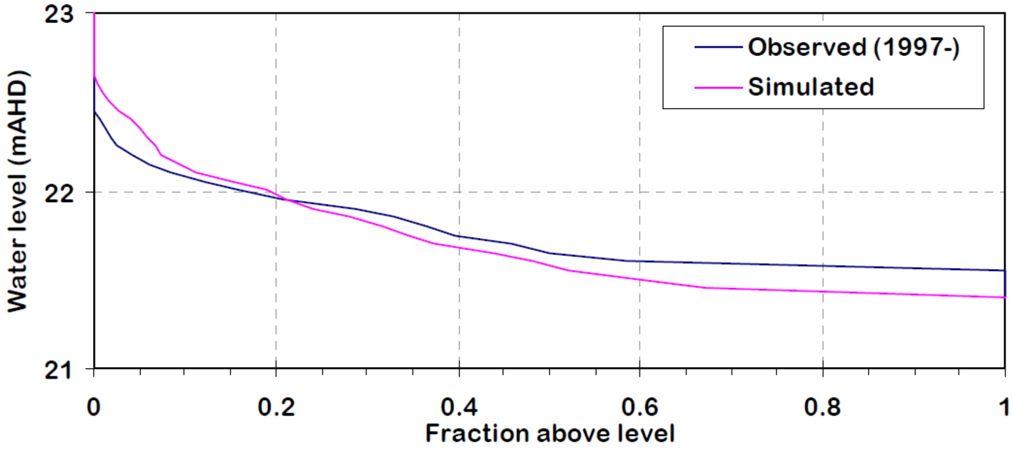

Figure 27 Inundation duration curves for Forrestdale Lake for simulated and observed data

Figure 33: Inundation duration curves for Forrestdale Lake for simulated and observed data

These results suggest that the model is reasonably accurate at determining water levels within Forrestdale Lake and that the inputs and assumptions are accurate. Therefore, this would suggest that Forrestdale Lake is predominantly rainfall driven.

The report also identified the simulated annual average recharge to the aquifer. Under Forrestdale Lake this represented low infiltration (approximately 50% recharging 0-100mm, and 50% recharging 101-200mm) compared to the catchment average of 400-500mm under Bassendean Sands. "*The areas of low recharge at Forrestdale Lake and other wetlands on the Bassendean Sands have low-permeability lacustrine sediments in the surface layer and thus a low rate of infiltration and recharge. Extremely high rates (>500 mm) of recharge were found in low-lying areas of Bassendean Sands adjacent to lacustrine deposits, indicating some overflow from the wetlands on these deposits."* This small area on the eastern side of Forrestdale Lake would be the area of interaction between groundwater and surface water and thus it could be predicted that groundwater inflow would be minimal relative to rainfall (**Figure 34**).

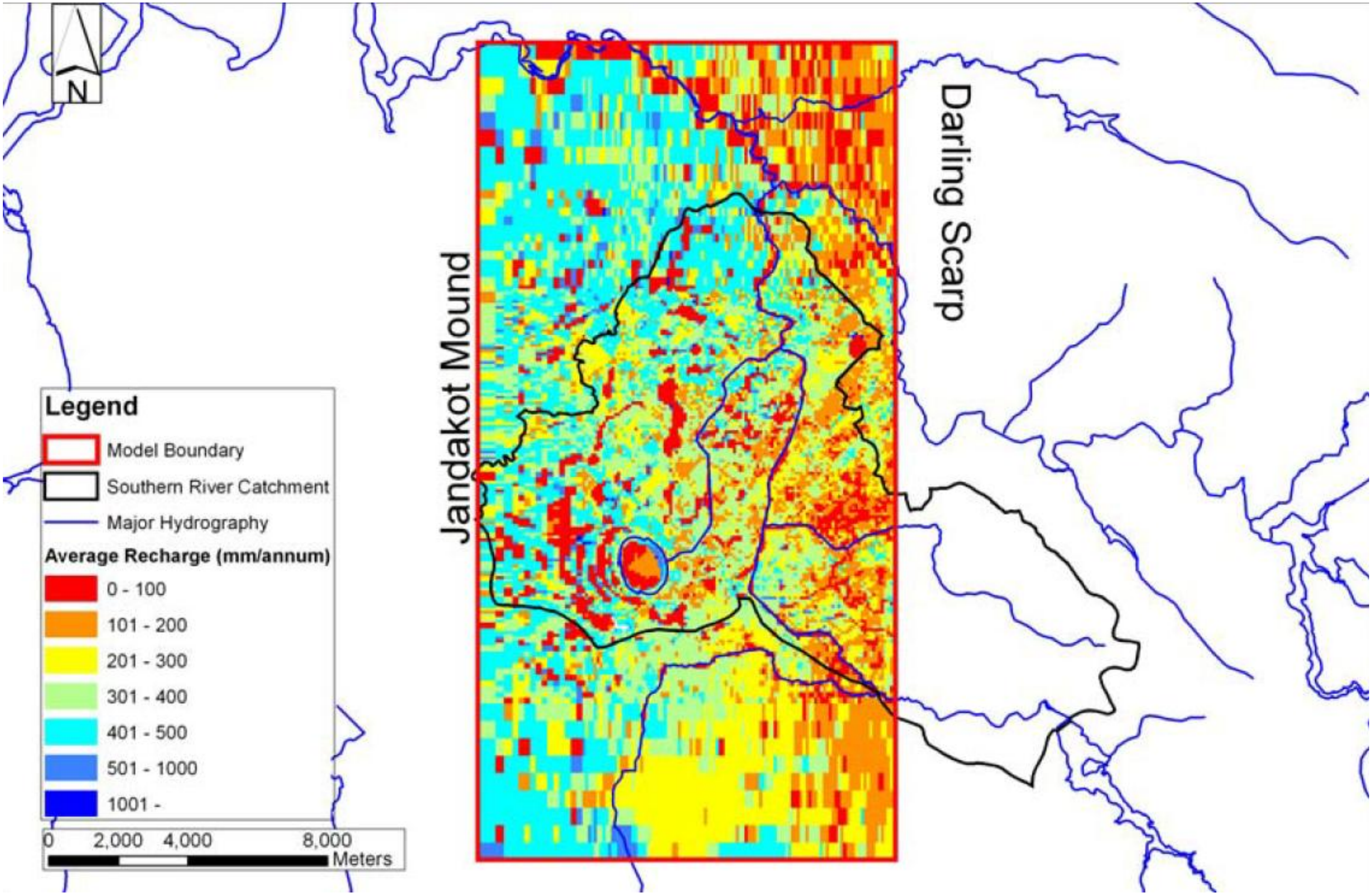

Figure 34: Simulated Average Annual Recharge Rates

> *"The variation in wetland hydraulic cycle was studied in four wetlands: Forrestdale Lake, Armadale Road wetland, Harrisdale Swamp, and Lake Balannup. Figure 52 shows Inundation Duration Curves (IDCs), similar to Flow Duration Curves frequently used in hydrology, for these wetlands."*
>
> *"The IDC for Forrestdale Lake shows that the water level in the lake is very sensitive to rainfall. Over the ten-year simulation period, the lake level is essentially dry 32% (116 days), 26% (94 days) and 21% (76 days) of the time for the drier, current and wetter scenarios respectively. There are greater differences at the higher lake levels. For the drier climate scenario, the lake rarely exceeds 0.7 m depth, whereas it exceeds this level for 10% and 20% of the simulation time for the current and wetter climates. This suggests a significant level of lake water balance dependence on rainfall."*

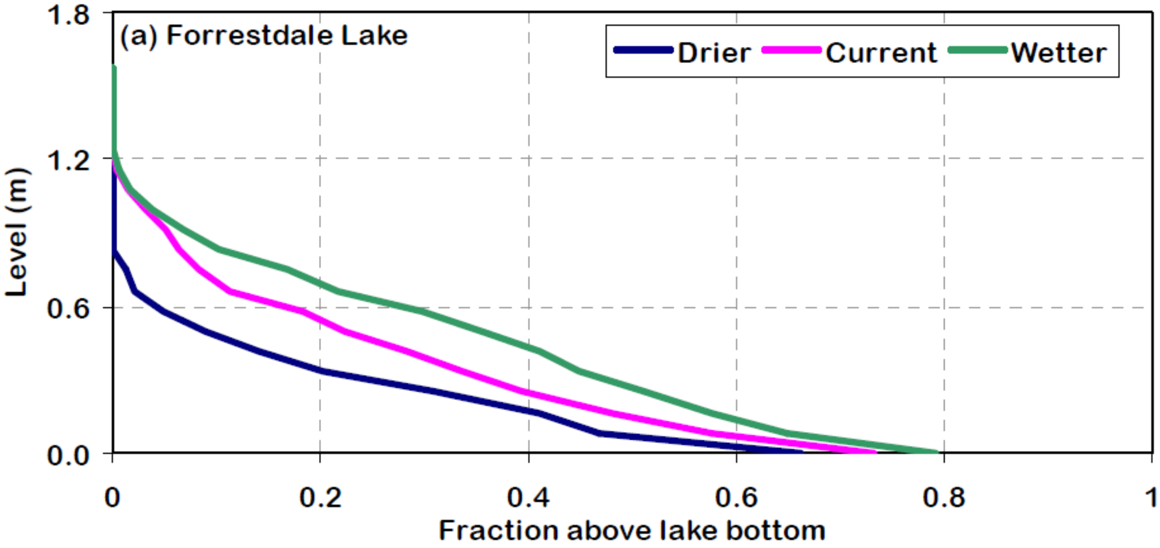

Figure 35: Inundation Duration Curves Forrestdale Lake (various climate scenarios)

> *"Apart from the wetland on Wungong Brook close to Armadale Rd, which is mainly a flow-through wetland, Forrestdale Lake, Harrisdale Swamp and Lake Balannup exhibit water levels that are strongly dependent on climate."*
>
> *"…perched wetlands such as Forrestdale Lake are predominantly surface water fed and the level in the lake is strongly dependent on rainfall. A 10% increase in rainfall increased the average level in the lake by 8 cm, decreasing the average time the lake was dry by about 21 days, and increasing the average time the lake depth was greater than 50 cm by 42 days. A decrease of 10% in the rainfall decreased the average lake level by 10 cm, increased the time the lake was dry by an average of 25 days a year and decreased the time the lake level exceeded 50 cm by 48 days."*

The *Barr et al.* (2009) report has clearly demonstrated that through a detailed regional hydrologic groundwater – surface water model and calibration to real-time data that water levels in Forrestdale Lake are driven by rainfall with very little interaction with the local and regional groundwater system.

2.9 Vegetation

The Study Area is within the Swan Coastal Plain Biogeographic Region of the Southwest Botanical Province (Thackway and Cresswell 1995, Paczkowska and Chapman 2000), an area that extends from Jurien Bay to the north to Dunsborough to the south, and west of the Darling Scarp. Historically this biogeographic region has been extensively cleared for both urban and agricultural purposes.

The site is essentially cleared with sporadic Melaleuca preissiana and Kunzea glabrescens occasionally over native sedges such as Gahnia trifida. A number of non-endemic eucalypts are also present. It has historically been used for grazing of stock and as such has resulted in highly degraded vegetation consisting mainly of introduced pasture grasses.

Bioscience conducted a modified Environmental Protection Authority's Guidance 51 Vegetation Survey (EPA 2004) Level 1 flora and vegetation assessment which consisted of both desktop assessment and site investigation as outlined below:

A desktop study of potential rare and endangered flora and ecological communities listed under the Wildlife and Conservation Act 1950 and EPBC Act 1999 was undertaken by analysis of the following databases:

- NatureMap: Western Australia's biodiversity online mapping (DEC 2011)
- Florabase: WA Herbarium guide to Western Australian Flora online (Western Australian Herbarium, 1998)
- Protected Matters: National Environmental Significance online mapping (DoSEWPaC 2010)

A site investigation of all flora and vegetation units present was conducted by Bioscience however the vegetation was so degraded that the protocols for a Level 1 or a Level 2 EPA Guidance 51 assessment could not be applied. Accordingly, Bioscience undertook a modified vegetation survey of the subject land involving a careful walk-through of all areas containing native vegetation to document all species present. The area within Lot 12 which is mapped as Bush Forever and has been fenced off does not form part of this assessment. The landowner, Mr Stephen Catellani, acknowledges that his Bush Forever land will not be part of the rezoning, but rather will eventually be acquired by WAPC under a negotiated settlement.

The local vegetation complex is Bassendean central and south with an area towards the north of the property being the Southern River complex. The dominant species should be: *Eucalyptus marginata* and *Eucalyptus todtiana*, with *Eucalyptus rudis* along creek lines. There should also be *Allocasuarina fraseriana, Acacia saligna* and *Melaleuca rhaphiophylla* and *Banksia* spp. in the area (Heddle et al. 1980).

The site visit found that the Study Area can be subdivided into three vegetation zones or areas:

- Melaleuca zone –Woodland dominated by *Melaleuca preissiana* of varying size and several *Melaleuca rhaphiophylla*. The understorey consists mainly of cape weed, arum lily and invasive grasses. Soils were higher and drier than the surrounding land.

- Mixed Woodland – Consisting of a mixture of small Tuart (*Eucalyptus gomphocephela*), along with *Melaleuca preissiana*, *Melaleuca rhaphiophylla* and *Allocasuarina fraseriana*. This was heavily grazed and the understorey consisted of mixed grasses and broad leaf weeds.
- The remainder of the properties are made up of a pastureland of mixed grasses, but with a large number of invasive weeds, including; lupins (*Lupinus cosentinii*), cape weed (*Arctotheca calendula*), *Pelargonium capitatum*, *Euphorbia terracina* and arum lilies (*Zantedeschia aethiopica*). The properties have been grazed for at least 45 years and the native vegetation has been degraded. The tree cover consisted of a number of introduced species, along with a few Marri (*Corymbia calophylla*).

Further information on vegetation is included within the Environmental Impact Assessment (Bioscience, 2015), **Appendix H**.

2.9.1 Flora of Conservation Significance

A search on DEC's NatureMap online indicated that five Declared Rare Flora (DRF) and 14 Priority flora exist within 5km of the centre of the subject site (32° 10' 23 S, 115° 56' 41 E) (**Appendix I**). Of the DRF and Priority flora 5 are listed under the *EPBC Act* (1999) as endangered (**Table 9**). However, due close proximity to Lake Forrestdale Nature Reserve it is suspected that majority species listed in the search may belong to the protected area within and surrounding Lake Forrestdale. Accordingly, a narrower search of 1 km was conducted (largely encompassing the subject site only) revealing no listed DRF or Priority flora. The purpose however of conducting a broader search of the DEC NatureMap database is based on accuracy of the search data and as such DRF and Priority flora from the broader search were considered.

Table 9: DRF and Priority Flora within search area (NATUREMAP, accessed 15/09/2016)

Species	Conservation Code	EPBC Act Category
Byblis gigantea (Rainbow Plant)	Priority 3	-
Caledenia huegelii (Grand Spider Orchid)	Threatened (DRF)	-
Chordifex jacksonii	Priority 3	
***Diuris purdiei* (Purdie's Donkey Orchid)**	Threatened (DRF)	Endangered
***Drakaea elastic* (Glossy-Leaved Hammer Orchid)**	Threatened (DRF)	Endangered
Drakaea micrantha	Threatened (DRF)	Endangered
Drosera occidentalis ssp. occidentalis	Priority 4	-
Jacksonia gracillima	Priority 3	-
***Jacksonia sericea* (Waldjumi)**	Priority 4	-
Lepidosperma rostratum	Threatened (DRF)	Endangered
Ornduffia submersa	Priority 4	
Schoenus pennisetis	Priority 3	-
Stylidium aceratum	Priority 2	
***Stylidium longitubum* (Jumping Jacks)**	Priority 4	-
Stylidium paludicola	Priority 3	
***Tetratheca* sp. *Granite* (S. Patrick SP1224)**	Priority 3	-
Thysanotus glaucus	Priority 4	
Tripterococcus sp Brachylobus (A.S. George 14234)	Priority 4	
Verticordia lindleyi* ssp. *lindleyi	Priority 4	-

No DRF or Priority flora was identified within the subject area, however this is not to say that they are not present as the survey was not conducted during spring whilst plants are flowering. DPaW have noted that some of the species, specifically *Dralcaea elastica, Lepidospenna rostratwn* and *Austrostipa jacobsiana* and *Ptilotus sericostacllyus* subsp. *roseus* may exist in degraded areas (**Appendix J**). Further vegetation surveys will be required to specifically target these species and confirm the presence/absence of the species prior to the conclusion of structure planning.

2.9.2 Threatened Ecological Communities

The DPaW aims to conserve Western Australia's biological diversity by identifying elements that are under threat and seeking to offer protection. An 'ecological community' is a naturally occurring biological assemblage or group of plants and/or animals (or other living things such as microbes) that occurs in a particular type of habitat. Together with their habitat, ecological communities form ecosystems.

A threatened ecological community (TEC) is one that has been endorsed by Western Australia's Environment Minister as being subject to processes that threaten to destroy or significantly modify it across much of its range. It must also fit into one of the categories 'presumed totally destroyed', 'critically endangered', 'endangered' or 'vulnerable'. TECs may be at risk from threatening processes including land clearing, inappropriate fire regimes, inappropriate grazing, trampling, pollution, competition or predation from introduced animals, weed invasion, hydrological changes, salinity and diseases.

The list of Threatened Ecological Communities (TEC) from the Department of Parks and Wildlife's TEC Database indicates no TECs are likely to be present within the subject area. This is consistent with field observations by Bioscience environmental scientists, as reported in the Environmental Impact Assessment.

It is noted that two TECs are present within the Bush Forever 345 associated with Forrestdale Lake. One is type 8 – 'Herbrich shrublands in clay pans', and the other type 10a – 'Shrublands on dry clay flats'.

Community type 8 consists of clay pan communities that can be dominated by *Viminaria juncea*, *Melaleuca viminea*, *M. lateritia* or *M. uncinata* but occasionally by *Eucalyptus wandoo*. Aquatic annuals are also common (Gibson *et al.* 1994). Community type 8 is listed in Western Australia as 'vulnerable'.

Community type 10a forms on the most rapidly drying of the clay flats. It contains aquatic annuals and geophytes such as *Schoenus natans*, *Crassula natans* and *Amphibromus neesii* (Gibson *et al.* 1994). Community type 10a is listed in Western Australia as 'endangered'.

2.10 Fauna

A desktop study of potential rare and endangered fauna listed under the *Wildlife and Conservation Act 1950* and *EPBC Act 1999* was undertaken by analysis of *NatureMap:* Western Australia's biodiversity online mapping (DPaW, 2016). A site investigation was conducted by Bioscience for the presence of rare and endangered fauna and fauna habitat. Fauna survey of the subject land involved a careful walk-through of the subject area documenting all native species present and presence of fauna habitat.

The subject area has been historically cleared for making it largely devoid of native vegetation as a result there is very little habitat for native fauna. Site inspection indicated very little native fauna habitat and evidence of introduced species. Some of the existing Melaleuca and Eucalyptus trees provide some food and habitat for passing native birds. Pastureland is likely to attract some native grazing animals such as Kangaroos residing in neighbouring bushland, however for the most part, the properties have substantial cattle fences restricting such use.

A search on DEC's *NatureMap* online indicated that eight Threatened, six Priority and one specially protected fauna exists within 5km of the centre of the subject site (32° 10' 23 S, 115° 56' 41 E) (**Table 10**). Of those Threatened and Priority fauna two are listed as Vulnerable (Numbat and Black-Cockatoo), three listed as Endangered (Australasian Bittern, Curlew Sandpiper, and Carnaby's Cockatoo) and two are listed as Critically Endangered (two Native Bees) under the EPBC Act 1999. In addition to Threatened and Priority fauna eighteen species of migratory bird are listed under international agreement (Japan - JAMBA, China - CAMBA, and Korea - ROKAMBA) under the EPBC Act 1999. However again due close proximity to Lake Forrestdale it is suspected that the species listed in the search reside within the protected area within and surrounding Lake Forrestdale (particularly migratory birds under international agreement) as such a narrower search of 1 km was conducted revealing only one individual listed as a Priority 5 species (Bandicoot) and one bird under international agreement (Rainbow Bee-eater). The purpose however of conducting a broader search of the DEC NatureMap database is based on accuracy of the search data and as such Threatened and Priority fauna from the broader search was considered.

Table 10: Conservation Fauna within search area (NATUREMAP, accessed 15/09/2016)

Species	Conservation Code	EPBC Act Category
***Apus pacificus* (Fork-tailed Swift)**	IA	-
***Ardea ibis* (Cattle Egret)**	IA	-
Ardea modesta (Eastern Great Egret)	IA	
***Arenaria interpres* (Ruddy Turnstone)**	IA	-
Botaurus poiciloptilus (Australasian Bittern)	T	Endangered
***Calidris acuminate* (Sharp-tailed Sandpiper)**	IA	-
***Calidris ferruginea* (Curlew Sandpiper)**	T	Endangered
***Calidris melanotos* (Pectoral Sandpiper)**	IA	-
***Calidris ruficollis* (Red-necked Stint)**	IA	-
***Calidris subminuta* (Long-toed Stint)**	IA	-
***Calyptorhynchus banksii subsp. naso* (Forest Red-tailed Black-Cockatoo)**	T	Vulnerable
***Calyptorhynchus latirostris* (Carnaby's Cockatoo (Short-Billed Black Cockatoo))**	T	Endangered
***Charadrius leschenaultia* (Greater Sand Plover)**	IA	-
***Falco Peregrinus* (Peregrine Falcon)**	S	-
***Haliaeetus leucogaster* (White-bellied Sea-Eagle)**	IA	-
***Hydromys chrysogaster* Water-rat**	P4	
***Isoodon obesulus* ssp. *fusciventer* (Southern Brown Bandicoot)**	P5	-
***Leioproctus contrarius* (Bee)**	P3	-
***Leioproctus douglasiellus* (A Short Tongued Bee)**	T	Critically Endangered
***Lerista lineata* (Perth Slider, Lined Skink)**	P3	-
Limosa Limosa (Black-tailded Godwit)	IA	
***Merops ornatus* (Rainbow Bee-eater)**	IA	-
***Macropus irma* (Western Brush Wallaby)**	P4	
***Myrmecobius fasciatus* (Numbat)**	T	Vulnerable
***Neopasiphae simplicior* (Bee)**	T	Critically Endangered
Oxyura australis (Blue-billed Duck)	P4	
***Plegadis falcinellus* (Glossy Ibis)**	IA	-
***Pluvialis fulva* (Pacific Golden Plover)**	IA	-
***Pluvialis squatarola* (Grey Plover)**	IA	-
***Stercorarius longicaudus* (Long-tailed Skua)**	IA	-
***Tringa glareola* (Wood Sandpiper)**	IA	-
***Tringa nebularia* (Common Greenshank)**	IA	-
Westralunio carteri (Carter's Freshwater Mussel)	T	

According to EPA's *Guidance Statement Number 33 – Environmental Guidance for Planning and Development* (2008), fauna is best protected by retaining bushland areas. In the Study Area, the majority of the native vegetation is cleared and has been for a significant period of time (over 45 years). It is highly likely that apart from some birds, invertebrates, small vertebrates (i.e. lizards) and few larger vertebrates such as Kangaroos, very few other fauna species inhabit the Study Area.

The Department of Environment and Energy's website (accessed 09/09/2016) notes:

> *"Neopasiphae simplicior is restricted in range, and is thought to only occur in a single location within the bushland of the Forrestdale Lake Nature Reserve adjacent to Forrestdale Lake and the Armadale Golf Course, with a previous population known from Cannington (Perth's southern suburbs). Forrestdale Lake is located on the southern fringes of Perth's metropolitan area, and is one of the few remaining examples of the lakes and vegetation originally found on the Swan Coastal Plain. Only 20% of all the wetlands that once existed now remain, therefore it is likely that suitable habitat for this species has been cleared (Houston 1994).*
>
> *The current extent of occurrence is approximately 1 km² within the Forrestdale Lake Nature Reserve. No other extant populations are known, with the only previous record from Cannington in 1954 (Houston 1994). Given that the Cannington population is presumed to be extinct this suggests a significant decline in the historical extent of occurrence for the species."*

Noting that this population is located directly north of the Study Area, it is vital that as part of any future development that habitat creation is considered to potentially extend the foraging range of the species. DPaW's previous correspondence (**Appendix J**) has also suggested this be incorporated within the design of the development. The species has been collected only on flowers of

- Thread-leaved Goodenia (*Goodenia filiformis*), an erect to ascending, slender perennial herb up to 0.25 m high, occurring on sandy soils and winter-wet depression, flowering between November to January
- Slender Lobelia (*Lobelia tenuior*), a slender erect annual herb to 0.5 m high, occurring on sand dunes, coastal limestone and low-lying areas, flowering between October to January
- *Angianthus preissianus*, an erect or prostrate annual herb up to 0.16 m high, occurring on sand and clay and favouring saline habitats, winter-wet flats, claypans and granite rocks, flowering between October to December
- *Velleia* sp. (Department of Environment and Energy website, accessed 09/09/20 16).

The Male is also known to roost overnight in flowers of Asteraceae, and in most cases, the flowers are low-growing ephemerals (Houston 2000). *Neopasiphae simplicior* is associated with the two listed threatened ecological communities, Type 8 and Type 10a (Department of Environment and Energy website, accessed 09/09/216). The conservation advice is included in **Appendix K**.

2.11 Contamination

According to the DEC's Contaminated Sites Database Lots 5, 7, and 9 Oxley Road, Lot 6, 8, 10 and 200 Rowley Road and 5066 Kargotich Road are not registered as contaminated sites and the current and past land use is not registered as being a potentially contaminating. The surrounding 2km area is also not registered as a contaminated site.

An area located approximately 2km north, north-west of the site is classified as "Remediated – Restricted Use" due to presence of Asbestos Containing Material (ACM). This is of no concern to the subject site and its proposed development.

The Contaminated Sites Act 2003 and associated regulations and guidelines require a tiered assessment process, and if no evidence of contamination is found from both desktop and initial field investigations, no further action is required. Previous land use is not considered to be potentially contaminating.

3 Water Services and Efficiencies

Better Urban Water Management (BUWM) guidelines indicate that a development should sustainably manage the supply and usage of water within it.

3.1 Water Conservation

Practical water conservation methods should be considered to maintain water efficiency. Conservation methods should incorporate both the use of potable and non-potable water sources. The Water Corporation promotes "waterwise" systems aimed at overall reduction in scheme water use. In line with BUWM (WAPC, 2008) a target consumption rate of 100kL/person/year (state water target), including no more than 40-60kL/person/year potable water will be applied. These targets are designed for urban household use, and therefore should be easily managed within an industrial development.

3.1.1 Fixtures and Fittings

Water efficient fixtures and fittings will be incorporated into the development from the design stage as a mandatory requirement to Australian Standards and Building Codes of Australia (BCA). The following minimum applies:

- All tap fittings (other than bath outlets and garden taps) will be a minimum 4-star WELS rated.
- All showerheads will be a minimum 3-star WELS rated.
- All sanitary flushing systems will be a minimum dual-flush, 4-stars WELS rated
- All internal hot water outlets will be connected to a hot water system or a re-circulating hot water system with pipes installed and insulated in accordance with AS/NZS 3500: Plumbing and Drainage, Part 4 Heated Water Services.
- The pipe from the hot water system or re-circulating hot water system to the furthest hot water outlet will be less than either 20 m in length or 2 litres of internal volume.

3.1.2 Grey Water Recycling

Grey water is water that has previously been used. Recycling involves installing a system that treats grey water to an acceptable quality for other uses such as toilet flushing or sprinkler irrigation. Consideration should be made during selection of available options to ensure the treated water is "fit-for-purpose". Grey water systems should be incorporated at design stage as considerations need to be made for plumbing and external treatment systems. This is a beneficial solution when scheme water is limited and wastewater discharge levels are capped. Industrial processes do not always require potable scheme water quality.

As a minimum, a third piped reticulation main will be included within the development to allow for connection into the future once adequate infrastructure is available for larger scale recycling systems. Individual grey water systems should be considered at structure planning once industry types are known to determine its suitability.

3.1.3 Rainwater Harvesting

Large amounts of potable scheme water are used externally on gardens and in wash down facilities. Rainwater tanks are employed to retain runoff to be used in dry periods and act as peak water retention device as flow is released slowly. Rainwater tanks are optional additions for property owners and cannot be sufficiently relied on to reduce run-off flow rates.

A review within the Local Water Management Strategy will investigate the likely types of industry to occur within the South Forrestdale Industrial Area and determine the feasibility of rainwater tanks. Due to the fragmented ownership and site required to be purpose built, it would not be expected that the developer will provide rainwater tanks. It is more likely that caveats could be placed on titles requiring the purchaser to install rainwater tanks as part of the Development Application and construction phase.

3.1.4 Waterwise Landscaping

Waterwise landscaping forms a large portion of water conservation strategy as successful approaches reduce the quantity of water required for irrigation and also reduce the total runoff. Landscaped drainage within the site boundaries is located in road reserves, drainage basins and any open space where possible. It shall be designed to meet the requirements of Liveable Neighbourhoods (WAPC, 2009a) and the City of Armadale's Planning Department. Any irrigation required should be from an appropriate source and identified in the Local Water Management Strategy (LWMS).

Water conservation through landscaping is achieved by planting drought tolerant indigenous species (xeriscaping), hydrozoning (planting plants of similar water requirements together), reducing areas of lawn, increasing pervious areas, improving soil water holding capacity and, where irrigation is required, the installation of water efficient systems.

Indigenous vegetation has minimal or no irrigation requirements and should be planted throughout the development including within the road reserves and basins. Such plants help to promote a natural ecological environment and minimise the introduction of alien species whilst offering a habitat for native fauna species. Where irrigation of vegetated areas cannot be avoided, it should be restricted to below the average 6,250kL/ha/year by a definitive management plan including early morning use, efficient system, landscape selection and fit for purpose water supply i.e. harvested rainwater.

Road reserve vegetation shall be protected from vehicular damage by a kerb stone perimeter. The road gradient should also act to convey surface water directly into the entry points for rapid entry into infiltration systems. The plant species should have low requirements for irrigation and upkeep. Where possible, road reserve vegetation areas associated with lots should be utilised for lot stormwater requirements, thereby utilising this area for two functions and ensuring that lot stormwater is treated prior to infiltration.

Areas associated with drainage will be designed with appropriate plants that do not require irrigation in summer and can withstand periods of inundation during winter rainfall events. It is currently not proposed that additional POS areas are provided and therefore no irrigation should be required on an estate scale.

3.2 Groundwater Use

The shallow depth to groundwater in the area makes this a cost effective option for irrigation. Currently the DoW Water Register identifies the Perth Superficial, City of Armadale subarea as not fully allocated. Areas larger than 2000m^2 requiring irrigation must have a groundwater license. Any open space is also likely to serve a drainage function in an industrial landscape and be planted with drought tolerant native plants minimising grass areas.

As the development is industrial in nature, it is not envisaged that large useable POS will be included within the development. Therefore, through the use of suitable plant species and the fact that the majority of open space will serve a drainage function, it is not envisaged that irrigation will be required in the long term. Irrigation through an establishment period may be required. This will be designed as part of structure planning.

A single groundwater license, GWL 153722, is available within the Study Area. This license is on Lot 5 Oxley Road Forrestdale, with a groundwater allocation of 6,650KL for domestic/livestock/garden irrigation.

3.3 Water Supply and Wastewater

The water supply and wastewater management proposals were reviewed as part of the Servicing Report for the South Forrestdale Industrial Precinct by The Civil Group in December 2010 and revised in April 2013. This was subsequently superseded by a servicing report by Shawmac (2015).

The site will be serviced with water supply and sewer.

Currently there is no service network or formal water scheme future planning for the subject land. The Water Corporation has advised the area could be served through the Armadale-Kelmscott scheme subject to supply being via 5.8km extension from the DN760 on Armadale Road. The size of supply mains or route has not been considered in any detail. Preliminary advice indicated that a DN300 main would be required as a minimum, though it is likely a greater size would be needed to in order to achieve flows sufficient for fire fighting.

Similarly to the water supply there is no formal wastewater scheme for the subject land, however WC suggests the land could be serviced for sewerage via a temporary pump station located at a suitable low point within the industrial area, with discharge to the east to the Armadale Pump Station 2, Hilbert Rd. The temporary pump station, pressure main and related works would be undertaken at the developers’ cost.

Indicative potential alignments are provided in **Appendix L**.

3.4 Disease Vector and Nuisance Insect Management

Mosquitoes breed in standing water in natural and man-made wetlands, as well as a range of water holding systems in urban environments. To reduce health risks from mosquitoes, retention and detention treatments should be designed to ensure that detained immobile water is fully infiltrated or released in less than 96 hours for man-made systems.

4 Post Development Water Management

4.1 Surface Water Management

This DWMS addresses management of surface and stormwater quantity and quality to protect ecological, socio-economic and cultural values. It will assist decision making ensuring structural and non-structural remedial measures are undertaken in a cost-effective, integrated and coordinated manner.

4.1.1 Conceptual Management Strategy

The key objectives WSUD practices for surface water management are consistent with BUWM (WAPC, 2008) and the Stormwater Management Manual for WA (DoW, 2004-2007) and protect:

- Wetlands and waterways from the impact of urban runoff
- Infrastructure and assets from flooding and inundation
- Human life and property on floodplains

A minor and major approach to stormwater management should be considered. Minor drainage is designed to attenuate the peak volume in a safe manner whilst maximising infiltration and offering water quality treatment prior to discharge for events up to the critical 1 in 10 year Annual Recurrence Interval (ARI) whilst major drainage conveys stormwater from events up to and including the critical 1% AEP year ARI storms.

The stormwater management strategy addresses both quantity and quality. Components of the system will be applied at lot, street and estate scales with integration of the entire system to achieve WSUD objectives. The drainage strategy will require the following guidelines are met:

- Ensure water quality treatment of first flush events.

  Bioretention Areas will be required to treat first flush events (generally the 1 year 1 hour ARI) prior to discharge to estate level drainage system or infiltration to groundwater. This will be required for treatment at-source at both lot level and within the road reserves. Where soakage devices are considered within lot level drainage, first flush treatment will be required prior to overflow into soakage devices. Bioretention areas will be required to have amended soils which allow for infiltration while having reasonable phosphorus binding capacity. Note that biorentention areas will be located within 20 m wide road reserves.
- Provide a drainage network to cater for the critical 10 year ARI.

  Generally, this is completed via a pit (with local infiltration) and pipe system, though an overland conveyance system should also be investigated. An overland conveyance system may be more practical where imported fill is required and could be suitable where larger lots exist (such as within an industrial estate), with less cross overs required. Maintenance can be higher for overland conveyance, though it provides for greater at-source infiltration and treatment of stormwater.
- Maintain predevelopment peak flow rates for the critical 10 year ARI and 1% AEP

DoW currently have advised that the 100 year (1% AEP) peak flow rate leaving South Forrestdale Industrial Area under Rowley Road is 2.85m^3/s. This is for the southern section (majority of development area); the peak flow rate for the NW and NE catchment are 0.418 and 0.393m^3/s respectively.

- Maintain predevelopment flood storage.

  Areas within the Birriga Catchment require that predevelopment flood storage is maintained in order to prevent additional flooding downstream of the development. DoW have advised that 59ML of flood storage is required for the southern section of the Study Area. This does not include all flood storage for South Forrestdale Industrial Area. Further liaison with the DoW is required to determine this. DoW have also advised that refinement to this flood storage requirement could be made (and potentially reduced) with further modelling (see Section 2.7.1). Also note that flood event will be managed via the road reserves.
- Finished floor levels to have a clearance *of at least 0.3 m above the 1% annual exceedance probability (AEP) flood level of the urban drainage system and at least 0.5 m above the 1% annual exceedance probability (AEP) flood level of waterways(*(DoW, July 2016)*.* This is to ensure protection to the built environment as well as human safety.
- Provide suitability designed detention basins considering human safety.

  Any storage areas should provide a maximum depth of 1.2m with no steeper than 1 in 4 slopes. Where design requires areas to alter from this, the design must be to the satisfaction of CoA.
- Maintain public safety.

  Main Roads require that arterial roads have a maximum velocity depth product of 0.3m^2/s. For kerb side flows the maximum depth at the kerb side should be no greater than the top of kerb, and the product of gutter flow depth by average velocity should not exceed 0.4m^2/s. Melbourne Water have more detailed floodway safety criteria, with specific requirements for industrial developments. These should be considered for design constraints within this development.
- Manage risk to public health from disease vector and nuisance insects.

  A maximum ponding time of 96 hours should be designed within any detention storage. Where storage is underground, prevention of access for disease vector and nuisance insects should be considered.
- Adequate clearance to groundwater.

  A minimum of 0.3m separation from the base of any infiltration devices to groundwater is required. This will ensure that any infiltration device can still provide infiltration during and after storm events and ensure that ponding of water is less than 96 hours.
- Design of bioretention areas in line with relevant guidelines

  All areas designed for water quality treatment will give due regard to the Adoption Guidelines for Stormwater Biofiltration Systems from the Cooperative Research Centre for Water Sensitive Cities. (Payne et al., 2015) as well as Vegetation Guidelines for Stormwater

Biofilters in south-west of Western Australia (Monash Water for Liveability Centre, 2014). This includes but not limited to vegetation type, filter media, sizing, and overall design.

While the above are mandatory requirements for the stormwater design, the following should be investigated further as part of the overall drainage design requirements specific to South Forrestdale Industrial Area:

- Investigation for the use of a MUC.

  The South Forrestdale Industrial Area is split by an easement for high voltage powerlines. This also aligns with low points in the landscape, where flooding/inundation occurs and conveyance of stormwater from the site exits under Rowley Road. It also aligns with the only REW on-site and is a direct connection to where *Neopasiphae simplicior* species exists (within TEC Type 8 and 10a) and the Study Area. Suitable vegetation in which *Neopasiphae simplicior* are known to exist will be incorporated within the development and several of these species are suitable within drainage areas (i.e. can handle inundation). It therefore, makes sense to utilise this area as a MUC. Discussions with Western Power would be required to determine their requirements.
- Utilise the REW buffer for drainage functions.

  The REW is currently within a drainage line within the site and is within close proximity to the main outflow of stormwater, under Rowley Road. The change in land use will alter the hydrology of the site and therefore careful management will be required for the REW. Stormwater drainage should be considered within the REW buffer, to the satisfaction of CoA on advice from DPaW, as part of the overall drainage design.

4.1.1.1 Non-structural Best Management Practices

Control of pollutants at source using non-structural measures, by minimisation or input prevention, is an efficient cost effective water quality management system. These do not utilise permanent physical infrastructure but rather work by changing behavioural traits through government regulation, persuasion and/or economic instruments capitalising on lower maintenance costs through regulatory planning, economic incentives and education policies;

- Education campaigns can increase awareness of pollutant control (i.e. by using fertilisers/ pesticides properly, minimising runoff pollutants and increasing infiltration), the design of the drainage system, and associated sensitive environmental areas
- Prevention of unsuitable industries through tight control on Development Application process
- Inclusion of native planting in landscaping strategies
- Street sweeping program to reduce sediment entering stormwater
- Fertiliser management and prevention wherever possible

4.1.1.2 Structural Best Management Practices

Structural BMPs provide source control of pollutants (nutrients) and maximise infiltration by implementing civil infrastructure into the drainage system. Specific structural controls will be determined as part of stormwater design in line with the structure plan.

4.1.2 Surface Water Quality Targets

The Study Area mostly drains to the Peel- Harvey catchment. Extensive work has been carried out across the Peel-Harvey catchment area assessing not only volumes and flow rates in regards to water quantity but also in terms of water quality. The reports referenced in this section are Hydrological and Nutrient Modelling of the Peel-Harvey Catchment (DoW 2011), Peel-Harvey Coastal Catchment Water Quality Improvement Plan (2009).

The principle for surface water quality management is to maintain pre-development conditions (levels) and, if possible, improve the quality of water leaving the development in order to maintain and restore ecological systems within the catchment.

DoW (2011) indicates that the best way of maintaining pre-development hydrological flows and of reducing nutrient input is with the application of WSUD practices and a post development monitoring programme to assess impacts. Common WSUD target requirements for developments in the Peel-Harvey Catchment Area provided in the follow sub-sections.

As the majority of the site drains to the Peel-Harvey catchment and Forrestdale Lake, an important ecosystem, is directly north of the development, the guidelines for water quality improvement within Peel-Harvey should be adhered to for the entire development. It is likely that the development will use no fertilisers and strict requirements on individual lots to prevent any pollutant sources will be applied. This will require further investigation within the LWMS with specific objectives endorsed to ensure that nutrient and pollution management is followed.

4.1.2.1 Total Phosphorous Import and Export

The level of phosphorous import into the system will not exceed 15kg/ha/annum and levels above this are deemed environmentally unacceptable and shall be referred to the DoW.

The current land use of rural (livestock grazing) has a general land fertilisation rate of 9.9 kg/ha/annum (DoW, 2011; Table 3.2). Non-heavy industry is not expected to export phosphorous onto the land. Phosphorous export would only be generated by the application of fertiliser to the vegetated landscape. The development will incorporate native vegetation that require little or no additional nutrients and will therefore have an export of less than 2.5kg/ha/annum. In reality, it is expected that this rate is to be much smaller as all ‘open space’ would have a drainage function and through utilizing native plants, the application of fertiliser will not be required.

4.1.2.2 Total Nitrogen Import and Export

The level of nitrogen import into the system should not exceed 150kg/ha/annum. The future level is set by the Australian & New Zealand Environment Conservation Council (ANZECC) which is 1.2mg/l in the final water.

The current land use of rural (livestock grazing) has a land fertilisation rate of 79.5 kg/ha/annum (DoW, 2011). It is expected that a non-heavy industry would not export large quantities of nitrogen after at-source treatment of runoff. Nitrogen export would only be generated by the application of fertiliser to the vegetated landscape. The development will incorporate native vegetation that require little or no additional nutrients and will therefore have an export of less than 5.0kg/ha/annum. In line with phosphorus, it is expected that the actual export would be even smaller than this.

4.1.2.3 Soil Amendment

In order to maximise the retention of pollutants and nutrients, any device designed to capture first flush or short duration storm events will be required to have suitable plants and soil amendment (including lot level infiltration). Soil amendment should be developed based on the intended requirements. Where infiltration to groundwater is required, soil amendment has to ensure that a suitable infiltration rate is available while still hiving a high phosphorus retention capacity. Where it is deemed that infiltration is not suitable, design of first flush devices can retain the stormwater for longer and thus have higher phosphorus retention capacities.

Adoption Guidelines for Stormwater Biofiltration Systems from the Cooperative Research Centre for Water Sensitive Cities. (Payne et al., 2015) should be used to determine design and specifications requirements. Where specific requirements are determined as part of structure planning, these will be identified within the subsequent LWMS.

4.2 Groundwater Management Strategy

Groundwater management is to show compatibility with planning policies for Western Australia, the Department of Water and the CoA, namely:

- Protection of infrastructure and assets from flooding by high seasonal groundwater levels and perching
- Protection of groundwater dependent ecosystems
- Maintain and, if possible, improve groundwater quality pre and post development

4.2.1 Groundwater Level Management

The CoA has set the following general groundwater level management criteria*: "a 1.2m separation from peak controlled groundwater level where lot scale infiltration is proposed and consideration of reduction in this value down to 0.75m where specific measures are mandated to ensure infiltration devices remain above the phreatic curve of the controlled groundwater*". Due to the identified surface inundation and groundwater levels within the Study Area, the importation of fill and/or subsoil drainage to control groundwater will be required.

Groundwater levels and soil profiles are variable across the Study Area and groundwater management strategies will be specific to local conditions. Controlled groundwater levels (CGL) by subsoil drains may be required where an appropriate separation cannot be achieved naturally or through importation of fill.

Subsoil drains control groundwater levels by introducing a local drainage invert level to decant maximum groundwater levels into local drainage networks. Applying subsoil drains can affect the local groundwater dependent ecosystems and alter the hydrological regimes. Investigations into suitable exclusion zones, if required, around wetlands and remnant vegetation within and surrounding the site will be required to prevent major hydrological impacts. The CGL should also be set at an appropriate level to prevent the rise of groundwater without having an impact. Generally, this is set at or above the AAMGL, though further investigations are warranted to determine if this is suitable for this development.

Where clay is present as part of the cut and fill program and subsoil drains are to be installed, the clay must be graded towards the subsoil drain. This is to prevent localised perching of groundwater. Subsoil drains are also required to have free draining outlets and receive treatment prior to discharge off site.

If subsoil drainage is required, a free draining outlet is required with treatment of groundwater prior to conveyance from site.

4.2.2 Groundwater Quality Management

Groundwater quality is to be maintained at predevelopment levels and if possible improved. Groundwater quality will be improved by the use of structural and nonstructural BMPs to ensure treatment of stormwater (first flush) prior to any infiltration. Structural controls include Biofiltration systems, such as swales and basins, as well as importing high PRI soils in water treatment areas. Nonstructural controls include public education on fertiliser use and fertiliser wise plantings. By physical removal of potential contaminants ad nutrients prior to reaching groundwater, the groundwater quality will improve.

Implementation of biofiltration and bioretention pond systems use vegetation and biological systems to strip and store nutrients. The development will maximise infiltration of stormwater through swales and bioretention areas so natural biological systems remove nutrients from the water prior to it reaching the groundwater. Groundwater entering subsoil drains will be treated prior to regional discharge in bioretention areas to limit the export of nutrients from the Study Area. The subsoil characteristics of some areas of the site do not allow rapid infiltration and so retention systems such as rain gardens and roadside swales will provide primary treatment and slow release into the drainage network.

Groundwater quality objectives will fundamentally be set by the requirements for the Peel Harvey catchment long-term goals (WQIP). The catchment management focuses on phosphorus and nitrogen reduction to prevent eutrophication of waterways and receiving environments.

4.2.3 Wetland Management

The Armadale Local Biodiversity Strategy states

–*Protect, retain and manage a network of viable Local Natural Areas that support biodiversity and related processes by providing priorities, guidance and integration with land use planning and community involvement*''

As outlined previously the area does not currently support a high biodiversity with few native species existing on the properties.

Although the Study Area borders Forrestdale Lake Nature Reserve, a RAMSAR wetland of significant regional importance, there are no perceived restraints on the land in regards to wetlands. Borders to both the Nature Reserve and Bush Forever sites may require further management. Buffer areas will be reviewed as part of the LWMS consistent with WAPC advice. The Bush Forever site and CCW on Lot 12 are not proposed to be developed and suitable buffers will be applied.

4.3 Perceived Impact on Forrestdale Lake

Local groundwater mapping identifies that the majority of the proposed South Forrestdale Industrial Precinct heads in a south easterly to southerly direction, away from Forrestdale Lake. Current localised monitoring suggests that a groundwater ridge exists near the boundary of Lot 9 (**Figure 12**). Noting the most detailed studies incorporating Forrestdale Lake suggest that limited groundwater interaction occurs, and is most likely rainfall driven, the risk of the development providing a negative impact to Forrestdale Lake is low.

The area in question is a small portion of the entire industrial development and strict conditions can be utilized to reduce any perceived risk within Lot 9. Furthermore, the surface water catchments and groundwater catchments do not align. Therefore, with the increased hardstand areas associated with an Industrial development, Lot 9 can be managed in such a way to reduce infiltration and allow for greater stormwater to be directed to the south. Development conditions or zonings could also be placed within this area to ensure that low impact industries are included to reduce the perceived risk further. This information and potential restrictions would need to be discussed as part of structure planning and would require finalizations as part of a subsequent Local Water Management Strategy.

The low risk of impact to Forrestdale Lake using the evidence-based approach within this section suggests that no referral under the EPBC Act would be required and this development can be managed under usual planning and environmental processes. While it is acknowledged that further, more detailed, work is required as part of the continuation of this development, the investigations completed confirm that the site constraints are well known and do not limit the development from proceeding. More detailed on-site investigations would be completed in line with the current planning and environment policies, with the relevant detail required at each planning stage.

4.4 Water Supplementation for Forrestdale Lake

As stated in Section 2.8, water levels within Forrestdale lake have been declining and reducing the available habitat for migratory water birds. With declining rainfall and declining groundwater levels, it is likely that this situation is likely to get worse or at least become the norm. In light of this, investigations into supplementing water into Forrestdale Lake should be considered, either by increasing flows through the regional drains (James and Skeet Drains) or by diverting flows. The South Forrestdale Industrial Area is likely to be one of only a few larger scale developmentsin close proximity to Forrestdale lake and therefore diversion of flows from Forrestdale Lake should be considered.

This recommendation was mentioned within the EIA (Bioscience, 2015) and was commented on by both DPaW and DoW through subsequent reviews of the DWMS. DPaW noted:

> *"Water level monitoring at Forrestdale Lake over the last twenty years shows declining lake levels and decreasing periods of inundation. This in turn has been responsible for increasing coverage of introduced weed species and terrestrial native vegetation on the lake, increasing the incidence of uncontrolled fire and reduced waterbird usage.*
>
> *The department is supportive of the proposal in section 3.7.4 that states 'As planning progresses towards structure planning and subdivision, consideration should be given to options for capturing stormwater from roofs and hardstand areas in ways which enable supplementing the hydrological cycle of Forrestdale Lake.' The department recommends that the proponent consult with the department at the earliest opportunity to further discuss this proposal in order to minimise adverse impacts on wetlands associated with Forrestdale Lake and identify opportunities for design aspects*

> *that could lead to environmental benefits on the more significant elements within this internationally significant wetland system."*

While DoW noted:

> *"The Environmental Impact Assessment (EIA) section 3.7.4 states 'As planning progresses towards structure planning and subdivision, consideration should be given to options for capturing stormwater from roofs and hardstand areas in ways which enable supplementing the hydrological cycle of Forrestdale Lake.' Whilst no mention of this proposal is made in the DWMS, the DoW is supportive of innovative ways to manage stormwater and groundwater particularly where there is a positive outcome for significant environmental assets."*

It should be noted that any changes to hydrology of Forrestdale Lake, as proposed, would require federal approval under the EPBC Act. The Native Title Act requires that the South-West Aboriginal Land and Sea Council be advised when a management plan is being prepared or major public works undertaken on the conservation estate. Furthermore, the *Environmental Protection (Swan Coastal Plain Lakes) Policy (2004)* policy protects the environmental values of Forrestdale Lake and prohibits any unauthorised filling, mining, draining (into and out of the wetland), effluent discharge and alteration of water levels. This would be on top of the generally liaison with DoW, DPaW, and CoA. The cost to complete the additional studies and liaison with all the various landholders would be significantly more than going through the normal process to complete this industrial estate. The land within the South Forrestdale Industrial Area is also fragmented and owned by long term landholders/farmers who do not have the ability to pursue the aspirational and environmental benefit of sending stormwater into Forrestdale Lake. Therefore, based on the above and the fact that both DoW and DPaW agree that water supplementation could be a good and possibly feasibly option for Forrestdale Lake, it is recommended that this process be championed by a state body. It would be suggested that either DoW or DPaW could find sufficient resources to pursue this if it is deemed politically palatable.

The idea of water supplementation has also been mentioned within the Perth and Peel Green Growth Plan for 3.5 Million (Department of Premier and Cabinet, 2015). Specific details are included within the Draft EPBC Act Strategic Impact Assessment Report, where it notes that the following conservation commitments are included within the Strategic Conservation Plan:

"Conduct an investigation into a potential stormwater supplementation program for Forrestdale Lake to identify limits of acceptable change, incorporate findings into adaptive management arrangements and future planning"

This process would need to be completed as part of the next phase of work to help determine the stormwater design strategy and inform the LWMS. Alternatively, the development would proceed as normal, with the design of most, if not all, stormwater being treated on-site prior to discharge to the Birriga Drain.

5 Implementation Framework

The aim of the DWMS is to demonstrate that the land is capable of supporting the change in land use and is able to achieve appropriate urban water management outcomes. The DWMS informs the decision making process associated with the proposed land use change. This involves demonstrating that the development:

- will not detrimentally impact water resources and associated environmental values
- can manage surface water and groundwater
- can be serviced with water and wastewater (DoW, 2013).

While it is noted that sensitive environments exist within the vicinity of the proposed South Forrestdale Industrial Area, this DWMS along with the DWMS for Lots 6,8 and 200 have taken into account all water related issues and shown that the development can proceed with 1.) no detrimental impact to water resources and environmental values; 2.) can manage surface water and groundwater; and 3.) has the ability to be serviced by Water Corporation for water and wastewater.

The DWMS is designed to provide suitable advice as part of an amendment to the MRS and as such acknowledges that additional, more detailed information, would be required as part of subsequent planning stages. This document is therefore designed to provide the framework and scope for the additional work required to ensure that water management is taken into account at each planning stage and prove that the development can proceed with no detrimental impact to the surrounding users and the environment. The following site specific investigations will need to proceed for inclusion with a subsequent LWMS to prove this:

- Identify landscape design and irrigation requirements. It is proposed that all POS/Drainage areas are dry and require no irrigation. If, for unforeseen reasons, this is not possible, the irrigation requirements and proof a groundwater license is available will need to be identified.
- Identify potential specific pollution and water quality requirements at lot level and determine the best way to manage these, be it specific management measures or prevention from operating within the South Forrestdale Industrial Area.
- Identify specific structural controls to help water quality, conveyance of stormwater and to maintain predevelopment flows.
- Finalise predevelopment flood storage requirements. The DoW modelling can be used, however, refinement can reduce the overall flood storage requirements and therefore is recommended. An appropriate model would need to be completed to the satisfaction of DoW. It is also recommended that this scope is completed prior to the LWMS and is included within the LWMS once approved.
- Finalise modelling to identify stormwater storage requirements for the post development scenario, maintaining predevelopment peak flow rates. This will also require the stormwater management strategy to be finalized with modelling used for proof of concept.
- Produce the on-going predevelopment monitoring results and identify the post development trigger values.

- Define business types allowed within the development and determine if a setback for some industries is required to sensitive areas.
- Determine if physical buffers are required to sensitive areas, including the REW inside the South Forrestdale Industrial Area.
- Determine suitability of MUC within the high voltage powerline easement along with stormwater storage within REW buffer. The REW is also associated with the high voltage powerline easement.
- Include further detailed ASS investigations. This may be deferred to UWMP as preliminary results have been completed already, noting that further work is required. Therefore, as long as further detailed investigations are completed and approved prior to construction activities to inform any ASS management plan requirements, this should be satisfactory.
- Include further detailed geotechnical investigations. This may be deferred to UWMP as preliminary results have been completed already, noting that further work is required. Therefore, as long as further detailed investigations are completed and approved prior to construction activities to inform building requirements, this should be satisfactory.
- Determine suitability of existing stormwater infrastructure outside the South Forrestdale Industrial Estate (receiving environment). Where upgrades may be required, this should be identified within the LWMS.
- An additional detailed vegetation audit is required to confirm if priority species that DPaW are concerned about exist within Study Area.
- Liaison with government agencies to determine suitability of water supplementation to Forrestdale Lake. While liaison should occur, for this to continue it should be championed by either a State or Federal Government Agency. It is recommended that either DoW or DPaW complete this.

Currently two DWMS's have been completed for the South Forrestdale Industrial Area. This occurred due to the perception that the southern section relating to Lots 6, 8 and 200 were less complex hydrologically with less impact on the surrounding environment and users, therefore making it easier to manage. In reality the impact from the development would be same as the design and management of development on all lots will need to coincide together and therefore would be the same. It is Bioscience's understanding that an LWMS for Lots 6, 8 and 200 has not yet proceeded. With this in mind, it is recommended that a single LWMS is completed for the entire South Forrestdale Industrial Area based on the following:

- The complex groundwater hydrology affects both areas and therefore any further investigations should be completed as one program to ensure consistency across the entire area
- The design of the stormwater infrastructure will need connection between both areas and therefore the strategy would need to be the same, if not similar
- The South Forrestdale Industrial Area is at the top of the Peel Harvey and Swan Canning catchment divided. Therefore, no interaction from a planning point of view would occur and management downstream can be managed by ensuring predevelopment conditions are maintained. There is however, interaction within sub-catchments of the South Forrestdale Industrial Area of which both DWMS's cover.
- Any future monitoring program can be done in a holistic approach across the entire development

- Fragmentation of land already exists and the inclusion of a larger area for the LWMS would be no more difficult than completing it for a smaller area
- Better planning outcomes can be managed by ensuring that any structure plan takes into account the entire South Forrestdale Industrial Area rather than ensuring that connections to future developments will occur.
- The approvals process would theoretically be easier as any design and management would not need to take into account the impact on surrounding future development.
- A developer contribution scheme is likely to be required and can be handled much easier if the development progresses at the same rate.

In many ways the TPS amendment, formation of the structure plan, and its associated LWMS is the most important stage to the development. Work at this point will define the design of the industrial area, ensure that suitable land has been provided for stormwater, and ensure that any impacts on surrounding users are removed or minimized. This will also require significant liaison with relevant state and local authorities, which includes but not limited to:

- City of Armadale – will be involved in all facets of the design including planning, engineering, stormwater, and environment;
- Department of Water – review and approve LWMS; possible inclusion in water supplementation of Forrestdale Lake;
- Department of Parks and Wildlife – involvement in managing REW wetland; managing potential risk to Bush Forever and associated areas to Forrestdale Lake; possible inclusion in water supplementation of Forrestdale Lake;
- Main Roads – ensure connection of development to Rowley Road is suitable with the proposed increase to this road;
- Water Corporation – liaison for possible temporary versus final solution for reticulated wastewater and potable water supply;
- Western Power – discussion on the use of high voltage powerline easement for use as a MUC; and
- Department of Environment and Regulation – assessment of further ASS investigations.

5.1 Planning Considerations

The principles of the BUWM guidelines (WAPC, 2008) will be implemented in the development. The development of the site will require an MRS amendment and an application to the City of Armadale to change the zoning of the site from rural to industrial, under the Town Planning Scheme, to allow the development to proceed. Managing urban water requires a stepped approach at local and subdivision planning stages.

5.1.1 Local Planning Considerations

Local Water Management Strategies (LWMS) are provided to support the development as per BUWM guidelines and will address the following key issues:

- Principles, objectives and requirements for the total water cycle management as outlined in the State Planning Policy 2.9: Water Resources, Liveable Neighbourhoods and the Stormwater Management Manual for WA including the decision process for stormwater management
- Existing site characteristics such as geology, hydrogeology, groundwater, surface water – further refined as required from DWMS
- Site constraints and opportunities based on site characteristics
- Further demonstration of the capacity of the land to sustain the proposed landuse
- Conceptual urban water management system
- Landscape concept for POS and structural BMPs
- Monitoring framework revising predevelopment monitoring and identifying post development requirements in line with the DWMS
- Implementation strategy including roles and responsibilities, funding and maintenance
- Issues to be addressed at subdivision stage (UWMP)

5.1.2 Subdivision Planning Considerations

At this stage an Urban Water Management Plan (UWMP) is required for each subdivision at the landowners' expense. The UWMP is largely an extension of the LWMS as it provides the detailed design proposed in the local structure plan (LWMS).

5.2 Monitoring Programs

The water monitoring program ensures compatibility between pre and post development conditions and identify inconsistencies:

- Quantify impacts of development on surface water quality and flow rates, seasonal groundwater levels and quality
- Set baseline levels to establish trigger values
- Utilise trigger values to accurately inform on effectiveness of management strategies in place and activate contingency plans
- Assist in the development of regional data set

The post development monitoring program will address both groundwater and surface water levels, quantity and quality. The trigger values are set on a site by site basis but will conform with regional and local targets. The responsibility for implementation of the monitoring program shall be with the developer. Monitoring will be undertaken at strategic points at critical locations i.e. inflow and outflow points, water levels in basins, groundwater levels across development.

Due to the fragmented ownership within the development, it is possible that different developments area will be constructed at different times. It is therefore recommended that a developer contribution scheme is set up to include estate scale monitoring.

It is proposed that additional predevelopment monitoring occurs to pick up gaps identified within the original datasets. Groundwater quality was only conducted sporadically across parts of the Study Area. It is recommended that quarterly sampling is conducted for 18 months, capturing two peak winters. This will ensure that a minimum of eight water quality samples are completed for each analyte. Groundwater levels should be conducted monthly during this period to ensure that the peak water levels are captured. Previous monitoring was conducted on a bimonthly basis.

No surface water monitoring has been previously conducted. Grab samples at known outlets from the development should be conducted during periods of flow/water inundation, in particular from the Rowley Road culverts. A minimum of monthly samples should be collected during this period, though fortnightly samples would be beneficial. As this sampling will need to be completed on an opportunistic basis, it is further recommended that this continue up to and including when construction activities occur on-site and the into post-development monitoring.

As the current monitoring data provided would be suitable for inclusion within a LWMS, the proposed monitoring should not be used to prevent the development from proceeding and the LWMS being completed. The monitoring program can be run concurrently with results up to the date of lodgment included within the report. The final monitoring program can be included within subsequent UWMPs. The LWMS will follow the proposed monitoring regime within this DWMS. Where justified based on further monitoring results, the monitoring regime may be altered for final inclusion within the UWMPs. This would be subject to approval from the DoW.

5.2.1 Parameters

As a minimum the following parameters will be collected/tested:

- Water Level/Flow
- pH
- Electrical conductivity (EC)
- Total Suspended Solids (TSS) (surface water only)
- Total Nitrogen (TN)
- Ammonia (NH4)
- Nitrate and Nitrite (NOx)
- Total Phosphorous (TP)
- Filterable Reactive Phosphorus (FRP)
- Heavy metals
- Hydrocarbons

5.3 Responsibilities

Table 11 summarises the key persons and the obligated responsibilities during the monitoring phase along with the timing of the process.

Table 11: Roles and Responsibilities

Planning Phase	Responsible	Monitoring Requirement
Local	Landowner	Pre development monitoring of hydrological regimes, buffers and ecological links. Monitor superficial groundwater levels, flows and quality. Monitor surface water quality when possible.
Local	Developer	Post development monitoring of hydrological regimes, buffers and ecological links. Monitor superficial groundwater levels, flows and quality. Monitor surface water flows and quality with attention to peak flows.
District	Applicant	Monitor groundwater levels and water quality.

The monitoring program has been designed in accordance with the joint Australian/New Zealand Standards (1998 a, b, c) to allow quantitative assessment of hydrological impacts of development (**Table 12**). Groundwater data has been captured over three winters and will continue to understand the conditions and inform engineering design.

Table 12: Monitoring Schedule

Monitoring Type	Parameter	Location	Method	Frequency	Reporting
Predevelopment Groundwater Levels	Water levels (mAHD)	All current monitoring bores	Water Interface Probe/ Meter	Monthly for 18 months (including two winters)	Inclusion within LWMS and/ or UWMP
Predevelopment Groundwater Quality	pH, EC, TN, NH4, NOx, TP, FRP, Heavy Metals, Hydrocarbons	All current monitoring bores	Pumped Bore Sample/ Bailer	Monthly for 18 months (including two winters)	
Predevelopment Surface Water Flow Levels	Water Level (m) and/or Flow (m^3/s)	4 Outlets from South Forrestdale Industrial Area	Gauge and/ or Flow Meter	Opportunistic Samples during periods of flow/inundation (minimum monthly; preferred fortnightly)	
Predevelopment Surface Water Quality	pH, EC, TSS, TN, NH4, NOx, TP, FRP, Heavy Metals,	4 Outlets from South Forrestdale Industrial	Grab Sample	Opportunistic Samples during periods of flow/inundation	

	Hydrocarbons	Area		(minimum monthly; preferred fortnightly)	
Post Development Groundwater Levels	Water levels (mAHD)	All current monitoring bores	Water Interface Probe/ Meter	Monthly for three years post development	Annual assessment reports to be submitted to DoW & CoA for 3 years post-development.
Post Development Groundwater Quality	pH, EC, TN, NH4, NOx, TP, FRP, Heavy Metals, Hydrocarbons	10 monitoring bores	Pumped Bore Sample/ Bailer	Quarterly for three years post development	
Post Development Surface Water Flow Levels	Water Level (m) and/or Flow (m^3/s)	4 Outlets from South Forrestdale Industrial Area. Internal location TBD at structure planning	Gauge and/ or Flow Meter	Opportunistic Samples during periods of flow/inundation (minimum monthly; preferred fortnightly) for three years	
Post Development Surface Water Quality	pH, EC, TSS, TN, NH4, NOx, TP, FRP, Heavy Metals, Hydrocarbons	4 Outlets from South Forrestdale Industrial Area. Internal location TBD at structure planning	Grab Sample	Opportunistic Samples during periods of flow/inundation (minimum monthly; preferred fortnightly) for three years	
Vegetation	Number of dead plants and weeds	Areas where plants have been planted in POS areas.	Visual inspection	3 years post-development or until hand over of infrastructure	Compliance data at handover of infrastructure
Erosion	Signs of erosion	Along the entire drainage	Visual inspection	3 years post-development or until hand over of	

		corridor.		infrastructure	

Regular inspection and maintenance of the drains and streams will be required to ensure designed flow rates are maintained post development. This includes clearance of excessive vegetation and debris blockages in open drains and culverts. Maintenance will be by landscape contractors during development and the Council post establishment. Regional drains will remain under the Water Corporation's governance.

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Appendix A: Aboriginal Heritage Inquiry System

Aboriginal Heritage Inquiry System

Survey Report Catalogue

Search Criteria

24 none

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South West Settlement ILUA Disclaimer

Your heritage enquiry is on land within the following Indigenous Land Use Agreement(s): Gnaala Karla Booja People ILUA, Whadjuk People ILUA

On 8 June 2015, six identical Indigenous Land Use Agreements (ILUAs) were executed across the South West by the Western Australian Government and, respectively, the Yued, Whadjuk People, Gnaala Karla Booja, Ballardong People, South West Boojarah #2 and Wagyl Kaip & Southern Noongar groups, and the South West Aboriginal Land and Sea Council (SWALSC).

The ILUAs bind the parties (including 'the State', which encompasses all State Government Departments and certain State Government agencies) to enter into a Noongar Standard Heritage Agreement (NSHA) when conducting Aboriginal Heritage Surveys in the ILUA areas, unless they have an existing heritage agreement. It is also intended that other State agencies and instrumentalities enter into the NSHA when conducting Aboriginal Heritage Surveys in the ILUA areas. It is recommended a NSHA is entered into, and an 'Activity Notice' issued under the NSHA, if there is a risk that an activity will ‘impact’ (i.e. by excavating, damaging, destroying or altering in any way) an Aboriginal heritage site. The Aboriginal Heritage Due Diligence Guidelines, which are referenced by the NSHA, provide guidance on how to assess the potential risk to Aboriginal heritage.

Likewise, from 8 June 2015 the Department of Mines and Petroleum (DMP) in granting Mineral, Petroleum and related Access Authority tenures within the South West Settlement ILUA areas, will place a condition on these tenures requiring a heritage agreement or a NSHA before any rights can be exercised.

If you are a State Government Department, Agency or Instrumentality, or have a heritage condition placed on your mineral or petroleum title by DMP, you should seek advice as to the requirement to use the NSHA for your proposed activity. The full ILUA documents, maps of the ILUA areas and the NSHA template can be found at https://www.dpc.wa.gov.au/lantu/Claims/Pages/SouthWestSettlement.aspx.

Further advice can also be sought from the Department of Aboriginal Affairs (DAA) at heritageenquiries@daa.wa.gov.au.

Copyright

Access

Some reports are restricted.

Report ID	Title	Authors
20143	Desktop investigative study of Aboriginal Heritage issues relating to the Brookdale District Structure Plan Review Land at Brookdale, Western Australia	Parker, Susan
20633	Management report of Aboriginal Heritage aspects of the Dampier to Bunbury Natural Gas Pipeline corridor through the Perth Metropolitan Area	Hames Consultancy Group
20946	The Metro Sites audit review (NOT a Heritage Survey Report)	Coldrick, Bryn
21422	Report on the archaeological and ethnographic survey of the proposed route of the Perth Seawater Desalination Plant Projects Kwinana Beach Navel Base Nicholson Road Forrestdale in Western Australia	Australian Interaction Consultants
22481	A report of an Aboriginal Heritage Survey of the proposed Wungong Transfer Mains and Outlet Pipe.	Western Heritage Research Pty. Ltd.
23130	Wungong Urban Water Master Plan Volume 1: Phase 1 Archaeological Reconnaissance Survey	Tempus Archaeology
23132	Wungong Urban Water Master Plan Aboriginal Heritage Investigations Volume III: Aboriginal Heritage Managment Plan : May 2007	Tempus Archaeology
27585	Report on an Archaeological Survey for Indigenous Sites: Wungong River Connection Drain, Ranford Road Upgrade Project, Forrestdale and Seville Grove, Western Australia	Thomson, Jo-Anne
28551	A Report of an Aboriginal Heritage Survey of the Proposed Southern Corridor Infrastructure Upgrade Project	Western Heritage Research Pty. Ltd.
28870	Report on an Archaeological Survey for Indigenous Sites: Ranford Road Realignment and Living Streams Projects Forrestdale and Seville Grove, Western Australia	Thomson, Jo-Anne
101972	Report of an Aboriginal Heritage Survey, South-East Corridor Structure Plan. Oct.1995.	Blockley, E
102051	Revised Report of an Aboriginal Heritage Survey South-East Corridor Structure Plan. March. 1996.	Blockley, E
102670	Preliminary Report on the Survey of Aboriginal Areas of Significance in the Perth Metropolitan & Murray River Regions July 1985.	O'Connor, R
103701	Addendum to a Report of an Aboriginal Heritage Survey Proposed Tonkin Highway Extention (Option 1c). Mar.1996.	Blockley, E
104072	Forrestdale Lake Nature Reserve Draft Management Plan.	Polglaze, R.
104311	Report on an Ethnographic and Archaeological Survey for Aboriginal Sites of the Proposed New Southern River Road Bridge: Southern River, Gosnells. March 1990.	Murphy, A.
104505	Aboriginal Sites in the Perth Metropolitan Area: A Management Scheme. June 1987, Revised 1988 [Centre for Prehistory, Uwa].	Strawbridge, L.
105120	Forrestdale Lake Nature Reserve Summary of Public Submissions. Management Plan no. 3. May 1987.	Dept of Conservation & Land Management.

Aboriginal Heritage Inquiry System

Survey Report Catalogue

Report ID	Title	Authors
105699	Aboriginal Heritage issues and cable crossings : upper Canning River downstream from Nicholson Road traffic bridge adjacent downstream from Canning Bridge and Narrows bridge utilzing internal bridge structure Swan River adjacent upstream to Causeway	Machin, Barrie
106005	Site identification, ethnographic survey under the Aboriginal Heritage Act (1972) of the proposed Armadale Road duplication project from Nicholson Road to Wungong Brook in Armadale	Parker, Susan
106039	Site identification, ethnographic survey under the Aboriginal Heritage Act (1972) of the proposed Armadale Road Duplication project from Nicholson Road to Wungong Brook in Armadale	Parker, Susan
106093	Report of an Aboriginal Heritage survey proposed Armadale Road duplication project Forrestdale, Western Australia	McDonald, Hales and Associates.
106204	Metropolitan Sites Project Southern Region : draft report	Yates Heritage Consultants
106241	Summary report : section 18 notice to disturb Aboriginal sites Armadale Road duplication	BSD Consultants Pty Ltd

Aboriginal Heritage Inquiry System

Aboriginal Sites Database

Search Criteria

5 Registered Aboriginal Sites in Custom search area (5); 398215.59mE, 6438427.91mN z50 (MGA94) : 402324.82mE, 6442793.82mN z50 (MGA94)

Disclaimer

The *Aboriginal Heritage Act 1972* preserves all Aboriginal sites in Western Australia whether or not they are registered. Aboriginal sites exist that are not recorded on the Register of Aboriginal Sites, and some registered sites may no longer exist.

The information provided is made available in good faith and is predominately based on the information provided to the Department of Aboriginal Affairs by third parties. The information is provided solely on the basis that readers will be responsible for making their own assessment as to the accuracy of the information. If you find any errors or omissions in our records, including our maps, it would be appreciated if you email the details to the Department at heritageenquiries@daa.wa.gov.au and we will make every effort to rectify it as soon as possible.

South West Settlement ILUA Disclaimer

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Coordinate Accuracy

Accuracy is shown as a code in brackets following the coordinates. Map coordinates (Latitude/Longitude and Easting/Northing) are based on the GDA 94 Datum. The Easting/Northing map grid can be across one or more zones. The zone is indicated for each Easting on the map, i.e. '500000mE:Z50' means Easting=500000, Zone=50.

Terminology (NB that some terminology has varied over the life of the legislation)

Place ID/Site ID: This a unique ID assigned by the Department of Aboriginal Affairs to the place

Status:

- **Registered Site**: The place has been assessed as meeting Section 5 of the *Aboriginal Heritage Act 1972*
- **Other Heritage Place which includes:**
  - **Stored Data / Not a Site:** The place has been assessed as not meeting Section 5 of the *Aboriginal Heritage Act 1972*
  - **Lodged:** Information has been received in relation to the place, but an assessment has not been completed at this stage to determine if it meets Section 5 of the *Aboriginal Heritage Act 1972*

Status Reason: e.g. Exclusion - Relates to a portion of an Aboriginal site or heritage place as assessed by the Aboriginal Cultural Material Committee (ACMC). e.g. such as the land subject to a section 18 notice.

Origin Place ID: Used in conjuction with Status Reason to indicate which Registered Site this Place originates from.

Access and Restrictions:

- **File Restricted = No:** Availability of information (other than boundary) that the Department of Aboriginal Affairs holds in relation to the place is not restricted in any way.
- **File Restricted = Yes:** Some of the information that the Department of Aboriginal Affairs holds in relation to the place is restricted if it is considered culturally sensitive. This information will only be made available if the Department of Aboriginal Affairs receives written approval from the informants who provided the information. Download the Request to Access Restricted Information letter and form.
- **Boundary Restricted = No:** place location is shown as accurately as the information lodged with the Registrar allows.
- **Boundary Restricted = Yes:** To preserve confidentiality the exact location and extent of the place is not displayed on the map. However, the shaded region (generally with an area of at least 4km²) provides a general indication of where the place is located. If you are a landowner and wish to find out more about the exact location of the place, please contact DAA.
- **Restrictions:**
  - **No Restrictions:** Anyone can view the information.
  - **Male Access Only:** Only males can view restricted information.
  - **Female Access Only:** Only females can view restricted information

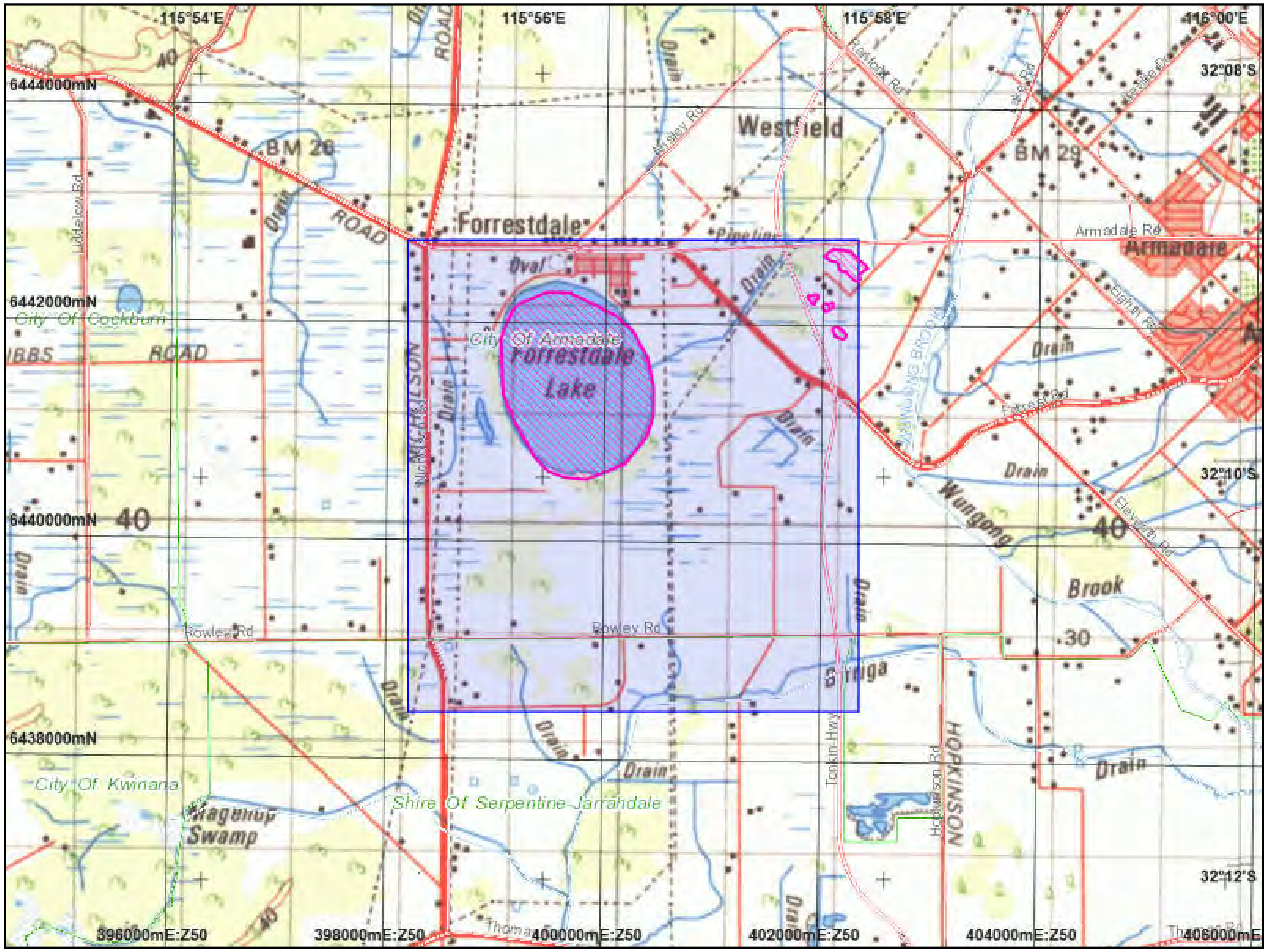
Legacy ID: This is the former unique number that the former Department of Aboriginal Sites assigned to the place. This has been replaced by the Place ID / Site ID.

List of Registered Aboriginal Sites with Map

Site ID	Site Name	File Restricted	Boundary Restricted	Restrictions	Status	Status Reason	Origin Place ID	Site Type	Knowledge Holders	Coordinates	Legacy ID
3713	LAKE FORRESTDALE.	No	No	No Gender Restrictions	Registered Site			Mythological, Camp, Hunting Place	*Registered Knowledge Holder names available from DAA	399737mE 6441427mN Zone 50 [Reliable]	S02213
18605	SEC/1C-3	No	No	No Gender Restrictions	Registered Site			Artefacts / Scatter		402153mE 6441939mN Zone 50 [Reliable]	
26083	Brookdale Archaeological Site 001	No	No	No Gender Restrictions	Registered Site			Artefacts / Scatter, Arch Deposit		401912mE 6442254mN Zone 50 [Reliable]	
26084	Brookdale Archaeological Site 002	No	No	No Gender Restrictions	Registered Site			Artefacts / Scatter, Arch Deposit		402045mE 6442172mN Zone 50 [Reliable]	
26107	Brookdale Archaeological Site 060	No	No	No Gender Restrictions	Registered Site			Artefacts / Scatter		402218mE 6442578mN Zone 50 [Reliable]	

Aboriginal Heritage Inquiry System

Aboriginal Sites Database



Legend

Selected Heritage Sites

▨	Registered Sites
●	Aboriginal Community Occupied
●	Aboriginal Community Unoccupied
●	Town
☐	Search Area

Appendix B: Geotechnical Report (Bioscience, 2010)

GEOTECHNICAL INVESTIGATION

LOTS 6, 8 AND 200 ROWLEY ROAD, FORRESTDALE

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1. Introduction

This report describes the geotechnical investigations undertaken by Bioscience Pty Ltd on Lots 6, 8, and 200 Rowley Road, a proposed industrial zoned development. Bioscience was asked to investigate the land with the objective of determining any geotechnical constraints which may be present, and whether it is suitable for industrial zoning.

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

2. Site Description

The study area is located approximately 25 km south-west of Perth and 22 km east of Fremantle town centre and has a combined area of approximately 101 Ha (Figure 1). It is currently used for grazing livestock and is zoned by the City of Armadale's Town Planning Scheme No 4 as Rural Living (RL 20).

2.1. Geomorphology and Topography

The area has a low relief with minor variations in topography. The south western corner of Lot 200 has an elevation of a little over 25m Australian Height Datum (AHD), whereas small two depressions on lot 6 and a substantial proportion of lot 8 are below 24 AHD (Figure 2).

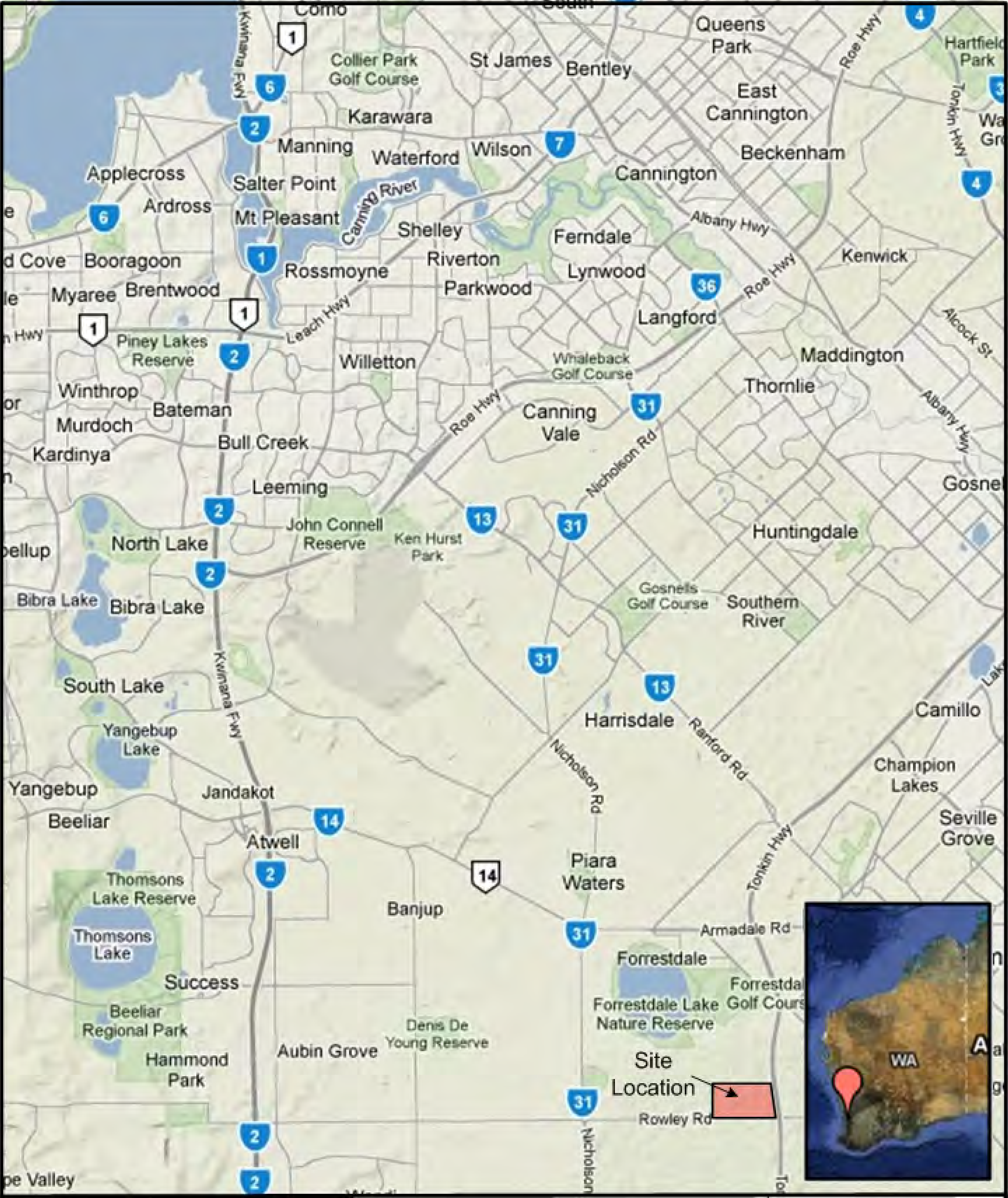


Figure 1 - Location of Study Area

Legend

🟥 Site Location

Bioscience

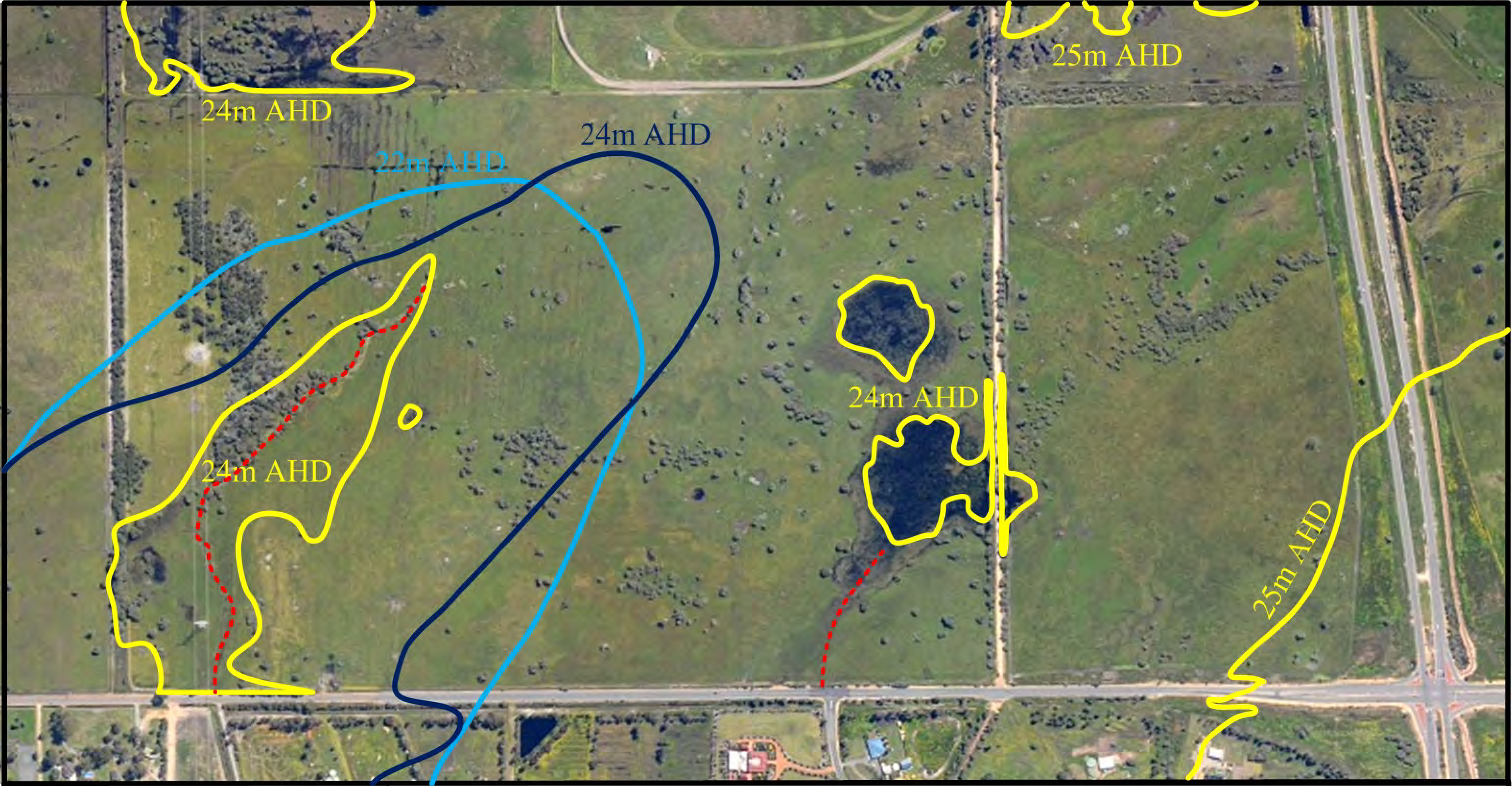


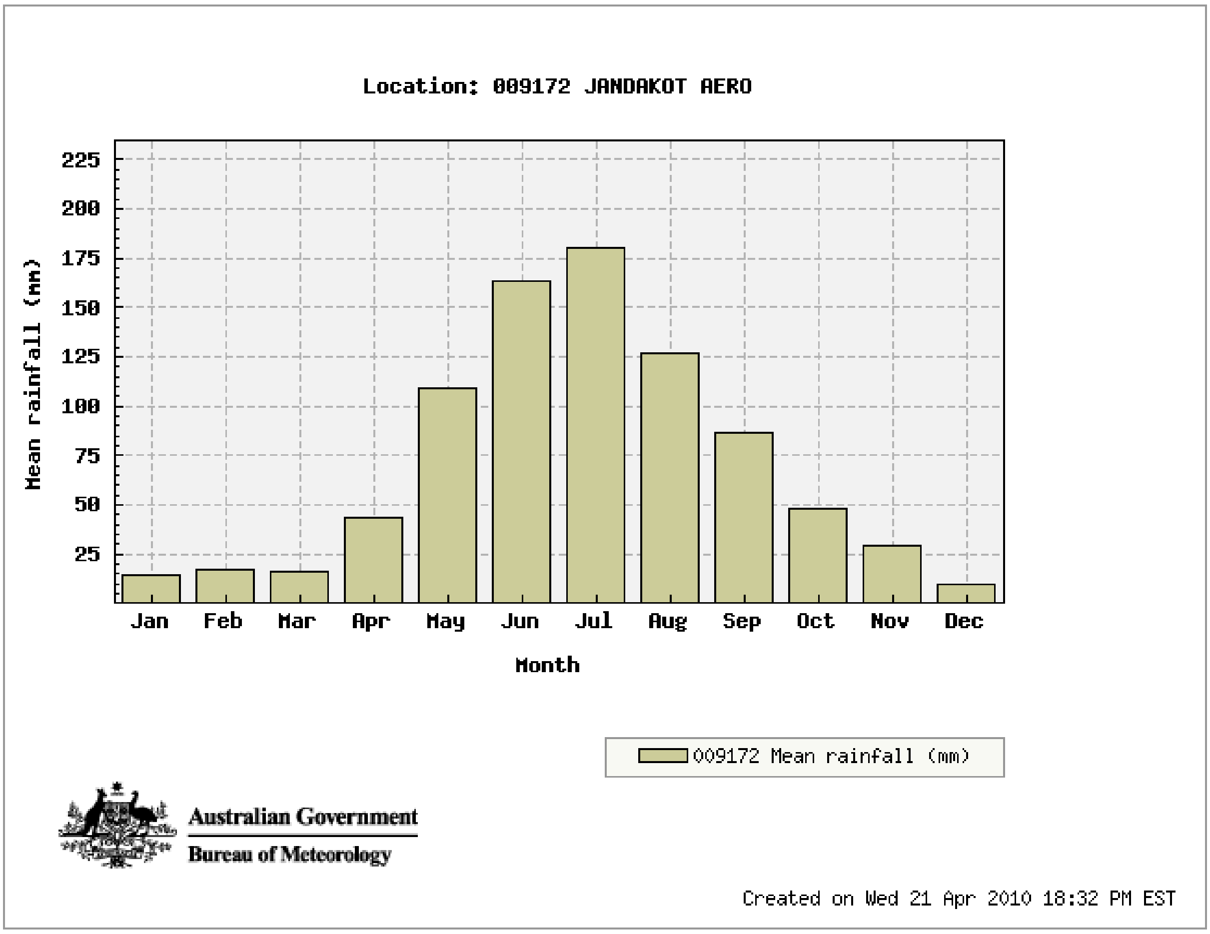
Figure 2 – Topography and Groundwater Levels as per the Perth Groundwater Atlas.

Legend

2.2. Climate

The south west of Western Australia is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. According to the Bureau of Meteorology the average annual rainfall within the vicinity of the proposed development is 837mm (Jandakot Aero No. 009172). The monthly distribution of rainfall (Figure 3) indicates approximately 85% of the rainfall occurs during the months of May to October. The potential annual *evaporation* of the area is 1800 mm, which is significantly more than annual precipitation (Davidson and Yu, 2006). The prevailing wind is from a south-westerly direction, however easterly winds common, particularly in the summer months.

Figure 3 - Monthly distribution of rainfall for Jandakot Airport



2.3. Vegetation

Bioscience undertook modified vegetation survey of the subject land involving a careful walk-through of all the wetland and surrounding areas to document all native species present. With the exception of a few small pockets, the site is almost completely devoid of native vegetation. The only remaining native vegetation identified on site was swamp paperbarks (*Melaleuca raphiophilla) and* Spearwood (*Kunzea* glabrescens) trees.

2.4. Regional Geology

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

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

2.5. Local Geology

The geology at the site as per the Geological Survey of Western Australia 1:50000 Environmental Geological Series Armadale Map Sheets 2033 I and 2133 IV (Gozzard, 1985) are (Figure 4):

- SP1 – PEATY SAND – grey to black, fine-medium grained, moderately sorted quartz sand, slightly peaty of lacustrine origin.
- S9 – SAND – white to pale brown, fine-grained to medium-course grained rounded quartz, occasionally fossiliferous.

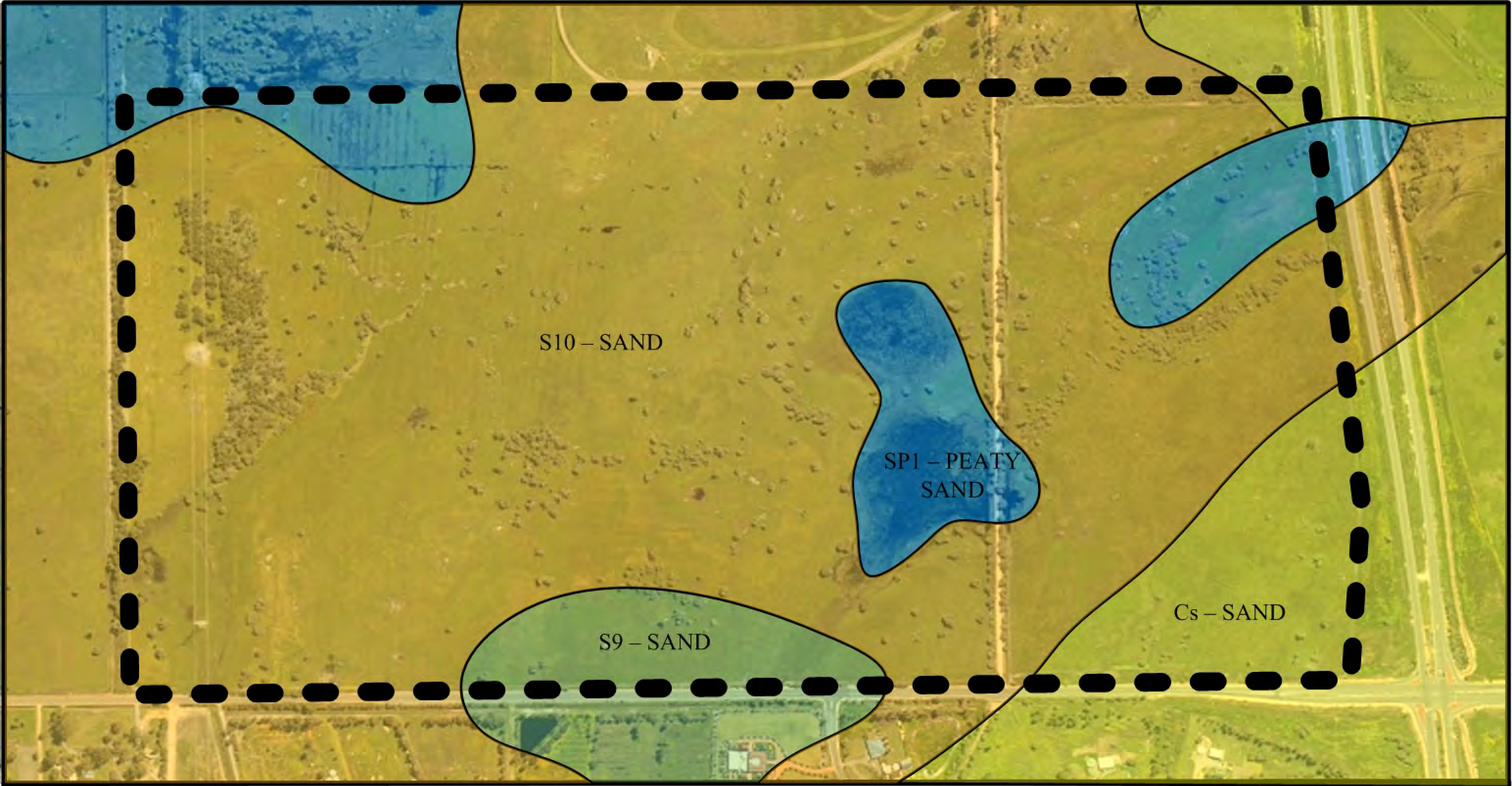


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Figure 4 – Soil Geology Mapping as per Armadale Geological Survey of Western Australia

Legend

S9 – SAND	S10 – SAND	Cs – SAND	SP1 – PEATY SAND

- S10 – SAND – as S8 over sandy clay to clayey sand of the Guildford Formation of Aeolian origin, (Bassendean Sand over Guildford Formation).
- Cs – SANDY CLAY – White-grey to brown, fine to coarse-grained, subangular to round sand, clay of moderate plasticity gravel and silt layers near scarp.

2.6. Acid Sulfate Soils

Acid sulfate soils are soils which contain reduced forms of sulfur which typically originate from the reducing conditions associated with anaerobic soils in wetlands. In Western Australia, Acid Sulfate Soils occur in low lying coastal lands such as Holocene swamps and Lakes. If such soils are exposed to oxygen, for example by excavation or dewatering, reduced sulfides convert to sulfuric acid and significantly lower pH, causing a range of undesirable environmental consequences. If they remain undisturbed and inundated, they are stable.

According to the Planning bulletin 64 on Acid Sulfate Soils (WAPC 2003), the site has been classified as having mostly a moderate to low risk of Acid Sulfate Soils (ASS) occurring within 3 m of the natural soil surface and activities disturbing soils at depths greater than 3m carry a high to moderate risk of disturbing ASS. However there are three small pockets in which a high to moderate risk of Acid Sulfate Soils (ASS) occurring within 3 m of the natural soil surface (Figure 5).

Acid sulfate soils do not pose an environmental hazard if they are left in their natural state. If they become subject to oxidation by excavation or by dewatering, they can for acid as sulfides oxidise to sulfuric acid, and this can create significant environmental problems. The current development proposal does not involve excavation or dewatering to the depth of acid sulfate soils for the installation of services. Accordingly, the proposed development does not represent and Acid Sulfate hazard, however the presence of these soil conditions needs to be noted.

Total Sulfur and Carbon Determination

Soils were dried overnight in a laboratory oven at 100^{o}C, then milled to less a fine powder (< 50 um) using a Retch counter-rotating laboratory mill. Samples were analysed using a LECO SC200 induction furnace carbon/sulfur analyser.

Bioscience

Figure 5 – Risk Mapping of ASS occurrence within ±3m of the natural surface.

Legend

🟥 Class 1 – High to Moderate Risk <3m

🟨 Class 2 – Moderate to low Risk >3m

The internal standards used throughout analyses were LECO calibration standards containing 0.040 and 0.004% S respectively; thereby ensuring the instrument was accurately measuring total sulfur at around and below critical threshold values for reduced sulfur.

Note: The DEC guidance does not mention the use of this technique, but it does refer to Ahearn *et al* (2004) as the authority.

Ahearn, at Section A2-3, “The measurement of total sulfur provides a low-cost alternative for estimating the maximum potential environmental risk from acid produced by the oxidation of sulfides.” However this publication has the caveat “Instrumental total sulfur determination…..is generally not suitable for accurate determinations on soil with low sulfur contents (e.g. Sands) unless instruments have been specifically set up for low levels analysis.” (as the Bioscience instrument is indeed set up).

Later at Section B5-2 details Method Code 20A2 for Total Sulfur by combustion furnace, including the requirement to follow manufacturer’s instructions to optimise procedures with particular reference to the combustion catalyst used.

Bioscience contends that this approach is a superior screening test to complement field pH testing. It accurately measures total sulfur, which is a combination of elemental sulfur, organic-bound sulfur, oxidised sulfur and reduced sulfur. If the total sulfur measured is under the environmental threshold for reduced sulfur, the sample cannot possibly be ASS or PASS thus can be eliminated from further analysis.

2.6.1. ASS Results

Action criteria for determining the acid-sulfate potential of samples were derived from the DEC guidance (see Table 1 below). For a sample to be classified as actual acid sulfate soil (AASS total sulphur at greater than 0.03% if a sand, or greater than 0.06% if a sandy loams and light clay or greater than 0.1% for silts and clays.

Table 1 – Acid Sulphate Soil Action Criteria (Ahern et al, 1998).

Type of Material		Action Criteria, <1000 tonnes		Action Criteria, >1000 tonnes	
Texture	Approx. Clay Content (%<0.002mm)	Sulfur Trail SP_{OS} %	Acid Trail TPA mole H^+/t	Sulfur Trail SPOS %	Acid Trail TPA mole H^+/t
Coarse (sand)	≤5	0.03	18	0.03	18
Medium (Loams to Light Clays)	5 to 40	0.06	36	0.03	18
Fines (Silts and Clays)	≥40	0.10	62	0.03	18

S_{POS} gives a measure of the maximum "oxidisable" sulphur present in a soil sample, where as total sulphur or S_{TOTAL} (as measured in this report) gives a measure of total sulphur present with a soil sample, consequently S_{TOTAL} will always be equal to or greater than S_{POS}). Leco total sulphur analysis indicates that none of the samples tested has levels over the action criteria as per table 1. Consequently, all samples tested were classed as non acid sulphate soils (NASS).

2.7. *Regional Hydrogeology*

According to Davidson and Yu (2006) the study area appears to be located within the Armadale superficial aquifers which is bounded to the north by the Canning River, to the east by the Darling Scarp, to the south by the Byford aquifer and to the west by Lake Forrestdale and the Southern River (Davidson and Yu, 2006). It should be noted however, that the study area is also located within close proximity of a transitional zone between its neighbouring superifical aquifers, namely the Jandakot and Byford aquifers. Given this mapping was conducted on a regional scale the actual hydrogeology of the site may be rather complex.

The majority of groundwater recharge like other areas within the Swan Coastal Plain, results from rainfall infiltration, however additional recharge results from rainwater runoff from the Darling Scarp (Davidson and Yu, 2006). An estimated annual recharge of only 5% is relatively low for the Swan Coastal Plain and due in part to low hydraulic conductivities of clayey sediments and the shallow water table.

The Armadale aquifer has a transmissivity of approximately 100m^2/day, an average annual fluctuation of approximately 0.8m and ultimately discharges into either the Southern River (4900m^3/day) or Lake Forrestdale (1000m^3/day).

2.8. Local Hydrogeology

According to the Department of Environment's (DoE's) Perth Groundwater Atlas (DoE, 2004) the site is characterised by having a high groundwater table. Groundwater levels at the site in May 2005 (i.e. minimum) were approximately 22m ADH, whereas the all time maximum groundwater levels for the site is approximately 24m ADH. As the described previously the topography of the site varies from 24m AHD to 25m AHD, consequently the site is suspected to become inundated in the winter months particularly in the lower lying areas (i.e. <24m AHD).

Groundwater levels from six Department of Water (DoW) monitoring bores (Bore WIN ID's 3116, 3117, 4343, 4781, 4782 and 4910) located within the vicinity of the study area support the *Perth Groundwater Atlas* levels (Figures 6 to 11).

Bores 3116 and 3117 (located approximately 2km to the east of the study area), 4343 (located approximately 2km to the west of the study area) and 4910 (located approximately 2km to the north east of the study area) all suggest that the average annual fluctuation is approximately 1.5 to 2m. In each of these bores there has been a general downward trend in groundwater levels throughout the past 35year, presumable this is in response from greater groundwater extraction, coupled with decreased rainfall (i.e. decreased recharge).

Interestingly, groundwater levels in the nearby 4781 bore (located approximately 2km to the west north west of the study area) have remained level, whereas levels in bore 4782 (located approximately 2km to the north west of the study area) have risen approximately 0.6m over this same period.

Clearly the hydrogeology of the study area is complex, and thus further site investigations are required to quantify hydraulic gradients, groundwater flows, average annual maximum groundwater levels (AAMGL) for the site, and controlled groundwater levels (CGL) if required.

2.8.1. Wetlands

The Geomorphic Wetlands Dataset displays the location, boundary, geomorphic classification and management category of wetlands on the Swan Coastal Plain. The information contained within the dataset was originally digitised from the *Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas*, which was captured at a scale of 1:25,000 (Hill et al. 1996b). According to the dataset the vast majority of the land is comprised of four multiple use wetlands (MUW) (i.e. 15714 Palusplain, 7534 Sumpland, 7535 Sumplamd, and 14484 Sumpland). One relatively small plausplain conservation category wetland (CCW) is located to the southern west-central part of the site, under power lines (7379 Palusplain) (Figure 12).

Forrestdale Lake is situated just north west of the land. It lies in a slight geological depression and falls within the Southern River catchment. This lake is listed as a RAMSAR wetland and holds international importance. A wetland protection area for the Lake has been drawn to ensure ground water is managed to an acceptable environmental standard. This Environmental Management Area (EMA) was advised by the Department of Environment and Protection (now DEC) and the Water and Rivers Commission (WRC) using groundwater capture modelling and defines the lakes catchment area. The Environmental Protection Authority (EPA) advises that it would not support development on or any adjustment to the EMA without adequate scientific investigations.

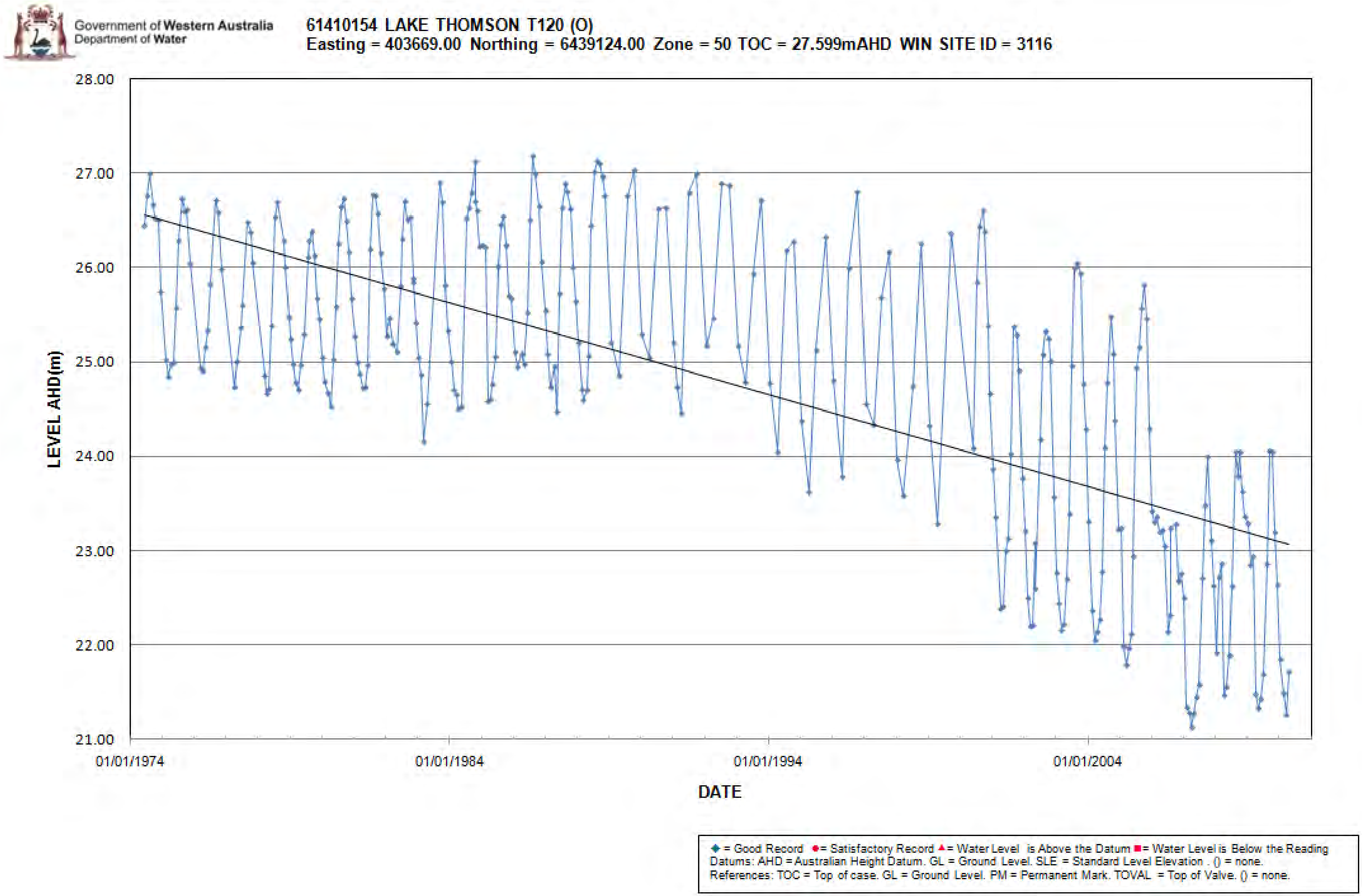

Figure 6– DoW WIN Site 3116 historical bore levels.

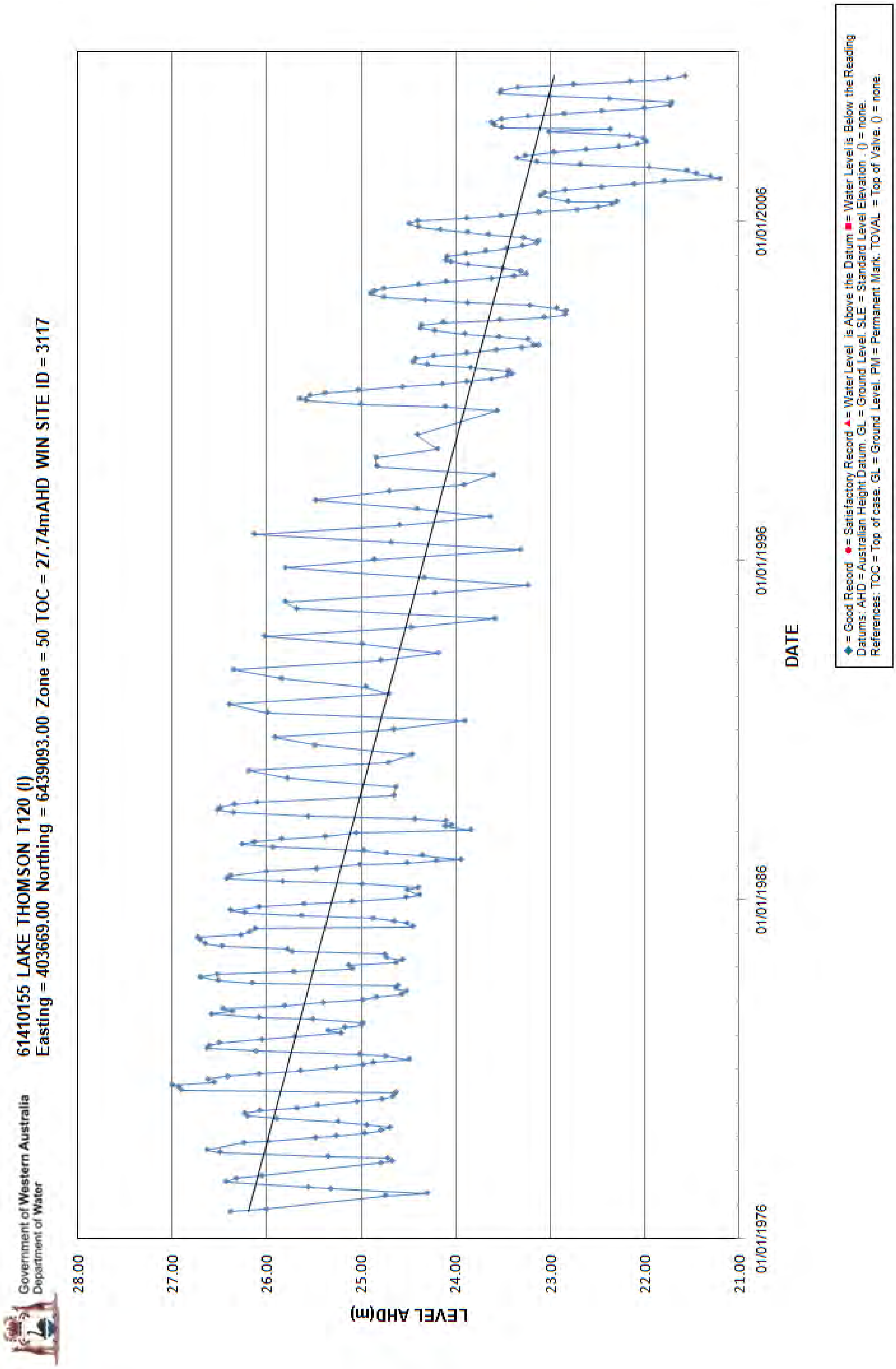

Figure 7 – DoW WIN Site 3117 historical bore levels.

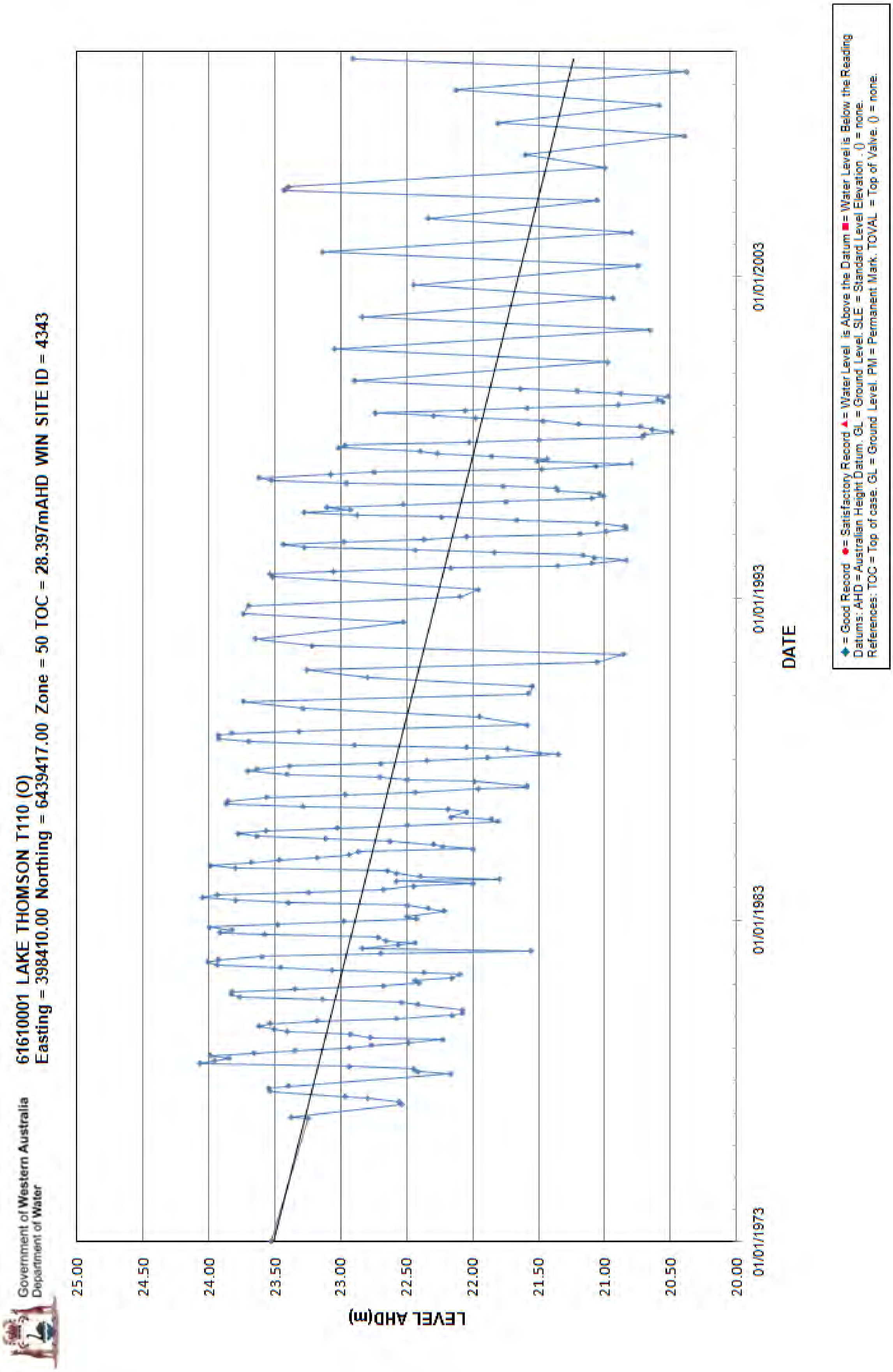

Figure 8 – DoW WIN Site 4343 historical bore levels.

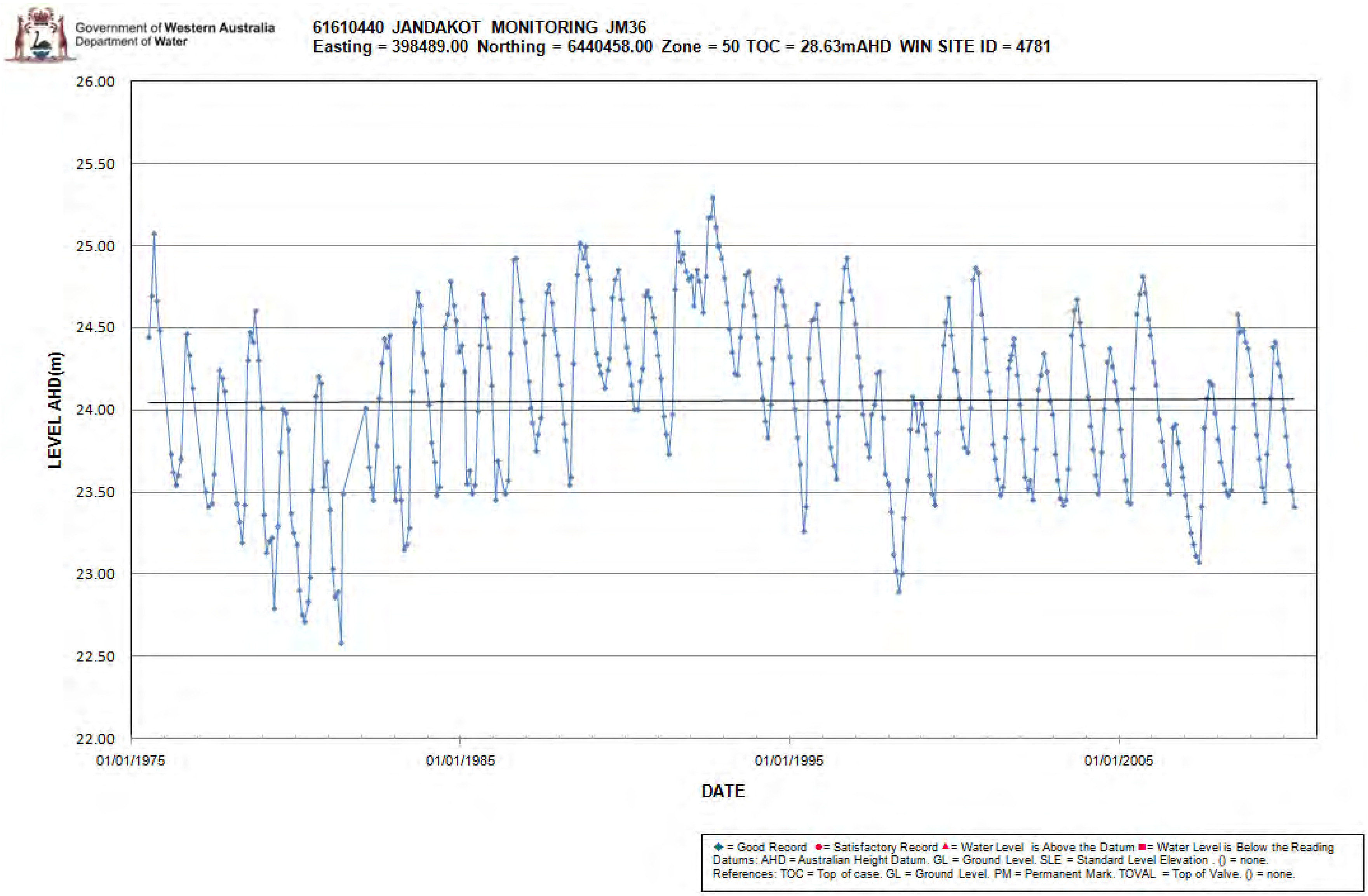

Figure 9 – DoW WIN Site 4781 historical bore levels.

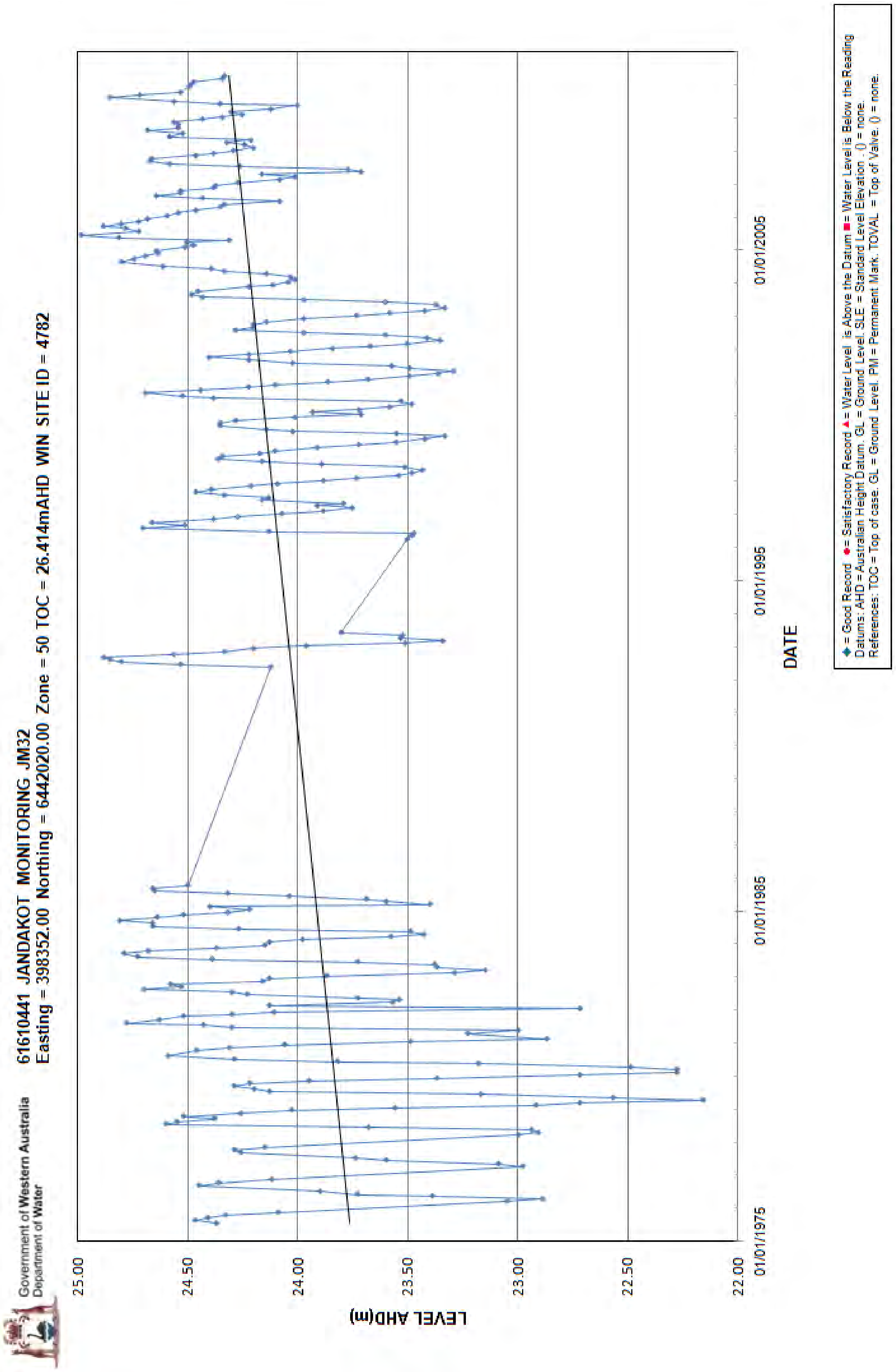

Figure 10 – DoW WIN Site 4782 historical bore levels.

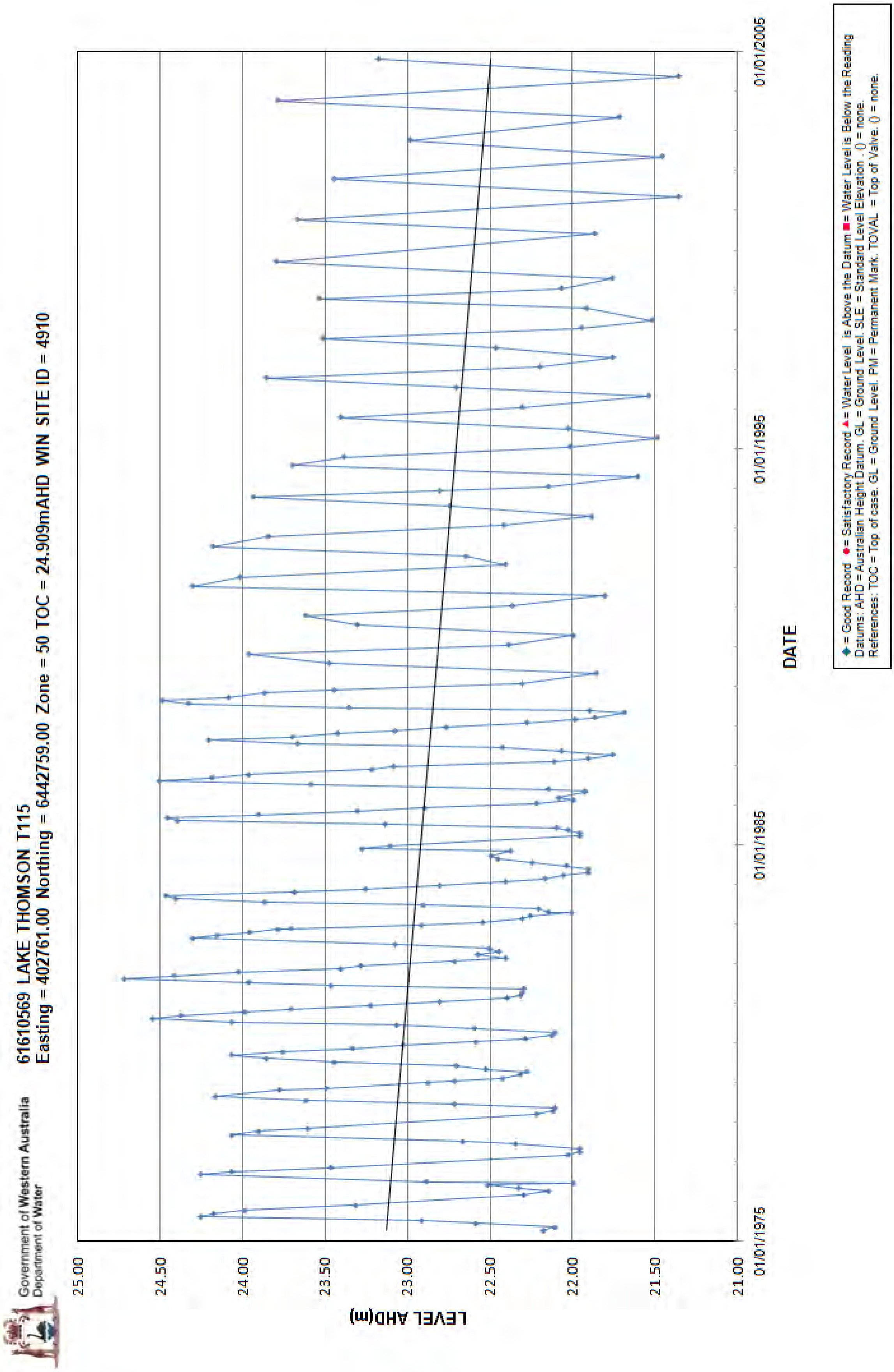

Figure 11 – DoW WIN Site 4910 historical bore levels.

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Figure 12 – DEC Swan Coastal Plain Wetland Mapping

Legend

🟩 Conservation

🟥 Multiple Use

3. Geotechnical Investigations

3.1. Objectives

The Objectives of the geotechnical investigations proposed are:

- To determine subsurface soil, rock and groundwater conditions to 2.5 meters below existing surface levels (BGL).
- Determine the site classification according to AS 2870 (1996) and, if appropriate, determine the boundary between areas which may have different classification and recommend suitable measures to upgrade classification.
- To determine the nature and extent of any uncontrolled fill, if encountered.
- To determine soil permeability and suitability of the site for the disposal of stormwater runoff by infiltration into drainage basins.
- To advise on construction considerations related to the proposed development, including site preparation, excavation conditions, suitability of materials for structural fill, compaction control and groundwater control.

3.2. Field Investigations

An intensive field investigation for this project was undertaken in May 2010 and followed by a series of monthly visits in which groundwater levels were recorded and water samples collected for further analysis. Lithological logs and soil samples collected from the installation of the 25 piezometer were used to determine the geotechnical characteristics of the study area.

3.2.1. Groundwater

Twenty five piezometers were installed across the site in May of 2010. Since the installation groundwater levels have been monitored only twice. Early indications suggest that groundwater like surface water flows in a southerly direction and maximum depths are between 4.123m and 0.866 mBGL (Figure 13). More information regarding the AAMGL and groundwater flows will be describes in the Hydrogeological Investigation currently being conducted by Bioscience.

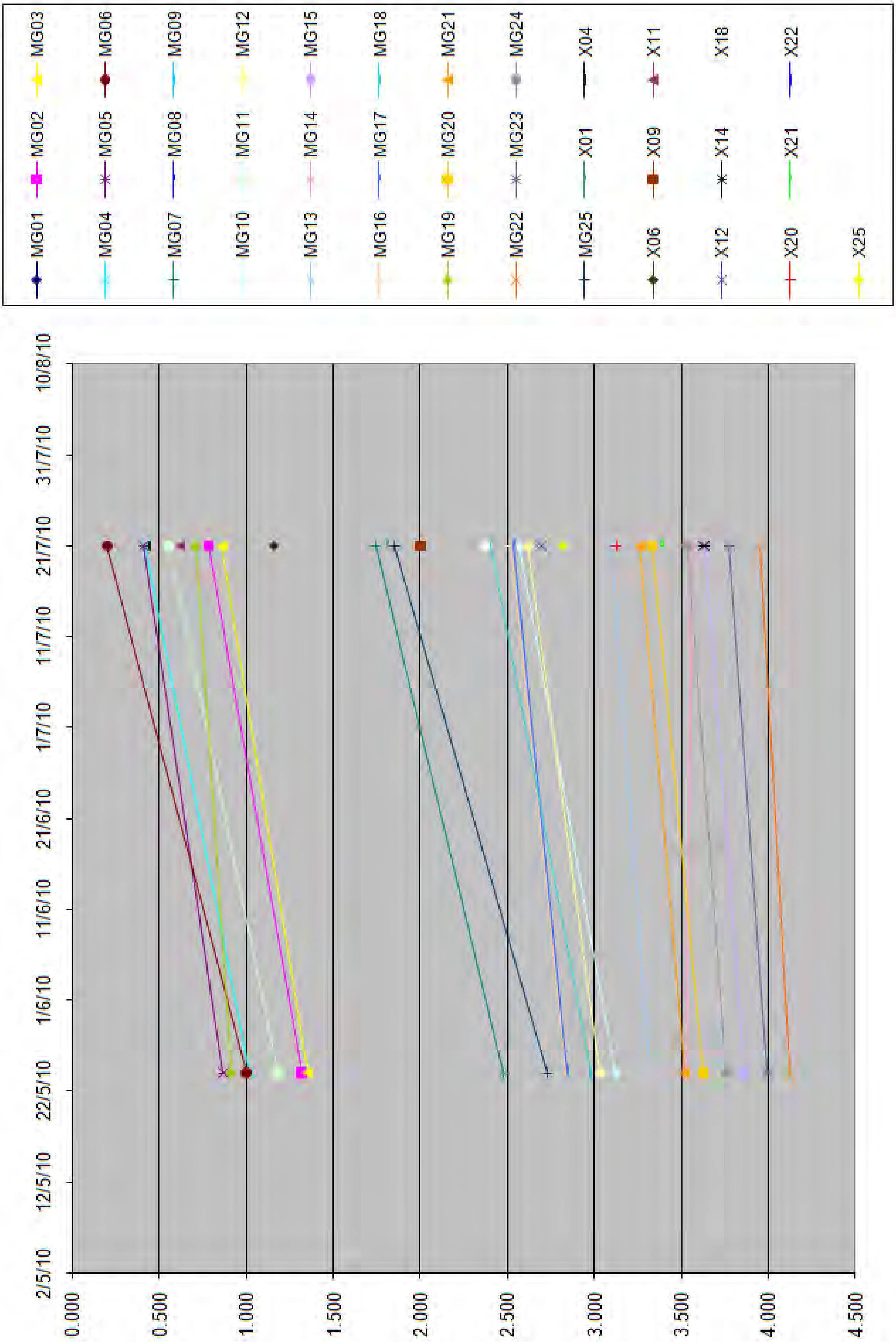

Figure 13 – Groundwater levels in meters below ground level (mBGL).

3.3. Laboratory Investigations

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

- Particle size distribution – AS1289.3.6.1
- Atterberg limit
  - Liquid limit – AS1289.3.1.2
  - Plastic limit - AS1289.3.2.1
  - Plasticity index – AS1289.3.3.1
  - Linear shrinkage – AS1289.3.4.1
- Acid Sulfate Soil SPOCAS Suite - AS 4969.12

The laboratory tests were carried out in accordance with the requirements specified in AS 1289 and AS 4969.12 by Bioscience's soil laboratory in Forrestdale.

3.3.1. Particle size distribution

Particle size distribution (PSD) was determined on selected soil samples collected during the geotechnical investigation (Appendix 1). The percentage of fines (i.e. the proportion less than 0.075µm) varied significantly in the soils analysed from 3.56% (MG02, 0 to 200mm) to as high as 67.92% (MG15, 2000 to 3000mm).

3.3.2. Atterberg Limit

The Atterberg limits tests are simple standardized tests that were developed to determine the water contents that will induce particular behaviour, and provides a useful measure of potential soil reactivity and ground movements, which are fundamental in foundation design. Of the samples collected during the installation of the 25 piezometers, only those described as loamy sands to sandy clays underwent Atterburg analysis.

Guildford formation soils are typically slightly too moderately reactive. Laboratory analysis indicates that the liquid limits varies from 28.18 to 69.03%, the linear shrinkage varies from 3.33 to 12.66%, whereas the plastic index varies from 10.66 to 46.30% (Table 2).

Table 2 - Atterberg limits results

Borehole	Sample Depth (m)		Soil Weight		Liquid Limits			Plastic Limits	Plastic Index (PI)	Linear Shrinkage (LS)	Atterburg Classification
			Total soil Weight (g)	% Fines (<425um)	No Blows (15 to 35)	Water content (%)	Liquid Limits (LL) (%)	Water content (%) OR Plastic Limits (PL)	PI = LL - PL	Linear Shrinkage (LS) (%)	
MG20	1000	2000	250.4	34.71	23	37.44	37.05	25.57	11.48	9.33	MI
MG07	200	800	284.2	63.27	24	31.44	31.24	18.92	12.32	9.33	CL
MG15	0	1000	206.2	39.07	33	63.62	65.50	31.95	33.55	12.00	CH
MG23	1000	2000	348.1	73.45	28	42.68	43.09	23.69	19.40	7.33	CI
MG11	1300	1600	258.5	78.24	31	65.65	67.07	20.77	46.30	3.33	CH
MG08	200	400	344.8	48.35	22	28.59	28.18	17.52	10.66	11.00	CL
MG07	2000	2200	313.9	54.27	18	42.16	40.88	21.86	19.02	10.67	CI
MG08	400	800	333.1	39.1	30	67.84	69.03	23.04	45.99	9.33	CH
MG11	1600	2100	314.6	50.18	31	56.13	57.34	22.38	34.96	6.00	CH
MG07	200	700	363.9	38.16	18	45.31	43.93	20.89	23.04	12.67	CI
MG12	2100	2400	286.4	56.97	31	50.76	51.86	22.26	29.60	10.67	CH
MG13	2000	3000	262.0	51.27	26	45.14	45.21	21.77	23.44	12.00	CI

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

Of the twelve soil samples tested for Atterberg limits, two had low plasticity, five had intermediate plasticity whereas the remaining five had high plasticity (Figure 14). Results indicate that only one sample plotted below the A-line suggesting it is more silty than clayey. The remaining eleven samples plot above the A-line, which is indicative of clayey soils. Given that these soils contain between 21.76 and 78.24% non-fines (i.e. greater than 425µm), this would have the effect of moderating the reactivity of the in situ clayey soils. However, given the high plasticity of a number of samples, post development surface levels will need to carefully considered to ensure that adequate separation is maintained between these reactive soils and building foundations through the importation of sand fill.

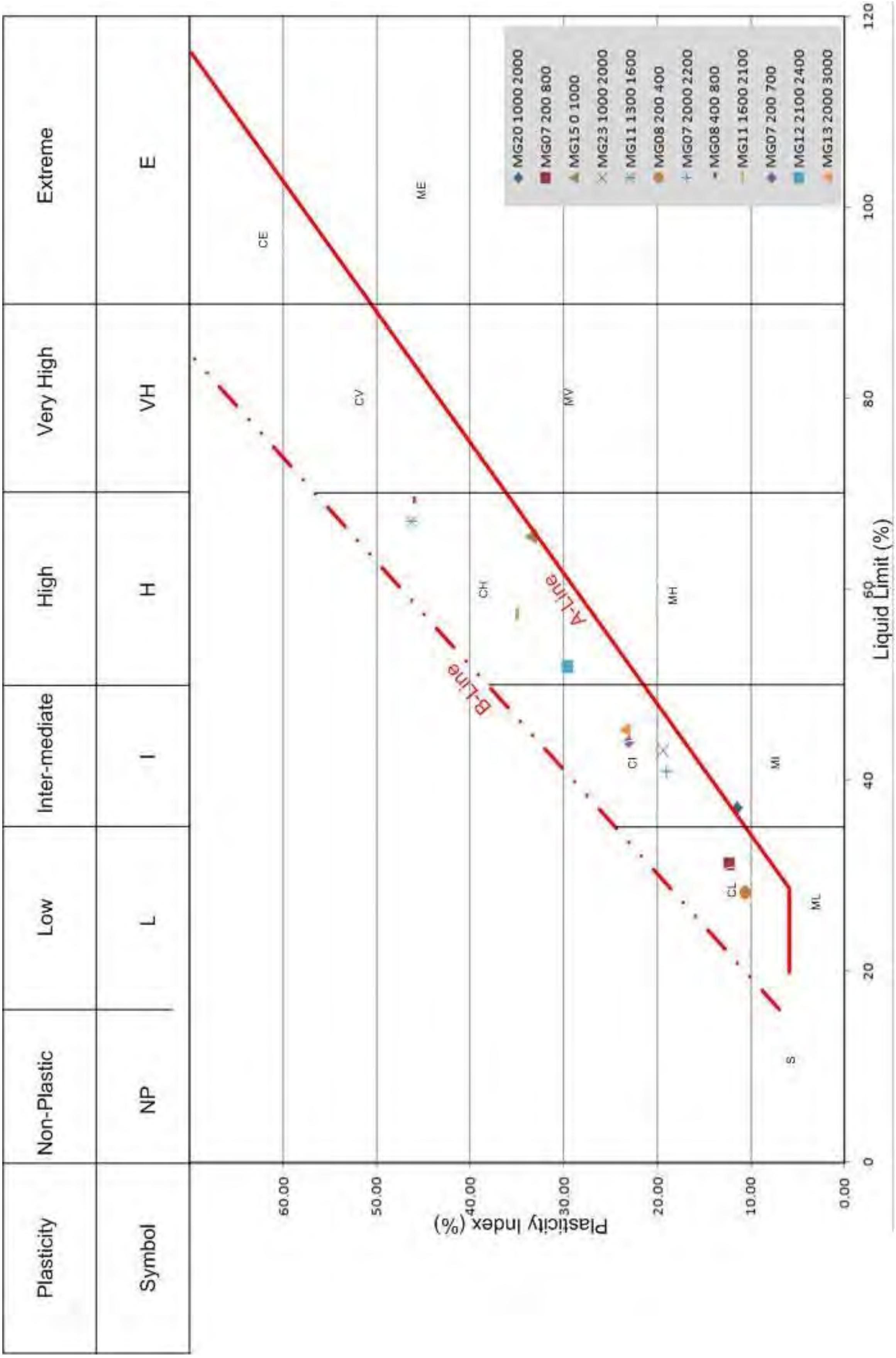

Figure 14- Atterberg limits results

3.3.3. Acid Sulphate Soil – Total Sulphur

No soil samples tested were indicative of potential ASS. For a sample to be classified as potential acid sulphate soil the minimum "oxidisable" (S_{POS}) sulphur present must be greater than 0.03% for a sand, or greater than 0.06% for sandy loams and light clay or greater than 0.1% for silts and clays. As can be seen in Table 3 below, total sulphur content of all samples tested is lower than the minimum "oxidisable" sulphur required for potential acid sulphate soils to occur.

Table 3 – Total Sulfur levels in selected site soils.

Bore ID	Depth (mm)	Soil Type	Total Sulphur (%)
MG02	1400-1600	Loamy Sand	0.031
MG11	900-1200	Sand	0.004
MG16	0-1000	Sandy Clay	0.017
MG16	1000-2000	Sand	0.0149
MG16	2000-3000	Sand	0.034
MG17	0-1000	Loamy Sand	0.018
MG17	1000-2000	Sandy Clay	0.016
MG21	1000-2000	Sandy Clay	0.02
MG21	0-1000	Clayey Sand	0.018

4. Site Evaluation and Recommendations

4.1. Site Classification

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

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

The site classification was determined using a combination of field and laboratory investigations and aerial photography analysis. Due to the significant variation in soil classification recorded within the study area, caution must be taken when assuming that site classification is continues between any two investigation sites.

The majority of the site is classified as "Class M" as defined in the Residential Slab and Footings (Australian Standard 2870), as the natural sand cover over the loamy/clayey soils are less than 0.8m and the clayey soils are slightly (low) to moderately (intermediated) reactive. A proportion of the site which currently has less than 1.5m, but greater than 0.8m of natural sand cover over the clay layer is classified as "Class S", as it may be slightly reactive and thus result in slight movement from moisture changes. The remaining land is classified as "Class A" as defined in the Residential Slab and Footings (Australian Standard 2870), as the natural sand cover over the loamy layer is greater than 1.5m, thus little to no ground movement from moisture is expected (Figure 15).

"Class S and M" areas can be upgraded to "Class A" via the application of engineered sandy fill, provided the sand cover over the clay is greater than 1.5m thick.

Bioscience

Figure 15 – AS 2870-1996 Site Classification

Legend

🟦 Class A

🟨 Class S

🟥 Class M

4.2. Soil Reactivity

Of the twelve soil samples tested for Atterberg limits, two had low plasticity, five had intermediate plasticity whereas the remaining five had high plasticity (Figure 14). Given the high plasticity of a number of samples, post development surface levels will need to carefully considered to ensure that adequate separation is maintained between these reactive soils and building foundations via the importation of sand fill.

4.3. Soil Permeability and Drainage

Guildford soils of which the site is comprised have a low transmissivities, thus the soil permeability of the site is theoretically not suitable for the disposal of stormwater runoff by infiltration into drainage basins.

4.4. Site Preparation

The following site preparation procedure is recommended:

- Identification and diversion or protection of any buried services within the work areas.
- Removal of topsoil, organics, roots, old services and any other deleterious material from the site.
- Contouring/shaping of the ground surface to ensure surface runoff drains appropriately from the site.
- Proof compact the exposed surface using a suitable compaction plant. A minimum of 12 tonne static mass vibratory smooth drum roller is preferred to achieve densification of sandy soil at depth. A minimum of eight overlapping passes should be provided.
- Where the surface deforms excessively during compaction or wet and/or weak material is exposed, over-excavation and replacement with compacted few draining sand fill may be required.
- Site works and preparation should be undertaken in summer or autumn, where groundwater levels are near their seasonal lows, as soil will become very difficult to work with in wet conditions.

- Dewatering or drainage may be required to control groundwater levels. Experience indicates that difficulties with compaction may occur when groundwater is present within about 1.0 to 1.5m of the level at which compaction is applied.
- Confirm that adequate compaction is achieved as outlined below.
- Should compaction to satisfactory depth not be achieved by surface compaction it may be necessary to over excavate, compact the base of the excavation and replace the soil in compaction layers.
- Place and compact approved clean free draining fill material in layers of no greater than 0.3m thickness, up to the level required.

4.5. Excavation and Dewatering

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

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

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

There remains a small potential of ASS occurring during dewatering and/or excavation, consequently Bioscience recommends that site works attempt to maintain a low project risk and defined by table 4 below. A dewatering licence would need to be obtained from the Department of Water before any such work is undertaken. A suitable discharge point would be towards the south of the site and away from the environmentally sensitive areas, being the Conservation Category Wetland and Jandakot regional Park immediately to the north of the site.

Table 4 – Project Scope Dewatering Risk Assignment.

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

4.6. Compaction

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

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

4.7. *Fill Material*

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

5. Conclusions

The results of this investigation indicate that the site is physically capable of development for an industrial subdivision, subject to the recommendation of this report. The site can best be summarised as having a thin Bassendean sand layer underlying the Guildford formation. Instability issues arise due to the relatively thin layer of Bassendean sand overlaying the reactive clays of the Guildford formation. Guildford soils of which the site is comprised have a low transmissivities, thus the soil permeability of the site is theoretically not suitable for the disposal of stormwater runoff by infiltration into drainage basins.

The high plasticity of a number of samples, post development surface levels will need to carefully considered to ensure that adequate separation is maintained between these reactive soils and building foundations via the importation of sand fill.

The majority of the site is classified as "Class M" as the natural sand cover over the loamy/clayey soils are less than 0.8m and the clayey soils are slightly (low) to moderately (intermediated) reactive. A proportion of the site which currently has less than 1.5m, but greater than 0.8m of natural sand cover over the clay layer is classified as "Class S", as it may be slightly reactive and thus result in slight movement from moisture changes. The remaining land is classified as "Class A" as the natural sand cover over the loamy layer is greater than 1.5m, thus little to no ground movement from moisture is expected (Figure 15). Due to the significant variation in soil classification recorded within the study area, cautionary approach is advised as zones or pockets of more reactive soils may exits across the sites. "Class S and M" areas can be upgraded to "Class A" via the application of engineered sandy fill, provided the sand cover over the clay is greater than 1.5m thick. Given the low lying areas of the site will require considerable fill to maintain a 1.5m separation from AAMGL.

6. References

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

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Statement of Planning Policy No. 2.3 – Jandakot Groundwater Protection Policy

7. Appendix – Particle Size Distribution

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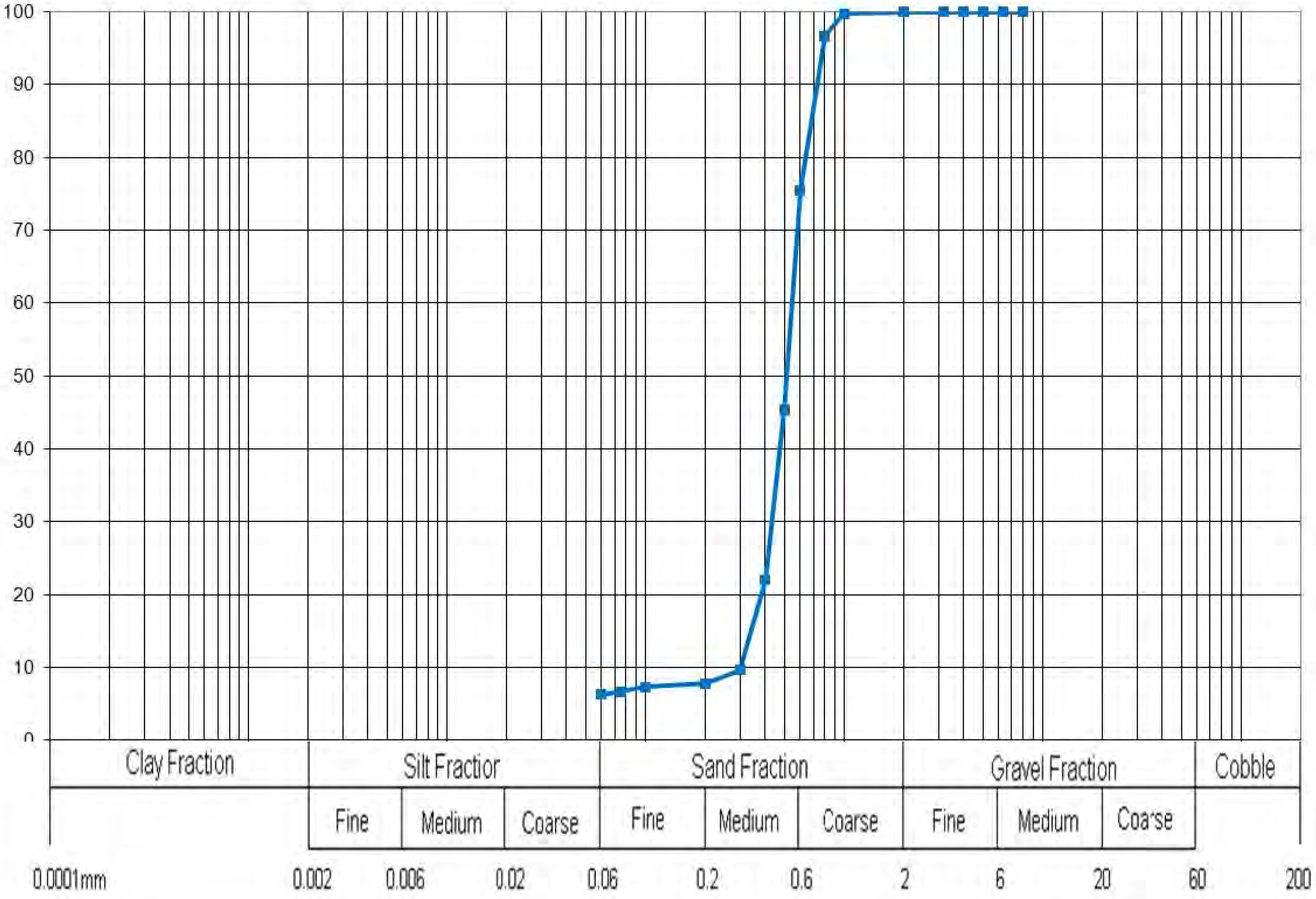
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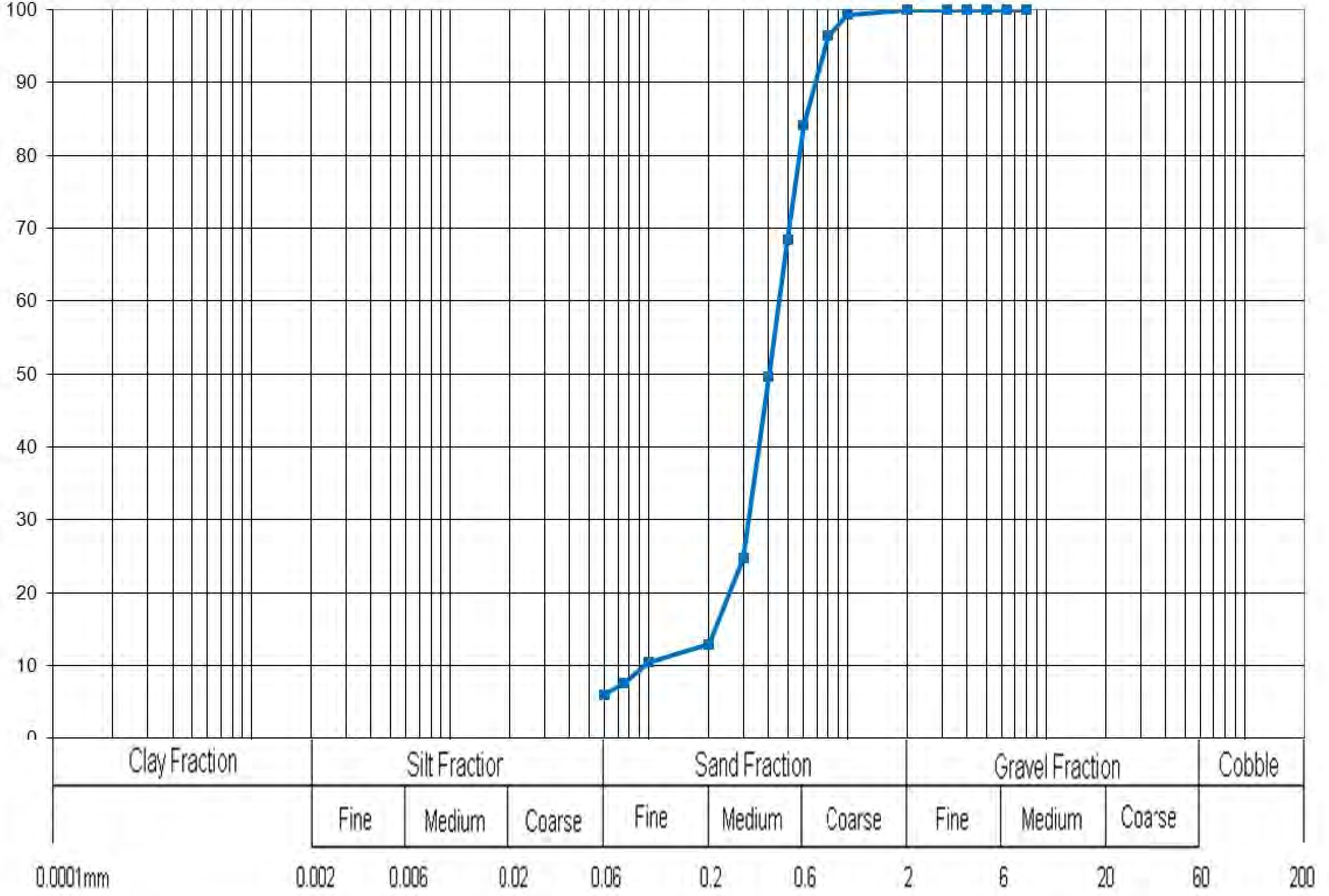

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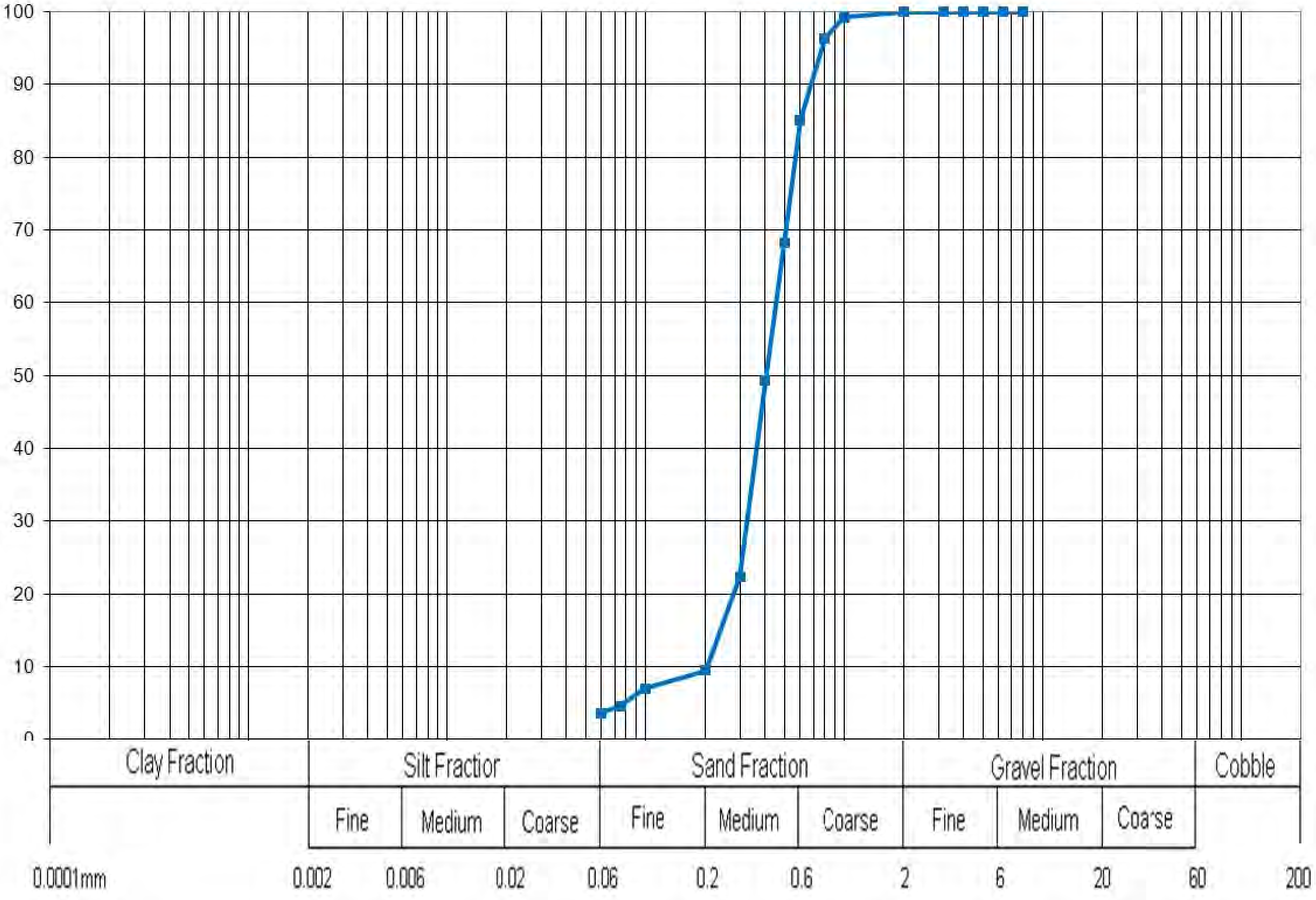

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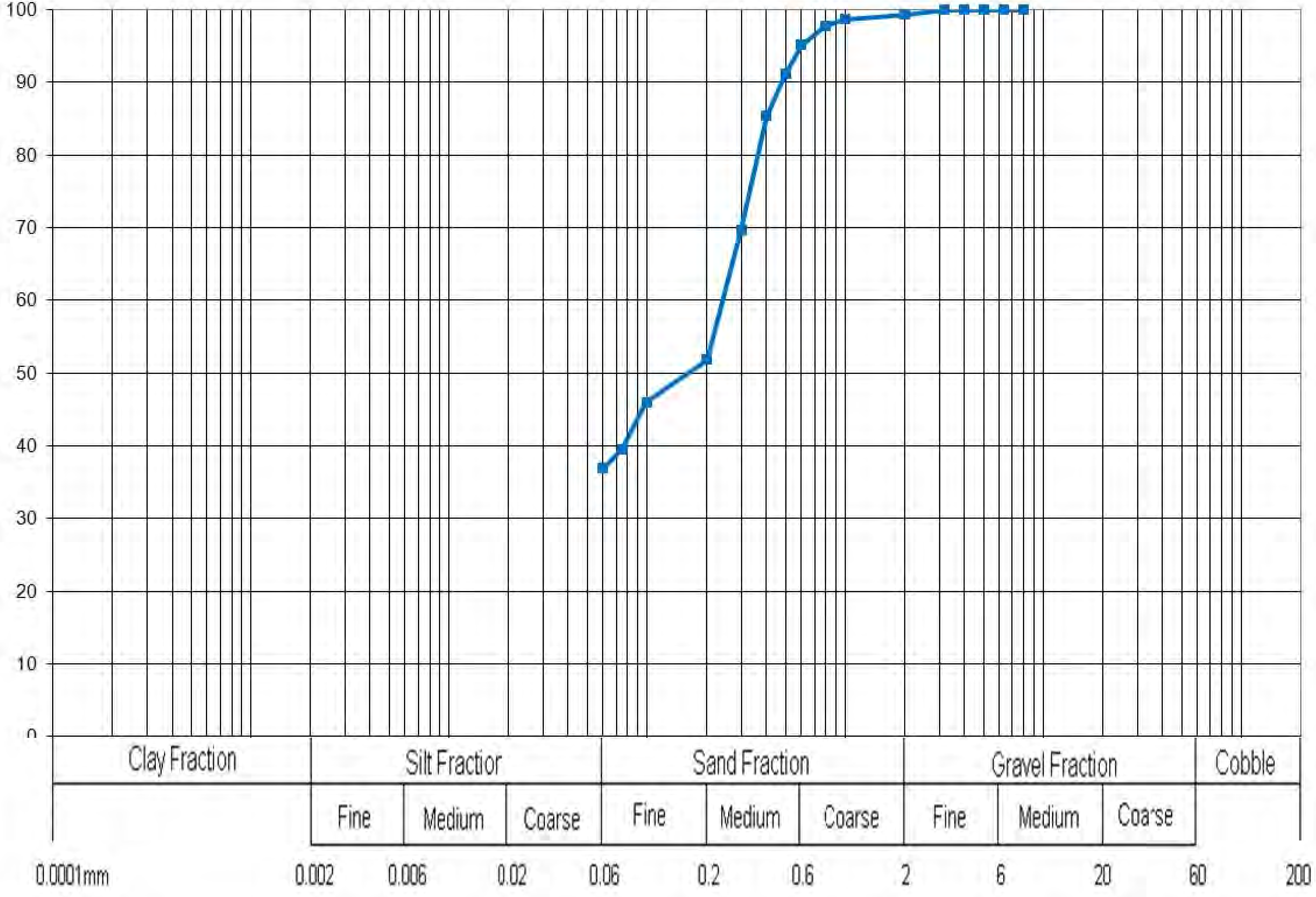

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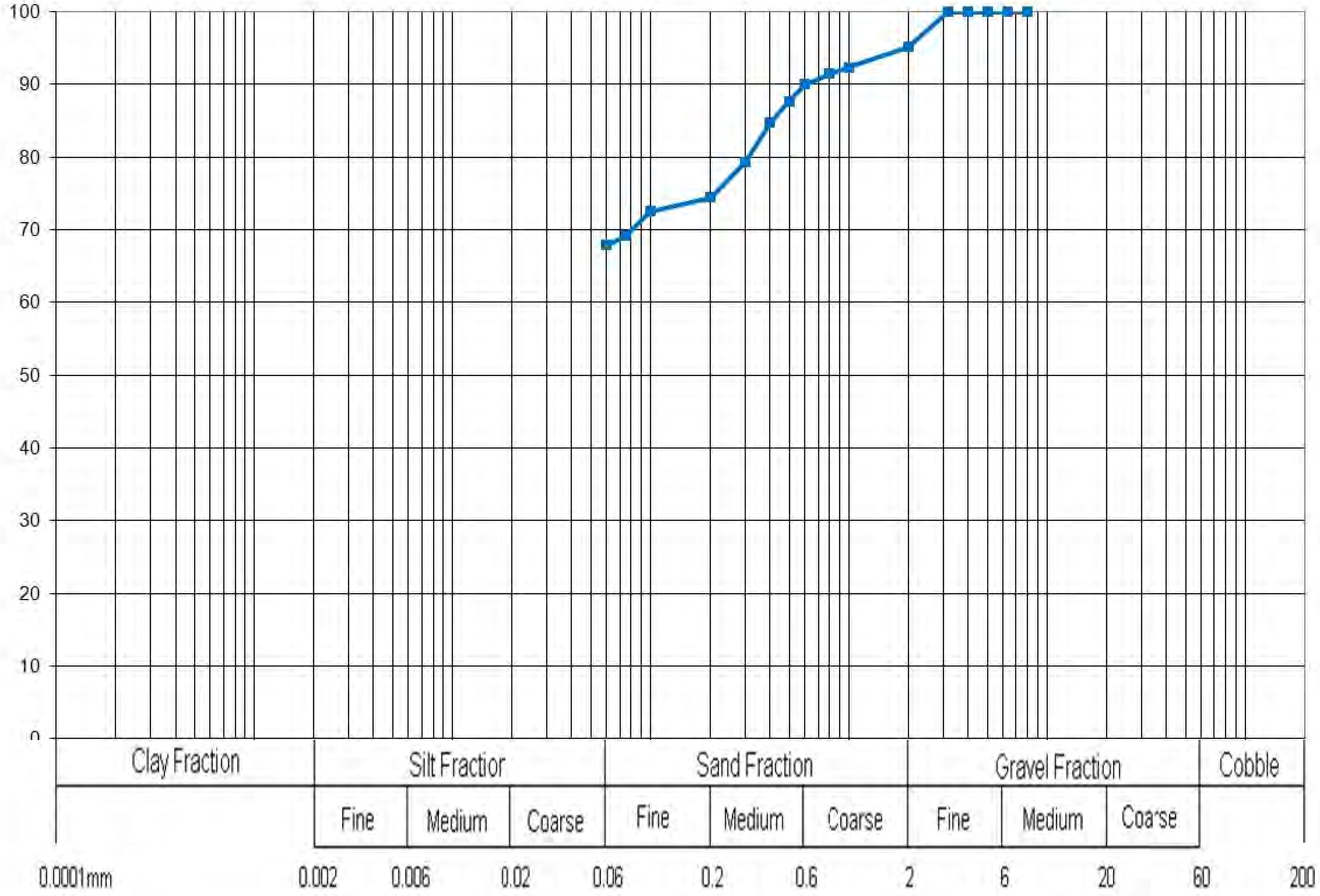

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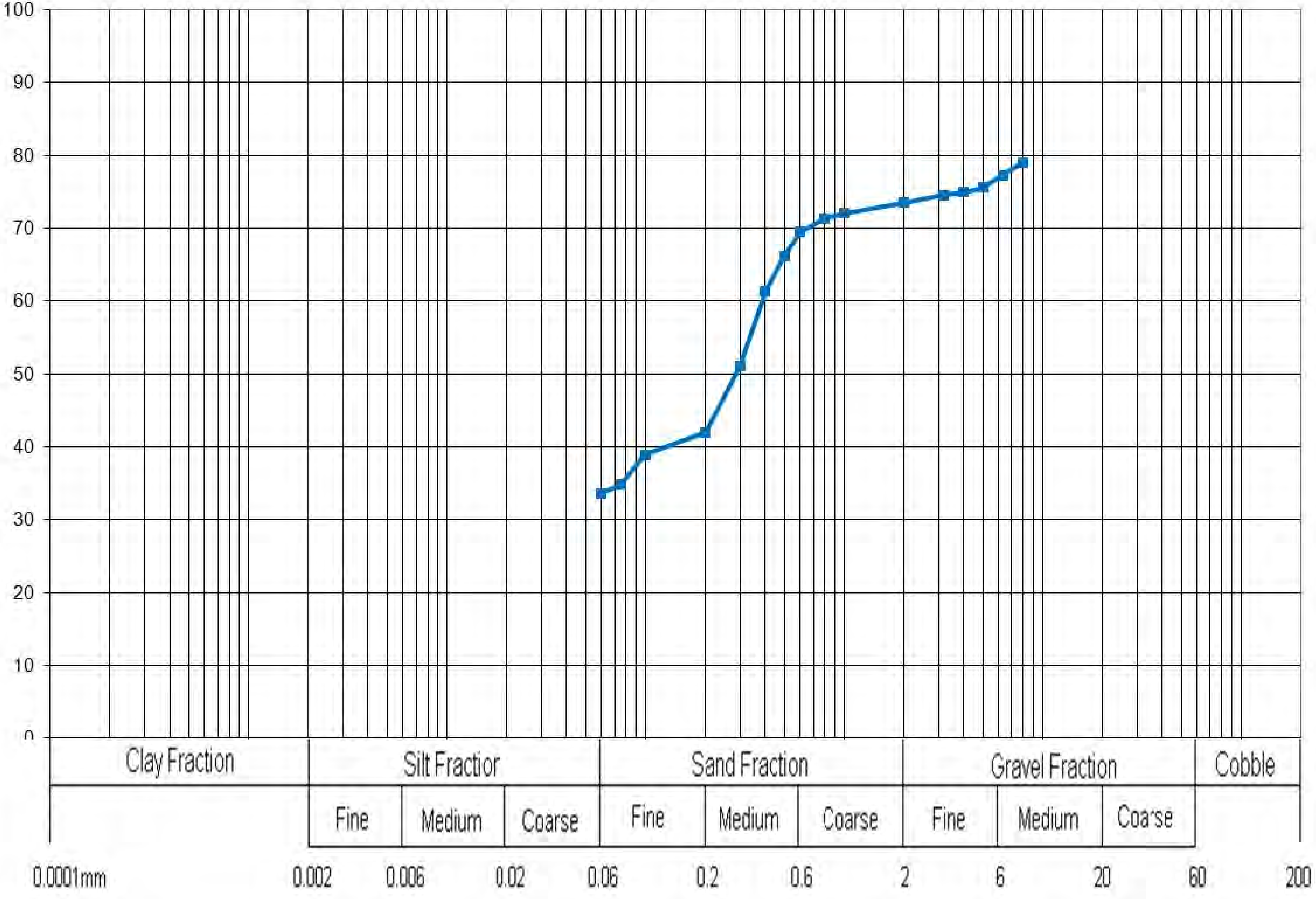

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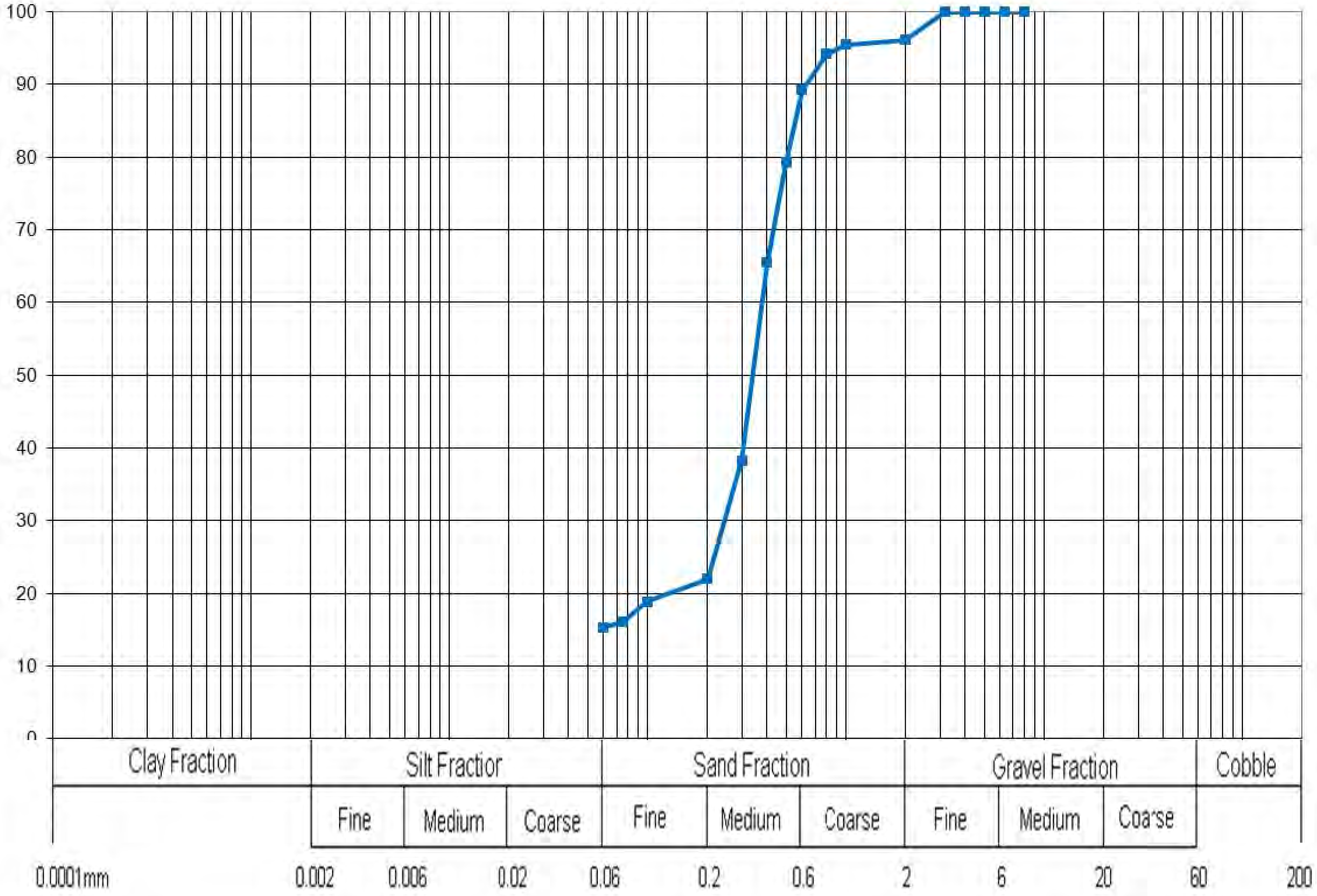

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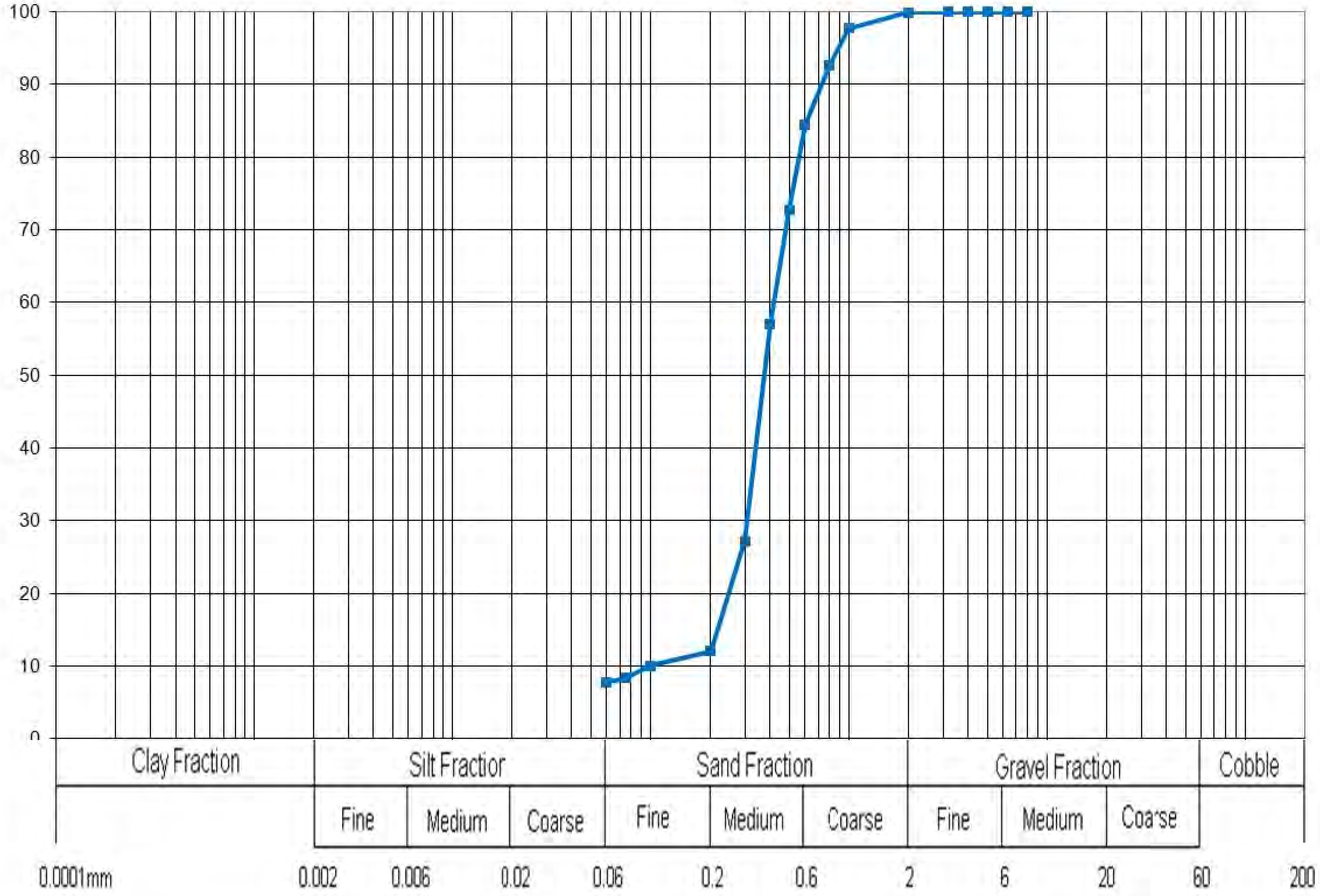

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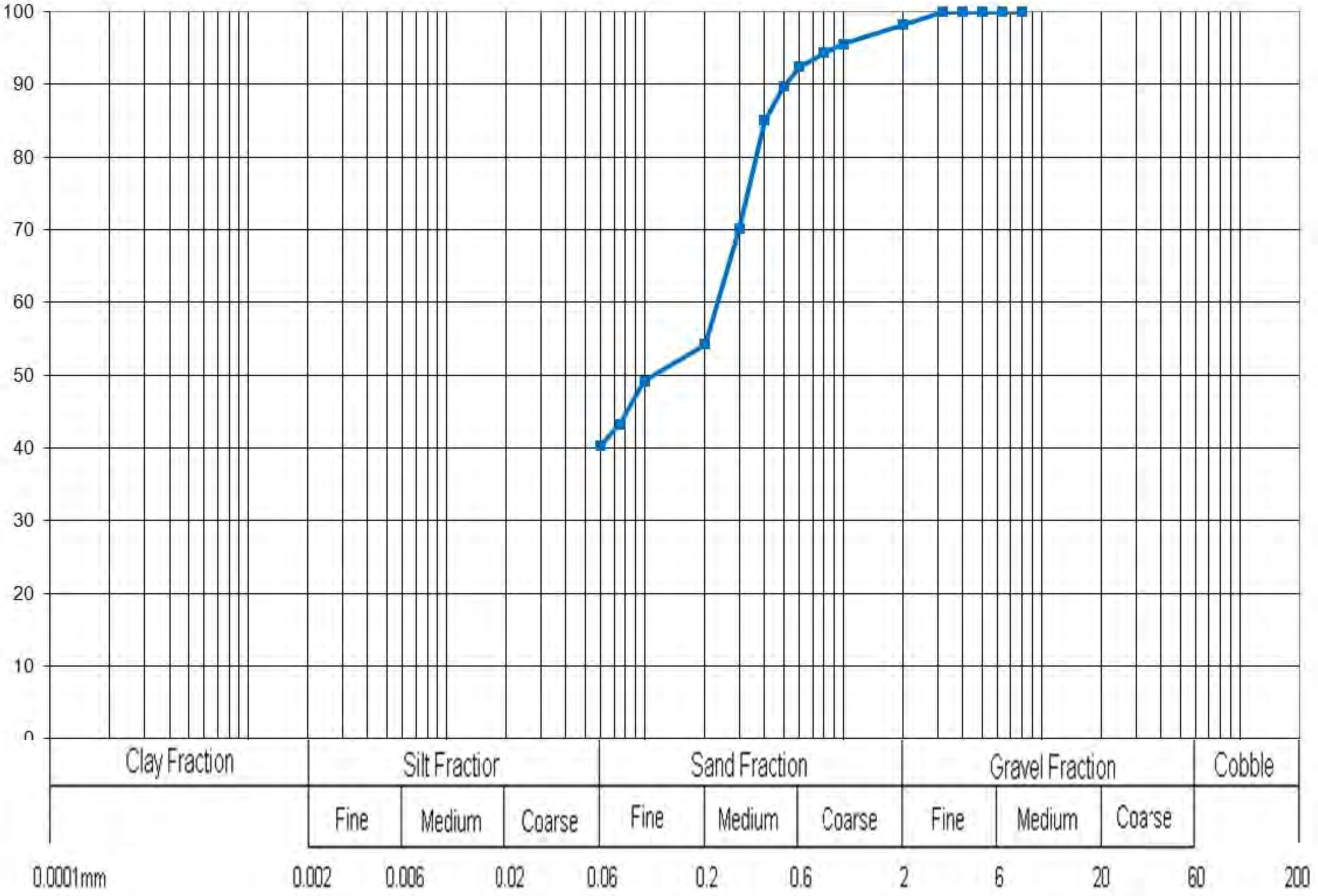

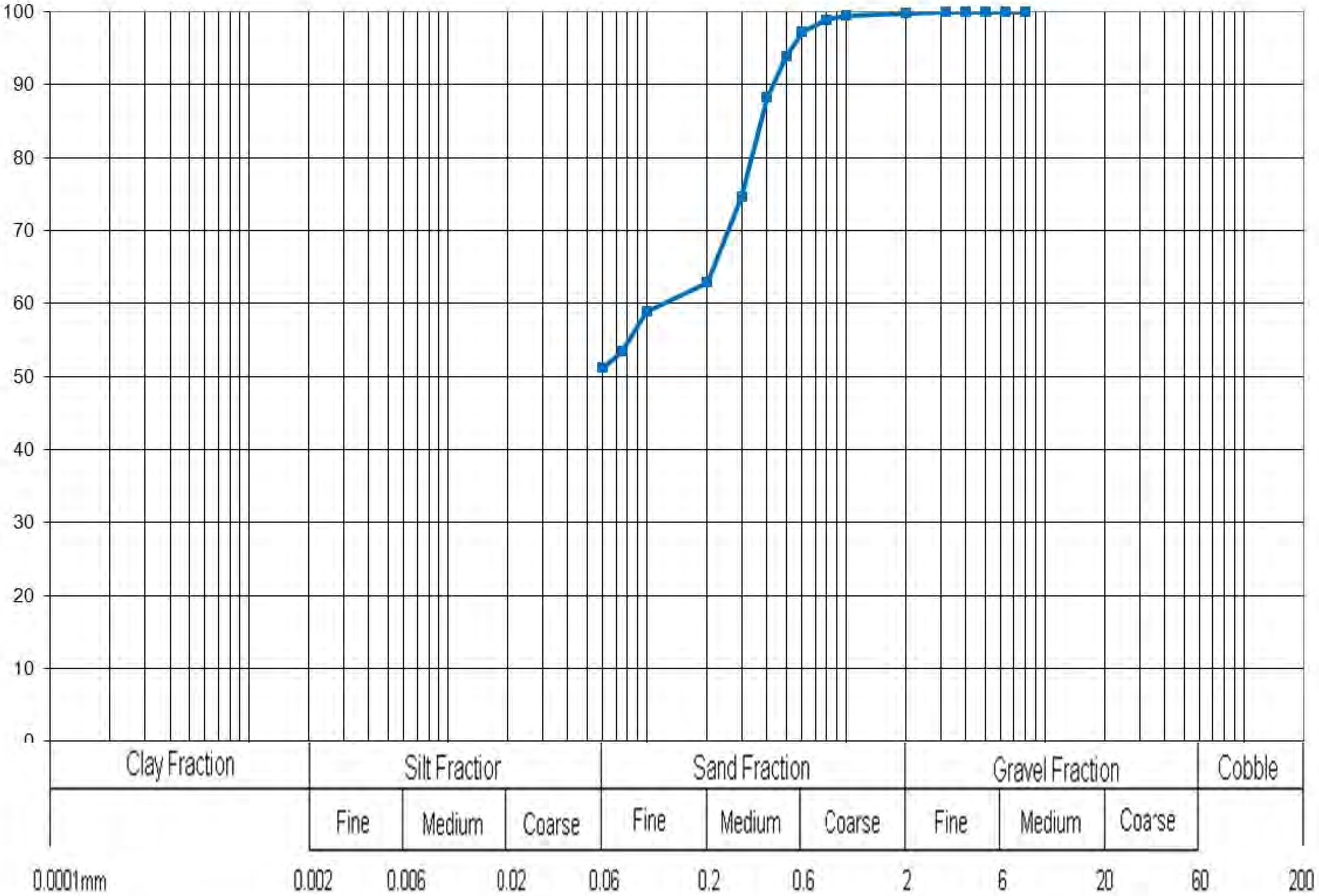
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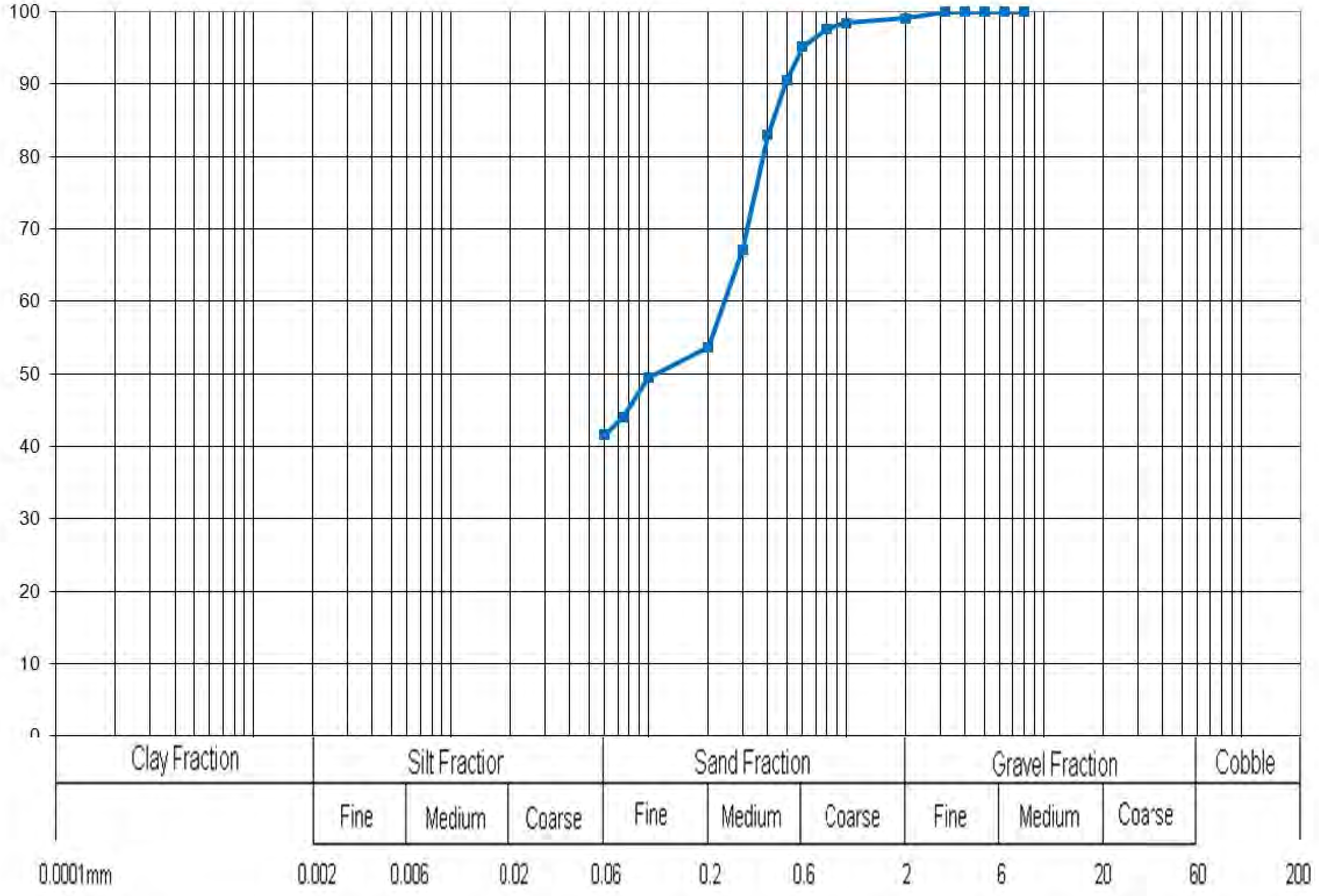

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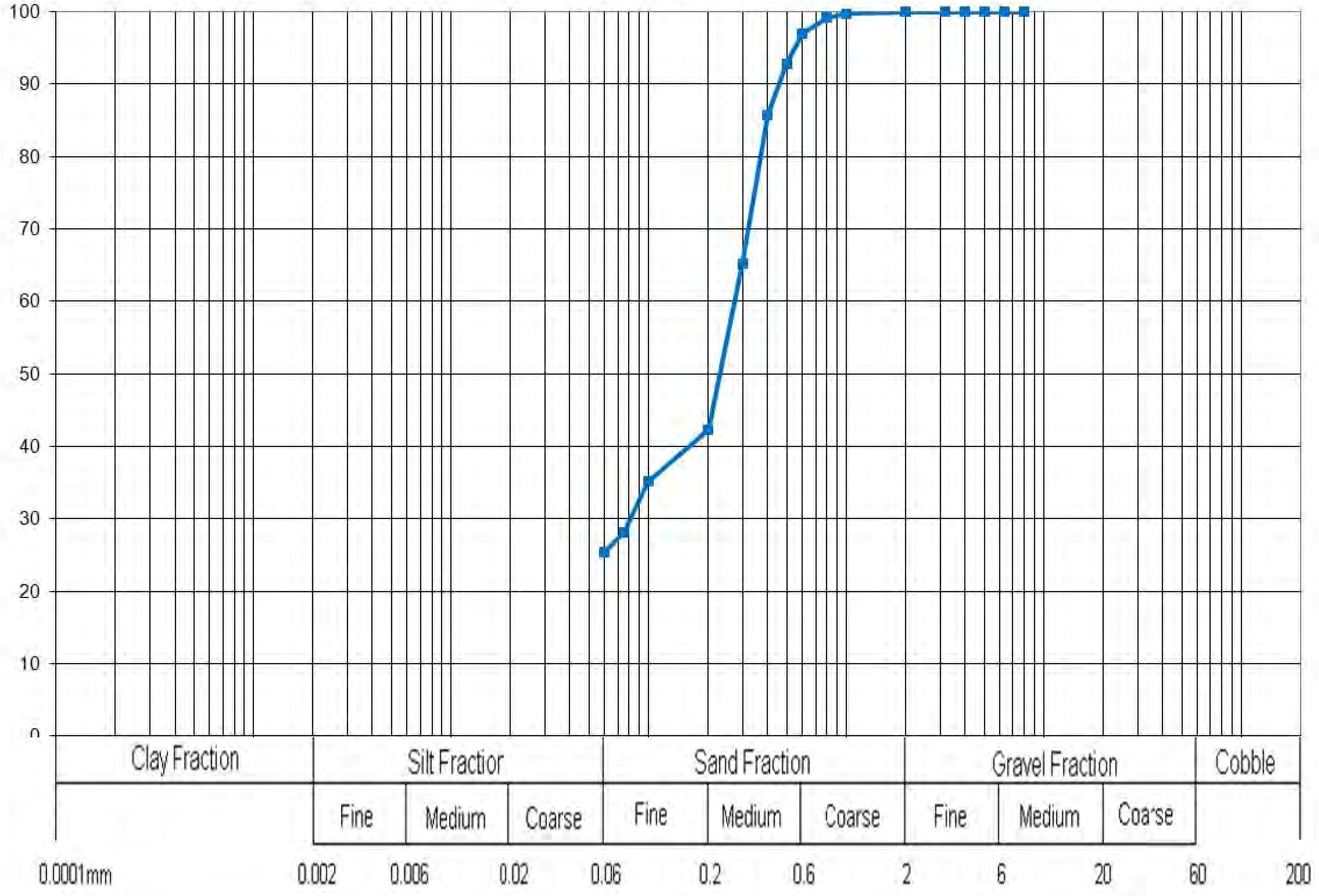

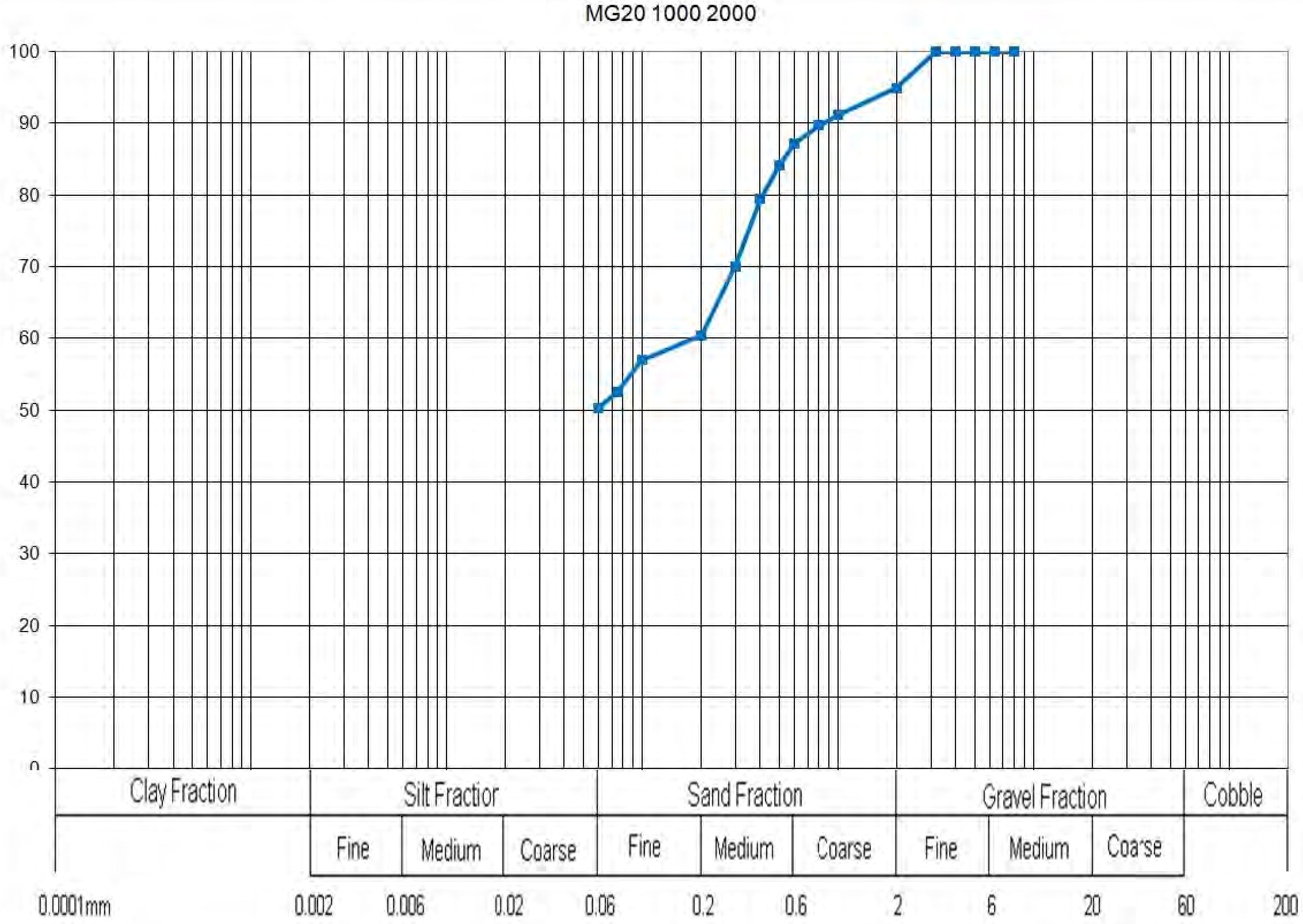
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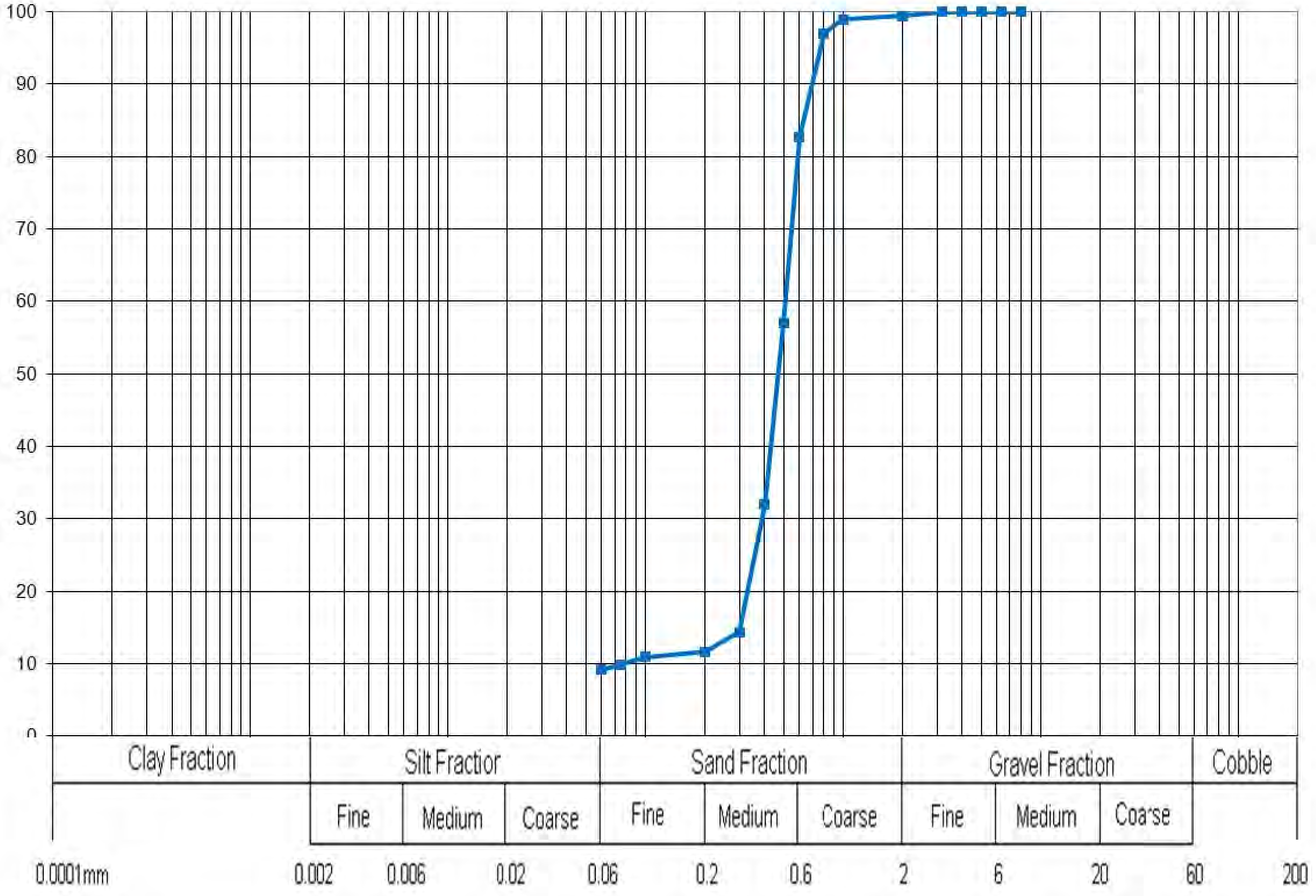
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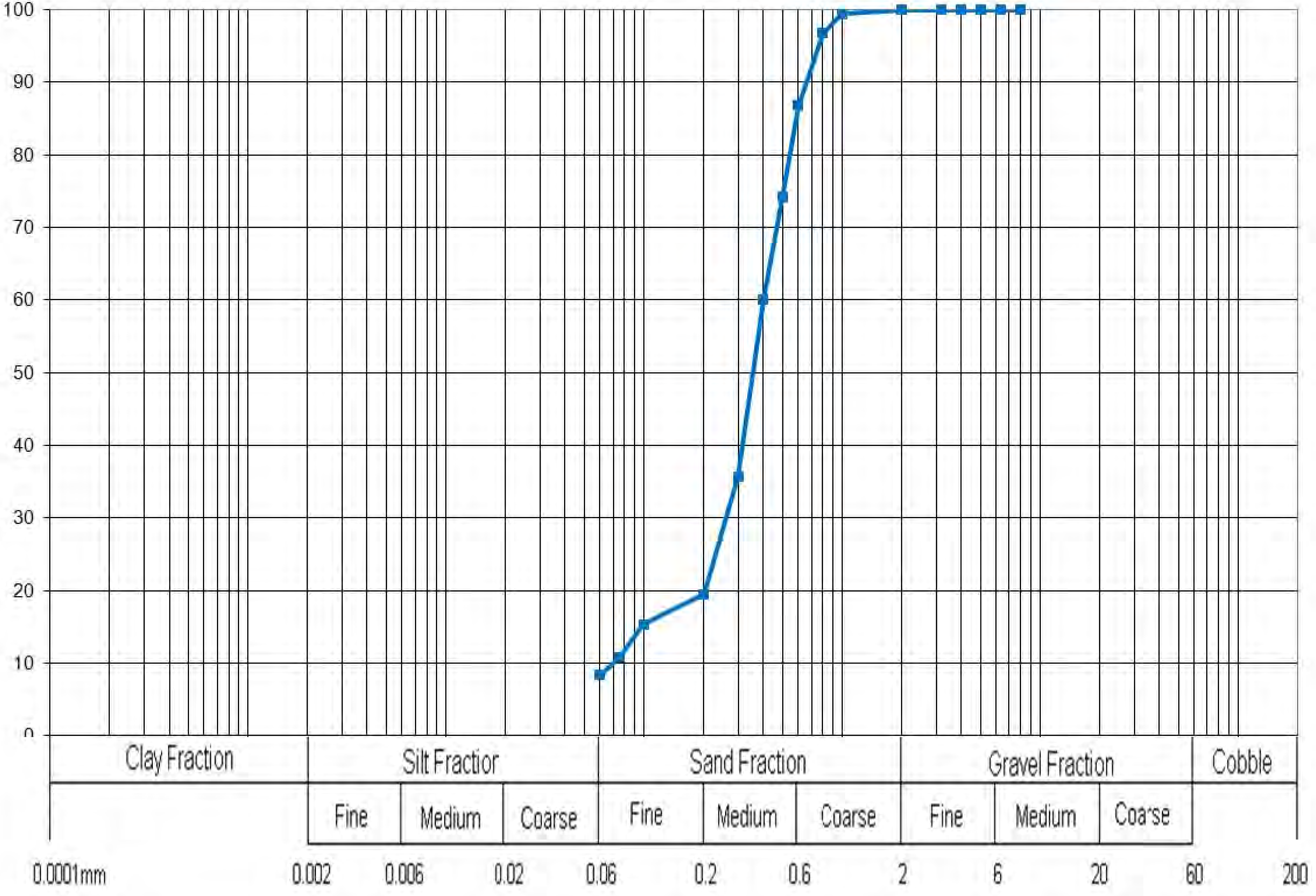

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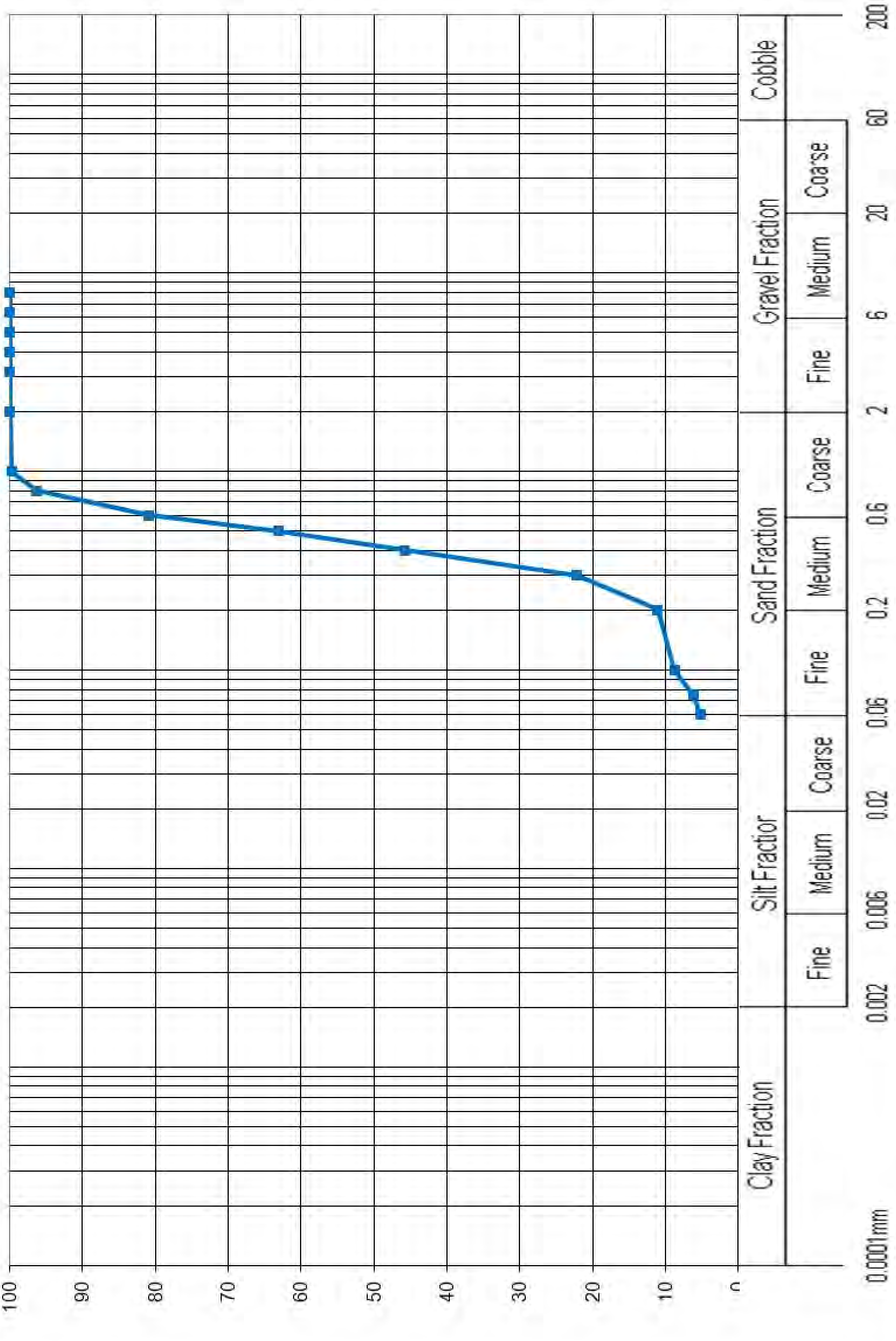

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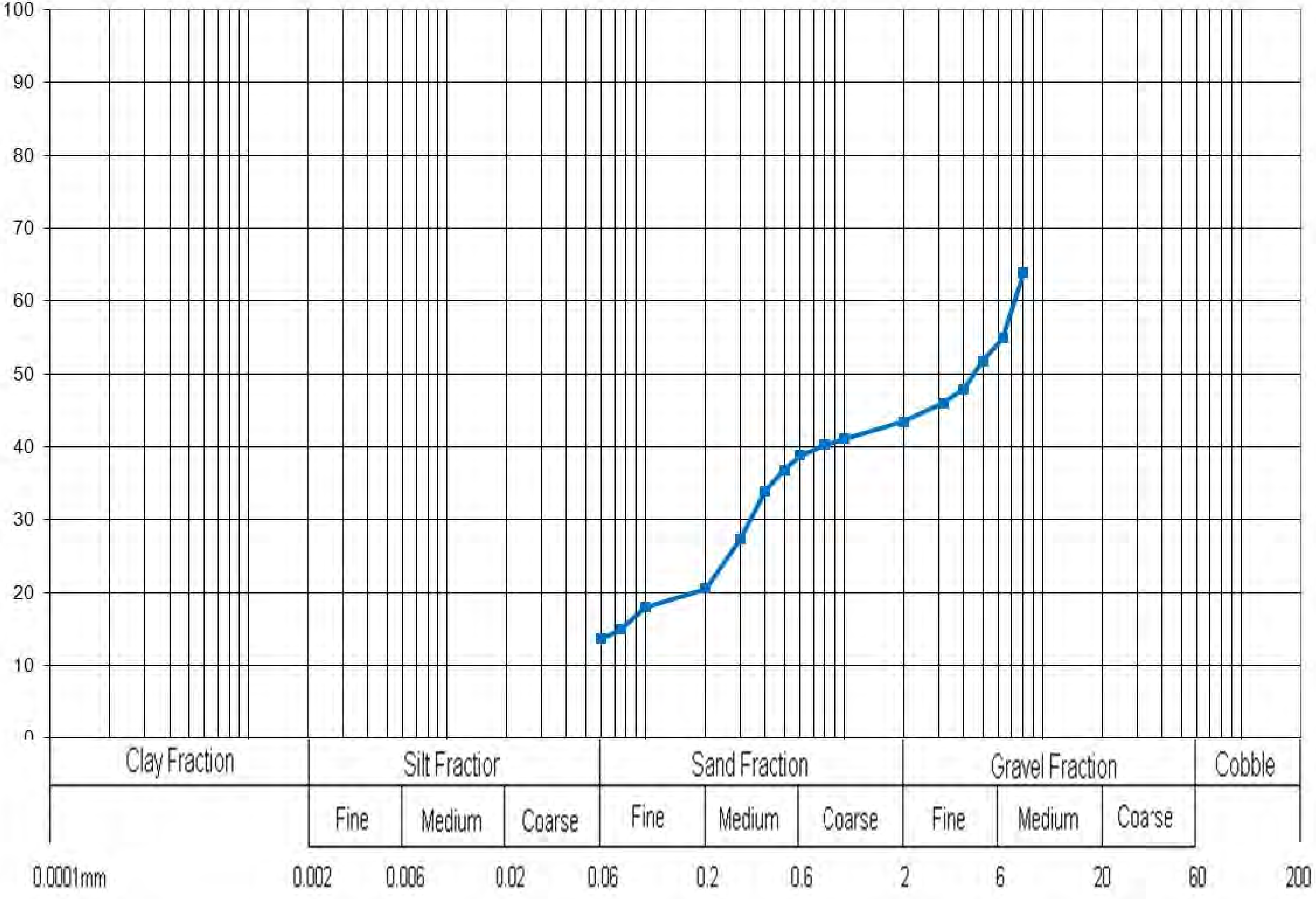
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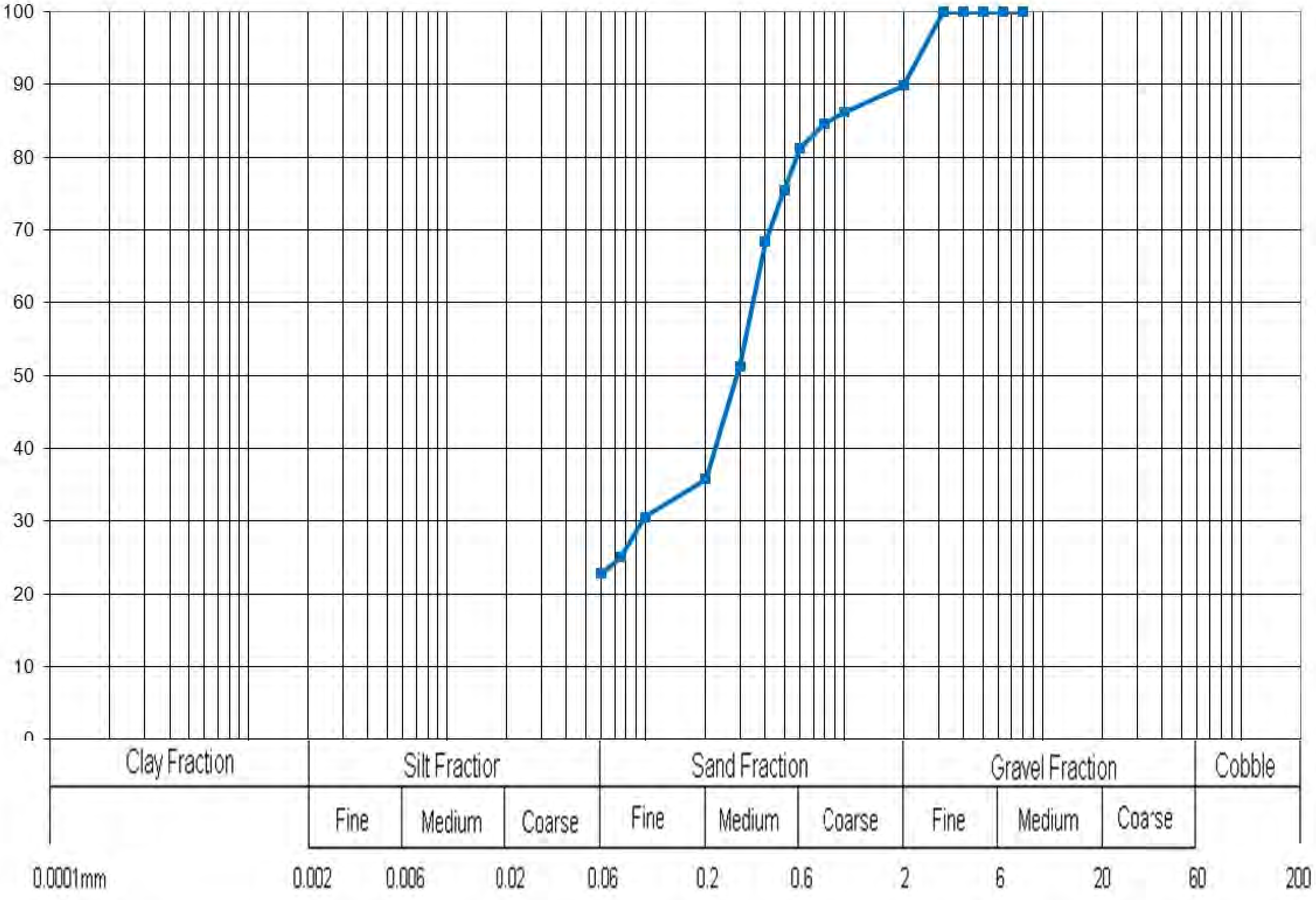

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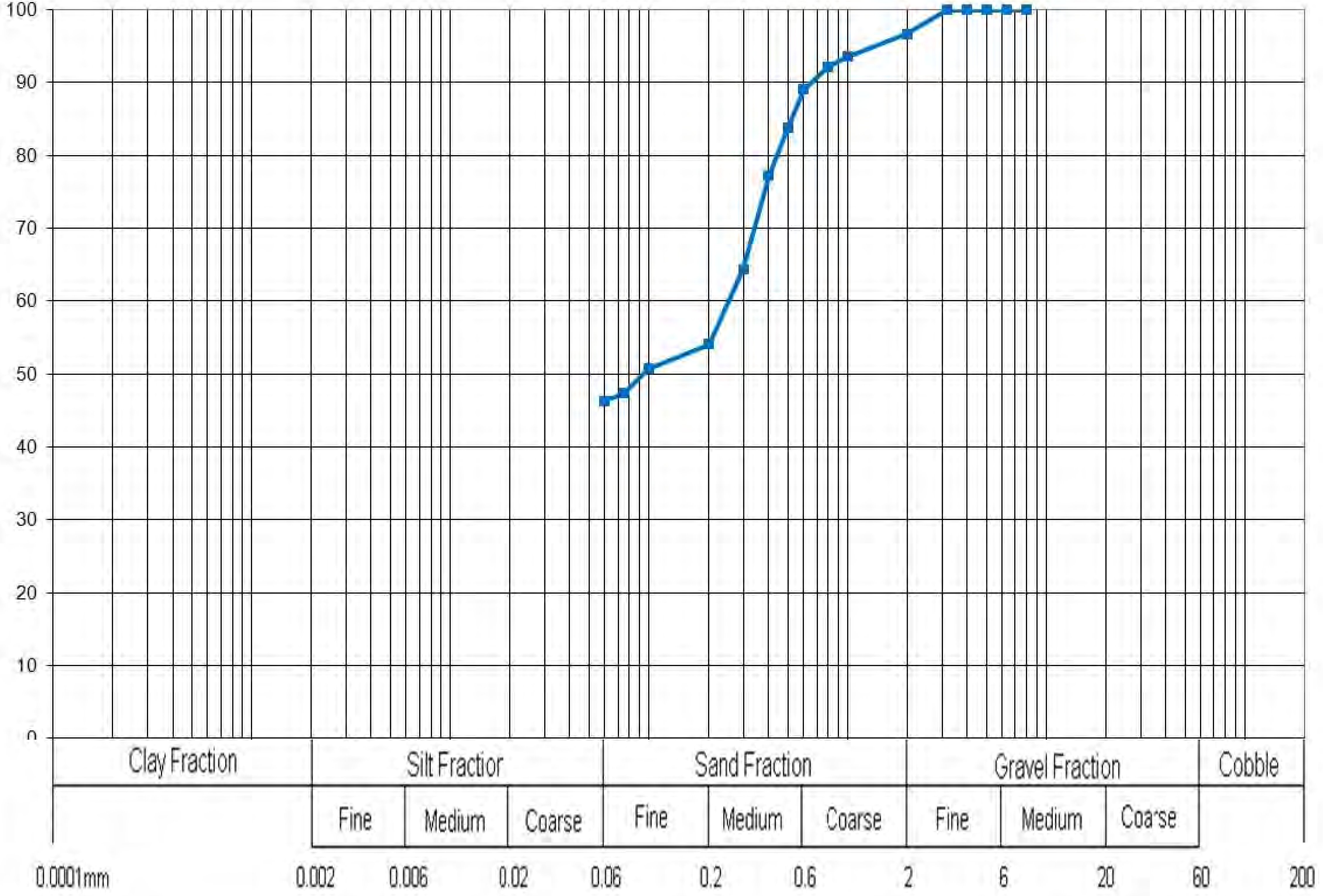

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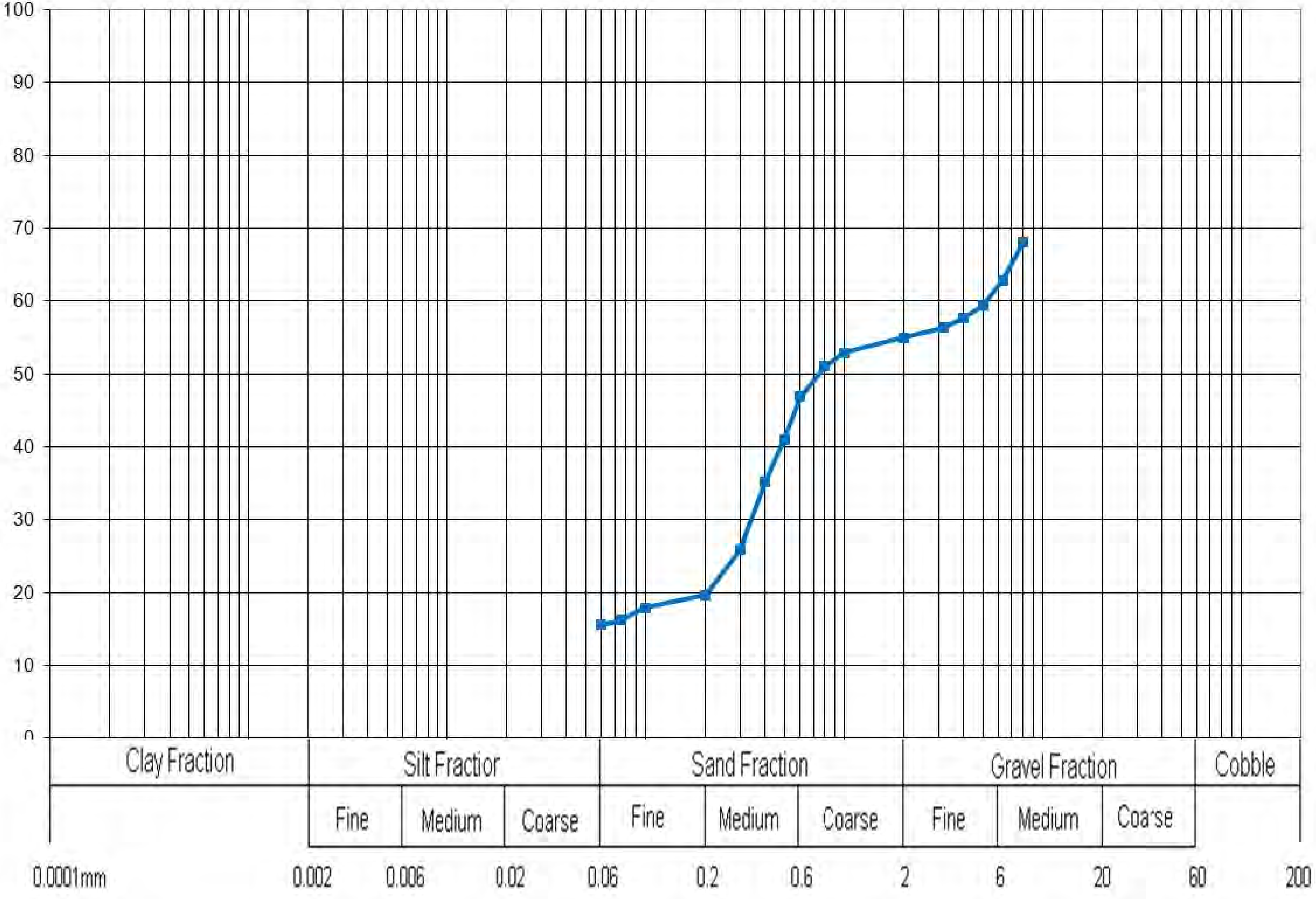

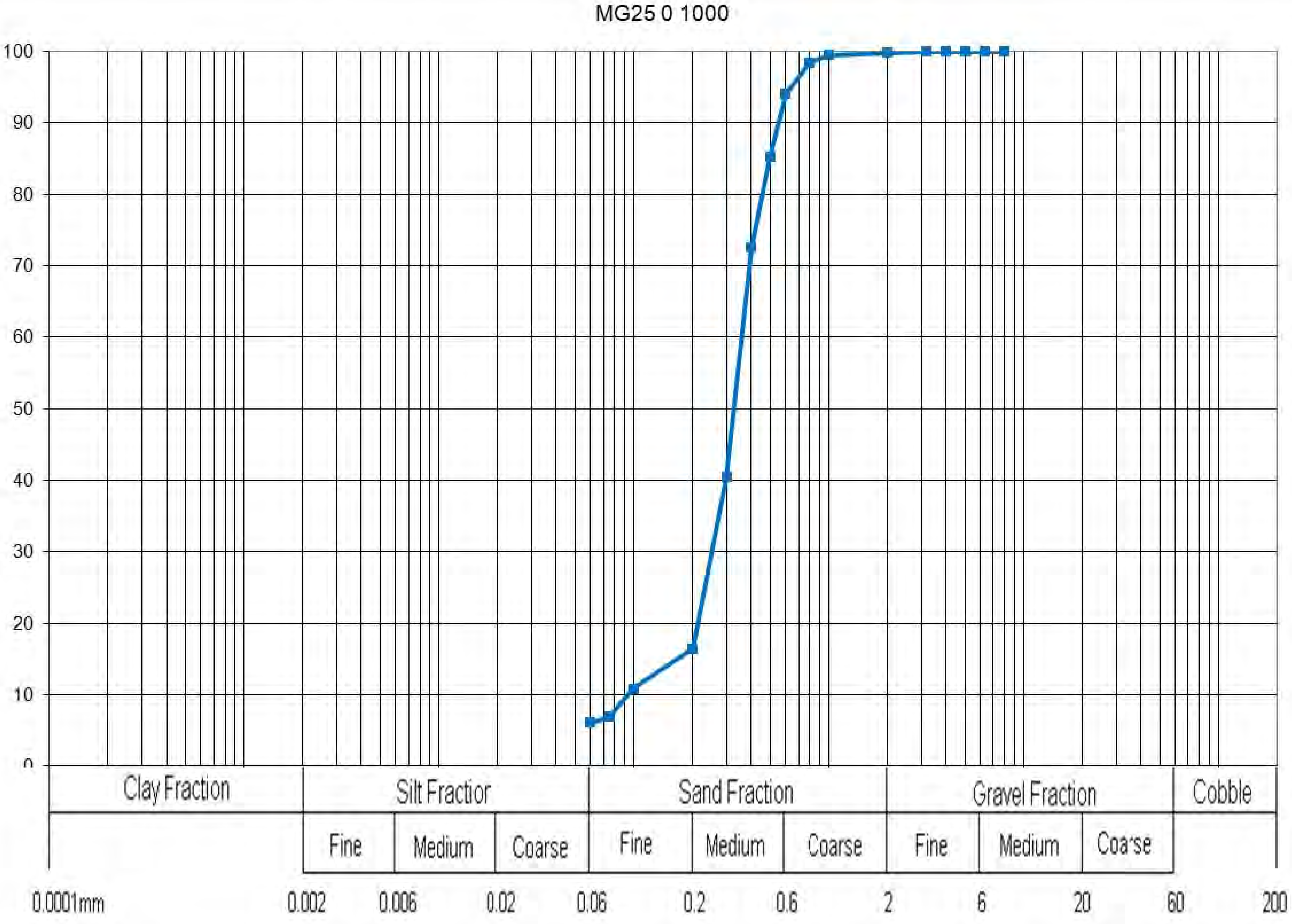
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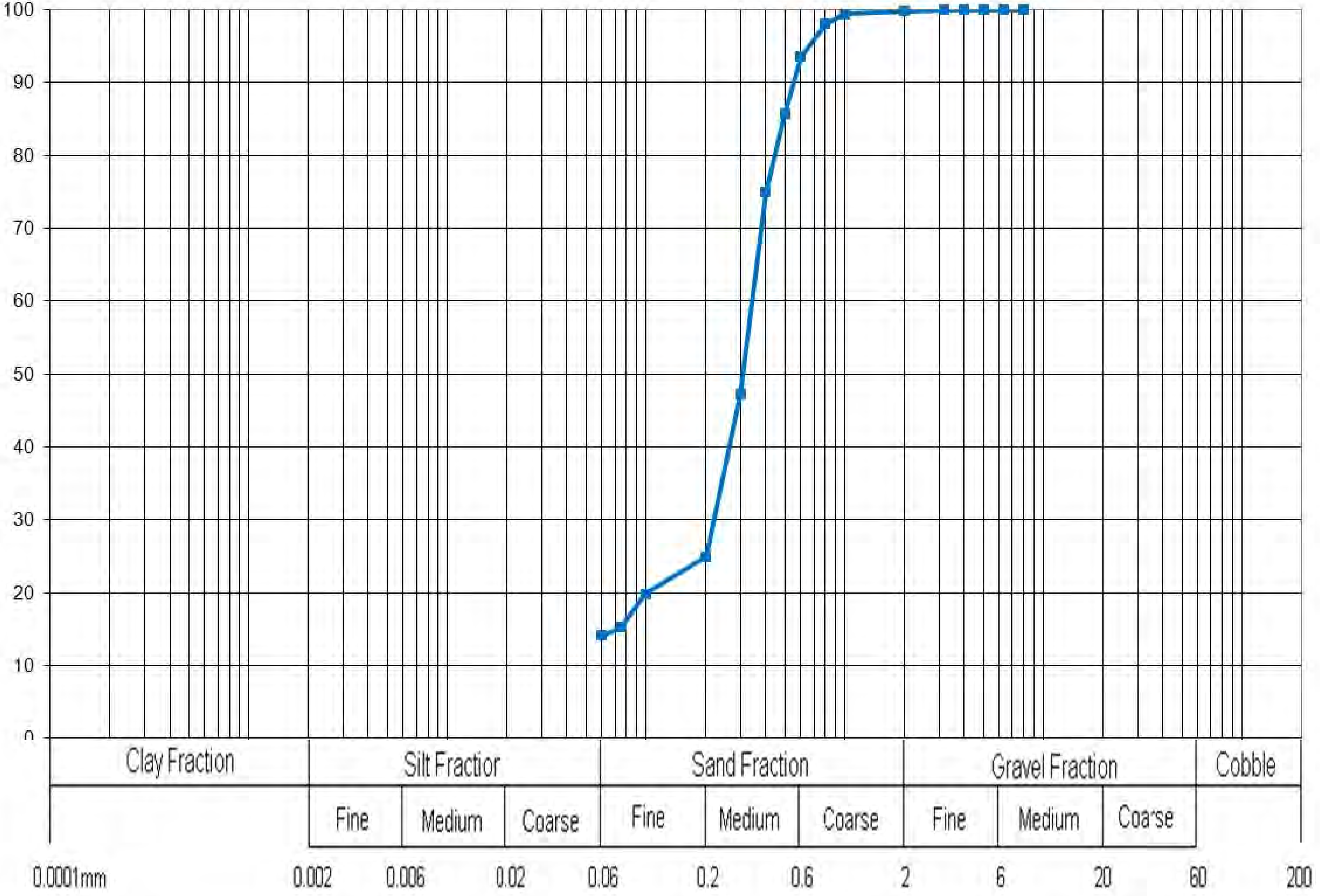

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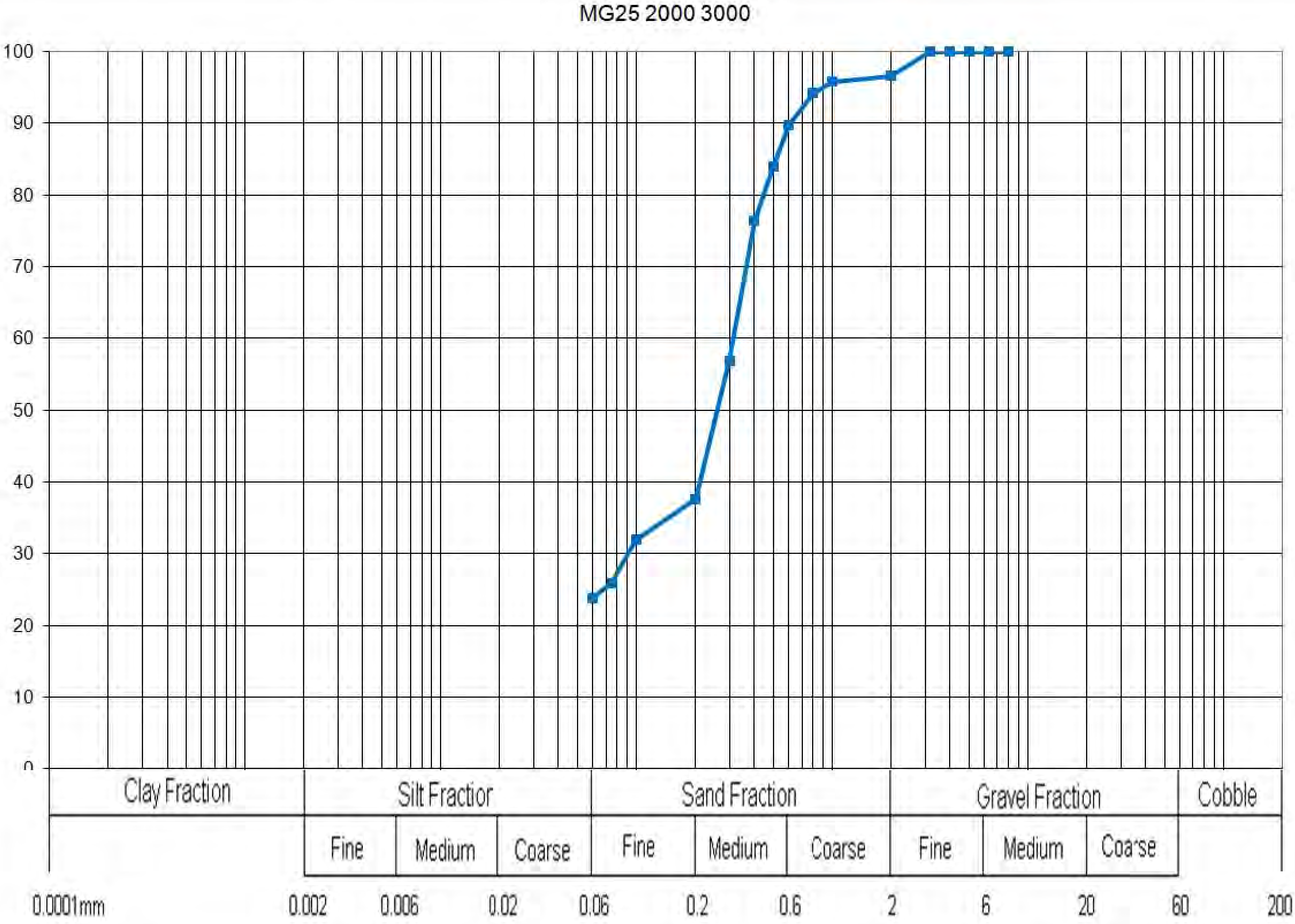
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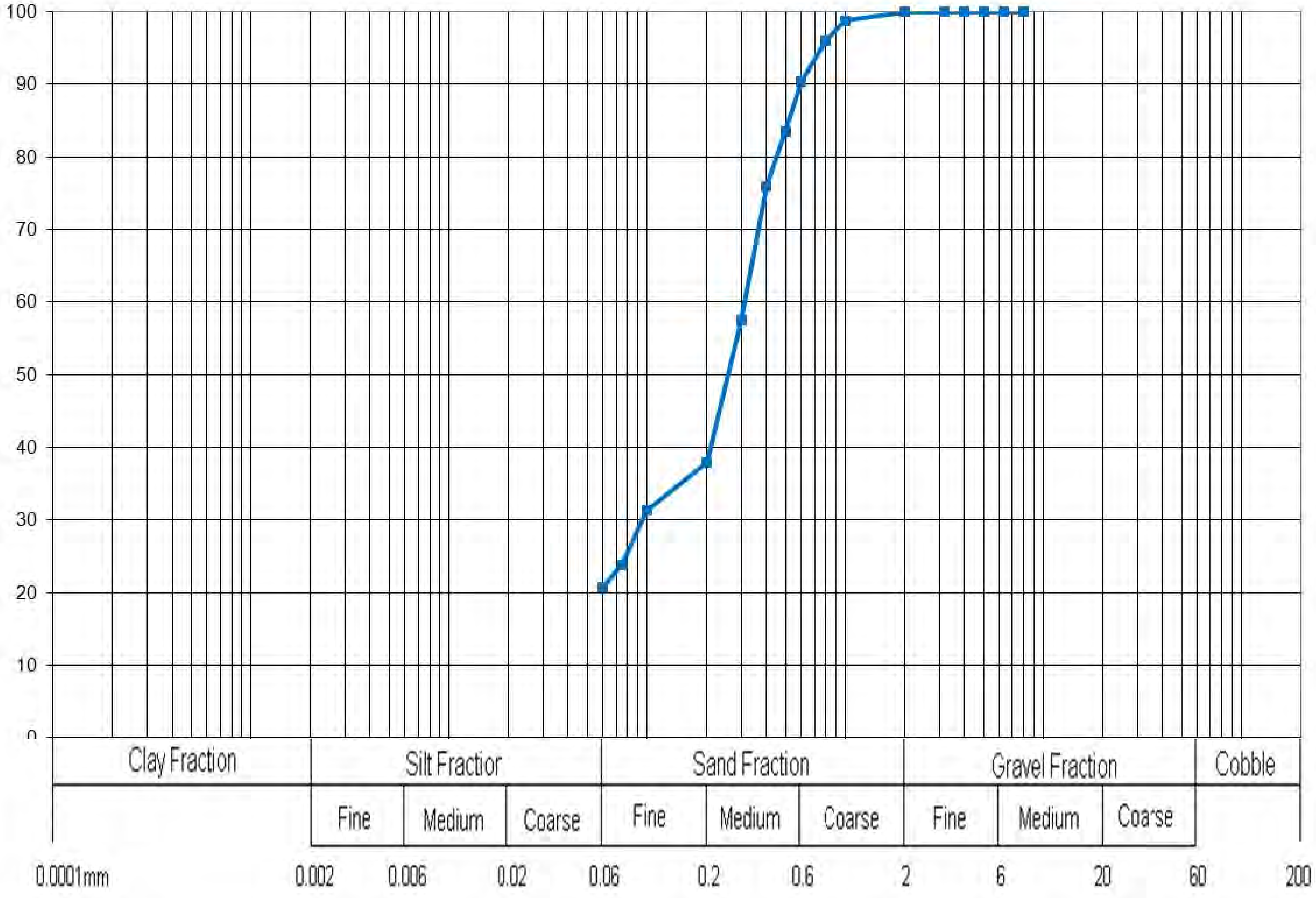

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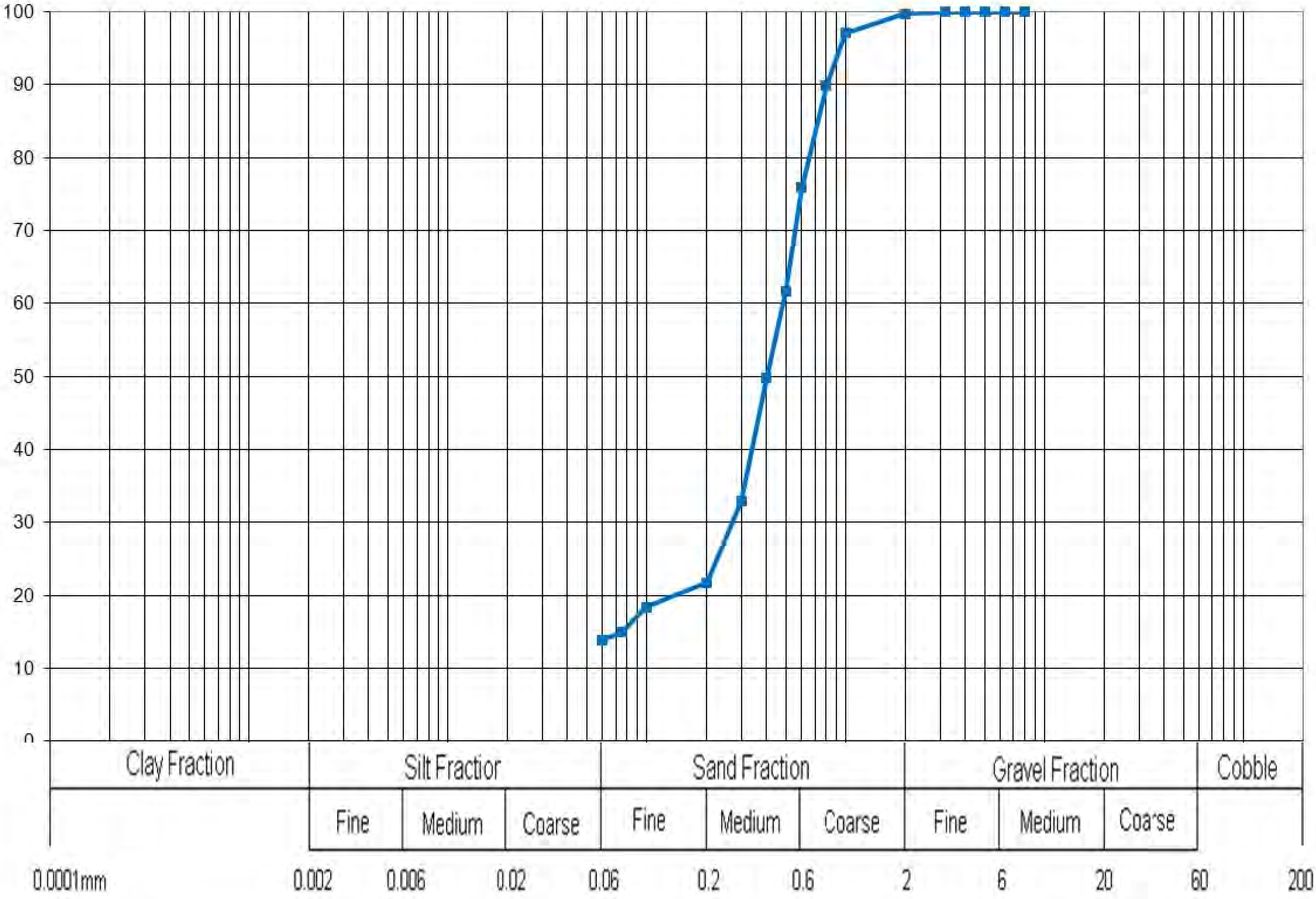

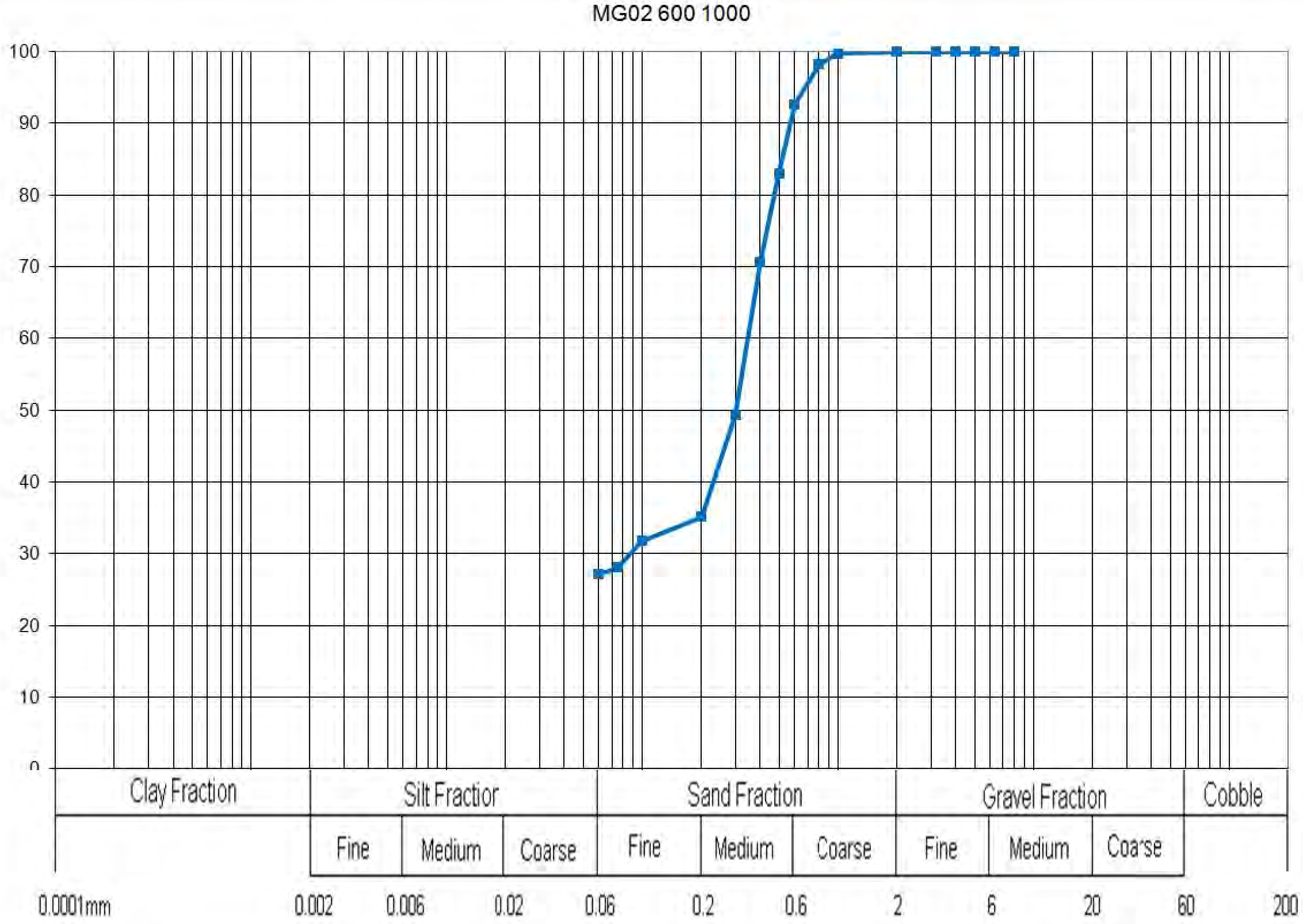
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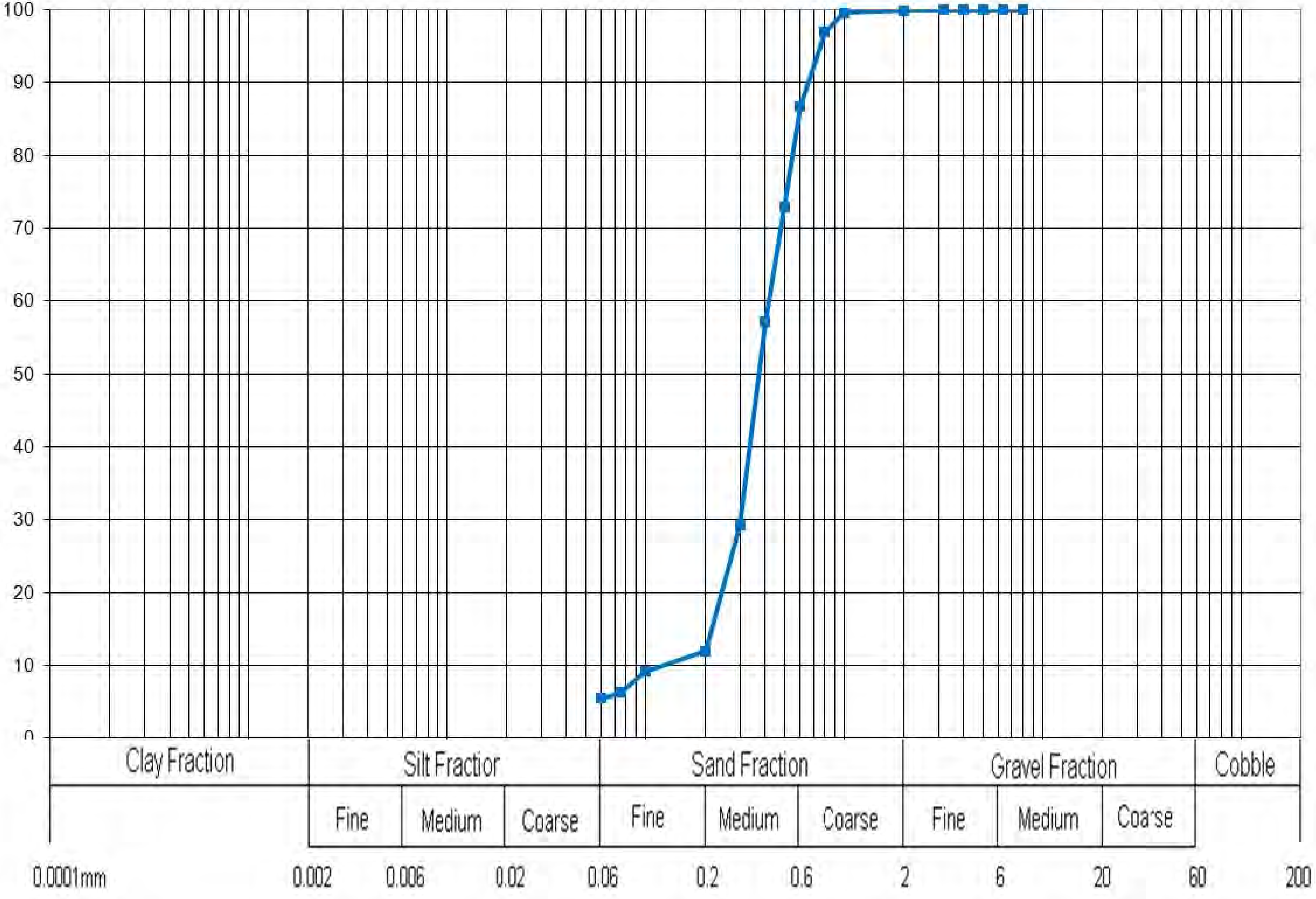
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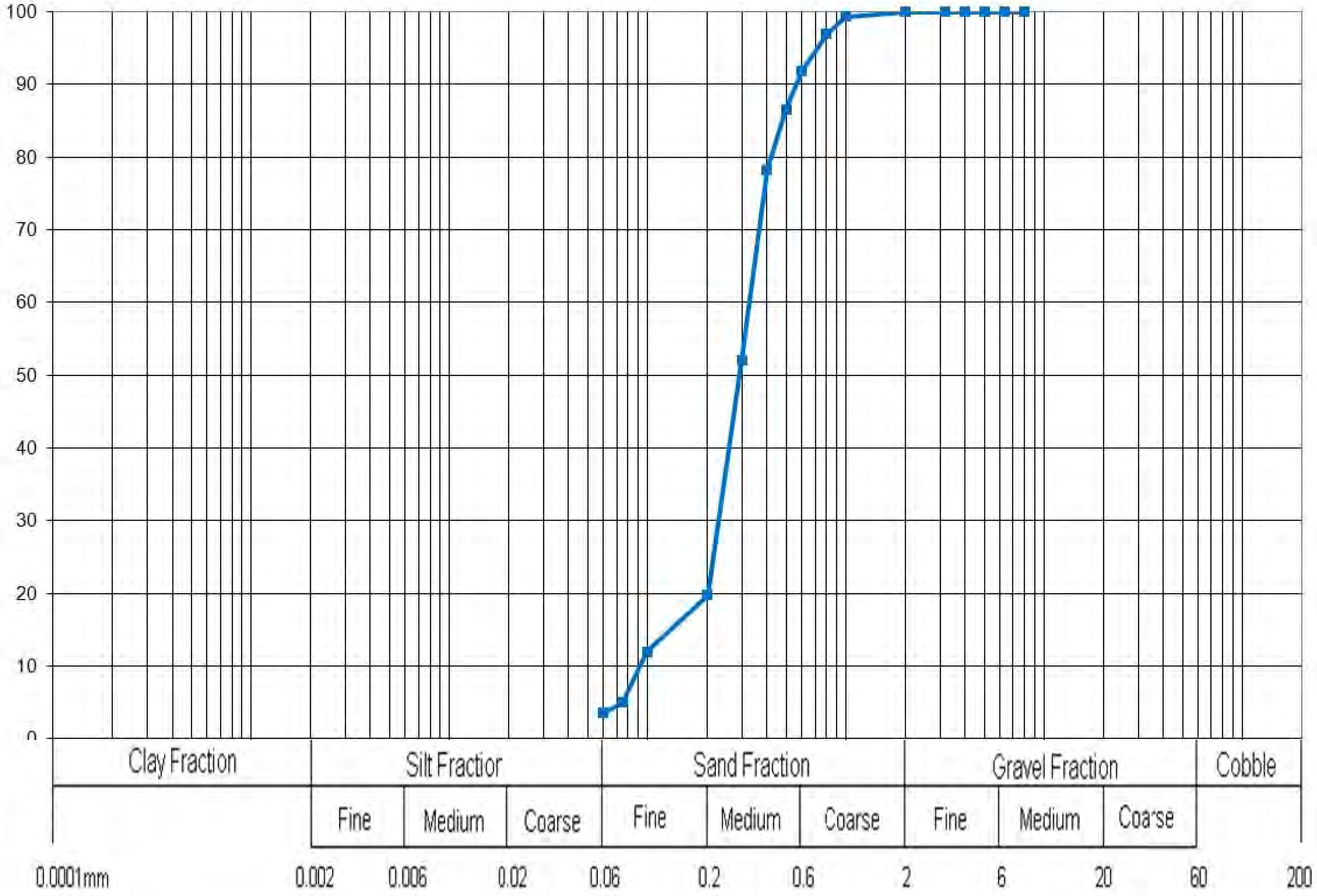

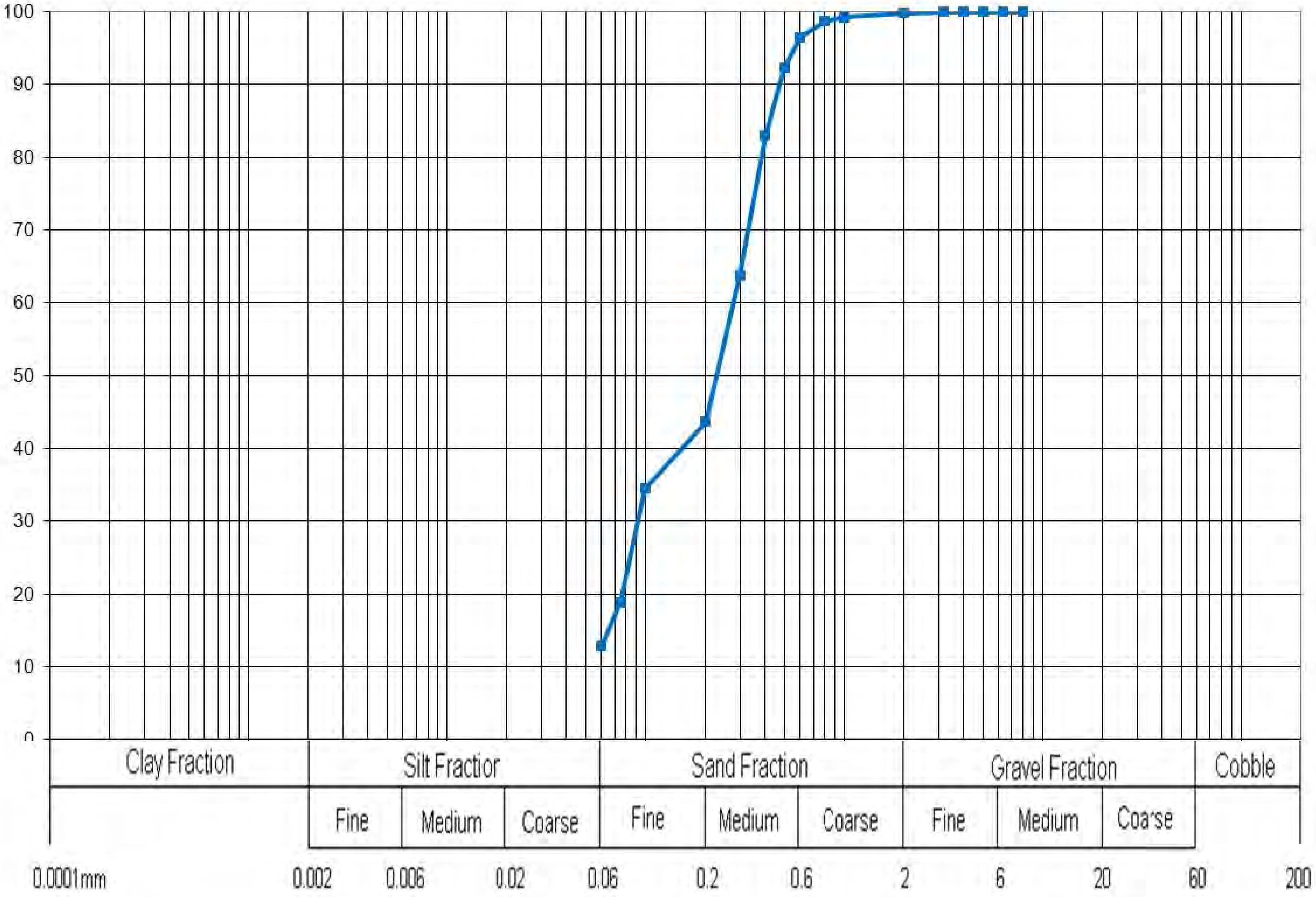

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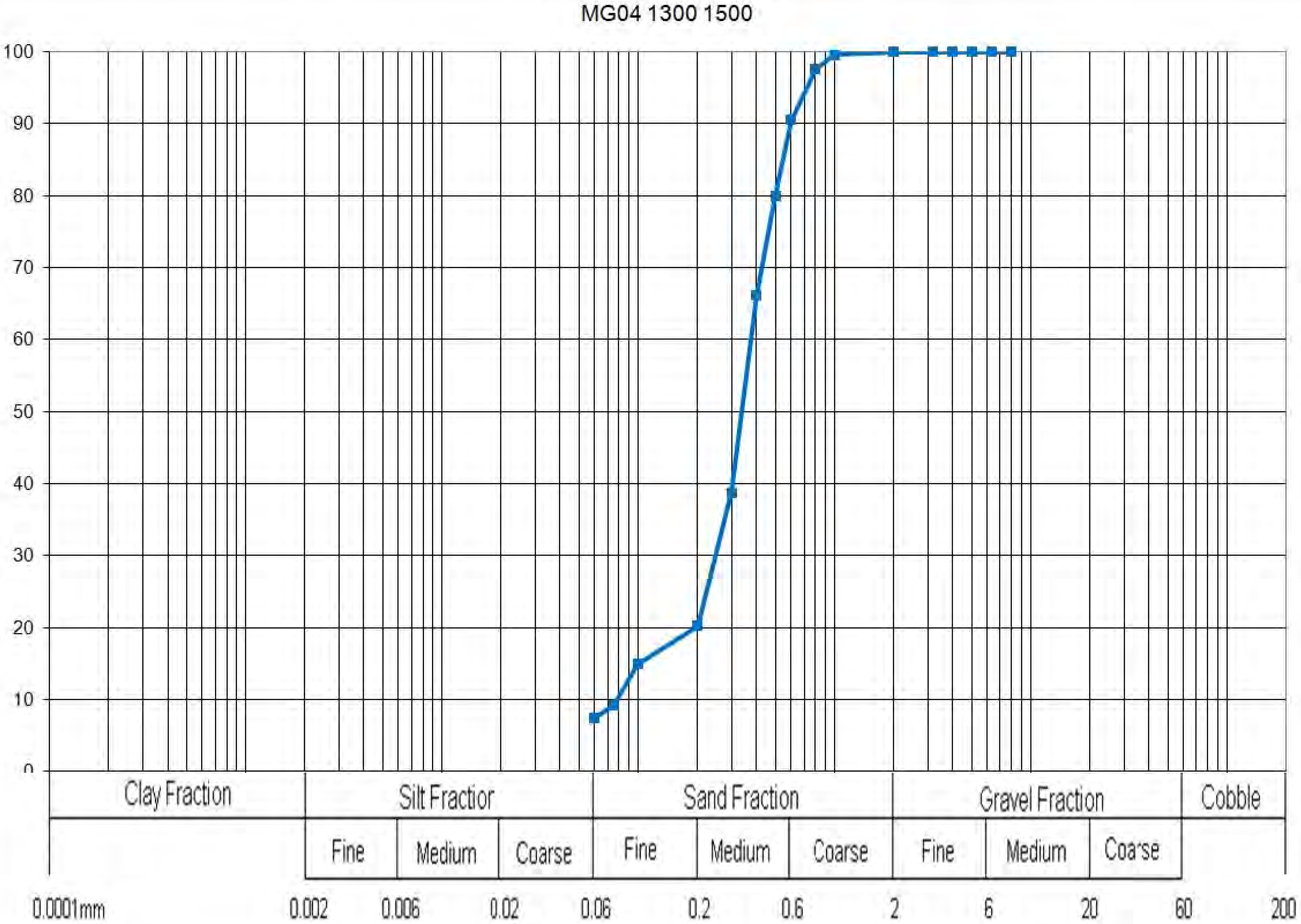

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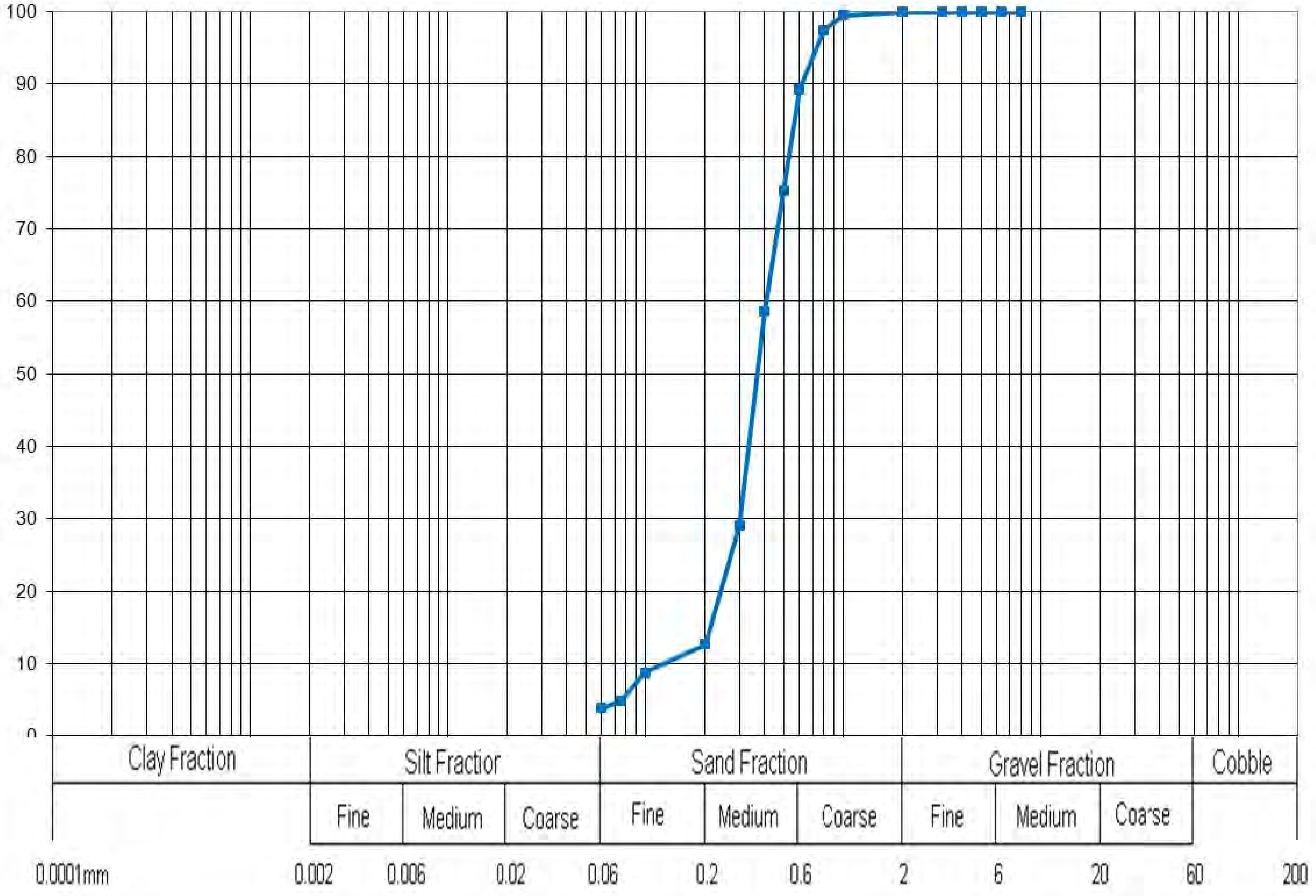

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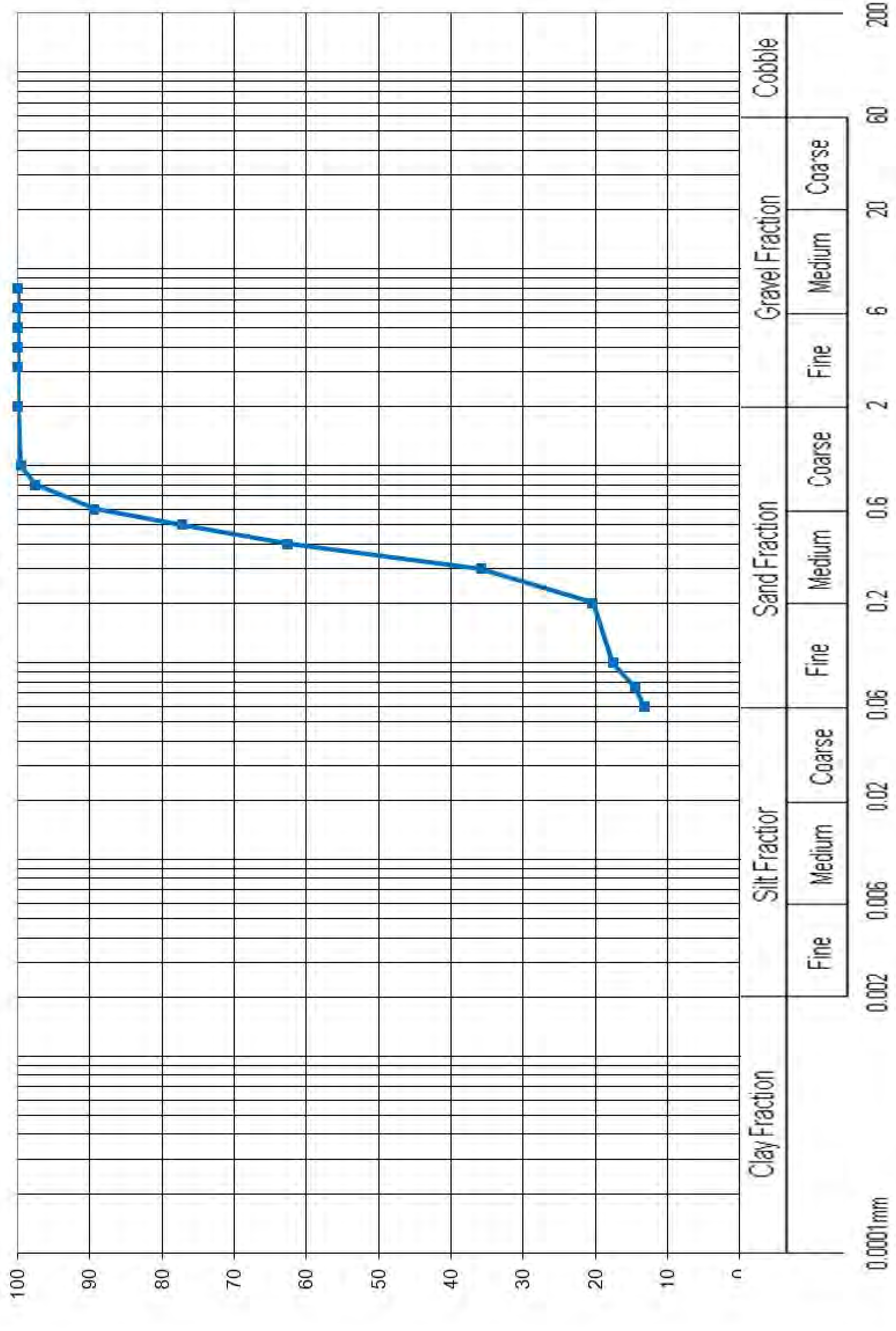

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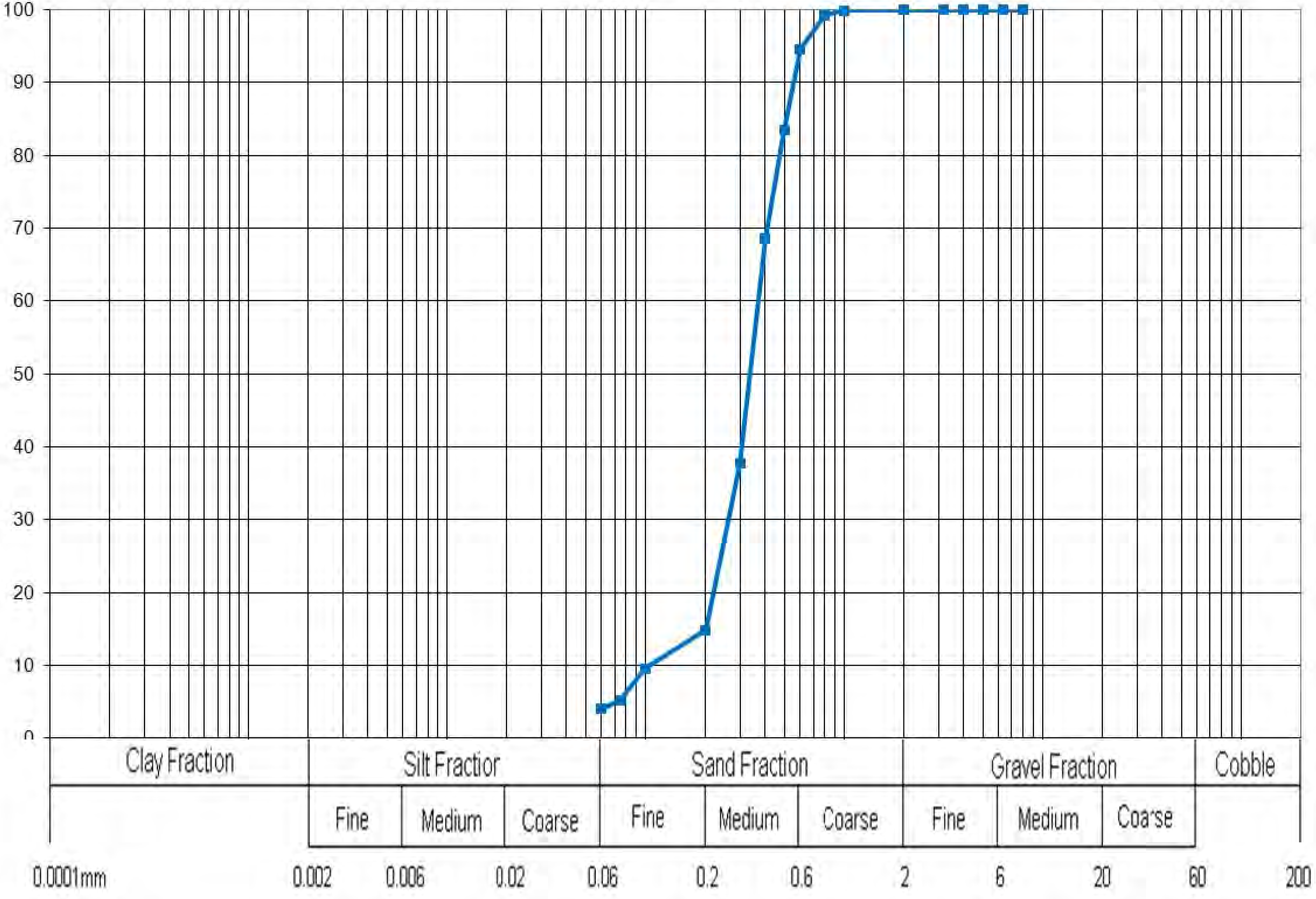
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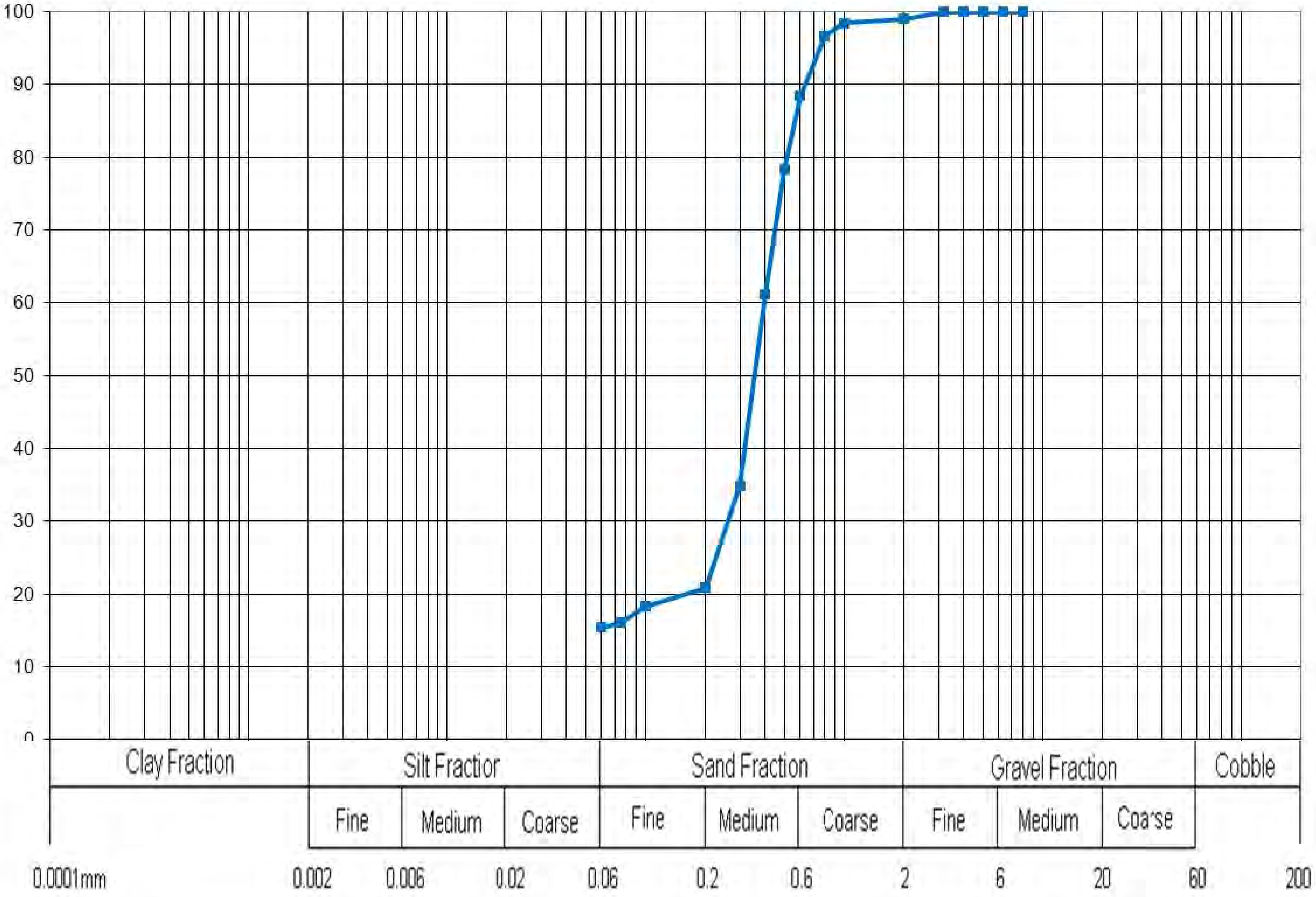

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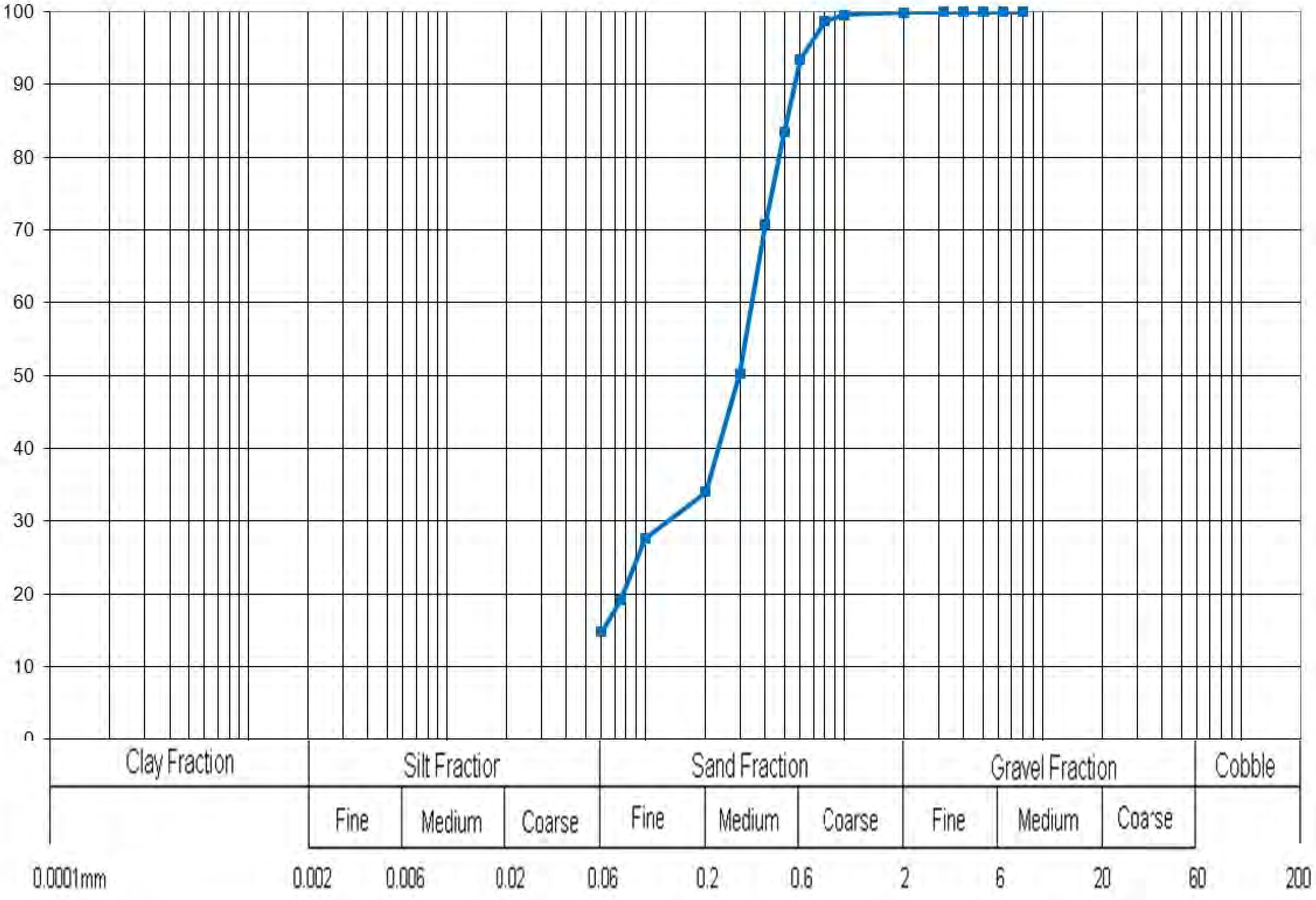
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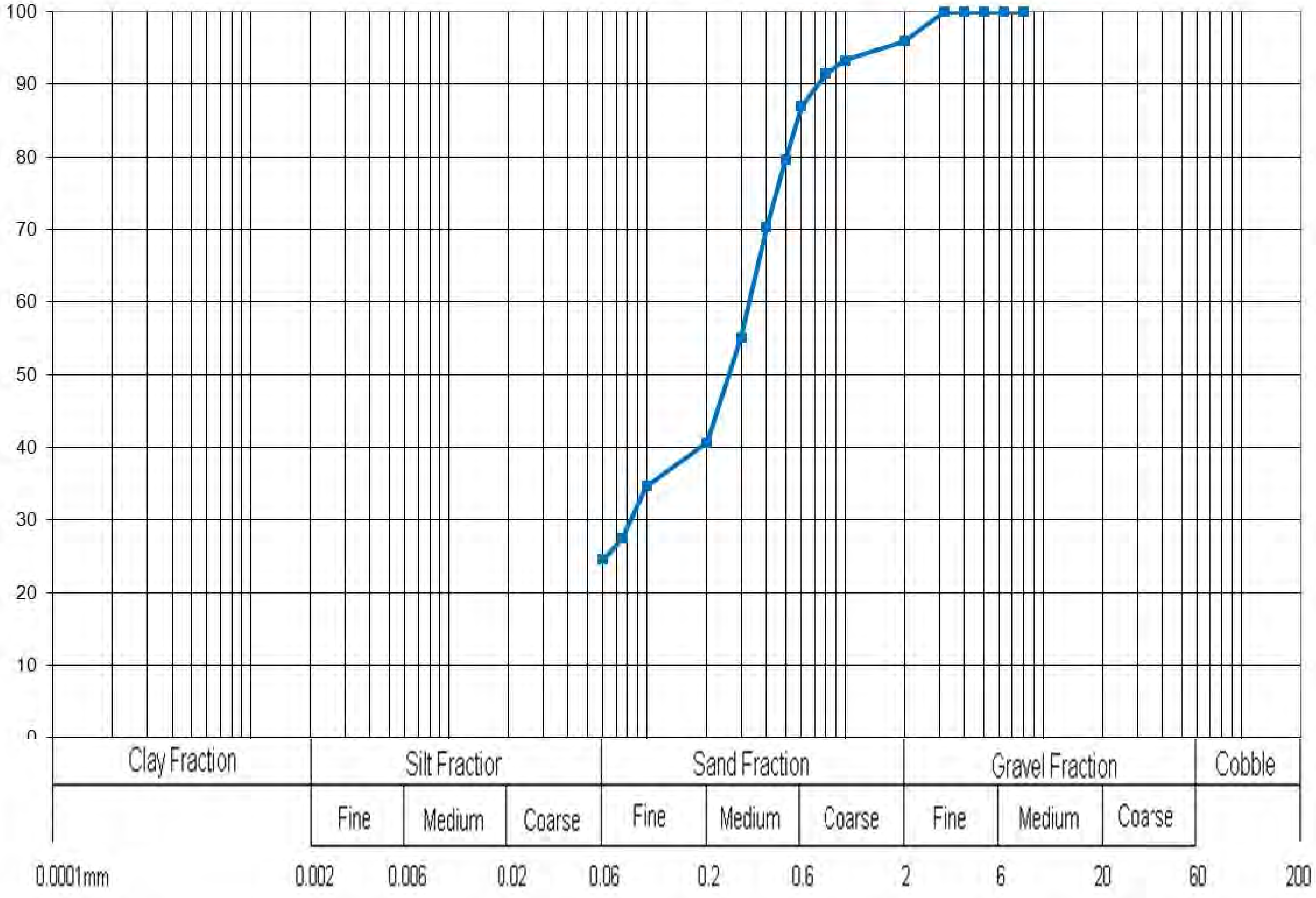

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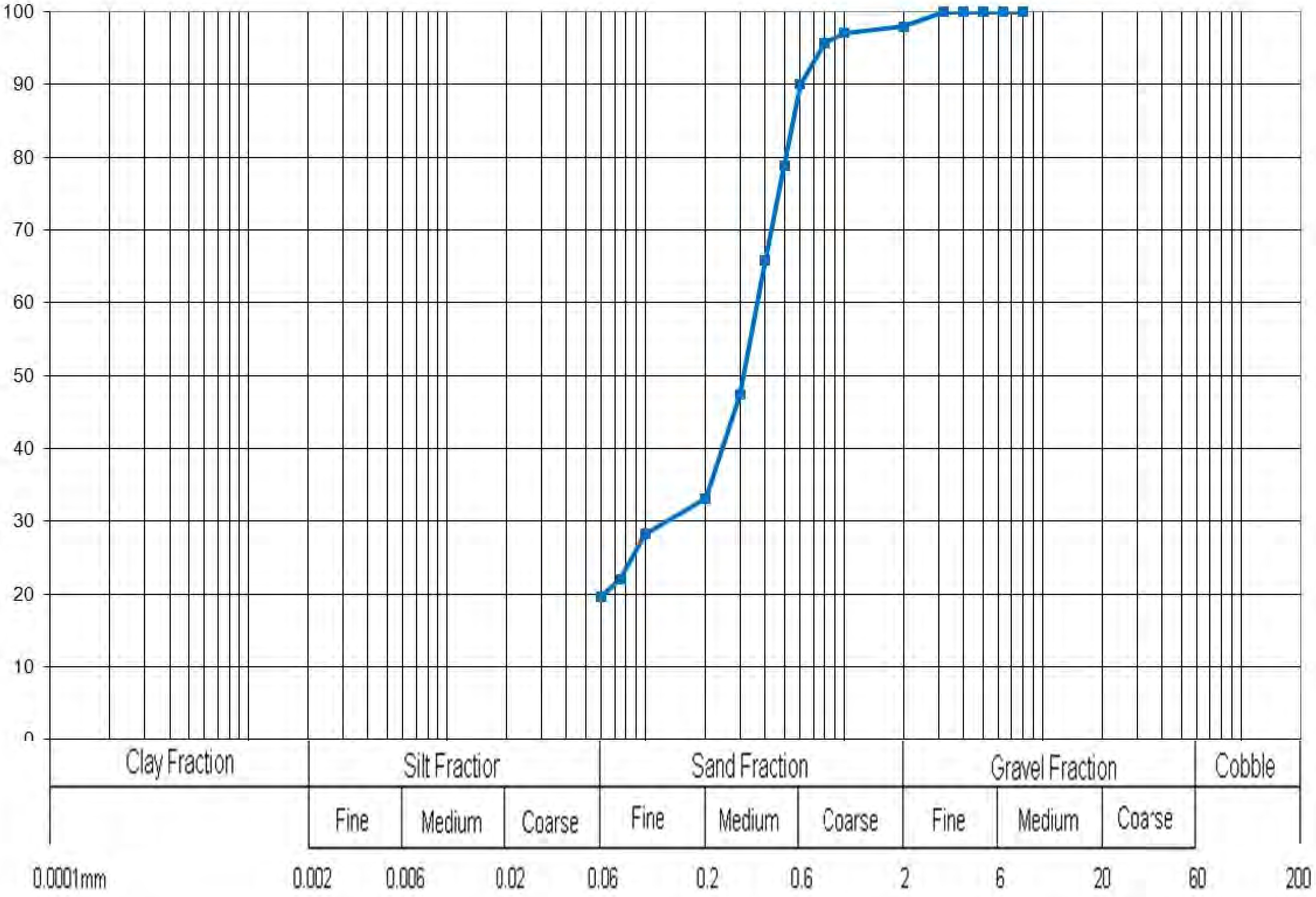

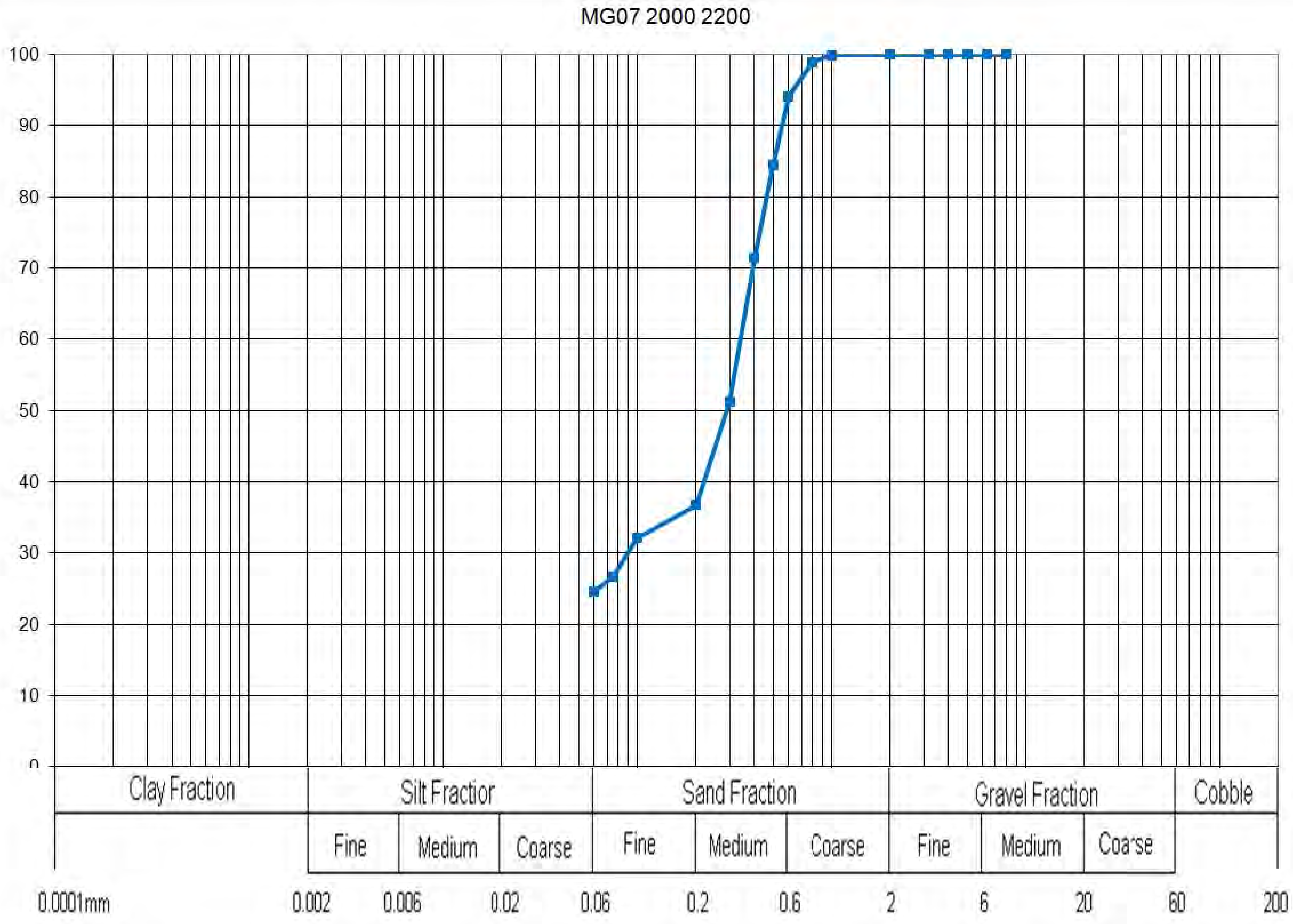
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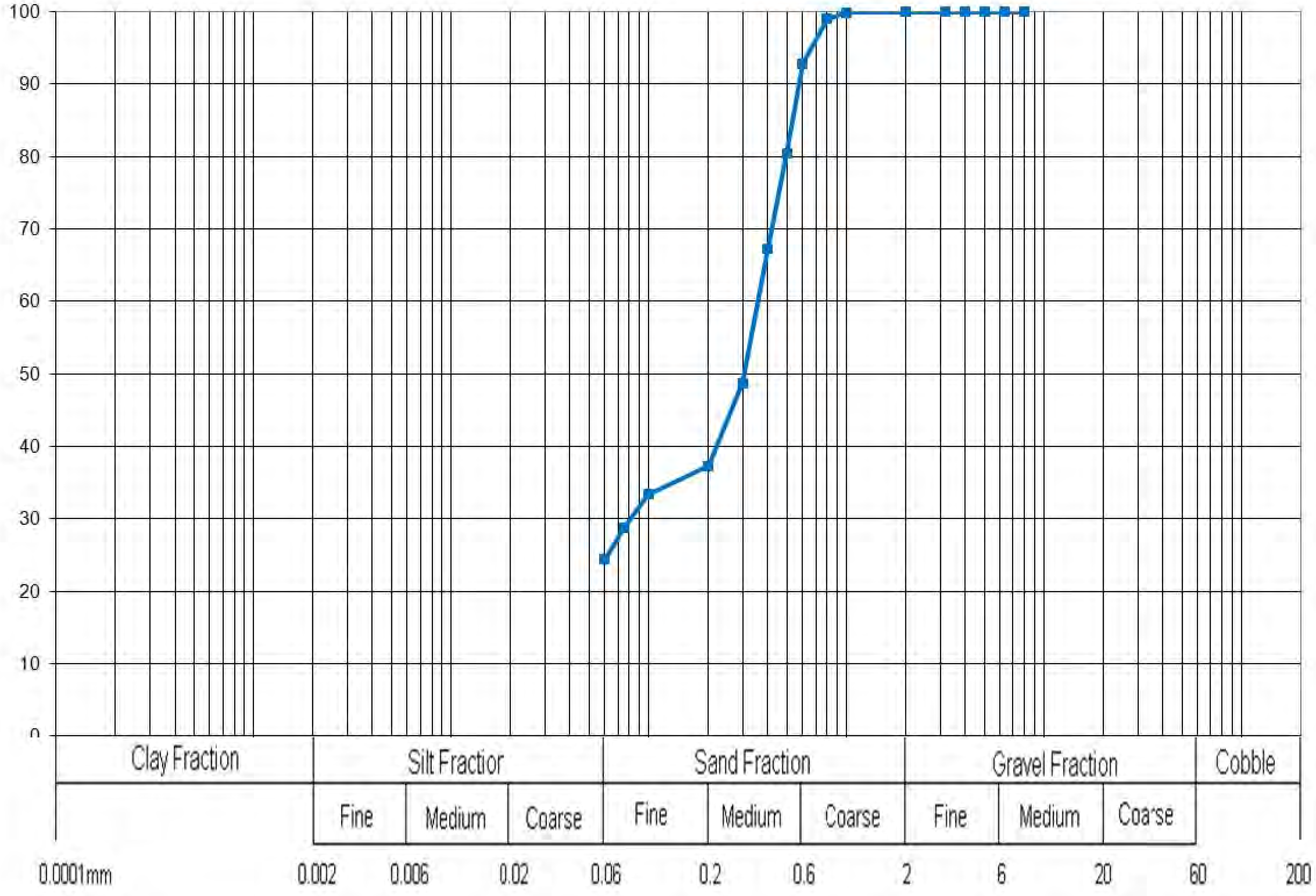
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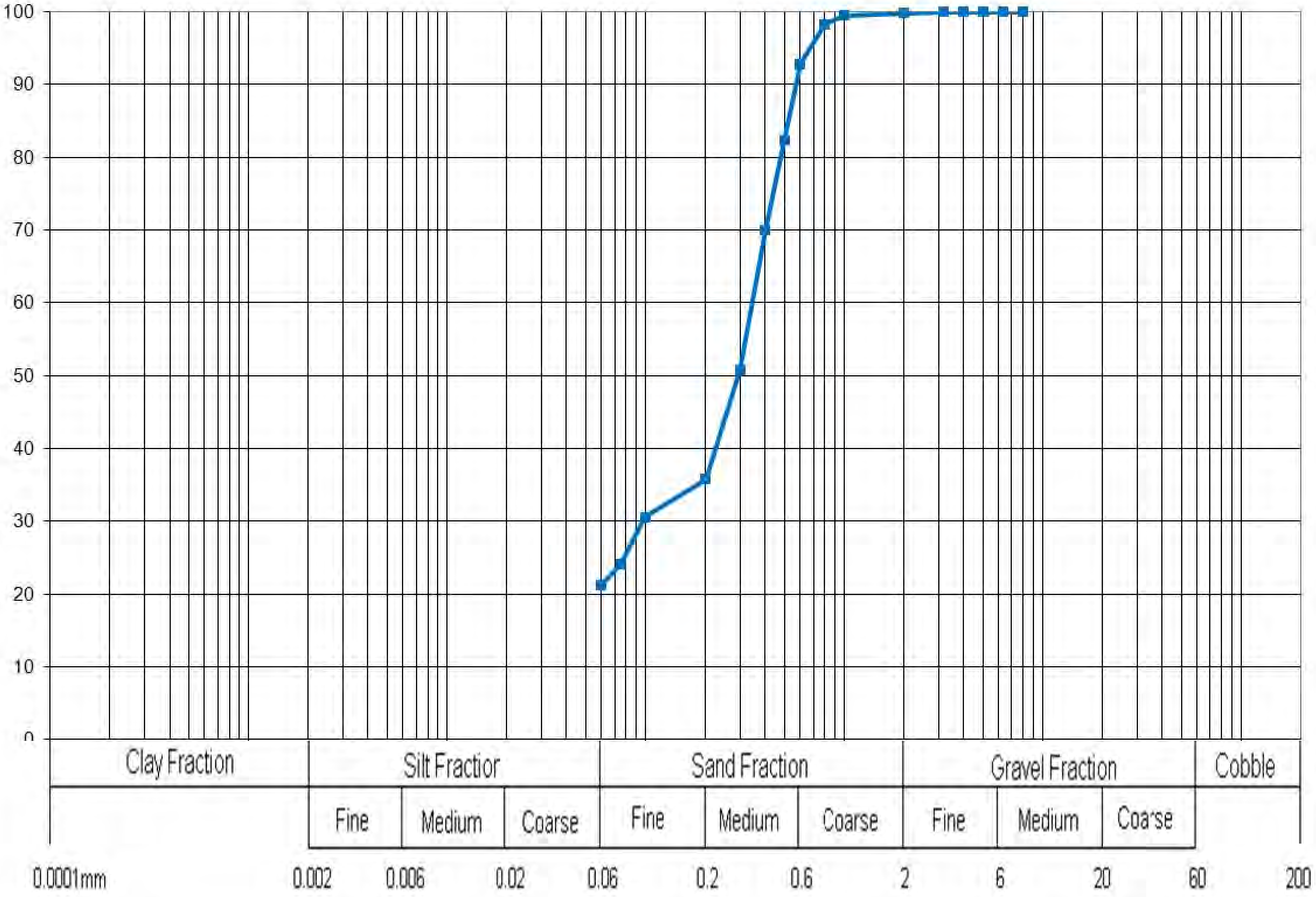

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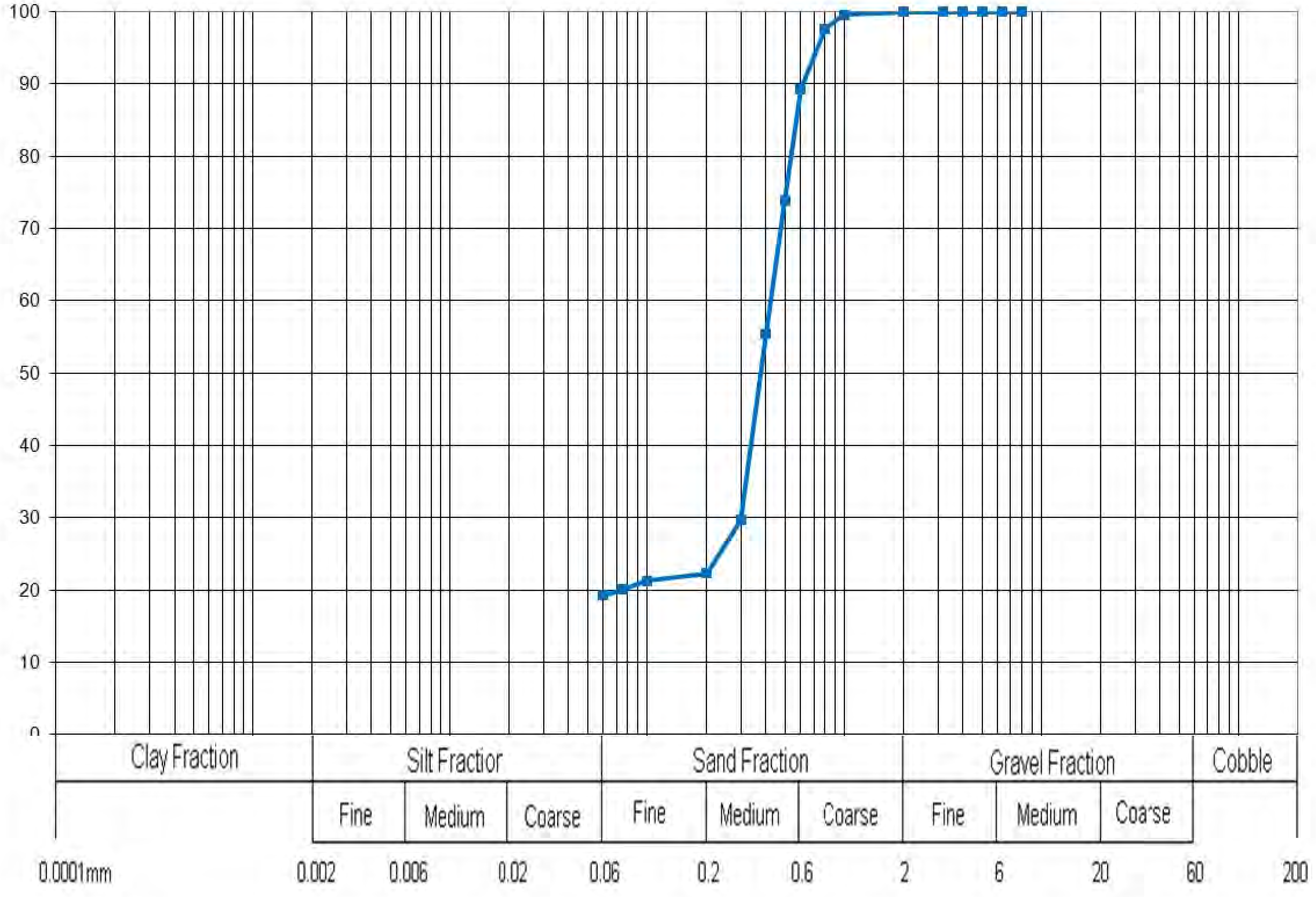

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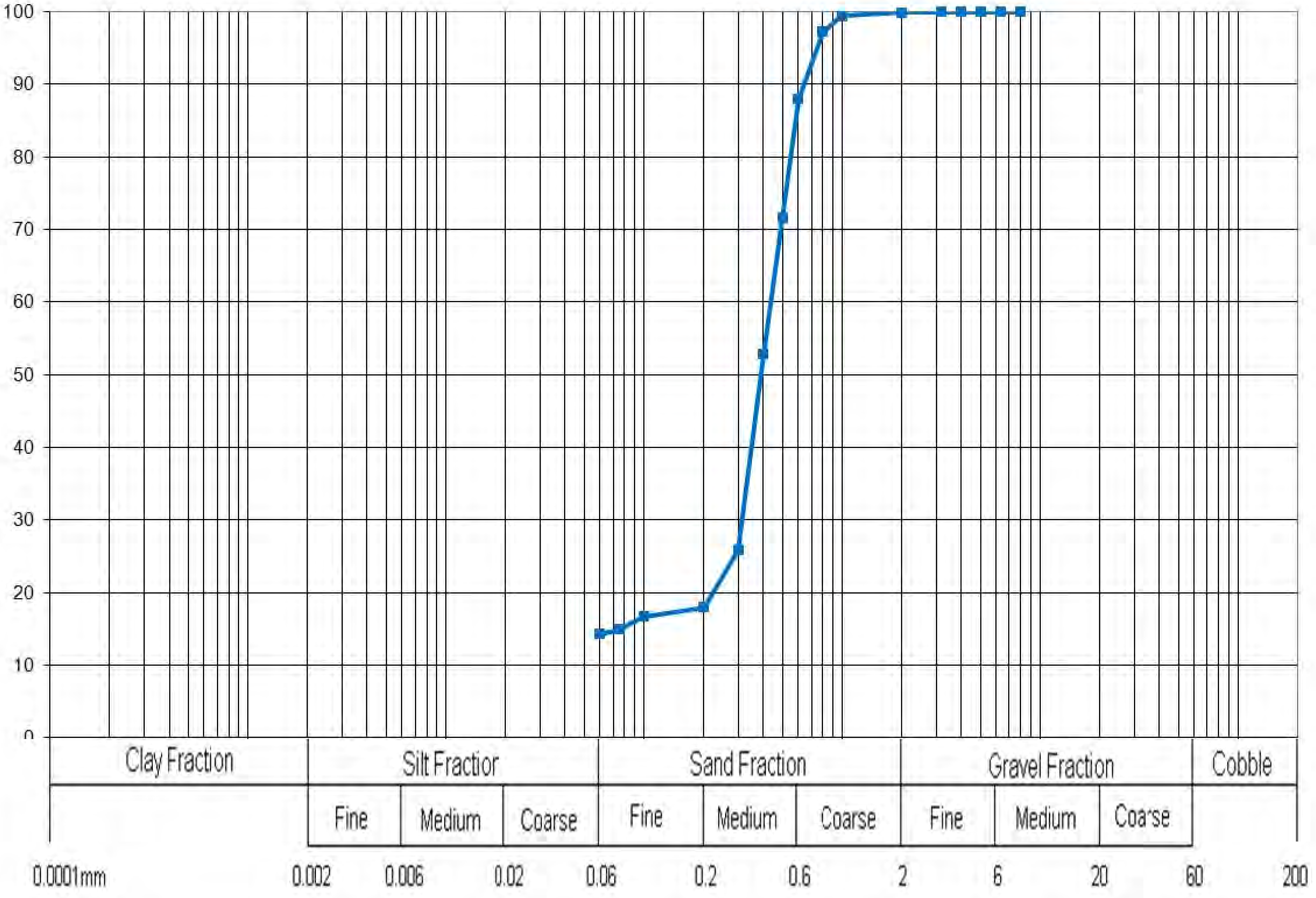

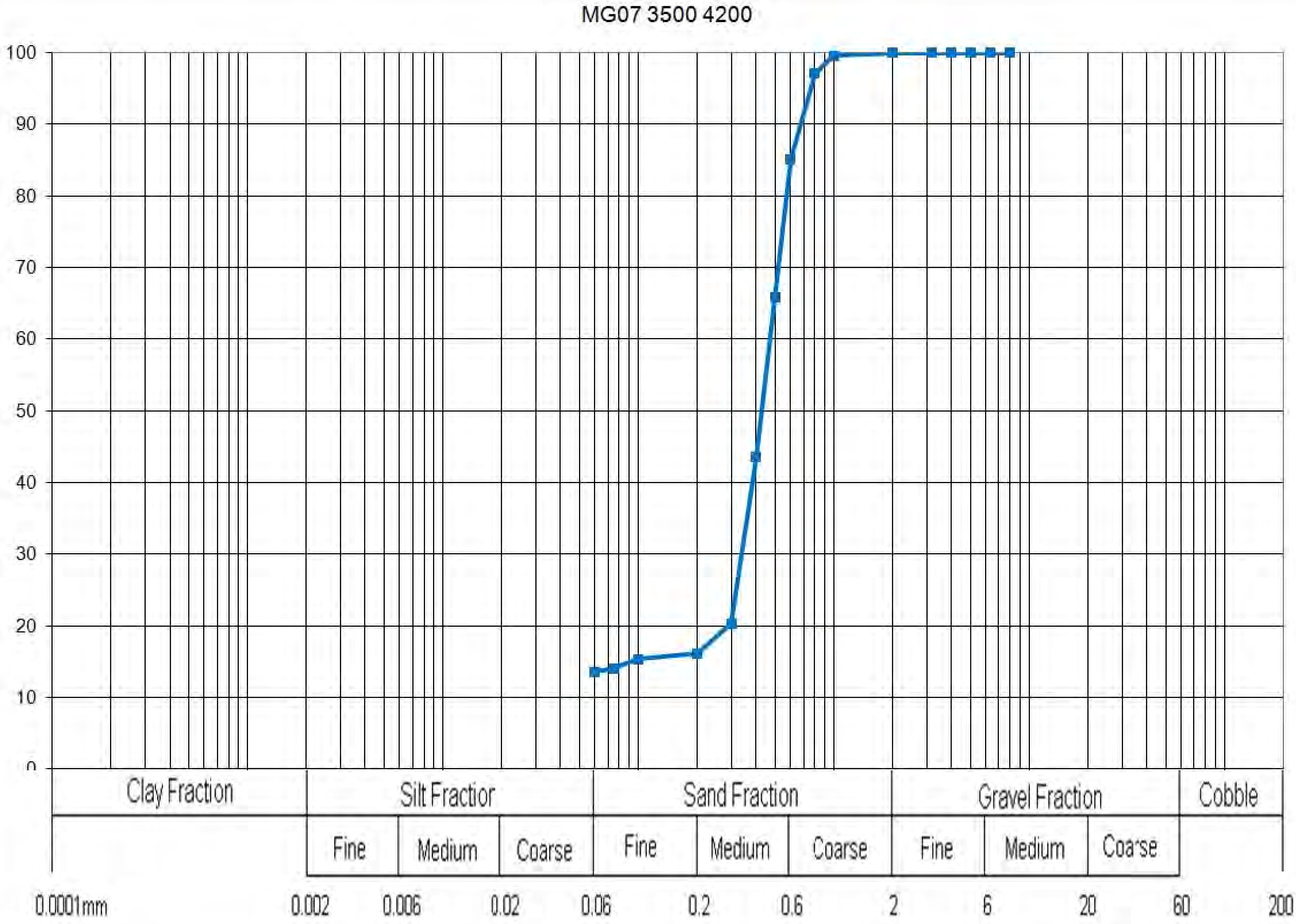
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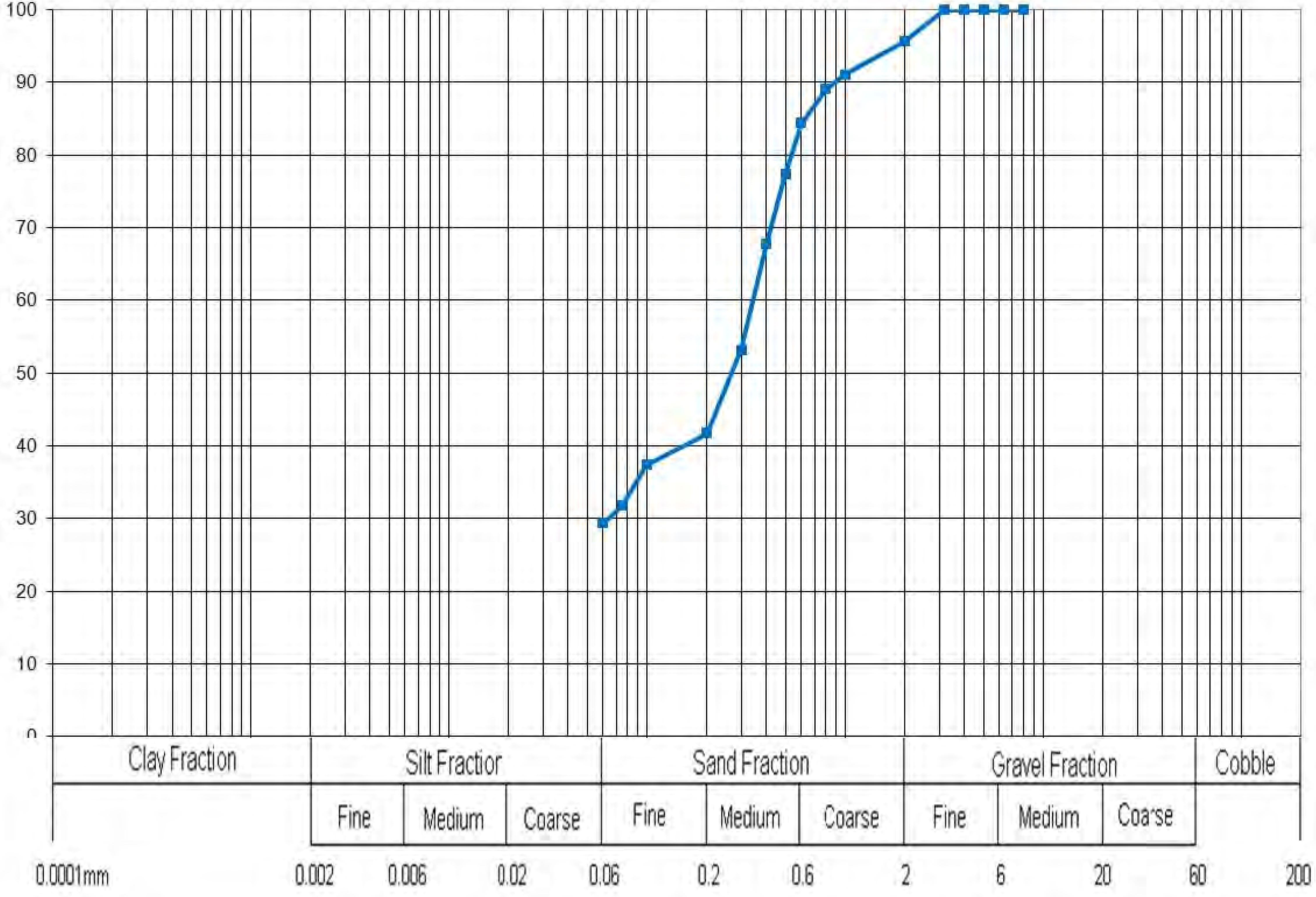

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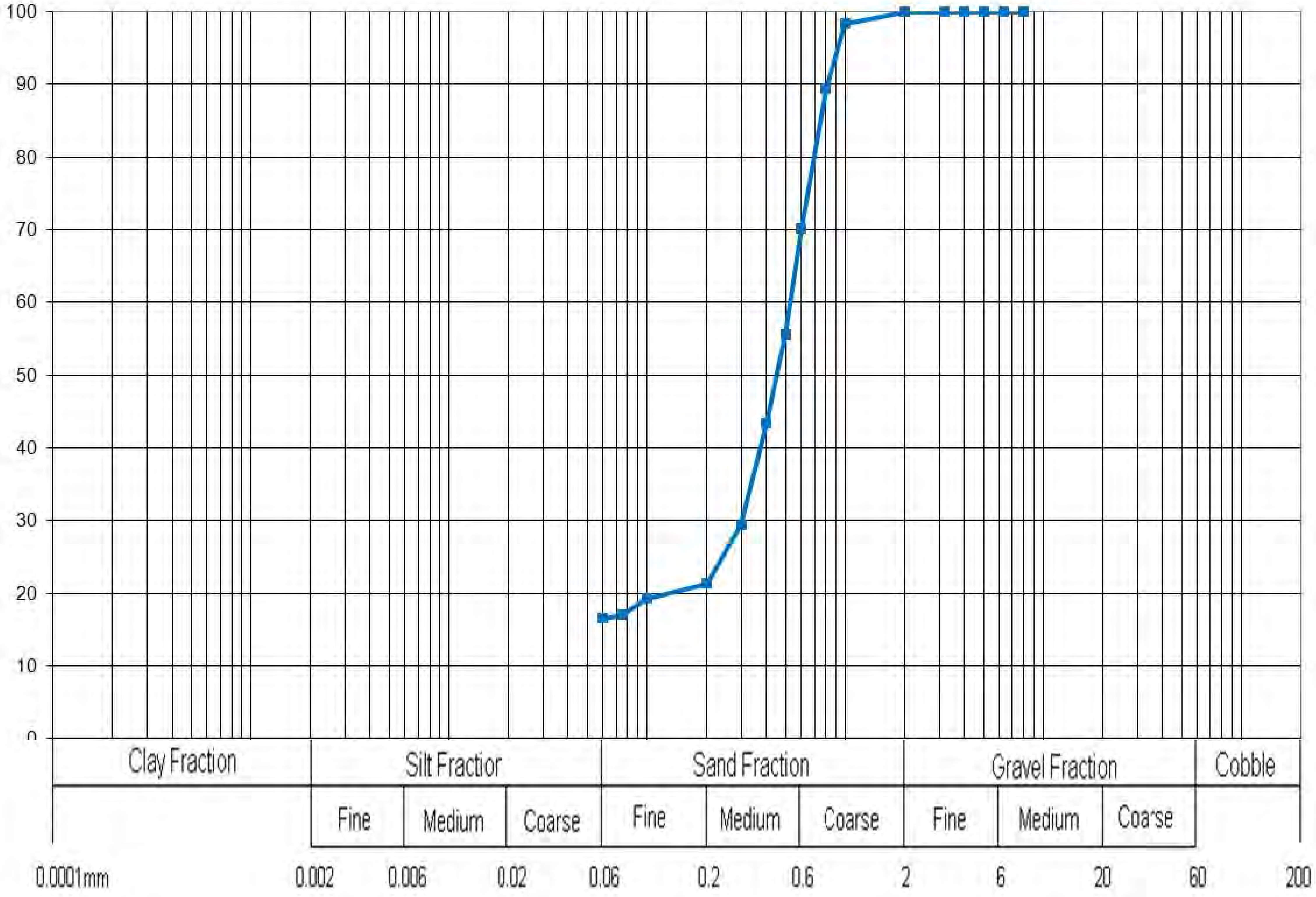

Appendix C: Geotechnical Report (Bioscience, 2015)

Geotechnical Report

South Forrestdale Industrial Area

December 2012

South Forrestdale Industrial Area
Geotechnical Report

December 2012

Prepared for: South Forrestdale Industrial Area Land Owners
Prepared by: Jonathan Cousins
Approved by: Peter Keating

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www.biosciecnewa.com

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1.0 Executive Summary

This report covers part of the proposed South Forrestdale Industrial Area, which falls within land identified as potential medium term non-heavy industrial land in the Perth metropolitan and Peel regions Economic & Employment Lands Strategy (EELS) report. This report aims at determining the suitability of the area for industrial development from a geotechnical perspective.

Whilst installing 24 water monitoring bores Bioscience undertook field sampling and laboratory investigations of the soils over the site to identify physical and chemical properties in relation to soil profiles and permeability. The water monitoring bores were mechanically augered from which soils profiles were logged and sampled.

Soil profiles varied across the study area but typically comprise of three profiles; sand to depth, sand to clayey sand (and sand/ clay layers), and clay over sandy clay/ sand. This is typical of the region i.e. Bassendean sand over Guildford Formation clay. The clayey layer is within 200mm from the surface in the central north and eastern section of the study area.

Sands were found to be medium textured and often poorly sorted with layer thicknesses ranging from 0.4 to 5.5 metres, whilst the clays are sandy clays.

The majority of the site is a combination of Class "A" and "M" as defined in the Residential Slab and Footings (Australian Standard 2870).

Acid sulphate soil exclusion testing was also undertaken. The results identified actual acid sulphate soils in trial holes OX11, OX15 and OX21 and potential acid sulphate soils in OX15 and OX17. However, AASS did not occur in the within 3m of the surface in OX11. Similarly PASS in OX15 did not occur within 3m of the surface.

2.0 Introduction

This report describes the geotechnical investigations undertaken by Bioscience Pty Ltd on the proposed South Forrestdale Industrial Area (figure1). The investigation was commissioned by the owners of the properties who are seeking an Metropolitan Regional Scheme amendment to change the zoning of the land from rural to medium term non heavy industrial.

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

3.0 Proposed Development

The site is proposed to be developed into an industrial subdivision consisting of varying industrial land uses in accordance with the industrial landuse survey (WAPC, 1997). The quantity of imported fill and/or surface gradient alteration will be determined by soil profiles and drainage characteristics determined in this report.

4.0 Site Description

4.1 Site Location

The "South Forrestdale Industrial Area" site is located approximate 25km south east of Perth and approximately 6km south west of the Armadale town centre. This report covers the combined sites of the four land owners; a total area of 135ha not investigated in previous geotechnical studies.

4.2 Land Use

The land is currently used for animal grazing, horse paddocks and stables as well as the residence of one of the owners. There are various clusters of residential and agricultural buildings around the study area. Throughout the remainder of the site are numerous horse shelters and fences separating the site into paddocks (figure2).

4.3 Topography

The area has a low relief with minor variations in topography. The area generally lies between 24m AHD and 25m AHD (figure 3) with minor depressions and elevations.

4.4 Vegetation

The site is mostly devoid of native vegetation as it has been cleared for grazing in the past. The majority of the vegetation on the site is introduced trees, pasture and low scrub. There are however a few small pockets of melaleuca trees in the central part of the site and the trees on the site are large and in good health.

4.5 Geology and Geomorphology

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

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

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

- S10 – SAND – As for S8 over sandy clay to clayey sand of the Guilford formation, of eolian origin
- Sp1 - PEATY SAND - Grey to black, fine to medium grained, moderately sorted, slightly peaty, of lacustrine origin

A soil geology map can be seen in figure 4.

4.6 Groundwater

According to Davidson and Yu (2006) the study area appears to be located within the Armadale superficial aquifers which is bounded to the north by the Canning River, to the east by the Darling Scarp, to the south by the Byford aquifer and to the west by Lake Forrestdale and the Southern River (Davidson and Yu, 2006). It should be noted however, that the study area is also located within close proximity of a transitional zone between its neighbouring superficial aquifers, namely the Jandakot and Byford aquifers. Given this mapping was conducted on a regional scale the actual hydrogeology of the site may be rather complex.

The majority of groundwater recharge like other areas within the Swan Coastal Plain, results from rainfall infiltration, however additional recharge results from rainwater runoff from the Darling Scarp (Davidson and Yu, 2006). An estimated annual recharge of only 5% is relatively low for the Swan Coastal Plain and due in part to low hydraulic conductivities of clayey sediments and the shallow water table.

According to the Department of Environment's (DoE's) Perth Groundwater Atlas (DoE, 2004) the site is characterised by having a high groundwater table. Groundwater levels at the site in May 2005 (i.e. minimum) were approximately 22m ADH (figure 5), whereas the all time maximum groundwater levels for the site is approximately 24m ADH. As the described previously the topography of the site varies from 24m AHD to 25m AHD, consequently the site is suspected to become inundated in the winter months particularly in the lower lying areas (i.e. <24m AHD).

4.7 Site Surface Drainage

There are no major surface water features on the site. Parts of the study area drain internally to the central areas which becomes inundated in the winter months due to a rise in groundwater as well as slow infiltration of surface water. Surface water inundation was present during the drilling of the bores in and around holes OX 4 and OX6.

4.8 Wetlands

The Geomorphic Wetlands Dataset displays the location, boundary, geomorphic classification and management category of wetlands on the Swan Coastal Plain. The information contained within the dataset was originally digitised from the *Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas*, which was captured at a scale of 1:25,000 (Hill et al. 1996b). According to the dataset the site is composed of two Multiple Use Wetlands (MUW) (15797 Palusplain and 14884 Sumpland). On the north side of Oxley road there is a Conservation Category Wetland (CCW), Palusplain 7783 and a Resource Enhancement Wetland (REW), Sumpland 7537. Forrestdale Lake, a RAMSAR wetland and CCW is located within a kilometre northwest of the site.

5.0 Geotechnical Investigation

5.1 Objectives

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

5.2 Field Investigations

Field investigations took place in August, October & November 2012 with a total of 24 boreholes were dug (figure 6) using a mechanical hollow tipped auger drill rig that provided core samples of the soil profile as the hole is drilled. From the soils cores, soil profiles were logged and samples taken for laboratory analysis. Piezometers were installed into the drilled boreholes for groundwater monitoring.

5.3 Soil Profiles

The study area is large and soil profiles naturally varied across the site. The bore logs for each trial hole are given in Appendix 1. There were typically variations of three profiles identified on site; sand to depth, sand to clayey sand (and sand/ clay layers), and clay over sandy clay/ sand.

Figure 7 gives a representation of the depth to sandy clay layers (under sand). The clayey layer is closest to the surface in the central north and eastern section of the study area. This is identifiable during the winter months when surface ponding is present. Where clay is present it is generally between 0.2-2.5m BGL. This is typical of the region i.e. Bassendean sand over Guildford Formation clay.

5.4 Groundwater

Groundwater conditions at the site during the installation of monitoring bores was logged as part of the soil profiling and levels can be found in the appendix. Levels generally fluctuated across the site with the change in surface elevation ranging from 0.6m BGL and not being encountered during the investigation. The groundwater is to be monitored for an allotted time prior to the commencement of the project.

5.5 Laboratory Investigations

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

- Particle Size Distribution – AS1289.3.6.1
- Atterberg limit
    - Liquid limit – AS1289.3.1.2
    - Plastic limit - AS1289.3.2.1
    - Plasticity index – AS1289.3.3.1
    - Linear shrinkage – AS1289.3.4.1

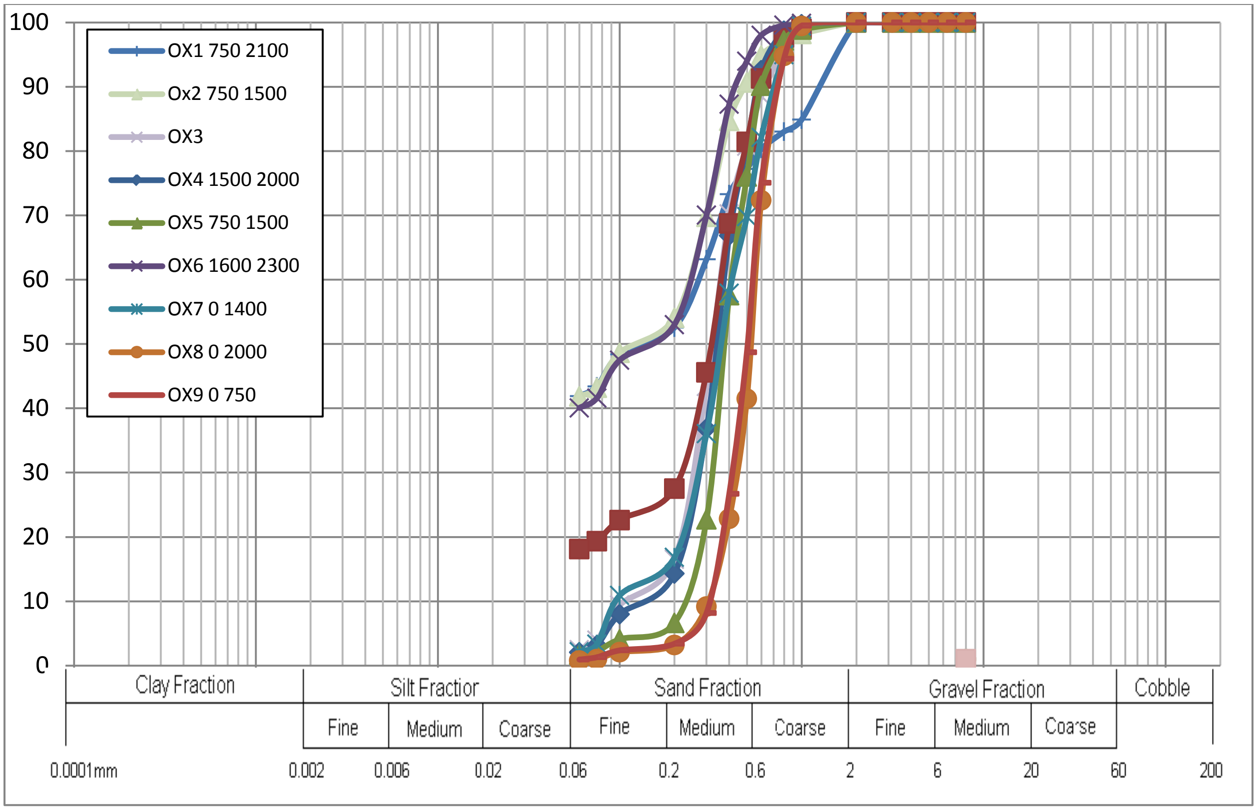
The laboratory tests were carried out in accordance with the requirements specified in AS1289 by Bioscience soil laboratories in Forrestdale.

5.5.1 Particle Size Distribution

Particle size distribution (PSD) was determined on a selection of soils collected during the field investigation to give a representation of soil profile at the site. Sands and clayey sands are selected for PSD analysis. The nine samples containing high percentages of clay (fines) were washed prior to PSD analysis.

The results of the PSD analysis (graphs 1-3) show that soils mainly composed of sands are generally a medium textured, mostly uniformly sorted sand with less than 10 per cent fines (<0.075mm) i.e. a moderately clean sand. Two of the samples, OX4 & OX22, showed partial gap grading trends indicated by "drops" in the graph curve. The clayey sands on the site contain a fines content between 18 and 53 per cent with the sand content being medium textured, moderately uniform in sorting.

Graphs 1-3: Particle Size Distribution Graphs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OX5 750 1500
OX6 1600 2300
OX7 0 1400
OX8 0 2000
OX9 0 750
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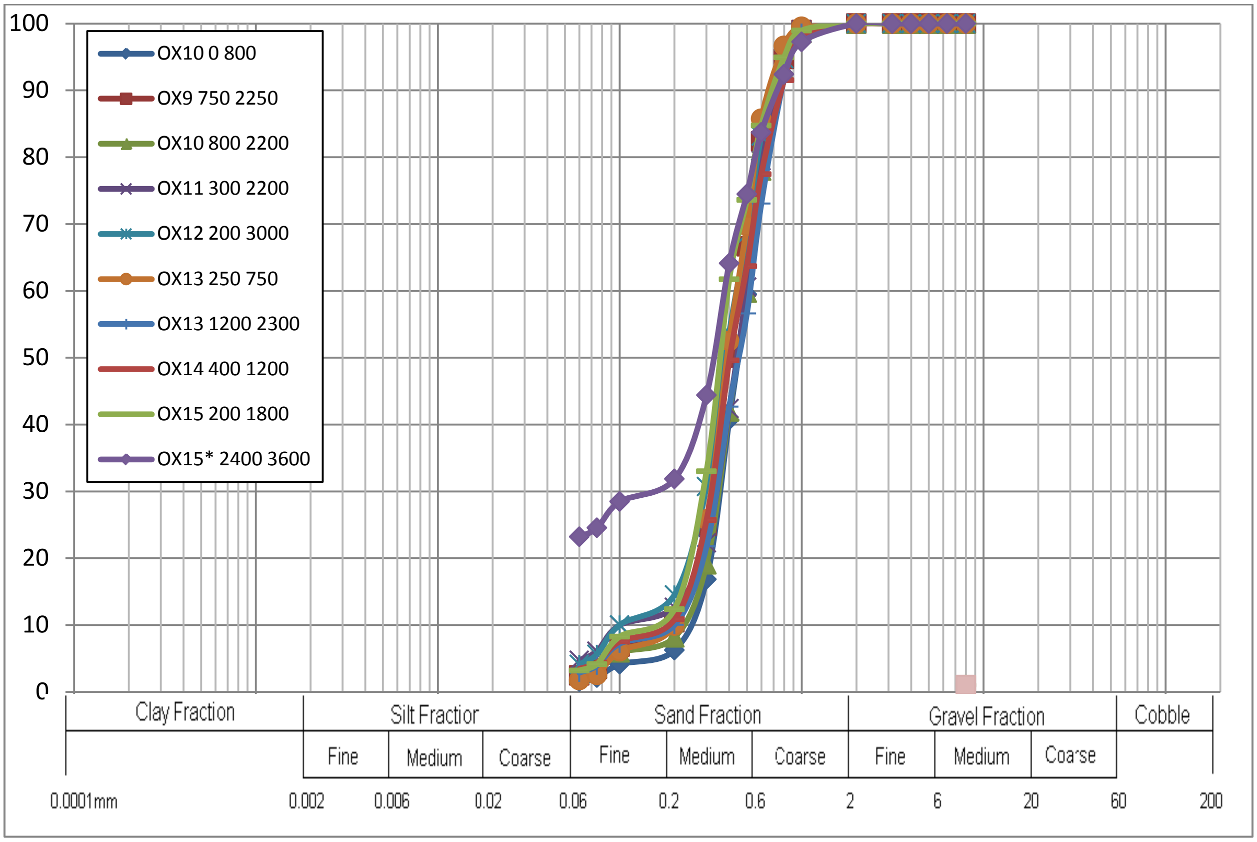
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OX15 200 1800
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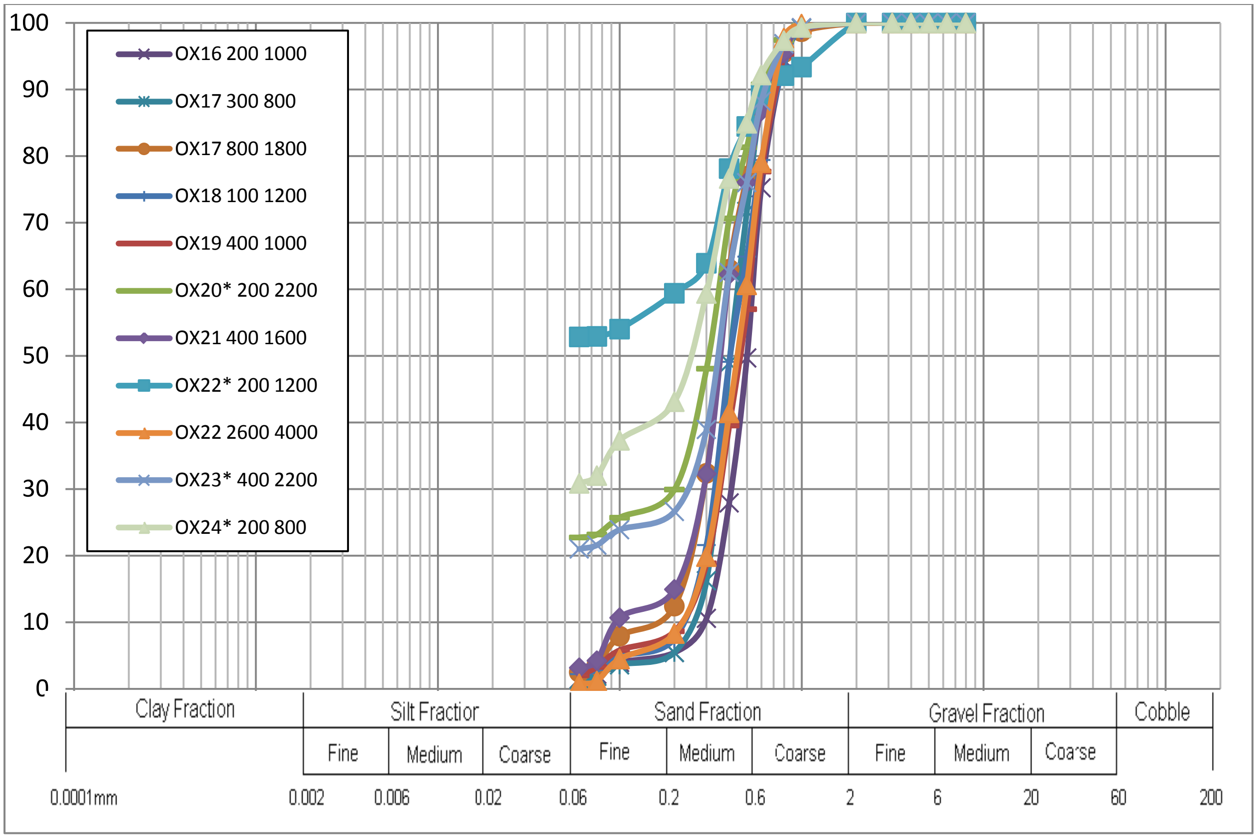


5.5.2 Attergberg Limit

The standardised Atterberg limits tests were developed to determine the physical state characteristics at a given water content for fine samples i.e. clays. These properties effect shear strength and compressibility and are derived by the plasticity of the soil. Atterberg tests provide a useful indication of soil reactivity and potential ground movements fundamental to foundation design. The tests are used to define the upper and lower limits of plasticity, representing liquid limit (LL) and plastic limit (PL) states respectively. The range between the two outer states is termed the plasticity index (PI) and is used to sub-group fine soils into five degrees of plasticity;

Low plasticity:	LL < 35%
Intermediate plasticity:	LL = 35% - 50%
High plasticity:	LL = 50% - 70%
Very high plasticity:	LL = 70% - 90%
Extremely high plasticity:	LL > 90%

Samples that contained more than 20% of fines in PSD analysis are tested to find these limits. The results are summarised in Table 1

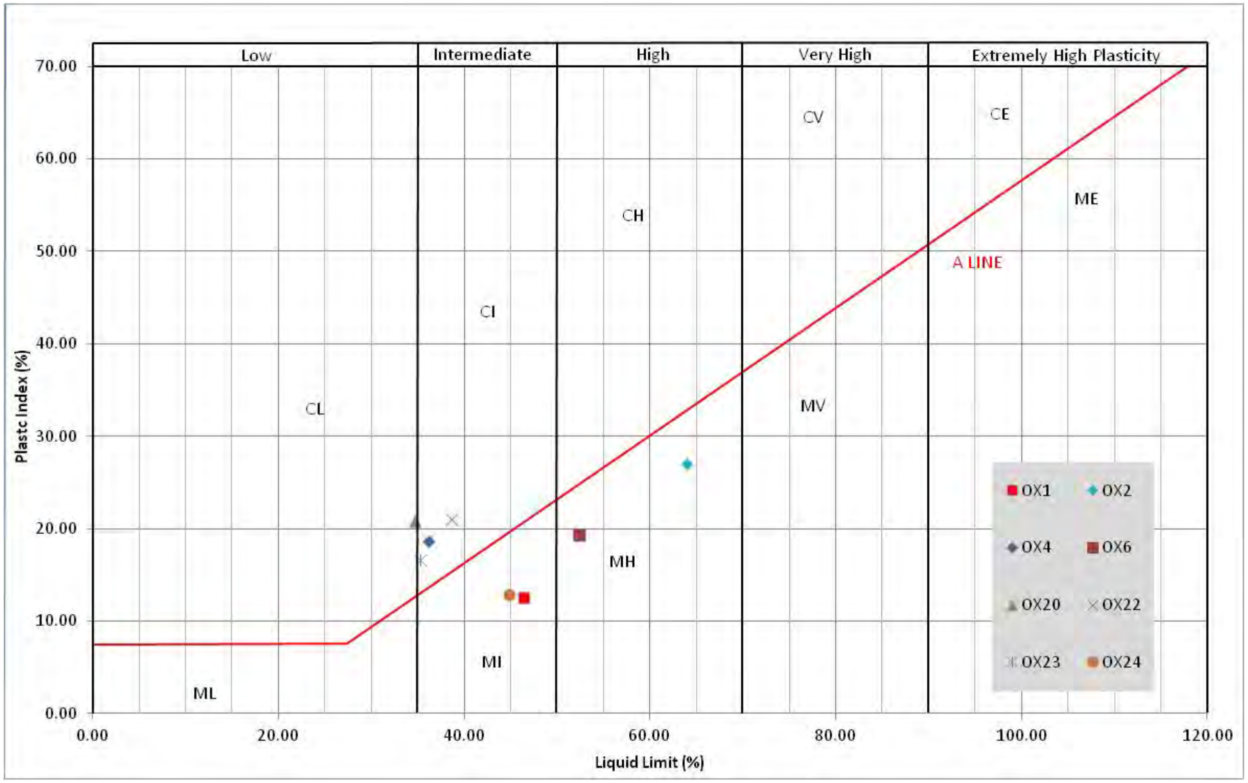
Table 1: Summary of Atterberg Limits

Borehole	Sample Depth (m)		soil weight		Liquid Limits			Plastic Limits (PL)	Plastic Index (PI)	Linear Shrinkage (LS)	Atterberg Classification
			Total Soil Weight	% fines (<425um)	No Blows (15 to 35)	Water content (%)	Liquid Limits (LL)	Water content (%) OR Plastic Limits (PL)	PI = LL - PL	Linear Shrinkage (LS) (%)	
OX1	300	750	211.4	43.56	22	47.02	46.34	12.56	33.78	6.67	MI
OX2	2300	3000	177.3	48.06	27	63.61	63.97	27.09	36.88	4.00	MH
OX4	1500	2000	233.3	36.38	16	37.55	36.11	18.64	17.47	0.67	CI
OX6	1600	2300	174.3	56.94	31	51.22	52.33	19.34	32.99	7.33	MH
OX20	200	1200	281.3	47.26	31	34.00	34.73	20.87	13.87	4.00	CI
OX22	1200	2600	232.4	50.87	33	37.50	38.61	21.06	17.55	7.33	CI
OX23	400	2200	280.3	39.86	32	34.40	35.28	16.69	18.59	6.67	CI
OX24	200	800	265.5	42.91	35	43.17	44.79	12.92	31.87	8.00	MI

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

Four samples plotted above the arbitrary "A" Line (graph 4), which represents a separation between soils behaving in the way of organics and silts. The liquid limit range is between 34.73 and 63.61% i.e. intermediate to high plasticity. However samples OX4, OX20, OX22 & OX23 are very low in the intermediate reactivity range. Samples OX2 and OX6 are of high plasticity and would thus be classed as a highly reactive silt although they occur at a depth greater than 1600mm. Generally the clay on site is of a moderate reactivity.

Graph 4: Plasticity Chart for the Classification of Fine Soils



5.5.3 Acid Sulphate Soil Exclusion Tests

The acid sulphate risk maps for the site (figure 8) shows a subject area to have a large area of potentially high risk of acid sulphate soils occurring within 3m of the natural soil surface. This area generally coincides with clay layers being close to surface as indicated in figure 7. The rest of the site has a moderate to low risk of acid sulphate soils occurring within 3m of the natural soil surface, but high to moderate risk below 3m. As a result of this, exclusion testing was done on the soils collected during field investigation to determine the acid sulphate potential.

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

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

Selected soil samples collected during geotechnical investigation were analysed using the DEC field test procedure as well as LECO carbon sulphur analyser and redox potential. Overall these give an indication of whether or not soils are actual, potential or non acid sulphate soils. Table 2 summarises the results of the acid sulphate testing.

Eighteen samples underwent these tests and 3 samples came back as being actual acid sulphate soil (AASS) and two were potential acid sulphate soils (PASS). The AASS soils are all found deeper than 1600 mm in sand or silty sand. PASS occurs at depths greater than 2400mm in sands and clayey sands. The strong reactions of samples from bore OX22 is possibly caused by the presence of manganese in the soil sample. There is no AASS and an unlikely PASS in OX22.

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

Table 2: Summary of Acid Sulphate Testing

Sample	Depth	Soil Type	pHf	pHfox	Change in pH	Reaction	Carbon %	Sulphur %	Result (PASS or AASS)
OX11	300-2200	SAND	4.00	3.17	0.83	Low	0.0994	0.0036	
OX11	2200-3800	SAND	3.81	2.70	1.11	Low	0.1183	0.0054	
OX11	3800-4000	SAND	3.72	2.58	1.14	Low	0.4027	0.0305	AASS
OX14	400-1200	SAND	4.52	2.37	2.15	Low	0.1090	0.0071	
OX14	1200-1600	CLAYEY SAND	3.91	2.68	1.23	Low	2.0980	0.0200	
OX14	2000-4000	SAND	4.88	1.80	3.08	Low	0.0396	0.0055	
OX15	200-1800	SAND	4.02	3.02	1.00	Low	0.0916	0.0009	
OX15	1800-2100	SAND	3.85	2.64	1.21	Low	1.9380	0.1224	AASS
OX15	2100-2400	SAND	4.20	3.43	0.77	Low	0.4343	0.0245	
OX15	3600-4000	SAND	4.74	3.77	0.97	Low	3.0090	0.2003	PASS
OX17	1800-2400	SAND	4.72	1.33	3.39	Low	0.1779	0.0068	
OX17	2400-3500	CLAYEY SAND	3.92	3.22	0.70	Low	1.6800	0.0854	PASS
OX19	1800-2200	SAND	4.11	3.03	1.08	Low	0.1984	0.0182	
OX19	2200-4000	SILTY SAND	4.08	3.09	0.99	Low	0.4575	0.0584	
OX21	1600-2000	SILTY SAND	3.66	2.76	0.90	Low	2.2250	0.1705	AASS
OX21	2000-2500	SAND	4.69	1.34	3.35	Low	0.0952	0.0057	
OX22	200-1200	CLAYEY SAND	6.13	7.04	0.91	High	0.0335	0.0244	
OX22	1200-2600	CLAYEY SAND	5.77	5.70	0.07	Medium	0.0615	0.0390	

*Note: Red indicates components that are above/ below threshold limits

6.0 Site Evaluation and Recommendations

6.1 Site Classification

The “Residential Slab and Footings Australian Standard 2870” provides a site classification system and associated generic foundation design recommendations for residential development. The site classification system is based on the potential soil reactivity, and associated ground movements, attributable to seasonal soil moisture variations or potential problems sites due to adverse geotechnical conditions. The general definition of site classes from AS 2870 2.1.2 is;

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites which may experience only slight ground movement from moisture changes (ys<20mm)
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes (ys 20-40mm)
H1	Highly reactive clay site, which may experience high ground movement from moisture, changes (ys 40-60mm)
H2	Highly reactive clay site, which may experience very high ground movement from moisture, changes (ys 60-75mm)
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes (ys>75mm)

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

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

The study area has a mixed classification based on the depth to (figure 7), and the reactivity of the clay layer. The areas where sand cover over clay is greater than 1.5m is classified "A". The remainder of the site shall be classified "M" due to the presence of an intermediately reactive clay and silt layer. This area can be improved to class "A" with the application of suitable engineered fill material after the removal of the reactive clays and creation of a separation of 1.5m to the loamy/clayey soils.

6.2 Soil Permeability and Drainage

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

6.3 Site Preparation

The following site preparation procedure is recommended

- Removal of topsoil, organics, root, old services and other deleterious material from the site
- Contouring/shaping of the ground surface to ensure surface runoff drains appropriately form the site
- Proof compact the exposed surface using a suitable compaction plant. A minimum of 12 tonne static mass vibratory smooth drum roller is preferred to achieve densification of sandy soil at depth. A minimum of eight overlapping passes should be provided
- Where the surface deforms excessively during compaction or wet and/or weak material is exposed, over-excavation and replacement with compacted free draining sand fill may be required
- Site works and preparation should be undertaken in summer or autumn, where groundwater levels are near their seasonal lows, as soil will become very difficult to work with in wet conditions
- Dewatering or drainage may be required to control groundwater levels. Experience indicates that difficulties with compaction may occur when groundwater is present within about 1.0 to 1.5m of the level at which compaction is applied
- Should compaction to satisfactory depth not be achieved by surface compaction it may be necessary to over excavate, compact the base of the excavation and replace the soil in compaction layers
- Place and compact approved clean free draining fill material in layers of no greater than 0.3m thickness, up to the level required

6.4 Excavation and Dewatering

Based on the observed soil properties intersected during the fieldwork the following comments are provided;

Excavations in sand areas are prone to instability; consequently care must be exercised in such excavation and appropriate safety measures adapted where necessary i.e. supports, battered side slopes.

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

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

There remains a small potential of ASS occurring during dewatering and/or excavation, consequently Bioscience recommends that site works attempt to maintain a low project risk and defined by table 2 below. A dewatering licence would need to be obtained from the Department of Water before any such work is undertaken. Any dewatering would require a dewatering management plan and effluent discharge carefully monitored due to the proximity to the Southern River.

Table 2: Acid Sulphate Soils Project Risk Assessment

Project Factors	Project Risk Level		
	Low	Medium	High
Duration of Project	**Less than 1 month**	**1-3 months**	**Greater than 3 months**
Volume of Excavation	**< 100m^3**	**100 - 1000m^3**	**> 1000m^3**
Depth of Excavation	**Less than 3m BGL**	**3-10m BGL**	**Greater than 10m BGL**
Depth of Groundwater	**Depth to groundwater > depth of excavation**	**Depth of excavation <3m below groundwater**	**Depth of excavation >3m below groundwater**
Distance to Sensitive Receptors	**> 500m**	**200 - 500m**	**< 200m**
Sensitivity of	**Unclassified water**	**Multiple use**	**Conservation**

Environmental Receptors	**body**		
Beneficial Use of Groundwater Resources	**Irrigation or lower quality**	**Priority 3 resource**	**Priority 1/2 resource**

6.5 Compaction

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

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

6.6 Fill Material

Fill material will be required on site to ensure that an adequate separation of groundwater is maintained (i.e. greater than 1.2m above AAMGL) on the provision that it contains less than 5% fines (i.e. <0.075mm) and has a maximum particle size of 40mm and is free of any organic or deleterious material.

7.0 References

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

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

AS 2870 - 1996, Residential Slabs and Footings - Construction. Standards Australia.

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

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

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

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

Perth Groundwater Atlas (2004) - Department of Water.

WAPC (1997). Industrial Landuse Survey 1997, Perth Metropolitan Region. Western Australian Panning Commission.

8.0 Limitations

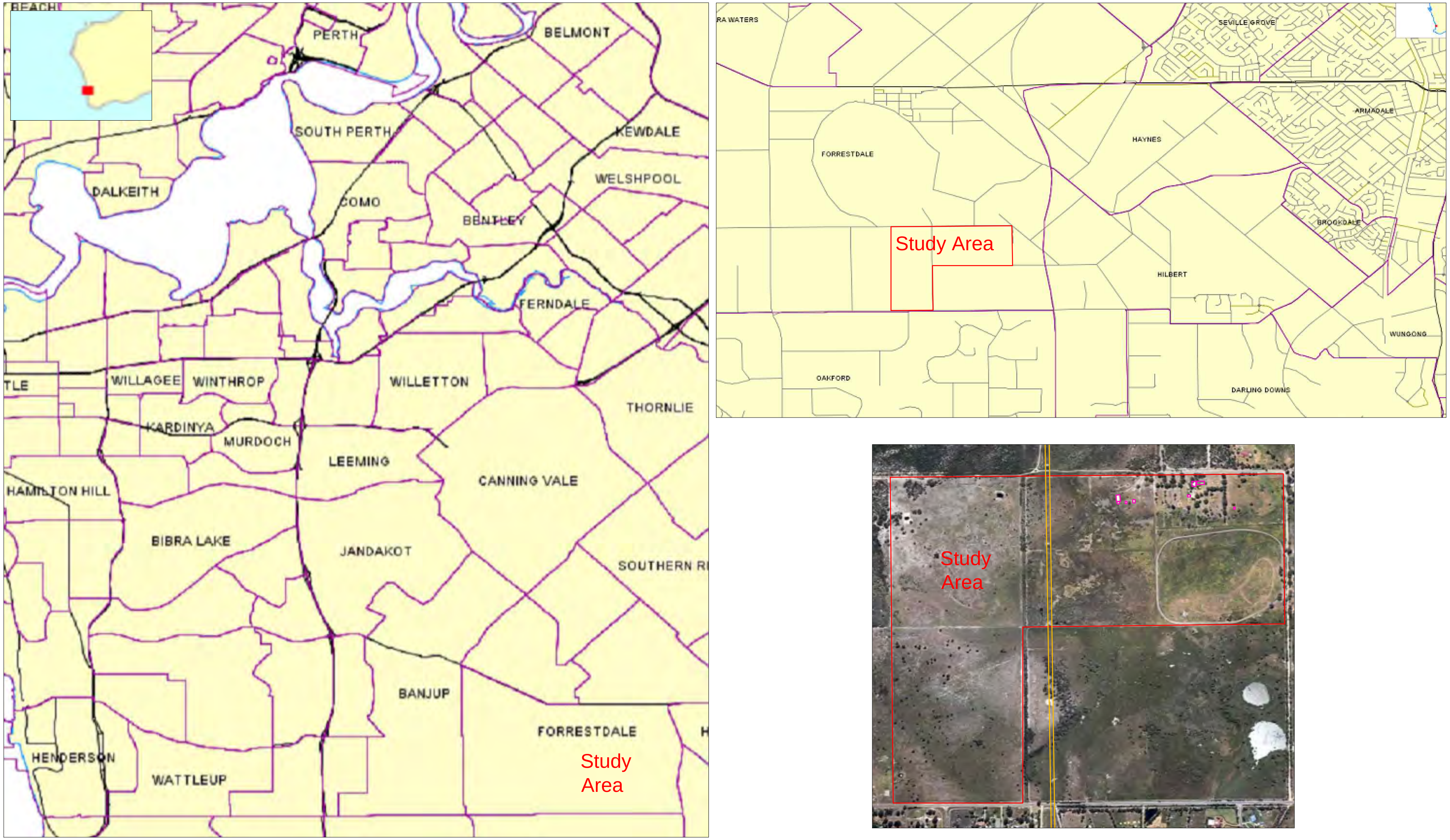
Bioscience Pty Ltd has prepared this report for the proposed South Forrestdale Industrial Area, WA. The work was carried out under Bioscience's Conditions of Engagement. This report is provided for the exclusive use of the landholders for this project only and for the purposes described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. In preparing this report Bioscience has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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



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Data Source: Perth Groundwater Atlas & Nearmaps

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Figure 1: Location Plan

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Aerial Photograph: Do not scale

▭ Buttons
— Power Lines

Data Source: Near Maps (17/10/2012)

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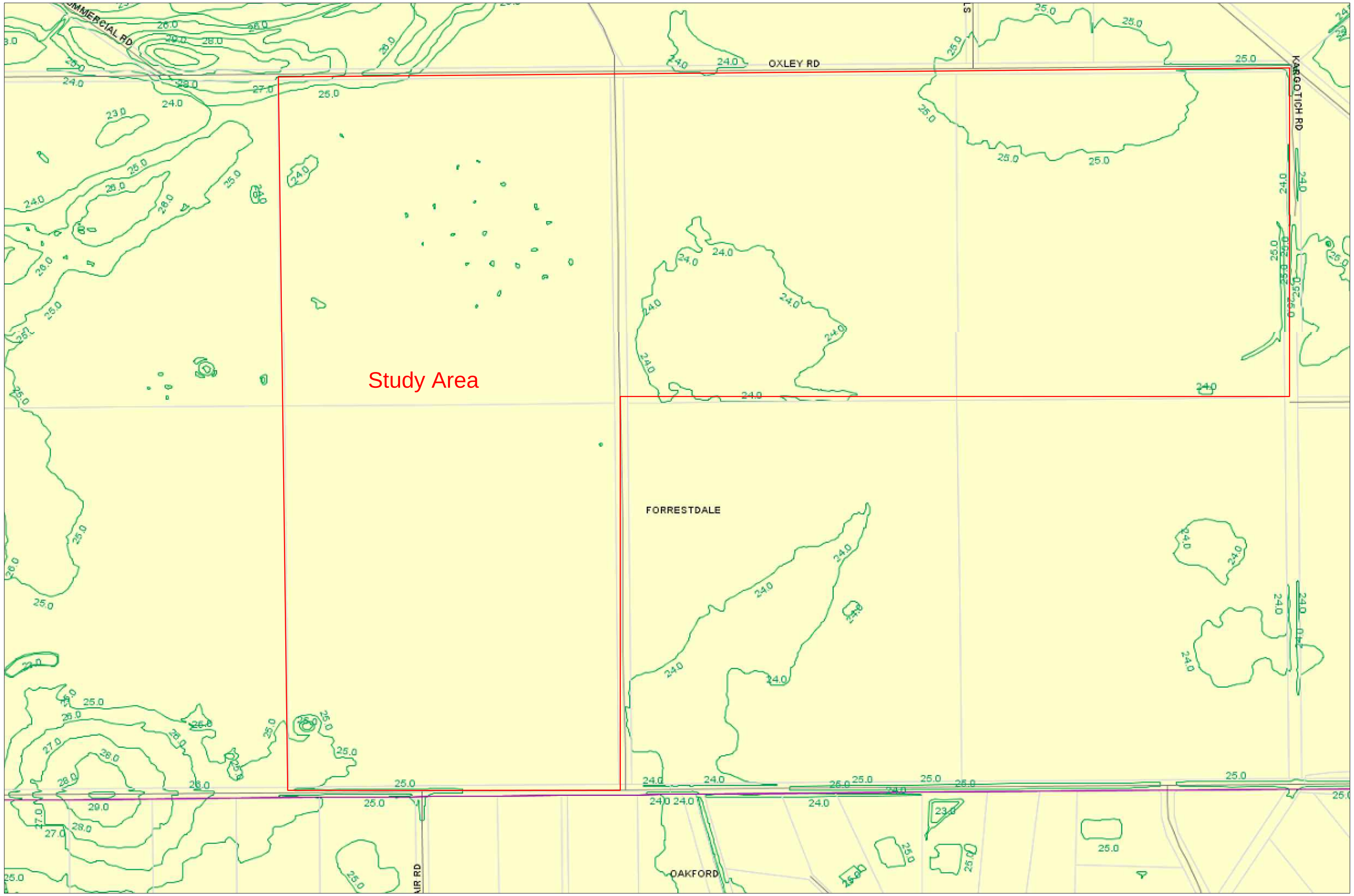
Figure 2: Current Landuse



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— Ground Contour Lines (all elevations subject to survey)

Data Source: Perth Groundwater Atlas

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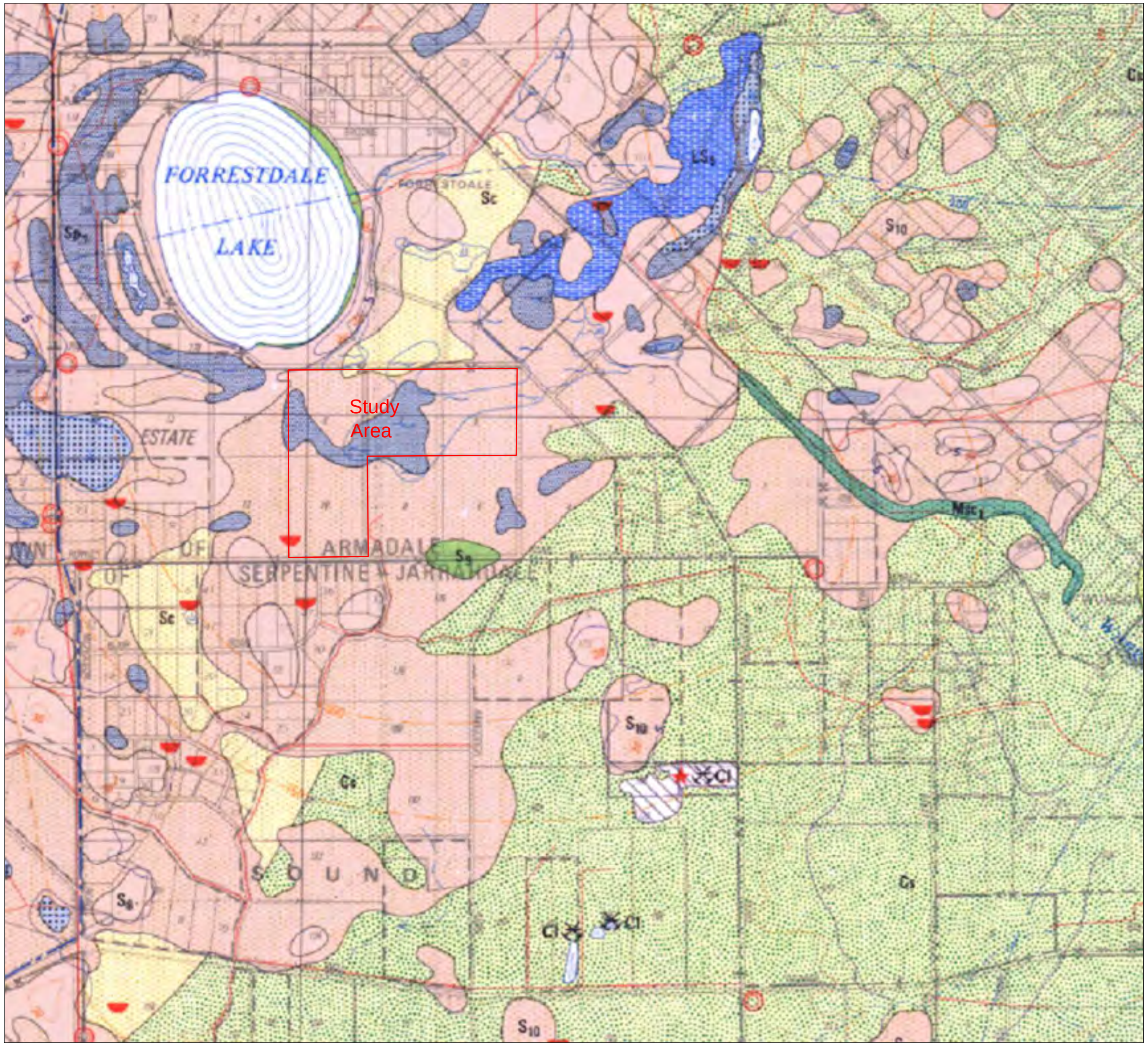
Figure 3: Topography



ARMADALE

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

S_8	SAND - white to pale grey at surface, yellow at depth, fine to medium grained, moderately sorted, subangular to sub rounded, minor heavy minerals, of eolian origin
S_{10}	SAND - as S8 over sandy clay to clayey sand of the Guildford Formation, of Eolian origin
Sc	CLAYEY SAND - silty in part, pale grey to brown, medium to coarse grained, poorly sorted, subangular to rounded, frequent heavy minerals, rare feldspar, of alluvial origin
Sp_1	PEATY SAND - grey to black, fine to medium grained, moderately sorted quartz sand, slightly peaty, of lacustrine origin

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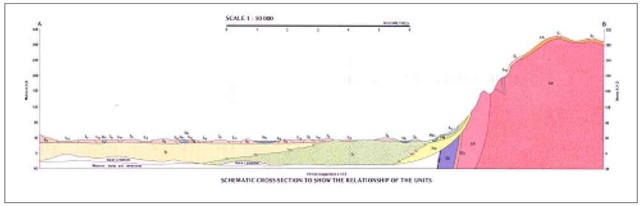

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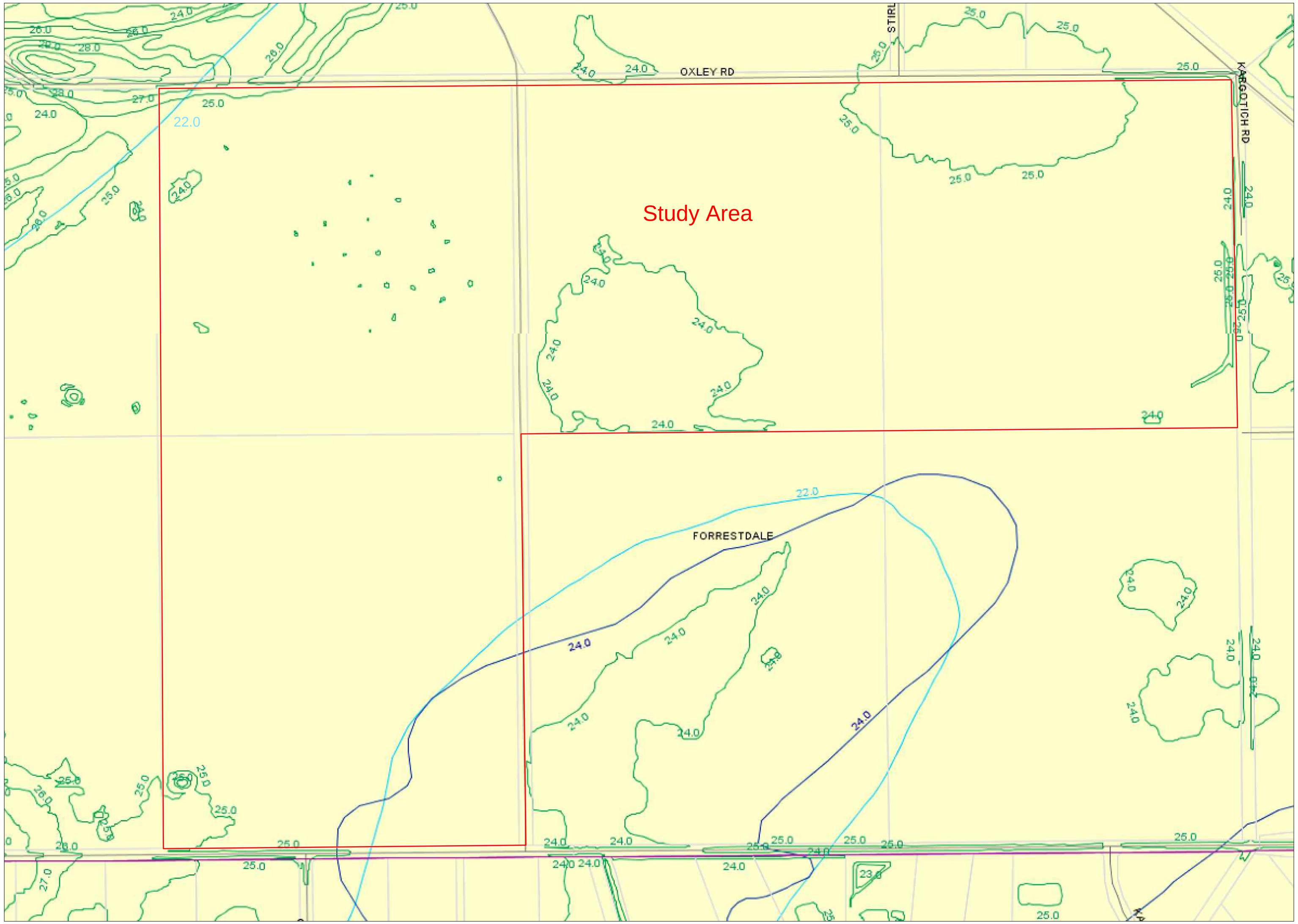
Figure 4: Armadale Geological Survey sheets 2033 I & 2133 IV



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— Groundwater Level
— Maximum Groundwater Level

Data Source: Perth Groundwater Atlas

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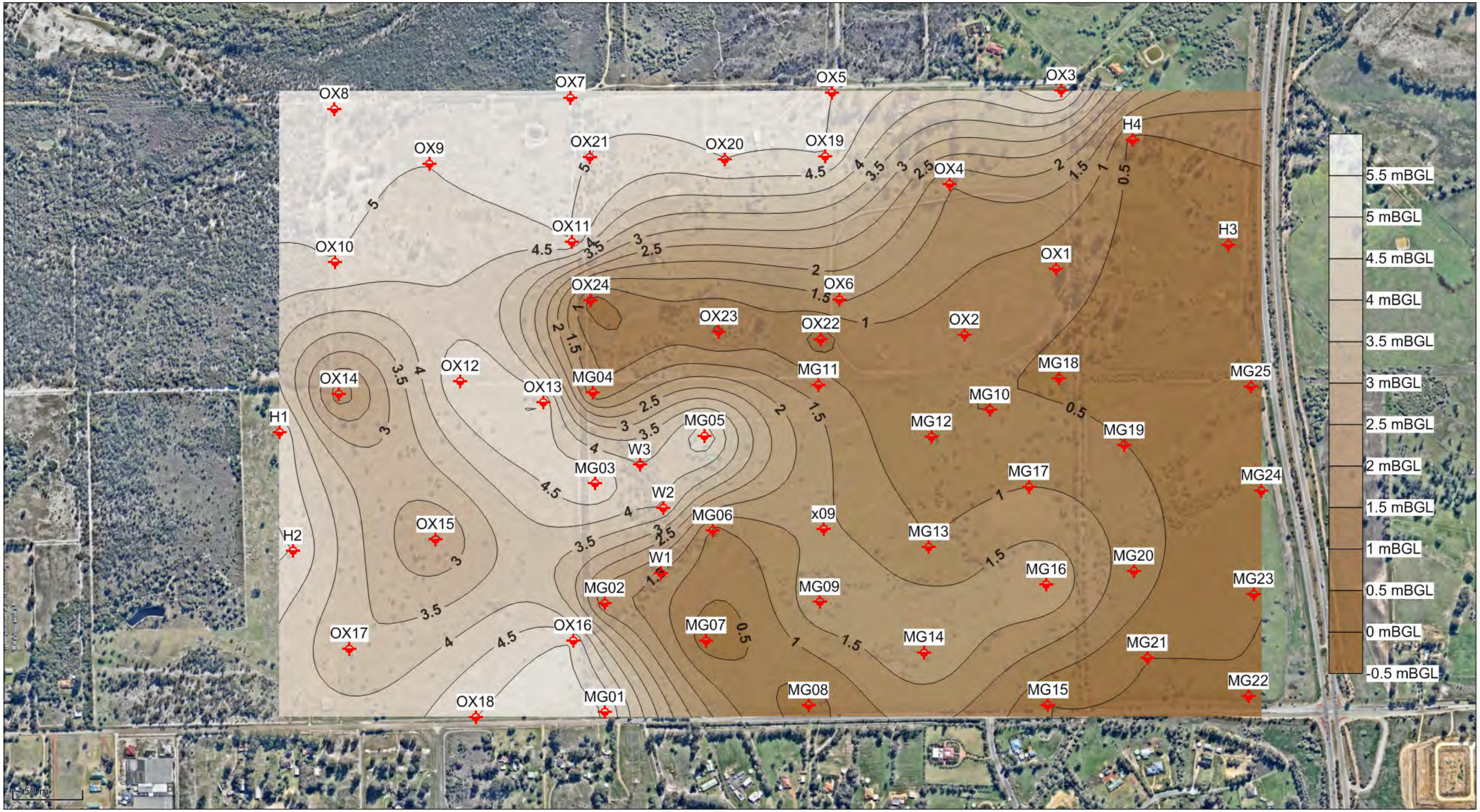
Figure 5: Groundwater Levels



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Integrating Resource Management

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✛ Bore Locations

Note: Geotechnical investigations not undertaken accross the total area identified by EELS as potential Non-heavy Industrial Land as access prohibited.
*Depth to clay contouring is interpolated between bores.

Data Source: Bioscience Pty Geotechnical Reports

0m 200m 400m 600m 800m

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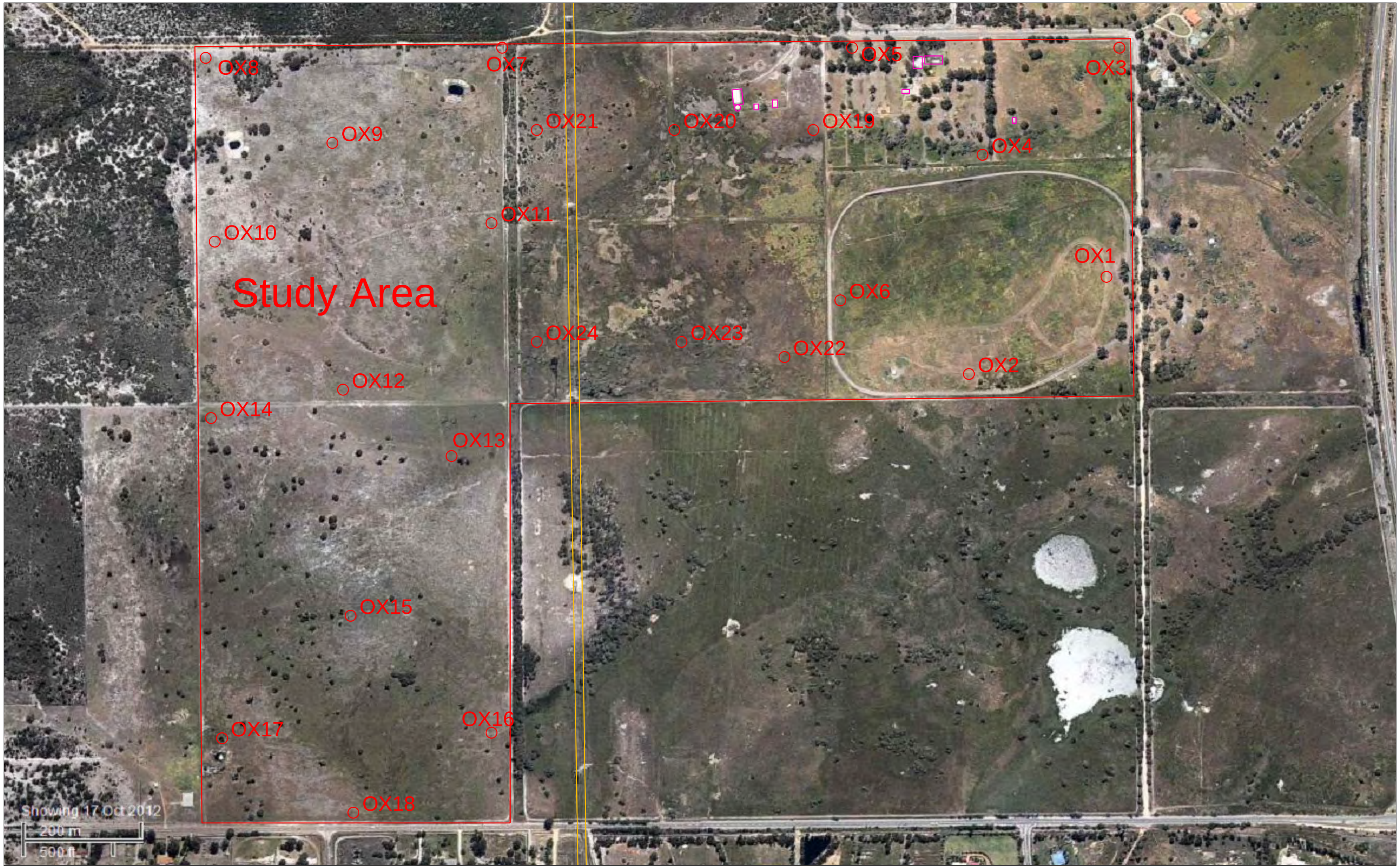
District Water Management Strategy

25/08/2015

Figure 5: Geotechnical Assessment (Depth to Clay)



○ Bore Hole Locations

Aerial Photograph: do not scale

Data Source: Nearmap (Base Map)

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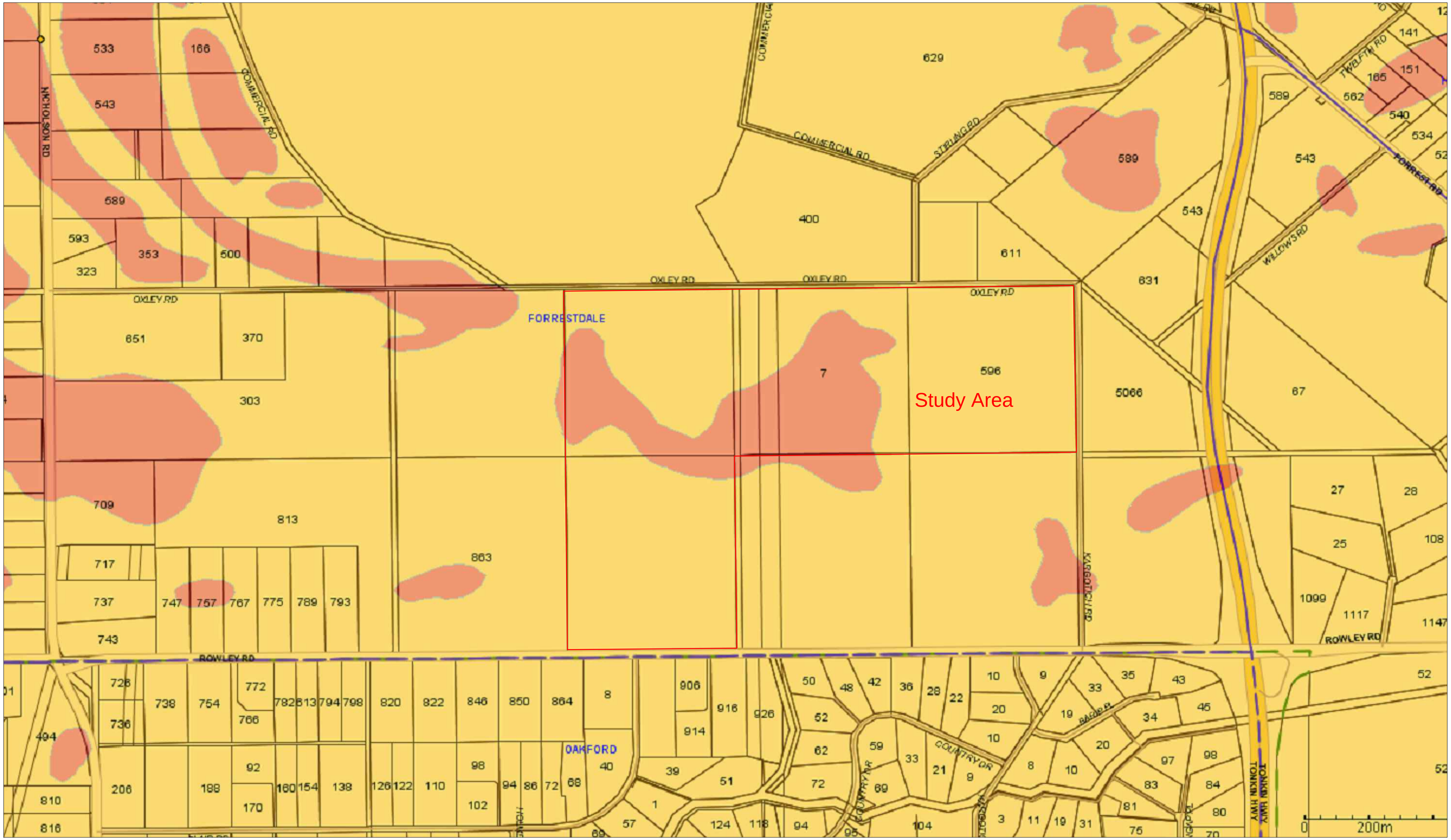
Figure 6: Geotechnical Assessment Locations



🟨	Moderate to low risk of acid sulfate soil in the 3m BGL
🟧	High risk of acid sulfate soil in the 3m BGL

Data Source: WA Atlas

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Figure 8: Acid Sulfate Soil Risk

Appendix 1: Soil Profile Logs

BORE COMPLETION LOG

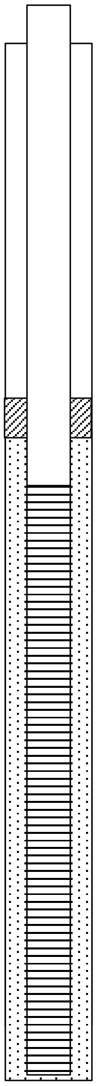
BORE NO.
OX1
SHEET 1 OF 24

Client: Toby ....
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0	Dark Grey Sand	SP	
	Light Brown Loamy Sand to Sandy Clay	SC	
1	White Gravelly Clay	GC	
2	Orange Brown Sandy Clay	SC	∇ 16/08/2012
3	Orange Clayey Sand	SC	
4	No Sample		
5			

Completion



Details

GENERAL INFORMATION
Easting: 401553mE
Northing: 6440108mN
Top of casing: 0.5mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.25mBGL
Diameter: 100mm

CASING
From: 0 to: 5.25 mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.25 to: 5.25 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.80 mBGL
Seal type: Benonite
From: 1.80 to: 2.00 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 2.00 to: 5.25 mBGL

FIELD WATER QUALITY
pH: 7.04
Conductivity:1112 $\mu S.cm^{-1}$

Notes:

Bioscience

BORE COMPLETION LOG

BORE NO.
OX2
SHEET 2 OF 24

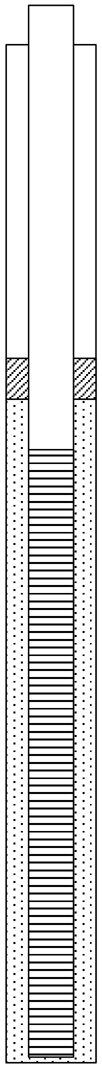
Client: Toby ....
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log
0	Dark Grey Sand	SP
1	White and Orange Clayey Sand	SC
2	Orange Brown Clayey Sand	SC
	Orange Brown Clay	CL
3	Orange Clayey Sand	SC
4	Grey Sand	SP
5		

WL: ◁16/08/2012

Completion



Details

GENERAL INFORMATION
Easting: 401357mE
Northing: 6439968mN
Top of casing: 0.60mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.00mBGL
Diameter: 100mm

CASING
From: 0 to: 5.00mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.00 to: 5.00 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.50 mBGL
Seal type: Benonite
From: 1.50 to: 1.75 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 1.75 to: 5.00mBGL

FIELD WATER QUALITY
pH: 7.25
Conductivity: 1733 μS.cm^{-1}

Notes:

Bioscience

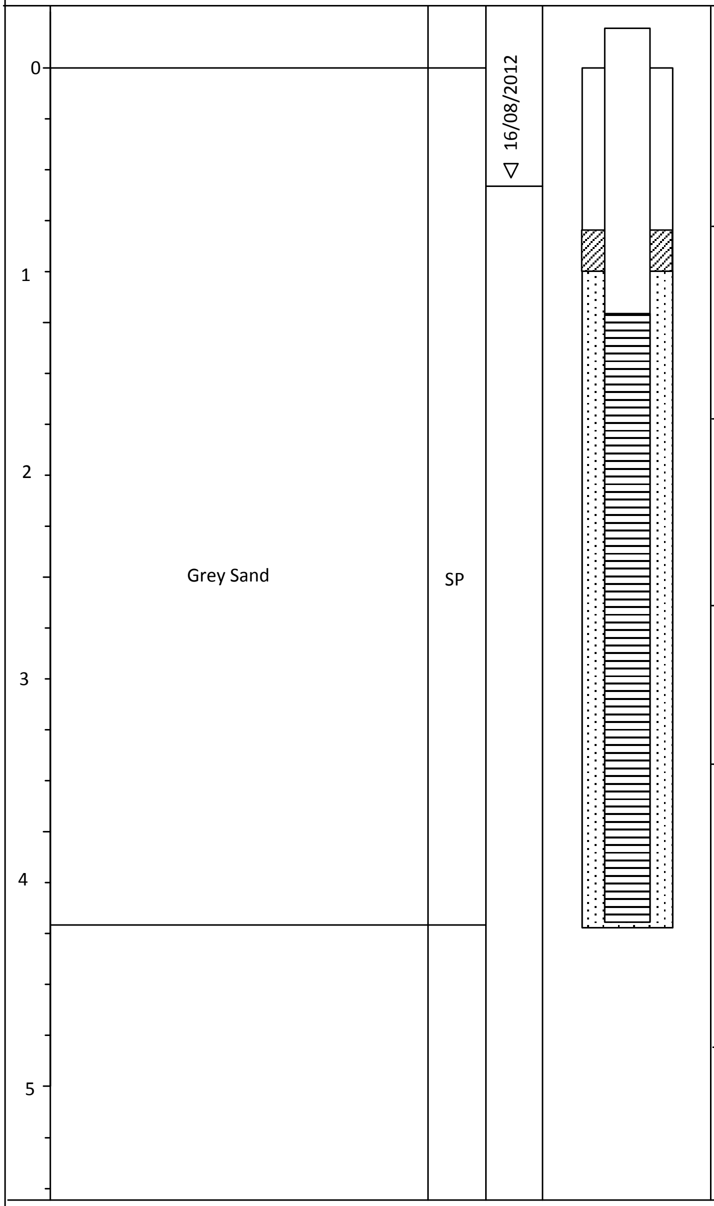
BORE COMPLETION LOG

BORE NO.
OX3
SHEET 3 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale | Lithological Description | Log | WL | Completion | Details



GENERAL INFORMATION
Easting: 401564mE
Northing: 6440489mN
Top of casing:0.59 mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 4.20mBGL
Diameter: 100mm

CASING
From: 0 to: 4.20mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 1.20 to: 4.20 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 0.80 mBGL
Seal type: Benonite
From: 0.80 to: 1.00 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 1.00 to: 4.20 mBGL

FIELD WATER QUALITY
pH: 6.36
Conductivity: 1341 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

BORE NO.
OX4
SHEET 4 OF 24

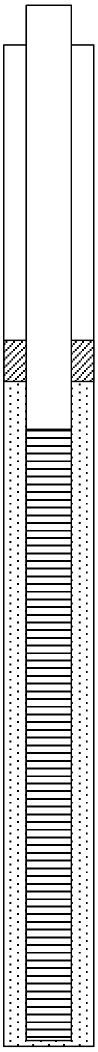
Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log
0 – ~0.4	Brown Sand	SP
~0.4 – ~1.5	Grey Sand	SP
~1.5 – 2.0	Grey Clayey Sand	SC
2.0 – ~2.8	Light Brown Clayey Sand	SC
~2.8 – 3.0	Black Clayey Sand	SC
3.0 – ~4.9	No Sample	

WL: ▽ 16/08/2012

Completion



Details

GENERAL INFORMATION
Easting: 401325mE
Northing: 6440289mN
Top of casing: 0.60mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 4.90mBGL
Diameter: 100mm

CASING
From: 0 to: 4.90mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 1.90 to: 4.90 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.50 mBGL
Seal type: Benonite
From: 1.50 to: 1.70 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 1.70 to: 4.90 mBGL

FIELD WATER QUALITY
pH: 6.06
Conductivity: 2482 $\mu S.cm^{-1}$

Notes:

BORE COMPLETION LOG

BORE NO.
OX5
SHEET 5 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

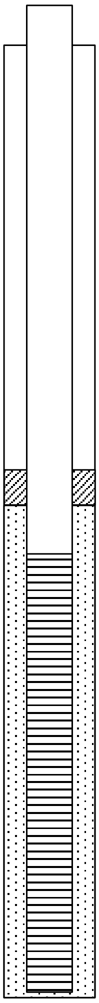
Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Scale: 0, 1, 2, 3, 4, 5, 6, 7

Lithological Description	Log
Grey Brown Sand	SP
Grey Sand	SC
No Sample	
Brown Silty Sand	SM
No Sample	

WL: ▽ 16/08/2012

Completion



Details

GENERAL INFORMATION
Easting: 401073mE
Northing: 6440484mN
Top of casing: 0.66mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 6.15mBGL
Diameter: 100mm

CASING
From: 0 to: 6.15mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 3.15 to: 6.15 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 2.80 mBGL
Seal type: Benonite
From: 2.80 to: 3.00 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 3.00 to: 6.15 mBGL

FIELD WATER QUALITY
pH: 4.76
Conductivity: 2820 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

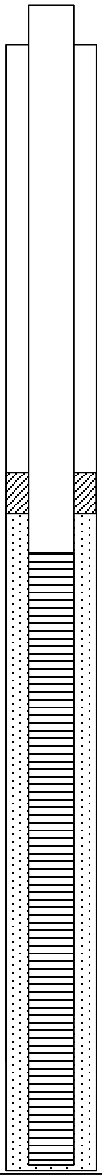
BORE NO.
OX6
SHEET 6 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0	Black Sand	SP	
	Grey Sand	SP	
1	Light Brown Sandy Clay	SC	
2	Orange Brown Clay	CL	▽ 16/08/2012
	Orange Brown Sandy Clay	SC	
3 4 5	No Sample		

Completion



Details

GENERAL INFORMATION
Easting: 401088mE
Northing: 64440044mN
Top of casing: 0.62mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.50mBGL
Diameter: 100mm

CASING
From: 0 to: 5.50mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.50 to: 5.50 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 2.10 mBGL
Seal type: Benonite
From: 2.10 to: 2.30 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 2.30 to: 5.50 mBGL

FIELD WATER QUALITY
pH: 6.56
Conductivity: 20300 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

BORE NO.
OX7
SHEET 1 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX7
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing: Type	Depth	Sample	Notes	Water
0.2	Sand – Loose topsoil, dark brown	░	SW				
1.0 1.4	Sand – loose to medium dense, brown/ grey, moderately sorted grained, dry sand	░	S				
2.0	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S			Water encountered @ 1400mm	Water encountered @ 1400mm
2.25	Sandy Silt – medium dense, brown, fine grained, wet	▒	SM				
3.0	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S				
4.0							
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440474
Easting: 400515
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX8
SHEET 2 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 25m AHD approx
Bore Number: OX8
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
1.0	Sand – loose, brown/ grey, moderately sorted grained, dry sand with rootlets in top 200mm		S				Water not encountered
2.0	Sand – Loose to medium dense, light brown, fine to medium grained, wet sand		S				
2.25	Sand – medium dense, white/ grey, moderately sorted grained, wet sand		S				
2.75							
3.0							
4.0							
5.0						Water not encountered @ 5000mm	

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440450 Easting: 400010

REMARKS: Surface level interpolated from contour plan map. Bore hole collapsed in on self @3000mm+

BORE COMPLETION LOG

BORE NO.
OX9
SHEET 3 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX9
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, brown/ grey, moderately sorted grained, dry organic sand with rootlets top 400mm		S				Water encountered @ 1500mm
0.75 1.0 2.0	Sand – medium dense, light brown, moderately sorted grained, moist to wet sand		S			Water encountered @ 1500mm	
2.25 3.0 4.0 5.0	Sand – medium dense, brown, moderately sorted grained, wet sand		S				

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440333
Easting: 400213
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX10
SHEET 4 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX10
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, white, moderately sorted grained, dry organic sand with rootlets top 400mm	░	S				Water encountered @ 2000mm
0.8 1.0	Sand – medium dense, light brown, moderately sorted grained, moist sand	░	S				
2.0 2.2						Water encountered @ 2000mm	
3.0 4.0 5.0	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S				

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440123 Easting: 400011

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX11
SHEET 5 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX11
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand with rootlets	░	S				
1.0 2.0 2.2	Sand – loose to medium dense, light brown, moderately sorted grained, moist to wet sand	░	S			Water encountered @ 1000mm	Water encountered @ 1000mm
3.0 3.8	Sand – medium dense, dark brown, moderately sorted grained, wet sand	▒	S				
4.0	Sand – stiff, dark brown, moderately sorted grained, wet sand	▒	S				
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440167
Easting: 400517
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX12
SHEET 6 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX12
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand with rootlets		S				
1.0 2.0 3.0	Sand – loose to medium dense, white to light brown, moderately sorted grained, moist to wet sand		S			Water encountered @ 800mm	Water encountered @ 800mm
4.0	Sand – medium dense, light brown, moderately sorted grained, wet sand		S				
5.0							

RIG: Mechanical Auger   DRILLER: LOGGED: JC
TYPE OF BORING:
Northing: 6439869   Easting: 400279
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX13
SHEET 7 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX13
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.25	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets	░	S				
0.75	Sand – medium, light brown, moderately sorted grained, dry organic sand	▒	S				
1.0 1.2	Sand – medium, light orange, moderately sorted grained, wet organic sand	▒	S			Water encountered @ 700mm	Water encountered @ 700mm
2.0 2.3	Sand – medium dense, grey, moderately sorted grained, wet organic sand	▒	S				
3.0	Sand – medium dense, grey to brown, moderately sorted grained, wet organic sand	▒	S				
4.0	Sand – medium dense, brown, moderately sorted grained, wet organic sand	▒					
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439824 Easting: 400456

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX14
SHEET 8 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX14
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry sand with rootlets		S				
0.4	Sand – medium, light brown, moderately sorted grained, wet organic sand		S			Water encountered @ 700mm	Water encountered @ 700mm
1.0							
1.2	Clayey sand – dense, dark brown, fine to medium sorted grained, wet organic sand		CS			Compact sand	
1.6	Coffee Rock – dense, coffee brown		CR				
2.0							
2.3							
3.0	Sand – dense, light brown, moderately sorted grained, moist organic sand		S				
4.0							
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439842 Easting: 400020

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX15
SHEET 9 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX15
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets	░	S				
1.0 1.8	Sand – loose, grey, moderately sorted grained, moist to wet organic sand	░	S			Water encountered @ 600mm	Water encountered @ 600mm
2.0 2.1	Sand– medium dense, brown, moderately sorted grained, wet organic sand	▒	S				
2.4	Sand – dense, dark brown, moderately sorted grained, wet organic sand	▒	S			Very dense @ 2200mm	
3.0 3.6	Clayey sand – dense, brown, moderately sorted grained, wet, organic	▓	CS				
4.0	Sand – dense, black, moderately sorted grained, wet organic sand	▒	S				
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439532 Easting: 400226

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX16
SHEET 10 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX16
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets	░	S				
1.0	Sand – loose, grey brown, moderately sorted grained, dry organic sand	░	S			Water encountered @ 800mm	Water encountered @ 800mm
1.2 2.0 3.0	Sand – medium dense, light brown, moderately sorted grained, wet organic sand	▒	S				
4.0	Sand– medium dense, dark brown, moderately sorted grained, wet sand	▒	S				
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439316 Easting: 400520

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX17
SHEET 11 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.7m AHD approx
Bore Number: OX17
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry sand with rootlets	░	S				
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand	░	S				
0.8 1.0	Sand – medium dense, light brown, moderately sorted grained, wet organic sand	▒	S			Water encountered @ 800mm Compact sand	Water encountered @ 800mm
1.8 2.0	Sand – dense, light brown, moderately sorted grained, moist organic sand	▒	S				
2.4 3.0	Clayey sand – dense, very dark brown, fine to medium sorted grained, wet organic	▨	CS				
3.5	Coffee Rock – dense, coffee brown	▩	CR				
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439299 Easting: 400042

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX18
SHEET 12 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX18
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.1	Sand – loose, dry sand with rootlets		S				
1.0 1.2	Sand – loose, grey brown, moderately sorted grained, moist organic sand		S S			Water encountered @ 900mm	Water encountered @ 900mm
2.0 2.2	Sand – medium dense, light brown, moderately sorted grained, wet organic sand		S				
2.8	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
3.0 3.9	Sand – medium dense, light brown, moderately sorted grained, wet organic sand		S				
4.0 5.0	Peaty sand – dense, dark brown to black, moderately sorted grained, wet organic peaty sand		PT				

RIG: Mechanical Auger　　DRILLER:　　LOGGED: JC

TYPE OF BORING:

Northing: 6439153　　Easting: 400312

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX19
SHEET 13 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.6m AHD approx
Bore Number: OX19
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry organic sandy topsoil		S				
0.4	Sand – loose, grey brown, moderately sorted grained, moist organic sand		S			Water encountered @ 700mm	Water encountered @ 700mm
1.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand		S				
1.8 2.0	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
2.2	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
2.8 3.0	Silty sand – dense, dark brown, moderately sorted grained, wet, rich organic peaty sand		PT				
4.0							
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440346 Easting: 401059

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX20
SHEET 14 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.7m AHD approx
Bore Number: OX20
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing Type	Depth	Sample	Notes	Water
	Sand – loose, orange, dry sand	░	S				
0.2 1.0 2.0	Clayey sand – dense, grey orange mottled, fine to medium sorted grained, wet organic	▨	CS			Water encountered @ 600mm	Water encountered @ 600mm
2.2 2.4	Clayey sand – dense, grey, fine to medium sorted grained, wet organic	▨	CS				
3.0	Sand – medium dense, grey brown, moderately sorted grained, wet organic sand	░	S				
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440342 Easting: 400845

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX21
SHEET 15 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.3m AHD approx
Bore Number: OX21
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand– loose, grey brown, sandy topsoil		S				Water depth not recorded
0.2	Sand – loose, grey, dry organic sand		S				
1.0	Sand – medium dense, white, moderately sorted grained, wet organic sand		S				
1.6	Silty sand – dense, dark brown, moderately sorted grained, wet, rich organic peaty sand		PT				
2.0	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
2.5							
3.0	Sand – medium dense, dark brown, moderately sorted grained, wet organic sand		S				
4.0							
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440347 Easting: 400556

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX22
SHEET 16 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX22
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, dry sand	░	S				Water not recorded
0.2	Clayey sand – dense, grey brown mottled, fine to medium sorted grained, wet organic	▨	CS				
1.0							
1.2	Clayey sand – dense, orange, fine to medium sorted grained, wet organic	▨	CS				
2.0							
2.6	Sand – medium dense, grey, moderately sorted grained, wet organic sand	░	S				
3.0							
4.0							
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6439959
Easting: 401050
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX23
SHEET 17 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX23
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.4	Sand – loose, brown orange, moist organic sandy topsoil	░	S				
1.0 2.0 2.2	Sandy clay – dense, grey and light brown mottled, fine to medium sorted grained, moist organic	▨	SC				Water not recorded
3.0 4.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand	▒	S				
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC

TYPE OF BORING:

Northing: 6439975
Easting: 400832

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX24
SHEET 18 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX24
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, dry sand	⋯	S				Water not recorded
0.2	Clayey sand – dense, light brown mottled, fine to medium sorted grained, dry organic	▨	CS				
0.8 1.0	Clayey sand – dense, grey orange mottled, fine to medium sorted grained, moist organic	▨	CS				
2.0	Clay – dense, orange, fine, moist organic	▥	C				
2.2 3.0	Clayey sand – dense, grey light brown mottled, fine to medium sorted grained, wet organic	▨	CS				
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440042 Easting: 400558

REMARKS: Surface level interpolated from contour plan map

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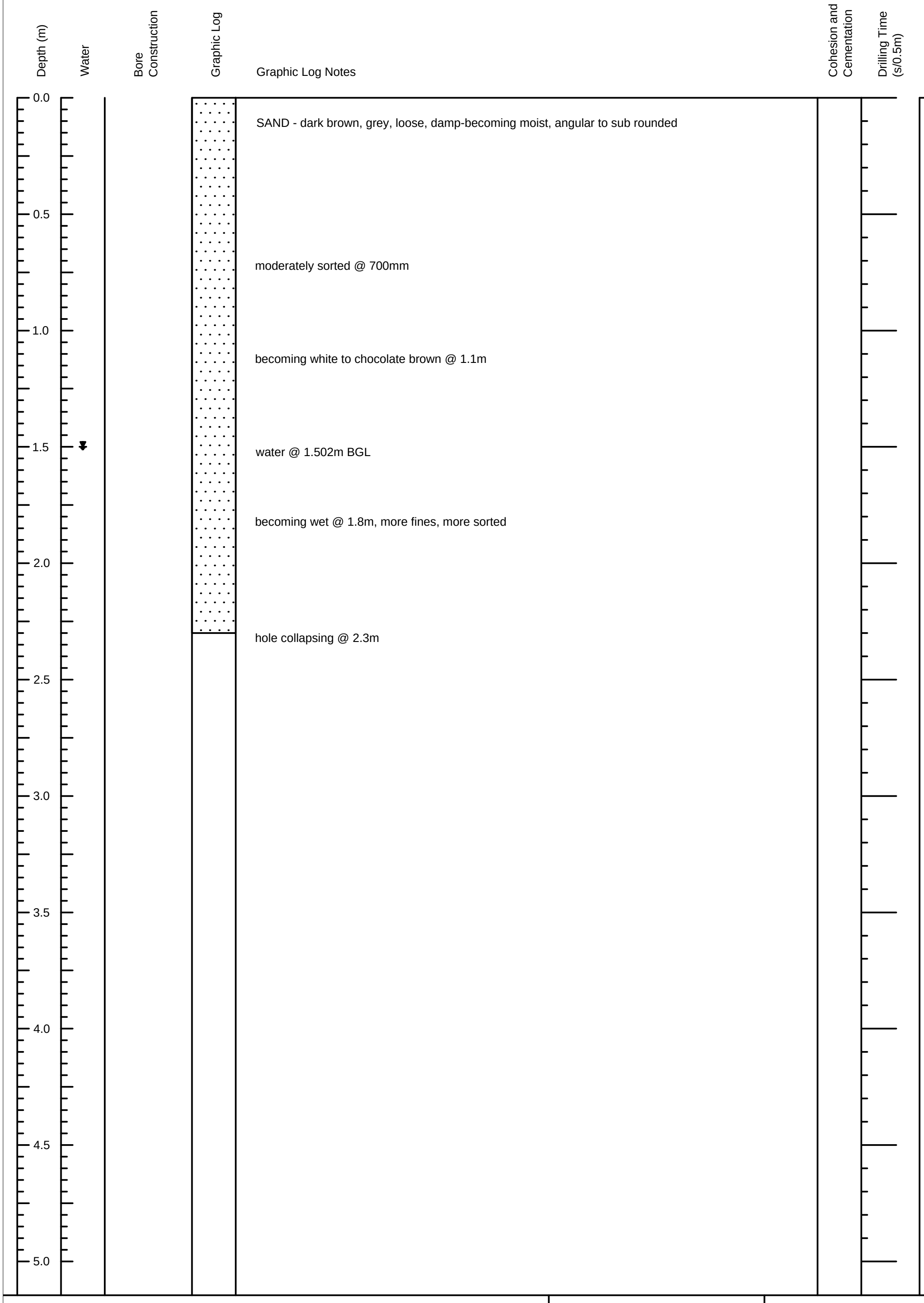
EMAIL: bioscience@biosciencewa.com
WEBSITE: www.biosciencewa.com

ENGINEERING PROFILE LOG

Client: South Forrestdale Industrial Area
Project: Geotechnical Investigation
Location: Lot 12 Rowley Rd, South Forrestdale, Western Australia
Date: 01/04/2015

Hole No. 1
Sheet No. 1 of 4
Logged by: JC

Position: E: 399892   N: 6439760   Surface Elevation: 28 mAHD   Approx.   Rig Type: Hand Auger



Graphic Log Notes

SAND - dark brown, grey, loose, damp-becoming moist, angular to sub rounded

moderately sorted @ 700mm

becoming white to chocolate brown @ 1.1m

water @ 1.502m BGL

becoming wet @ 1.8m, more fines, more sorted

hole collapsing @ 2.3m

Further Testing Notes:
SPT- Standard Penetration Test
PL- Point Load
UCS- Uniaxial Compressive Strength Test
PSP- Perth Sand Penetrometer

Legend: Graphic Log

- ▩ GRAVEL
- ☰ CLAY
- ▨ SANDY CLAY
- ▨ CLAYEY SAND
- ⛆ LOOSE SAND
- ⛆ MEDIUM SAND
- ▨ SILTY SAND

Legend: Bore Construction

- ■ Cement
- ▒ Sand
- ▓ Bentonite
- ▩ Gravel
- ☰ PVC Screen

SOIL CLASSIFICATION & DESCRIPTORS

COURSE GRAINED
BOULDERS: > 200mm
COBBLES: 63-200mm
GRAVELS- GW: Well-graded gravel/sand mix
GP: Poorly-graded gravel/sand mix
GM: Silty gravel/sand/silt mix
GC: Clayey gravel/sand/clay mix
SANDS- SW: Well-graded sand/gravel
SP: Poorly-graded uniform sands
SM: Silty sands
SC: Clayey sands

FINE GRAINED
SILTS & CLAYS (liquid limit <50%)
ML: Inorganic silts and v. fine sands, rock dust
CL, CI: Inorganic clays of low- med plasticity
OL: Organic silts & clays of low plasticity
SILTS & CLAYS (liquid limit >50%)
MH: Inorganic silts of low-med strength
CH: Inorganic clays of high plasticity
OH: Organic clays of med- high plasticity
Pt: Peats & other organic soils

CONSISTENCY TERMS
COHESIVE SOILS

V.soft	≤12kPa
Soft	12-25kPa
Firm	25-50kPa
Stiff	50-100kPa
V.stiff	100-200kPa
Hard	>200kPa

NON-COHESIVE SOILS (density index)

V.loose	≤ 15%
Loose	15-35%
Medium Dense	35-65%
Dense	65-85%
V.dense	>85%

ROCK CLASSIFICATION
CEMENTATION
VWc: v. weakly cemented
Wc: weakly cemented
MWc: mod. weakly cemented
Mc: moderately cemented
Hc: well cemented
VHc: v. well cemented
WEATHERING
RS: residual soil
XW: extremely weathered
HW: highly weathered
MW: moderately weathered
SW: slightly weathered
FR: fresh rock

STRENGTH (Point Load Index)
EL: extremely low- material crumbles under finger pressure
VL: very low - material crumbles under blow from pick & can be easily peeled with knife (<0.1MPa)
L: low - Easily scored with knife. Cores 150x50mm can be easily broken by hand (0.1-0.3MPa)
M: medium - Readily scored with knife. Core 150x50mm can be broken by hand with difficultly (0.3-1MPa)
H: high - Cores 150x50mm cannot be broken by hand but with a single blow from a pick (1-3MPa)
VH: very high - More than 1 blow required to break specimen (3-10MPa)
EH: extremely high - Specimen requires many blows with pick to break (>10MPa)

BIOSCIENCE PTY LTD

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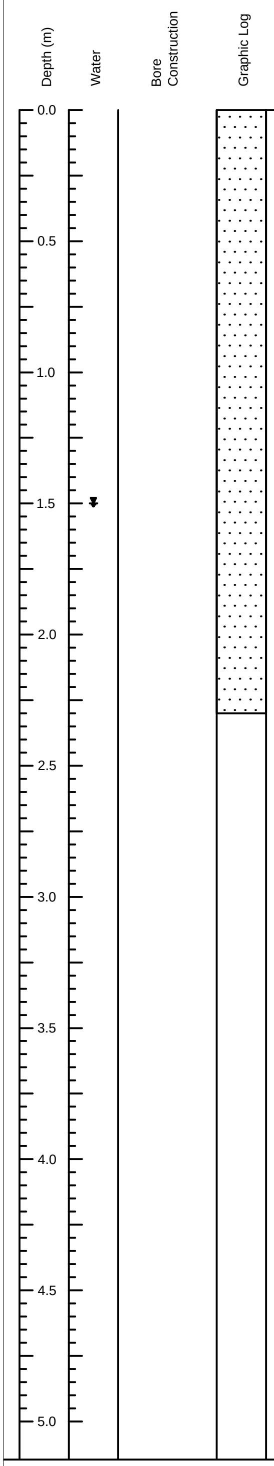
EMAIL: bioscience@biosciencewa.com
WEBSITE: www.biosciencewa.com

ENGINEERING PROFILE LOG

Client: South Forrestdale Industrial Area
Project: Geotechnical Investigation
Location: Lot 12 Rowley Rd, South Forrestdale, Western Australia
Date: 01/04/2015

Hole No. 2
Sheet No. 2 of 4
Logged by: JC

Position: E:399921   N: 6439507   Surface Elevation: 26 mAHD   Approx.   Rig Type: Hand Auger



Graphic Log Notes

SAND - dark brown, loose, damp-becoming moist, angular to sub rounded

becoming light brown @ 1m, light brown, moderately sorted, damp

becoming wet @ 1.4m

more fines @ 1.5m
water @ 1.5m BGL

becoming brown @ 1.8m

hole collapsing @ 2.3m

Cohesion and Cementation

Drilling Time (s/0.5m)

Further Testing Notes:
SPT- Standard Penetration Test
PL- Point Load
UCS- Uniaxial Compressive Strength Test
PSP- Perth Sand Penetrometer

Legend: Graphic Log

- GRAVEL
- CLAY
- SANDY CLAY
- CLAYEY SAND
- LOOSE SAND
- MEDIUM SAND
- SILTY SAND

Legend: Bore Construction

- ■ Cement
- Sand
- Bentonite
- Gravel
- ▤ PVC Screen

SOIL CLASSIFICATION & DESCRIPTORS

COURSE GRAINED
BOULDERS: > 200mm
COBBLES: 63-200mm
GRAVELS- GW: Well-graded gravel/sand mix
GP: Poorly-graded gravel/sand mix
GM: Silty gravel/sand/silt mix
GC: Clayey gravel/sand/clay mix
SANDS- SW: Well-graded sand/gravel
SP: Poorly-graded uniform sands
SM: Silty sands
SC: Clayey sands

FINE GRAINED
SILTS & CLAYS (liquid limit <50%)
ML: Inorganic silts and v. fine sands, rock dust
CL, CI: Inorganic clays of low- med plasticity
OL: Organic silts & clays of low plasticity
SILTS & CLAYS (liquid limit >50%)
MH: Inorganic silts of low-med strength
CH: Inorganic clays of high plasticity
OH: Organic clays of med- high plasticity
Pt: Peats & other organic soils

CONSISTENCY TERMS
COHESIVE SOILS

V.soft	≤12kPa
Soft	12-25kPa
Firm	25-50kPa
Stiff	50-100kPa
V.stiff	100-200kPa
Hard	>200kPa

NON-COHESIVE SOILS (density index)

V.loose	≤ 15%
Loose	15-35%
Medium Dense	35-65%
Dense	65-85%
V.dense	>85%

ROCK CLASSIFICATION

CEMENTATION
VWc: v. weakly cemented
Wc: weakly cemented
MWc: mod. weakly cemented
Mc: moderately cemented
Hc: well cemented
VHc: v. well cemented

WEATHERING
RS: residual soil
XW: extremely weathered
HW: highly weathered
MW: moderately weathered
SW: slightly weathered
FR: fresh rock

STRENGTH (Point Load Index)
EL: extremely low- material crumbles under finger pressure
VL: very low - material crumbles under blow from pick & can be easily peeled with knife (<0.1MPa)
L: low - Easily scored with knife. Cores 150x50mm can be easily broken by hand (0.1-0.3MPa)
M: medium - Readily scored with knife. Core 150x50mm can be broken by hand with difficultly (0.3-1MPa)
H: high - Cores 150x50mm cannot be broken by hand but with a single blow from a pick (1-3MPa)
VH: very high - More than 1 blow required to break specimen (3-10MPa)
EH: extremely high - Specimen requires many blows with pick to break (>10MPa)

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WEBSITE: www.biosciencewa.com

ENGINEERING PROFILE LOG

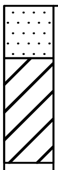
Client: South Forrestdale Industrial Area
Project: Geotechnical Investigation
Location: Lot 5066 Kargotisch Road, South Forrestdale, Western Australia
Date: 01/04/2015

Hole No. 3
Sheet No. 3 of 4
Logged by: JC

Position: E: 401921 N: 6440160 Surface Elevation: 28 mAHD Approx. Rig Type: Hand Auger

Depth (m) | Water | Bore Construction | Graphic Log | Graphic Log Notes | Cohesion and Cementation | Drilling Time (s/0.5m)

Further Testing Notes:
SPT- Standard Penetration Test
PL- Point Load
UCS- Uniaxial Compressive Strength Test
PSP- Perth Sand Penetrometer



Depth (m)	Graphic Log Notes
0.0	SAND - grey, grass covered, loose- medium, fine/silty
	SANDY CLAY - light brown, soft-firm, limey, pebbles
0.5	
	SANDY CLAY - light brown, soft-firm, limey, pebbles, becoming grey/brown, more cohesive, flecks of laterite (weathered), angular-subrounded above, no water table
1.0	
1.5	
2.0	
2.5	
3.0	
3.5	
4.0	
4.5	
5.0	

Legend: Graphic Log

▨	GRAVEL
▤	CLAY
▨	SANDY CLAY
▨	CLAYEY SAND
⁘	LOOSE SAND
⁘	MEDIUM SAND
▨	SILTY SAND

Legend: Bore Construction

■	Cement
⁘	Sand
▩	Bentonite
▨	Gravel
▤	PVC Screen

SOIL CLASSIFICATION & DESCRIPTORS

COURSE GRAINED
BOULDERS: > 200mm
COBBLES: 63-200mm
GRAVELS- GW: Well-graded gravel/sand mix
GP: Poorly-graded gravel/sand mix
GM: Silty gravel/sand/silt mix
GC: Clayey gravel/sand/clay mix
SANDS- SW: Well-graded sand/gravel
SP: Poorly-graded uniform sands
SM: Silty sands
SC: Clayey sands

FINE GRAINED
SILTS & CLAYS (liquid limit <50%)
ML: Inorganic silts and v. fine sands, rock dust
CL, CI: Inorganic clays of low- med plasticity
OL: Organic silts & clays of low plasticity
SILTS & CLAYS (liquid limit >50%)
MH: Inorganic silts of low-med strength
CH: Inorganic clays of high plasticity
OH: Organic clays of med- high plasticity
Pt: Peats & other organic soils

CONSISTENCY TERMS

COHESIVE SOILS

V.soft	≤12kPa
Soft	12-25kPa
Firm	25-50kPa
Stiff	50-100kPa
V.stiff	100-200kPa
Hard	>200kPa

NON-COHESIVE SOILS (density index)

V.loose	≤ 15%
Loose	15-35%
Medium Dense	35-65%
Dense	65-85%
V.dense	>85%

ROCK CLASSIFICATION

CEMENTATION
VWc: v. weakly cemented
Wc: weakly cemented
MWc: mod. weakly cemented
Mc: moderately cemented
Hc: well cemented
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WEATHERING
RS: residual soil
XW: extremely weathered
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STRENGTH (Point Load Index)
EL: extremely low- material crumbles under finger pressure
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VH: very high - More than 1 blow required to break specimen (3-10MPa)
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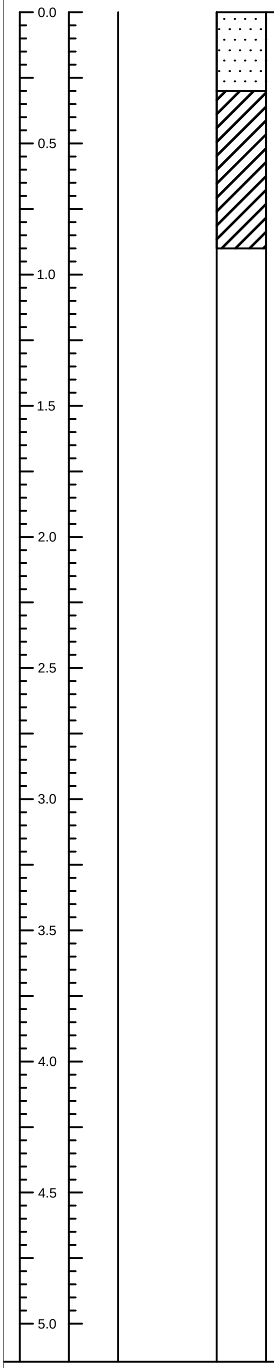
ENGINEERING PROFILE LOG

Client: South Forrestdale Industrial Area
Project: Geotechnical Investigation
Location: Lot 5066 Kargotisch Road, South Forrestdale, Western Australia
Date: 01/04/2015

Hole No. 4
Sheet No. 4 of 4
Logged by: JC

Position: E: 401716 N: 6440334 Surface Elevation: 28 mAHD Approx. Rig Type: Hand Auger

Depth (m) | Water | Bore Construction | Graphic Log | Graphic Log Notes | Cohesion and Cementation | Drilling Time (s/0.5m)



SAND - orange/ light brown, loose, dry, moderately sorted, angular to sub rounded, non-cohesive

CLAYED SAND - orange-brown, soft-firm, becoming more cohesive

SANDY CLAY - orange-brown, soft-firm, becoming more cohesive, no water table

Further Testing Notes:
SPT- Standard Penetration Test
PL- Point Load
UCS- Uniaxial Compressive Strength Test
PSP- Perth Sand Penetrometer

Legend: Graphic Log

▨	GRAVEL
▤	CLAY
▨	SANDY CLAY
▨	CLAYEY SAND
⁙	LOOSE SAND
⁙	MEDIUM SAND
▨	SILTY SAND

Legend: Bore Construction

■	Cement
⁙	Sand
▦	Bentonite
▨	Gravel
▤	PVC Screen

SOIL CLASSIFICATION & DESCRIPTORS

COURSE GRAINED
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V.stiff	100-200kPa
Hard	>200kPa

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Loose	15-35%
Medium Dense	35-65%
Dense	65-85%
V.dense	>85%

ROCK CLASSIFICATION
CEMENTATION

VWc:	v. weakly cemented
Wc:	weakly cemented
MWc:	mod. weakly cemented
Mc:	moderately cemented
Hc:	well cemented
VHc:	v. well cemented

WEATHERING

RS:	residual soil
XW:	extremely weathered
HW:	highly weathered
MW:	moderately weathered
SW:	slightly weathered
FR:	fresh rock

STRENGTH (Point Load Index)

EL:	extremely low- material crumbles under finger pressure
VL:	very low - material crumbles under blow from pick & can be easily peeled with knife (<0.1MPa)
L:	low - Easily scored with knife. Cores 150x50mm can be easily broken by hand (0.1-0.3MPa)
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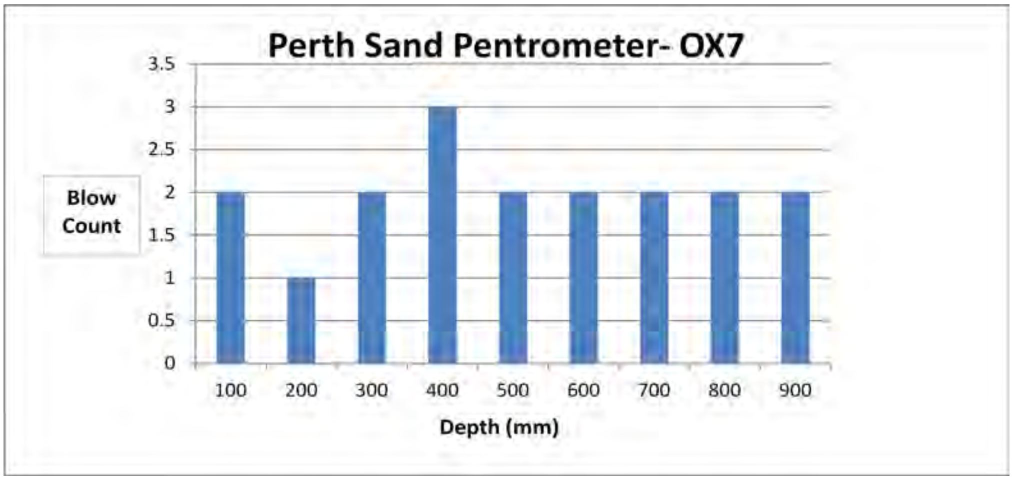
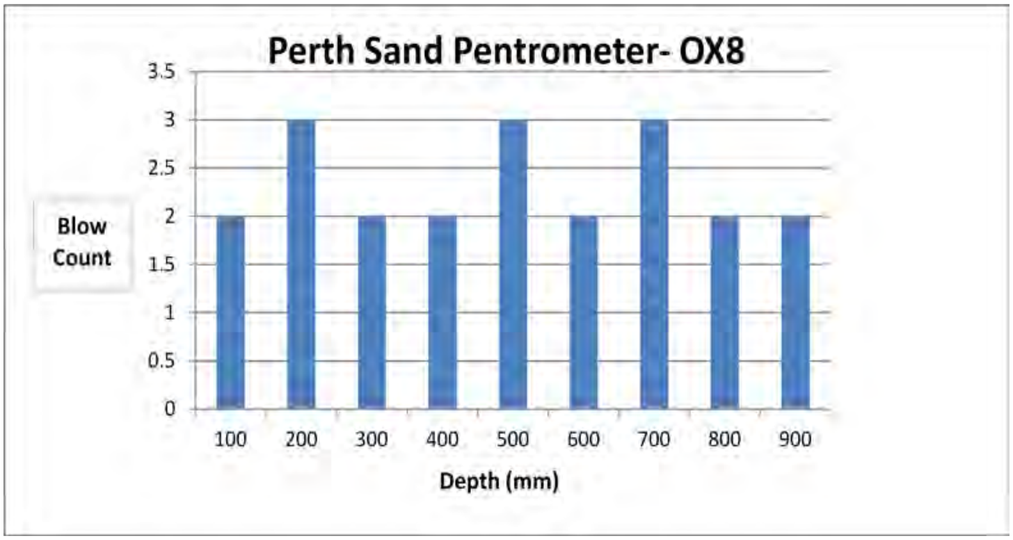
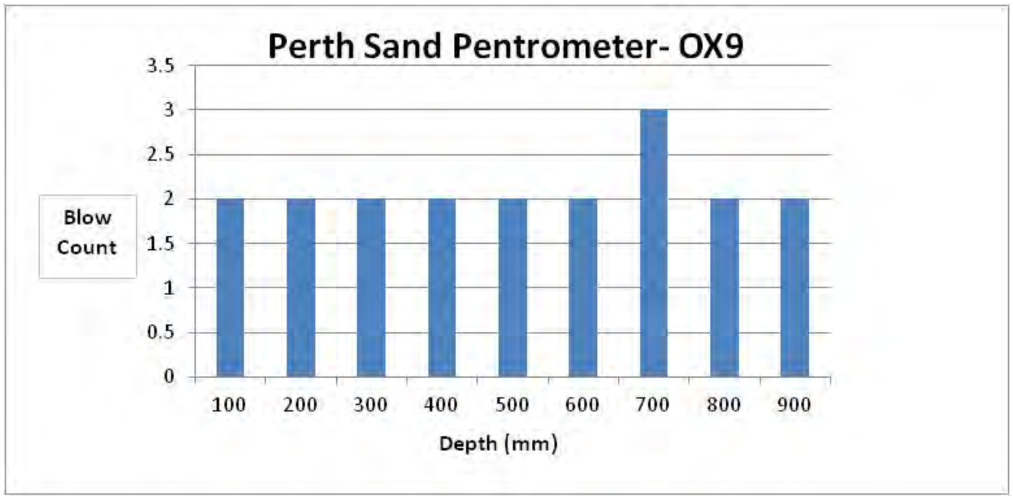
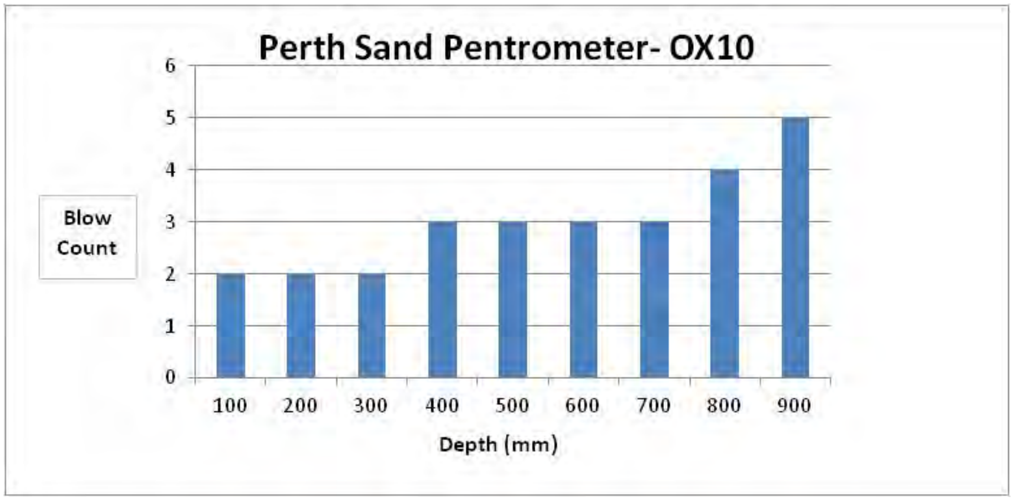
EH:	extremely high - Specimen requires many blows with pick to break (>10MPa)

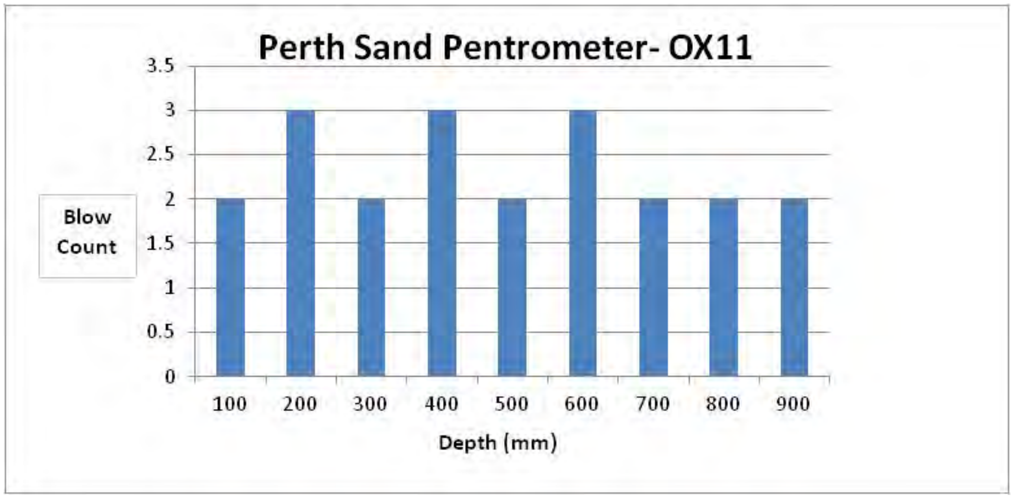
Appendix 2: Perth Sand Penetrometer Results

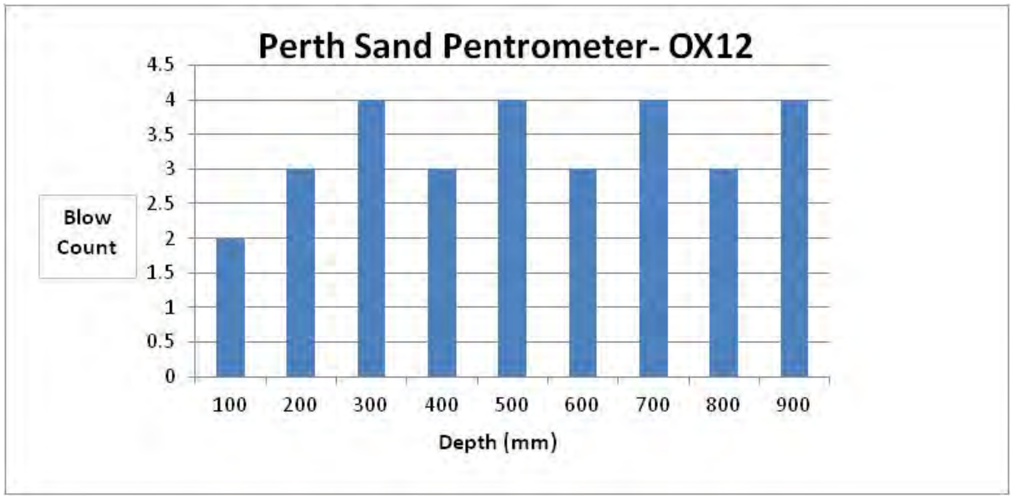


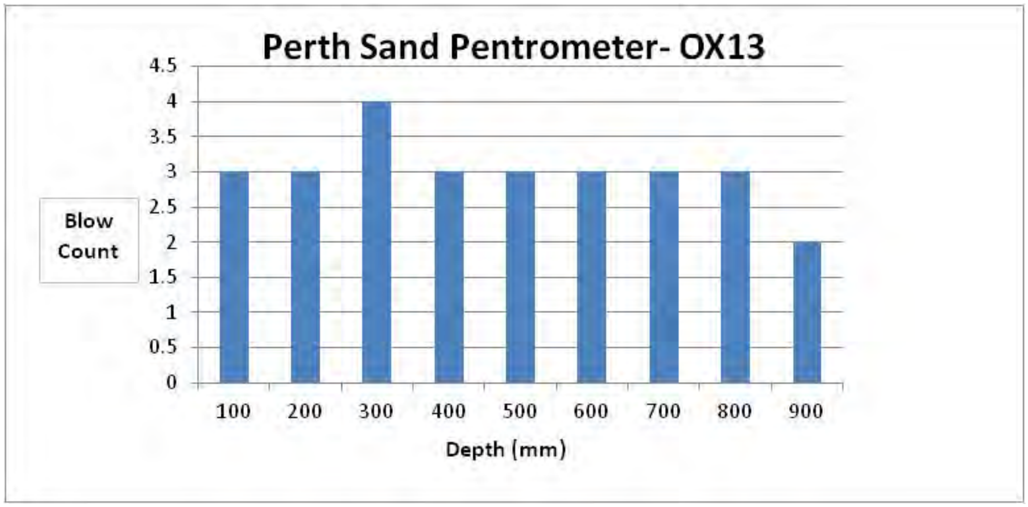


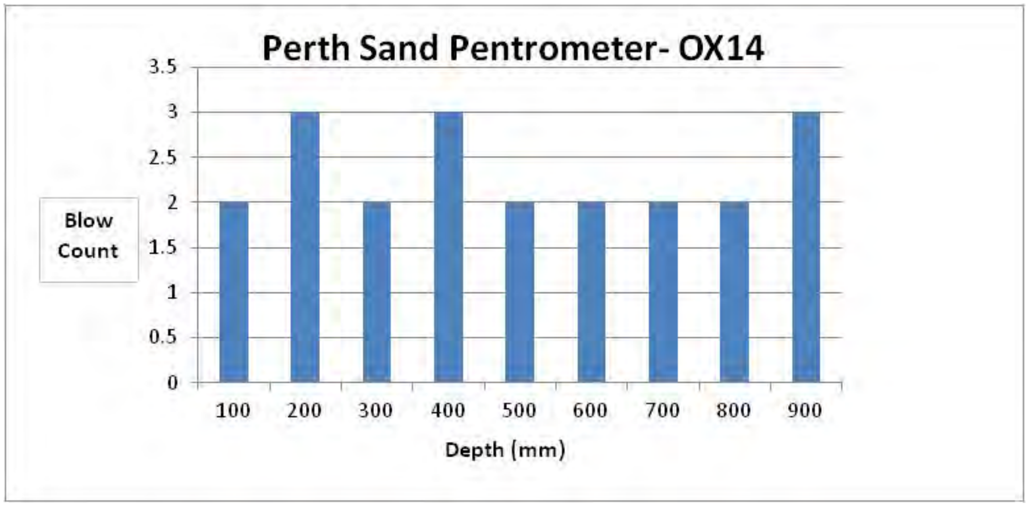


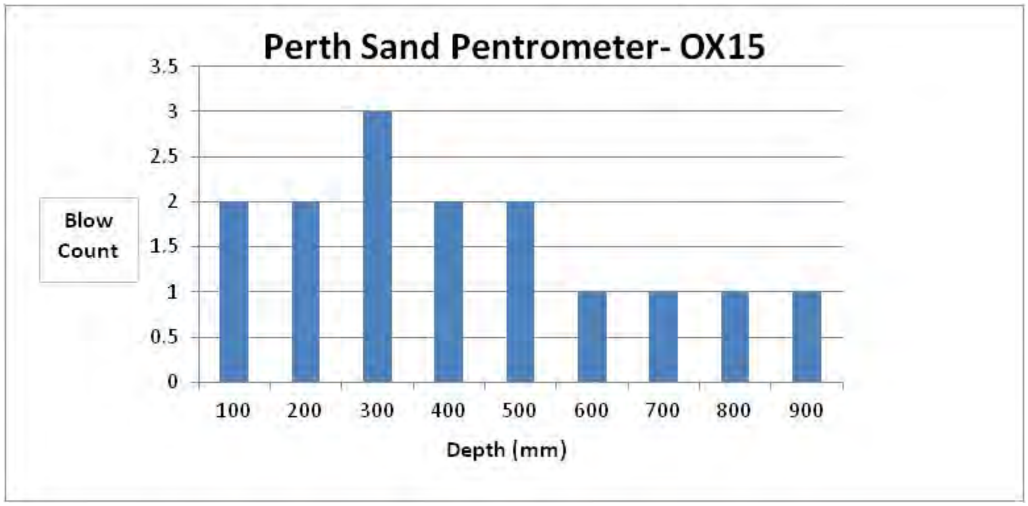

Perth Sand Pentrometer- OX10
Blow Count
0
1
2
3
4
5
6
100
200
300
400
500
600
700
800
900
Depth (mm)

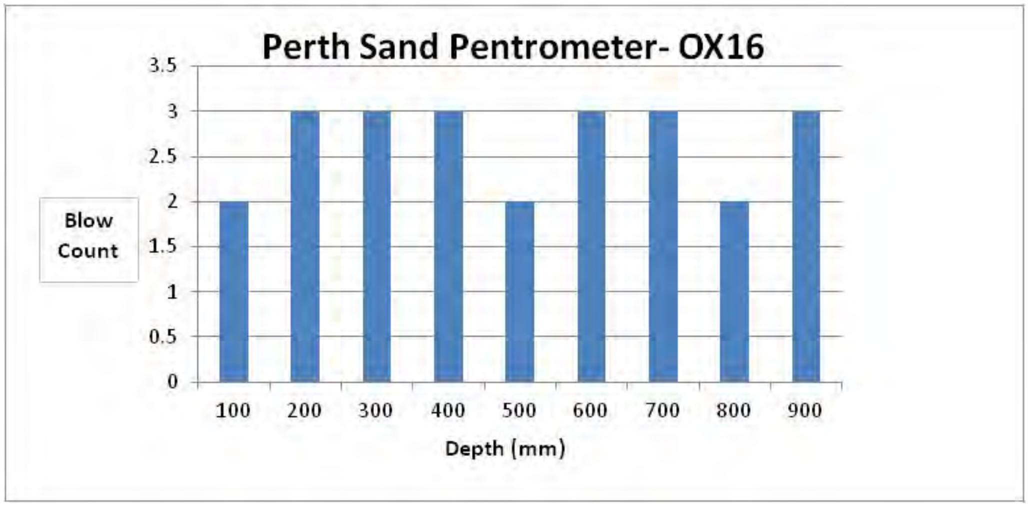

Perth Sand Pentrometer- OX11
Blow Count
0
0.5
1
1.5
2
2.5
3
3.5
100
200
300
400
500
600
700
800
900
Depth (mm)

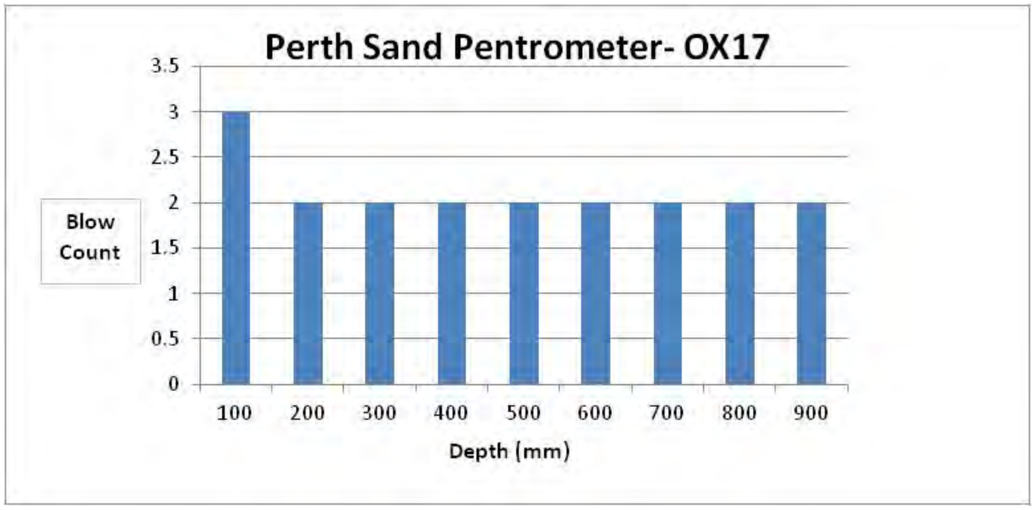

Perth Sand Pentrometer- OX12
Blow Count
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
100
200
300
400
500
600
700
800
900
Depth (mm)

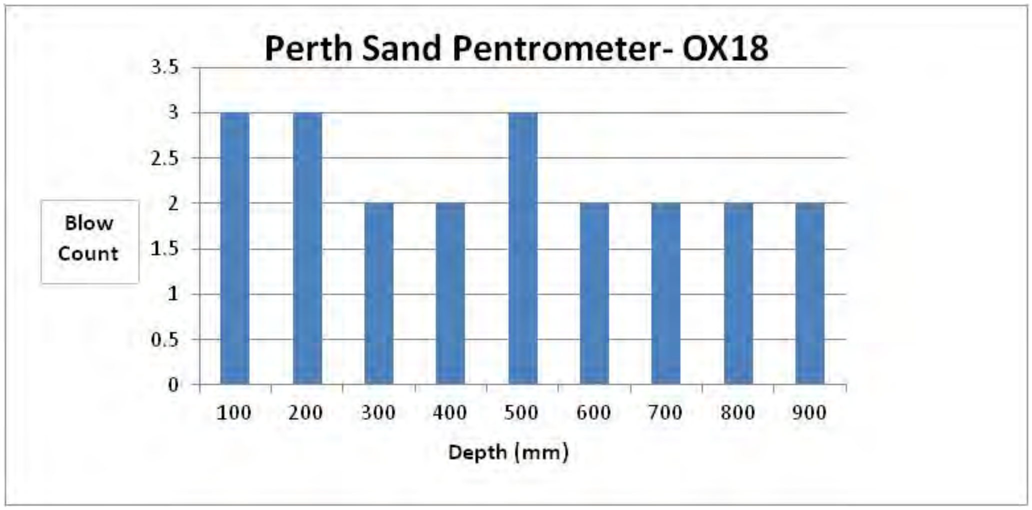

Perth Sand Pentrometer- OX13
Blow Count
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

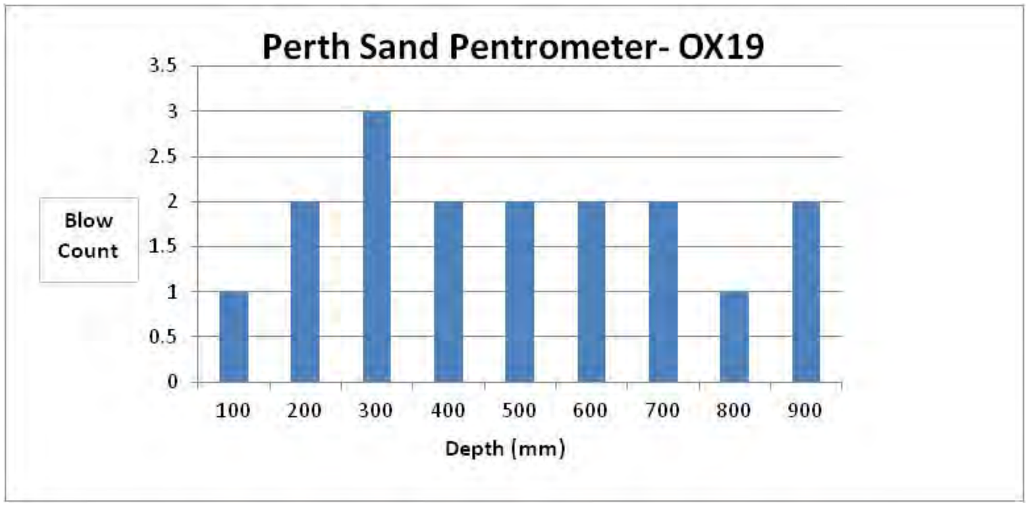

Perth Sand Pentrometer- OX14
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

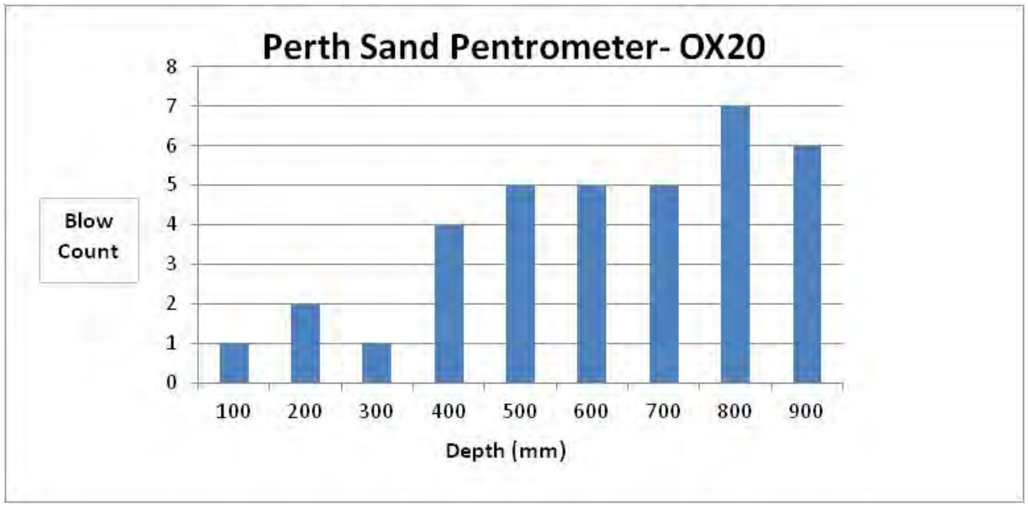

Perth Sand Pentrometer- OX15
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

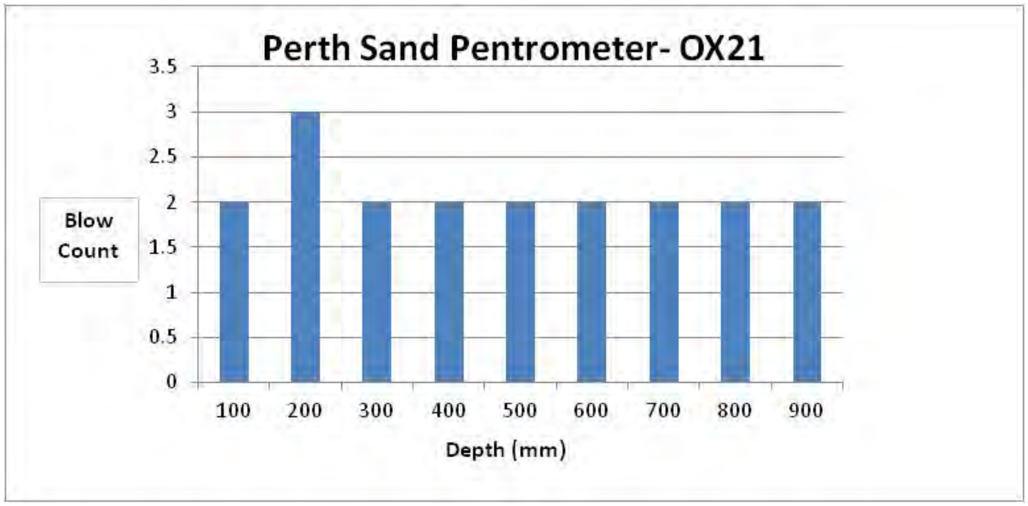

Perth Sand Pentrometer- OX16
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

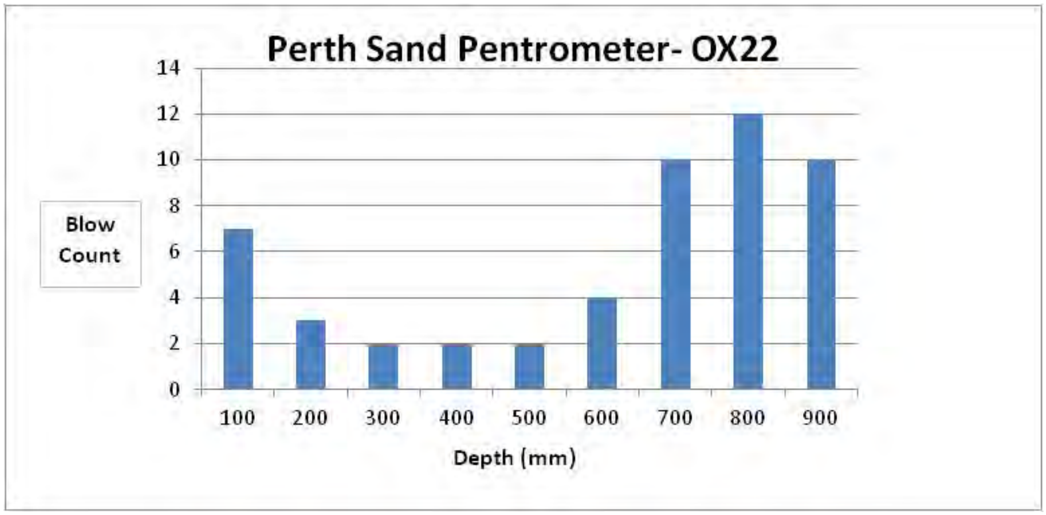

Perth Sand Pentrometer- OX17
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

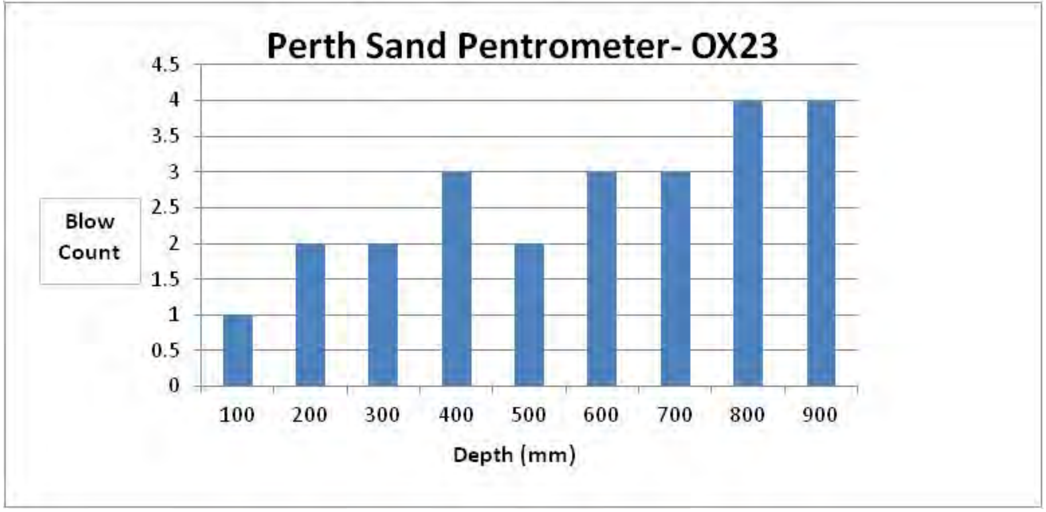

Perth Sand Pentrometer- OX18
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)

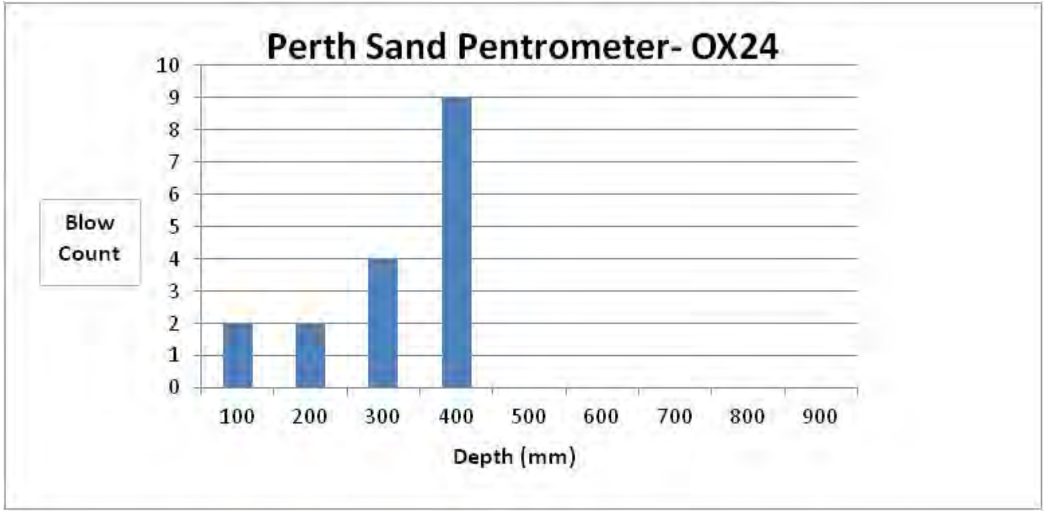

Perth Sand Pentrometer- OX19
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)


Perth Sand Pentrometer- OX20
Blow Count
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
Depth (mm)


Perth Sand Pentrometer- OX21
Blow Count
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)


Perth Sand Pentrometer- OX22
Blow Count
14
12
10
8
6
4
2
0
100
200
300
400
500
600
700
800
900
Depth (mm)


Perth Sand Pentrometer- OX23
Blow Count
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
100
200
300
400
500
600
700
800
900
Depth (mm)


Perth Sand Pentrometer- OX24
Blow Count
10
9
8
7
6
5
4
3
2
1
0
100
200
300
400
500
600
700
800
900
Depth (mm)

Appendix D: Maximum Groundwater Levels (WIN Bores)

3104		3103		3115		3117		12781400		4343		4674		4675		4781	
1975	25.414	1975	24.39	1975	26.696	1976	26.01	1996	23.31	1976	23.377	1975	25.82	1975	26.63	1975	25.07
1976	25.234	1976	23.9	1976	26.686	1977	26.44	1997	23.23	1977	23.547	1976	25.42	1976	26.4	1976	24.46
1977	25.024	1977	23.65	1977	26.366	1978	26.64	1998	23.59	1978	24.067	1977	25.46	1977	26.18	1977	24.24
1978	25.704	1978	24.25	1978	26.666	1979	26.24	1999	23.21	1979	23.617	1978	26.27	1978	26.73	1978	24.6
1979	24.674	1979	23.77	1979	26.296	1980	27.01	2000	23.37	1980	23.827	1979	25.4	1979	26.23	1979	24
1980	25.134	1980	24.11	1980	26.656	1981	26.64	2001	23.15	1981	24.007	1980	25.91	1980	26.46	1980	24.2
1981	25.494	1981	24.27	1981	26.686	1982	26.59	2002	23.28	1982	23.997	1981	26.04	1981	26.5	1981	23.49
1982	25.014	1982	24.33	1982	26.436	1983	26.71	2003	23.3	1983	24.047	1982	26.21	1982	26.73	1982	24.45
1983	24.944	1983	24.62	1983	26.636	1984	26.74	2004	23.26	1984	23.987	1983	24.5	1983	26.63	1983	24.71
1984	25.024	1984	24.46	1984	26.826	1985	26.39	2005	23.26	1985	23.777	1984	25.784	1984	26.52	1984	24.78
1985	24.934	1985	24.144	1985	26.536	1986	26.43	2006	22.94	1986	23.867	1985	25.894	1985	26.33	1985	24.7
1986	25.389	1986	24.124	1986	26.546	1987	26.27	2007	23.17	1987	23.707	1986	26.224	1986	26.57	1986	24.92
1987	24.794	1987	23.924	1987	26.436	1988	26.53	2008	23.19	1988	23.927	1987	25.384	1987	26.4	1987	24.76
1988	25.004	1988	24.164	1988	26.606	1989	26.2	2009	23.16	1989	23.737	1988	25.714	1988	26.69	1988	25.01
1989	24.924	1989	23.894	1989	26.436	1990	25.92	2010	22.96	1990	23.257	1989	25.344	1989	26.25	1989	24.85
1990	24.564	1990	23.474	1990	26.106	1991	26.4	2011	23.22	1991	23.647	1990	24.794	1990	26.08	1990	24.72
1991	25.904	1991	24.174	1991	26.426	1992	26.36	2012	22.93	1992	23.737	1991	25.904	1991	26.62	1991	25.08
1992	25.784	1992	24.414	1992	26.326	1993	26.03	2013	23.2	1993	23.537	1992	26.464	1992	26.91	1992	25.29
1993	24.824	1993	23.734	1993	26.216	1994	25.81	2014	23.119	1994	23.437	1993	25.084	1993	26.31	1993	24.84
1994	24.224	1994	23.654	1994	26.166	1995	25.81	2015	22.969	1995	23.277	1994	25.344	1994	26.33	1994	24.79
1995	24.637	1995	23.464	1995	25.726	1996	26.14			1996	23.617	1995	25.14	1995	26.2	1995	24.64
1996	24.797	1996	23.834	1996	26.066	1997	25.49	AAMGL	23.1909	1997	23.017	1996	26.2	1996	26.56	1996	24.92
1997	24.467	1997	23.304	1997	25.756	1998	24.84			1998	22.737	1997	24.84	1997	26.24	1997	24.52
1998	24.197	1998	23.034	1998	25.656	1999	24.85			1999	22.897	1998	24.12	1998	25.96	1998	24.08
1999	24.567	1999	23.084	1999	25.746	2000	25.66			2000	23.047	1999	25.88	1999	26.08	1999	24.68
2000	24.947	2000	23.714	2000	25.656	2001	25.04			2001	22.837	2000	26.11	2000	26.34	2000	24.86
2001	24.177	2001	23.114	2001	24.846	2002	24.38			2002	22.447	2001	25.89	2001	26.05	2001	24.43
2002	24.097	2002	22.734	2002	24.806	2003	24.91			2003	23.137	2002	25.58	2002	25.99	2002	24.34
2003	24.487	2003	23.524	2003	25.336	2004	24.77			2004	22.337	2003	26.03	2003	26.14	2003	24.67
2004	24.197	2004	23.124	2004	24.236	2005	24.5			2005	23.427	2004	25.83	2004	25.97	2004	24.37
2005	24.457	2005	23.714	2005	25.146	2006	24.41			2006	21.597	2005	26.24	2005	26.37	2005	24.81
2006	23.057	2006	22.464	2006	22.276	2007	23.36			2007	21.807	2006	25.61	2006	25.72	2006	24.29
2007	23.117	2007	22.344	2007	23.246	2008	23.63			2008	22.127	2007	25.64	2007	25.8	2007	24.17
2008	23.867	2008	23.034	2008	23.446	2009	23.54			2009	22.907	2008	25.95	2008	25.99	2008	24.58
2009	24.267	2009	22.924	2009	23.426	2010	22.76			2010	20.537	2009	25.82	2009	25.965	2009	24.41
2010	22.657	2010	21.634	2010	21.216	2011	22.57			2011	21.937	2010	25.22	2010	25.37	2010	24
2011	23.857	2011	22.574	2011	22.696	2012	22.38			2012	21.527	2011	25.68	2011	25.89	2011	24.31
2012	23.457	2012	22.144	2012	22.546	2013	22.13			2013	22.05	2012	25.44	2012	25.54	2012	24.01
2013	23.795	2013	22.564	2013	22.806	2014	22.12			2014	22.05	2013	25.757	2013	25.923	2013	24.143
2014	23.705	2014	22.554	2014	22.616	2015	21.46			2015	21.15	2014	26.087	2014	26.143	2014	24.123
2015	22.505	2015	21.494	2015	20.876							2015	25.547	2015	25.913	2015	23.653
										AAMGL	23.039225						
AAMGL	24.519902			AAMGL	25.21649	AAMGL	25.15275							AAMGL	26.235463	AAMGL	24.51144
		AAMGL	23.459122									AAMGL	25.648171				

4782		4910		4676		4678		4783		4785		4879		3083		3086	
1975	24.47	1975	24.259	1975	26.2	1975	25.97	1979	25.96	1975	25.18	1975	22.85	1975	24.21	1984	26.559
1976	24.45	1976	24.259	1976	25.79	1976	25.79	1980	25.92	1976	25.33	1976	22.6	1976	23.86	1985	26.109
1977	24.29	1977	24.069	1977	25.63	1977	25.59	1981	26.1	1977	24.98	1977	22.63	1977	23.58	1986	26.309
1978	24.6	1978	24.169	1978	26.22	1978	26.33	1982	25.44	1978	25.56	1978	22.47	1978	24.13	1987	26.089
1979	24.29	1979	24.069	1979	25.87	1979	25.93	1983	26.47	1979	25.12	1979	22.65	1979	23.32	1988	26.289
1980	24.59	1980	24.549	1980	25.83	1980	26.1	1984	26.21	1980	25.47	1980	22.84	1981	24.11	1989	26.089
1981	24.78	1981	24.719	1981	25.76	1981	26.23	1985	26.89	1981	25.57	1981	21.91	1982	24.46	1990	25.909
1982	24.7	1982	24.309	1982	25.46	1982	26.02	1986	26.34	1982	25.47	1982	21.79	1983	24.6	1991	26.219
1983	24.79	1983	24.469	1983	25.62	1983	26.22	1987	26.1	1983	25.7	1983	21.87	1984	24.51	1992	26.769
1984	24.81	1984	23.279	1984	25.63	1984	26.14	1988	25.21	1984	25.56	1984	21.09	1985	24.3	1993	26.119
1985	24.66	1985	24.459	1985	25.41	1985	26.22	1989	25.91	1985	25.46	1985	21.86	1986	24.55	1994	25.999
1992	24.884	1986	24.509	1986	25.54	1986	26.92	1990	25.61	1986	25.55	1986	21.94	1987	24.21	1995	25.809
1993	23.964	1987	24.209	1987	25.82	1987	26.74	1991	26.15	1987	25.26	1987	21.8	1988	24.12	1996	25.959
1996	24.704	1988	24.489	1988	25.73	1988	26.65	1992	26.28	1988	25.415	1988	21.93	1989	23.92	1997	25.659
1997	24.464	1989	23.969	1989	25.41	1989	25.86	1993	25.98	1989	25.11	1989	22.08	1990	23.78	1998	25.209
1998	24.364	1990	23.619	1990	25.34	1991		1994	26.11	1990	25.02	1990	21.279	1991	24.38	1999	25.429
1999	24.354	1991	24.309	1991	25.5	1992	26.72	1995	25.92	1991	25.34	1991	21.569	1992	24.82	2000	25.809
2000	24.694	1992	24.184	1992	25.51	1993	26.19	1996	26.2	1992	25.51	1992	21.549	1993	24.08	2001	25.439
2001	24.404	1993	23.939	1993	25.32	1994	26.32	1997	25.82	1993	25.28	1993	21.489	1994	23.89	2002	25.029
2002	24.284	1994	23.699	1994	25.45	1995	26.15	1998	25.78	1994	25.45	1994	21.409	1995	23.89	2003	25.469
2003	24.484	1995	23.409	1995	25.28	1996	26.41	1999	25.88	1995	25.16	1995	21.279	1996	24.15	2004	25.289
2004	24.804	1996	23.859	1996	25.39	1997	26.13	2000	26.4	1996	25.25	1996	21.439	1997	23.78	2005	25.719
2005	24.984	1997	23.519	1997	25.02	1998	25.93	2001	25.95	1997	25.03	1997	20.729	1998	23.47	2006	25.249
2006	24.644	1998	23.539	1998	24.75	1999	26.22	2002	25.91	1998	24.92	1998	21.079	1999	23.49	2007	25.099
2007	24.674	1999	23.799	1999	24.96	2000	26.55	2003	26.13	1999	25.01	1999	21.339	2000	23.99	2008	25.399
2008	24.684	2000	23.669	2000	25.36	2001	26.14	2004	25.88	2000	25.23	2000	21.339	2001	23.37	2009	25.369
2009	24.854	2001	23.449	2001	25.14	2002	26	2005	26.22	2001	24.97	2001	21.009	2002	22.8	2010	24.769
2010	24.484	2002	22.989	2002	24.97	2003	26.34	2006	25.68	2002	24.79	2002	21.139	2003	23.71	2011	25.139
2011	24.724	2003	23.789	2003	25.37	2004	26.13	2007	25.59	2003	25.25	2003	21.299	2004	23.53	2012	25.079
2012	24.524	2004	23.179	2004	25.11	2005	26.46	2008	25.82	2004	25.13	2004	20.819	2005	23.85	2013	25.259
2013	24.774	AAMGL	23.9578333	2005	25.77	2006	25.78	2009	25.775	2005	24.98	2005	21.419	2006	22.63	2014	25.229
2014	24.854			2006	24.59	2007	25.83	2010	25.26	2006	24.38	2006	20.509	2007	22.36	2015	24.669
2015	24.624			2007	24.69	2008	26.43	2011	25.71	2007	24.7	2007	21.009	2008	23.02		
				2008	24.82	2009	26.29	2012	25.655	2008	24.9	2008	21.089	2009	22.66	AAMGL	25.64181
AAMGL	24.595697			2009	24.99	2010	25.84	2013	26.19	2009	24.78	2009	21.109	2010	21.69		
				2010	24.66			2014	26.37	2010	24.81	2010	20.309	2011	22.3		
				2011	24.77	AAMGL	26.19324	2015	26.16	2011	25.087	2011	21.069	2012	21.85		
				2012	24.83					2012	25.022	2012	20.809	2013	22.31		
				2013	25.148			AAMGL	25.97243	2013	25.167	2013	21.289	2014	22.11		
				2014	24.898					2014	25.147			2015	21.35		
				2015	25.048					2015	24.937	AAMGL	21.53041				
														AAMGL	23.5285		
				AAMGL	25.3318					AAMGL	25.17036585						

3209	
1973	24.606
1974	24.922
1975	24.756
1976	24.726
1977	24.306
1978	24.506
1979	24.716
1980	24.866
1981	24.676
1982	24.626
1983	24.476
1984	24.526
1985	24.456
1986	24.456
1987	24.466
1988	24.376
1989	24.316
1990	24.356
1991	24.426
1992	24.626
1993	24.326
1994	24.776
AAMGL	24.558545

3210	
1973	26.04
1976	25.82
1977	25.73
1978	25.748
1979	25.868
1980	25.988
1981	26.088
1982	26.068
1983	26.168
AAMGL	25.9464444

3212	
1984	26.425
1985	26.185
1986	26.505
1987	26.255
1988	26.615
1989	26.305
1990	25.685
1991	26.415
1992	26.815
1993	26.225
1994	26.365
1995	26.215
1996	26.745
1997	25.985
1998	25.375
1999	26.025
2000	26.515
2001	26.085
2002	26.135
2003	26.245
2004	26.095
2005	26.475
2006	25.205
2007	25.385
2008	25.785
2009	25.975
2010	24.855
2011	25.275
2012	25.055
2013	25.715
2014	25.975
2015	26.035
AAMGL	26.02969

4575	
1982	26.339
1983	26.826
1984	26.97
1985	26.59
1986	26.908
1987	26.578
1988	26.808
1989	26.508
1990	25.858
1991	26.608
1992	26.948
1993	26.478
1994	26.618
1995	25.988
1996	26.188
1997	25.548
1998	25.038
1999	25.268
2000	25.678
2001	25.468
2002	24.938
2003	25.538
2004	25.318
2005	26.058
2006	25.398
2007	25.178
2008	25.848
2009	25.698
2010	25.068
2011	25.628
2012	25.548
2013	25.808
2014	25.948
2015	25.448
AAMGL	25.95985

4586	
1975	27.38
1976	27.17
1977	26.95
1978	27.51
1979	27.07
1980	27.18
1981	27.16
1982	27.3
1983	27.45
1984	27.56
1985	27.28
1986	27.51
1987	27.35
1988	27.49
1989	27.19
1990	26.76
1991	27.08
1992	27.45
1993	27.24
1994	27.28
1995	27
1996	27.28
1997	26.82
1998	26.51
1999	26.7
2000	27.09
2001	26.79
2002	26.61
2003	26.85
2004	26.7
2005	27.15
2006	26.48
2007	26.37
2008	26.85
2009	26.79
2010	26.17
2011	26.47
2012	26.15
2013	26.68
2014	26.84
2015	26.43
AAMGL	26.9778

WIN Site	Easting	Northing	Period	AAMGL
3103	397898	6437450	1975-2015	**23.46**
3104	397847	6439081	1975-2015	**24.52**
3115	403197	6436042	1975-2015	**25.22**
3117	403669	6439093	1976-2015	**25.15**
4343	398401	6439411	1976-2015	**23.04**
4674	396886	6440903	1975-2015	**25.65**
4675	396862	6442071	1975-2015	**26.24**
4781	398491	6440451	1975-2015	**24.51**
4782	398352	6442020	1975-2015	**24.60**
4910	402761	6442759	1975-2004	**23.96**
12781400	399919	6442341	1996-2015	**23.19**
23023904*	400945	6440811	2007-2008	**23.35**
4676	396909	6443397	1975-2016	**25.33**
4678	397523	6444745	1975-2010	**26.19**
4783	398114	6444096	1979-2015	**25.97**
4785	398736	6445295	1975-2015	**25.17**
4879	402225	6445829	1975-2013	**21.53**
3083	395320	6437658	1975-2015	**23.53**
3086	395292	6439057	1984-2015	**25.64**
3209	394609	6440409	1973-1994	**24.56**
3210	395209	6442416	1973-1983	**25.95**
3212	395209	6442439	1984-2015	**26.03**
4575	396059	6440580	1982-2015	**25.96**
4586	395200	6443765	1975-2015	**26.98**

Appendix E: Groundwater Bore Logs

Appendix 1: Soil Profile Logs

Bioscience

BORE COMPLETION LOG

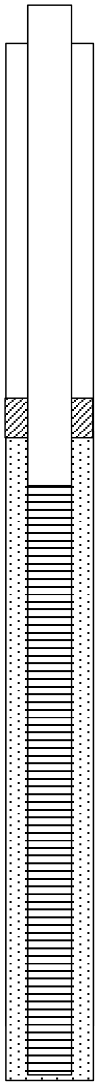
BORE NO.
OX1
SHEET 1 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0	Dark Grey Sand	SP	
	Light Brown Loamy Sand to Sandy Clay	SC	
1 2	White Gravelly Clay	GC	
	Orange Brown Sandy Clay	SC	▽ 16/08/2012
3	Orange Clayey Sand	SC	
4 5	No Sample		

Completion



Details

GENERAL INFORMATION
Easting: 401553mE
Northing: 6440108mN
Top of casing: 0.5mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.25mBGL
Diameter: 100mm

CASING
From: 0 to: 5.25 mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.25 to: 5.25 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.80 mBGL
Seal type: Benonite
From: 1.80 to: 2.00 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 2.00 to: 5.25 mBGL

FIELD WATER QUALITY
pH: 7.04
Conductivity:1112 $\mu S.cm^{-1}$

Notes:

Bioscience

BORE COMPLETION LOG

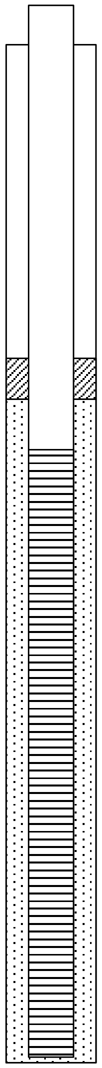
BORE NO.
OX2
SHEET 2 OF 24

Client: Toby ....
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0			
	Dark Grey Sand	SP	
1	White and Orange Clayey Sand	SC	
2	Orange Brown Clayey Sand	SC	
	Orange Brown Clay	CL	◁16/08/2012
3	Orange Clayey Sand	SC	
4	Grey Sand	SP	
5			

Completion



Details

GENERAL INFORMATION
Easting: 401357mE
Northing: 6439968mN
Top of casing: 0.60mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.00mBGL
Diameter: 100mm

CASING
From: 0 to: 5.00mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.00 to: 5.00 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.50 mBGL
Seal type: Benonite
From: 1.50 to: 1.75 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 1.75 to: 5.00mBGL

FIELD WATER QUALITY
pH: 7.25
Conductivity: 1733 $\mu S.cm^{-1}$

Notes:

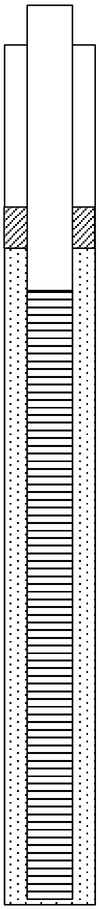
Bioscience

BORE COMPLETION LOG

BORE NO.
OX3
SHEET 3 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 07/08/2012
Date Completed: 07/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL	Completion	Details
0 1 2 3 4 5	Grey Sand	SP	▽ 16/08/2012		GENERAL INFORMATION Easting: 401564mE Northing: 6440489mN Top of casing:0.59 mAGL DRILLING PROTOCOL Driller: Edge Drilling Rig type: Auger Depth: 4.20mBGL Diameter: 100mm CASING From: 0 to: 4.20mBGL Material: PVC Diameter: 50mm Protective casing : Steel Lockable Cover SCREEN From: 1.20 to: 4.20 mBGL Screen type: Slotted PVC Diameter: 50mm ANNULAR FILL Surface seal: Concrete Annular backfill type: Drill Cuttings From: 0.20 to: 0.80 mBGL Seal type: Benonite From: 0.80 to: 1.00 mBGL Pack type/size: Gravel 1.6-3.2mm From: 1.00 to: 4.20 mBGL FIELD WATER QUALITY pH: 6.36 Conductivity: 1341 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

BORE NO.
OX4
SHEET 4 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

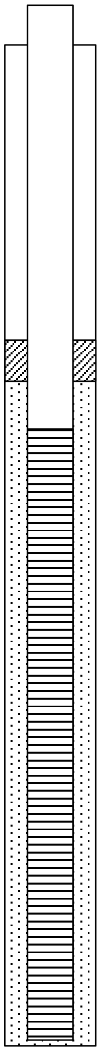
Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Lithological Description	Log
Brown Sand	SP
Grey Sand	SP
Grey Clayey Sand	SC
Light Brown Clayey Sand	SC
Black Clayey Sand	SC
No Sample	

WL: ▽ 16/08/2012

Scale: 0, 1, 2, 3, 4, 5

Completion



Details

GENERAL INFORMATION
Easting: 401325mE
Northing: 6440289mN
Top of casing: 0.60mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 4.90mBGL
Diameter: 100mm

CASING
From: 0 to: 4.90mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 1.90 to: 4.90 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 1.50 mBGL
Seal type: Benonite
From: 1.50 to: 1.70 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 1.70 to: 4.90 mBGL

FIELD WATER QUALITY
pH: 6.06
Conductivity: 2482 $\mu S.cm^{-1}$

Notes:

Bioscience

BORE COMPLETION LOG

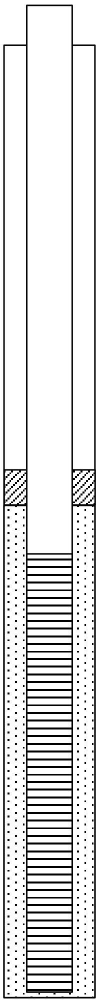
BORE NO.
OX5
SHEET 5 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0			∇ 16/08/2012
1	Grey Brown Sand	SP	
	Grey Sand	SC	
2	No Sample		
3	Brown Silty Sand	SM	
4	No Sample		
5			
6			
7			

Completion



Details

GENERAL INFORMATION
Easting: 401073mE
Northing: 6440484mN
Top of casing: 0.66mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 6.15mBGL
Diameter: 100mm

CASING
From: 0 to: 6.15mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 3.15 to: 6.15 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 2.80 mBGL
Seal type: Benonite
From: 2.80 to: 3.00 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 3.00 to: 6.15 mBGL

FIELD WATER QUALITY
pH: 4.76
Conductivity: 2820 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

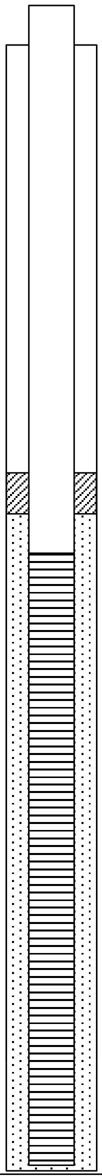
BORE NO.
OX6
SHEET 6 OF 24

Client: Toby ……..
Project: South Forrestdale Industrial Land Area
Bore Location: Lot 596 Oxley Road

Date Commenced: 08/08/2012
Date Completed: 08/08/2012
Recorded By: R. Bromfield

Scale	Lithological Description	Log	WL
0	Black Sand	SP	
	Grey Sand	SP	
1	Light Brown Sandy Clay	SC	
2	Orange Brown Clay	CL	▽ 16/08/2012
	Orange Brown Sandy Clay	SC	
3			
4			
5	No Sample		

Completion



Details

GENERAL INFORMATION
Easting: 401088mE
Northing: 64440044mN
Top of casing: 0.62mAGL

DRILLING PROTOCOL
Driller: Edge Drilling
Rig type: Auger
Depth: 5.50mBGL
Diameter: 100mm

CASING
From: 0 to: 5.50mBGL
Material: PVC
Diameter: 50mm
Protective casing : Steel Lockable Cover

SCREEN
From: 2.50 to: 5.50 mBGL
Screen type: Slotted PVC
Diameter: 50mm

ANNULAR FILL
Surface seal: Concrete
Annular backfill type: Drill Cuttings
From: 0.20 to: 2.10 mBGL
Seal type: Benonite
From: 2.10 to: 2.30 mBGL
Pack type/size: Gravel 1.6-3.2mm
From: 2.30 to: 5.50 mBGL

FIELD WATER QUALITY
pH: 6.56
Conductivity: 20300 μS.cm^{-1}

Notes:

Bioscience

BORE COMPLETION LOG

BORE NO.
OX7
SHEET 1 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX7
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – Loose topsoil, dark brown	░	SW				
1.0	Sand – loose to medium dense, brown/ grey, moderately sorted grained, dry sand	░	S				
1.4	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S			Water encountered @ 1400mm	Water encountered @ 1400mm
2.0	Sandy Silt – medium dense, brown, fine grained, wet	▒	SM				
2.25	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S				
3.0							
4.0							
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440474
Easting: 400515
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX8
SHEET 2 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 25m AHD approx
Bore Number: OX8
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
1.0	Sand – loose, brown/ grey, moderately sorted grained, dry sand with rootlets in top 200mm		S				Water not encountered
2.0	Sand – Loose to medium dense, light brown, fine to medium grained, wet sand		S				
2.25	Sand – medium dense, white/ grey, moderately sorted grained, wet sand		S				
2.75							
3.0							
4.0							
5.0						Water not encountered @ 5000mm	

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440450
Easting: 400010
REMARKS: Surface level interpolated from contour plan map. Bore hole collapsed in on self @3000mm+

Bioscience

BORE COMPLETION LOG

BORE NO.
OX9
SHEET 3 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX9
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.75	Sand – loose, brown/ grey, moderately sorted grained, dry organic sand with rootlets top 400mm	░	S				
1.0 2.0 2.25	Sand – medium dense, light brown, moderately sorted grained, moist to wet sand	░	S			Water encountered @ 1500mm	Water encountered @ 1500mm
3.0 4.0 5.0	Sand – medium dense, brown, moderately sorted grained, wet sand	▒	S				

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440333
Easting: 400213
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX10
SHEET 4 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX10
Date: 03/10/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, white, moderately sorted grained, dry organic sand with rootlets top 400mm		S				Water encountered @ 2000mm
0.8 1.0 2.0	Sand – medium dense, light brown, moderately sorted grained, moist sand		S			Water encountered @ 2000mm	
2.2 3.0 4.0 5.0	Sand – medium dense, brown, moderately sorted grained, wet sand		S				

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440123 Easting: 400011

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX11
SHEET 5 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX11
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand with rootlets	░	S				
1.0 2.0 2.2	Sand – loose to medium dense, light brown, moderately sorted grained, moist to wet sand	░	S			Water encountered @ 1000mm	Water encountered @ 1000mm
3.0 3.8	Sand – medium dense, dark brown, moderately sorted grained, wet sand	▒	S				
4.0	Sand – stiff, dark brown, moderately sorted grained, wet sand	▒	S				
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440167 Easting: 400517

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX12
SHEET 6 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX12
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand with rootlets		S				
1.0 2.0 3.0	Sand – loose to medium dense, white to light brown, moderately sorted grained, moist to wet sand		S			Water encountered @ 800mm	Water encountered @ 800mm
4.0	Sand – medium dense, light brown, moderately sorted grained, wet sand		S				
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439869 Easting: 400279

REMARKS: Surface level interpolated from contour plan map

BORE COMPLETION LOG

BORE NO.
OX13
SHEET 7 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX13
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets	░	S				
0.25	Sand – medium, light brown, moderately sorted grained, dry organic sand	▒	S				
0.75 1.0	Sand – medium, light orange, moderately sorted grained, wet organic sand	▒	S			Water encountered @ 700mm	Water encountered @ 700mm
1.2 2.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand	▒	S				
2.3 3.0	Sand – medium dense, grey to brown, moderately sorted grained, wet organic sand	▒	S				
	Sand – medium dense, brown, moderately sorted grained, wet organic sand	▒					
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439824 Easting: 400456

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX14
SHEET 8 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX14
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry sand with rootlets		S				
0.4	Sand – medium, light brown, moderately sorted grained, wet organic sand		S			Water encountered @ 700mm	Water encountered @ 700mm
1.0							
1.2	Clayey sand – dense, dark brown, fine to medium sorted grained, wet organic sand		CS			Compact sand	
1.6	Coffee Rock – dense, coffee brown		CR				
2.0							
2.3	Sand – dense, light brown, moderately sorted grained, moist organic sand		S				
3.0							
4.0							
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439842 Easting: 400020

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX15
SHEET 9 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX15
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets	░	S				
1.0	Sand – loose, grey, moderately sorted grained, moist to wet organic sand	░	S			Water encountered @ 600mm	Water encountered @ 600mm
1.8 2.0	Sand– medium dense, brown, moderately sorted grained, wet organic sand	▒	S				
2.1	Sand – dense, dark brown, moderately sorted grained, wet organic sand	▒	S			Very dense @ 2200mm	
2.4 3.0	Clayey sand – dense, brown, moderately sorted grained, wet, organic	▓	CS				
3.6	Sand – dense, black, moderately sorted grained, wet organic sand	▒	S				
4.0 5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6439532
Easting: 400226
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX16
SHEET 10 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.2m AHD approx
Bore Number: OX16
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – loose, dark brown, moderately sorted grained, dry sand with rootlets		S				
1.0	Sand – loose, grey brown, moderately sorted grained, dry organic sand		S			Water encountered @ 800mm	Water encountered @ 800mm
1.2							
2.0	Sand – medium dense, light brown, moderately sorted grained, wet organic sand		S				
3.0							
4.0	Sand – medium dense, dark brown, moderately sorted grained, wet sand		S				
5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC
TYPE OF BORING:
Northing: 6439316 Easting: 400520
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX17
SHEET 11 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.7m AHD approx
Bore Number: OX17
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry sand with rootlets	░	S				
0.3	Sand – loose, brown, moderately sorted grained, dry organic sand	░	S				
0.8 1.0	Sand – medium dense, light brown, moderately sorted grained, wet organic sand	▒	S			Water encountered @ 800mm Compact sand	Water encountered @ 800mm
1.8 2.0	Sand – dense, light brown, moderately sorted grained, moist organic sand	▒	S				
2.4 3.0	Clayey sand – dense, very dark brown, fine to medium sorted grained, wet organic	▨	CS				
3.5	Coffee Rock – dense, coffee brown	▦	CR				
4.0 5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6439299 Easting: 400042
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX18
SHEET 12 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX18
Date: 01/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.1	Sand – loose, dry sand with rootlets		S				
1.0 1.2	Sand – loose, grey brown, moderately sorted grained, moist organic sand		S S			Water encountered @ 900mm	Water encountered @ 900mm
2.0 2.2	Sand – medium dense, light brown, moderately sorted grained, wet organic sand		S				
2.8	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
3.0 3.9	Sand – medium dense, light brown, moderately sorted grained, wet organic sand		S				
4.0 5.0	Peaty sand – dense, dark brown to black, moderately sorted grained, wet organic peaty sand		PT				

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6439153 Easting: 400312
REMARKS: Surface level interpolated from contour plan map

BORE COMPLETION LOG

BORE NO.
OX19
SHEET 13 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.6m AHD approx
Bore Number: OX19
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, moderately sorted grained, dry organic sandy topsoil		S				
0.4	Sand – loose, grey brown, moderately sorted grained, moist organic sand		S			Water encountered @ 700mm	Water encountered @ 700mm
1.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand		S				
1.8 2.0	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
2.2	Sand – medium dense, brown, moderately sorted grained, wet organic sand		S				
2.8 3.0	Silty sand – dense, dark brown, moderately sorted grained, wet, rich organic peaty sand		PT				
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6440346 Easting: 401059

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX20
SHEET 14 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.7m AHD approx
Bore Number: OX20
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Type	Depth	Sample	Notes	Water
0.2	Sand – loose, orange, dry sand	░	S				
1.0	Clayey sand – dense, grey orange mottled, fine to medium sorted grained, wet organic	▨	CS			Water encountered @ 600mm	Water encountered @ 600mm
2.0							
2.2							
2.4	Clayey sand – dense, grey, fine to medium sorted grained, wet organic	▨	CS				
3.0	Sand – medium dense, grey brown, moderately sorted grained, wet organic sand	░	S				
4.0							
5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440342
Easting: 400845
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX21
SHEET 15 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.3m AHD approx
Bore Number: OX21
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand– loose, grey brown, sandy topsoil	░	S				Water depth not recorded
0.2	Sand – loose, grey, dry organic sand	░	S				
1.0	Sand – medium dense, white, moderately sorted grained, wet organic sand	▒	S				
1.6	Silty sand – dense, dark brown, moderately sorted grained, wet, rich organic peaty sand	≡	PT				
2.0	Sand – medium dense, brown, moderately sorted grained, wet organic sand	▒	S				
2.5 3.0	Sand – medium dense, dark brown, moderately sorted grained, wet organic sand	▒	S				
4.0 5.0							

RIG: Mechanical Auger
DRILLER:
LOGGED: JC
TYPE OF BORING:
Northing: 6440347
Easting: 400556
REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX22
SHEET 16 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24.5m AHD approx
Bore Number: OX22
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
0.2	Sand – loose, grey brown, dry sand	░	S				Water not recorded
1.0 1.2	Clayey sand – dense, grey brown mottled, fine to medium sorted grained, wet organic	▨	CS				
2.0 2.6	Clayey sand – dense, orange, fine to medium sorted grained, wet organic	▨	CS				
3.0 4.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand	░	S				
5.0							

RIG: Mechanical Auger

DRILLER:

LOGGED: JC

TYPE OF BORING:

Northing: 6439959 Easting: 401050

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX23
SHEET 17 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX23
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, brown orange, moist organic sandy topsoil	░	S				Water not recorded
0.4							
1.0	Sandy clay – dense, grey and light brown mottled, fine to medium sorted grained, moist organic	▨	SC				
2.0							
2.2							
3.0	Sand – medium dense, grey, moderately sorted grained, wet organic sand	▒	S				
4.0							
5.0							

RIG: Mechanical Auger   DRILLER: LOGGED: JC

TYPE OF BORING:

Northing: 6439975   Easting: 400832

REMARKS: Surface level interpolated from contour plan map

Bioscience

BORE COMPLETION LOG

BORE NO.
OX24
SHEET 18 OF 18

Location: South Forrestdale Industrial Area,
Perth, Western Australia

Surface Level: 24m AHD approx
Bore Number: OX24
Date: 02/11/2012

Depth (m)	Lithological Description	Log	Sampling & In Situ Testing				Water
			Type	Depth	Sample	Notes	
	Sand – loose, grey brown, dry sand	⁙	S				Water not recorded
0.2	Clayey sand – dense, light brown mottled, fine to medium sorted grained, dry organic	▨	CS				
0.8 1.0	Clayey sand – dense, grey orange mottled, fine to medium sorted grained, moist organic	▨	CS				
2.0	Clay – dense, orange, fine, moist organic	▥	C				
2.2 3.0	Clayey sand – dense, grey light brown mottled, fine to medium sorted grained, wet organic	▨	CS				
4.0 5.0							

RIG: Mechanical Auger DRILLER: LOGGED: JC
TYPE OF BORING:
Northing: 6440042 Easting: 400558
REMARKS: Surface level interpolated from contour plan map

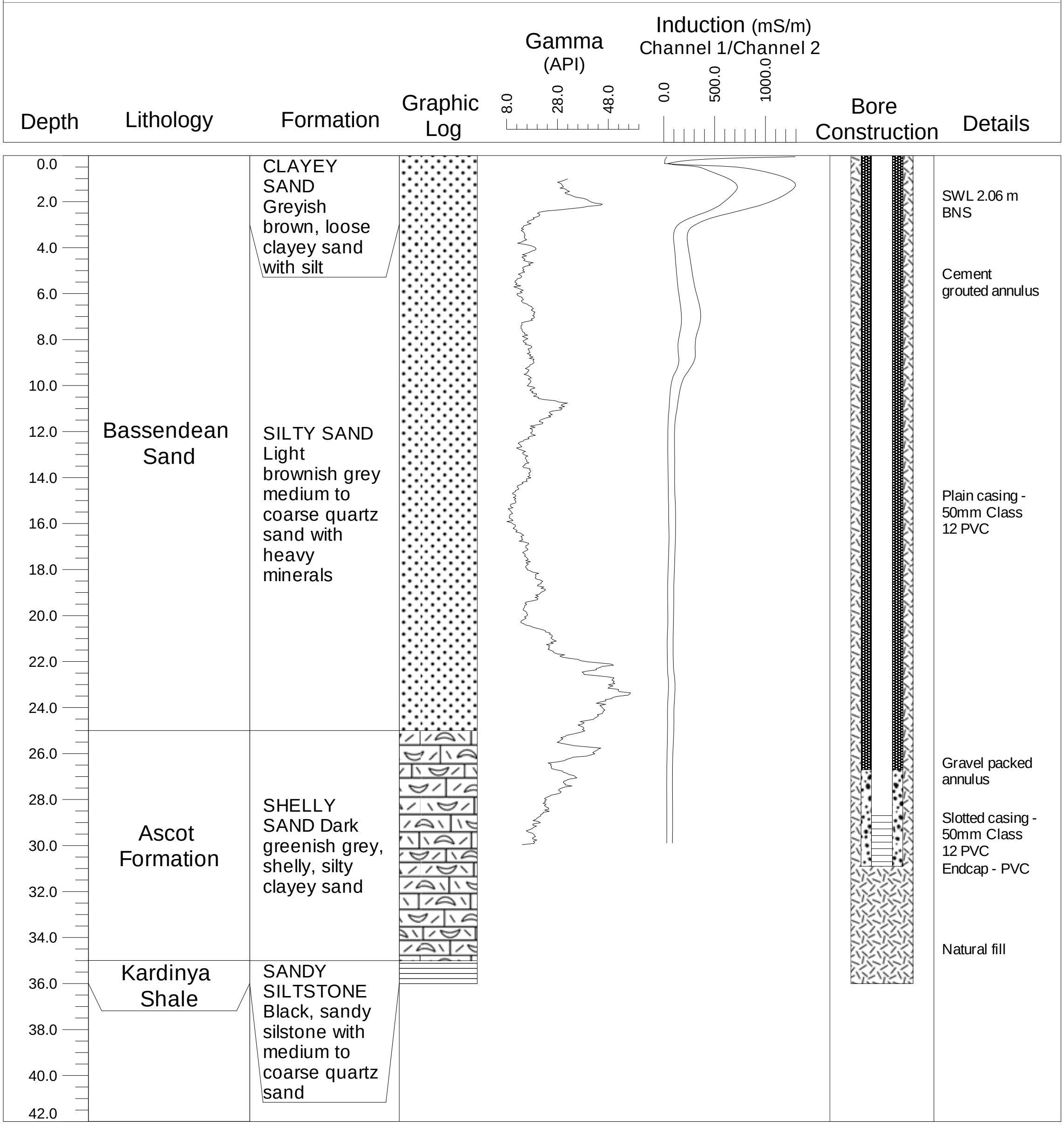
Appendices

Appendix A — Bore construction details and lithology

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name:	**FRD_NWa**
AWRC Number:	**61611428**



Drilled by:	Great Southern Drilling	Northing (Z50):	6441734.572	Screens (m BNS):	28.65 - 30.65
Date drilled:	5/17/07	Easting (Z50):	397656.051	SWL (m BNS):	2.06
Logged by:	Sarah Bourke	Surface (m AHD):	24.511	EC (mS/cm):	0.565
Aquifer:	Superficial	Drill depth (m BNS):	36	pH:	8

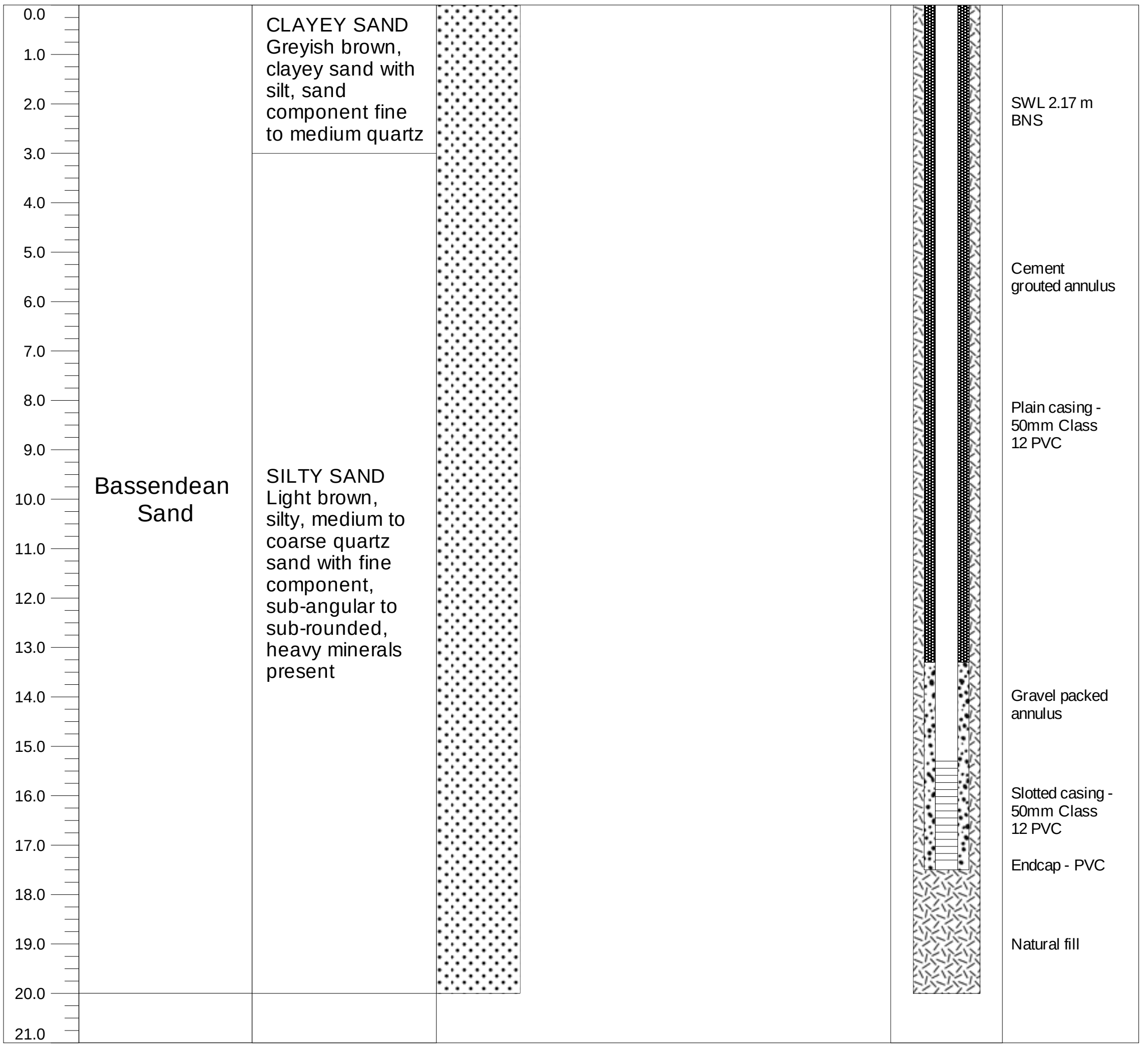
BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name:	**FRD_NWb**
AWRC Number:	**61611427**

Depth	Formation	Lithology	Graphic Log	Bore Construction	Details



Bassendean Sand

CLAYEY SAND Greyish brown, clayey sand with silt, sand component fine to medium quartz

SILTY SAND Light brown, silty, medium to coarse quartz sand with fine component, sub-angular to sub-rounded, heavy minerals present

SWL 2.17 m BNS

Cement grouted annulus

Plain casing - 50mm Class 12 PVC

Gravel packed annulus

Slotted casing - 50mm Class 12 PVC

Endcap - PVC

Natural fill

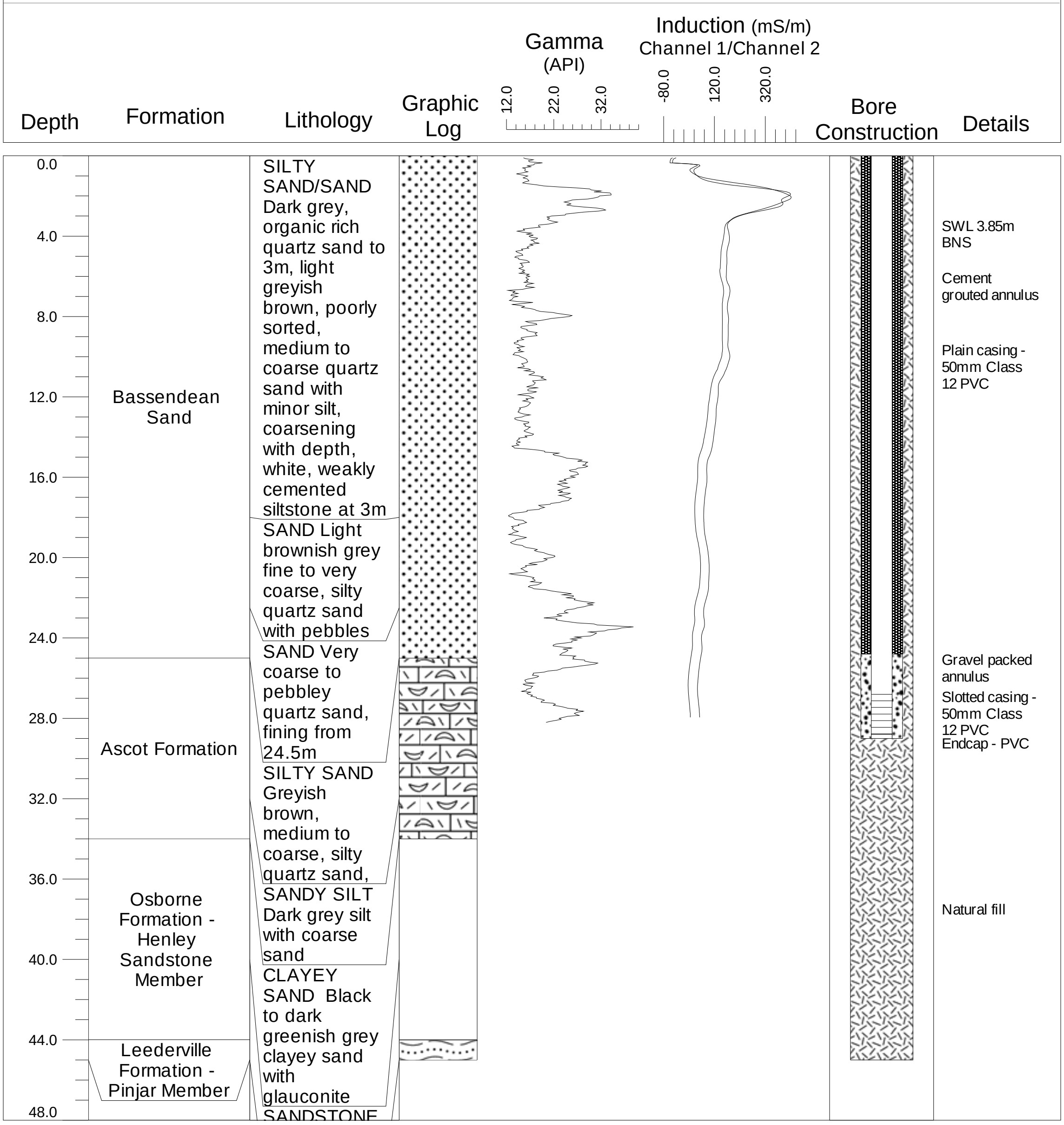
Drilled by:	Great Southern Drilling	Northing (Z50):	6441791.572	Screens (m BNS):	15.31 - 17.31
Date drilled:	5/17/07	Easting (Z50):	397655.547	SWL (m BNS):	2.17
Logged by:	Sarah Bourke	Surface (m AHD):	24.51	EC (mS/cm):	0.761
Aquifer:	Superficial	Drill depth (m BNS):	20	pH:	7.96

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name: **FRD_Wa**

AWRC Number: **61611430**



SILTY SAND/SAND Dark grey, organic rich quartz sand to 3m, light greyish brown, poorly sorted, medium to coarse quartz sand with minor silt, coarsening with depth, white, weakly cemented siltstone at 3m

SAND Light brownish grey fine to very coarse, silty quartz sand with pebbles

SAND Very coarse to pebbley quartz sand, fining from 24.5m

SILTY SAND Greyish brown, medium to coarse, silty quartz sand,

SANDY SILT Dark grey silt with coarse sand

CLAYEY SAND Black to dark greenish grey clayey sand with glauconite

SANDSTONE

Drilled by:	Great Southern Drilling	Northing (Z50):	6441440.853	Screens (m BNS):	26.72 - 28.72
Date drilled:	5/10/07	Easting (Z50):	398974.892	SWL (m BNS):	3.85
Logged by:	Sandie McHugh	Surface (m AHD):	23.971	EC (mS/cm):	1.64
Aquifer:	Superficial	Drill depth (m BNS):	45	pH:	7.51

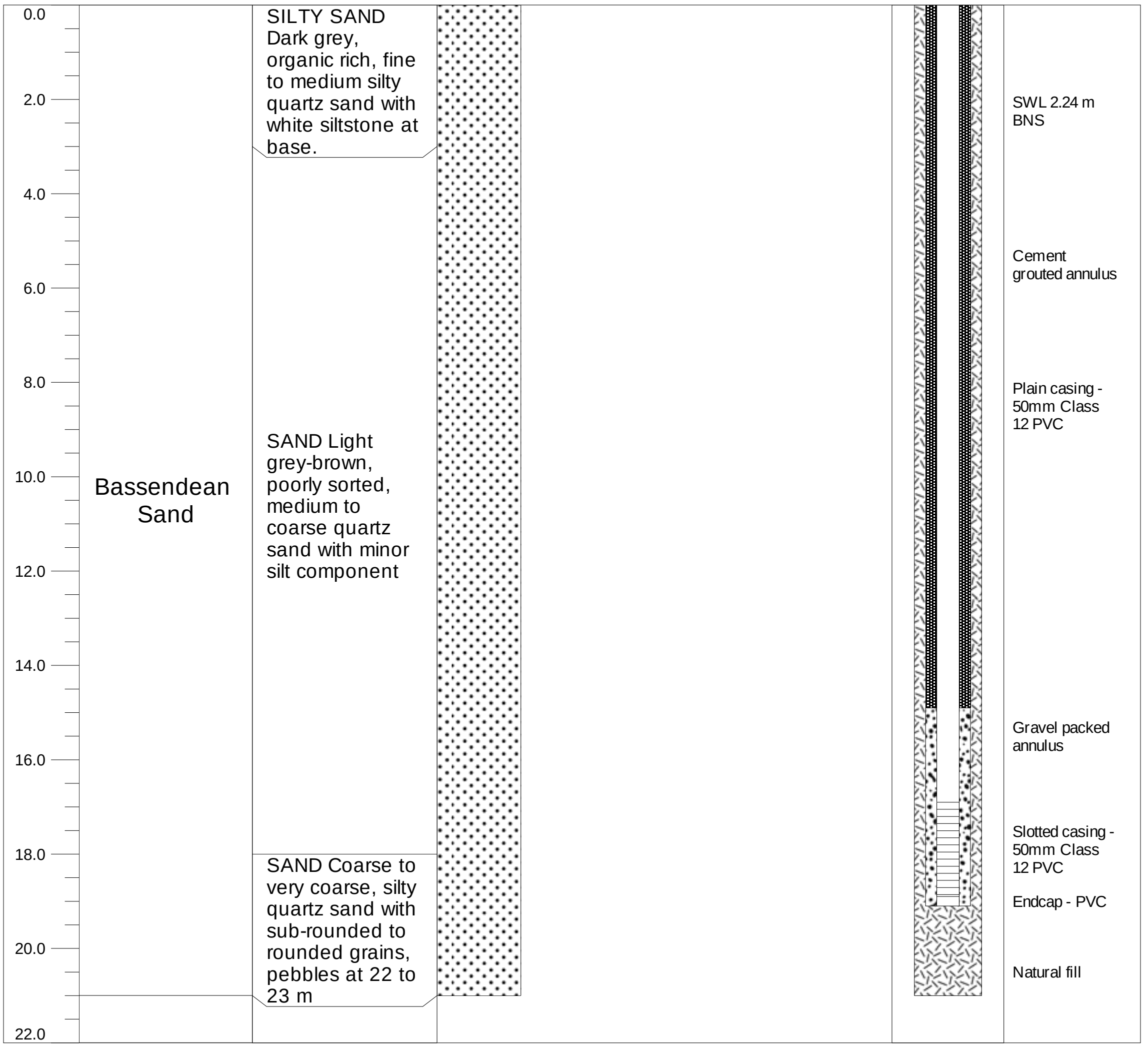
BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_Wb**
AWRC Number: **61611429**

Depth | Formation | Lithology | Graphic Log | Bore Construction | Details



SILTY SAND Dark grey, organic rich, fine to medium silty quartz sand with white siltstone at base.

SAND Light grey-brown, poorly sorted, medium to coarse quartz sand with minor silt component

SAND Coarse to very coarse, silty quartz sand with sub-rounded to rounded grains, pebbles at 22 to 23 m

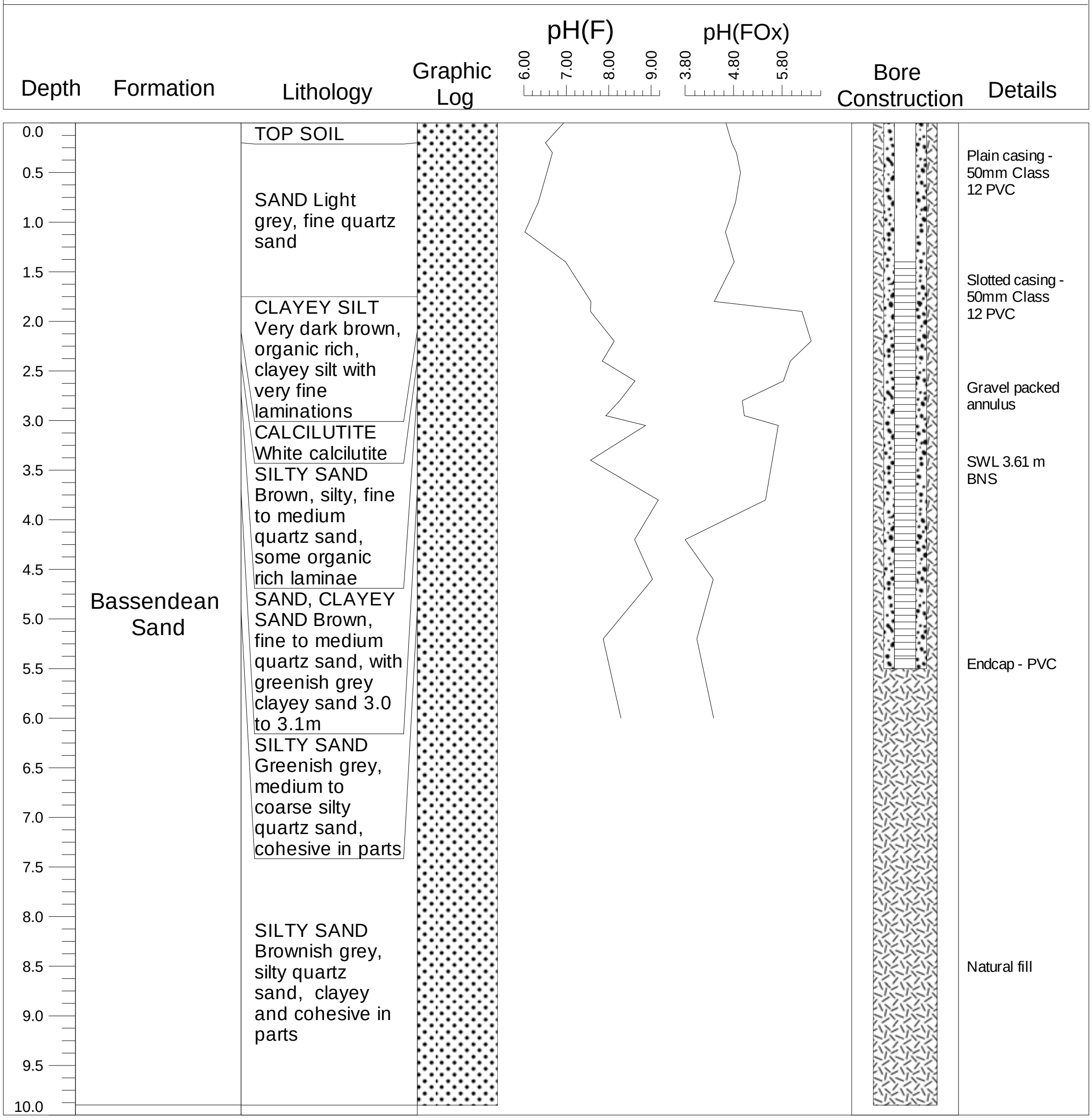
Drilled by:	Great Southern Drilling	Northing (Z50):	6441443.13	Screens (m BNS):	16.93 - 18.93
Date drilled:	5/11/07	Easting (Z50):	398975.29	SWL (m BNS):	2.24
Logged by:	Sandie McHugh	Surface (m AHD):	23.975	EC (mS/cm):	2.44
Aquifer:	Superficial	Drill depth (m BNS):	21	pH:	7.38

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name: **FRD_Wc**

AWRC Number: **61611446**



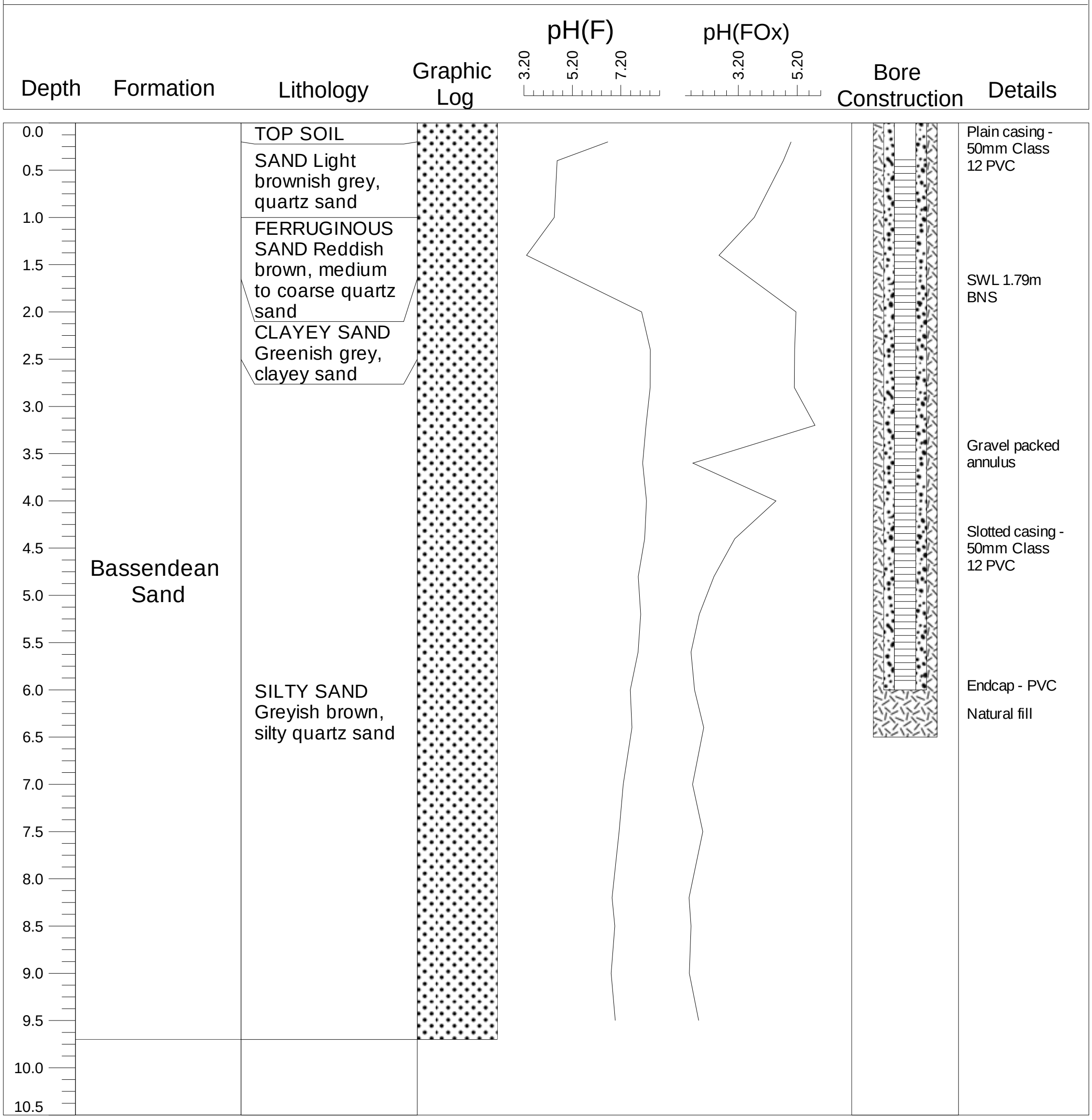
Drilled by:	Great Southern Drilling	Northing (Z50):	6441497.25	Screens (m BNS):	1.40 - 5.40
Date drilled:	5/3/07	Easting (Z50):	398973.26	SWL (m BNS):	3.61
Logged by:	Sandie McHugh	Surface (m AHD):	23.672	EC (mS/cm):	1.192
Aquifer:	Superficial	Drill depth (m BNS):	9.9	pH:	7.01

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name:	**FRD_E2c**
AWRC Number:	**61611431**

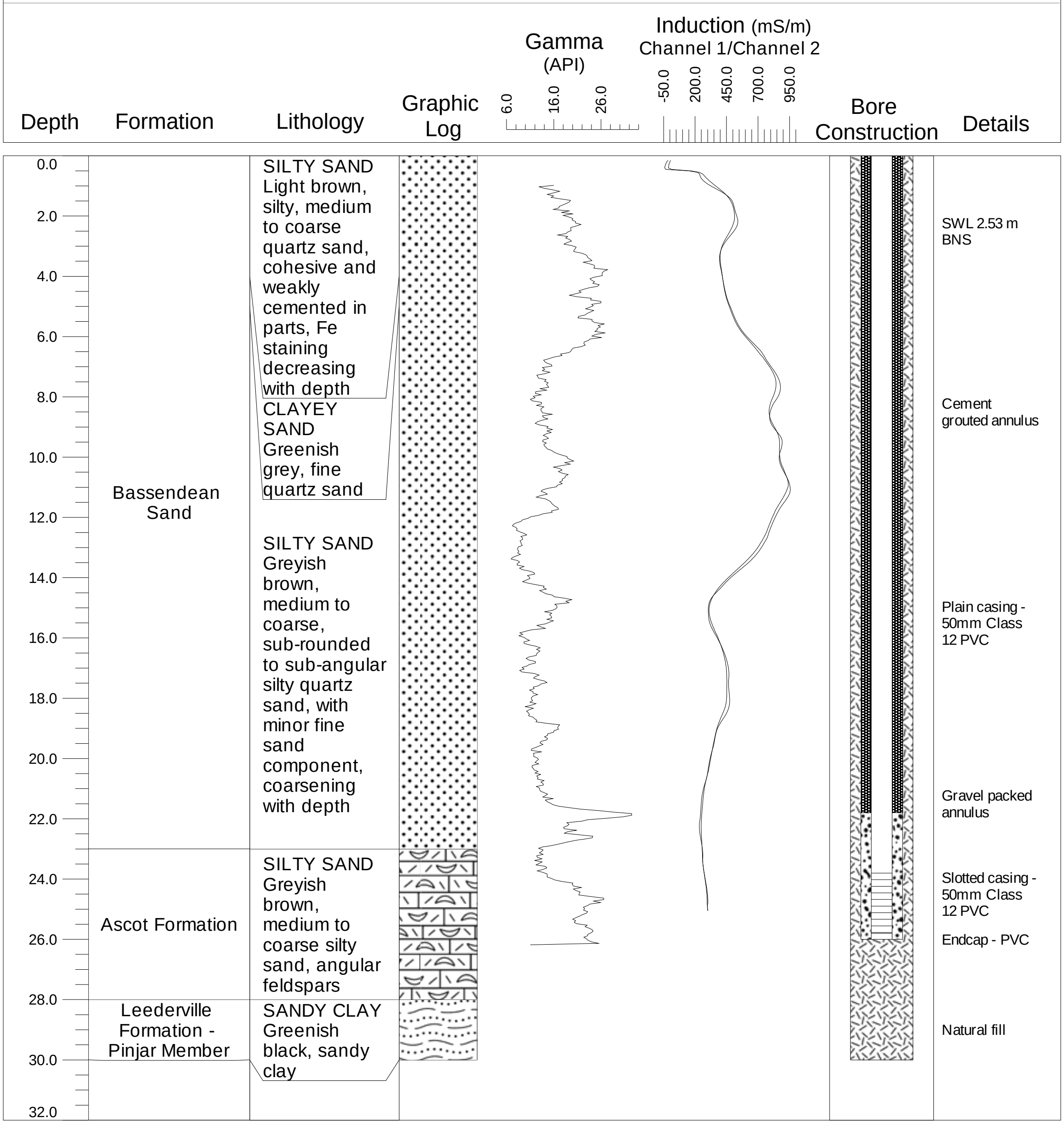


Drilled by:	Great Southern Drilling	Northing (Z50):	6440867.243	Screens (m BNS):	0.88 - 5.88
Date drilled:	5/10/07	Easting (Z50):	400343.896	SWL (m BNS):	1.79
Logged by:	Sandie McHugh	Surface (m AHD):	22.526	EC (mS/cm):	2.49
Aquifer:	Superficial	Drill depth (m BNS):	6.5	pH:	7.24

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name:	**FRD_Ea**
AWRC Number:	**61611433**



SILTY SAND Light brown, silty, medium to coarse quartz sand, cohesive and weakly cemented in parts, Fe staining decreasing with depth

CLAYEY SAND Greenish grey, fine quartz sand

SILTY SAND Greyish brown, medium to coarse, sub-rounded to sub-angular silty quartz sand, with minor fine sand component, coarsening with depth

SILTY SAND Greyish brown, medium to coarse silty sand, angular feldspars

SANDY CLAY Greenish black, sandy clay

Drilled by:	Great Southern Drilling	Northing (Z50):	6440790.086	Screens (m BNS):	23.79 - 25.79
Date drilled:	5/16/07	Easting (Z50):	400544.857	SWL (m BNS):	2.53
Logged by:	Sandie McHugh	Surface (m AHD):	24.015	EC (mS/cm):	10.18
Aquifer:	Superficial	Drill depth (m BNS):	30	pH:	8.61

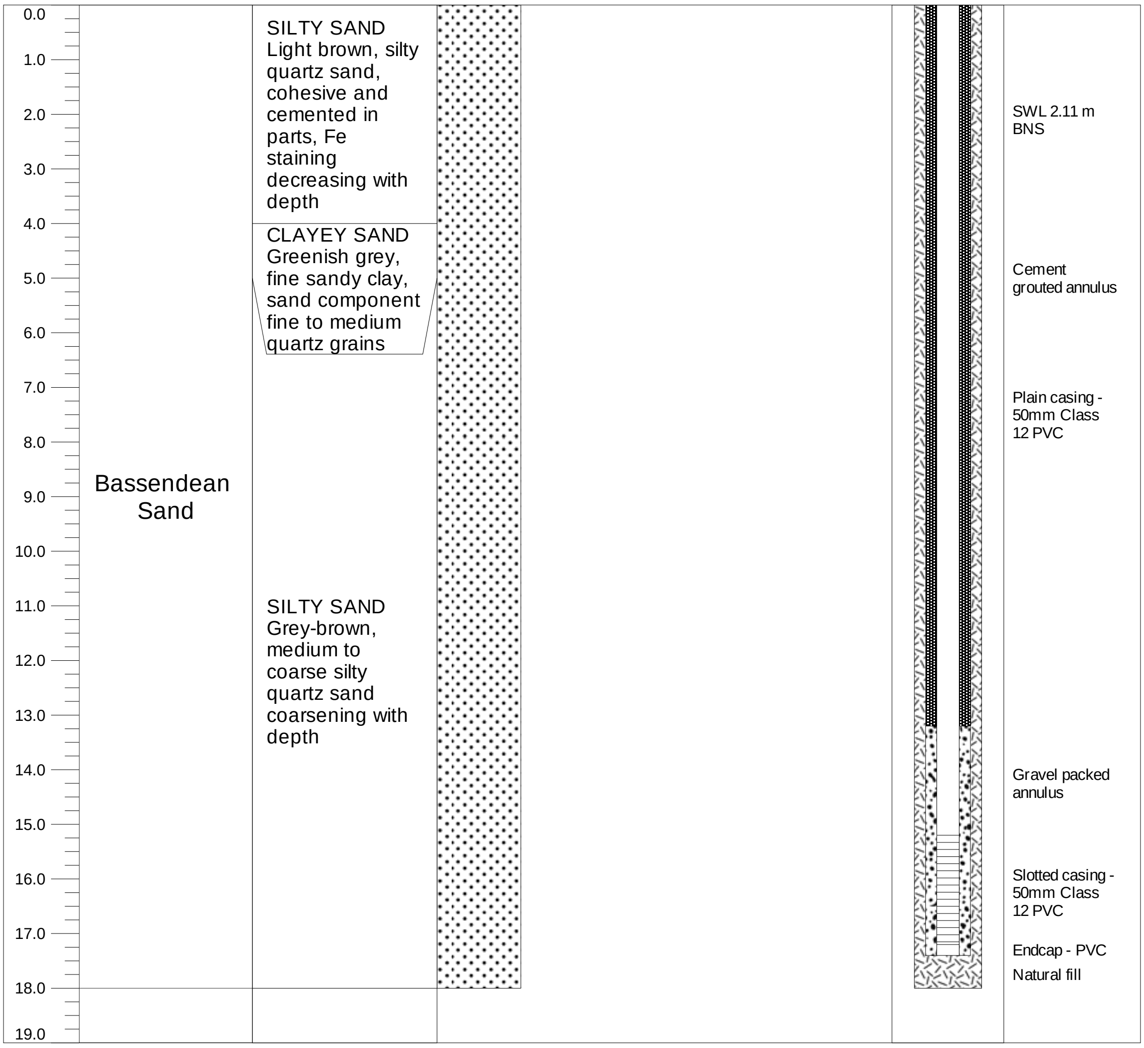
BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name:	**FRD_Eb**
AWRC Number:	**61611432**

Depth Formation Lithology Graphic Log Bore Construction Details



SILTY SAND
Light brown, silty quartz sand, cohesive and cemented in parts, Fe staining decreasing with depth

CLAYEY SAND
Greenish grey, fine sandy clay, sand component fine to medium quartz grains

SILTY SAND
Grey-brown, medium to coarse silty quartz sand coarsening with depth

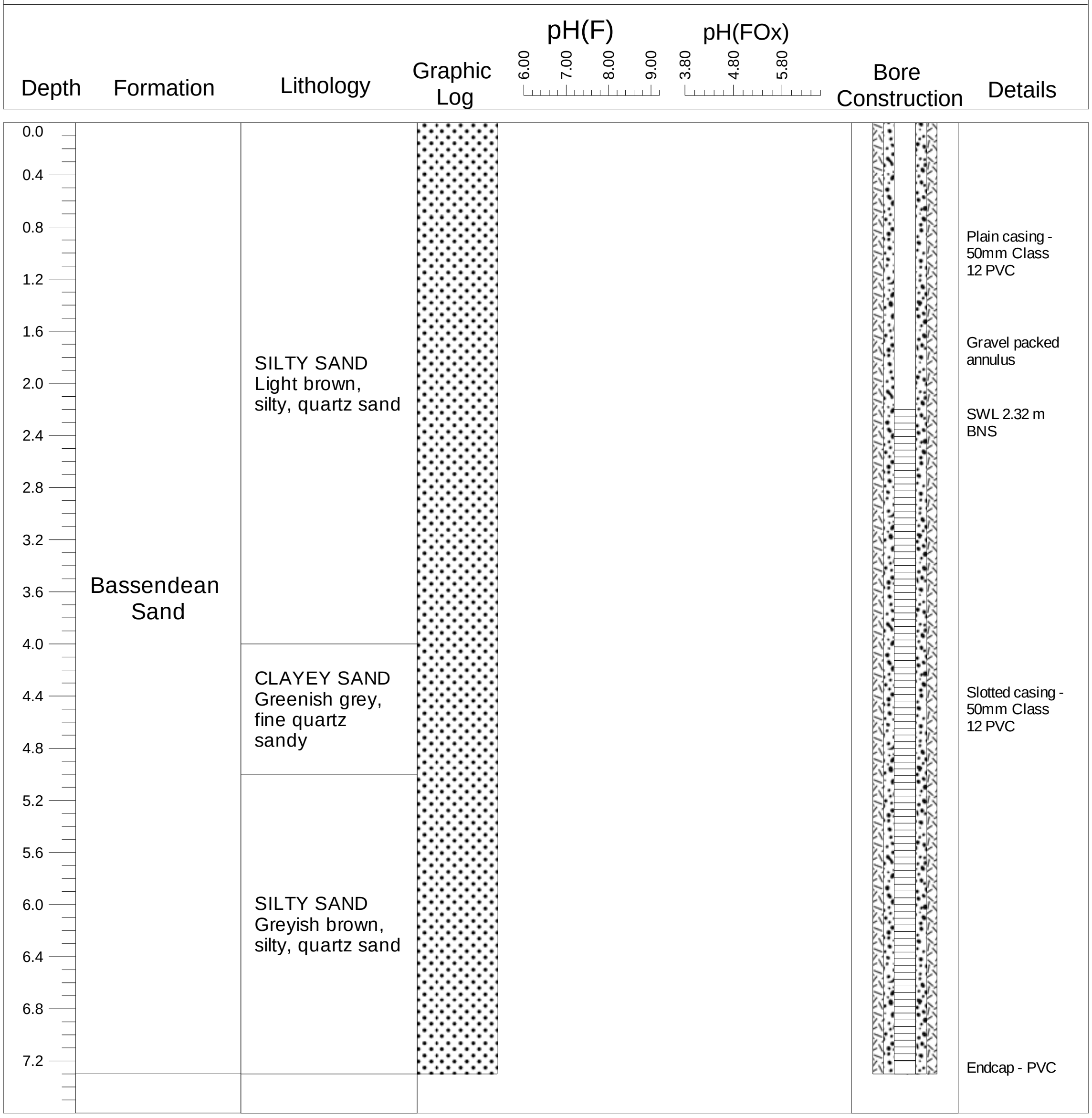
Drilled by:	Great Southern Drilling	Northing (Z50):	6440791.713	Screens (m BNS):	15.22 - 17.22
Date drilled:	5/17/07	Easting (Z50):	400544.812	SWL (m BNS):	2.11
Logged by:	Sandie McHugh	Surface (m AHD):	24.003	EC (mS/cm):	12.82
Aquifer:	Superficial	Drill depth (m BNS):	18	pH:	7.63

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_Ec**
AWRC Number: **61611447**



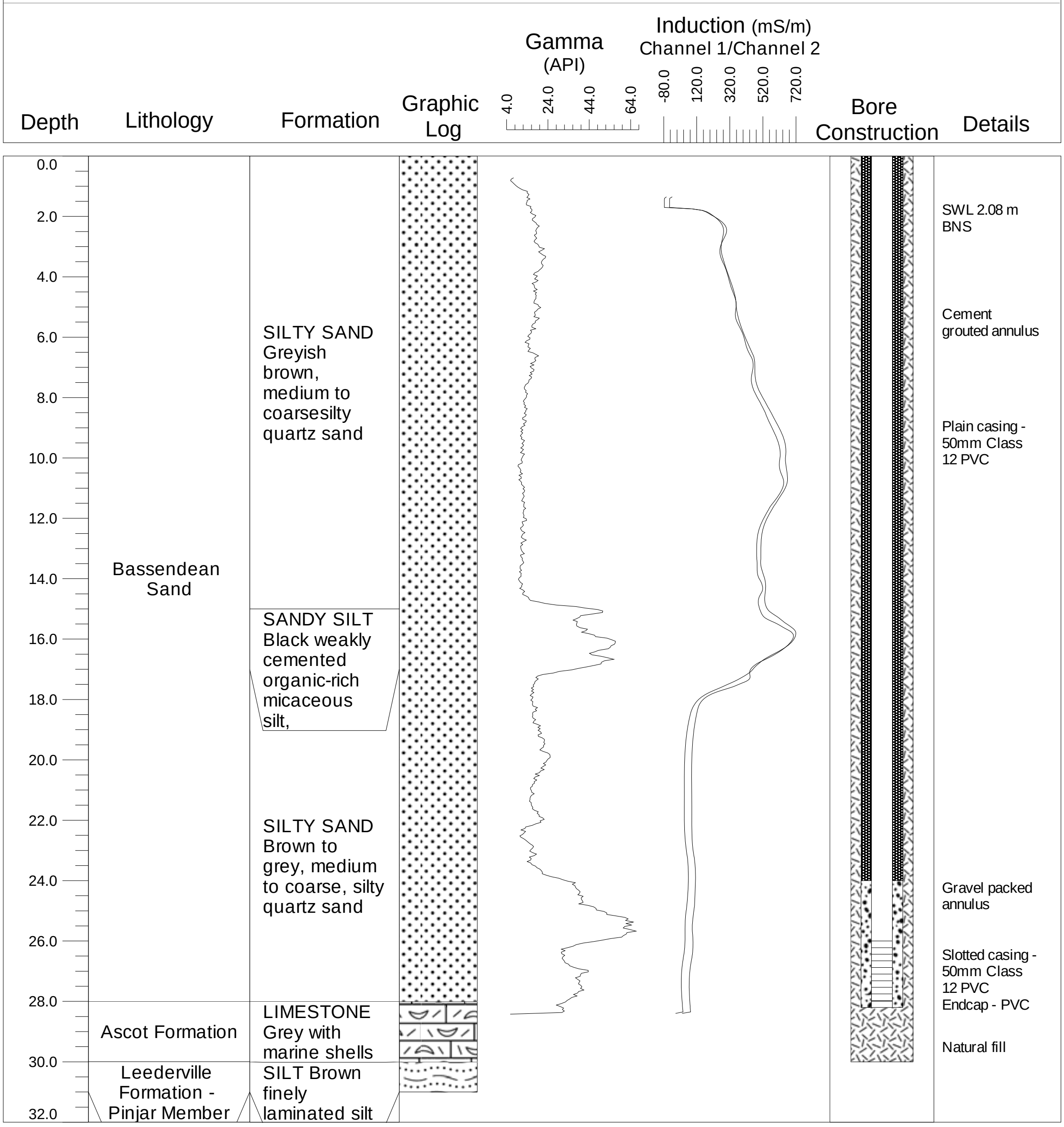
Drilled by:	Great Southern Drilling	Northing (Z50):	6440793.313	Screens (m BNS):	2.24 - 7.24
Date drilled:	5/17/07	Easting (Z50):	400544.849	SWL (m BNS):	2.32
Logged by:	Sarah Bourke	Surface (m AHD):	24.006	EC (mS/cm):	17.41
Aquifer:	Superficial	Drill depth (m BNS):	7.3	pH:	7.81

BORE COMPLETION DETAILS Department of Water Government of Western Australia

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name: **FRD_SEa**

AWRC Number: **61611436**



Drilled by:	Great Southern Drilling	Northing (Z50):	6440809.402	Screens (m BNS):	25.98 - 27.98
Date drilled:	4/27/07	Easting (Z50):	400944.116	SWL (m BNS):	2.08
Logged by:	Sarah Bourke	Surface (m AHD):	24.033	EC (mS/cm):	2.02
Aquifer:	Superficial	Drill depth (m BNS):	30	pH:	8.04

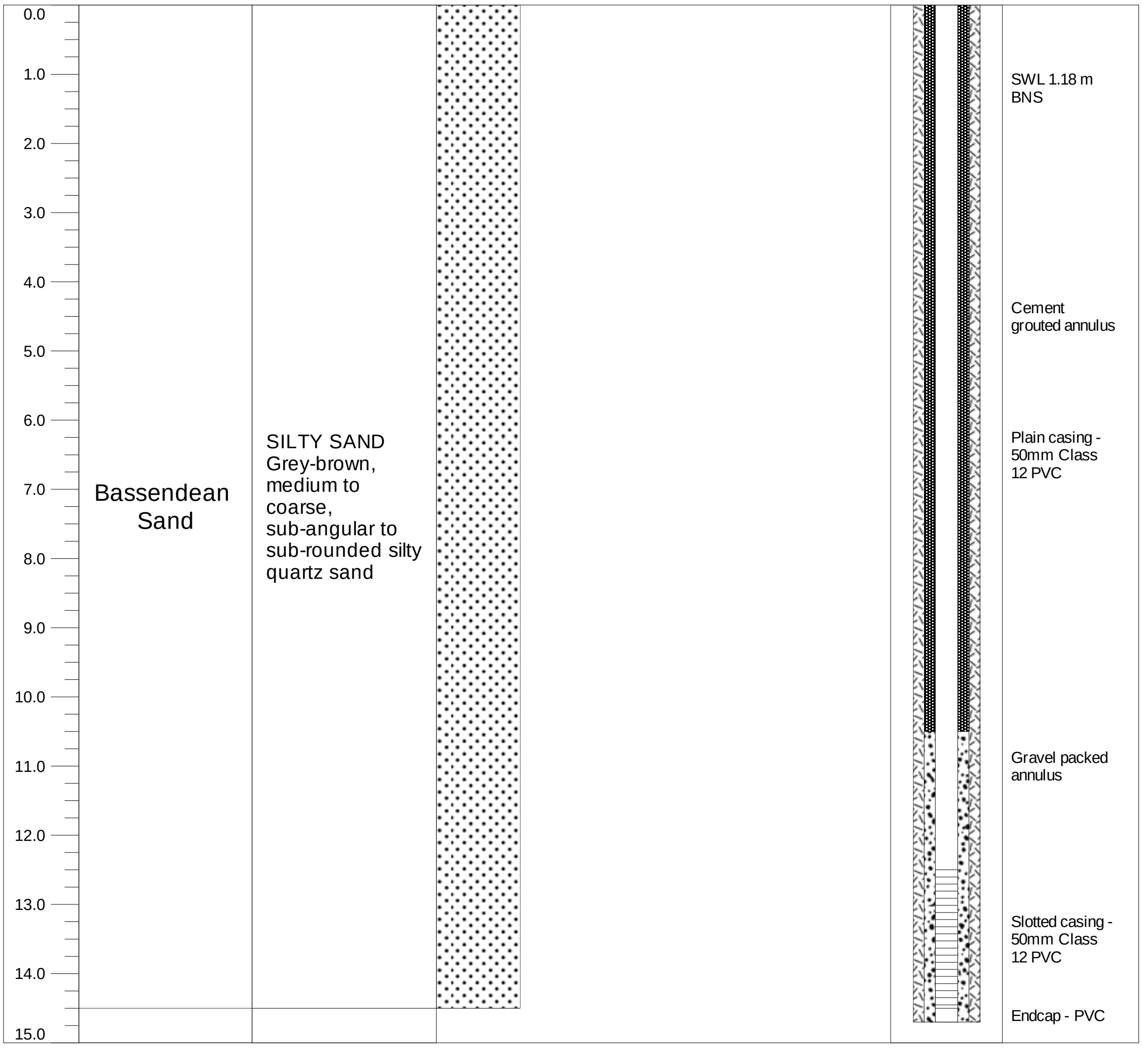
BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_SEb**
AWRC Number: **61611435**

Depth	Formation	Lithology	Graphic Log	Bore Construction	Details



SILTY SAND Grey-brown, medium to coarse, sub-angular to sub-rounded silty quartz sand

SWL 1.18 m BNS

Cement grouted annulus

Plain casing - 50mm Class 12 PVC

Gravel packed annulus

Slotted casing - 50mm Class 12 PVC

Endcap - PVC

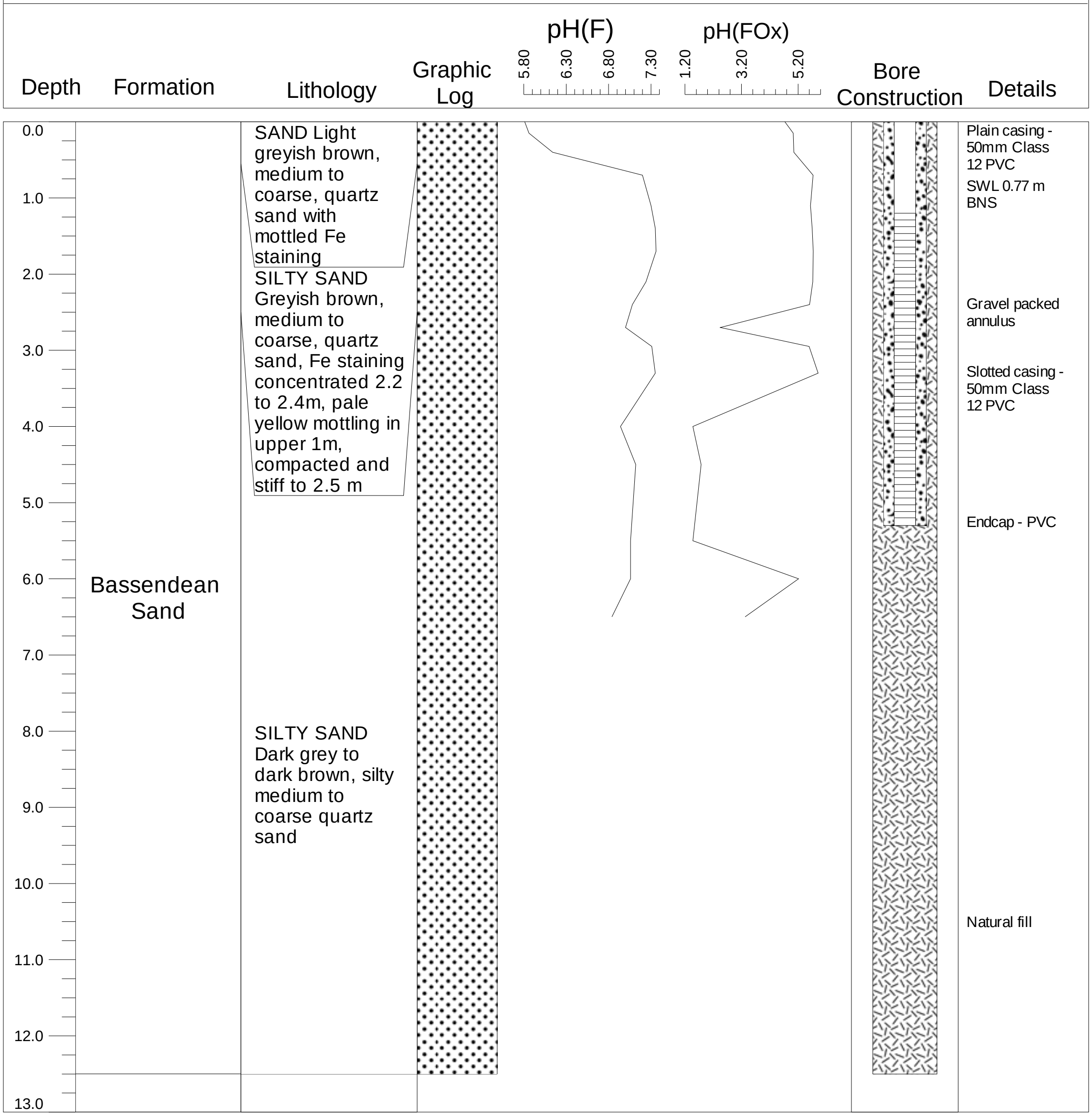
Drilled by:	Great Southern Drilling	Northing (Z50):	6440810.701	Screens (m BNS):	12.49 - 14.49
Date drilled:	4/27/07	Easting (Z50):	400945.457	SWL (m BNS):	1.18
Logged by:	Sandie McHugh	Surface (m AHD):	24.061	EC (mS/cm):	15.8
Aquifer:	Superficial	Drill depth (m BNS):	14.5	pH:	7.64

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_SEc**
AWRC Number: **61611434**



SAND Light greyish brown, medium to coarse, quartz sand with mottled Fe staining

SILTY SAND Greyish brown, medium to coarse, quartz sand, Fe staining concentrated 2.2 to 2.4m, pale yellow mottling in upper 1m, compacted and stiff to 2.5 m

SILTY SAND Dark grey to dark brown, silty medium to coarse quartz sand

Plain casing - 50mm Class 12 PVC

SWL 0.77 m BNS

Gravel packed annulus

Slotted casing - 50mm Class 12 PVC

Endcap - PVC

Natural fill

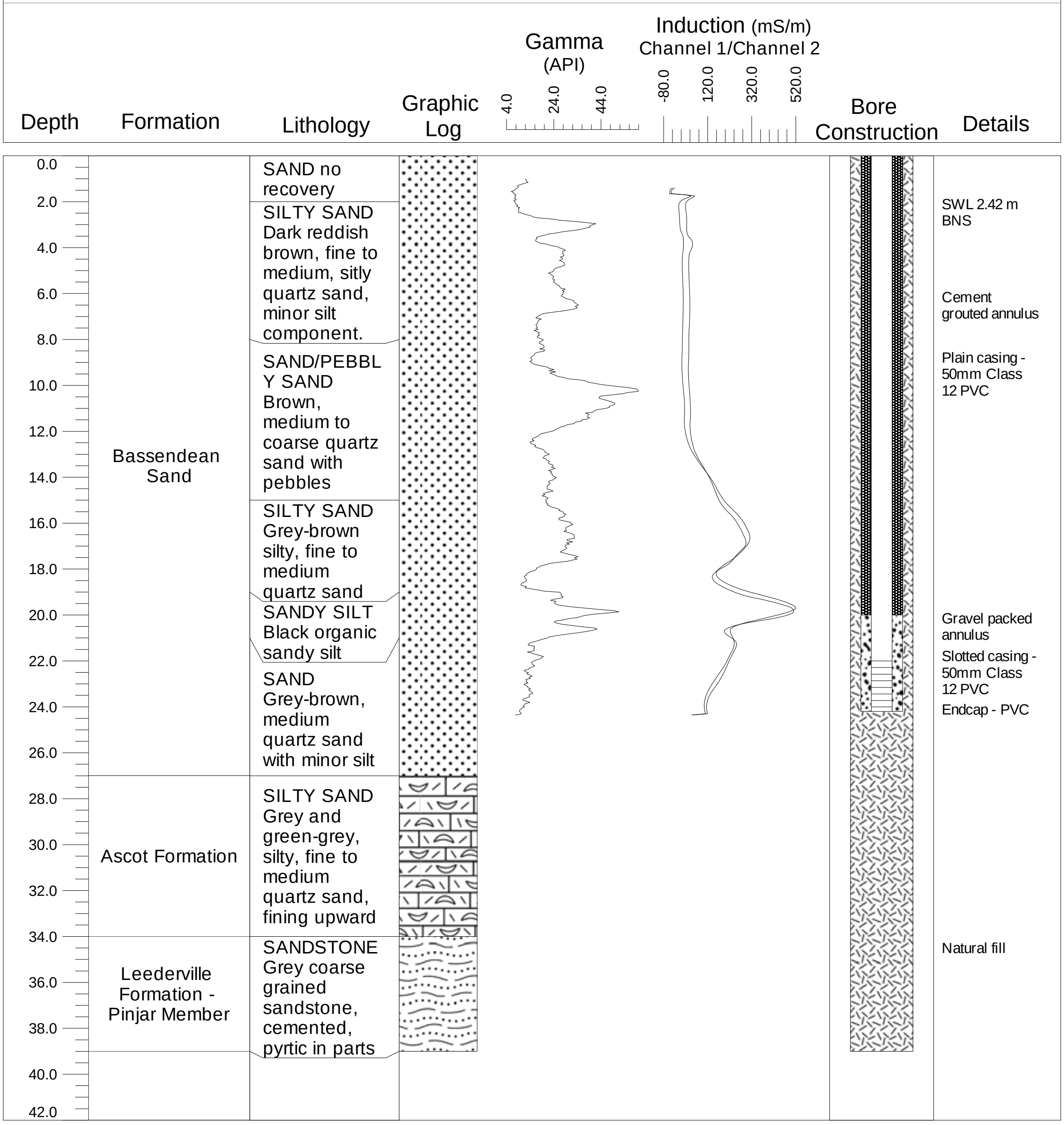
Drilled by:	Great Southern Drilling	Northing (Z50):	6440807.213	Screens (m BNS):	1.22 - 5.22
Date drilled:	4/27/07	Easting (Z50):	400941.96	SWL (m BNS):	0.77
Logged by:	Sandie McHugh	Surface (m AHD):	23.996	EC (mS/cm):	0.277
Aquifer:	Superficial	Drill depth (m BNS):	12.5	pH:	6.03

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

AWRC Name: **FRD_NEa**

AWRC Number: **61611439**



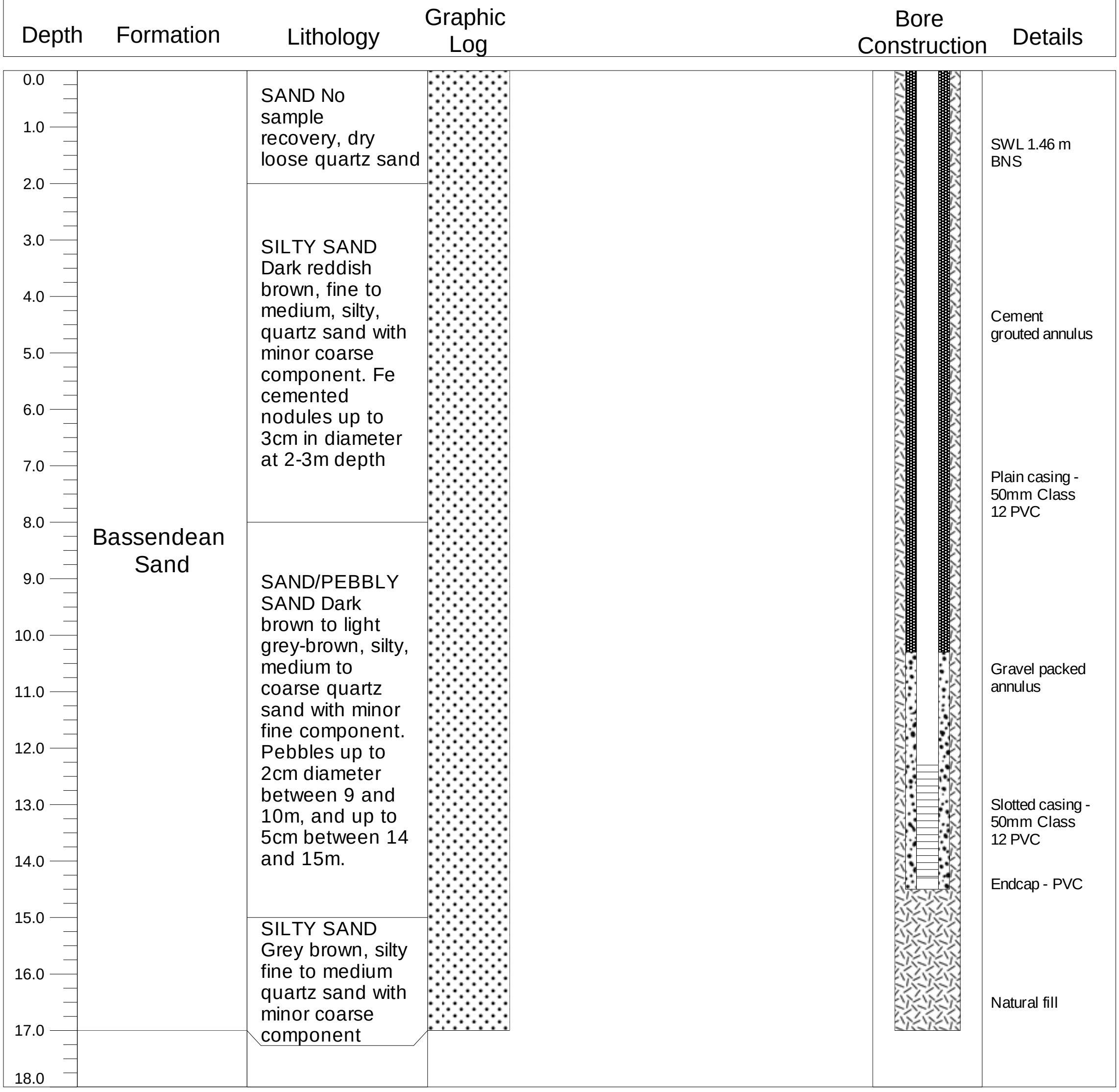
Drilled by:	Great Southern Drilling	Northing (Z50):	6442218.593	Screens (m BNS):	22.03 - 24.03
Date drilled:	6/1/07	Easting (Z50):	400079.384	SWL (m BNS):	2.42
Logged by:	Sandie McHugh	Surface (m AHD):	24.001	EC (mS/cm):	4.72
Aquifer:	Superficial	Drill depth (m BNS):	39	pH:	7.45

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_NEb**
AWRC Number: **61611438**



SAND No sample recovery, dry loose quartz sand

SILTY SAND Dark reddish brown, fine to medium, silty, quartz sand with minor coarse component. Fe cemented nodules up to 3cm in diameter at 2-3m depth

SAND/PEBBLY SAND Dark brown to light grey-brown, silty, medium to coarse quartz sand with minor fine component. Pebbles up to 2cm diameter between 9 and 10m, and up to 5cm between 14 and 15m.

SILTY SAND Grey brown, silty fine to medium quartz sand with minor coarse component

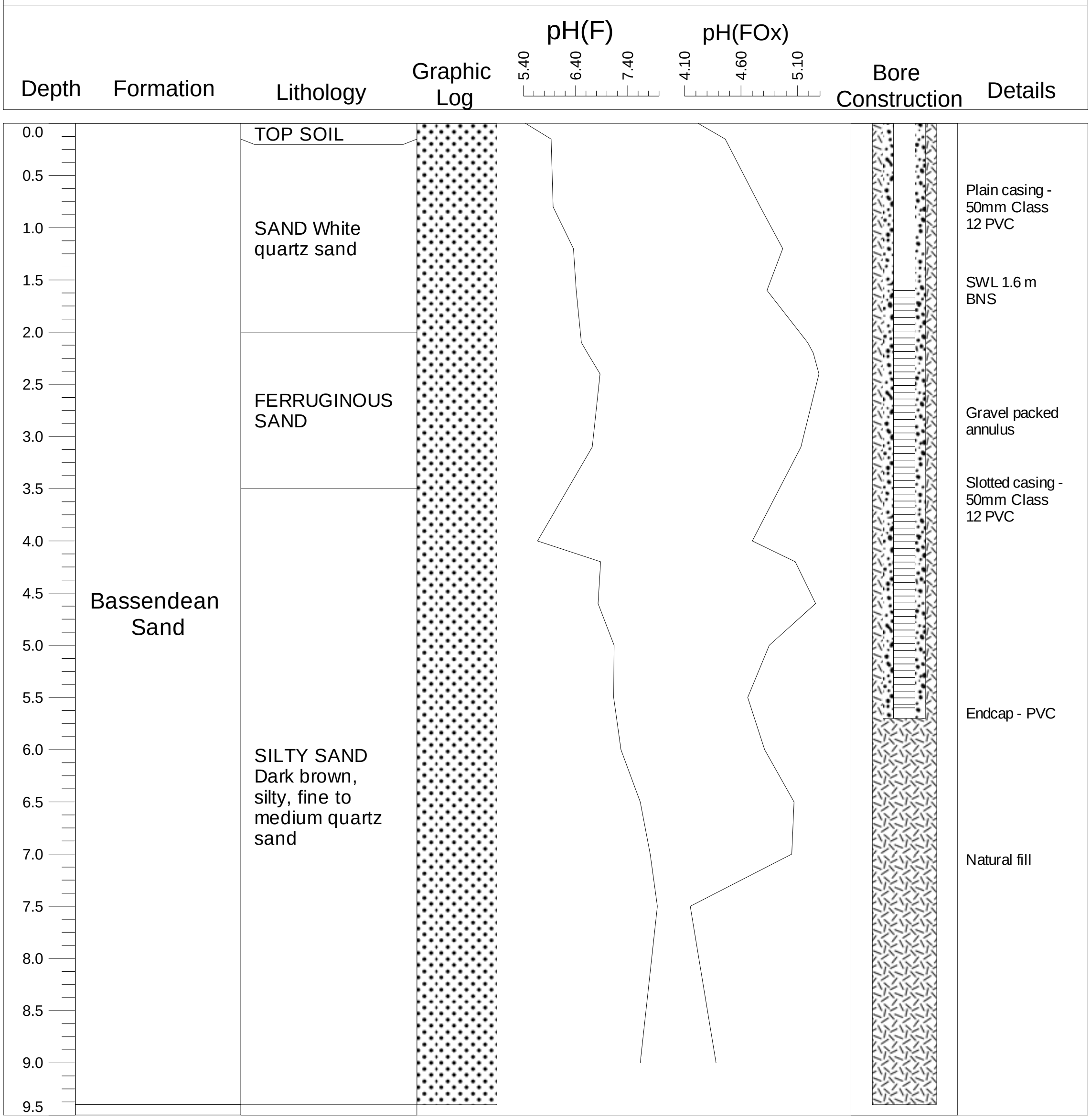
Drilled by:	Great Southern Drilling	Northing (Z50):	6442223.587	Screens (m BNS):	12.30 - 14.30
Date drilled:	5/3/07	Easting (Z50):	40074.055	SWL (m BNS):	1.46
Logged by:	Sandie McHugh	Surface (m AHD):	24.003	EC (mS/cm):	4.35
Aquifer:	Superficial	Drill depth (m BNS):	17	pH:	7.43

BORE COMPLETION DETAILS

Perth Shallow Groundwater Systems Investigation - Stage 1

Department of Water
Government of Western Australia

AWRC Name: **FRD_NEc**
AWRC Number: **61611437**



Drilled by:	Great Southern Drilling	Northing (Z50):	6442231.441	Screens (m BNS):	1.56 - 5.56
Date drilled:	5/2/07	Easting (Z50):	400069.273	SWL (m BNS):	1.6
Logged by:	Sandie McHugh	Surface (m AHD):	24.338	EC (mS/cm):	0.84
Aquifer:	Superficial	Drill depth (m BNS):	9.4	pH:	6.6

Investigator/s: PK and LC

Client: Maddestra Group

Location: Rowley Road

Site No: MG01

Date: 31/03/2010

Photo No:

Northings/Lat: 6439166

Eastings/Long: 400588

Notes: Piezometer Length -

Up Stick Length -

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	1750	Sand	Grey		Round	Dry	Layer			
1750	2500	Sand	Brown		Round	Moist to Wet	Layer			

Investigator/s: PK and LC
Client: Maddestra Group
Location: Rowley Road
Site No: MG02

Date: 31/03/2010
Photo No: 3
Northings/Lat:
Eastings/Long:

Notes: Piezometer Length – 2.566m
Up Stick Length – 0.570m

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic	Comments
From	To									
0	1000	Sand	Dk Grey		Round	Dry				
1000	1500	Sand	L Brown		Round	Moist				
1500	1800	Clayey sand	Brown to Black			Moist				
1800	2000	Clayey sand	Brown to Black			Moist to Wet				

Investigator/s:	PK and LC	Date:	30/03/2010	Notes:	Piezometer Length – 3.000m?
Client:	Maddestra Group	Photo No:			Up Stick Length – 0.500m?
Location:	Rowley Road	Northings/Lat:	6439617		
Site No:	MG03	Eastings/Long:	400702		

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic	Comments
From	To									
0	200	Sand	Dk Grey	Poor	Sub-angular	Dry	NS	Layer		
1000	1100	Sand	L Grey to White	Poor	Sub-angular	Moist	NS	Layer		
1500	1600	Sand	L Grey to White	Poor	Sub-angular	Wet	NS	Layer		

No Photo

Investigator/s: PK and LC
Client: Maddestra Group
Location: Rowley Road
Site No: MG04

Date: 31/03/2010
Photo No: 4
Northings/Lat: 64398429
Eastings/Long: 400564

Notes: Piezometer Length – 2.705m
Up Stick Length – 0.480m

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	200	Sand	Grey			Dry				
200	1050	Sand	White to L Brown			Moist				
1050	1300	Clayey Sand	Brown			Moist				
1300	1500	Clayey Sand	Grey			Wet				

Investigator/s: PK and LC
Client: Maddestra Group
Location: Rowley Road
Site No: MG05

Date: 02/04/2010
Photo No: 857
Northings/Lat: 64397548
Eastings/Long: 4008040

Notes: Piezometer Length – 3.000m
Up Stick Length – 0.550m

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	50	Sand	Grey			Dry				Top Soil
50	600	Sand	White			Dry				
600	1000	Sand	L Brown			Moist				
1000	2500	Sand	L Brown			Wet				

Investigator/s:	PK and LC	Date:	02/04/2010	Notes:	Piezometer Length – 3.000m
Client:	Maddestra Group	Photo No:	858		Up Stick Length – 0.556m
Location:	Rowley Road	Northings/Lat:	6439754		
Site No:	MG06	Eastings/Long:	400804		

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	**Organic OR Waste**	**Comments**
From	To									
0	100	Clayey Sand	Dk Brown		Round	Dry	Layer			
100	600	Sand	Lt Yellow		Round	Dry	Layer			
600	800	Sand	Lt Brown			Moist				
800	1000	Clayey Sand	Green			Moist				
1000	1050	Rock	Dk Brown							
1050	1800	Sand	Green			Moist				
1800	2500	Sand	Whtie			Wet				

Investigator/s: ANJ
Client: Maddestra Group
Location: Rowley Road
Site No: MG07

Date: 05/05/2010
Photo No: 304/305
Northings/Lat: 6439321
Eastings/Long: 400804

Notes: Piezometer Length – 4.150 m
Up Stick Length –

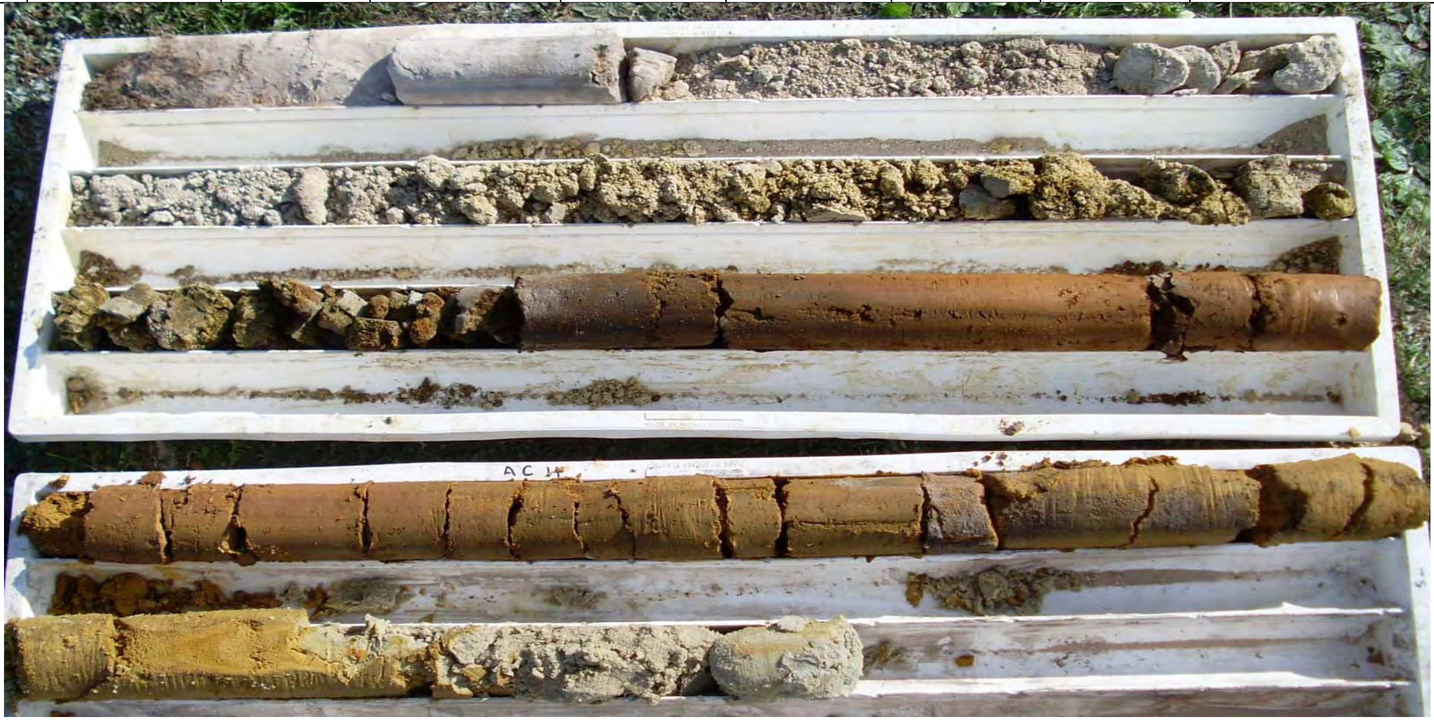
Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	200	Sand	Grey		Round	Dry	Layer			
200	800	Clayey Sand	Brown		Round	Moist to Wet	Layer			
800	1200	Rock								Limestone
1200	2000	Clay	Cream							
2000	2200	Clay	Orange							
2200	2500	Clay	Cream							
2500	3200	Clayey Sand	Green/Grey							
3200	4200	Clay	Green/Grey							

Investigator/s: ANJ
Client: Maddestra Group
Location: Rowley Road
Site No: MG08

Date: 05/05/2010
Photo No: 306/307
Northings/Lat: 6439580
Eastings/Long: 400547

Notes: Piezometer Length – 5.197m
Up Stick Length –

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	200	Sand	Grey			Dry				Top Soil
200	400	Clayey Sand	Grey			Dry				
400	1300	Rock	Cream			Dry				Limestone
1300	1800	Clayey Sand	Orange/Cream			Moist				
1800	2400	Sandy Clay	Orange/Brown			Moist				Coffee Rock
2400	4200	Clay	Orange/Brown			Moist				Coffee Rock
4200	4500	Sand	Grey			Wet				



Investigator/s: PK and LC
Client: Maddestra Group
Location: Rowley Road
Site No: MG09

Date: 05/05/2010
Photo No: 309/310
Northings/Lat: 6439166
Eastings/Long: 400588

Notes:

Depth		Type	Colour	Grade	Shape	Condition	Consistency	Structure	Organic OR Waste	Comments
From	To									
0	1000	Sand	Brown							
1000	2000	Sand	Cream Lt Brown							
2000	3000	Clayey Sand	Brown							
3000	5000	Sand	Yellow							
5000	6000	Sandy Clay	Yellow Brown							

Appendix F: Groundwater Monitoring

Bore ID	Easting	Northing	Surface Elevation (mAH	TOC Elevation (mAHD)	Stick Up (m)	Bore Depth (m)
MG01	400588	6E+06	24.034	24.604	0.57	2.5
MG02	400587	6E+06	24.139	24.739	0.6	6
MG03	400568	6E+06	24.736	25.326	0.59	2.5
MG04	400563	6E+06	24.028	24.578	0.55	2.25
MG05	400802	6E+06	24.022	24.582	0.56	2.5
MG06	400819	6E+06	23.833	24.413	0.58	2.5
MG07	400804	6E+06	24.23	24.9	0.67	4.2
MG08	401023	6E+06	24.626	25.176	0.55	7.5
MG09	401047	6E+06	24.475	25.035	0.56	7.5
MG10	401411	6E+06	24.479	25.089	0.61	3.3
MG11	401045	6E+06	24.324	24.844	0.52	2.5
MG12	401287	6E+06	24.446	24.976	0.53	3.5
MG13	401281	6E+06	24.351	25.031	0.68	7.5
MG14	401271	6E+06	24.562	25.172	0.61	7.5
MG15	401536	6E+06	24.568	25.108	0.54	7.5
MG16	401532	6E+06	23.594	24.154	0.56	7.5
MG17	401495	6E+06	23.693	24.233	0.54	7.5
MG18	401559	6E+06	24.319	24.819	0.5	3.2
MG19	401698	6E+06	24.628	25.148	0.52	
MG20	401719	6E+06	24.47	25.04	0.57	
MG21	401748	6E+06	24.335	25.105	0.77	7.5
MG22	401964	6E+06	24.955	25.435	0.48	7.5
MG23	401975	6E+06	24.85	25.43	0.58	
MG24	401992	6E+06	24.644	25.184	0.54	7.5
MG25	401970	6E+06	24.576	25.266	0.69	
X09	401056	6E+06	24.173	24.663	0.49	
W1	400708	6E+06	23.801	24.311	0.51	5
W2	400713	6E+06	24.347	25.197	0.85	2.3
W3	400663	6E+06	24.37	25.04	0.67	2.2
OX1	401554	6E+06	24.804	25.304	0.5	5.1
OX2	401357	6E+06	24.6	25.2	0.6	5
OX3	401564	6E+06	24.259	24.849	0.59	4.2
OX4	401326	6E+06	24.522	25.122	0.6	4.9
OX5	401073	6E+06	25.113	25.773	0.66	6.15
OX6	401090	6E+06	24.154	24.774	0.62	5.5
OX7	400516	6E+06	24.349	24.929	0.58	5.5
OX8	400010	6E+06	25.564	26.054	0.49	4.44
OX9	400212	6E+06	24.546	25.186	0.64	4.61
OX10	400012	6E+06	24.043	24.563	0.52	4.59
OX11	400518	6E+06	24.664	25.124	0.46	5.49
OX12	400277	6E+06	24.002	24.472	0.47	5.51
OX13	400457	6E+06	23.923	24.353	0.43	5.5
OX14	400021	6E+06	24.166	24.606	0.44	5.54
OX15	400225	6E+06	24.445	24.985	0.54	5.41
OX16	400518	6E+06	24.164	24.644	0.48	5.52
OX17	400040	6E+06	24.7	25.08	0.38	4.92
OX18	400311	6E+06	24.586	25.076	0.49	5.23
OX19	401059	6E+06	24.5	24.88	0.38	5.5
OX20	400844	6E+06	24.181	24.501	0.32	5.65
OX21	400556	6E+06	24.239	24.699	0.46	5.57
OX22	401050	6E+06	24.298	24.708	0.41	5.57
OX23	400830	6E+06	24.087	24.527	0.44	5.56
OX24	400558	6E+06	24.022	24.452	0.43	5.56
X01						
X04						
X06						
X11						
X12						
X14						
X18						
X20						
X21						
X22						
X25						

	mBTOC																																						
	24/05/2010	21/07/2010	3/09/2010	21/10/2010	21/01/2011	24/03/2011	2/05/2011	26/07/2011	30/09/2011	4/01/2012	16/03/2012	5/07/2012	16/08/2012	19/10/2012	9/11/2012	7/12/2012	9/01/2013	11/01/2013	14/02/2013	26/03/2013	30/05/2013	1/07/2013	18/07/2013	4/10/2013	14/10/2013	15/10/2013	13/11/2013	19/11/2013	31/12/2013	6/03/2014	21/04/2014	1/07/2014	3/07/2014	28/08/2014	9/09/2014	8/10/2014	2/12/2014	8/01/2015	20/02/2015
MG01	2.668	1.973	1.757	1.937	2.682			1.535	0.852	1.596	2.248	1.88	1.8	1.56		1.791		2.022	2.433	2.731	2.506		2.344		1.04				1.825										
MG02	1.917	1.384	1.221	1.481	1.93	2.105	2.26	1.138	0.857	1.367	1.756	1.32	1.39	1.241		1.406		1.571	1.763	1.85	1.652		1.452		0.978				1.522										
MG03	1.94	1.448	1.345	1.524	1.938	2.041	2.172	1.25	0.931	1.465	1.829	1.397	stomped by cows																										
MG04	1.57	0.969	0.717	1.227	1.569	1.64	1.75	0.485	0.443	1.346	1.588	0.985	0.99	1.057		1.2615		1.466	1.579	1.542	1.141		1.015		0.55				1.464										
MG05	1.426	0.968	0.711	1.214	1.445	1.474	1.562	0.485	0.455	1.218	1.386	0.989	0.99	1.077		1.2065		1.336	1.402	1.328	0.773		0.952		0.515				1.555										
MG06	1.581	0.78	0.685	1.268	1.758	1.663	1.813	0.574	0.558	1.345	1.774	1.08	1.08	1.092		1.3615		1.631	1.768	1.539	0.9		0.73		0.695														
MG07	3.15	2.411	2.223	2.268	3.097	3.294	3.432	2.185	1.805	2.327	2.903	2.364	2.32	2.2		2.439		2.678	2.962	3.19	3.01		2.79		1.935				2.519										
MG08	Blocked	Blocked	4.045	3.82	4.273	4.465	4.56	4.365	3.774	3.811	4.181	4.235	4	3.86		3.983		4.106	4.291	4.471	4.58		4.532		3.864				4.055										
MG09	Blocked	Blocked	3.72	3.562	3.902	4.105	4.198	4.124	3.561	3.487	3.81	3.97	3.9	3.627		3.6885		3.75	3.881	4.041	4.239		4.271		3.693				3.699										
MG10	3.733	3.178						3.63	1.622	2.737	3.636							2.739	2.973	3.216	3.191		2.92						2.54										
MG11	1.7	1.076	0.964	1.495	1.768	1.75	1.886	0.656	0.81	1.503	1.755			1.372		1.501		1.63	1.783	1.706	1.201		1.106		1.123				1.622										
MG12	3.562	3.142	2.638	2.762	3.535	3.74	3.802	3.305	1.96	2.623	3.442			2.675		3.0055		3.336	3.664	3.786	3.755		3.695		2.145				2.91										
MG13	3.995	3.774	3.53	3.492	4.016	4.203	4.292	4.02	3.215	3.4	3.906			3.432		3.62		3.808	4.002	4.156	4.261		4.222		3.403				3.701										
MG14	4.139	4.168	3.947	3.844	4.29	4.497	4.65	4.435	3.811	3.759	4.185			3.812		3.9535		4.095	4.265	4.46	4.579		4.566		3.918				4.035										
MG15	4.4	4.173	3.936	3.955	4.52	4.726	4.813	4.533	3.796	3.92	4.445			3.892		4.123		4.354	4.578	4.752	4.777		4.716		3.938				4.315				4.741						
MG16	3.395	3.079	2.835	2.87	3.518	3.695	3.758	3.3		2.782	3.387			2.722		2.9865		3.251	3.491	3.622	3.642		3.59						3.131				3.474						
MG17	3.386	3.077	2.824	2.85	3.49	3.654	3.73	3.33	2.53	2.773	3.376			2.75		3.008		3.266	3.492	3.618	3.651		3.61						3.131				3.549						
MG18	3.48	2.902	2.731	2.69	3.52	3.89	3.86	2.998		2.436				2.49		2.8845		3.279	3.522	3.627	3.657		2.982						2.898				3.251						
MG19	1.431	1.227	1.215	1.487	1.729	1.713	1.814	0.81	0.73	1.4	1.663			1.366		1.466		1.566	1.679	1.678	1.39		1.34		1.12				1.542				0.985						
MG20	4.195	3.903	3.657	3.653	4.29	4.477	4.552	4.19	3.451	3.557	4.164			3.54		3.7845		4.029	4.273	4.421	4.462		4.412		3.565				3.931				4.315						
MG21	4.288	4.032	3.782	3.788	4.392	4.583	4.67	4.352	3.645	3.699	4.261			3.668		3.9035		4.139	4.387	4.545	4.58		4.53		3.73				4.075				4.464						
MG22	4.603	4.433	4.151	4.102	4.638	4.84	4.947	4.795	4.133	3.968	4.5			3.992		4.1975		4.403	4.593	4.791	4.895		4.845		4.174				4.343				4.857						
MG23	4.574	4.355	4.088	4.042	4.632	4.817	4.91	4.695	4.002	3.907	4.497			3.942		4.1605		4.379	4.573	4.767	4.855		4.805		4.06				4.295				4.766						
MG24	4.293	4.074	3.782	3.734	4.327	4.514	4.608	4.388	3.655	3.603	4.202			3.66		3.872		4.084	4.304	4.479	4.574		4.524		3.721				3.984				4.466						
MG25	3.419	2.543	2.176	2.463	3.51	3.784	3.923	2.317	1.849	2.429	3.38			2.193		2.6025		3.012	3.437	3.364	3.222		3.172		1.831				3.785				1.85						
X09		2.492	2.056	2.35	3.007	3.304	3.44	2.27	1.752	2.4	2.891			2.235		2.487		2.739							1.97														
W1							1.99	0.703	0.615	1.152	1.82	0.899	0.9	0.979					2.048	2.004	1.361		1.075		0.654				1.482										
W2							2.09	1.292	1.095	1.629	1.925	1.506	1.49	1.424		1.4065		1.389	1.523	1.357	1.316		1.169		1.257				1.351										
W3							1.98	1.136	0.88	1.473	1.787	1.359	1.36	1.363		1.5095		1.656	1.809	1.822	1.588		1.433		1.085				1.604										
OX1													3.446	2.997		3.464	3.777		3.912	3.937	4.09		4.07		2.139				3.363			3.78			2.29	2.286	3.155	3.723	
OX2													3.311	2.903		3.387	3.676		3.864	3.988	4.052		3.997		2.08				3.26	3.877		3.701			2.219	2.275	3.076	3.622	3.853
OX3													1.165	1.261		1.479	1.667		1.98	2.15	1.873		1.71		0.826				1.592	2.131		1.114			0.633	0.839	1.408	1.657	1.972
OX4													2.751	2.575		2.76	3.061		3.409	3.502	3.412		3.304		1.891				2.67	2.7		3.055			2.413	2.219	2.433	2.926	2.875
OX5													2.336	2.312		2.579	2.784		3.136	3.304	3.198		3.102		2.033				2.812	3.438		2.904			2.155	2.119	2.588	2.953	3.328
OX6													2.908	2.427		2.953	3.215		3.424	3.566	3.65		3.512		2.75				2.81	3.411		3.244			1.805	1.779	2.622	3.12	3.393
OX7															1.971	2.198	2.453		2.722	2.809	2.496		2.301		1.332			1.83	2.248	2.784	2.86	2.013		1.42	1.216	1.378	1.943	2.383	2.715
OX8															3.855	3.984	4.138		4.383	4.383	4.383		4.383		3.257			3.52	3.782	4.328	Dry	4.007		3.49	3.409	3.376	3.693	3.949	4.293
OX9															2.04	2.165	2.304		2.556	2.722	2.591		2.404		1.54			1.81	2.088	2.549	2.66	2.106		1.73	1.603	1.707	2.029	2.267	2.53
OX10															1.5	1.638	1.81		2.103	2.277	2.172		2.005		0.746			1.28	1.544	2.122	2.23	1.639		1.2	1.02	1.124	1.492	1.783	2.112
OX11															1.503	1.645	1.811		2.081	2.19	1.964		1.748		0.95			1.5	1.74	2.167	2.24	1.477		1.16	0.995	1.153	1.589	1.844	2.091
OX12															1.161	1.271	1.4		1.628	1.841	1.755		1.564		0.438			1.190	1.288	1.677	1.8	1.278		0.77	0.425	0.768	1.206	1.384	1.656
OX13															1.116	1.279	1.368		1.504	1.565	1.352	1.13	1.134	0.43	0.453	0.47	1.15		1.15	1.63	1.63			0.58					
OX14															1.653	1.842	2.001		2.306	2.517	2.408	2.24	2.238	0.86	0.950	0.99	1.39		1.39	2.5	2.5			1.28					
OX15															1.265	1.361	1.388		1.678	1.758	1.275	1.17	1.167	0.68	0.838	0.83	1.15		1.15	1.7	1.7			0.79					
OX16															1.356	1.517	1.681		1.946	2.155	1.971	1.76	1.762	0.74	0.891	0.9	1.24		1.24	2.18	2.18			0.89					
OX17															1.113	1.241	1.364		1.565	1.558	1.281	1.13	1.125	0.62	0.770	0.77	1.08		1.08	1.69	1.69			0.77					
OX18															1.319	1.428	1.537		1.741	1.757	1.551	1.37	1.368	0.91	1.020	0.98	1.24		1.24	1.87	1.87			0.99					
OX19															1.274	1.414	1.514		1.692	1.699	1.444		1.288		0.827				1.392	1.691		0.982			0.646	0.852	1.271	1.541	1.806
OX20															1.259	1.688	2.144		2.606	2.626	2.068		1.485		0.637				2.151	2.815		0.926			0.655	0.699	1.71	2.34	2.701
OX21															1.265	1.457	1.648		1.987	2.137	1.812		1.604		0.913				2.028	2.116		1.422			0.784	0.956	1.408	1.736	2.101
OX22															2.538	2.828	3.082		3.3	3.407	3.433		3.385		1.665				2.675	3.283		3.046			1.725	1.718	2.509	2.998	3.271
OX23															1.2	1.569	1.875		2.405	2.354	1.777		1.192		0.613				1.812	2.506		0.698			0.54	0.615	1.534	1.942	2.384
OX24															1.275	1.804	2.22		2.636	2.586	1.634		1.09		0.497				2.238	2.779		0.685			0.585	0.534	1.82	2.27	2.721
X01		1.812																																					
X04		0.897																																					
X06		1.157																																					
X11		1.18																																					
X12		3.082																																					
X14		3.988																																					
X18		2.922																																					
X20		3.555																																					
X21		3.388																																					
X22																																							
X25		3.34																																					

	mBGL																																						
	24/05/2010	21/07/2010	3/09/2010	21/10/2010	21/01/2011	24/03/2011	2/05/2011	26/07/2011	30/09/2011	4/01/2012	16/03/2012	5/07/2012	16/08/2012	19/10/2012	9/11/2012	7/12/2012	9/01/2013	11/01/2013	14/02/2013	26/03/2013	30/05/2013	1/07/2013	18/07/2013	4/10/2013	14/10/2013	15/10/2013	13/11/2013	19/11/2013	31/12/2013	6/03/2014	21/04/2014	1/07/2014	3/07/2014	28/08/2014	9/09/2014	8/10/2014	2/12/2014	8/01/2015	20/02/2015
MG01	2.098	1.403	1.187	1.367	2.112			0.965	0.282	1.026	1.678	1.31	1.23	0.99		1.221		1.452	1.863	2.161	1.936		1.774		0.47				1.255										
MG02	1.317	0.784	0.621	0.881	1.33	1.505	1.66	0.538	0.257	0.767	1.156	0.72	0.79	0.641		0.806		0.971	1.163	1.25	1.052		0.852		0.378				0.922										
MG03	1.35	0.858	0.755	0.934	1.348	1.451	1.582	0.66	0.341	0.875	1.239	0.807																											
MG04	1.02	0.419	0.167	0.677	1.019	1.09	1.2	-0.065	-0.107	0.796	1.038	0.435	0.44	0.507		0.7115		0.916	1.029	0.992	0.591		0.465		0				0.914										
MG05	0.866	0.408	0.151	0.654	0.885	0.914	1.002	-0.075	-0.105	0.658	0.826	0.429	0.43	0.517		0.6465		0.776	0.842	0.768	0.213		0.392		-0.045				0.995										
MG06	1.001	0.2	0.105	0.688	1.178	1.083	1.233	-0.006	-0.022	0.765	1.194	0.5	0.5	0.512		0.7815		1.051	1.188	0.959	0.32		0.15		0.115														
MG07	2.48	1.741	1.553	1.598	2.427	2.624	2.762	1.515	1.135	1.657	2.233	1.694	1.65	1.53		1.769		2.008	2.292	2.52	2.34		2.12		1.265				1.849										
MG08			3.495	3.27	3.723	3.915	4.01	3.815	3.224	3.261	3.631	3.685	3.45	3.31		3.433		3.556	3.741	3.921	4.03		3.982		3.314				3.505										
MG09			3.16	3.002	3.342	3.545	3.638	3.564	3.001	2.927	3.25	3.41	3.34	3.067		3.1285		3.19	3.321	3.481	3.679		3.711		3.133				3.139										
MG10	3.123	2.568						3.02	1.012	2.127	3.026							2.129	2.363	2.606	2.581		2.31						1.93										
MG11	1.18	0.556	0.444	0.975	1.248	1.23	1.366	0.136	0.29	0.983	1.235			0.852		0.981		1.11	1.263	1.186	0.681		0.586		0.603				1.102										
MG12	3.032	2.612	2.108	2.232	3.005	3.21	3.272	2.775	1.43	2.093	2.912			2.145		2.4755		2.806	3.134	3.256	3.225		3.165		1.615				2.38										
MG13	3.315	3.094	2.85	2.812	3.336	3.523	3.612	3.34	2.535	2.72	3.226			2.752		2.94		3.128	3.322	3.476	3.581		3.542		2.723				3.021										
MG14	3.529	3.558	3.337	3.234	3.68	3.887	4.04	3.825	3.201	3.149	3.575			3.202		3.3435		3.485	3.655	3.85	3.969		3.956		3.308				3.425										
MG15	3.86	3.633	3.396	3.415	3.98	4.186	4.273	3.993	3.256	3.38	3.905			3.352		3.583		3.814	4.038	4.212	4.237		4.176		3.398				3.775				4.201						
MG16	2.835	2.519	2.275	2.31	2.958	3.135	3.198	2.74		2.222	2.827			2.162		2.4265		2.691	2.931	3.062	3.082		3.03						2.571				2.914						
MG17	2.846	2.537	2.284	2.31	2.95	3.114	3.19	2.79	1.99	2.233	2.836			2.21		2.468		2.726	2.952	3.078	3.111		3.07						2.591				3.009						
MG18	2.98	2.402	2.231	2.19	3.02	3.39	3.36	2.498		1.936				1.99		2.3845		2.779	3.022	3.127	3.157		2.482						2.398				2.751						
MG19	0.911	0.707	0.695	0.967	1.209	1.193	1.294	0.29	0.21	0.88	1.143			0.846		0.946		1.046	1.159	1.158	0.87		0.82		0.6				1.022				0.465						
MG20	3.625	3.333	3.087	3.083	3.72	3.907	3.982	3.62	2.881	2.987	3.594			2.97		3.2145		3.459	3.703	3.851	3.892		3.842		2.995				3.361				3.745						
MG21	3.518	3.262	3.012	3.018	3.622	3.813	3.9	3.582	2.875	2.929	3.491			2.898		3.1335		3.369	3.617	3.775	3.81		3.76		2.96				3.305				3.694						
MG22	4.123	3.953	3.671	3.622	4.158	4.36	4.467	4.315	3.653	3.488	4.02			3.512		3.7175		3.923	4.113	4.311	4.415		4.365		3.694				3.863				4.377						
MG23	3.994	3.775	3.508	3.462	4.052	4.237	4.33	4.115	3.422	3.327	3.917			3.362		3.5805		3.799	3.993	4.187	4.275		4.225		3.48				3.715				4.186						
MG24	3.753	3.534	3.242	3.194	3.787	3.974	4.068	3.848	3.115	3.063	3.662			3.12		3.332		3.544	3.764	3.939	4.034		3.984		3.181				3.444				3.926						
MG25	2.729	1.853	1.486	1.773	2.82	3.094	3.233	1.627	1.159	1.739	2.69			1.503		1.9125		2.322	2.747	2.674	2.532		2.482		1.141				3.095				1.16						
X09		2.002	1.566	1.86	2.517	2.814	2.95	1.78	1.262	1.91	2.401			1.745		1.997		2.249							1.48														
W1							1.48	0.193	0.105	0.642	1.31	0.389	0.39	0.469					1.538	1.494	0.851		0.565		0.144				0.972										
W2							1.24	0.442	0.245	0.779	1.075	0.656	0.64	0.574		0.5565		0.539	0.673	0.507	0.466		0.319		0.407				0.501										
W3							1.31	0.466	0.21	0.803	1.117	0.689	0.69	0.693		0.8395		0.986	1.139	1.152	0.918		0.763		0.415				0.934										
OX1													2.946	2.497		2.964	3.277		3.412	3.437	3.59		3.57		1.639				2.863			3.28			1.79	1.786	2.655	3.223	
OX2													2.711	2.303		2.787	3.076		3.264	3.388	3.452		3.397		1.48				2.66	3.277		3.101			1.619	1.675	2.476	3.022	3.253
OX3													0.575	0.671		0.889	1.077		1.39	1.56	1.283		1.12		0.236				1.002	1.541		0.524			0.043	0.249	0.818	1.067	1.382
OX4													2.151	1.975		2.16	2.461		2.809	2.902	2.812		2.704		1.291				2.07	2.1		2.455			1.813	1.619	1.833	2.326	2.275
OX5													1.68	1.65		1.92	2.12		2.48	2.64	2.54		2.44		1.37				2.15	2.78		2.24			1.50	1.46	1.93	2.29	2.67
OX6													2.288	1.807		2.333	2.595		2.804	2.946	3.03		2.892		2.13				2.19	2.791		2.624			1.185	1.159	2.002	2.5	2.773
OX7															1.391	1.618	1.873		2.142	2.229	1.916		1.721		0.752			1.25	1.668	2.204	2.28	1.433		0.84	0.636	0.798	1.363	1.803	2.135
OX8															3.365	3.494	3.648		3.893	3.893	3.893		3.893		2.767			3.03	3.292	3.838		3.517		3	2.919	2.886	3.203	3.459	3.803
OX9															1.4	1.525	1.664		1.916	2.082	1.951		1.764		0.9			1.17	1.448	1.909	2.02	1.466		1.09	0.963	1.067	1.389	1.627	1.89
OX10															0.98	1.118	1.29		1.583	1.757	1.652		1.485		0.226			0.76	1.024	1.602	1.71	1.119		0.68	0.5	0.604	0.972	1.263	1.592
OX11															1.043	1.185	1.351		1.621	1.73	1.504		1.288		0.49			1.04	1.28	1.707	1.78	1.017		0.7	0.535	0.693	1.129	1.384	1.631
OX12															0.691	0.801	0.93		1.158	1.371	1.285		1.094		-0.032			0.72	0.818	1.207	1.33	0.808		0.3	-0.045	0.298	0.736	0.914	1.186
OX13															0.686	0.849	0.938		1.074	1.135	0.922	0.7	0.704	0	0.023	0.04	0.72		0.72	1.2	1.2			0.15					
OX14															1.213	1.402	1.561		1.866	2.077	1.968	1.8	1.798	0.42	0.51	0.55	0.95		0.95	2.06	2.06			0.84					
OX15															0.725	0.821	0.848		1.138	1.218	0.735	0.63	0.627	0.14	0.298	0.29	0.61		0.61	1.16	1.16			0.25					
OX16															0.876	1.037	1.201		1.466	1.675	1.491	1.28	1.282	0.26	0.411	0.42	0.76		0.76	1.7	1.7			0.41					
OX17															0.733	0.861	0.984		1.185	1.178	0.901	0.75	0.745	0.24	0.39	0.39	0.7		0.7	1.31	1.31			0.39					
OX18															0.829	0.938	1.047		1.251	1.267	1.061	0.88	0.878	0.42	0.53	0.49	0.75		0.75	1.38	1.38			0.5					
OX19															0.894	1.034	1.134		1.312	1.319	1.064		0.908		0.447				1.012	1.311		0.602			0.266	0.472	0.891	1.161	1.426
OX20															0.939	1.368	1.824		2.286	2.306	1.748		1.165		0.317				1.831	2.495		0.606			0.335	0.379	1.39	2.02	2.381
OX21															0.805	0.997	1.188		1.527	1.677	1.352		1.144		0.453				1.568	1.656		0.962			0.324	0.496	0.948	1.276	1.641
OX22															2.128	2.418	2.672		2.89	2.997	3.023		2.975		1.255				2.265	2.873		2.636			1.315	1.308	2.099	2.588	2.861
OX23															0.76	1.129	1.435		1.965	1.914	1.337		0.752		0.173				1.372	2.066		0.258			0.1	0.175	1.094	1.502	1.944
OX24															0.845	1.374	1.79		2.206	2.156	1.204		0.66		0.067				1.808	2.349		0.255			0.155	0.104	1.39	1.84	2.291

	mAHD																																						
	24/05/2010	21/07/2010	3/09/2010	21/10/2010	21/01/2011	24/03/2011	2/05/2011	26/07/2011	30/09/2011	4/01/2012	16/03/2012	5/07/2012	16/08/2012	19/10/2012	9/11/2012	7/12/2012	9/01/2013	11/01/2013	14/02/2013	26/03/2013	30/05/2013	1/07/2013	18/07/2013	4/10/2013	14/10/2013	15/10/2013	13/11/2013	19/11/2013	31/12/2013	6/03/2014	21/04/2014	1/07/2014	3/07/2014	28/08/2014	9/09/2014	8/10/2014	2/12/2014	8/01/2015	20/02/2015
MG01	21.936	22.631	22.847	22.667	21.922			23.069	23.752	23.008	22.356	22.724	22.804	23.044		22.813		22.582	22.171	21.873	22.098		22.26		23.564				22.779										
MG02	22.822	23.355	23.518	23.258	22.809	22.634	22.479	23.601	23.882	23.372	22.983	23.419	23.349	23.498		23.333		23.168	22.976	22.889	23.087		23.287		23.761				23.217										
MG03	23.386	23.878	23.981	23.802	23.388	23.285	23.154	24.076	24.395	23.861	23.497	23.929																											
MG04	23.008	23.609	23.861	23.351	23.009	22.938	22.828	24.093	24.135	23.232	22.99	23.593	23.588	23.521		23.317		23.112	22.999	23.036	23.437		23.563		24.028				23.114										
MG05	23.156	23.614	23.871	23.368	23.137	23.108	23.02	24.097	24.127	23.364	23.196	23.593	23.592	23.505		23.376		23.246	23.18	23.254	23.809		23.63		24.067				23.027										
MG06	22.832	23.633	23.728	23.145	22.655	22.75	22.6	23.839	23.855	23.068	22.639	23.333	23.333	23.321		23.052		22.782	22.645	22.874	23.513		23.683		23.718														
MG07	21.75	22.489	22.677	22.632	21.803	21.606	21.468	22.715	23.095	22.573	21.997	22.536	22.58	22.7		22.461		22.222	21.938	21.71	21.89		22.11		22.965				22.381										
MG08			21.131	21.356	20.903	20.711	20.616	20.811	21.402	21.365	20.995	20.941	21.176	21.316		21.193		21.07	20.885	20.705	20.596		20.644		21.312				21.121										
MG09			21.315	21.473	21.133	20.93	20.837	20.911	21.474	21.548	21.225	21.065	21.135	21.408		21.347		21.285	21.154	20.994	20.796		20.764		21.342				21.336										
MG10	21.356	21.911						21.459	23.467	22.352	21.453							22.35	22.116	21.873	21.898		22.169						22.549										
MG11	23.144	23.768	23.88	23.349	23.076	23.094	22.958	24.188	24.034	23.341	23.089			23.472		23.343		23.214	23.061	23.138	23.643		23.738		23.721				23.222										
MG12	21.414	21.834	22.338	22.214	21.441	21.236	21.174	21.671	23.016	22.353	21.534			22.301		21.971		21.64	21.312	21.19	21.221		21.281		22.831				22.066										
MG13	21.036	21.257	21.501	21.539	21.015	20.828	20.739	21.011	21.816	21.631	21.125			21.599		21.411		21.223	21.029	20.875	20.77		20.809		21.628				21.33										
MG14	21.033	21.004	21.225	21.328	20.882	20.675	20.522	20.737	21.361	21.413	20.987			21.36		21.219		21.077	20.907	20.712	20.593		20.606		21.254				21.137										
MG15	20.708	20.935	21.172	21.153	20.588	20.382	20.295	20.575	21.312	21.188	20.663			21.216		20.985		20.754	20.53	20.356	20.331		20.392		21.17				20.793				20.367						
MG16	20.759	21.075	21.319	21.284	20.636	20.459	20.396	20.854		21.372	20.767			21.432		21.168		20.903	20.663	20.532	20.512		20.564						21.023				20.68						
MG17	20.847	21.156	21.409	21.383	20.743	20.579	20.503	20.903	21.703	21.46	20.857			21.483		21.225		20.967	20.741	20.615	20.582		20.623						21.102				20.684						
MG18	21.339	21.917	22.088	22.129	21.299	20.929	20.959	21.821		22.383				22.329		21.935		21.54	21.297	21.192	21.162		21.837						21.921				21.568						
MG19	23.717	23.921	23.933	23.661	23.419	23.435	23.334	24.338	24.418	23.748	23.485			23.782		23.682		23.582	23.469	23.47	23.758		23.808		24.028				23.606				24.163						
MG20	20.845	21.137	21.383	21.387	20.75	20.563	20.488	20.85	21.589	21.483	20.876			21.5		21.256		21.011	20.767	20.619	20.578		20.628		21.475				21.109				20.725						
MG21	20.817	21.073	21.323	21.317	20.713	20.522	20.435	20.753	21.46	21.406	20.844			21.437		21.202		20.966	20.718	20.56	20.525		20.575		21.375				21.03				20.641						
MG22	20.832	21.002	21.284	21.333	20.797	20.595	20.488	20.64	21.302	21.467	20.935			21.443		21.238		21.032	20.842	20.644	20.54		20.59		21.261				21.092				20.578						
MG23	20.856	21.075	21.342	21.388	20.798	20.613	20.52	20.735	21.428	21.523	20.933			21.488		21.27		21.051	20.857	20.663	20.575		20.625		21.37				21.135				20.664						
MG24	20.891	21.11	21.402	21.45	20.857	20.67	20.576	20.796	21.529	21.581	20.982			21.524		21.312		21.1	20.88	20.705	20.61		20.66		21.463				21.2				20.718						
MG25	21.847	22.723	23.09	22.803	21.756	21.482	21.343	22.949	23.417	22.837	21.886			23.073		22.664		22.254	21.829	21.902	22.044		22.094		23.435				21.481				23.416						
X09		22.171	22.607	22.313	21.656	21.359	21.223	22.393	22.911	22.263	21.772			22.428		22.176		21.924							22.693														
W1							22.321	23.608	23.696	23.159	22.491	23.412	23.411	23.332					22.263	22.307	22.95		23.236		23.657				22.829										
W2							23.107	23.905	24.102	23.568	23.272	23.691	23.707	23.773		23.791		23.808	23.674	23.84	23.881		24.028		23.94				23.846										
W3							23.06	23.904	24.16	23.567	23.253	23.681	23.68	23.677		23.531		23.384	23.231	23.218	23.452		23.607		23.955				23.436										
OX1													21.858	22.307		21.84	21.527		21.392	21.367	21.214		21.234		23.165				21.941			21.524			23.014	23.018	22.149	21.581	
OX2													21.889	22.297		21.813	21.524		21.336	21.212	21.148		21.203		23.12				21.94	21.323		21.499			22.981	22.925	22.124	21.578	21.347
OX3													23.684	23.588		23.37	23.182		22.869	22.699	22.976		23.139		24.023				23.257	22.718		23.735			24.216	24.01	23.441	23.192	22.877
OX4													22.371	22.547		22.362	22.061		21.713	21.62	21.71		21.818		23.231				22.452	22.422		22.067			22.709	22.903	22.689	22.196	22.247
OX5													23.44	23.46		23.19	22.99		22.64	22.47	22.58		22.67		23.74				22.96	22.34		22.87			23.62	23.65	23.19	22.82	22.45
OX6													21.866	22.347		21.821	21.559		21.35	21.208	21.124		21.262		22.024				21.964	21.363		21.53			22.969	22.995	22.152	21.654	21.381
OX7															22.958	22.731	22.476		22.207	22.12	22.433		22.628		23.597			23.099	22.681	22.145	22.069	22.916		23.509	23.713	23.551	22.986	22.546	22.214
OX8															22.199	22.07	21.916		21.671	21.671	21.671		21.671		22.797			22.534	22.272	21.726		22.047		22.564	22.645	22.678	22.361	22.105	21.761
OX9															23.146	23.021	22.882		22.63	22.464	22.595		22.782		23.646			23.376	23.098	22.637	22.526	23.08		23.456	23.583	23.479	23.157	22.919	22.656
OX10															23.063	22.925	22.753		22.46	22.286	22.391		22.558		23.817			23.283	23.019	22.441	22.333	22.924		23.363	23.543	23.439	23.071	22.78	22.451
OX11															23.621	23.479	23.313		23.043	22.934	23.16		23.376		24.174			23.624	23.384	22.957	22.884	23.647		23.964	24.129	23.971	23.535	23.28	23.033
OX12															23.311	23.201	23.072		22.844	22.631	22.717		22.908		24.034			23.282	23.184	22.795	22.672	23.194		23.702	24.047	23.704	23.266	23.088	22.816
OX13															23.237	23.074	22.985		22.849	22.788	23.001	23.223	23.219	23.923	23.9	23.883	23.203		23.203	22.723	22.723			23.773					
OX14															22.953	22.764	22.605		22.3	22.089	22.198	22.366	22.368	23.746	23.656	23.616	23.216		23.216	22.106	22.106			23.326					
OX15															23.72	23.624	23.597		23.307	23.227	23.71	23.815	23.818	24.305	24.147	24.155	23.835		23.835	23.285	23.285			24.195					
OX16															23.288	23.127	22.963		22.698	22.489	22.673	22.884	22.882	23.904	23.753	23.744	23.404		23.404	22.464	22.464			23.754					
OX17															23.967	23.839	23.716		23.515	23.522	23.799	23.95	23.955	24.46	24.31	24.31	24		24	23.39	23.39			24.31					
OX18															23.757	23.648	23.539		23.335	23.319	23.525	23.706	23.708	24.166	24.056	24.096	23.836		23.836	23.206	23.206			24.086					
OX19															23.606	23.466	23.366		23.188	23.181	23.436		23.592		24.053				23.488	23.189		23.898			24.234	24.028	23.609	23.339	23.074
OX20															23.242	22.813	22.357		21.895	21.875	22.433		23.016		23.864				22.35	21.686		23.575			23.846	23.802	22.791	22.161	21.8
OX21															23.434	23.242	23.051		22.712	22.562	22.887		23.095		23.786				22.671	22.583		23.277			23.915	23.743	23.291	22.963	22.598
OX22															22.17	21.88	21.626		21.408	21.301	21.275		21.323		23.043				22.033	21.425		21.662			22.983	22.99	22.199	21.71	21.437
OX23															23.327	22.958	22.652		22.122	22.173	22.75		23.335		23.914				22.715	22.021		23.829			23.987	23.912	22.993	22.585	22.143
OX24															23.177	22.648	22.232		21.816	21.866	22.818		23.362		23.955				22.214	21.673		23.767			23.867	23.918	22.632	22.182	21.731

pH	**16/08/2012**	**9/11/2012**	**15/02/2013**	**30/05/2013**	**6/03/2014**	**1/07/2014**	**9/09/2014**	**8/01/2015**	**pH**	**20/05/2010**	**21/10/2010**	**16/01/2013**	**30/05/2013**
OX1	7.04		7.09						**MG01**		4.72	4.17	4.910
OX2	7.25		7.3	7.400	7.120	7.58		7.62	**MG02**	4.58	4.06	3.78	
OX3	6.36		6.48			6.51		6.31	**MG03**		4.90		
OX4	6.06		6.55						**MG04**	6.98	6.93	6.41	6.740
OX5	4.76		5.13	4.830	4.930	4.84		4.31	**MG05**	6.31	6.35	5.77	6.260
OX6	6.56		6.49	6.680	6.320	6.87		6.53	**MG06**	6.63	6.70	6.31	
OX7		6.16	6.1	6.010			5.81	5.54	**MG07**	6.47	6.83	6.35	
OX8							3.92		**MG08**				
OX9		4.75	4.49	4.490	4.390		3.91	3.59	**MG09**				
OX10		5.73	5.8	6.020	5.650		5.71	5.7	**MG10**		7.05	7.69	
OX11		4.66	4.35	4.340	4.250		3.98	3.7	**MG11**	6.70	6.45		
OX12		5.69	5.62	5.760	5.570		5.48	5.49	**MG12**	6.29	6.52		
OX13		6.06	5.7	6.030					**MG13**	6.91	6.58	6.26	
OX14		4.55	4.72	4.410					**MG14**	6.60	6.49	6.34	
OX15		4.37	4.24	4.350					**MG15**	6.51	6.25	6.12	6.300
OX16		4.99	4.72	4.750					**MG16**	6.90	6.73	6.26	6.360
OX17		4.63	4.51	4.660					**MG17**	6.84	6.81	6.85	
OX18		4.7	4.86	4.870					**MG18**	6.52		6.03	6.020
OX19		4.92	4.68		4.690	4.46		4.19	**MG19**	6.19	6.67	6.67	
OX20			6.38	6.550	6.290			6.78	**MG20**	6.76	6.62	6.62	
OX21		4.9	4.3	4.580	4.240	3.78		3.63	**MG21**	6.60	7.09	7.09	
OX22		6.12	5.91		5.860	6.39		6.33	**MG22**	6.76	6.42	6.42	
OX23			6.7	6.900	6.610	7.29		7.24	**MG23**	6.07	6.58	6.58	
OX24		7.12	6.53	7.090	6.410	7.22		7.04	**MG24**	6.36	3.62	3.62	
									MG25	6.85	6.45	6.45	
									W1				
									W2			4.05	4.240
									W3			4.46	

EC (mS/cm)	**16/08/2012**	**9/11/2012**	**15/02/2013**	**30/05/2013**	**6/03/2014**	**1/07/2014**	**9/09/2014**	**8/01/2015**	**EC**	**20/05/2010**	**21/10/2010**	**16/01/2013**	**30/05/2013**
OX1	1.112		0.984						**MG01**		0.205	0.154	0.177
OX2	1.733		1.563	1.741	1.299	1.59		1.33	**MG02**	0.28	0.238	0.197	
OX3	1.341		1.06			1.16		0.84	**MG03**		0.173		
OX4	2.482		8.17						**MG04**	6.23	8.55	6.36	5.070
OX5	2.82		1.94	2.390	1.859	1.96		1.88	**MG05**	1.02	0.857	0.532	0.577
OX6	20.3		20	20.000	20.500	23.4		26.3	**MG06**	2.45	2.57	2.31	
OX7		1.152	0.628	0.661			1.1	2.17	**MG07**	3.84	4.51	2.87	
OX8							0.146		**MG08**				
OX9		0.123	0.098	0.108	0.114		0.116	0.14	**MG09**				
OX10		0.195	0.169	0.186	0.155		0.166	0.16	**MG10**		2.57	1.193	
OX11		0.247	0.243	0.249	0.195		0.191	0.24	**MG11**	0.88	0.454		
OX12		0.264	0.223	0.227	0.206		0.209	0.23	**MG12**	17.20	17.75		
OX13		0.547	0.47	0.543					**MG13**	2.68	2.85	2.88	
OX14		0.357	0.257	0.377					**MG14**	2.42	2.08	1.927	
OX15		0.456	0.52	0.556					**MG15**	1.74	1.63	1.0	1.033
OX16		0.242	0.236	0.285					**MG16**	4.06	4.11	3.47	3.380
OX17		0.755	0.726	0.626					**MG17**	3.64	5.08	5.15	
OX18		0.265	0.245	0.262					**MG18**	4.34		8.4	9.090
OX19		0.418	0.204		0.197	0.527		0.56	**MG19**	1.03	1.07	1.07	
OX20			11.62	10.670	9.950				**MG20**	2.40	2.36	2.36	
OX21		0.199	0.241	0.229	0.222	0.415		0.45	**MG21**	2.04	3.55	3.55	
OX22		13.59	17.51		15.790	17.5		18.2	**MG22**	2.28	2.33	2.33	
OX23			20	16.650	16.650	19.2		23	**MG23**	3.02	2.94	2.94	
OX24		20	20	20 (over)	over	48.1		59.2	**MG24**	8.04	11.73	11.73	
									MG25	1.02	0.543	0.543	
									W1				
									W2			1.0	1.040
									W3			0.582	

SO4 (mg/L)	**16/08/2012**	**9/11/2012**	**15/02/2013**	**30/05/2013**	**6/03/2014**	**1/07/2014**	**9/09/2014**	**8/01/2015**	**Sulphate**	**20/05/2010**	**21/10/2010**	**16/01/2013**	**30/05/2013**
OX1	30.24		34.61						**MG01**		<0.01	11.22	25.34
OX2	112.02		82.69	137.99	61.86	101.7		111	**MG02**		<0.01	17.58	
OX3	115.3		46			47.9		18.1	**MG03**		<0.01		
OX4	22.76		123.55						**MG04**		240	772.38	66.42
OX5	51.08		92.74	95.27	84.39	73.4		61.5	**MG05**			61.7	79.21
OX6	2294.4		1799.35	1846.15	1468.1	1887.3		2140	**MG06**		<0.01	102.7	
OX7		11.83	19.5				9.32	57.8	**MG07**		193	412.08	
OX8							43.1		**MG08**				
OX9		19.01	1.86	15.86	2.24		20.5	20.3	**MG09**				
OX10		13.85	14.57	2.49	5.23		18.6	5.74	**MG10**		276	85.22	
OX11		10.31	3.29	18.22	22.81		23.4	21.5	**MG11**		9		
OX12		2.93	33.41	7.46	9.51		14.8	6.81	**MG12**		206		
OX13		2.43	1.1	12.78					**MG13**		193	160.73	
OX14		68.96	47.43	22.49					**MG14**		240	283.71	
OX15		41.25	47.22	101.18					**MG15**		155	100.32	120.54
OX16		31.34	12.54	12.31					**MG16**		220	389.43	311.19
OX17		59.35	28.43	45.51					**MG17**		226	172.6	
OX18		15.37	18.76	23.86					**MG18**			432.58	313.65
OX19		0.2	21.74		20.39	23.3		22.2	**MG19**		<0.01	<0.01	
OX20			370.37	426.81	303.26			723	**MG20**		87	87	
OX21		34.48	56.51	53.63	50.87	28.8		22.2	**MG21**		220	220	
OX22		1314.46	2401.43		325.24	12.05		1290	**MG22**		232	232	
OX23			1182.8	639.61	292.27			1478	**MG23**		103	103	
OX24		2408.49	4384.7	2546.13	1534.1	2464.3		2160	**MG24**		232	232	
									MG25		52	52	
									W1				
									W2			98.17	111.93
									W3			30.42	

NO3 (mg/L)	**16/08/2012**	**9/11/2012**	**15/02/2013**	**30/05/2013**	**6/03/2014**	**1/07/2014**	**9/09/2014**	**8/01/2015**	**Nitrate N**	**20/05/2010**	**21/10/2010**	**16/01/2013**	**30/05/2013**
OX1	0.076		0.006						**MG01**		1.88	0.1	0.000
OX2	0		0.006	0.000	0.000	0		<0.01	**MG02**		2.2	<0.01	
OX3	1.72		0.34			0.23		0.01	**MG03**		5.2		
OX4	0.86		0.08						**MG04**		6.8	0.08	0.440
OX5	0		0	0.000	0.051	0		<0.01	**MG05**		1.44	<0.01	0.000
OX6	0		0.003	0.000	0.012	0		<0.01	**MG06**		0.13	<0.01	
OX7		<0.005	0.043	0.000			0.01	<0.01	**MG07**		0.33	0.15	
OX8							0.14		**MG08**				
OX9		0.003	0	0.000	0.006		0.028	<0.01	**MG09**				
OX10		<0.005	0.24	0.036	0.015		0.18	0.34	**MG10**		0.006	3.76	
OX11		<0.005	0	0.000	0.000		0.338	<0.01	**MG11**		0.003		
OX12		0.04	0	0.009	0.018		0.13	0.14	**MG12**		0.34		
OX13		<0.005	0.006	0.240					**MG13**		0.003	0.018	
OX14		<0.005	0.003	0.000					**MG14**		<0.01	<0.01	
OX15		0.063	0	0.900					**MG15**		0.015	0.028	0.006
OX16		<0.005	0	0.085					**MG16**		0.018	<0.01	0.000
OX17		<0.005	0	0.000					**MG17**		0.021	<0.01	
OX18		<0.005	0	0.028					**MG18**			<0.01	0.000
OX19		<0.005	0		0.000	0		<0.01	**MG19**		6.2	6.2	
OX20				0.000	0.000			0.01	**MG20**		<0.01	<0.01	
OX21		0.003	0	0.000	0.000	0		<0.01	**MG21**		<0.01	<0.01	
OX22		0.063	0		0.000	0.04		<0.01	**MG22**		0.04	0.04	
OX23		0	0.006	0.032	0.018	0.018		<0.01	**MG23**		0.003	0.003	
OX24		0	0.009	0.180	0.021	0.7		0.02	**MG24**		<0.01	<0.01	
									MG25		0.018	0.018	
									W1				
									W2			0.7	0.350
									W3			<0.01	

TN (mg/L)	16/08/2012	9/11/2012	15/02/2013	30/05/2013	6/03/2014	1/07/2014	9/09/2014	8/01/2015	total N	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1	<0.01		0.343						**MG01**			0.735	0.506
OX2	<0.01		0.4	0.245	0.118	0.0776		0.12	**MG02**			1.335	
OX3	<0.01		7.702			0.434		0.05	**MG03**				
OX4	0.09		0.981						**MG04**			0.936	0.751
OX5	<0.01		2.262	0.236	2.317	0.771		1.81	**MG05**			1.745	2.375
OX6	<0.01		0.141	0.021	0.025	0.043		<0.01	**MG06**			0.316	
OX7		1.216	0.327				1.86	1.63	**MG07**			0.152	
OX8							0.526		**MG08**				
OX9		0.462	0.448	0.363	0.742		0.711	0.47	**MG09**				
OX10		0.49	0.606	0.532	0.948		1.019	0.94	**MG10**			<0.01	
OX11		0.711	0.929	0.831	0.691		1.39	0.86	**MG11**				
OX12		0.936	4.006	0.920	0.826		1.06	0.8	**MG12**				
OX13		0.829	0.578	1.025					**MG13**			<0.01	
OX14		1.09	0.477	1.591					**MG14**			0.161	
OX15		1.828	1.611	1.915					**MG15**			<0.01	0.030
OX16		0.94	0	1.392					**MG16**			0.056	0.443
OX17		2.065	2.71	2.021					**MG17**			<0.01	
OX18		0.758	1.284	0.966					**MG18**			<0.01	0.300
OX19		0.557	0.864		1.357	0.339		0.94	**MG19**				
OX20			0.755	0.835	0.657			0.73	**MG20**				
OX21		1.121	0.529	0.312	1.736	0.135		0.64	**MG21**				
OX22		0.272	0		0.329	0.062		0.09	**MG22**				
OX23			0.452	0.435	0.438			0.45	**MG23**				
OX24		0.652	0.42	0.308	0.388	0.7		0.75	**MG24**				
									MG25				
									W1				
									W2			3.850	3.477
									W3			2.114	

TP (mg/L)	16/08/2012	9/11/2012	15/02/2013	30/05/2013	6/03/2014	1/07/2014	9/09/2014	8/01/2015	total P	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1	0.241		0.205						**MG01**			0.94	0.886
OX2	0.06		0.087	0.029	0.054	0.086		0.15	**MG02**			2.16	
OX3	0.382		0.347			0.967		0.54	**MG03**				
OX4	1.366		1.91						**MG04**			0.12	0.136
OX5	3.384		5.106	5.068	3.218	5.07		4.98	**MG05**			4.23	2.902
OX6	0.08		0.087	0.050	0.054	0.129		0.51	**MG06**			0.26	
OX7		0.528	0.016				2.12	1.59	**MG07**			0.28	
OX8							0.492		**MG08**				
OX9		<0.005	0.844	0.050	0.031		0.224	0.24	**MG09**				
OX10		<0.005	0.039	0.007	0.000		0.07	0.38	**MG10**			0.80	
OX11		<0.005	0.063	0.050	0.076		0.291	0.73	**MG11**				
OX12		<0.005	0	0.007	0.008		0.112	0.19	**MG12**				
OX13		<0.005	0.016	0.007					**MG13**			0.02	
OX14		0.288	0.513	0.822					**MG14**			0.33	
OX15		1.175	1.555	1.165					**MG15**			0.14	0.007
OX16		0.24	0.584	0.415					**MG16**			<0.01	0.000
OX17		1.055	1.578	1.594					**MG17**			<0.01	
OX18		<0.005	0.134	0.264					**MG18**			0.09	0.000
OX19		<0.005	0.253		0.076	0.73		0.6	**MG19**				
OX20			0	0.007	0.000			0.15	**MG20**				
OX21		<0.005	0.11	0.377	0.000	0.666		0.28	**MG21**				
OX22		<0.005	0		0.031	0.0883		0.02	**MG22**				
OX23			0	0.007	0.000			0.49	**MG23**				
OX24		<0.005	0	0.007	0.000	0.0222		0.22	**MG24**				
									MG25				
									W1				
									W2			12.13	11.502
									W3			2.80	

FRP (mg/L)	16/08/2012	9/11/2012	15/02/2013	30/05/2013	6/03/2014	1/07/2014	9/09/2014	8/01/2015	FRP	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1	0.25		0.284						**MG01**		3.2	1.10	1.008
OX2	0.057		0.047	0.033	0.436	0.086		0.15	**MG02**	6.40	4.8	2.44	
OX3	1.626		0.19			0.967		0.54	**MG03**		3.35		
OX4	2.162		1.895						**MG04**	5.81	0.96	0.13	0.212
OX5	4.381		5.615	5.665	4.243	5.07		4.98	**MG05**	1.32		4.03	2.660
OX6	0.115		0.071	0.113	0.092	0.129		0.08	**MG06**	0.27	0.02	0.07	
OX7		0.12	0.142	0.332			2.12	1.59	**MG07**	0.01	0.16	0.02	
OX8							0.492		**MG08**				
OX9		0.288	0.355	0.172	1.261		0.224	0.24	**MG09**				
OX10		0	0.024	0.013	0.023		0.067	0.17	**MG10**		0.64	0.67	
OX11		1.271	0.355	0.192	0.527		0.291	0.41	**MG11**	0.53	0.28		
OX12		0	0.071	0.033	0.161		0.112	0.11	**MG12**	0.03	0.3		
OX13		0.024	0.308	0.013					**MG13**	0.01	0.02	<0.01	
OX14		0.959	0.663	1.128					**MG14**	<0.01	0.36	0.20	
OX15		1.823	2.061	1.347					**MG15**	0.05	0.14	<0.01	0.000
OX16		0.696	0.782	0.590					**MG16**	0.01	0.04	<0.01	0.000
OX17		1.391	1.895	1.605					**MG17**	<0.01	0.06	<0.01	
OX18		0.408	0.284	0.192					**MG18**	0.03		<0.01	0.000
OX19		0.36	0.474		0.550	0.73		0.6	**MG19**	1.21	3.76	3.76	
OX20			0	0.013	0.000			0.02	**MG20**	0.01	<0.01	<0.01	
OX21		0.216	0.711	0.172	0.619	0.666		0.28	**MG21**	0.01	<0.01	<0.01	
OX22		0.024	0		0.000	0		0.02	**MG22**	0.03	0.08	0.08	
OX23			0	0.000	0.000			0.02	**MG23**	0.01	0.04	0.04	
OX24		0.024	0	0.000	0.000	0.021		0.02	**MG24**	<0.01	0.04	0.04	
									MG25	0.12	0.2	0.2	
									W1				
									W2			12.36	12.127
									W3			2.78	

Fe (mg/L)	16/08/2012	9/11/2012		30/05/2013	6/03/2014	1/07/2014	9/09/2014	8/01/2015	Fe	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1	0.039								**MG01**			1.089	0.475
OX2	0.0102			0.014	0.211	0.343		0.32	**MG02**	6.99		2.450	
OX3	0.1417					16.216		2.85	**MG03**				
OX4	17								**MG04**	1.17		1.414	0.930
OX5	1.0996			0.321	0.494	0.297		0.38	**MG05**	8.43		6.685	0.710
OX6	0.1462			0.075	0.086	0.362		0.16	**MG06**	2.38		2.279	
OX7		0.7705		3.565			23.38	0.87	**MG07**	0.09		0.171	
OX8							1.026		**MG08**				
OX9		0.2669		0.098	0.389		0.207	0.19	**MG09**				
OX10		0.3604		0.230	0.332		0.242	0.33	**MG10**			1.546	
OX11		1.6818		0.180	0.256		0.275	0.34	**MG11**	15.29			
OX12		0.7436		0.917	2.229		1.436	1.88	**MG12**	0.17			
OX13		0.7134		1.266					**MG13**	10.79		0.955	
OX14		0.9678		0.210					**MG14**	0.07		2.117	
OX15		0.4059		0.219					**MG15**	19.0		0.902	0.009
OX16		2.642		0.252					**MG16**	4.94		1.147	0.004
OX17		1.9091		0.663					**MG17**	8.28		0.041	
OX18		0.251		0.184					**MG18**	0.29		5.435	0.022
OX19		0.185			0.427	0.298		0.33	**MG19**	11.27			
OX20				0.232	0.156			0.25	**MG20**	0.09			
OX21		0.4313		0.610	2.489	2.301		2.39	**MG21**	0.11			
OX22		0.8221			0.558	4.953		0.22	**MG22**	0.16			
OX23				0.059	0.108			0.12	**MG23**	0.09			
OX24		0.0436		0.220	0.270	1.256		0.32	**MG24**	2.09			
									MG25	7.17			
									W1				
									W2			10.036	10.532
									W3			0.630	

Cl (µg/L)	16/08/2012	9/11/2012	15/02/2013	30/05/2013	6/03/2014	1/07/2014	9/09/2014	8/01/2015	Chloride	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1	95.21	71.105	47						**MG01**			42.041	49.46
OX2	175.58	87.79		154.56	435	163		380	**MG02**	1192		56.38	
OX3	110.05	55.525	1			150		170	**MG03**				
OX4	121.18	61.09	1						**MG04**	2153		2294.9	1337.89
OX5	216.39	117.695	19	216.39	598	176		405	**MG05**	159		81.61	120.19
OX6	9694.16	7480.58	5267	9743.62	11697	10708		6500	**MG06**	646		649.9	
OX7		79					360	400	**MG07**	1051		790.4	
OX8							3		**MG08**				
OX9		1	1	12.86	44		14	20	**MG09**				
OX10		1	1	10.88	43		37	28	**MG10**			192.89	
OX11		1	1	35.12	60		38	39	**MG11**	10			
OX12		1	1	2.97	32		65	42	**MG12**	6746			
OX13		1	1	24.24					**MG13**			757.97	
OX14		1	1	1.48					**MG14**			326.44	
OX15		13	17	29.18					**MG15**			139.97	132.31
OX16		56	1	5.94					**MG16**			776.52	826.97
OX17		161	9	87.54					**MG17**			1577.77	
OX18		55	23	17.31					**MG18**			4016.15	3135.76
OX19		72	1		50	77		100	**MG19**				
OX20			3467	6182.50	5169			3860	**MG20**				
OX21		46		6430.00	39	54		75	**MG21**				
OX22		638	5144		8161	7580		4450	**MG22**				
OX23			5713	8507.12	8285	8346		5681	**MG23**				
OX24		19744	20476	24556.89	22480	22677		15600	**MG24**				
									MG25				
									W1				
									W2			339.79	82.1
									W3			251.26	

NH4 (mg/L)	16/08/2012	9/11/2012	15/02/2013	30/05/2013	6/03/2014	1/07/2014	9/09/2014		Ammonia N	20/05/2010	21/10/2010	16/01/2013	30/05/2013
OX1			0.00						**MG01**		1.82	0.57	0.692
OX2			0.00	0.153	0.000	0.001			**MG02**		0.31	1.30	
OX3			0.16			0.134			**MG03**		0.2		
OX4			0.17						**MG04**	0.03	0.16	0.03	0.418
OX5			1.07	2.344	0.000	0.49			**MG05**	<0.01		1.57	1.542
OX6			0.00	0.091	0.000	0.043			**MG06**	<0.01	0.013	0.01	
OX7			0.36	0.762			1.73		**MG07**	0.02	0.18	<0.01	
OX8							0.0725		**MG08**				
OX9			0.13	0.606	0.169		0.616		**MG09**				
OX10			0.29	0.338	0.192		0.609		**MG10**		<0.01	<0.01	
OX11			0.38	0.553	0.595		0.868		**MG11**	<0.01	0.06		
OX12			0.61	0.660	0.687		0.738		**MG12**	<0.01	1.18		
OX13			0.09	0.679					**MG13**	<0.01	0.32	<0.01	
OX14			0.23	1.352					**MG14**	<0.01	0.02	<0.01	
OX15			1.53	1.073					**MG15**	<0.01	0.01	<.0.01	0.008
OX16			0.61	0.084					**MG16**	1.05	0.18	<0.01	0.416
OX17			2.14	1.282					**MG17**	<0.01	0.27	0.01	
OX18			0.38	0.333					**MG18**	<0.01		0.01	0.869
OX19			0.21		0.250	0.16			**MG19**	3.49	<0.01	<0.01	
OX20			0.71	0.429	0.000				**MG20**	<0.01	0.01	0.01	
OX21			0.08	0.099	0.664	0.06			**MG21**	<0.01	0..08	0..08	
OX22			0.04		0.000	0.022			**MG22**	<0.01	0.09	0.09	
OX23			0.57	0.177	0.699	0.121			**MG23**	<0.01	0.03	0.03	
OX24			0.23	0.039	0.284	0.001			**MG24**	<0.01	1	1	
									MG25	0.409	<0.01	<0.01	
									W1				
									W2			4.12	2.148
									W3			2.07	

K (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	3.568
OX8	0.114
OX9	0.27
OX10	0.326
OX11	0.518
OX12	1.12
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

K	20/05/2010
MG01	
MG02	6.38
MG03	
MG04	11.23
MG05	5.25
MG06	1.58
MG07	9.23
MG08	
MG09	
MG10	
MG11	6.25
MG12	5.86
MG13	20.5
MG14	5.47
MG15	12.08
MG16	15.1
MG17	16.83
MG18	1.12
MG19	33.0
MG20	15.0
MG21	11.06
MG22	10.31
MG23	10.8
MG24	15.34
MG25	3.49
W1	
W2	
W3	

Na (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	211.68
OX8	17.27
OX9	13.94
OX10	22.41
OX11	23.25
OX12	28.07
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

Na	20/05/2010
MG01	48.17
MG02	
MG03	1041.8
MG04	146.72
MG05	400.6
MG06	422.98
MG07	
MG08	
MG09	
MG10	151.61
MG11	2637.8
MG12	285.01
MG13	305.19
MG14	213.53
MG15	961.29
MG16	365.06
MG17	714.4
MG18	120.39
MG19	256.39
MG20	245.27
MG21	278.84
MG22	297.86
MG23	143.28
MG24	141.84
MG25	
W1	
W2	
W3	

Mn (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	0.033
OX8	0.024
OX9	0.005
OX10	0.101
OX11	0.002
OX12	0.049
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

Mn	20/05/2010
MG01	0.01
MG02	
MG03	<0.01
MG04	<0.01
MG05	<0.01
MG06	0.32
MG07	
MG08	
MG09	
MG10	<0.01
MG11	0.39
MG12	0.35
MG13	0.02
MG14	0.37
MG15	0.26
MG16	0.33
MG17	0.11
MG18	3.83
MG19	0.04
MG20	0.06
MG21	0.08
MG22	0.06
MG23	0.65
MG24	2.7
MG25	
W1	
W2	
W3	

Cu (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	0.022
OX8	0.009
OX9	0.007
OX10	0.003
OX11	0.004
OX12	0.004
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

Cu	20/05/2010
MG01	0.09
MG02	
MG03	0.04
MG04	0.03
MG05	0.03
MG06	0.01
MG07	
MG08	
MG09	
MG10	0.02
MG11	0.02
MG12	<0.01
MG13	<0.01
MG14	<0.01
MG15	<0.01
MG16	<0.01
MG17	0.02
MG18	<0.01
MG19	<0.01
MG20	<0.01
MG21	<0.01
MG22	<0.01
MG23	<0.01
MG24	<0.01
MG25	
W1	
W2	
W3	

Zn (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	0.026
OX8	0.023
OX9	0.041
OX10	0.032
OX11	0.02
OX12	0.017
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

ZN	20/05/2010
MG01	0.1
MG02	
MG03	0.05
MG04	0.05
MG05	0.05
MG06	0.05
MG07	
MG08	
MG09	
MG10	0.06
MG11	0.04
MG12	0.02
MG13	0.02
MG14	0.03
MG15	0.03
MG16	0.03
MG17	0.03
MG18	0.03
MG19	0.01
MG20	0.02
MG21	0.01
MG22	0.02
MG23	0.03
MG24	0.04
MG25	
W1	
W2	
W3	

Mg (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	18.68
OX8	2.344
OX9	2.892
OX10	4.718
OX11	3.966
OX12	4.648
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

Mg	20/05/2010
MG01	
MG02	6.01
MG03	
MG04	104.53
MG05	6.08
MG06	21.64
MG07	16.82
MG08	
MG09	
MG10	
MG11	3.34
MG12	703.53
MG13	141.42
MG14	118.48
MG15	71.24
MG16	272.39
MG17	287.57
MG18	82.0
MG19	13.29
MG20	91.0
MG21	56.51
MG22	69.55
MG23	138.69
MG24	565.31
MG25	16.71
W1	
W2	
W3	

Ca (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	15.87
OX8	4.67
OX9	1.69
OX10	3.83
OX11	3.73
OX12	3.46
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

NO2 (mg/L)	1/07/2014	9/09/2014
OX1		
OX2	0.001	
OX3	0.23	
OX4		
OX5	0.001	
OX6	0.001	
OX7		0.01
OX8		0.01
OX9		0.012
OX10		0.01
OX11		0.012
OX12		0.01
OX13		
OX14		
OX15		
OX16		
OX17		
OX18		
OX19	0.001	
OX20		
OX21	0.001	
OX22	0.04	
OX23	0.018	
OX24	0.7	

CO3 (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	15
OX8	0
OX9	0
OX10	5
OX11	0
OX12	0
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

TDS (mg/L)	9/09/2014
OX1	
OX2	
OX3	
OX4	
OX5	
OX6	
OX7	660
OX8	70
OX9	55
OX10	90
OX11	95
OX12	120
OX13	
OX14	
OX15	
OX16	
OX17	
OX18	
OX19	
OX20	
OX21	
OX22	
OX23	
OX24	

Ca	20/05/2010
MG01	14.79
MG02	
MG03	88.66
MG04	16.83
MG05	16.5
MG06	76.0
MG07	
MG08	
MG09	
MG10	7.00
MG11	405.51
MG12	58.14
MG13	42.91
MG14	27.48
MG15	99.9
MG16	18.0
MG17	36.76
MG18	10.55
MG19	51.83
MG20	38.19
MG21	4414
MG22	80.6
MG23	353.89
MG24	12.8
MG25	
W1	
W2	
W3	

Nitirite		21/10/2010
MG01		<0.01
MG02		0.015
MG03		<0.01
MG04		0.1
MG05		
MG06		0.018
MG07		<0.01
MG08		
MG09		
MG10		<0.01
MG11		0.1
MG12		<0.01
MG13		<0.01
MG14		<0.01
MG15		<0.01
MG16		<0.01
MG17		<0.01
MG18		
MG19		0.18
MG20		<0.01
MG21		<0.01
MG22		<0.01
MG23		<0.01
MG24		<0.01
MG25		<0.01
W1		
W2		
W3		

Appendix G: Communications with Department of Water

From: Jonathan Cousins [mailto:jonathan@biosciencewa.com]
Sent: Monday, 30 March 2015 10:37 AM
To: HALL Joel
Subject: Forrestdale Industrial Areas

Hi Joel,
Bioscience are currently working on a proposed industrial development in Forrestdale (Rowley Road). The area discharges surface water into Birriga Drain. I understand that a revised MIKE model is to include this area and I am hoping you could provide me details of the assumed runoff coefficients used. The area is relatively flat and has low lying grass coverage. The soils are predominantly clayey Guildford Formation. I have been informed that the model assumes a high coefficient of runoff in the undeveloped scenario, presumably for the saturated soil state.

If you could provide any clarity it would be most appreciated and beneficial to our internal modelling currently being undertaken.

I can be contacted by both email or on 9397 2446.

Best regards and thank you in advance.

Jonathan

Jonathan Cousins MEng (Hons)
Environmental Engineer/ Hydrologist

Bioscience
Integrating Resource Management

From: HALL Joel [mailto:Joel.HALL@water.wa.gov.au]
Sent: Tuesday, 7 April 2015 9:22 AM
To: 'Jonathan Cousins'
Subject: RE: Forrestdale Industrial Areas

Hi Jonathan,

Do you have a map of the area? I could give you a better estimate of Runoff Coefficients. They are not assumed in the Birriga model, but are calibrated based on a couple of flood events at a downstream gauge. If your development is draining to the Birriga drain there are some criteria that must be met for development:

1) The 100yr peak maximum flow rate must be maintained
2) The pre-development floodplain storage must be maintained.

DoW can provide estimates of peak 100yr inflows and outflows for your area (if it is in the Birriga catchment), as well as estimates of pre-development floodplain storage.

Let me know if you have any other queries or issues

Regards,
Joel Hall
Senior Environmental Modeller, Water Science

Department of Water
168 St Georges Terrace Perth Western Australia 6000
PO Box K822 Perth Western Australia 6842
Telephone (08) 6364 7835 Facsimile (08) 63647888
Email joel.hall@water.wa.gov.au
www.water.wa.gov.au

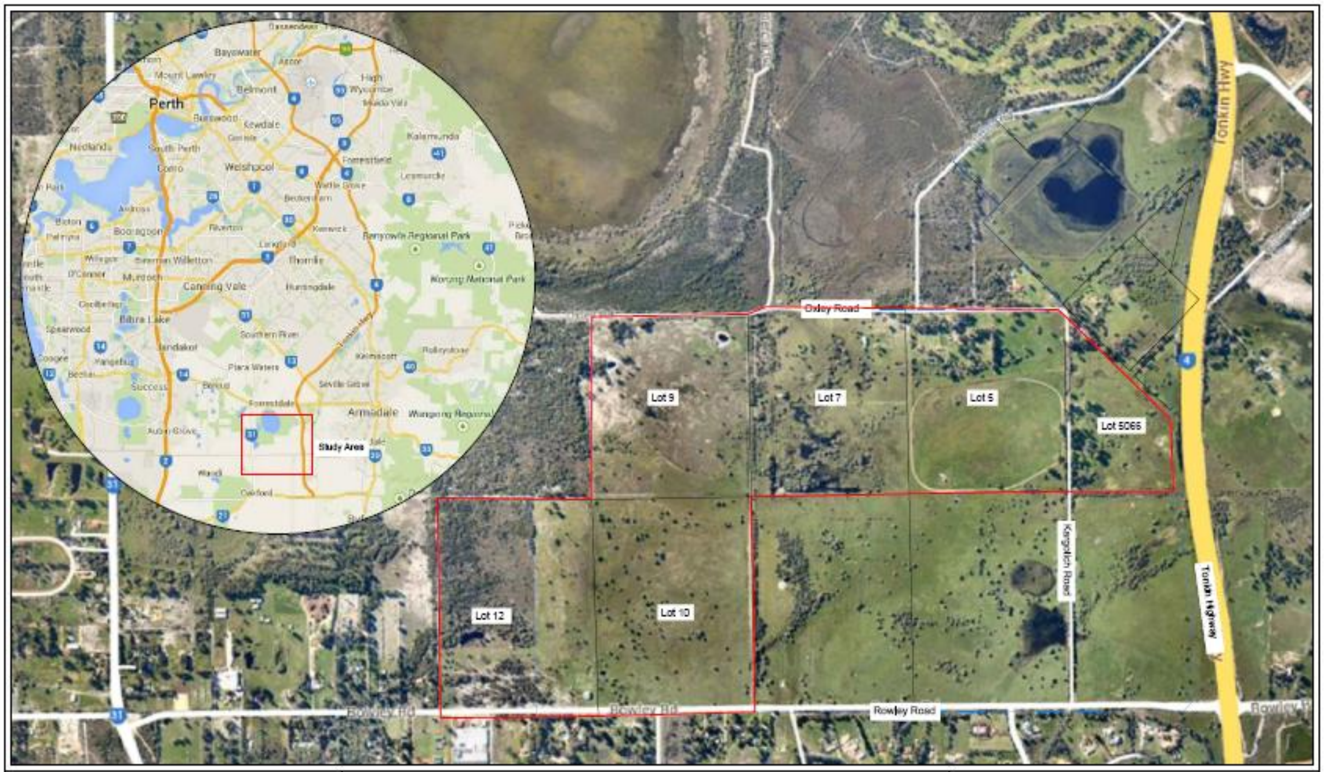
From: Jonathan Cousins [mailto:jonathan@biosciencewa.com]
Sent: Tuesday, 7 April 2015 9:49 AM
To: HALL Joel
Subject: RE: Forrestdale Industrial Areas

Hi Joel,
Thank you for the reply. Please see attached location plan (F1) of the study area. According to DoW mapping (F7- attached), much of the site will discharge south towards the Peel Estuary_ Serpentine River Catchment through culverts under Rowley Road and into the Birriga Drain.

During Geotech work much of the study area was found to contain clayey based soils.

If you require any more information to assist please let me know.

Best regards
Jonathan



Bioscience

BIOSCIENCE PTY LTD

488 NICHOLSON ROAD FORRESTDALE WA 6112
PO BOX 5466 CANNINGVALE SOUTH WA 6155
PHONE: (08) 9397 2446 FAX: (08) 9397 2447
EMAIL: bioscience@biosciencewa.com
WEBSITE: www.biosciencewa.com

☐ Land identified in EELS report with potential to provide non-heavy industrial land to be included in DWMS report
🟥 Study Area

N

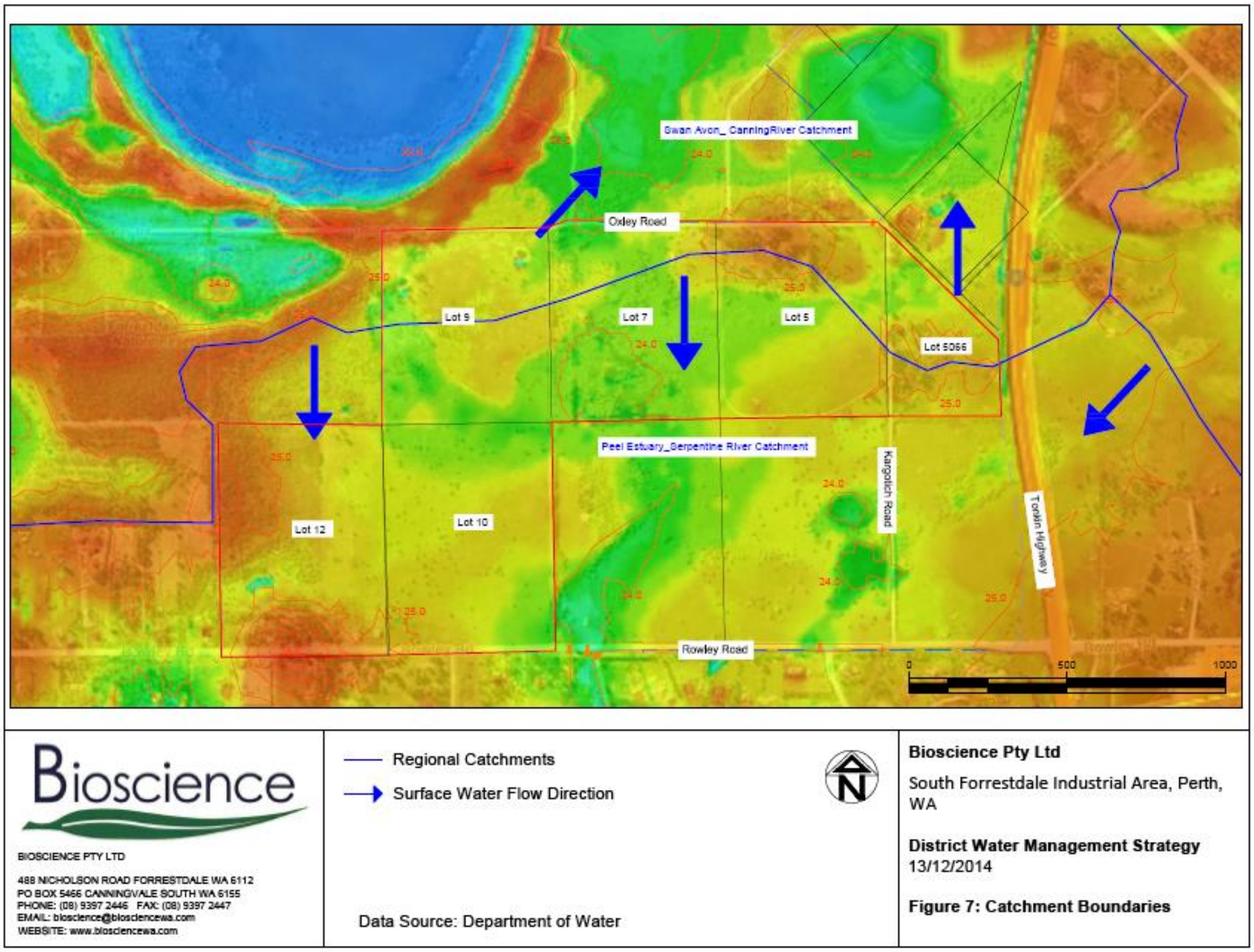
Data Source: Google Maps & Nearmaps

Bioscience Pty Ltd

South Forrestdale Industrial Area, Perth, WA

District Water Management Strategy
12/12/2014

Figure 1: Location Plan



BIOSCIENCE PTY LTD
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EMAIL: bioscience@biosciencewa.com
WEBSITE: www.biosciencewa.com

Data Source: Department of Water

Bioscience Pty Ltd
South Forrestdale Industrial Area, Perth, WA

District Water Management Strategy
13/12/2014

Figure 7: Catchment Boundaries

From: HALL Joel [mailto:Joel.HALL@water.wa.gov.au]
Sent: Tuesday, 7 April 2015 11:28 AM
To: 'Jonathan Cousins'
Cc: DUARTE Paola
Subject: RE: Forrestdale Industrial Areas

Hi Jonathan

I have had a look at the model for your area.

- The pre-development floodplain storage is 59ML
- The pre-development 100yr maximum discharge at Rowley Road (at the main drainage line that drains to Birriga Drain) is 2.85 m^3/sec (I realise that this outlet is not in your area, however it is likely that you will need to model this outlet as part of your studies.

- The coefficient of runoff is high, approximately 65%. As you pointed out – this is due to inundated landscape and clay soils.

Please be aware that a requirement for development in the Birriga catchment is to maintain pre-development flows and floodplain storage. So demonstrating that pre-development outflows are maintained is not enough in this catchment, and pre-development floodplain storage maintenance is a further requirement. Water Corporation (who are custodians of the drains in this district) will absolutely not budge from this standpoint – and DoW is supporting this approach as well. Maintenance of floodplain storage is required as an extra measure for flood protection, as the Birriga/Oaklands drains have limited hydraulic capacity and removing the pre-development floodplain storage is likely to result in overtopping or failure of levees/spoil banks downstream. Post-development there is also requirement for storage ADDITIONAL to the pre-development storage which accounts for the extra runoff that is delivered through the production of hard surfaces. The criteria for development in the catchment is as follows:

- 100yr pre-development floodplain storage is preserved. The provision of additional storage (additional to pre-development floodplain storage) for post development 100yr flows above the pre-development flows (from the introduction of hard surfaces to the landscape); and peak flow rates at downstream end of the development are not increased post-development.

- Road reserves and drainage reserves throughout the catchment can be included in the post-development 100yr flood storage.
- Consultant will do this modelling, however DOW will provide inflow and outflow hydrographs for the model as well as pre-development storage estimates (consultants do have the option to refine the pre-development storage estimates, however this will need to be accepted by DoW and supported by transparent modelling and calculations).
- The management of small events (the first 15mm of rainfall) must be stored 'at source' within the development, and will count towards the total storage requirement in the development area.

Therefore you will be required to store 59ML on site (floodplain storage) in addition to any extra storage that is required as a result of urban development. You will also be required to ensure that peak 100yr flood flows do not increase at Rowley Road (from 2.85 m^3/sec).

Please let me know if you require any extra information or would like any more explanation.

Kind regards,

Joel Hall

From: Jonathan Cousins [mailto:jonathan@biosciencewa.com]
Sent: Tuesday, 7 April 2015 2:13 PM
To: HALL Joel
Subject: RE: Forrestdale Industrial Areas

Hi Joel,

Thank you for all of the information.

I just have a few points to clarify with you if possible as Bioscience are developing a DWMS for only 190ha currently:

- Is the 59ML floodplain storage for the whole area within the red boundary on your plan or are external catchments contributing? (The highlighted red area is approximately 300ha so floodplain storage is about 200m3/ha currently)
- Is there a required duration to store the predevelopment 100 year floodplain water i.e. slow releasing into the system within 96 hours whilst not exceeding predevelopment flows?
- The 2.85m3/s: Is that also from the total development area highlighted red or contributing (south of Rowley Rd) catchments?

Realistically, post development modelling will be using a coefficient of say 90% for the developed land and will be dragged down a bit if weighted by landscaped areas. Increases to predevelopment storage requirements in basins would therefore be 25% - and less if the 1 year events is stored at source.

Bioscience will be using XP SWMM to model the developments so "*inflow and outflow hydrographs for the model as well as pre-development storage estimates*" would be most appreciated.

Best regards
Jonathan

From: HALL Joel [mailto:Joel.HALL@water.wa.gov.au]
Sent: Tuesday, 7 April 2015 3:28 PM
To: 'Jonathan Cousins'
Cc: DUARTE Paola
Subject: RE: Forrestdale Industrial Areas

Hey Jonathan,

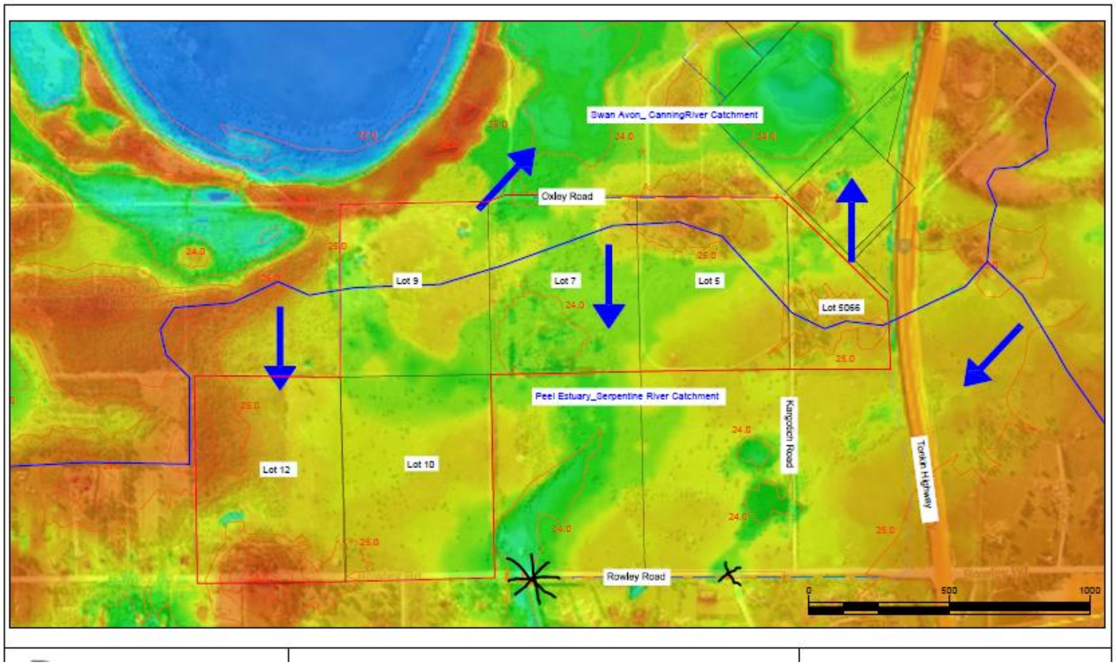
- 59ML is for the red boundary from your F1/F2 figures (note that this does not include the areas north of the blue catchment boundary lines). This is 190ha, so I assume this is the Bioscience area – please let me know if I am mistaken – this equates to approx. 310 KL/ha
- There is no required duration for the 100yr event – however there are for the smaller events (1yr and 5yr) for Mosquitos (I believe that this is 72hrs).
- The 2.85 m3/s is for the total development (the black star that I drew below). It is very difficult to get a maximum flow rate for the red areas only, as they are very flat and sheet-flow across the boundaries. I assume that most of the water will need to be drained to that drain either way – so it will be included in the model? If you are looking at a different drainage method, I could provide different data. There are no inflows to your area, as it is all part of a first-order catchment (in fact the

northern part of Lots 9,7,5 are in the Swan Catchment, and the southern part is in the Peel Harvey catchment – though you wouldn't know that you are on a major catchment ridge being out on site!). If you drain all water to the Swan Catchment, you do not have to maintain pre-development floodplain storage.

- I have provided the outflow hydrograph for the branch drain that attaches to the Birriga at Rowley Road (where the 2.85 m3/sec comes from). Note that I did not explicitly include culverts in this flow calcs- and they assume a non-restrictive culvert. I don't know what kind of culvert is there, or if it is capable of handling 2.85m3/sec without overtopping the road (this level of detail was not modelled). I realise that there is a second culvert (marked with an x on the diagram below) – our modelling shows that very little flow will occur through this culvert in a 100 year event (negligible)
- Agreed about the post-development land-use – however once you take into account the 1 year events at source and landscaped areas it will be a bit lower – so all in all you will require >59ML storage, but possibly not a huge amount more.

Hope this helps, please let us know if you need any more information or explanation

Cheers Joel



Time hr	Flow (m3/sec)	Time hr	Flow (m3/sec)	Time hr	Flow (m3/sec)
0.0	0.00	20.5	1.09	41.0	0.09
0.5	0.00	21.0	1.03	41.5	0.09

1.0	0.16	21.5	1.01	42.0	0.08
1.5	0.14	22.0	0.97	42.5	0.07
2.0	0.65	22.5	0.94	43.0	0.07
2.5	1.18	23.0	0.92	43.5	0.06
3.0	1.49	23.5	0.90	44.0	0.06
3.5	1.64	24.0	0.88	44.5	0.05
4.0	1.73	24.5	0.84	45.0	0.05
4.5	1.81	25.0	0.80	45.5	0.05
5.0	1.95	25.5	0.80	46.0	0.04
5.5	2.15	26.0	0.74	46.5	0.04
6.0	2.36	26.5	0.68	47.0	0.04
6.5	2.48	27.0	0.63	47.5	0.03
7.0	2.58	27.5	0.59	48.0	0.03
7.5	2.68	28.0	0.54	48.5	0.03
8.0	2.75	28.5	0.51	49.0	0.03
8.5	2.77	29.0	0.47	49.5	0.02
9.0	2.78	29.5	0.44	50.0	0.02
9.5	2.72	30.0	0.41	50.5	0.02
10.0	2.71	30.5	0.38	51.0	0.02
10.5	2.66	31.0	0.35	51.5	0.02
11.0	2.59	31.5	0.33	52.0	0.01
11.5	2.51	32.0	0.31	52.5	0.01
12.0	2.41	32.5	0.29	53.0	0.01
12.5	2.31	33.0	0.27	53.5	0.01
13.0	2.20	33.5	0.26	54.0	0.01
13.5	2.10	34.0	0.24	54.5	0.01
14.0	2.01	34.5	0.23	55.0	0.01
14.5	1.92	35.0	0.21	55.5	0.00
15.0	1.83	35.5	0.20	56.0	0.00
15.5	1.77	36.0	0.18	56.5	0.00
16.0	1.70	36.5	0.17	57.0	0.00
16.5	1.62	37.0	0.16	57.5	0.00
17.0	1.55	37.5	0.15	58.0	0.00
17.5	1.47	38.0	0.14	58.5	0.00
18.0	1.40	38.5	0.13	59.0	0.00
18.5	1.34	39.0	0.12	59.5	0.00
19.0	1.30	39.5	0.11	60.0	0.00
19.5	1.21	40.0	0.11		
20.0	1.15	40.5	0.10		

Appendix H: Environmental Impact Assessment (Bioscience, 2015)

Bioscience

ENVIRONMENTAL IMPACT ASSESSMENT

Lots 5, 7 and 9 Oxley Road,
Lots 10 and 12 Rowley Road
and Lot 5066 Kargotich Road
FORRESTDALE

26th August 2015

Urban Water Management Plan

Lots 5, 7 and 9 Oxley Rd, Lots 10 and 12 Rowley Rd, Forrestdale, Western Australia

Prepared for:	Landowner Consortium
Prepared by:	Mia Harris BSc
Project Supervisor:	Peter Keating, B.Sc (Hons) PhD

Bioscience Pty Ltd

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Document Control

Issue	Date	Author	Reviewer	Approved
1	26/05/2015	Mia Harris	N. Benker	P. Keating
2	26/08/2015	P.Keating	N.Benker	P.Keating

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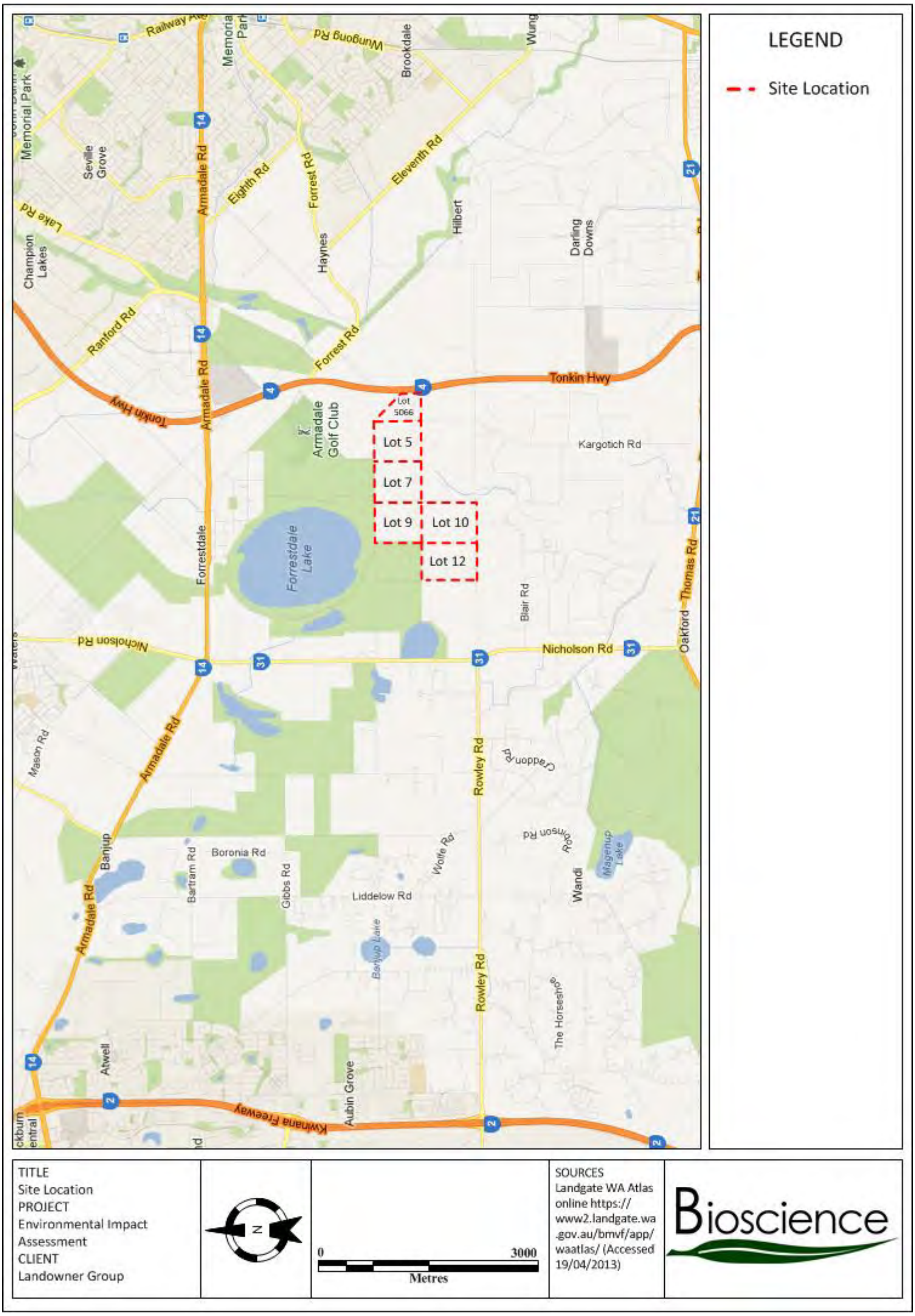
1. INTRODUCTION

1.1 Background

A groups of landowners, through town planners Gray and Lewis Landuse Planners, and Turner Master Planners, have commissioned Bioscience to undertake an Environmental Assessment of Lots 5, 7, and 9 Oxley Road, Lots 10 and 12 Rowley Road and 5066 Kargotich Road, in Forrestdale. The purpose of which is to identify any environmental constraints of a proposed rezoning of the land from “rural living” as per the Metropolitan Regional Scheme and the City of Armadale Town Planning Scheme No.4, to that of “general industry” by way of an MRS, then TPS amendment. This report is in accordance with the Environment Protection Authority (EPA) *Guidance Statement Number 33 – Environmental Guidance for Planning and Development* (2008). The aim of the work is to the identify biophysical factors, particularly those that may impede rezoning and land development, pollution management issues and issues relating to aesthetic, cultural and social surroundings of the land.

1.2 Site Location and Land Use

The study site consists of 6 Lots totalling around 190ha which is located approximately 25kms south, south east of Perth CBD and around 16km east of the coast (Figure 1). The land is currently being used for agriculture purposes, specifically grazing cattle and horses. This land use has not changed over the last 50 years.



TITLE
Site Location
PROJECT
Environmental Impact Assessment
CLIENT
Landowner Group

SOURCES
Landgate WA Atlas online https://www2.landgate.wa.gov.au/bmvf/app/waatlas/ (Accessed 19/04/2013)

Bioscience

Figure 1: Site Location

1.3 Purpose and Scope of Works

This report is in accordance with the Environment Protection Authority (EPA) *Guidance Statement Number 33 – Environmental Guidance for Planning and Development* (2008). The aim of which is to identify the biophysical factors that may impede rezoning and land development, pollution management issues and issues relating to aesthetic, cultural and social surroundings of the land.

An Environmental Assessment (EA) of Lots 5, 7, and 9 Oxley Road, Lots 10 and 12 Rowley Road and 5066 Kargotich Road has been commissioned by the landowners for the rezoning to Light Industrial, consistent with the Western Australian Planning Commissions *Economic and Employment Land Strategy: Light Industrial* EELS (April 2012)

The objectives of the EA are to:

- Provide information on key environmental characteristics within the subject site and surrounding area.
- Identify the environmental factors and constraints that affect the development of the subject site.
- Recommend appropriate management strategies to maximise development whilst protecting environmental functions, values, and attributes.
- Identify any relevant permissions or approvals required for development of the subject area.

The scope of the EA is as follows:

- Review of surrounding land uses and compatibility.
- Identify site soils, potential/actual Acid Sulfate Soils (ASS), geology and geomorphology.
- Identify any Aboriginal or European heritage via search on relevant databases.
- Ecological features of significance.
- Surface and groundwater hydrology with consideration of local catchment, wetlands and water bodies.
- Potential nuisance insects.
- On site hydrological and soil assessment.
- Level 1 on site assessment of flora and fauna.

2. PLANNING AND POLICY

The following State, District and Local planning documents are relevant to the subject area:

- State Planning Strategy (WAPC, 1997)
- Metropolitan Region Scheme (MRS) (WAPC, 2012)
- City of Armadale Town Planning Scheme No. 4 (WAPC, 2012)
- Southern River / Forrestdale / Brookdale / Wungong District Structure Plan (WAPC 2001)
- Economic and Employment Land Strategy: Light Industrial WAPC (April 2012)

The subject area including Lots 5, 7, and 9 Oxley Road, Lots 10 and 12 Rowley Road and 5066 Kargotich Road is zoned “Rural” as per the Metropolitan Region Scheme (MRS) and the Southern River / Forrestdale / Brookdale / Wungong District

Structure Plan. The subject area is also zoned “Rural Living” as per the City of Armadale Town Planning Scheme (TPS) No. 4 (Figure 2).

A recent MRS amendment has seen adjoining Lots 6,8 and 200 Rowley Road become zoned Industrial, with steps currently underway to likewise amend Armadale's TPS4.

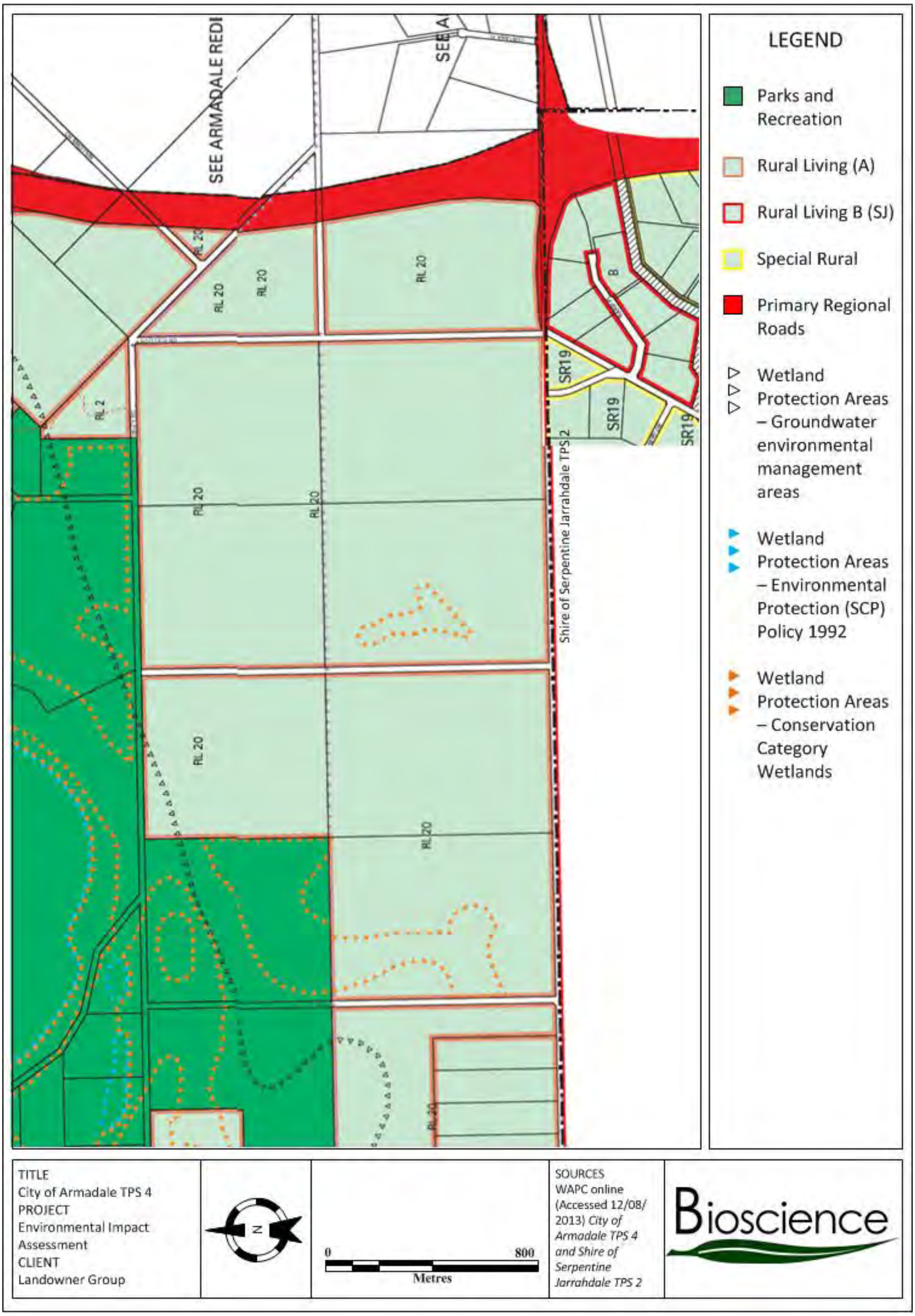


Figure 2: **City of Armadale Town Planning Scheme No. 4**

2.1 Economic and Employment Lands Strategy (EELS)

The Economic and Employment Lands Strategy (EELS) – Non-heavy Industrial has been prepared as part of the state governments response to a recognised deficit in Perth's industrial land supply.

The aims of the strategy include:

Identify the areas, type and locations of general and light industrial land required over the next 20 years.

Review the existing industrial land development program and identify possible extension opportunities.

Identify and evaluate the suitability of locations for new general and light industrial estates.

Develop a strategy to facilitate the delivery of general and light industrial land and assist in the restoration of the Government's long-term general and light industrial landbank.

Thirty-seven sites, totalling around 13 000ha have been identified as potential gross developable land for future use (20 year outlook). South Forrestdale has been identified as a potential medium term non-heavy industrial site comprising of eight main landowners and covering an area of 354ha (Figure 3). Within this area, the subject site is approximately 190 ha totalling around 54% of the South Forrestdale potential industrial site. The aforementioned MRS amendment for Lots 6,8 and 200 meant 106 ha (30% of the EELS area) has already been rezoned.

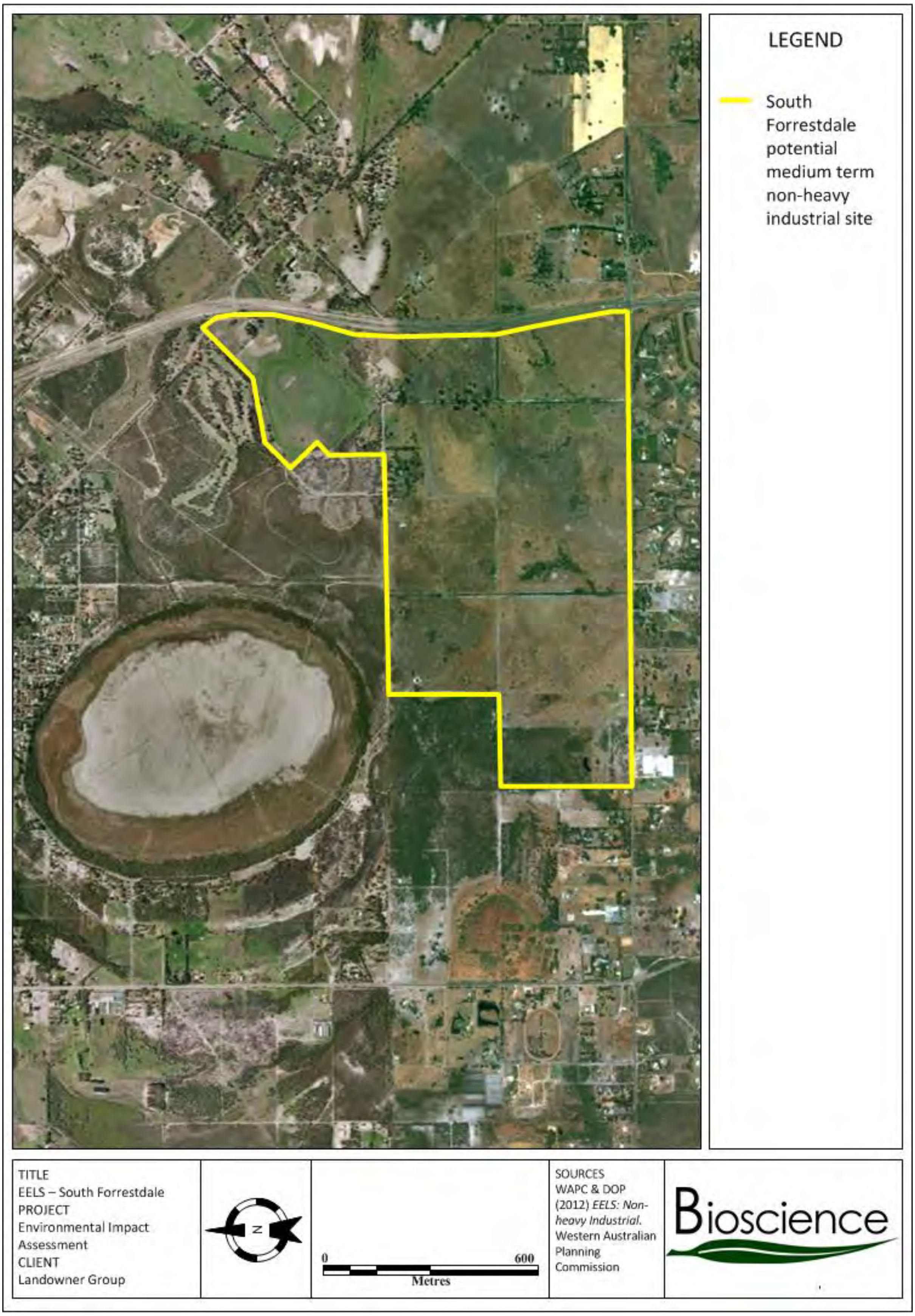


Figure 3: EELS - South Forrestdale Site

3. EXISTING ENVIRONMENT

3.1 Climate

The south west of Western Australia is characterised by a Mediterranean climate comprising hot dry summers and cool wet winters. According to the Bureau of Meteorology the average annual rainfall within the vicinity of the proposed development is 822.7mm (Jandakot Aero: 009172). The monthly distribution of rainfall (Figure 3) indicates nearly 80% of the rainfall occurs during the months of May to September.

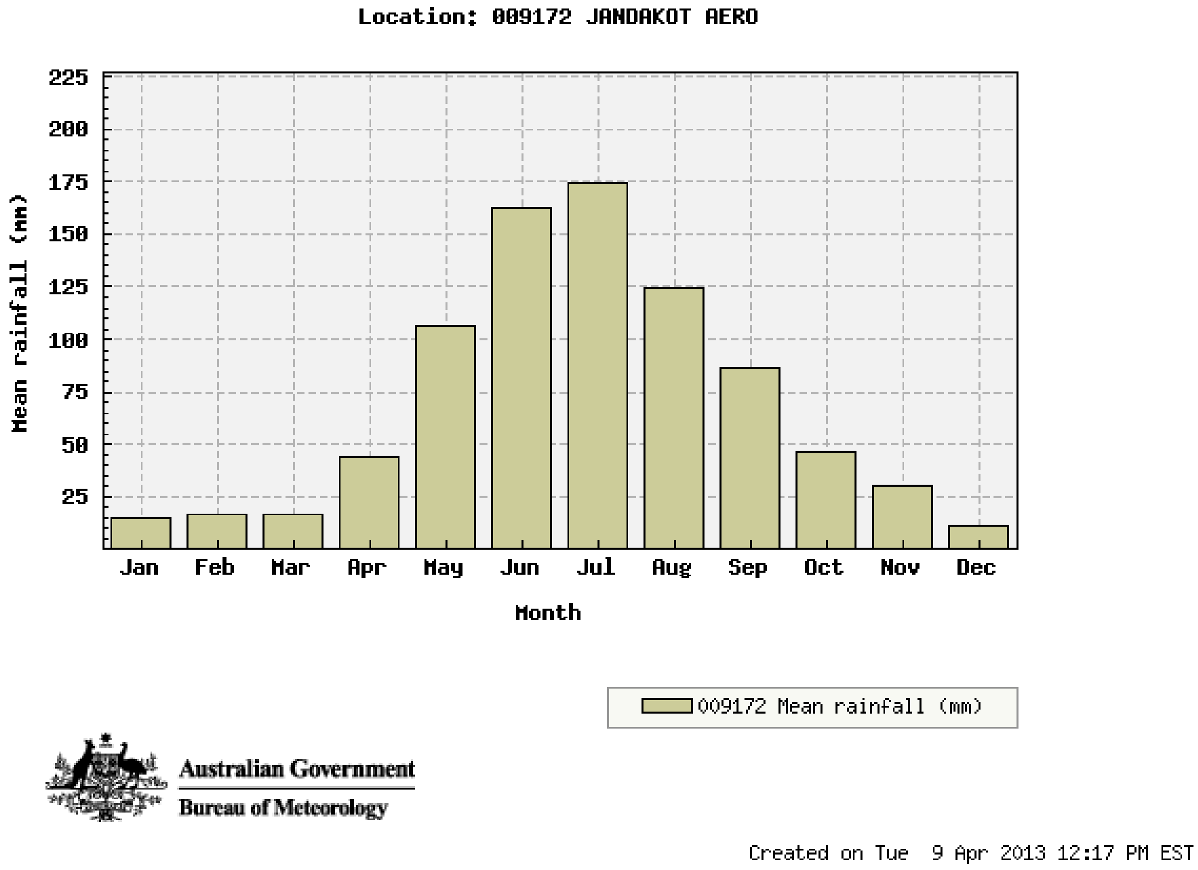


Figure 4: Average annual rainfall and temperature

3.2 Geology Geomorphology and Soils

3.2.1 Geology

According to the Department of Mines and Petroleum (DoMP) geological mapping of Western Australia (1:500 000) (DoMP, 2009) the subject area is within the Warnbro group. The Warnbro group is a sedimentary siliciclastic rock type described as undivided; interbedded sandstone, siltstone and shale, minor conglomerate; which includes Dandaragan sandstone, South Perth Shale and Leederville formation. The regolith consists of sandplain of mainly eolian origin including some residual deposits.

3.2.2 Geomorphology and Soils

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

Underlying the Bassendean formation is the Guildford formation. The soils of the Guildford formation are complex, and comprise a successive layering formed from erosion of material from the scarp to the east. Rivers and streams have mostly carried the eroded material, which is deposited from the water as fans of alluvium. The Guildford formation is characterised by poor drainage due to the low permeability of sub-soil clays which prevent the downward infiltration of rainfall, consequently during winter months water logging and surface inundation can occur. In addition, the clay fraction of the Guildford formation is known to have highly variable Plasticity Indices (Hillman et al., 2003). Soil Organic content varies between 1-3% of volume in the surface layers, dropping to between 0.2-1% in subsoils *(ASRIS).* There are also Swampy or Lacustrine (Vertosols) soils in the locality, which consist of peaty waterlogged soils.

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

- S8 – SAND – Very light grey at surface, yellow at depth, fine to medium grained, sub-rounded quartz, moderately well sorted, of eolian origin
- S10 – SAND- as S8 over sandy clay to clayey sand of the Guildford Formation of Aeolian origin (Bassendean Sand over Guildford Formation).
- Sc – SANDY CLAY – Silty in part, pale grey to brown, medium to coarse-grained, poorly sorted, subangular to rounded, frequent heavy minerals, rare feldspar, of alluvial origin
- Sp1 – PEATY SAND- Grey to black, fine to medium-grained, moderately sorted quartz sand, slightly peaty, of lacustrine origin

Geotechnical investigations to support the DWMS have confirmed the Geological Survey mapping, and have found that the western side of the subject site has sand to depths of 3.5 - 5 m over Guildford clay, but the depth of sand over clay declines in an easterly and southerly direction such that most of Lot 5066, and the south east corner of Lot 9 have clay very close to the surface of organic silty loam.

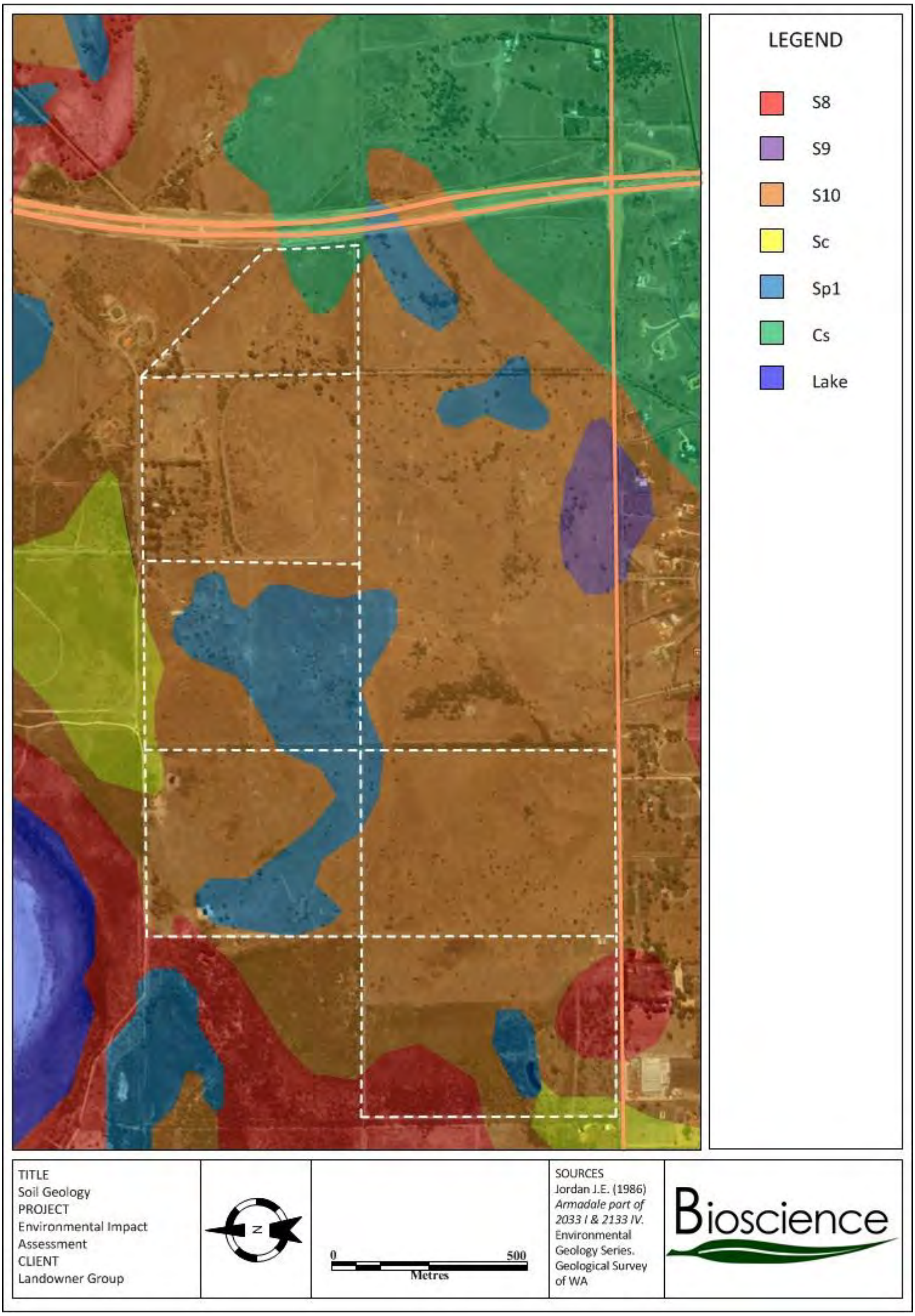


Figure 5: Soil types

3.3 Topography

The area has a low relief with minor variations in topography. The site is around 24m AHD (Figure 5) with the historical groundwater maximum around 24m AHD (DoW, accessed 10/04/2013) indicating that the site becomes waterlogged during winter months. This has been confirmed by three years of hydrological observations on the site by Bioscience for the development of a District Water Management Strategy (for both the original 3 Lots now zoned industrial, and the 6 Lots subject to this study).

TITLE
Topography
PROJECT
Environmental Impact Assessment
CLIENT
Madestra Group

N

0 500
Metres

SOURCES
Perth Groundwater Atlas online http://www.water.wa.gov.au/idelve/gwa/ (Accessed 19/03/2013)

Bioscience

Figure 6: Topography

3.4 Vegetation and Flora

The study area is within the Swan Coastal Plain Biogeographic Region of the South-west Botanical Province (Thackway and Cresswell 1995, Paczkowska and Chapman 2000), an area that extends from Jurien Bay to the north to Dunsborough to the south, and west of the Darling Scarp. Historically this biogeographic region has been extensively cleared for both urban and agricultural purposes.

The site is essentially cleared with sporadic *Melaleuca preissiana* and *Kunzea glabrescens* occasionally over native sedges such as *Gahnia trifida*. A number of non-endemic eucalypts are also present. It has historically been used for grazing of stock and as such has resulted in highly degraded vegetation consisting mainly of introduced pasture grasses.

Bioscience conducted a modified Environmental Protection Authority's Guidance 51 Vegetation Survey (EPA 2004) Level 1 flora and vegetation assessment which consisted of both desktop assessment and site investigation as outlined below:

A desktop study of potential rare and endangered flora and ecological communities listed under the *Wildlife and Conservation Act 1950* and *EPBC Act 1999* was undertaken by analysis of the following databases:

- *NatureMap*: Western Australia's biodiversity online mapping (DEC 2011)
- *Florabase*: WA Herbarium guide to Western Australian Flora online (Western Australian Herbarium, 1998)
- *Protected Matters*: National Environmental Significance online mapping (DoSEWPaC 2010)

A site investigation of all flora and vegetation units present was conducted by Bioscience however the vegetation was so degraded that the protocols for a Level 1 or a Level 2 EPA Guidance 51 assessment could not be applied. Accordingly Bioscience undertook a modified vegetation survey of the subject land involving a careful walk-through of all areas containing native vegetation to document all species present. That area of Lot 12 which is mapped as Bush Forever and has been fenced off does not form part of this assessment. The landowner, Mr Stephen Catellani, acknowledges that his Bush Forever land will not be part of the rezoning, but rather will eventually be acquired by WAPC under a negotiated settlement.

3.4.1 Flora of Conservation Significance

A search on DEC's NatureMap online indicated that six Declared Rare Flora (DRF) and nine Priority flora exist within 5km of the centre of the subject site (32° 10' 23 S, 115° 56' 41 E) (Appendix A). Of the DRF and Priority flora 5 are listed under the *EPBC Act* (1999) as Endangered. However due close proximity to Lake Forrestdale Nature Reserve it is suspected that majority species listed in the search may belong to the protected area within and surrounding Lake Forrestdale. Accordingly a narrower search of 1 km was conducted (largely encompassing the subject site only) revealing no listed DRF or Priority flora. The purpose however of conducting a broader search of the DEC NatureMap database is based on accuracy of the search data and as such DRF and Priority flora from the broader search was considered.

Table 1: DRF and Priority Flora within search area

Species	Conservation Code	EPBC Act Category
Byblis gigantea (Rainbow Plant)	Priority 3	-
Caledenia huegelii (Grand Spider Orchid)	Threatened (DRF)	-
Diuris purdiei (Purdie's Donkey Orchid)	Threatened (DRF)	Endangered
Drakaea elastic (glossy leaved Hammer Orchid)	Threatened (DRF)	Endangered
Drakaea micrantha	Threatened (DRF)	Endangered
Drosera occidentalis ssp. occidentalis	Priority 4	-
Jacksonia gracillima	Priority 3	-
Jacksonia sericea (Waldjumi)	Priority 4	-
Lepidosperma rostratum	Threatened (DRF)	Endangered
Schoenus pennisetis	Priority 1	-
Stylidium longitubum (Jumping Jacks)	Priority 3	-
Tetratheca sp. *Granite* (S. Patrick SP1224)	Priority 3	-
Tripterococcus paniculatus	Priority 4	-
Verticordia lindleyi ssp. *lindleyi*	Priority 4	-
Verticordia plumose var. *pleiobotrya*	Threatened (DRF)	Endangered

No DRF or Priority flora was identified within the subject area, however this is not to say that they are not present as the survey was not conducted during spring whilst plants are flowering. However due to the degraded state of the subject area it is very unlikely that any DRF or Priority flora is present due to their fragile and specific nature.

3.4.2 Vegetation Complexes and floristic community types

The vast majority of the site is almost completely devoid of native vegetation. As a result, it is quite difficult to determine the pre-European vegetation complex that existed within the study area. Vegetation complex mapping conducted by Heddle *et al* (1980) indicates that the site lies within three vegetation complexes including the Bassendean Complex – Central and South, Beermullah Complex, and the Southern River Complex (Figure 7). According to the Perth Biodiversity Project (WALGA 2010) both the Bassendean Complex– Central and South and the Southern River Complex have less than 30% of pre-European extent on the Swan Coastal Plain south of Moore River remaining (27.67% and 19.72% respectively). The EPA Position Statement No. 2 (2000a) considers the “threshold level” below which species loss appears to accelerate exponentially at an ecosystem level is at a level of 30% of the pre-clearing extent of the vegetation type. The Beermullah Complex has less than 10% of pre-European extent on the Swan Coastal Plain south of Moore River remaining (6.91%). The EPA Position Statement No. 2 (2000a) considers any complex <10% as ‘Critically Endangered’.

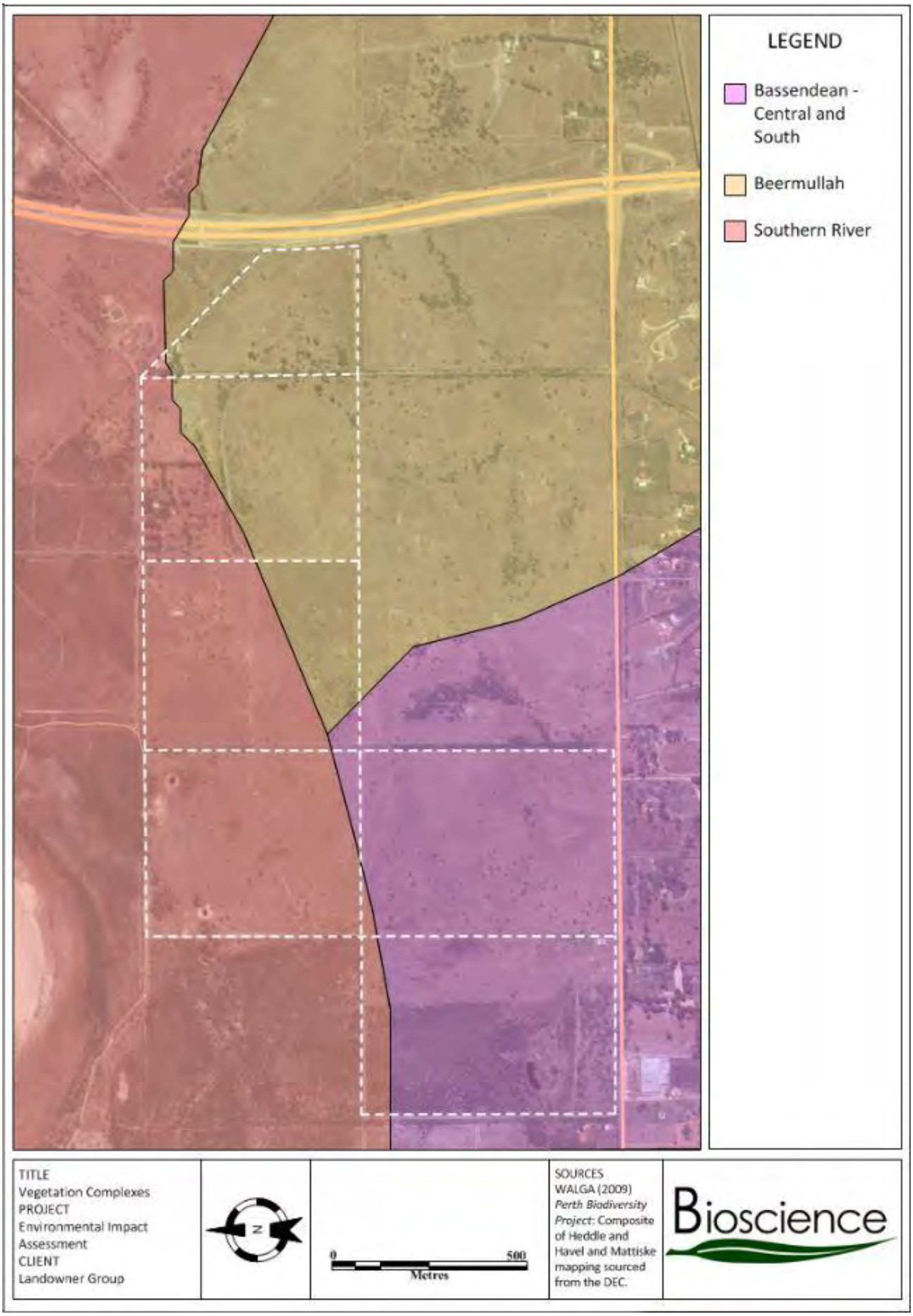


Figure 7: Vegetation Complexes

3.4.3 Vegetation of Conservation Significance

The list of Threatened Ecological Communities (TEC) from the Department of Environment and Conservation's TEC Database indicates no TECs are present within the subject area. However several TEC's are located within adjacent bushland to the north.

No potential TEC's were identified during site visits.

3.4.4 Adjacent off site Vegetation

North of Lot 9 on the northern side of the Oxley Rd Reserve is the Forrestdale Lake Nature Reserve. Within this reserve is Forrestdale Lake itself, a Ramsar Wetland of International Significance. This area is the subject of a Management Plan, published by the Conservation Commission in 2005. To the West of Lot 9, and extending into the western half of Lot 12 is Bush Forever Site 345. These Bush Forever Sites also contain Conservation Category Wetlands. North of Lot 7 and part of Lot 9 is a Recreation Reserve vested in the City of Armadale and proposed to be included in the Forrestdale Lake Nature Reserve. The entire reserve area, irrespective of the four types of tenure, is designated Bush Forever Site 345.

Site visits on neighbouring properties has indicated that generally the borders to the subject land is somewhat degraded due to past agricultural activities, firebreaks, and Oxley Road and road reserve (See Photos 1, 2 and 3). Deeper into the Bush Forever site (i.e. West) the vegetation is in much better and more natural condition. The Forrestdale Lake Nature Reserve likewise is not in good condition immediately adjacent to the subject site. However in both areas there is evidence of recent conservation and rehabilitation activity, including replanting endemic native flora, removal of established exotic trees and shrubs, and herbicide application to weeds.

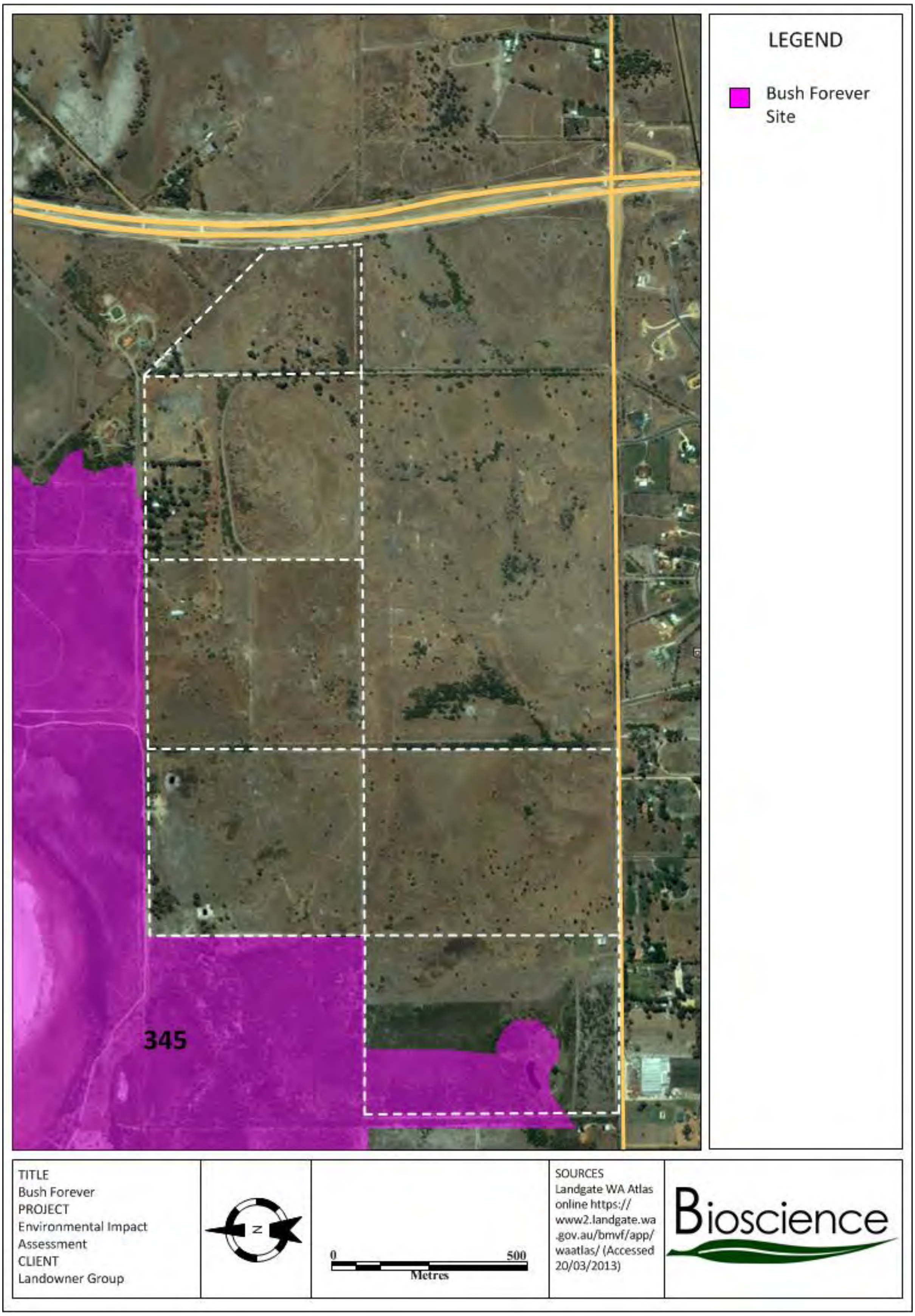


Figure 8: Location of Bush Forever Site 345

Photo 1. Midpoint of Boundary on Lot 9 looking west into Bush Forever CCW.

Photo 2. Same location looking south

Photo 3. Same location looking north

3.4.5 Recommendations

It is the recommendation of Bioscience that landscaping within the development contains native indigenous vegetation and retention of any existing native species (where practical) is undertaken to replace some natural quality to the area. A species list for revegetation can be obtained from Apace online nursery database for the Bassendean – Central and South, Beermullah, and the Southern River Complex (Apace WA 2012).

An environmentally integrated development strategy can provide cohesion between environmental functions, values and attributes as well as community values and aesthetic.

Given the need to improve the natural areas outside the study area, and the need to protect these areas from potential disturbance by future industrial land use:

- The outer areas of the study site adjoining natural areas should be restricted to the lowest impact industrial use.

- a development contribution scheme aimed at substantial rehabilitation within the bordering Reserves and Bush Forever areas should be considered as an offset against arbitrary generic buffer distances.
- wetland functions, values and attributes within the bush forever site needs to be determined, as do threatening processes, such that and appropriate rehabilitation scheme, and thereafter an appropriate buffer form and width can be determined.

3.5 Fauna

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

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

3.5.1 Fauna Habitat

The subject area has been historically cleared for making it largely devoid of native vegetation as a result there is very little habitat for native fauna. Site inspection indicated very little native fauna habitat and evidence of introduced species. Some of the existing *Melaleuca* and *Eucalyptus* trees provide some food and habitat for passing native birds. Pastureland is likely to attract some native grazing animals such as Kangaroos residing in neighbouring bushland, however for the most part, the properties have substantial cattle fences restricting such use.

3.5.2 Fauna of Conservation Significance

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

A search on DEC's *NatureMap* online indicated that four Threatened, three Priority and one specially protected fauna exists within 5km of the centre of the subject site (32° 10' 23 S, 115° 56' 41 E). Of those Threatened and Priority fauna one is listed as Vulnerable (Numbat), one is listed as Endangered (Carnaby's Cockatoo) and one listed as Critically Endangered (Native Bee) under the EPBC Act 1999. In addition to Threatened and Priority fauna eighteen species of migratory bird are listed under international agreement (Japan - JAMBA, China - CAMBA, and Korea - ROKAMBA) under the EPBC Act 1999. However again due close proximity to Lake Forrestdale it is suspected that the species listed in the search reside within the protected area within and surrounding Lake Forrestdale (particularly migratory birds under international agreement) as such a narrower search of 1 km was conducted revealing only one individual listed as a Priority 5 species and one bird under international agreement. The purpose however of conducting a broader search of the DEC NatureMap database is based on accuracy of the search data and as such Threatened and Priority fauna from the broader search was considered.

Table 2: Threatened and Priority Fauna within search area

Species	Conservation Code	EPBC Act Category
Apus pacificus (Fork-tailed Swift)	IA	-
Ardea ibis (Cattle Egret)	IA	-
Arenaria interpres (Ruddy Turnstone)	IA	-
Calidris acuminate (Sharp-tailed Sandpiper)	IA	-
Calidris ferruginea (Curlew Sandpiper)	IA	-
Calidris melanotos (Pectoral Sandpiper)	IA	-
Calidris ruficollis (Red-necked Stint)	IA	-
Calidris subminuta (Long-toed Stint)	IA	-
Calyptorhynchus latirostris (Carnaby's Cockatoo (Short-Billed Black Cockatoo)	T	Endangered
Charadrius leschenaultia (Greater Sand Plover)	IA	-
Falco Peregrinus (Peregrine Falcon)	S	-
Haliaeetus leucogaster (White-bellied Sea-Eagle)	IA	-
Isoodon obesulus ssp. *fusciventer* (Southern Brown Bandicoot)	P5	-
Leioproctus contrarius (Bee)	P3	-
Leioproctus douglasiellus (Bee)	T	-

Lerista lineata (Perth Slider, Lined Skink)	P3	-
Merops ornatus (Rainbow Bee-eater)	IA	-
Myrmecobius fasciatus (Numbat)	T	Vulnerable
Neopasiphae simplicior (Bee)	T	Critically Endangered
Ornduffia submersa	P4	-
Plegadis falcinellus (Glossy Ibis)	IA	-
Pluvialis fulva (Pacific Golden Plover)	IA	-
Pluvialis squatarola (Grey Plover)	IA	-
Schoenus pennisetis	P1	-
Stercorarius longicaudus (Long-tailed Skua)	IA	-
Tringa glareola (Wood Sandpiper)	IA	-
Tringa nebularia (Common Greenshank)	IA	-
Tringa stagnatilis (Marsh Sandpiper)	IA	-

3.5.3 Recommendations

According to EPA's *Guidance Statement Number 33 – Environmental Guidance for Planning and Development* (2008), fauna is best protected by retaining and enhancing native bushland areas. Therefore it is the recommendation of Bioscience that any remnant native species and mature trees be retained if possible and native indigenous vegetation should be used for landscaping. Rehabilitation programs should be considered for local wildlife with a focus on species in decline.

It is recommended that any landscaping within the development contains vegetation that may provide food and habitat for the critically endangered native Bee *Neopasiphae simplicior* and the endangered Carnaby's Cockatoo (*Calyptorhynchus latirostris*).

3.6 Biodiversity

City of Armadale Local Biodiversity Strategy (LBS) indicates that the subject area is within precinct 22. Precinct 22 is also classified as a category 1 meaning that it was zoned or proposed for urbanization but does not contain any structure plans. The target set out by the LBS is to protect 71 ha of Local Natural Area (LNA) in category 1 precincts, of which no more than 54 ha is wetland. The target minimum area to be protected for the whole of precinct 22 is 44 hectares or 13%.

The LBS aims to conserve natural areas of significance. Mapping of precincts was based on planning rather than existing natural characteristics. As a result the subject site does not contain any natural areas of significance as such the LBS does not apply. However it is worth noting that portions of the site used as part of the local stormwater drainage system offer opportunities for rehabilitation with local endemic flora.

3.7 Hydrogeology, Surface Water and Drainage

3.7.1 Hydrogeology

According to Davidson and Yu (2006) the study area is located within the Armadale superficial aquifers, which is bounded to the north by the Canning River, to the east by the Darling Scarp, to the south by the Byford aquifer and to the west by Lake Forrestdale and the Southern River. It should be noted however, that the study area is also located within close proximity of a transitional zone between its neighbouring superficial aquifers, namely the Jandakot and Byford aquifers. Given this mapping was conducted on a regional scale the actual hydrogeology of the site may be rather complex.

The majority of groundwater recharge, like other areas within the Swan Coastal Plain, results from rainfall infiltration, however additional recharge results from rainwater runoff from the Darling Scarp (Davidson and Yu 2006). The estimated annual groundwater recharge is only 5%, which is relatively low for the Swan Coastal Plain and due in part to low hydraulic conductivities of clayey sediments and the shallow water table.

The Armadale aquifer has a transmissivity of approximately 100m^2/day, an average annual fluctuation of approximately 0.8m between minimum and maximum groundwater levels, and it ultimately discharges into either the Southern River (4900m^3/day) or Lake Forrestdale (1000m^3/day) when groundwater levels are higher.

3.7.2 Local Groundwater

According to the Department of Environment's (DoE's) *Perth Groundwater Atlas* (DoE, 2004) the site is characterised by having a high groundwater table with moderate salinity (1000 – 1500 mg/L). Groundwater levels at the site in May 2005 (minimum) were approximately 22m ADH, whereas the all time maximum groundwater levels for the site is around 24m ADH. As described previously, the topography of the site varies from just under 24m AHD to 25m AHD, consequently the site becomes inundated in the winter months particularly in the lower lying areas (i.e. <24m AHD) (Figure 7).

Hydrological studies by Bioscience for production of a DWMS monitored groundwater levels in 24 piezometric bores across the site for three years. Coupled with data from a further 24 bores on the now industrial zoned are, a fine resolution picture has emerged which shows a very gentle groundwater hydraulic gradient which causes groundwater of the southern half of Lots 7 and 9 to move southward. whereas in the northern half, groundwater flow moves northward. In Lots 10 and 12, groundwater flow moves in a south easterly direction towards the already industrial zoned land.

Figure 9: Groundwater Contours

3.7.3 Surface Water and Drainage

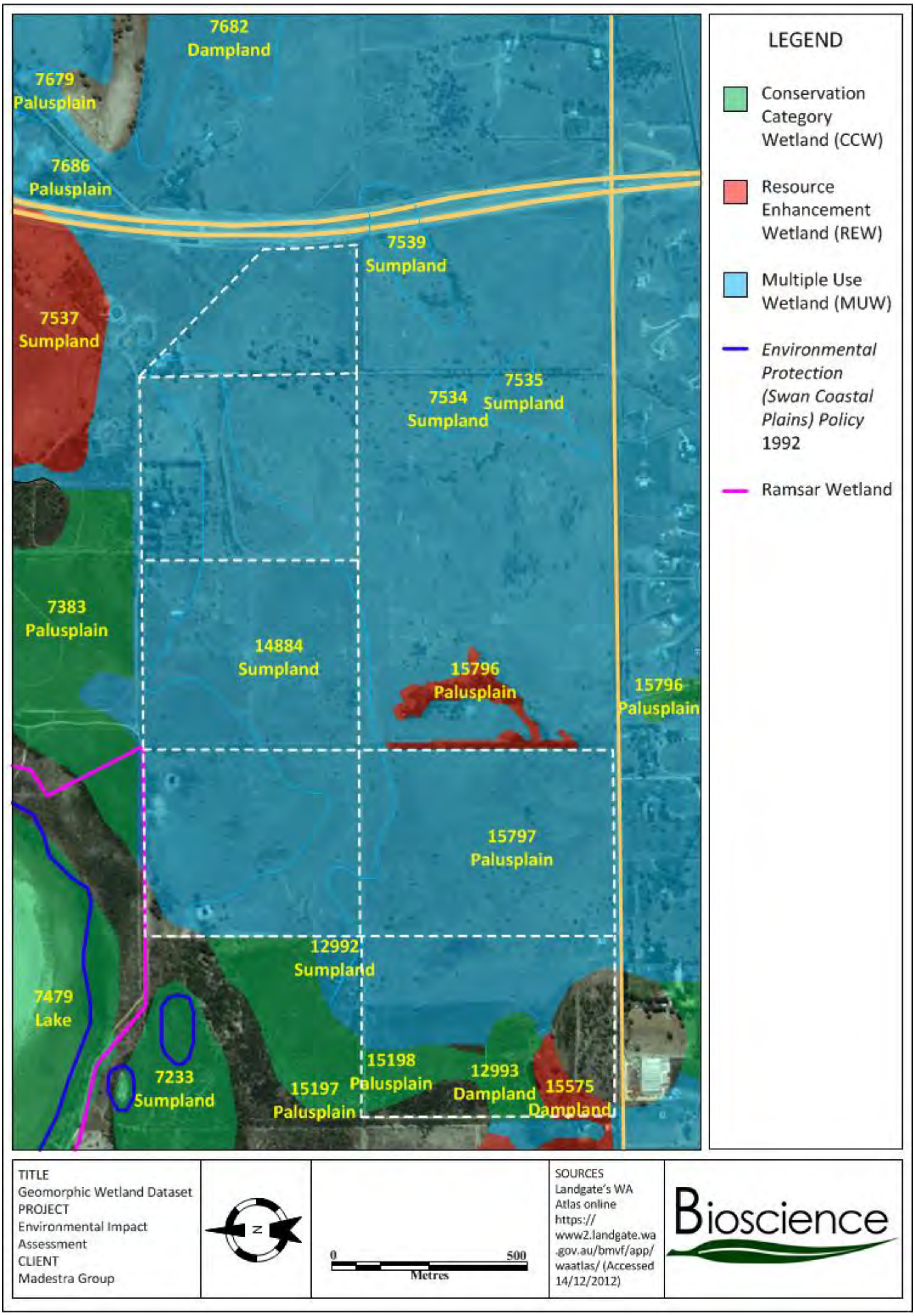
3.7.3.1 Wetlands

The Geomorphic Wetlands Dataset displays the location, boundary, geomorphic classification and management category of wetlands on the Swan Coastal Plain. The information contained within the dataset was originally digitised from the *Wetlands of the Swan Coastal Plain Volume 2B Wetland Mapping, Classification and Evaluation: Wetland Atlas*, which was captured at a scale of 1:25,000 (Hill *et al.* 1996). According to the DEC geomorphic wetland dataset the entire site lies within two multiple use wetlands (Figure 9), namely a sumpland and a palusplain or a seasonally waterlogged basin or flat area (UFI: 14884 and 15797). The site is in close proximity by many wetlands of conservation significance.

North of Lots 5,7 and 9 is a Palusplain Wetland (UFI 7383 which is a Conservation Category. The Ramsar Wetland Boundary is the road reserve north of Lot 9. Tp the west of Lot 9 in the Bush Forever land is a Conservation Category Sumpland (UFI 12992).

Within Lot 12 in the area reserved for Bush Forever are three wetlands, being Palusplain CCW (UFI 15198), Dampland CCW (UFI 12993) and Dampland Resource Enhancement Wetland (UFI 15575)

To the east of Lot 10, in the road reserve and adjoining Lot 8 is a Palusplain Resource Enhancement Wetland (15796). See Figure 8.



TITLE
Geomorphic Wetland Dataset
PROJECT
Environmental Impact Assessment
CLIENT
Madestra Group

SOURCES
Landgate's WA Atlas online https://www2.landgate.wa.gov.au/bmvf/app/waatlas/ (Accessed 14/12/2012)

Figure 10: Geomorphic Wetlands Dataset

Multiple Use Wetlands (MUWs) are areas where wetland functions, values and attributes have been seriously degraded such that they no longer serve any substantial ecological role. They are typically cleared of native vegetation and do not support wetland fauna. The management objective is to preserve hydrological functions, but otherwise they can be developed for more beneficial use.

However these wetlands are a significant environmental constraint in relation to the proposed development, due to the flooding risk. A detailed hydro geological site investigation has been undertaken to monitor and model the groundwater to determine the Average Annual Maximum Groundwater Level (AAMGL). It is likely that any proposed development will require the construction of appropriate drains. These provide the opportunity for rehabilitation as living streams to assist with environmental conservation, pollution and flood control and aid visual façade of the proposed development.

Wetland buffers are expected within EPA guidance 33 to create protection by means of separation of differing and conflicting landuses. Buffers are required where wetland values are high such as CCWs and REWs. The subject site largely contains only MUWs (with the exception of Lot 12 as described) which have very low functions, values, and attributes. As a result the wetlands within the site do not require wetland buffers.

CCW's and REW outside the site typically require a minimum 50m buffer unless site specific assessment can determine a more suitable alternative. EPA Guidance 33 refers to WAPC guidance on setting appropriate wetland buffers based on a study of threats to a wetlands values functions and attributes. The buffer is to appropriately protect against such identified threats. Such buffers are best set at structure planning stages when details of proposed land use become clearer.

3.7.3.2 Lakes

Lake Forrestdale located adjacent north is identified as an internationally recognised Ramsar site. The Ramsar Convention is an intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources. This has significant bearing on the potential hydrological effects of the development.

"Wise use" is defined as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches within the context of sustainable development".

The 2005 Forrestdale Lake Nature Reserve Management Plan highlights the major threat to ongoing wise use of the Lake is climate change significantly reducing runoff into the Lake which was historically permanent, and now typically dries out most years. The development of industrial in nearby land will involve the construction of hard surfaces such as roofs and roads. This creates the opportunity to provide a supplementary source of water to the lake by managing rainfall runoff towards the lake. A precedent already exists to supplement water into a Ramsar Wetland, where bore water is pumped into Thompsons Lake to maintain water levels.

3.7.3.3 Drainage

The majority of the subject site is largely flat with no constructed drainage. Surface water is expected to inundate lower areas and only slowly infiltrate on site. The north western corner of the subject site lies within the Lake Forrestdale Environmental Management Area. This is due to a very low topographical ridge that directs any runoff from the northern side of the ridge northward into Lake Forestdale.

Hydrological studies for the District Water Management Plan completed by Bioscience confirms that the site lies across two catchments (Figure 11); the Swan-Avon Canning River (SACR) catchment to the north (within the north Lots 5, 7, 9 and 5066) and the Peel Estuary Serpentine River (PESR) catchment to the south. However the soils in the northern catchment adjacent to the environmentally sensitive areas are typically deep sands, and between the subject land and Lake Forrestdale there are substantial sand dunes, thereby making the prospect for overland flow from the northern parts of the land into Lake Forrestdale virtually impossible.

Figure 11: Hydrological Catchments

3.7.4 Recommendations

As planning progresses towards structure planning and subdivision, consideration should be given to options for capturing stormwater from roofs and hardstand areas in ways which enable supplementing the hydrological cycle of Forrestdale Lake. Any alternation of the Lakes currently natural hydrological cycle requires careful and coordinated by studies focussed on the precautionary principle.

3.8 Acid Sulfate Soils

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

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

WAPC has compiled maps of ASS risk areas for several coastal regions of Western Australia. These maps are not an accurate representation of the risk areas but rather give a general indication and encourage site-specific investigations to determine management strategies. The land is generally moderate-low risk within 3m of natural soil surface with a high to moderate risk beyond 3m however an area within Lot 7 and 9 and a small portion of Lot 10 is a moderate to high risk of ASS within 3m of the natural soil surface (Figure 9).

Acid Sulfate Investigations of soils recovered during bore installations were undertaken as part of geotechnical studies to support the DWMS. For the most part they confirm the presence of Acid Sulfate at depth mostly coinciding with the risk maps.

Figure 12: Acid Sulfate Soil Risk Map

3.8.1 Recommendations

Bioscience recommends ASS testing be carried out prior to any ground works below the natural soil surface, for example, for the installation of services. However DER policy on Acid Sulphate Soils is to avoid disturbing them if possible. If disturbance or dewatering are unavoidable, investigations must be undertaken according to DER Guidance, and if necessary and Acid Sulfate Management Plan must be approved by DER before work begins.

3.9 Heritage

3.9.1 Indigenous

A search on the aboriginal heritage inquiry system on the Department of Indigenous Affairs (DIA) website (DIA 2011), indicated that no Aboriginal Heritage sites exist within the properties in question. However the DIA recommends that a comprehensive archaeological and ethnographic heritage survey be undertaken to identify any unidentified heritage sites. Aboriginal heritage is protected under the *Aboriginal Heritage Act 1972* which specifies that it is an offence to alter, damage, remove, destroy, conceal, deal with or assume possession of any object under or on an Aboriginal Heritage Site.

3.9.2 European

A search on the Heritage Council of Western Australia (2011) database reveals no European heritage exists within the subject area.

3.10 Contamination

According to the DEC's Contaminated Sites Database Lots 5, 7, and 9 Oxley Road, Lot 6, 8, 10 and 200 Rowley Road and 5066 Kargotich Road are not registered as a contaminated site and the current and past land use is not registered as being a potentially contaminating. The surrounding 2km area is also not registered as a contaminated site.

An area located approximately 2km north, north-west of the site is classified as "Remediated – Restricted Use" due to presence of Asbestos Containing Material (ACM). This is of no concern to the subject site and its proposed development.

The Contaminated Sites Act 2003 and associated regulations and guidelines require a tiered assessment process, and if no evidence of contamination is found from both desktop and initial field investigations, no further action is required. Previous land use is not considered to be potentially contaminating.

3.11 Nuisance Insects

The subject site contains Sumpland: 14884 Multiple Use Wetland (MUW) which gets seasonally inundated potentially providing breeding habitat for nuisance midge and mosquitoes. The risk of midge and mosquito populations becoming unacceptable is moderate to low due to the absence of permanent water bodies however due to winter inundation adequate stormwater management is required to reduce future risk. Water management for control and prevention of nuisance midge and mosquitoes can be found in EPA's *Guidance 40: Management of mosquitoes by land developers* (EPA 2000b).

3.11.1 Recommendations

Stormwater management and constructed wetlands should be in accordance with EPA's *Guidance 40: Management of mosquitoes by land developers* (EPA 2000b) for minimisation of mosquito breeding environments and integrate Water Sensitive Urban Design (WSUD) principles to ensure optimal management of stormwater run-off.

3.12 Fire Hazards

The site is adjacent to bushland to the north and west which requires consideration of protection from bushfire. Although no formal assessment has been undertaken of the Forrestdale Nature Reserve or Bush Forever land, using FESA guidance in

Planning for Bushfire Protection (2010) the area will rated as Extreme fire hazard where canopy closure of trees and/or a dense understorey is present.

The WAPC SPP 3.7 thus classifies the area as bushfire prone, and as the area is larger than 1 Ha. A Bushfire Management Strategy is thus required at the structure planning stage to determine how reduction in fire hazard is best managed.

A number of options are available to achieve the required separation of 100 m from bushfire prone areas. This are likely to include a combination of perimeter roads, particular treatment of buffer areas to minimise hazard, and the requirement to have car parking and hazard reduction landscaping at the front of buildings.

4. ENVIRONMENTAL APPROVALS

The following environmental legislations and policies are relevant to the proposed development and subject to approvals:

- *Environmental Protection Act 1986*
- *Environmental Protection and Biodiversity Conservation Act 1999*

The EPA acts as the regulatory authority under the *EP Act* 1986 who will consider all potential environmental impacts associated with the development including rezoning and subdivision.

Under the Commonwealth *EPBC Act* 1999 matters of national environmental significance are protected and subject to approvals. Matters of environmental significance include:

- Listed Threatened Ecological Communities
- Listed migratory species
- Declared Ramsar wetlands
- Commonwealth marine area
- World heritage
- National heritage

- Nuclear actions

Approvals will be required from the Department of Water with regard to water supply from bores, wells, rivers, and Water Corporation drains and connection of private and local authority drains to Water Corporation drains.

5. SUMMARY: ENVIRONMENTAL CONSTRAINTS AND RECOMMENDATIONS

The vast majority of the site is farmland which has been grazed for over 50 years, so has few remaining natural environment features. About half of Lot 12 is part of Bush Forever Site 345, and the MRS amendment application does not cover this area, which once acquired by WAPC, will eventually be rezoned Parks and Recreation.

Of the remaining land proposed for industrial rezoning, where possible, any matrue native trees should be retained. The major constraint relates to groundwater levels rising to inundate large areas which in the historic past have been poorly drained.

The construction of drainage infrastructure will provide the opportunity to restore some of the original vegetation types which were formerly present.

While the site is next to an important Ramsar Wetland, the hydrological studies undertaken for the DWMS show it is hydraulically isolated from that Lake, so industrial development of the site is unlikely to impact on water levels or quality in the Lake.

The existing Forrestdale Lake Nature Reserve Management Plan notes that climate change is the major threat to maintaining the Ramsar Wetland attributes and character with reduced rainfall. Other Conservation Category Wetlands in neighbouring Bush Forever areas are likewise imperilled by declining rainfall. However land use change from rural to industrial significantly alters the fate of rainfall and stormwater, so the opportunity arises to capture clean water and to capture and treat water from hard surfaces in the industrial area to supplement the natural environmental assets of the area. These should be investigated further during structure planning.

The interface between the industrial zone and surrounding environmental assets, both dryland and wetland, needs to be sensitive to the current condition of the natural areas and the need to protect them. There is an opportunity for developers to contribute to the rehabilitation and restoration of the Reserve land as a part of constructing effective buffers against threats which might otherwise reduce the long term future of these important environmental assets.

The low lying nature of the land means Acid Sulfate Soils will require assessment and management of excavation below the surface, or dewatering is required for the installation of services.

6. REFERENCES

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Appendix A

DEC NatureMap Species Report

3km search radius 32°38’52 S, 115°49’09 E

NatureMap Species Report

Created By Guest user on 05/03/2013

Current Names Only Yes
Core Datasets Only Yes
Method 'By Circle'
Centre 115°56' 44" E,32°10' 20" S
Buffer 3km

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
1.	3374	*Acacia huegelii*			
2.	3408	*Acacia lasiocalyx (Silver Wattle)*			
3.	3502	*Acacia pulchella (Prickly Moses)*			
4.	3527	*Acacia saligna (Orange Wattle)*			
5.	3557	*Acacia stenoptera (Narrow Winged Wattle)*			
6.	24260	*Acanthiza apicalis (Broad-tailed Thornbill)*			
7.	24261	*Acanthiza chrysorrhoa (Yellow-rumped Thornbill)*			
8.	24262	*Acanthiza inornata (Western Thornbill)*			
9.	24560	*Acanthorhynchus superciliosus (Western Spinebill)*			
10.	25535	*Accipiter cirrocephalus (Collared Sparrowhawk)*			
11.	25536	*Accipiter fasciatus (Brown Goshawk)*			
12.	-19786	*Acritoscincus trilineatus*			
13.	25755	*Acrocephalus australis (Australian Reed Warbler)*			
14.	1775	*Adenanthos cygnorum (Common Woollybush)*			
15.	1791	*Adenanthos obovatus (Basket Flower)*			
16.	1261	*Agrostocrinum scabrum (Blue Grass Lily)*			
17.	184	*Aira caryophyllea (Silvery Hairgrass)*	Y		
18.	187	*Aira praecox (Early Hairgrass)*	Y		
19.	200	*Amphipogon turbinatus*			
20.	-14144	*Aname mainae*			
21.	24310	*Anas castanea (Chestnut Teal)*			
22.	24312	*Anas gracilis (Grey Teal)*			
23.	24315	*Anas rhynchotis (Australasian Shoveler)*			
24.	24316	*Anas superciliosa (Pacific Black Duck)*			
25.	1411	*Anigozanthos manglesii (Mangles Kangaroo Paw)*			
26.	11566	*Anigozanthos viridis subsp. viridis*			
27.	24561	*Anthochaera carunculata (Red Wattlebird)*			
28.	24562	*Anthochaera lunulata (Western Little Wattlebird)*			
29.	-14278	*Antichiropus variabilis*			
30.	1117	*Aphelia cyperoides*			
31.	17845	*Apodasmia ceramophila*			
32.	25554	*Apus pacificus (Fork-tailed Swift)*		IA	
33.	24285	*Aquila audax (Wedge-tailed Eagle)*			
34.	25558	*Ardea ibis (Cattle Egret)*		IA	
35.	24341	*Ardea pacifica (White-necked Heron)*			
36.	25736	*Arenaria interpres (Ruddy Turnstone)*		IA	
37.	1264	*Arnocrinum preissii*			
38.	25566	*Artamus cinereus (Black-faced Woodswallow)*			
39.	24352	*Artamus cinereus subsp. melanops*			
40.	-13888	*Artoria flavimana*			
41.	-14569	*Artoria linnaei*			
42.	17234	*Austrostipa compressa*			
43.	231	*Avellinia michelii*	Y		
44.	24318	*Aythya australis (Hardhead)*			
45.	80	*Azolla filiculoides (Pacific Azolla)*			
46.	1800	*Banksia attenuata (Slender Banksia)*			
47.	1834	*Banksia menziesii (Firewood Banksia)*			
48.	743	*Baumea juncea (Bare Twigrush)*			
49.	24319	*Biziura lobata (Musk Duck)*			
50.	1417	*Blancoa canescens (Winter Bell)*			
51.	4417	*Boronia dichotoma*			
52.	4441	*Boronia spathulata (Boronia)*			
53.	3710	*Bossiaea eriocarpa (Common Brown Pea)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
54.	6341	*Brachyloma preissii (Globe Heath)*			
55.	7878	*Brachyscome iberidifolia*			
56.	244	*Briza maxima (Blowfly Grass)*	Y		
57.	245	*Briza minor (Shivery Grass)*	Y		
58.	1383	*Burchardia bairdiae*			
59.	1385	*Burchardia multiflora (Dwarf Burchardia)*			
60.	25713	*Cacatua galerita (Sulphur-crested Cockatoo)*			
61.	25716	*Cacatua sanguinea (Little Corella)*			
62.	24729	*Cacatua tenuirostris (Eastern Long-billed Corella)*	Y		
63.	25598	*Cacomantis flabelliformis (Fan-tailed Cuckoo)*			
64.	1277	*Caesia occidentalis*			
65.	1592	*Caladenia flava (Cowslip Orchid)*			
66.	1605	*Caladenia marginata (White Fairy Orchid)*			
67.	15503	*Caladenia paludosa*			
68.	24779	*Calidris acuminata (Sharp-tailed Sandpiper)*		IA	
69.	24784	*Calidris ferruginea (Curlew Sandpiper)*		IA	
70.	24786	*Calidris melanotos (Pectoral Sandpiper)*		IA	
71.	24788	*Calidris ruficollis (Red-necked Stint)*		IA	
72.	24789	*Calidris subminuta (Long-toed Stint)*		IA	
73.	5415	*Calothamnus lateralis*			
74.	25717	*Calyptorhynchus banksii (Red-tailed Black-Cockatoo)*			
75.	24734	*Calyptorhynchus latirostris (Carnaby's Cockatoo (short-billed black-cockatoo))*		T	
76.	5460	*Calytrix fraseri (Pink Summer Calytrix)*			
77.	1162	*Cartonema philydroides*			
78.	2957	*Cassytha racemosa (Dodder Laurel)*			
79.	1121	*Centrolepis aristata (Pointed Centrolepis)*			
80.	1125	*Centrolepis drummondiana*			
81.	1134	*Centrolepis polygyna (Wiry Centrolepis)*			
82.	17685	*Chaetanthus aristatus*			
83.	24186	*Chalinolobus gouldii (Gould's Wattled Bat)*			
84.	25575	*Charadrius leschenaultii (Greater Sand Plover)*		IA	
85.	24377	*Charadrius ruficapillus (Red-capped Plover)*			
86.	24321	*Chenonetta jubata (Australian Wood Duck)*			
87.	763	*Chorizandra enodis (Black Bristlerush)*			
88.	24980	*Christinus marmoratus (Marbled Gecko)*			
89.	6543	*Cicendia filiformis (Slender Cicendia)*	Y		
90.	24833	*Cincloramphus cruralis (Brown Songlark)*			
91.	24834	*Cincloramphus mathewsi (Rufous Songlark)*			
92.	24288	*Circus approximans (Swamp Harrier)*			
93.	24774	*Cladorhynchus leucocephalus (Banded Stilt)*			
94.	25675	*Colluricincla harmonica (Grey Shrike-thrush)*			
95.	24399	*Columba livia (Domestic Pigeon)*	Y		
96.	6348	*Conostephium pendulum (Pearl Flower)*			
97.	1418	*Conostylis aculeata (Prickly Conostylis)*			
98.	1436	*Conostylis juncea*			
99.	7939	*Conyza bonariensis (Flaxleaf Fleabane)*	Y		
100.	7941	*Conyza parva*	Y		
101.	20074	*Conyza sumatrensis*	Y		
102.	25568	*Coracina novaehollandiae (Black-faced Cuckoo-shrike)*			
103.	38776	*Cortinarius phalarus*			
104.	25592	*Corvus coronoides (Australian Raven)*			
105.	24417	*Corvus coronoides subsp. perplexus*			
106.	1285	*Corynotheca micrantha (Sand Lily)*			
107.	7945	*Cotula coronopifolia (Waterbuttons)*	Y		
108.	25701	*Coturnix ypsilophora (Brown Quail)*			
109.	24673	*Coturnix ypsilophora subsp. australis*			
110.	25595	*Cracticus tibicen (Australian Magpie)*			
111.	25596	*Cracticus torquatus (Grey Butcherbird)*			
112.	25398	*Crinia georgiana (Quacking Frog)*			
113.	25400	*Crinia insignifera (Squelching Froglet)*			
114.	30893	*Cryptoblepharus buchananii*			
115.	25027	*Ctenotus australis*			
116.	768	*Cyathochaeta avenacea*			
117.	24322	*Cygnus atratus (Black Swan)*			
118.	783	*Cyperus congestus (Dense Flat-sedge)*	Y		
119.	815	*Cyperus tenellus (Tiny Flatsedge)*	Y		
120.	10916	*Cyrtostylis huegelii*			
121.	30901	*Dacelo novaeguineae (Laughing Kookaburra)*	Y		
122.	7454	*Dampiera linearis (Common Dampiera)*			
123.	7484	*Dampiera trigona (Angled-stem Dampiera)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
124.	25673	*Daphoenositta chrysoptera (Varied Sittella)*			
125.	1218	*Dasypogon bromeliifolius (Pineapple Bush)*			
126.	3832	*Daviesia physodes*			
127.	1259	*Dianella revoluta (Blueberry Lily)*			
128.	25607	*Dicaeum hirundinaceum (Mistletoebird)*			
129.	306	*Dichelachne crinita (Longhair Plumegrass)*			
130.	1287	*Dichopogon capillipes*			
131.	17838	*Dielsia stenostachya*			
132.	-13563	*Dingosa serrata*			
133.	1634	*Diuris laxiflora (Bee Orchid)*			
134.	1637	*Diuris purdiei (Purdie's Donkey Orchid)*		T	
135.	1639	*Drakaea elastica (Glossy-leaved Hammer Orchid)*		T	
136.	13635	*Drakaea micrantha*		T	
137.	3095	*Drosera erythrorhiza (Red Ink Sundew)*			
138.	3097	*Drosera gigantea (Giant Sundew)*			
139.	3101	*Drosera heterophylla (Swamp Rainbow)*			
140.	11853	*Drosera menziesii subsp. menziesii*			
141.	13216	*Drosera menziesii subsp. penicillaris*			
142.	3113	*Drosera neesii (Jewel Rainbow)*			
143.	13191	*Drosera occidentalis subsp. occidentalis*		P4	
144.	3124	*Drosera pulchella (Pretty Sundew)*			
145.	347	*Ehrharta calycina (Perennial Veldt Grass)*	Y		
146.	1645	*Epiblema grandiflorum (Babe-in-a-cradle)*			
147.	6131	*Epilobium billardiereanum (Glabrous Willow Herb)*			
148.	24567	*Epthianura albifrons (White-fronted Chat)*			
149.	379	*Eragrostis elongata (Clustered Lovegrass)*			
150.	1646	*Eriochilus dilatatus (White Bunny Orchid)*			
151.	15415	*Eriochilus scaber subsp. scaber*			
152.	6219	*Eryngium pinnatifidum (Blue Devils)*			
153.	24379	*Erythrogonys cinctus (Red-kneed Dotterel)*			
154.	5790	*Eucalyptus todtiana (Coastal Blackbutt)*			
155.	3872	*Euchilopsis linearis (Swamp Pea)*			
156.	24368	*Eurostopodus argus (Spotted Nightjar)*			
157.	3880	*Eutaxia virgata*			
158.	835	*Evandra pauciflora*			
159.	25621	*Falco berigora (Brown Falcon)*			
160.	25622	*Falco cenchroides (Australian Kestrel)*			
161.	25623	*Falco longipennis (Australian Hobby)*			
162.	25624	*Falco peregrinus (Peregrine Falcon)*		S	
163.	894	*Fimbristylis velata*			
164.	25727	*Fulica atra (Eurasian Coot)*			
165.	907	*Gahnia trifida (Coast Saw-sedge)*			
166.	25729	*Gallinula tenebrosa (Dusky Moorhen)*			
167.	24763	*Gallinula tenebrosa subsp. tenebrosa*			
168.	25730	*Gallirallus philippensis (Buff-banded Rail)*			
169.	25530	*Gerygone fusca (Western Gerygone)*			
170.	1520	*Gladiolus caryophyllaceus (Wild Gladiolus)*	Y		
171.	24735	*Glossopsitta porphyrocephala (Purple-crowned Lorikeet)*			
172.	3957	*Gompholobium tomentosum (Hairy Yellow Pea)*			
173.	6161	*Gonocarpus pithyoides*			
174.	12551	*Goodenia micrantha*			
175.	7538	*Goodenia pulchella*			
176.	19286	*Goodenia pulchella subsp. Coastal Plain A (M. Hislop 634)*			
177.	24443	*Grallina cyanoleuca (Magpie-lark)*			
178.	13429	*Grevillea diversifolia subsp. diversifolia*			
179.	1475	*Haemodorum spicatum (Mardja)*			
180.	2179	*Hakea marginata*			
181.	2212	*Hakea sulcata (Furrowed Hakea)*			
182.	2216	*Hakea varia (Variable-leaved Hakea)*			
183.	24293	*Haliaeetus leucogaster (White-bellied Sea-Eagle)*		IA	
184.	24295	*Haliastur sphenurus (Whistling Kite)*			
185.	25410	*Heleioporus eyrei (Moaning Frog)*			
186.	25119	*Hemiergis quadrilineata*			
187.	19778	*Hibbertia glomerata subsp. darlingensis*			
188.	5134	*Hibbertia huegelii*			
189.	5162	*Hibbertia racemosa (Stalked Guinea Flower)*			
190.	25734	*Himantopus himantopus (Black-winged Stilt)*			
191.	24491	*Hirundo neoxena (Welcome Swallow)*			
192.	444	*Holcus lanatus (Yorkshire Fog)*	Y		
193.	6222	*Homalosciadium homalocarpum*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
194.	3968	*Hovea trisperma (Common Hovea)*			
195.	12741	*Hyalosperma cotula*			
196.	6226	*Hydrocotyle callicarpa (Small Pennywort)*			
197.	5817	*Hypocalymma angustifolium (White Myrtle)*			
198.	5825	*Hypocalymma robustum (Swan River Myrtle)*			
199.	8086	*Hypochaeris glabra (Smooth Catsear)*	Y		
200.	1070	*Hypolaena exsulca*			
201.	17841	*Hypolaena pubescens*			
202.	1503	*Hypoxis occidentalis*			
203.	-14290	*Idiosoma sigillatum*			
204.	910	*Isolepis cernua (Nodding Club-rush)*			
205.	917	*Isolepis marginata (Coarse Club-rush)*	Y		
206.	919	*Isolepis oldfieldiana*			
207.	24153	*Isoodon obesulus subsp. fusciventer (Quenda, Southern Brown Bandicoot)*		P5	
208.	2227	*Isopogon divergens (Spreading Coneflower)*			
209.	3992	*Isotropis cuneifolia (Granny Bonnets)*			
210.	4012	*Jacksonia furcellata (Grey Stinkwood)*			
211.	20462	*Jacksonia gracillima*		P3	
212.	1177	*Juncus articulatus (Jointed Rush)*	Y		
213.	1180	*Juncus capitatus (Capitate Rush)*	Y		
214.	4044	*Kennedia prostrata (Scarlet Runner)*			
215.	5832	*Kunzea ericifolia (Spearwood)*			
216.	5835	*Kunzea micrantha*			
217.	20019	*Lachnagrostis filiformis*			
218.	8095	*Lactuca saligna (Wild Lettuce)*	Y		
219.	11911	*Laxmannia ramosa subsp. ramosa*			
220.	1308	*Laxmannia sessiliflora (Nodding Lily)*			
221.	7572	*Lechenaultia expansa*			
222.	33982	*Leioproctus contrarius (bee)*		P3	
223.	33983	*Leioproctus douglasiellus (bee)*		T	
224.	925	*Lepidosperma angustatum*			
225.	937	*Lepidosperma longitudinale (Pithy Sword-sedge)*			
226.	942	*Lepidosperma rostratum*		T	
227.	945	*Lepidosperma squamatum*			
228.	1653	*Leporella fimbriata (Hare Orchid)*			
229.	19833	*Leptocarpus laxus*			
230.	6374	*Leucopogon conostephioides*			
231.	6447	*Leucopogon strictus*			
232.	25005	*Lialis burtonis*			
233.	24581	*Lichenostomus virescens (Singing Honeyeater)*			
234.	25661	*Lichmera indistincta (Brown Honeyeater)*			
235.	25415	*Limnodynastes dorsalis (Western Banjo Frog)*			
236.	25378	*Litoria adelaidensis (Slender Tree Frog)*			
237.	25388	*Litoria moorei (Motorbike Frog)*			
238.	7408	*Lobelia tenuior (Slender Lobelia)*			
239.	478	*Lolium rigidum (Wimmera Ryegrass)*	Y		
240.	1223	*Lomandra caespitosa (Tufted Mat Rush)*			
241.	1228	*Lomandra hermaphrodita*			
242.	1232	*Lomandra micrantha (Small-flower Mat-rush)*			
243.	-14776	*Lycosa ariadnae*			
244.	1097	*Lyginia barbata*			
245.	18049	*Lyginia imberbis*			
246.	2838	*Macarthuria apetala*			
247.	2839	*Macarthuria australis*			
248.	85	*Macrozamia riedlei (Zamia)*			
249.	24326	*Malacorhynchus membranaceus (Pink-eared Duck)*			
250.	25654	*Malurus splendens (Splendid Fairy-wren)*			
251.	24583	*Manorina flavigula (Yellow-throated Miner)*			
252.	17683	*Meeboldina cana*			
253.	17679	*Meeboldina coangustata*			
254.	17677	*Meeboldina roycei*			
255.	25758	*Megalurus gramineus (Little Grassbird)*			
256.	13273	*Melaleuca incana subsp. incana*			
257.	5926	*Melaleuca lateritia (Robin Redbreast Bush)*			
258.	20297	*Melaleuca osullivanii*			
259.	5952	*Melaleuca preissiana (Moonah)*			
260.	5959	*Melaleuca rhaphiophylla (Swamp Paperbark)*			
261.	5978	*Melaleuca teretifolia (Banbar)*			
262.	5984	*Melaleuca uncinata (Broom Bush)*			
263.	5987	*Melaleuca viminea (Mohan)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
264.	25184	*Menetia greyii*			
265.	24598	*Merops ornatus (Rainbow Bee-eater)*		IA	
266.	1658	*Microtis atrata (Swamp Mignonette Orchid)*			
267.	8106	*Millotia tenuifolia (Soft Millotia)*			
268.	-13593	*Missulena granulosa subsp. granulosa*			
269.	7410	*Monopsis debilis*	Y		
270.	25610	*Myiagra inquieta (Restless Flycatcher)*			
271.	8117	*Myriocephalus helichrysoides*			
272.	33984	*Neopasiphae simplicior (bee)*		T	
273.	24738	*Neophema elegans (Elegant Parrot)*			
274.	492	*Neurachne alopecuroidea (Foxtail Mulga Grass)*			
275.	25748	*Ninox novaeseelandiae (Boobook Owl)*			
276.	24820	*Ninox novaeseelandiae subsp. boobook (Boobook Owl)*			
277.	25252	*Notechis scutatus (Tiger Snake)*			
278.	2401	*Nuytsia floribunda (Christmas Tree)*			
279.	25564	*Nycticorax caledonicus (Rufous Night Heron)*			
280.	24194	*Nyctophilus geoffroyi (Lesser Long-eared Bat)*			
281.	24742	*Nymphicus hollandicus (Cockatiel)*			
282.	24407	*Ocyphaps lophotes (Crested Pigeon)*			
283.	-13203	*Ommatoiulus moreletii*			
284.	36200	*Ornduffia submersa*		P4	
285.	24328	*Oxyura australis (Blue-billed Duck)*			
286.	25679	*Pachycephala pectoralis (Golden Whistler)*			
287.	25680	*Pachycephala rufiventris (Rufous Whistler)*			
288.	502	*Panicum capillare (Witchgrass)*	Y		
289.	3618	*Paraserianthes lophantha (Albizia)*			
290.	25253	*Parasuta gouldii*			
291.	25681	*Pardalotus punctatus (Spotted Pardalote)*			
292.	25682	*Pardalotus striatus (Striated Pardalote)*			
293.	7090	*Parentucellia viscosa (Sticky Bartsia)*	Y		
294.	1550	*Patersonia occidentalis (Purple Flag)*			
295.	30472	*Patersonia occidentalis var. occidentalis*			
296.	24648	*Pelecanus conspicillatus (Australian Pelican)*			
297.	6006	*Pericalymma ellipticum (Swamp Teatree)*			
298.	16477	*Pericalymma ellipticum var. ellipticum*			
299.	24659	*Petroica goodenovii (Red-capped Robin)*			
300.	20391	*Petrophile juncifolia*			
301.	2299	*Petrophile linearis (Pixie Mops)*			
302.	25697	*Phalacrocorax carbo (Great Cormorant)*			
303.	24667	*Phalacrocorax sulcirostris (Little Black Cormorant)*			
304.	25699	*Phalacrocorax varius (Pied Cormorant)*			
305.	24409	*Phaps chalcoptera (Common Bronzewing)*			
306.	1172	*Philydrella drummondii*			
307.	14306	*Philydrella pygmaea subsp. pygmaea*			
308.	1478	*Phlebocarya ciliata*			
309.	24596	*Phylidonyris novaehollandiae (New Holland Honeyeater)*			
310.	4	*Phylloglossum drummondii (Pigmy Clubmoss)*			
311.		*Phytophthora cinnamomi*			
312.	11404	*Pimelea imbricata var. major*			
313.	11402	*Pimelea imbricata var. piligera*			
314.	24841	*Platalea flavipes (Yellow-billed Spoonbill)*			
315.	24843	*Plegadis falcinellus (Glossy Ibis)*		IA	
316.	24382	*Pluvialis fulva (Pacific Golden Plover)*		IA	
317.	24383	*Pluvialis squatarola (Grey Plover)*		IA	
318.	25703	*Podargus strigoides (Tawny Frogmouth)*			
319.	25704	*Podiceps cristatus (Great Crested Grebe)*			
320.	8175	*Podolepis gracilis (Slender Podolepis)*			
321.	38826	*Podoserpula pusio*			
322.	8183	*Podotheca chrysantha (Yellow Podotheca)*			
323.	24681	*Poliocephalus poliocephalus (Hoary-headed Grebe)*			
324.	4578	*Polygala virgata*	Y		
325.	25722	*Polytelis anthopeplus (Regent Parrot)*			
326.	25731	*Porphyrio porphyrio (Purple Swamphen)*			
327.	24769	*Porzana fluminea (Australian Spotted Crake)*			
328.	25732	*Porzana pusilla (Baillon's Crake)*			
329.	24771	*Porzana tabuensis (Spotless Crake)*			
330.	1670	*Prasophyllum drummondii (Swamp Leek Orchid)*			
331.	1673	*Prasophyllum gibbosum (Humped Leek Orchid)*			
332.	25259	*Pseudonaja affinis subsp. affinis (Dugite)*			
333.	25433	*Pseudophryne guentheri (Crawling Toadlet)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
334.	1698	*Pterostylis vittata (Banded Greenhood)*			
335.	4177	*Pultenaea ochreata*			
336.	16367	*Pyrorchis nigricans (Red beaks)*			
337.	8195	*Quinetia urvillei*			
338.	24245	*Rattus rattus (Black Rat)*	Y		
339.	24776	*Recurvirostra novaehollandiae (Red-necked Avocet)*			
340.	6012	*Regelia ciliata*			
341.	25614	*Rhipidura leucophrys (Willie Wagtail)*			
342.	1556	*Romulea rosea (Guildford Grass)*	Y		
343.	984	*Schoenus curvifolius*			
344.	986	*Schoenus efoliatus*			
345.	992	*Schoenus grandiflorus (Large Flowered Bogrush)*			
346.	1006	*Schoenus odontocarpus*			
347.	17614	*Schoenus plumosus*			
348.	1011	*Schoenus rigens*			
349.	1018	*Schoenus subfascicularis*			
350.	1023	*Schoenus tenellus*			
351.	6033	*Scholtzia involucrata (Spiked Scholtzia)*			
352.	6	*Selaginella gracillima (Tiny Clubmoss)*			
353.	25534	*Sericornis frontalis (White-browed Scrubwren)*			
354.	8225	*Siloxerus humifusus (Procumbent Siloxerus)*			
355.	30948	*Smicrornis brevirostris (Weebill)*			
356.	1312	*Sowerbaea laxiflora (Purple Tassels)*			
357.	2912	*Spergula arvensis (Corn Spurry)*	Y		
358.	24516	*Stercorarius longicaudus (Long-tailed Skua)*		IA	
359.	24329	*Stictonetta naevosa (Freckled Duck)*			
360.	2316	*Stirlingia latifolia (Blueboy)*			
361.	25589	*Streptopelia chinensis (Spotted Turtle-Dove)*	Y		
362.	25590	*Streptopelia senegalensis (Laughing Turtle-Dove)*	Y		
363.	30950	*Streptopelia senegalensis subsp. senegalensis*	Y		
364.	7693	*Stylidium brunonianum (Pink Fountain Triggerplant)*			
365.	7713	*Stylidium dichotomum (Pins-and-needles)*			
366.	7717	*Stylidium divaricatum (Daddy-long-legs)*			
367.	7719	*Stylidium ecorne (Foot Triggerplant)*			
368.	7721	*Stylidium emarginatum (Biddy-four-legs)*			
369.	7742	*Stylidium inundatum (Hundreds and Thousands)*			
370.	7785	*Stylidium repens (Matted Triggerplant)*			
371.	7790	*Stylidium roseoalatum (Pink-wing Triggerplant)*			
372.	7806	*Stylidium utricularioides (Pink Fan Triggerplant)*			
373.	1260	*Stypandra glauca (Blind Grass)*			
374.	-13193	*Supunna funerea*			
375.	25705	*Tachybaptus novaehollandiae (Australasian Grebe)*			
376.	24331	*Tadorna tadornoides (Australian Shelduck)*			
377.	15741	*Tamarix aphylla (Athel Tree)*	Y		
378.	24167	*Tarsipes rostratus (Honey Possum)*			
379.	14333	*Tetratheca sp. Granite (S. Patrick SP1224)*		P3	
380.	20728	*Thelymitra xanthotricha*			
381.	24844	*Threskiornis molucca (Australian White Ibis)*			
382.	24845	*Threskiornis spinicollis (Straw-necked Ibis)*			
383.	1318	*Thysanotus arbuscula*			
384.	1339	*Thysanotus multiflorus (Many-flowered Fringe Lily)*			
385.	1351	*Thysanotus sparteus*			
386.	1357	*Thysanotus thyrsoideus*			
387.	1358	*Thysanotus triandrus*			
388.	25549	*Todiramphus sanctus (Sacred Kingfisher)*			
389.	6280	*Trachymene pilosa (Native Parsnip)*			
390.	17684	*Tremulina tremula*			
391.	1481	*Tribonanthes australis*			
392.	1485	*Tribonanthes violacea*			
393.	25723	*Trichoglossus haematodus (Rainbow Lorikeet)*			
394.	24158	*Trichosurus vulpecula subsp. vulpecula (Common Brushtail Possum)*			
395.	1361	*Tricoryne elatior (Yellow Autumn Lily)*			
396.	1363	*Tricoryne tenella*			
397.	1038	*Tricostularia neesii*			
398.	24806	*Tringa glareola (Wood Sandpiper)*		IA	
399.	24808	*Tringa nebularia (Common Greenshank)*		IA	
400.	24809	*Tringa stagnatilis (Marsh Sandpiper)*		IA	
401.	-14745	*Urodacus novaehollandiae*			
402.	8255	*Ursinia anthemoides (Ursinia)*	Y		
403.	24386	*Vanellus tricolor (Banded Lapwing)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
404.	-13948	*Venator immansueta*			
405.	6076	*Verticordia densiflora (Compacted Featherflower)*			
406.	12411	*Verticordia densiflora var. cespitosa*			
407.	6077	*Verticordia drummondii (Drummond's Featherflower)*			
408.	14714	*Verticordia lindleyi subsp. lindleyi*		P4	
409.	6110	*Verticordia plumosa (Plumed Featherflower)*			
410.	12452	*Verticordia plumosa var. pleiobotrya*		T	
411.	722	*Vulpia bromoides (Squirrel Tail Fescue)*	Y		
412.	724	*Vulpia myuros (Rat's Tail Fescue)*	Y		
413.	1256	*Xanthorrhoea preissii (Grass tree)*			
414.	6289	*Xanthosia huegelii*			
415.	1049	*Zantedeschia aethiopica (Arum Lily)*	Y		
416.	25765	*Zosterops lateralis (Grey-breasted White-eye)*			

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

Appendix B

DEC NatureMap Species Report

1 Km Search Radius

NatureMap Species Report

Created By Guest user on 11/04/2013

Current Names Only	Yes
Core Datasets Only	Yes
Method	'By Circle'
Centre	115°56' 40" E,32°10' 23" S
Buffer	1km

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
1.	24260	*Acanthiza apicalis (Broad-tailed Thornbill)*			
2.	24261	*Acanthiza chrysorrhoa (Yellow-rumped Thornbill)*			
3.	24560	*Acanthorhynchus superciliosus (Western Spinebill)*			
4.	24316	*Anas superciliosa (Pacific Black Duck)*			
5.	24561	*Anthochaera carunculata (Red Wattlebird)*			
6.	24562	*Anthochaera lunulata (Western Little Wattlebird)*			
7.	1162	*Cartonema philydroides*			
8.	24288	*Circus approximans (Swamp Harrier)*			
9.	25568	*Coracina novaehollandiae (Black-faced Cuckoo-shrike)*			
10.	25592	*Corvus coronoides (Australian Raven)*			
11.	25595	*Cracticus tibicen (Australian Magpie)*			
12.	25596	*Cracticus torquatus (Grey Butcherbird)*			
13.	25027	*Ctenotus australis*			
14.	25622	*Falco cenchroides (Australian Kestrel)*			
15.	25530	*Gerygone fusca (Western Gerygone)*			
16.	24443	*Grallina cyanoleuca (Magpie-lark)*			
17.	24491	*Hirundo neoxena (Welcome Swallow)*			
18.	24153	*Isoodon obesulus subsp. fusciventer (Quenda, Southern Brown Bandicoot)*		P5	
19.	24581	*Lichenostomus virescens (Singing Honeyeater)*			
20.	25661	*Lichmera indistincta (Brown Honeyeater)*			
21.	25654	*Malurus splendens (Splendid Fairy-wren)*			
22.	24598	*Merops ornatus (Rainbow Bee-eater)*		IA	
23.	25680	*Pachycephala rufiventris (Rufous Whistler)*			
24.	25682	*Pardalotus striatus (Striated Pardalote)*			
25.	24409	*Phaps chalcoptera (Common Bronzewing)*			
26.	24596	*Phylidonyris novaehollandiae (New Holland Honeyeater)*			
27.	25614	*Rhipidura leucophrys (Willie Wagtail)*			
28.	25590	*Streptopelia senegalensis (Laughing Turtle-Dove)*	Y		
29.	24844	*Threskiornis molucca (Australian White Ibis)*			
30.	25765	*Zosterops lateralis (Grey-breasted White-eye)*			

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T - Rare or likely to become extinct
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S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

Appendix I: Nature Map

NatureMap Species Report

Created By Guest user on 05/10/2016

Current Names Only Yes
Core Datasets Only Yes
Method 'By Circle'
Centre 115° 56' 41'' E,32° 10' 23'' S
Buffer 5km
Group By Species Group

Species Group	Species	Records
Amphibian	8	63
Bird	180	25924
Dicotyledon	232	475
Fungus	7	34
Gymnosperm	2	7
Hepatic (Liverwort)	1	1
Invertebrate	39	193
Lichen	5	5
Mammal	15	122
Monocotyledon	181	414
Pteridophyte (Fern)	3	6
Reptile	28	143
TOTAL	**701**	**27387**

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
Amphibian					
1.	25398	*Crinia georgiana (Quacking Frog)*			
2.	25400	*Crinia insignifera (Squelching Froglet)*			
3.		*Crinia sp.*			
4.	25410	*Heleioporus eyrei (Moaning Frog)*			
5.	25415	*Limnodynastes dorsalis (Western Banjo Frog)*			
6.	25378	*Litoria adelaidensis (Slender Tree Frog)*			
7.	25388	*Litoria moorei (Motorbike Frog)*			
8.	25433	*Pseudophryne guentheri (Crawling Toadlet)*			
Bird					
9.	24260	*Acanthiza apicalis (Broad-tailed Thornbill, Inland Thornbill)*			
10.	24261	*Acanthiza chrysorrhoa (Yellow-rumped Thornbill)*			
11.	24262	*Acanthiza inornata (Western Thornbill)*			
12.	24560	*Acanthorhynchus superciliosus (Western Spinebill)*			
13.	25535	*Accipiter cirrocephalus (Collared Sparrowhawk)*			
14.	25536	*Accipiter fasciatus (Brown Goshawk)*			
15.	25755	*Acrocephalus australis (Australian Reed Warbler)*			
16.	24310	*Anas castanea (Chestnut Teal)*			
17.	24312	*Anas gracilis (Grey Teal)*			
18.	24315	*Anas rhynchotis (Australasian Shoveler)*			
19.	24316	*Anas superciliosa (Pacific Black Duck)*			
20.		*Anhinga novaehollandiae*			
21.		*Anser anser*			
22.	24561	*Anthochaera carunculata (Red Wattlebird)*			
23.	24562	*Anthochaera lunulata (Western Little Wattlebird)*			
24.	25554	*Apus pacificus (Fork-tailed Swift)*		IA	
25.	24285	*Aquila audax (Wedge-tailed Eagle)*			
26.	25558	*Ardea ibis (Cattle Egret)*		IA	
27.	41324	*Ardea modesta (Eastern Great Egret)*		IA	
28.	24340	*Ardea novaehollandiae (White-faced Heron)*			
29.	24341	*Ardea pacifica (White-necked Heron)*			
30.	25736	*Arenaria interpres (Ruddy Turnstone)*		IA	
31.	25566	*Artamus cinereus (Black-faced Woodswallow)*			
32.	24352	*Artamus cinereus subsp. melanops (Black-faced Woodswallow)*			
33.	24353	*Artamus cyanopterus (Dusky Woodswallow)*			
34.		*Aythya (Nyroca) australis*			
35.	24318	*Aythya australis (Hardhead)*			
36.		*Barnardius zonarius*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
37.	24319	*Biziura lobata (Musk Duck)*			
38.	24345	*Botaurus poiciloptilus (Australasian Bittern)*		T	
39.	25713	*Cacatua galerita (Sulphur-crested Cockatoo)*			
40.	25714	*Cacatua pastinator (Western Long-billed Corella)*			
41.	25715	*Cacatua roseicapilla (Galah)*			
42.	25716	*Cacatua sanguinea (Little Corella)*			
43.		*Cacatua sp.*			
44.	24729	*Cacatua tenuirostris (Eastern Long-billed Corella)*	Y		
45.	25598	*Cacomantis flabelliformis (Fan-tailed Cuckoo)*			
46.	42307	*Cacomantis pallidus (Pallid Cuckoo)*			
47.	24779	*Calidris acuminata (Sharp-tailed Sandpiper)*		IA	
48.	24784	*Calidris ferruginea (Curlew Sandpiper)*		T	
49.	24786	*Calidris melanotos (Pectoral Sandpiper)*		IA	
50.	24788	*Calidris ruficollis (Red-necked Stint)*		IA	
51.	24789	*Calidris subminuta (Long-toed Stint)*		IA	
52.	25717	*Calyptorhynchus banksii (Red-tailed Black-Cockatoo)*			
53.	24731	*Calyptorhynchus banksii subsp. naso (Forest Red-tailed Black-Cockatoo)*		T	
54.	24734	*Calyptorhynchus latirostris (Carnaby's Cockatoo (short-billed black-cockatoo), Carnaby's Cockatoo)*		T	
55.		*Calyptorhynchus sp.*			
56.	25575	*Charadrius leschenaultii (Greater Sand Plover)*		IA	
57.	24373	*Charadrius melanops (Black-fronted Dotterel)*			
58.	24377	*Charadrius ruficapillus (Red-capped Plover)*			
59.	24321	*Chenonetta jubata (Australian Wood Duck, Wood Duck)*			
60.		*Chroicocephalus novaehollandiae*			
61.	24833	*Cincloramphus cruralis (Brown Songlark)*			
62.	24834	*Cincloramphus mathewsi (Rufous Songlark)*			
63.	24288	*Circus approximans (Swamp Harrier)*			
64.	24289	*Circus assimilis (Spotted Harrier)*			
65.	24774	*Cladorhynchus leucocephalus (Banded Stilt)*			
66.	24396	*Climacteris rufa (Rufous Treecreeper)*			
67.	25675	*Colluricincla harmonica (Grey Shrike-thrush)*			
68.	24399	*Columba livia (Domestic Pigeon)*	Y		
69.	25568	*Coracina novaehollandiae (Black-faced Cuckoo-shrike)*			
70.	25592	*Corvus coronoides (Australian Raven)*			
71.	24417	*Corvus coronoides subsp. perplexus (Australian Raven)*			
72.	24671	*Coturnix pectoralis (Stubble Quail)*			
73.	25701	*Coturnix ypsilophora (Brown Quail)*			
74.	24673	*Coturnix ypsilophora subsp. australis (Brown Quail)*			
75.	25595	*Cracticus tibicen (Australian Magpie)*			
76.	25596	*Cracticus torquatus (Grey Butcherbird)*			
77.	24322	*Cygnus atratus (Black Swan)*			
78.	30901	*Dacelo novaeguineae (Laughing Kookaburra)*	Y		
79.	25673	*Daphoenositta chrysoptera (Varied Sittella)*			
80.	25607	*Dicaeum hirundinaceum (Mistletoebird)*			
81.		*Egretta garzetta*			
82.		*Egretta novaehollandiae*			
83.		*Elanus axillaris*			
84.		*Elseyornis melanops*			
85.		*Eolophus roseicapillus*			
86.	24652	*Eopsaltria georgiana (White-breasted Robin)*			
87.	24567	*Epthianura albifrons (White-fronted Chat)*			
88.	24379	*Erythrogonys cinctus (Red-kneed Dotterel)*			
89.	24368	*Eurostopodus argus (Spotted Nightjar)*			
90.	25621	*Falco berigora (Brown Falcon)*			
91.	25622	*Falco cenchroides (Australian Kestrel)*			
92.	25623	*Falco longipennis (Australian Hobby)*			
93.	25624	*Falco peregrinus (Peregrine Falcon)*		S	
94.	25727	*Fulica atra (Eurasian Coot)*			
95.	24761	*Fulica atra subsp. australis (Eurasian Coot)*			
96.	25729	*Gallinula tenebrosa (Dusky Moorhen)*			
97.	24763	*Gallinula tenebrosa subsp. tenebrosa (Dusky Moorhen)*			
98.	25730	*Gallirallus philippensis (Buff-banded Rail)*			
99.		*Gelochelidon nilotica*			
100.	25530	*Gerygone fusca (Western Gerygone)*			
101.	24735	*Glossopsitta porphyrocephala (Purple-crowned Lorikeet)*			
102.	24443	*Grallina cyanoleuca (Magpie-lark)*			
103.	24293	*Haliaeetus leucogaster (White-bellied Sea-Eagle)*		IA	
104.	24295	*Haliastur sphenurus (Whistling Kite)*			
105.	25734	*Himantopus himantopus (Black-winged Stilt)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
106.	24491	*Hirundo neoxena (Welcome Swallow)*			
107.	25629	*Hirundo nigricans (Tree Martin)*			
108.		*Ixobrychus dubius*			
109.	25661	*Lichmera indistincta (Brown Honeyeater)*			
110.	25741	*Limosa limosa (Black-tailed Godwit)*		IA	
111.		*Lophoictinia isura*			
112.	24326	*Malacorhynchus membranaceus (Pink-eared Duck)*			
113.	25650	*Malurus elegans (Red-winged Fairy-wren)*			
114.	25654	*Malurus splendens (Splendid Fairy-wren)*			
115.	24583	*Manorina flavigula (Yellow-throated Miner)*			
116.	25758	*Megalurus gramineus (Little Grassbird)*			
117.	24598	*Merops ornatus (Rainbow Bee-eater)*		IA	
118.		*Microcarbo melanoleucos*			
119.	25542	*Milvus migrans (Black Kite)*			
120.	25610	*Myiagra inquieta (Restless Flycatcher)*			
121.	24738	*Neophema elegans (Elegant Parrot)*			
122.	25748	*Ninox novaeseelandiae (Boobook Owl)*			
123.	24820	*Ninox novaeseelandiae subsp. boobook (Boobook Owl)*			
124.	25564	*Nycticorax caledonicus (Rufous Night Heron)*			
125.	24742	*Nymphicus hollandicus (Cockatiel)*			
126.	24407	*Ocyphaps lophotes (Crested Pigeon)*			
127.	24328	*Oxyura australis (Blue-billed Duck)*		P4	
128.	25679	*Pachycephala pectoralis (Golden Whistler)*			
129.	25680	*Pachycephala rufiventris (Rufous Whistler)*			
130.		*Pandion cristatus*			
131.	25681	*Pardalotus punctatus (Spotted Pardalote)*			
132.	25682	*Pardalotus striatus (Striated Pardalote)*			
133.	24648	*Pelecanus conspicillatus (Australian Pelican)*			
134.	24659	*Petroica goodenovii (Red-capped Robin)*			
135.	24660	*Petroica multicolor subsp. campbelli (Scarlet Robin)*			
136.	25697	*Phalacrocorax carbo (Great Cormorant)*			
137.	25698	*Phalacrocorax melanoleucos (Little Pied Cormorant)*			
138.	24667	*Phalacrocorax sulcirostris (Little Black Cormorant)*			
139.	25699	*Phalacrocorax varius (Pied Cormorant)*			
140.	24409	*Phaps chalcoptera (Common Bronzewing)*			
141.	25587	*Phaps elegans (Brush Bronzewing)*			
142.	24594	*Phylidonyris melanops (Tawny-crowned Honeyeater)*			
143.	25669	*Phylidonyris nigra (White-cheeked Honeyeater)*			
144.	24596	*Phylidonyris novaehollandiae (New Holland Honeyeater)*			
145.	24841	*Platalea flavipes (Yellow-billed Spoonbill)*			
146.	24747	*Platycercus spurius (Red-capped Parrot)*			
147.	25721	*Platycercus zonarius (Australian Ringneck, Ring-necked Parrot)*			
148.	24843	*Plegadis falcinellus (Glossy Ibis)*		IA	
149.	24382	*Pluvialis fulva (Pacific Golden Plover)*		IA	
150.	24383	*Pluvialis squatarola (Grey Plover)*		IA	
151.	25703	*Podargus strigoides (Tawny Frogmouth)*			
152.	25704	*Podiceps cristatus (Great Crested Grebe)*			
153.	24681	*Poliocephalus poliocephalus (Hoary-headed Grebe)*			
154.	25722	*Polytelis anthopeplus (Regent Parrot)*			
155.	25731	*Porphyrio porphyrio (Purple Swamphen)*			
156.	24767	*Porphyrio porphyrio subsp. bellus (Purple Swamphen)*			
157.	24769	*Porzana fluminea (Australian Spotted Crake)*			
158.	25732	*Porzana pusilla (Baillon's Crake)*			
159.	24771	*Porzana tabuensis (Spotless Crake)*			
160.		*Psittacula krameri*			
161.		*Purpureicephalus spurius*			
162.	24776	*Recurvirostra novaehollandiae (Red-necked Avocet)*			
163.	25613	*Rhipidura fuliginosa (Grey Fantail)*			
164.	25614	*Rhipidura leucophrys (Willie Wagtail)*			
165.	25534	*Sericornis frontalis (White-browed Scrubwren)*			
166.	24279	*Sericornis frontalis subsp. maculatus (White-browed Scrubwren)*			
167.	30948	*Smicrornis brevirostris (Weebill)*			
168.	24645	*Stagonopleura oculata (Red-eared Firetail)*			
169.	24516	*Stercorarius longicaudus (Long-tailed Skua)*		IA	
170.	24329	*Stictonetta naevosa (Freckled Duck)*			
171.	25597	*Strepera versicolor (Grey Currawong)*			
172.	25589	*Streptopelia chinensis (Spotted Turtle-Dove)*	Y		
173.	25590	*Streptopelia senegalensis (Laughing Turtle-Dove)*	Y		
174.	30950	*Streptopelia senegalensis subsp. senegalensis (Laughing Turtle-Dove)*	Y		
175.	25705	*Tachybaptus novaehollandiae (Australasian Grebe, Black-throated Grebe)*			

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176.	24682	*Tachybaptus novaehollandiae subsp. novaehollandiae (Australasian Grebe, Black-throated Grebe)*			
177.	24331	*Tadorna tadornoides (Australian Shelduck, Mountain Duck)*			
178.	24844	*Threskiornis molucca (Australian White Ibis)*			
179.	24845	*Threskiornis spinicollis (Straw-necked Ibis)*			
180.	25549	*Todiramphus sanctus (Sacred Kingfisher)*			
181.		*Tribonyx ventralis*			
182.	25723	*Trichoglossus haematodus (Rainbow Lorikeet)*			
183.	24806	*Tringa glareola (Wood Sandpiper)*		IA	
184.	24808	*Tringa nebularia (Common Greenshank)*		IA	
185.	24852	*Tyto alba subsp. delicatula (Barn Owl)*			
186.	24386	*Vanellus tricolor (Banded Lapwing)*			
187.	25765	*Zosterops lateralis (Grey-breasted White-eye, Silvereye)*			
188.	24856	*Zosterops lateralis subsp. gouldi (Grey-breasted White-eye)*			

Dicotyledon

189.	3374	*Acacia huegelii*			
190.	3409	*Acacia lasiocarpa (Panjang)*			
191.	3502	*Acacia pulchella (Prickly Moses)*			
192.	15481	*Acacia pulchella var. glaberrima*			
193.	3527	*Acacia saligna (Orange Wattle, Kudjong)*			
194.	3557	*Acacia stenoptera (Narrow Winged Wattle)*			
195.	14970	*Adenanthos barbiger*			
196.	1775	*Adenanthos cygnorum (Common Woollybush)*			
197.	1791	*Adenanthos obovatus (Basket Flower)*			
198.	12724	*Anthotium junciforme*			
199.	3688	*Aotus gracillima*			
200.	3692	*Aotus procumbens*			
201.	20350	*Astartea affinis*			
202.	20283	*Astartea scoparia*			
203.	7851	*Asteridea pulverulenta (Common Bristle Daisy)*			
204.	2471	*Atriplex prostrata (Hastate Orache)*	Y		
205.	1800	*Banksia attenuata (Slender Banksia, Piara)*			
206.	1822	*Banksia ilicifolia (Holly-leaved Banksia)*			
207.	1834	*Banksia menziesii (Firewood Banksia)*			
208.	1852	*Banksia telmatiaea (Swamp Fox Banksia)*			
209.	5393	*Beaufortia squarrosa (Sand Bottlebrush, Puno)*			
210.	16636	*Boronia crenulata subsp. viminea*			
211.	4417	*Boronia dichotoma*			
212.	4420	*Boronia fastigiata (Bushy Boronia)*			
213.	4441	*Boronia spathulata (Boronia)*			
214.	3710	*Bossiaea eriocarpa (Common Brown Pea)*			
215.	6341	*Brachyloma preissii (Globe Heath)*			
216.	7878	*Brachyscome iberidifolia*			
217.	3178	*Byblis gigantea (Rainbow Plant)*		P3	
218.	16365	*Calandrinia sp. Kenwick (G.J. Keighery 10905)*			
219.	5411	*Calothamnus hirsutus*			
220.	5415	*Calothamnus lateralis*			
221.	5439	*Calytrix angulata (Yellow Starflower)*			
222.	5458	*Calytrix flavescens (Summer Starflower)*			
223.	5460	*Calytrix fraseri (Pink Summer Calytrix)*			
224.	2795	*Carpobrotus edulis (Hottentot Fig)*	Y		
225.	2957	*Cassytha racemosa (Dodder Laurel)*			
226.	2490	*Chenopodium glaucum (Glaucous Goosefoot)*	Y		
227.	6543	*Cicendia filiformis (Slender Cicendia)*	Y		
228.	7937	*Cirsium vulgare (Spear Thistle, Scotch Thistle)*	Y		
229.	4554	*Comesperma flavum*			
230.	6348	*Conostephium pendulum (Pearl Flower)*			
231.	7939	*Conyza bonariensis (Flaxleaf Fleabane)*	Y		
232.	7941	*Conyza parva*	Y		
233.	20074	*Conyza sumatrensis*	Y		
234.	7945	*Cotula coronopifolia (Waterbuttons)*	Y		
235.	3137	*Crassula colorata (Dense Stonecrop)*			
236.	7454	*Dampiera linearis (Common Dampiera)*			
237.	7462	*Dampiera pedunculata*			
238.	7484	*Dampiera trigona (Angled-stem Dampiera)*			
239.	5508	*Darwinia citriodora (Lemon-scented Darwinia)*			
240.	3832	*Daviesia physodes*			
241.	3095	*Drosera erythrorhiza (Red Ink Sundew)*			
242.	13217	*Drosera erythrorhiza subsp. erythrorhiza*			
243.	3097	*Drosera gigantea (Giant Sundew)*			

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244.	15453	*Drosera gigantea subsp. gigantea*			
245.	3098	*Drosera glanduligera (Pimpernel Sundew)*			
246.	3101	*Drosera heterophylla (Swamp Rainbow)*			
247.	14298	*Drosera macrantha subsp. macrantha*			
248.	3109	*Drosera menziesii (Pink Rainbow)*			
249.	11853	*Drosera menziesii subsp. menziesii*			
250.	3113	*Drosera neesii (Jewel Rainbow)*			
251.	11768	*Drosera neesii subsp. neesii*			
252.	13191	*Drosera occidentalis subsp. occidentalis*		P4	
253.	13188	*Drosera paleacea subsp. paleacea*			
254.	3124	*Drosera pulchella (Pretty Sundew)*			
255.	8911	*Drosera rosulata*			
256.	2501	*Dysphania glomulifera*			
257.	11368	*Dysphania glomulifera subsp. glomulifera*			
258.	6131	*Epilobium billardiereanum (Glabrous Willow Herb)*			
259.	6219	*Eryngium pinnatifidum (Blue Devils)*			
260.	5790	*Eucalyptus todtiana (Coastal Blackbutt)*			
261.	3872	*Euchilopsis linearis (Swamp Pea)*			
262.	4648	*Euphorbia terracina (Geraldton Carnation Weed)*	Y		
263.	3880	*Eutaxia virgata*			
264.	12624	*Gnephosis angianthoides*			
265.	3948	*Gompholobium capitatum*			
266.	3954	*Gompholobium polymorphum*			
267.	3957	*Gompholobium tomentosum (Hairy Yellow Pea)*			
268.	6160	*Gonocarpus paniculatus*			
269.	6161	*Gonocarpus pithyoides*			
270.	7508	*Goodenia filiformis (Thread-leaved Goodenia)*			
271.	12551	*Goodenia micrantha*			
272.	7538	*Goodenia pulchella*			
273.	19286	*Goodenia pulchella subsp. Coastal Plain A (M. Hislop 634)*			
274.	19628	*Grevillea bipinnatifida subsp. bipinnatifida*			
275.	13429	*Grevillea diversifolia subsp. diversifolia*			
276.		*Grevillea robusta*			Y
277.	2179	*Hakea marginata*			
278.	2197	*Hakea prostrata (Harsh Hakea)*			
279.	2212	*Hakea sulcata (Furrowed Hakea)*			
280.	2216	*Hakea varia (Variable-leaved Hakea)*			
281.	6839	*Hemiandra pungens (Snakebush)*			
282.	38320	*Hemiandra sp. Jurien (B.J. Conn & M.E. Tozer BJC 3885)*			
283.		*Hemiandra sp. Jurien (B.J.Conn 3885 & M.E.Tozer)*			
284.	19778	*Hibbertia glomerata subsp. darlingensis*			
285.	5134	*Hibbertia huegelii*			
286.	5162	*Hibbertia racemosa (Stalked Guinea Flower)*			
287.	6222	*Homalosciadium homalocarpum*			
288.	3968	*Hovea trisperma (Common Hovea)*			
289.	12859	*Hovea trisperma var. trisperma*			
290.	12741	*Hyalosperma cotula*			
291.	6223	*Hydrocotyle alata*			
292.	6226	*Hydrocotyle callicarpa (Small Pennywort)*			
293.	5817	*Hypocalymma angustifolium (White Myrtle, Kudjid)*			
294.	35070	*Hypocalymma angustifolium subsp. Swan Coastal Plain (G.J. Keighery 16777)*			
295.	5825	*Hypocalymma robustum (Swan River Myrtle)*			
296.	8086	*Hypochaeris glabra (Smooth Catsear)*	Y		
297.	2227	*Isopogon divergens (Spreading Coneflower)*			
298.	3992	*Isotropis cuneifolia (Granny Bonnets)*			
299.	4012	*Jacksonia furcellata (Grey Stinkwood)*			
300.	20462	*Jacksonia gracillima*		P3	
301.	4027	*Jacksonia sericea (Waldjumi)*		P4	
302.	4044	*Kennedia prostrata (Scarlet Runner)*			
303.	5832	*Kunzea ericifolia (Spearwood, Pondil)*			
304.	15498	*Kunzea glabrescens (Spearwood)*			
305.	5835	*Kunzea micrantha*			
306.	17461	*Kunzea micrantha subsp. micrantha*			
307.		*Lachnostachys sp.*			
308.	8095	*Lactuca saligna (Wild Lettuce)*	Y		
309.	5033	*Lasiopetalum floribundum (Free Flowering Lasiopetalum)*			
310.	4052	*Latrobea tenella*			
311.	7572	*Lechenaultia expansa*			
312.	7574	*Lechenaultia floribunda (Free-flowering Leschenaultia)*			
313.	2344	*Leptomeria empetriformis*			

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314.	5850	*Leptospermum laevigatum (Coast Teatree)*	Y		
315.	6360	*Leucopogon australis (Spiked Beard-heath)*			
316.	6374	*Leucopogon conostephioides*			
317.	6416	*Leucopogon nutans (Drooping Leucopogon)*			
318.	6425	*Leucopogon oxycedrus*			
319.		*Leucopogon sp.*			
320.	40803	*Leucopogon squarrosus subsp. squarrosus*			
321.	6447	*Leucopogon strictus*			
322.	6451	*Leucopogon tenuis*			
323.	7677	*Levenhookia stipitata (Common Stylewort)*			
324.	7408	*Lobelia tenuior (Slender Lobelia)*			
325.	36860	*Lobelia tenuior subsp. dictyosperma*			
326.	4059	*Lotus angustissimus (Narrowleaf Trefoil)*	Y		
327.	6456	*Lysinema ciliatum (Curry Flower)*			
328.	6458	*Lysinema elegans*			
329.	2838	*Macarthuria apetala*			
330.	2839	*Macarthuria australis*			
331.	37580	*Melaleuca acutifolia*			
332.	13273	*Melaleuca incana subsp. incana*			
333.	5926	*Melaleuca lateritia (Robin Redbreast Bush)*			
334.	20297	*Melaleuca osullivanii*			
335.	5952	*Melaleuca preissiana (Moonah)*			
336.	5959	*Melaleuca rhaphiophylla (Swamp Paperbark)*			
337.	5978	*Melaleuca teretifolia (Banbar)*			
338.	5980	*Melaleuca thymoides*			
339.	5984	*Melaleuca uncinata (Broom Bush, Kwidjard)*			
340.	5987	*Melaleuca viminea (Mohan)*			
341.	13280	*Melaleuca viminea subsp. viminea*			
342.	8106	*Millotia tenuifolia (Soft Millotia)*			
343.	7410	*Monopsis debilis*	Y		
344.	37440	*Monopsis debilis var. depressa*	Y		
345.	8117	*Myriocephalus helichrysoides*			
346.	2401	*Nuytsia floribunda (Christmas Tree, Mudja)*			
347.	8143	*Olearia paucidentata (Autumn Scrub Daisy)*			
348.	36200	*Ornduffia submersa*		P4	
349.	3618	*Paraserianthes lophantha (Albizia)*			
350.	7090	*Parentucellia viscosa (Sticky Bartsia)*	Y		
351.	4343	*Pelargonium capitatum (Rose Pelargonium)*	Y		
352.	6006	*Pericalymma ellipticum (Swamp Teatree)*			
353.	16477	*Pericalymma ellipticum var. ellipticum*			
354.	11020	*Persicaria hydropiper*			
355.	11052	*Persicaria prostrata*			
356.	20391	*Petrophile juncifolia*			
357.	2299	*Petrophile linearis (Pixie Mops)*			
358.	2308	*Petrophile seminuda*			
359.	16177	*Phyllangium paradoxum*			
360.	4141	*Phyllota gracilis*			
361.	11404	*Pimelea imbricata var. major*			
362.	11402	*Pimelea imbricata var. piligera*			
363.	5252	*Pimelea lanata*			
364.	8175	*Podolepis gracilis (Slender Podolepis)*			
365.	8183	*Podotheca chrysantha (Yellow Podotheca)*			
366.	8184	*Podotheca gnaphalioides (Golden Long-heads)*			
367.	4578	*Polygala virgata*	Y		
368.	4177	*Pultenaea ochreata*			
369.	4181	*Pultenaea reticulata*			
370.	8195	*Quinetia urvillei*			
371.	6012	*Regelia ciliata*			
372.		*Rhaponticum australe*			Y
373.	7619	*Scaevola lanceolata (Long-leaved Scaevola)*			
374.	7636	*Scaevola platyphylla (Broad-leaved Fanflower)*			
375.	6263	*Schoenolaena juncea*			
376.	6033	*Scholtzia involucrata (Spiked Scholtzia)*			
377.	25878	*Senecio condylus*			
378.	8203	*Senecio diaschides*			
379.	8225	*Siloxerus humifusus (Procumbent Siloxerus)*			
380.	2912	*Spergula arvensis (Corn Spurry)*	Y		
381.	4205	*Sphaerolobium linophyllum*			
382.	19403	*Stenopetalum gracile*			
383.	2316	*Stirlingia latifolia (Blueboy)*			

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384.	18564	*Stylidium aceratum*		P2	
385.	7684	*Stylidium amoenum (Lovely Triggerplant)*			
386.	30278	*Stylidium androsaceum*			
387.	7693	*Stylidium brunonianum (Pink Fountain Triggerplant)*			
388.	7696	*Stylidium calcaratum (Book Triggerplant)*			
389.	7713	*Stylidium dichotomum (Pins-and-needles)*			
390.	7717	*Stylidium divaricatum (Daddy-long-legs)*			
391.	7719	*Stylidium ecorne (Foot Triggerplant)*			
392.	7721	*Stylidium emarginatum (Biddy-four-legs)*			
393.	7734	*Stylidium guttatum (Dotted Triggerplant)*			
394.	7742	*Stylidium inundatum (Hundreds and Thousands)*			
395.	7756	*Stylidium longitubum (Jumping Jacks)*		P4	
396.	25800	*Stylidium paludicola*		P3	
397.	7774	*Stylidium piliferum (Common Butterfly Triggerplant)*			
398.	7785	*Stylidium repens (Matted Triggerplant)*			
399.	7790	*Stylidium roseoalatum (Pink-wing Triggerplant)*			
400.	45594	*Stylidium tenue subsp. majusculum (Showy Fountain Triggerplant)*			
401.	7806	*Stylidium utricularioides (Pink Fan Triggerplant)*			
402.	6476	*Styphelia tenuiflora (Common Pinheath)*			
403.	15741	*Tamarix aphylla (Athel Tree)*	Y		
404.	37360	*Tamarix ramosissima*	Y		
405.	20135	*Taxandria linearifolia*			
406.	4535	*Tetratheca hirsuta (Black Eyed Susan)*			
407.	14333	*Tetratheca sp. Granite (S. Patrick SP1224)*		P3	
408.	6280	*Trachymene pilosa (Native Parsnip)*			
409.	4737	*Tripterococcus brunonis (Winged Stackhousia)*			
410.	44444	*Tripterococcus sp. Brachylobus (A.S. George 14234)*		P4	
411.	8255	*Ursinia anthemoides (Ursinia)*	Y		
412.	7145	*Utricularia menziesii (Redcoats)*			
413.	6076	*Verticordia densiflora (Compacted Featherflower)*			
414.	12411	*Verticordia densiflora var. cespitosa*			
415.	6077	*Verticordia drummondii (Drummond's Featherflower)*			
416.	14714	*Verticordia lindleyi subsp. lindleyi*		P4	
417.	6110	*Verticordia plumosa (Plumed Featherflower)*			
418.	12449	*Verticordia plumosa var. brachyphylla*			
419.	7389	*Wahlenbergia preissii*			
420.	6289	*Xanthosia huegelii*			

Fungus

421.	38776	*Cortinarius phalarus*			
422.		*Hohenbuehelia sp.*			
423.		*Hymenochaete sp.*			
424.	31280	*Lichenomphalia chromacea*			
425.		*Nidula emodensis*			
426.		*Phytophthora cinnamomi*			
427.	38826	*Podoserpula pusio*			

Gymnosperm

428.	36600	*Callitris pyramidalis (Swamp Cypress)*			
429.	85	*Macrozamia riedlei (Zamia, Djiridji)*			

Hepatic (Liverwort)

430.		*Marchantia berteroana*			

Invertebrate

431.		*Aname mainae*			
432.		*Aname tepperi*			
433.		*Anisops hyperion*			
434.		*Anisops thienemanni*			
435.		*Antichiropus variabilis*			
436.		*Aplopsis lineoligera*			
437.		*Archiargiolestes parvulus*			
438.		*Archiargiolestes pusillus*			
439.		*Arenopsaltria fullo*			
440.		*Artoria flavimana*			
441.		*Artoria linnaei*			
442.		*Asadipus kunderang*			
443.		*Bibulmena kadjina*			
444.		*Bothriembryon (Bothriembryon) bulla*			
445.		*Bothriembryon (Bothriembryon) kendricki*			
446.		*Calomela sp.*			
447.		*Dingosa serrata*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
448.		*Geitoneura minyas*			
449.		*Hemicordulia tau*			
450.		*Hesperotermes infrequens*			
451.		*Heteronympha merope subsp. duboulayi*			
452.	33982	*Leioproctus contrarius (bee)*		P3	
453.	33983	*Leioproctus douglasiellus (bee)*		T	
454.		*Lycidas michaelseni*			
455.		*Lycosa ariadnae*			
456.		*Missulena granulosa*			
457.	33984	*Neopasiphae simplicior (bee)*		T	
458.		*Nyungara bunni*			
459.		*Nyungara ellitasha*			Y
460.		*Ommatoiulus moreleti*			
461.		*Ommatoiulus moreletii*			
462.		*Onthophagus haagi*			
463.		*Orthetrum caledonicum*			
464.		*Paratoxicum iridescens*			Y
465.		*Saprinus (Saprinus) cyaneus*			
466.		*Supunna funerea*			
467.		*Urodacus novaehollandiae*			
468.		*Venator immansueta*			
469.	34113	*Westralunio carteri (Carter's Freshwater Mussel)*		T	

Lichen

470.	28208	*Cladonia cervicornis subsp. verticillata*			
471.	27778	*Heterodermia speciosa*			
472.		*Menegazzia sp.*			
473.	27892	*Pannoparmelia wilsonii*			
474.		*Rimelia sp.*			

Mammal

475.	30883	*Canis lupus subsp. familiaris (Dog)*	Y		
476.	24186	*Chalinolobus gouldii (Gould's Wattled Bat)*			
477.	24041	*Felis catus (Cat)*	Y		
478.	24215	*Hydromys chrysogaster (Water-rat)*		P4	
479.	25478	*Isoodon obesulus (Southern Brown Bandicoot)*		P5	
480.	24153	*Isoodon obesulus subsp. fusciventer (Quenda, Southern Brown Bandicoot)*		P5	
481.	24132	*Macropus fuliginosus (Western Grey Kangaroo)*			
482.	24133	*Macropus irma (Western Brush Wallaby)*		P4	
483.	24223	*Mus musculus (House Mouse)*	Y		
484.	24146	*Myrmecobius fasciatus (Numbat, Walpurti)*		T	
485.	24194	*Nyctophilus geoffroyi (Lesser Long-eared Bat)*			
486.	24085	*Oryctolagus cuniculus (Rabbit)*	Y		
487.	24245	*Rattus rattus (Black Rat)*	Y		
488.	24167	*Tarsipes rostratus (Honey Possum, Noolbenger)*			
489.	24158	*Trichosurus vulpecula subsp. vulpecula (Common Brushtail Possum)*			

Monocotyledon

490.	1261	*Agrostocrinum scabrum (Blue Grass Lily)*			
491.	184	*Aira caryophyllea (Silvery Hairgrass)*	Y		
492.	187	*Aira praecox (Early Hairgrass)*	Y		
493.	20184	*Amphipogon laguroides subsp. laguroides*			
494.	199	*Amphipogon strictus (Greybeard Grass)*			
495.	200	*Amphipogon turbinatus*			
496.	1411	*Anigozanthos manglesii (Mangles Kangaroo Paw, Kurulbrang)*			
497.	11566	*Anigozanthos viridis subsp. viridis*			
498.	1117	*Aphelia cyperoides*			
499.	17845	*Apodasmia ceramophila*			
500.		*Apodasmia ceramophila MS*			
501.	207	*Aristida contorta (Bunched Kerosene Grass)*			
502.	1264	*Arnocrinum preissii*			
503.	17234	*Austrostipa compressa*			
504.	231	*Avellinia michelii*	Y		
505.	235	*Avena sativa (Common Oat)*	Y		
506.	743	*Baumea juncea (Bare Twigrush)*			
507.	1417	*Blancoa canescens (Winter Bell)*			
508.	749	*Bolboschoenus caldwellii (Marsh Club-rush)*			
509.	244	*Briza maxima (Blowfly Grass)*	Y		
510.	245	*Briza minor (Shivery Grass)*	Y		
511.	1383	*Burchardia bairdiae*			
512.	12770	*Burchardia congesta*			
513.	1385	*Burchardia multiflora (Dwarf Burchardia)*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
514.	1277	*Caesia occidentalis*			
515.	15330	*Caladenia arenicola*			
516.	1592	*Caladenia flava (Cowslip Orchid)*			
517.	15348	*Caladenia flava subsp. flava*			
518.	1596	*Caladenia huegelii (Grand Spider Orchid)*		T	
519.	1599	*Caladenia latifolia (Pink Fairy Orchid)*			
520.	15361	*Caladenia longicauda subsp. calcigena*			
521.	1605	*Caladenia marginata (White Fairy Orchid)*			
522.	15503	*Caladenia paludosa*			
523.	1162	*Cartonema philydroides*			
524.	1121	*Centrolepis aristata (Pointed Centrolepis)*			
525.	1125	*Centrolepis drummondiana*			
526.	1134	*Centrolepis polygyna (Wiry Centrolepis)*			
527.	17685	*Chaetanthus aristatus*			
528.	17687	*Chaetanthus tenellus*			
529.	17675	*Chordifex jacksonii*		P3	
530.		*Chordifex sp.*			
531.	763	*Chorizandra enodis (Black Bristlerush)*			
532.	1418	*Conostylis aculeata (Prickly Conostylis)*			
533.	11695	*Conostylis festucacea subsp. festucacea*			
534.	1436	*Conostylis juncea*			
535.	1455	*Conostylis setosa (White Cottonhead)*			
536.	1285	*Corynotheca micrantha (Sand Lily)*			
537.	768	*Cyathochaeta avenacea*			
538.	783	*Cyperus congestus (Dense Flat-sedge)*	Y		
539.	815	*Cyperus tenellus (Tiny Flatsedge)*	Y		
540.	10916	*Cyrtostylis huegelii*			
541.	17692	*Cytogonidium leptocarpoides*			
542.	1218	*Dasypogon bromeliifolius (Pineapple Bush)*			
543.	15831	*Desmocladus castaneus*			
544.	16595	*Desmocladus flexuosus*			
545.	1259	*Dianella revoluta (Blueberry Lily)*			
546.	306	*Dichelachne crinita (Longhair Plumegrass)*			
547.	1287	*Dichopogon capillipes*			
548.	17838	*Dielsia stenostachya*			
549.	1634	*Diuris laxiflora (Bee Orchid)*			
550.	1635	*Diuris longifolia (Common Donkey Orchid)*			
551.	1637	*Diuris purdiei (Purdie's Donkey Orchid)*		T	
552.	1639	*Drakaea elastica (Glossy-leaved Hammer Orchid)*		T	
553.	1640	*Drakaea glyptodon (King-in-his-carriage)*			
554.	13635	*Drakaea micrantha*		T	
555.	347	*Ehrharta calycina (Perennial Veldt Grass)*	Y		
556.	822	*Eleocharis acuta (Common Spikerush)*			
557.	1645	*Epiblema grandiflorum (Babe-in-a-cradle)*			
558.	376	*Eragrostis curvula (African Lovegrass)*	Y		
559.	379	*Eragrostis elongata (Clustered Lovegrass)*			
560.		*Eragrostis sp.*			
561.	1646	*Eriochilus dilatatus (White Bunny Orchid)*			
562.	15414	*Eriochilus helonomos*			
563.	1647	*Eriochilus scaber (Pink Bunny Orchid)*			
564.	15415	*Eriochilus scaber subsp. scaber*			
565.	835	*Evandra pauciflora*			
566.	1515	*Ferraria crispa (Black Flag)*	Y		
567.	894	*Fimbristylis velata*			
568.	907	*Gahnia trifida (Coast Saw-sedge)*			
569.	1520	*Gladiolus caryophyllaceus (Wild Gladiolus)*	Y		
570.	1524	*Gladiolus undulatus (Wild Gladiolus)*	Y		
571.	17043	*Glyceria declinata*	Y		
572.	1475	*Haemodorum spicatum (Mardja)*			
573.	1293	*Hensmania turbinata*			
574.	444	*Holcus lanatus (Yorkshire Fog)*	Y		
575.		*Hydrorchis orbicularis*			
576.	1070	*Hypolaena exsulca*			
577.	17841	*Hypolaena pubescens*			
578.	910	*Isolepis cernua (Nodding Club-rush)*			
579.	917	*Isolepis marginata (Coarse Club-rush)*			
580.	919	*Isolepis oldfieldiana*			
581.	924	*Isolepis stellata (Star Club-rush)*			
582.	1177	*Juncus articulatus (Jointed Rush)*	Y		
583.	1180	*Juncus capitatus (Capitate Rush)*	Y		

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
584.	20019	*Lachnagrostis filiformis*			
585.	19955	*Lachnagrostis plebeia*			
586.	11911	*Laxmannia ramosa subsp. ramosa*			
587.	11464	*Laxmannia sessiliflora subsp. australis*			
588.	1309	*Laxmannia squarrosa*			
589.	925	*Lepidosperma angustatum*			
590.	937	*Lepidosperma longitudinale (Pithy Sword-sedge)*			
591.	942	*Lepidosperma rostratum*		T	
592.		*Lepidosperma sp.*			
593.	945	*Lepidosperma squamatum*			
594.	1653	*Leporella fimbriata (Hare Orchid)*			
595.	19833	*Leptocarpus laxus*			
596.	478	*Lolium rigidum (Wimmera Ryegrass)*	Y		
597.	1223	*Lomandra caespitosa (Tufted Mat Rush)*			
598.	1228	*Lomandra hermaphrodita*			
599.	1232	*Lomandra micrantha (Small-flower Mat-rush)*			
600.	1236	*Lomandra odora (Tiered Matrush)*			
601.	1246	*Lomandra suaveolens*			
602.	1097	*Lyginia barbata*			
603.	18049	*Lyginia imberbis*			
604.	17683	*Meeboldina cana*			
605.	17679	*Meeboldina coangustata*			
606.	17677	*Meeboldina roycei*			
607.		*Meeboldina roycei MS*			
608.	953	*Mesomelaena graciliceps*			
609.	957	*Mesomelaena tetragona (Semaphore Sedge)*			
610.	485	*Microlaena stipoides (Weeping Grass)*			
611.	1658	*Microtis atrata (Swamp Mignonette Orchid)*			
612.	10954	*Microtis media (Tall Mignonette Orchid)*			
613.	1660	*Microtis orbicularis (Dark Mignonette Orchid)*			
614.	19179	*Moraea flaccida (One-leaf Cape Tulip)*	Y		
615.	492	*Neurachne alopecuroidea (Foxtail Mulga Grass)*			
616.	502	*Panicum capillare (Witchgrass)*	Y		
617.	1550	*Patersonia occidentalis (Purple Flag, Koma)*			
618.	30472	*Patersonia occidentalis var. occidentalis*			
619.	20460	*Pheladenia deformis*			
620.	1172	*Philydrella drummondii*			
621.	14306	*Philydrella pygmaea subsp. pygmaea*			
622.	1478	*Phlebocarya ciliata*			
623.	1479	*Phlebocarya filifolia*			
624.	583	*Polypogon tenellus*			
625.	11066	*Prasophyllum cucullatum (Hooded Leek Orchid)*			
626.	1670	*Prasophyllum drummondii (Swamp Leek Orchid)*			
627.	1672	*Prasophyllum fimbria (Fringed Leek Orchid)*			
628.	1673	*Prasophyllum gibbosum (Humped Leek Orchid)*			
629.	1680	*Prasophyllum parvifolium (Autumn Leek Orchid)*			
630.	44723	*Pterostylis glebosa*			
631.	1693	*Pterostylis recurva (Jug Orchid)*			
632.	12217	*Pterostylis sanguinea*			
633.		*Pterostylis sp.*			
634.	18655	*Pterostylis sp. crinkled leaf (G.J. Keighery 13426)*			
635.	1698	*Pterostylis vittata (Banded Greenhood)*			
636.	16367	*Pyrorchis nigricans (Red beaks, Elephants ears)*			
637.	1556	*Romulea rosea (Guildford Grass)*	Y		
638.	973	*Schoenus asperocarpus (Poison Sedge)*			
639.	984	*Schoenus curvifolius*			
640.	986	*Schoenus efoliatus*			
641.	992	*Schoenus grandiflorus (Large Flowered Bogrush)*			
642.	1006	*Schoenus odontocarpus*			
643.	1008	*Schoenus pennisetis*		P3	
644.	17614	*Schoenus plumosus*			
645.	1011	*Schoenus rigens*			
646.		*Schoenus sp.*			
647.	1018	*Schoenus subfascicularis*			
648.	1023	*Schoenus tenellus*			
649.	1312	*Sowerbaea laxiflora (Purple Tassels)*			
650.	1560	*Sparaxis pillansii (Harlequin Flower)*	Y		
651.	1260	*Stypandra glauca (Blind Grass)*			
652.	20728	*Thelymitra xanthotricha*			
653.	1318	*Thysanotus arbuscula*			

	Name ID	Species Name	Naturalised	Conservation Code	[1]Endemic To Query Area
654.	1334	*Thysanotus glaucus*		P4	
655.	1338	*Thysanotus manglesianus (Fringed Lily)*			
656.	1339	*Thysanotus multiflorus (Many-flowered Fringe Lily)*			
657.	1351	*Thysanotus sparteus*			
658.	1354	*Thysanotus tenellus*			
659.	1357	*Thysanotus thyrsoideus*			
660.	1358	*Thysanotus triandrus*			
661.	17684	*Tremulina tremula*			
662.	1481	*Tribonanthes australis*			
663.	1485	*Tribonanthes violacea*			
664.	1361	*Tricoryne elatior (Yellow Autumn Lily)*			
665.	1363	*Tricoryne tenella*			
666.	722	*Vulpia bromoides (Squirrel Tail Fescue)*	Y		
667.	724	*Vulpia myuros (Rat's Tail Fescue)*	Y		
668.	18108	*Watsonia meriana var. bulbillifera*	Y		
669.	1256	*Xanthorrhoea preissii (Grass tree, Palga)*			
670.	1049	*Zantedeschia aethiopica (Arum Lily)*	Y		

Pteridophyte (Fern)

671.	42902	*Azolla rubra*			
672.	4	*Phylloglossum drummondii (Pigmy Clubmoss)*			
673.	6	*Selaginella gracillima (Tiny Clubmoss)*			

Reptile

674.	42368	*Acritoscincus trilineatus (Western Three-lined Skink)*			
675.	24991	*Aprasia repens (Sand-plain Worm-lizard)*			
676.	43380	*Chelodina colliei (Oblong Turtle)*			
677.	24980	*Christinus marmoratus (Marbled Gecko)*			
678.	30893	*Cryptoblepharus buchananii*			
679.	25027	*Ctenotus australis*			
680.	25766	*Delma fraseri (Fraser's Legless Lizard)*			
681.	24999	*Delma grayii*			
682.	25296	*Demansia psammophis subsp. reticulata (Yellow-faced Whipsnake)*			
683.	25100	*Egernia napoleonis*			
684.	25119	*Hemiergis quadrilineata*			
685.	25131	*Lerista distinguenda*			
686.	25133	*Lerista elegans*			
687.	25147	*Lerista lineata (Perth Slider, Lined Skink)*		P3	
688.	25005	*Lialis burtonis*			
689.	25184	*Menetia greyii*			
690.	25252	*Notechis scutatus (Tiger Snake)*			
691.	25253	*Parasuta gouldii*			
692.	25007	*Pletholax gracilis subsp. gracilis (Keeled Legless Lizard)*			
693.	25510	*Pogona minor (Dwarf Bearded Dragon)*			
694.	24907	*Pogona minor subsp. minor (Dwarf Bearded Dragon)*			
695.	25511	*Pseudonaja affinis (Dugite)*			
696.	25259	*Pseudonaja affinis subsp. affinis (Dugite)*			
697.	42416	*Pseudonaja mengdeni (Western Brown Snake)*			
698.	25008	*Pygopus lepidopodus (Common Scaly Foot)*			
699.	25519	*Tiliqua rugosa*			
700.	25218	*Varanus gouldii (Bungarra or Sand Monitor)*			
701.	25225	*Varanus rosenbergi (Heath Monitor)*			

Conservation Codes
T - Rare or likely to become extinct
X - Presumed extinct
IA - Protected under international agreement
S - Other specially protected fauna
1 - Priority 1
2 - Priority 2
3 - Priority 3
4 - Priority 4
5 - Priority 5

[1] For NatureMap's purposes, species flagged as endemic are those whose records are wholely contained within the search area. Note that only those records complying with the search criterion are included in the calculation. For example, if you limit records to those from a specific datasource, only records from that datasource are used to determine if a species is restricted to the query area.

Appendix J: DPaW Correspondence

Government of **Western Australia**
Department of **Parks and Wildlife**
Regional & Fire Management Services Division

Your ref: 833-2-29-14 (RLS/0586/1)
Our ref: 38525
Enquiries: Cho Lamb
Phone: 9442 0309
Email: cho.lamb@dpaw.wa.gov.au

Mr Andrew Hawkins
Secretary
Western Australian Planning Commission
Locked Bag 2506
PERTH WA 6001

Attention: Anthony Muscara

Dear Sir

PROPOSED MRS AMENDMENT – SOUTH FORRESTDALE BUSINESS PARK – STAGE 2 REQUEST FOR PRELIMINARY COMMENT

Reference is made to your correspondence dated 1 October 2015 in respect of the above. The Department of Parks and Wildlife has reviewed the proposal and has the following comments to make.

The department is aware that *Economic Employment and Lands Strategy* (EELS) (WAPC 2012) identifies the site for further planning investigation as a general industrial area.

The proposed development site is located at a minimum of 80 metres from the southern boundary of Forrestdale Lake, which is recognised as internationally significant under the Ramsar Convention and is a matter of national environmental significance under the Commonwealth *Environmental Protection and Biodiversity Conservation Act* 1999 (EPBC Act). Forrestdale Lake is identified as a Conservation category wetland (CCW) in the *Geomorphic Wetlands Swan Coastal Plain* dataset and is identified under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992.* The lake forms part of Forestdale Lake Nature Reserve (R27175), a class 'A' nature reserve managed by Parks and Wildlife for the conservation of flora and fauna.

The proposed development site is also adjacent to Conservation category palusplain (UFI 7383) and Conservation category sumpland (UFI 15182) and within 50 metres of Conservation category palusplain (UFI 15198), Conservation category dampland (UFI 13536) and Resource Enhancement dampland (UFI 15943).

A threatened ecological community (TEC) 'Herb rich shrublands in claypans' is located to the north of the development site (within Conservation category palusplain UFI 7383) and is listed as Critically Endangered under EPBC Act.

Bush Forever site 345 (*Forrestdale Lake and adjacent bushland, Forrestdale*) is located directly north and west of the development site and a regional ecological linkage passes north-south through Forrestdale Lake and the western portion of part Lot 12 within the development site.

Swan Region
Cnr Australia II Drive and Hackett Drive, Crawley WA 6009
Locked Bag 104, Bentley Delivery Centre, Western Australia 6983
Phone: (08) 9422 0300 Fax (08) 9386 6399 Email: cho.lamb@dpaw.wa.gov.au
www.dpaw.wa.gov.au

Environmental Impact Assessment

The *Environmental Impact Assessment* (EIA) (Bioscience 2015) has not clearly identified the potential adverse impacts of the proposed development to Forrestdale Lake, the nature reserve or the adjacent wetland areas, including CCWs and the nationally listed TEC.

The department is generally supportive of many of the recommendations listed in the EIA such as those is sections 3.4.5, and 3.5.3:

a) The landscaping within the development site should contain native vegetation and existing native species should be retained (where practical).
b) The outer areas of the development site adjoining natural areas should be restricted to the lowest impact industrial use.
c) Any remnant native species and mature trees should be retained if possible.
d) Rehabilitation programs should be considered for wildlife with a focus on species in decline.
e) A wetland buffer study should be conducted to determine an appropriate buffer form and width.
f) Landscaping within the development site should contain vegetation which can provide food and habitat for the critically endangered native bee (*Neopasiphae simplicior*) and the endangered Carnaby's Cockatoo (*Calyptorhynchus latirostris*).

Wetlands

The proposed scheme amendment contains contradictory information with regard to the wetland buffer areas. The proposal acknowledges that the EELS document specifies buffer distances of 100m around CCWs and 50 m around Resource Enhancement category wetlands (REW). The department is supportive of this approach. In particular, the department supports the inclusion of a 100 metre buffer around wetlands that are listed under the Ramsar Convention in order to protect the high conservation significance of the wetland ecosystem from altered land uses, including clearing of native vegetation and altered hydrology. Buffers should be revegetated using locally native vegetation.

Mapping provided within both Figure 13 of the District Water Management Strategy (Bioscience, 2015) and Figure 4 of the Proposal for Rezoning to Industrial Zone (Turner Masters Planners, 2015) appear to propose varying buffer distances. The EIA document refers to a minimum 50m buffer stipulated by EPA *Guidance Statement 33* within the text. The department is supportive of the recommendation in section 3.4.5 of the EIA studies being conducted to determine the appropriate buffer form and width. The department is not supportive of the recommendation in section 3.4.5 of the EIA that '*A development contribution scheme aimed at substantial rehabilitation within the bordering Reserves and Bush Forever areas should be considered as an offset against arbitrary generic buffer distances*'.

The proposed concept plan includes the construction of Oxley Road with the wetland buffer to the south of the road. The department recommends that the proposed alignment for Oxley Road is moved outside of the wetland buffer.

Water supplementation of Forrestdale Lake

Water level monitoring at Forrestdale Lake over the last twenty years shows declining lake levels and decreasing periods of inundation. This in turn has been responsible for increasing coverage of introduced weed species and terrestrial native vegetation on the lake, increasing the incidence of uncontrolled fire and reduced waterbird usage.

The department is supportive of the proposal in section 3.7.4 that states '*As planning progresses towards structure planning and subdivision, consideration should be given to options for capturing stormwater from roofs and hardstand areas in ways which enable supplementing the hydrological cycle of Forrestdale Lake.*' The department recommends that the proponent consult with the department at the earliest opportunity to further discuss this proposal in order to minimise adverse impacts on wetlands associated with Forrestdale Lake and identify opportunities for design aspects that could lead to environmental benefits on the more significant elements within this internationally significant wetland system.

Matters of National Environmental Significance

The department recommends that the proponent contact the Federal Department of the Environment for decisions regarding requirements for assessment of impacts. This is recommended due to the high conservation significance of Forrestdale Lake, the proximity of the proposed development to this Ramsar site and the potential impact from proposed future land use.

Threatened Flora

The EIA indicates that the fenced Bush Forever portion on Lot 12 is to be retained. A portion of the bushland on Lot 12 extends beyond the Bush Forever boundary. The department recommends that if any of this vegetation will be impacted by the development including for fencing or fire protection measures then appropriately timed targeted surveys for threatened and priority flora should be undertaken in this area (i.e. the Bush Forever and adjoining vegetation on Lot 12). The department recommends that a setback and/or hard edge (e.g. road) to the remnant native vegetation on Lot 12 be applied to ensure that both direct and indirect impacts to this area are avoided.

A current search of the flora databases has not been provided in the EIA. The EIA references a NatureMap search from 2013 (5km radius), and some of the priority taxa identified in the area have since had changes to their conservation status. The EIA indicates that an assessment of the vegetation and species list has been undertaken. This list should be included in the EIA.

The remnant vegetation on the site has been described in the EIA as degraded *Melaleuca preissiana* and *Kunzea glabrescens* occasionally over native sedges such as *Gahnia trifida*. It is acknowledged in the EIA that the timing was not appropriate for identifying declared rare flora (DRF) and priority taxa. There is also potential for the DRF species *Drakaea elastica*, *Lepidosperma rostratum* and *Austrostipa jacobsiana*, and possibly some of the priority taxa, in particular *Ptilotus sericostachyus* subsp. *roseus* (Priority 1) to be found on the site. Some of these taxa can persist in degraded areas, in particular *L. rostratum* and *A. jacobsiana*. So although the areas of vegetation on the other lots are small, sparsely vegetated and appear degraded from the aerial photography, the department recommends that a targeted survey over these areas is undertaken prior to the structure plan being prepared.

The flora survey should be appropriately timed to detect the presence of targeted conservation significant taxa and be conducted by a suitably qualified botanist. A current search of the department's flora databases should be requested from flora.data@dpaw.wa.gov.au prior to survey. If threatened or priority taxa are proposed to be impacted, the extent of the local population should be recorded to enable an assessment of the proportional impact of the proposal to the local population. If threatened (declared rare) taxa are recorded within the area proposed to be impacted, the proponent will need to apply to the Department's Species and Communities Branch for a permit to take DRF.

Thank you for the opportunity to comment on this proposal. Please contact Cho Lamb at Parks and Wildlife's Swan Region office on 9442 0309 or by email on cho.lamb@dpaw.wa.gov.au if you have any queries regarding this advice.

Yours sincerely

Stefan de Haan

Stefan de Haan

REGIONAL MANAGER
Swan Region

30 November 2015

Appendix K: *Neopasiphae simplicior* Conservation Advice

Advice to the Minister for the Environment, Heritage and the Arts from the Threatened Species Scientific Committee (the Committee) on Amendments to the list of Threatened Species under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

1. Scientific name (common name)

Neopasiphae simplicior (a short-tongued bee)

2. Description

Neopasiphae simplicior is a small bee. It is black in colour and smaller, with less modified antennae and legs, than other species belonging to the same genus. Males are 7 mm in length, with a wing length of 5 mm (Michener 1965).

3. National Context

Neopasiphae simplicior is endemic to Western Australia and occurs as a single population in the Forestdale Lake Nature Reserve (Houston 1994).

Neopasiphae simplicior is listed in Western Australia under the *Wildlife Conservation Act 1950* as Schedule 1 (fauna that is rare or is likely to become extinct) and is managed as endangered (according to IUCN criteria) by the Western Australian Government.

The species has been collected only at flowers of Thread-leaved Goodenia (*Goodenia filiformis*), a perennial herb, Slender Lobelia (*Lobelia tenulor*), an annual herb, *Angianthus preissianus* (males only), an annual herb, and *Velleia* sp (Houston 2000; CALM Florabase).

4. How judged by the Committee in relation to the EPBC Act criteria

The Committee judges the species to be **eligible** for listing as **critically endangered** under the EPBC Act. The justification against the criteria is as follows:

Criterion 1 – It has undergone, is suspected to have undergone or is likely to undergo in the immediate future a very severe, severe or substantial reduction in numbers

A single population of *Neopasiphae simplicior* currently occurs within bushland at Forestdale Lake Nature Reserve (approximately 25 km south-east of Perth in the City of Armadale). A previous population of the species was recorded at Cannington (south Perth) in 1954 (Houston 1994). This population is now presumed to be extinct as intensive surveying in the area has failed to record any further individuals of the species.

While the species is thought to have undergone a reduction in numbers, inferred from the loss of the Cannington population, there are insufficient quantitative data available on the species' numbers to assess it against this criterion.

Criterion 2 – Its geographic distribution is precarious for the survival of the species and is very restricted, restricted or limited

Neopasiphae simplicior is found at a single location within Forrestdale Lake Nature Reserve. The extent of occurrence and area of occupancy of the species are estimated at 1 km^2.

The single extant population of *Neopasiphae simplicior* occurs within bushland in Forrestdale Lake Nature Reserve. No other extant populations are known despite intensive surveys, with the only previous record from Cannington in 1954. Given that the Cannington population is presumed to be extinct it can be concluded that there has been a decline in both the previously known area of occupancy and extent of occurrence for the species.

Activities in areas adjacent to Forrestdale Lake Nature Reserve, such as clearing of bushland for residential, rural and industrial development, draining of winter-wet depressions and fire, may pose a threat to the habitat of *Neopasiphae simplicior*. An additional threat to many species in the same genus as *Neopasiphae simplicior* is competition with introduced honeybees (Houston 2000).

Neopasiphae simplicior's geographic distribution is very restricted to a single location in Forrestdale Lake Nature Reserve and occupies a total area of approximately 1 km^2. Given that there is a range of threats operating within its known habitat and on its single known population, the species' geographic distribution is precarious for its survival. Therefore, the species is **eligible** for listing as **critically endangered** under this criterion.

Criterion 3 – The estimated total number of mature individuals is limited to a particular degree and: (a) evidence suggests that the number will continue to decline at a particular rate; or (b) the number is likely to continue to decline and its geographic distribution is precarious for its survival

As there are no estimates available of total population size for *Neopasiphae simplicior,* there is insufficient quantitative information available to determine whether the population size is limited to a particular degree.

Therefore, there are insufficient data available to assess the species against this criterion.

Criterion 4 – The estimated total number of mature individuals is extremely low, very low or low

As discussed under criterion 3, there are currently no estimates of total population size for *Neopasiphae simplicior*. Therefore, there are insufficient data available to assess the species against this criterion.

Criterion 5 – Probability of extinction in the wild

There is no information regarding the probability of extinction in the wild of *Neopasiphae simplicior*, therefore there is insufficient quantitative data available to assess the species against this criterion.

5. CONCLUSION

Neopasiphae simplicior has undergone a significant decline in its known extent of occurrence and area of occupancy and is eligible for listing as critically endangered under Criterion 2. This conclusion is based on evidence that there is currently a single extant population with a very restricted area of occupancy of approximately 1km^2 at Forrestdale Lake Nature Reserve. The only additional recorded population at Cannington is presumed extinct as it has not been recorded since 1954, despite comprehensive survey effort. Given that there are a range of threats operating within the species' known habitat, the population's geographic distribution is considered precarious for its survival and the species is eligible for listing as critically endangered.

Recovery Plan

The Committee considers that there should not be a recovery plan for this species. *Neopasiphae simplicior* occurs entirely within a managed nature reserve. Therefore the approved Conservation Advice for the species provides sufficient direction to implement priority actions and manage the threats of clearing, draining of winter-wet depressions and fire. A recovery plan is not considered to be necessary at this time.

6. Recommendation

(i) The Committee recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the **critically endangered** category:

***Neopasiphae simplicior* (a short-tongued bee)**

(ii) The Committee recommends that there not be a recovery plan for this species.

Associate Professor Robert J.S. Beeton

Chair

Threatened Species Scientific Committee

References cited in the advice

Conservation Commission of Western Australia and Department of Conservation and Land Management (2005). Forrestdale Lake Nature Reserve Management Plan 2005. Conservation Commission of Western Australia and Department of Conservation and Land Management, Perth.

Houston, T.F. (1994). Proposed addition deletion or change to the schedules of declared threatened or specially protected fauna or the reserve list. *Neopasiphae simplicior*. Department of Conservation and Land Management, Perth.

Houston, T.F. (2000). Native Bees on Wildflowers in Western Australia. Special Publication No. 2 of the Western Australian Insect Study Society Inc. WA Museum, Perth.

Michener, C.D. (1965). Bees. Bulletin of the American Museum of Natural History 130: 262-3.

Approved Conservation Advice for *Neopasiphae simplicior* (a short-tongued bee)

(s266B of the *Environment Protection and Biodiversity Conservation Act 1999*)

This Conservation Advice has been developed based on the best available information at the time this Conservation Advice was approved; this includes existing plans, records or management prescriptions for this species.

Description

Neopasiphae simplicior, Family Colletidae, is a small species of bee. It is black in colour and smaller, with less modified antennae and legs, than other species belonging to the same genus. Males are 7mm in length, with a wing length of 5mm.

Conservation Status

Neopasiphae simplicior is listed as **critically endangered**. This species is eligible for listing as critivally endangered under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth) (EPBC Act) as the species occurs in a single location in Forrestdale Lake Nature Reserve and occupies a total area of approximately 1 km^2. Given that there are a range of threats operating within the species' known habitat, the species' geographic distribution is considered precarious for its survival (TSSC, 2006).

The species is also listed on Schedule 1 (fauna that is rare or is likely to become extinct) of the Western Australian *Wildlife Conservation Act 1950* and is managed as 'endangered' (according to IUCN criteria) by the Western Australian Government.

Distribution and Habitat

Neopasiphae simplicior is found at a single location within Forrestdale Lake Nature Reserve. The extent of occurrence and area of occupancy of the species are estimated at 1 km^2 and there has been past decline in the species geographic distribution.

The species has been collected only at flowers of Thread-leaved Goodenia (*Goodenia filiformis*), a perennial herb, Slender Lobelia (*Lobelia tenulor*), an annual herb, *Angianthus preissianus* (males only), an annual herb, and *Velleia* sp (Houston, 2000).

This species occurs within the Swan Natural Resource Management Region.

The distribution of this species is not known to overlap with any EPBC Act-listed threatened ecological community.

Threats

The main threats to *Neopasiphae simplicior* include clearing of bushland for residential, rural and industrial development, draining of winter-wet depressions and fire. An additional threat to many species in the same genus as *Neopasiphae simplicior* is competition with introduced honeybees.

Regional Priority Actions

The following regional priority recovery and threat abatement actions can be done to support the recovery of *Neopasiphae simplicior*.

- Design and implement a monitoring program or, if appropriate, support and enhance existing programs.

- Protect areas of native vegetation which contain populations of the species or which could support populations in the future.
- Ensure herbicides used to eradicate weeds on roadside verges do not impact on the species.
- Develop and implement a suitable fire management strategy for *Neopasiphae simplicior*.

Local Priority Actions

The following local priority recovery and threat abatement actions can be done to support the recovery of *Neopasiphae simplicior*.

- Undertake survey work in suitable habitat and potential habitat to locate any additional populations/occurrences/remnants.
- Ensure no inappropriate build up of woody debris or herbaceous debris, which could act as fuel for a potential fire.

This list does not necessarily encompass all actions that may be of benefit to *Neopasiphae simplicior*, but highlights those that are considered to be of highest priority at the time of preparing the conservation advice.

Existing Plans/Management Prescriptions that are Relevant to the Species

Forrestdale Lake Nature Reserve Management Plan 2005. Conservation Commission of Western Australia and Department of Conservation and Land Management, Perth.

These prescriptions were current at the time of publishing; please refer to the relevant agency's website for any updated versions.

Information Sources:

Houston, T.F. (2000). Native Bees on Wildflowers in Western Australia. Special Publication No. 2 of the Western Australian Insect Study Society Inc. WA Museum, Perth.

TSSC (2006). Threatened Species Scientific Committee listing advice for *Neopasiphae simplicior* (a short-tongued bee).

WA Herbarium (2005). *Florabase – The Western Australian Flora.* Department of Conservation and Land Management. http://florabase.calm.wa.gov.au/

Appendix L: Services Report (Shawmac, 2015)

SHAWMAC

CONSULTING CIVIL & TRAFFIC ENGINEERS, RISK MANAGERS.

Project: Local Structure Plan – Rowley Road Industrial Precinct, Forrestdale
Servicing Report

Client: Turner Master Planners and Gray and Lewis for the landowners

Job Number: 1506007

Author: Gavin Carter

Date: 31-08-15

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Document Status

Version No.	Author	Reviewed by	Date	Document status	Signature	Date
A	G.Carter	R.Needham	29-07-15	Client Review		29-07-15
B	R.Needham		24-08-15	Minor Amendments		24-08-15
C	R.Needham		27-08-15	Minor Amendments		27-08-15
D	R.Needham		31-08-15	Final		31-08-15

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Contents

1. Introduction and Background

Shawmac was commissioned by Turner Master Planners Australia and Gray & Lewis on behalf of the landowners to prepare a preliminary servicing report associated with the proposed rezoning to industrial use of Lots 5, 7 and 9 Oxley Road, Lots 6, 8, 10 & 200 Rowley Road, part of Lot 12 Rowley Road and 5066 Kargotich Road.

Lots 5, 7 & 9 are owned by RE & LJ Roney, C & F Valentino and N D'Orazio, M Jabado and G Di Flori respectively. Existing Lots 6, 8 and 200 Rowley Road are managed by Maddestra Group and Lot 10 Rowley Road is managed by Gray & Lewis. Lot 12 Rowley Road is owned by SM Catelloni and Lot 5066 is owned by DM Kendrick.

1.1 Purpose

The purpose of this report is to detail existing infrastructure within the immediate area of the proposed development and identify any deficiencies, necessary improvements/upgrades to existing or new services and to identify whether there are any constraints to the development with respect to the required servicing infrastructure.

2. Site Location

The subject land area is located between Rowley Road, Oxley Road and to the west of Tonkin Hwy in Forrestdale, approximately 25km south-east of the Perth CBD and is approximately 290ha in area. Figure 1 shows the site location.

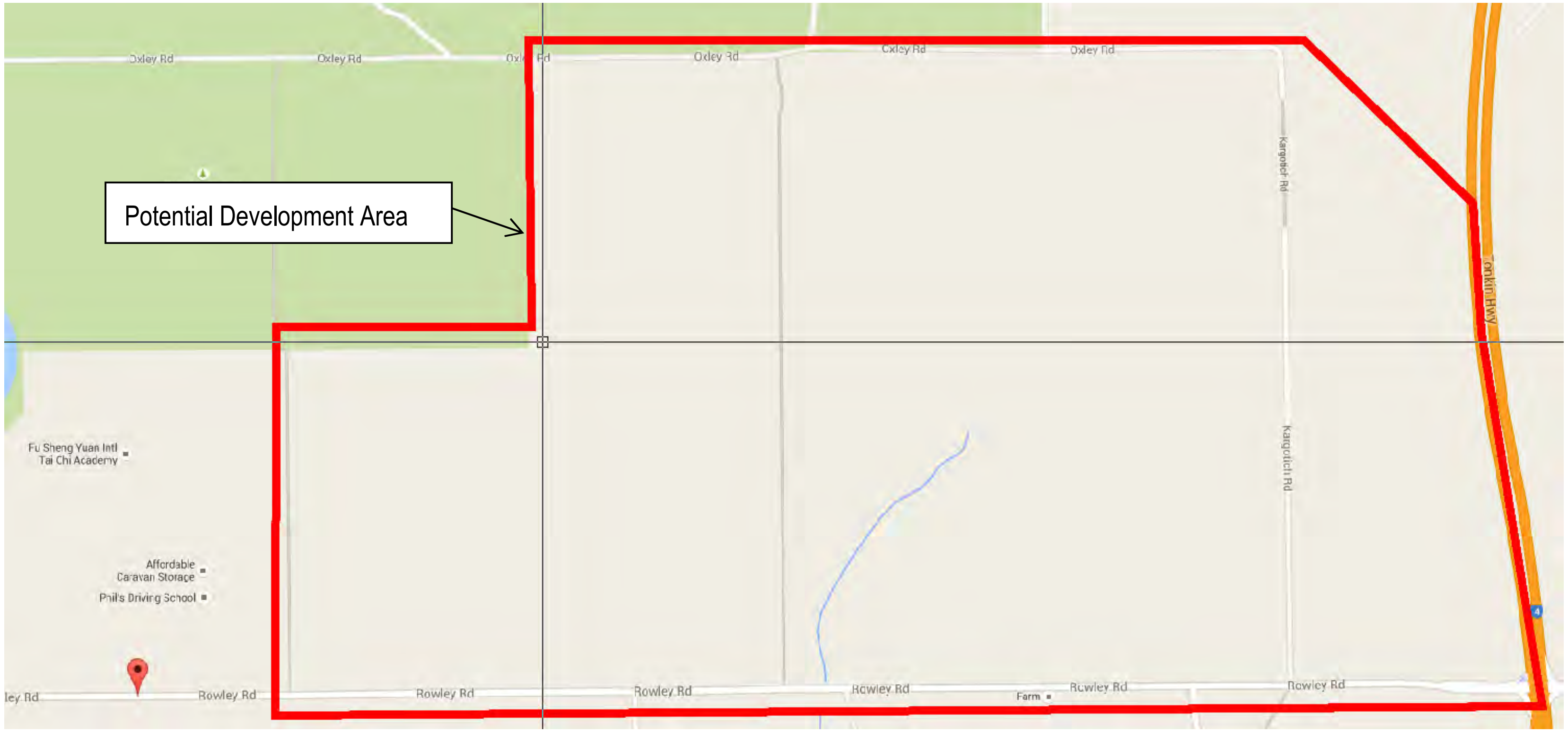

Figure 1. Site Location

3. Services Assessment

3.1 Water Reticulation

Currently there is no service network or formal water scheme future planning for the subject land. The Water Corporation has advised the area could be served through the Armadale-Kelmscott scheme subject to supply being via 5.8km extension from the DN760 on Armadale Road. The size of supply mains or route has not been considered in any detail. Preliminary advice indicated that a DN300 main would be required as a minimum, though it is likely a greater size would be needed to in order to achieve flows sufficient for fire fighting. An indicative potential alignment for the water main extension is shown in Figure 2 below and is approximately 5.8km in length. All mains extensions to serve the industrial area will be at the developers’ cost.

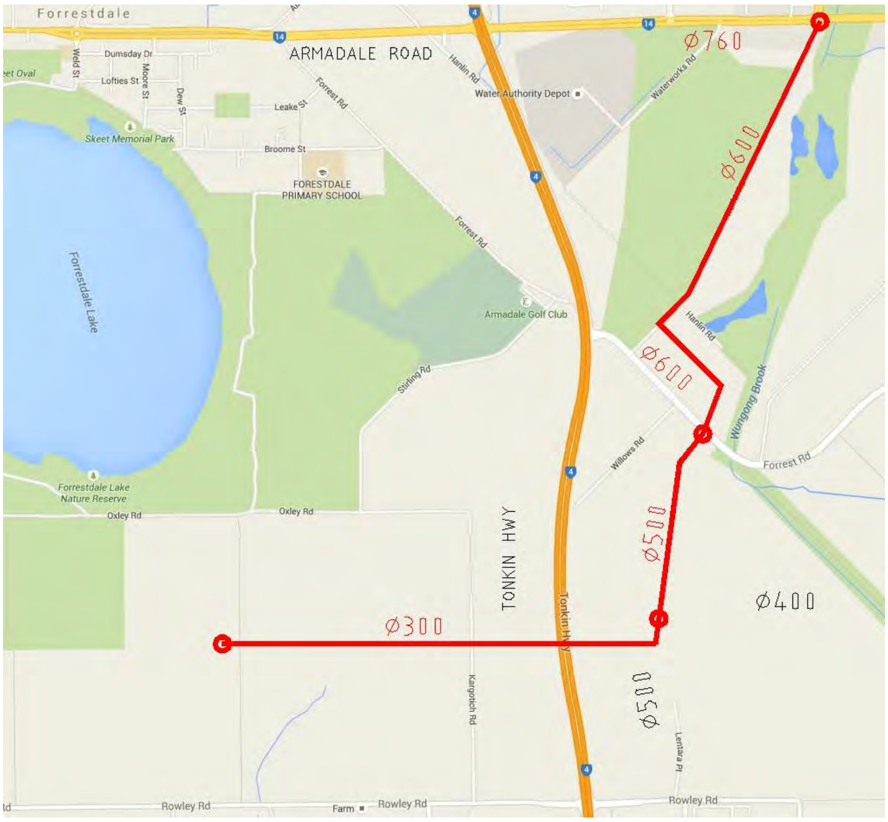

Figure 2. Potential Water Supply Strategy

3.2 Drainage

The Water Corporation has advised that it is premature to assume that drainage discharge to existing rural drains in the area would be permitted. The subject land falls largely within the within Peel-Harvey Catchment but a small area also drains towards 2 other locations within the Forrestdale Main Drain catchment, and the Department of Water's *Forrestdale Main Drain Arterial Drainage Study (FMDADS)* has assumed rural land use for the subject land. The rezoning of this land to industrial would necessitate a review of the FMDADS in order for Water Corporation to be able to comment.

The Water Corporation has previously advised the WAPC that it was opposed to rezoning Lots 6, 8 and 200 Rowley Road to industrial until the Department of Water had reviewed district level drainage planning for the wider area. This review is currently being progressed by the Department of Water. Notwithstanding this, the WAPC did rezone lots 6 and 8 to Industrial under the MRS, which was supported by the preparation of a District Water Management Strategy (DWMS).

Similarly, a DWMS has been prepared by Bioscience (August 2015) for the subject land which demonstrates that the drainage of the site can be appropriately managed.

The DWMS has been prepared in liaison with the Department of Water and proposes the following:

- Water sustainability measures including the installation of Waterwise fixtures and fittings, grey water recycling, rainwater harvesting, waterwise landscaping and use of groundwater for landscaping irrigation;
- Retention and/or detention of the 1 year, 1 hour ARI event at source for infiltration, slow release into system or reuse;
- The installation of vegetated swales, rain gardens and bioretention pockets to treat surface water before discharge;
- Pre-development runoff flow rates and paths to be maintained post development through the installation of stormwater compensating basins;
- Maintenance of pre-development flood storage volumes;
- Habitable floor levels set a minimum of 0.5m above natural waterway flood levels and 0.3m above 100year ARI stormwater levels; and
- Placement of fill and installation of subsoil drainage to provide a controlled groundwater level where required to provide adequate separation between lot levels and groundwater.

3.3 Sewer

The Water Corporation (WC) has previously undertaken some preliminary desktop considerations of likely servicing options for the subject land. Similarly to the water supply there is no formal wastewater scheme for the subject land, however WC suggests the land could be serviced for sewerage via a temporary pump station located at a suitable low point within the industrial area, with discharge to the east to the Armadale Pump Station 2, Hilbert Rd. The temporary pump station, pressure main and related works would be undertaken at the developers' cost. An indicative potential alignment for the sewer pressure main is shown in Figure 3 below and is approximately 4.1km in length.

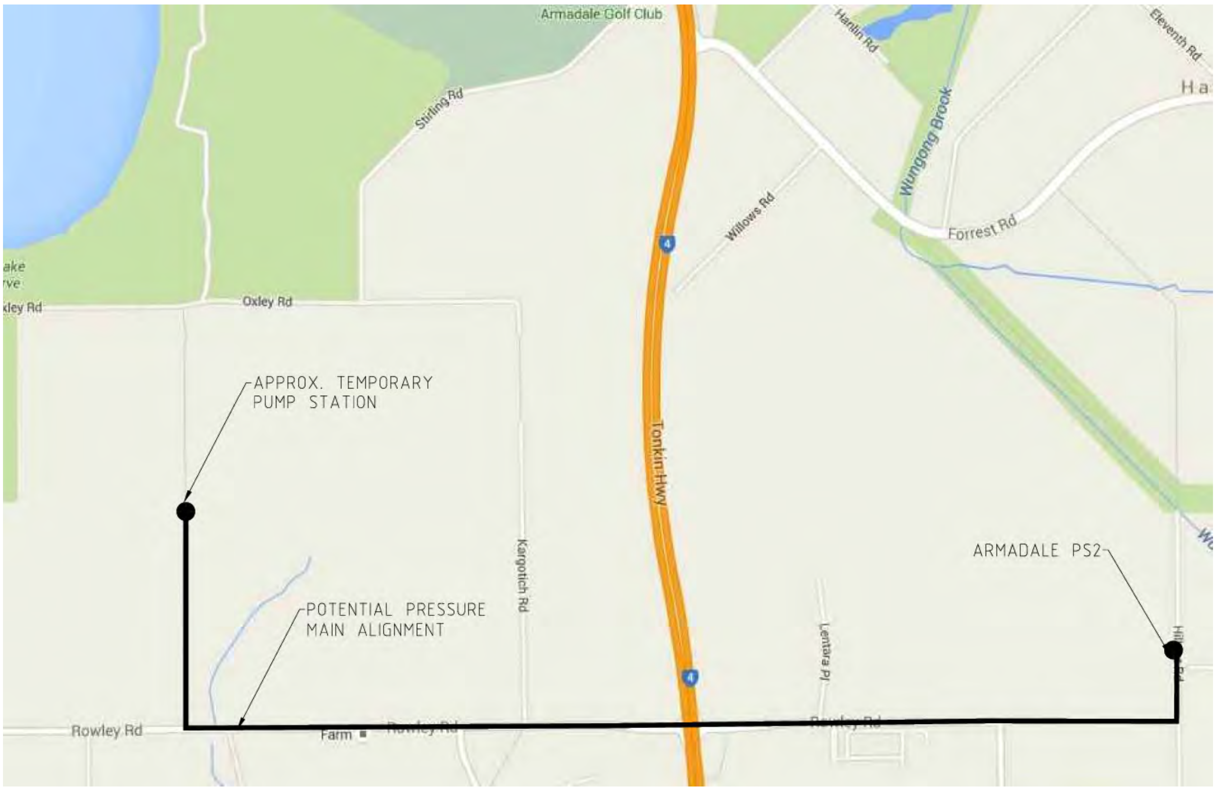

Figure 3. Potential Sewerage Strategy

3.4 Power

Western Power (WP) has indicated that there is only 1 High Voltage (HV) feeder in the vicinity of the subject land. WP strongly recommends that the subject land be serviced from the BYF527 feeder backbone located 1.2km east of the proposed land development area.

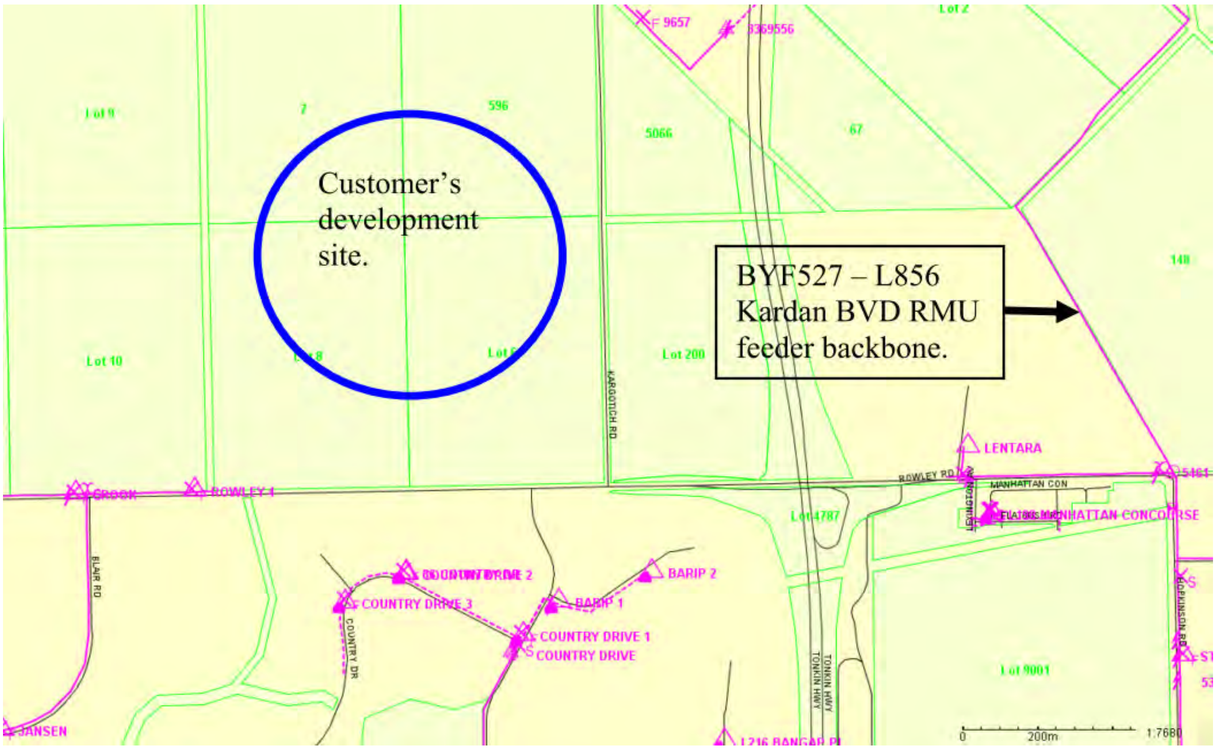

Figure 4. Potential Electricity Strategy

Subsequent stages can be connected to the same feeder until capacity is fully utilised. The final solution would depend on the network capacity available when a full application is submitted.

3.5 Gas

The existing gas network east of Tonkin Hwy has the capacity to support 850scmh. It would require an approximate 950m mains extension to bring gas to the edge of the site.

There is the possibility of increasing capacity up to 3,5000scmh. However this would require additional details of exact loads and location of connection points.

Figure 5. Potential Gas Strategy

3.6 Communications

NBN build preparation has not yet commenced for the subject site and the timing for NBN installation is unknown, however it is expected that NBN's current policy of servicing larger scale new developments would remain and NBN could be provided in developer installed pit and pipe at the time of construction. Should NBN not wish to service the development, as the provider of last resort, Telstra would be required to service the development, and this would be via a connection to the existing network in Rowley Road.

4. Conclusion

The report confirms that there are no unmanageable impediments to development in terms of the available utility infrastructure. The likely required utility upgrades to service the development include:

- Construction of a water main extension from Armadale Road, in the order of 6km in length;
- Construction of a sewer pump station and an approximately 4.1km long pressure main;
- Construction of a 1.2km extension to Western Powers electrical supply network;
- Construction of a 950m gas main extension;
- Implementation of recommendations contained in Bioscience DWMS for drainage management.