Government of **Western Australia**
Public Transport Authority

Forrestfield Airport Link Project

Stage 2 Geotechnical Investigation

Groundwater Conditions Report

Prepared by: Golder Associates Pty Ltd

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The signatures below certify that this report has been reviewed, endorsed and approved, and that the signatories are aware of all the requirements contained herein and are committed to ensuring their provision.

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May 2015

FORRESTFIELD-AIRPORT LINK PROJECT, STAGE 2 GEOTECHNICAL INVESTIGATION

Groundwater Conditions Report

FOR INFORMATION

Submitted to:
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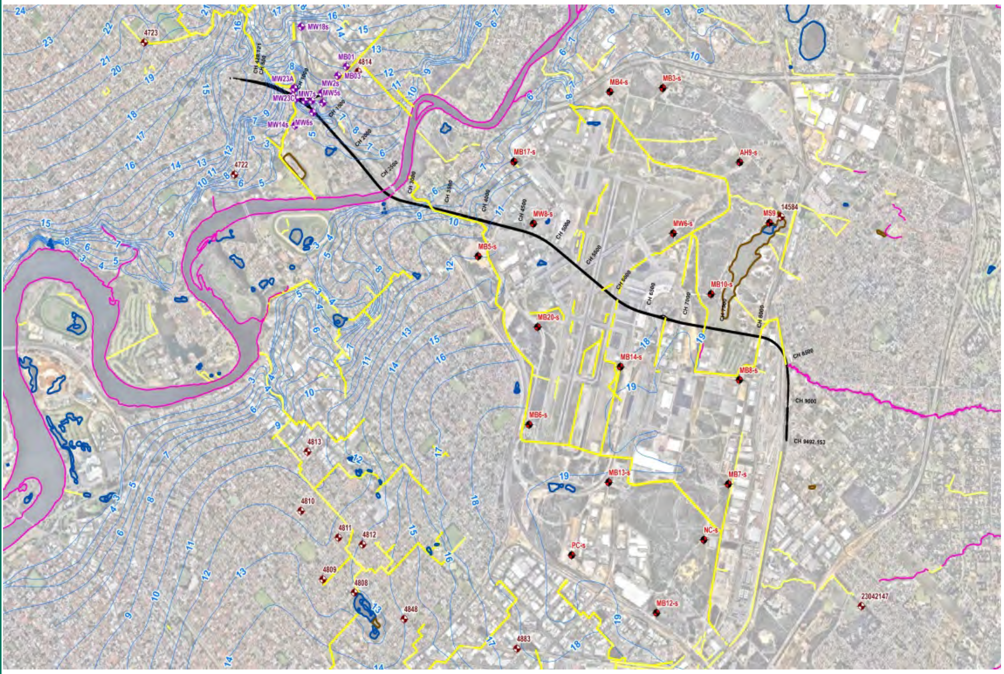

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REPORT

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List of Abbreviations, Acronyms, Definitions and Units

This list contains abbreviations, acronyms, definitions and units used on this project and in the complete Golder Associates Pty Ltd (Golder) Stage 2 geotechnical investigation report series.

AASS	Actual Acid Sulfate Soil
AF	Ascot Formation
AFa	Ascot Formation – Ascot Beds
AFj	Ascot Formation – Jandakot Beds
a_h	Peak horizontal ground acceleration
AHD	Australian Height Datum
AS	Australian Standard
ASS	Acid Sulfate Soil
ASTM	American Society for Testing and Materials
ATV	Acoustic Televiewer
AWS	Airport West Station
bgl	below ground level
BH	Borehole
BS	Bassendean Sand
$CaCO_3$	Calcium carbonate
CATS	Consolidated Airport Terminal Station
CBD	Central Business District
CBR	California Bearing Ratio
C_c	Compression index
CERCHAR	Laboratoire du Center d' Études et Recherches des Charbonnages de France, Abrasiveness Index
CH	Chainage
CIU	Consolidated, Isotropic and Undrained
CP	Cross Passage
CPT	Cone Penetration Test
CPTU	Piezocone Penetration Test
C_r	Recompression index
CRR	Cyclic Resistance Ratio
CRS	Chromium Reducible Sulfur
C_s	Swelling index
CSR	Cyclic Stress Ratio
c_u	Undrained shear strength (as shown on flat plate dilatometer test reports) = s_u
DBYD	Dial Before You Dig
DCP	Dynamic Cone Penetrometer
DDR	Dry Density Ratio
DIRD	Department of Infrastructure and Regional Development
DMT, D	Flat Plate Dilatometer
DPR	Drilling Parameter Recording

E’	Drained Young’s modulus
EA	axial stiffness of tunnel lining
EE	Emergency Egress shaft
EI	bending stiffness of tunnel lining
EPB	Earth Pressure Balance
E_r	Equivalent rock Young’s modulus
ERI	Electrical Resistivity Imaging
FAL	Forrestfield-Airport Link
FFS	Forrestfield Station
F_L	Liquefaction triggering factor
FR	Friction Ratio (cone penetration testing)
f_s	Sleeve friction (cone penetration testing)
FWS	Full Waveform Sonic
G_0	Small strain shear modulus
G	Working-strain shear modulus
GF	Guildford Formation
GPS	Global Positioning System
GS	Gnangara Sand
HA	Hand Augered borehole
HCl	Hydrochloric acid
IBC	Intermediate Bulk Containers
I_D	Material index (flat plate dilatometer testing)
I_r	Rigidity index = G/s_u
I_{s50}	Point Load Strength Index (PLI) corrected to 50 mm diameter
ISSMGE	International Society of Soil Mechanics and Geotechnical Engineering
k	hydraulic conductivity (in situ permeability)
k_h	horizontal hydraulic conductivity (permeability)
k_v	vertical hydraulic conductivity (permeability)
k_x	hydraulic conductivity (permeability) in the x direction in the model (= k_h)
k_y	hydraulic conductivity (permeability) in the y direction in the model (= k_v)
K_0	Coefficient of at-rest earth pressure
K_D	Horizontal stress index (flat plate dilatometer testing)
LCPC	Laboratoire des Ponts et Chaussées
LG	Gas monitoring well
M	Constrained modulus (flat plate dilatometer testing)
MASW	Multi-channel Analysis of Surface Waves
MG	Made Ground (Fill)
MIS	Marine Isotope Stage (palaeochannel reference)
MMDD	Maximum dry density/moisture content relationship using modified compactive effort
MRWA	Main Roads Western Australia
MW	Groundwater Monitoring Well
NATA	National Association of Testing Authorities, Australia
NQ	Drilling rod size with rod outside diameter = 69.9 mm
OF	Osborne Formation
OFf	Osborne Formation – Kardinya Shale Member fines dominated

OFm	Osborne Formation – Mirrabooka Member (including Molecap Greensand)
OFs	Osborne Formation – Kardinya Shale Member sand dominated
OLS	Obstacle Limitation Surfaces
P60	Piston sample (inner diameter 60 mm)
PAPL	Perth Airport Pty Ltd
PASS	Potential Acid Sulfate Soil
PCG94	Perth Coastal Grid 1994
PF	Perth Formation
PFc	Perth Formation clay
PFs	Perth Formation sand
PGA	Peak Ground Acceleration
Phi	Friction angle (as shown on flat plate dilatometer test reports) = ϕ'
PLI	Point Load Index = I_{s50}
PP	Pocket Penetrometer
PQ	Drilling core size with core diameter = 85 mm
PSD	Particle Size Distribution
PSP	Perth Sand Penetrometer
PTA	Public Transport Authority
PW	Pumping test Well
q_c	Cone resistance (cone penetration testing)
q_t	Cone resistance corrected for pore pressure at cone shoulder
R	Cone penetrometer radius
R	Return period factor
R_{int}	Interface strength parameter in Plaxis
RL	Reduced Level
RTK	Real Time Kinematic Global Positioning System
SAT	Soil Abrasion Test
SCPT	Seismic Cone Penetration Test (includes measurement of shear wave velocity)
SEM	Scanning Electron Microscopy
SF	Swan River Formation
SMDD	Maximum dry density/moisture content relationship using standard compactive effort
SPOCAS	Suspended Peroxide Oxidation Combined Acidity and Sulfur
SPT	Standard Penetration Test
SRA	Swan River Alluvium
SRB	Sulfate Reducing Bacteria
s_u	Undrained Shear Strength
SWTC	Scope of Works and Technical Criteria
T	Houlsby and Teh (1988) Modified Time Factor (for interpretation of piezocone dissipation tests)
T	Transmissivity
t_{50}	time to dissipate 50% of excess pore pressure (for interpretation of piezocone dissipation tests)
TBM	Tunnel Boring Machine
TDS	Total Dissolved Solids

TP	Test Pit
u	Pore pressure (piezocone penetration testing)
U63	Thin walled tube (inner diameter 63 mm)
UCS	Uniaxial Compressive Strength
Ud	Pore pressure index (flat plate dilatometer testing)
VS	Vane Shear
V_s	Measured shear wave velocity
VWP	Vibrating Wire Piezometer
XRD	X-Ray Diffraction
Z	seismic hazard factor
ν	Poisson's ratio
γ_{sat}	saturated unit weight
γ_{unsat}	unsaturated unit weight
ϕ'	effective friction angle
ϕ_g	geotechnical strength reduction factor
ρ	density
σ_{v0}	total vertical stress
σ'_{v0}	effective vertical stress
σ_{atm}	atmospheric pressure

Units:

°	degree
GPa	gigapascal
K	degrees Kelvin
ka	thousands of years ago
kg/m^3	kilograms per cubic metre
kg/t	kilograms per tonne
km	kilometre
kN/m^3	kilonewtons per cubic metre
kPa	kilopascal
L/s	litres per second
m	metre
m/d	metres per day
m^2/d	metres squared per day
m^2/yr	metres squared per year
Ma	millions of years ago
mg/L	milligrams per litre
mg/kg	milligrams per kilogram
ml/kg	millilitres per kilogram
mm	millimetre
μm	micrometre/micron
MPa	megapascal
ms	millisecond

ppm	parts per million
s	second
t/m^3	tonnes per cubic metre

Summary of soil particle size and soil description in accordance with Australian Standard AS1726-1993:

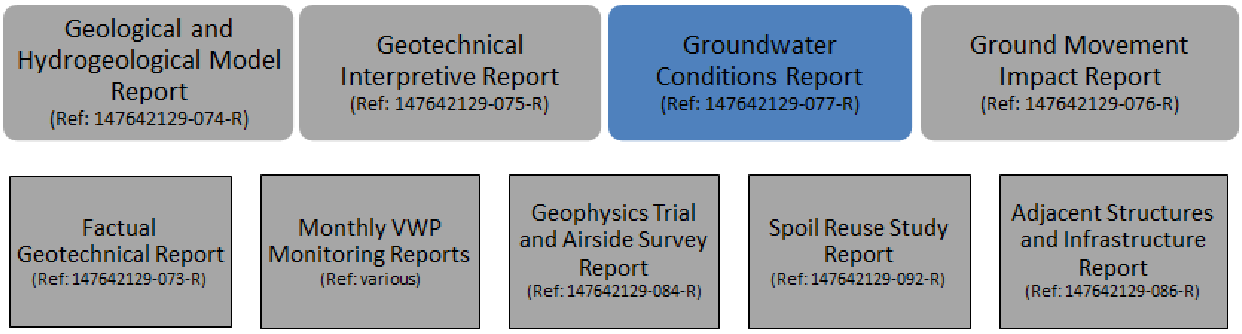
<table>
<tr><th>Major Division</th><th>Sub-Division</th><th>Particle Size</th><th>Generalised Material Description</th></tr>
<tr><td colspan="2">Boulders</td><td>> 200 mm</td><td rowspan="8">Coarse grained soils with less than 50% smaller than 0.075 mm.</td></tr>
<tr><td colspan="2">Cobbles</td><td>63 to 200 mm</td></tr>
<tr><td rowspan="3">Gravel</td><td>Coarse</td><td>20 to 63 mm</td></tr>
<tr><td>Medium</td><td>6.0 to 20 mm</td></tr>
<tr><td>Fine</td><td>2.0 to 6.0 mm</td></tr>
<tr><td rowspan="3">Sand</td><td>Coarse</td><td>0.6 to 2.0 mm</td></tr>
<tr><td>Medium</td><td>0.2 to 0.6 mm</td></tr>
<tr><td>Fine</td><td>0.075 to 0.2 mm</td></tr>
<tr><td colspan="2">Silt</td><td>0.002 to 0.075 mm</td><td>Fine grained soil with greater than 50% of material smaller than 0.075 mm. Material plots below the “A-Line” on plasticity charts.</td></tr>
<tr><td colspan="2">Clay</td><td>< 0.002 mm</td><td>Fine grained soil with greater than 50% of material smaller than 0.075 mm. Material plots above the “A-Line” on plasticity charts.</td></tr>
</table>

1.0 INTRODUCTION

This report presents the results of hydrogeological interpretive studies carried out as part of Stage 2 Geotechnical Investigation for the proposed Forrestfield-Airport Link (FAL) project. The work was carried out for the Public Transport Authority (PTA) under contract number PTA2014009.

1.1 Related Reports

This report is one of a set of reports that was produced during the Stage 2 geotechnical investigation as shown in Sketch A.



Sketch A: Forrestfield-Airport Link Project - Golder Report Series Breakdown. This report is shown coloured and other reports in the series are shown in grey.

The reports are arranged in the following manner, with a brief overview of the report content provided below as an aid to the reader, although each report should be referred to for full details of the work presented:

1) Primarily interpretive reports:

- The **Geological and Hydrogeological Model Report** presents the geological and hydrogeological conceptual models, descriptions of the geological units and hydrogeological features and interpretation of historic and current investigation data in the form of geological sections.
- The **Geotechnical Interpretive Report** includes interpretation of the subsurface conditions, geotechnical design parameters and key geotechnical risks and mitigation measures.
- The **Groundwater Conditions Report** includes groundwater level data, analysis of hydraulic testing (pumping tests, slug testing and infiltration testing), groundwater modelling results and discussion regarding groundwater control during construction, stormwater disposal and drainage control.
- The **Ground Movement Impact Report** includes analysis and discussion of the effects of construction on adjacent infrastructure, including ground movements from construction activities including any dewatering-related ground movements.

2) Reports containing both factual and interpretive components:

- The **Factual Geotechnical Report** contains the data from the field and laboratory investigations and includes the current monthly Vibrating Wire Piezometer (VWP) Monitoring Report at the date of the factual report.
- The monthly **VWP Monitoring Reports** contain the progressive results of VWP monitoring along the alignment.

- The **Geophysics Trial and Airside Survey Report** contains the results and interpretation of a geophysical investigation trial and airside geophysical survey along a selected part of the alignment.
- The **Spoil Reuse Study Report** contains the results and interpretation of a laboratory testing program aimed at assessing the suitability of construction spoil for reuse as engineered fill.
- The **Adjacent Structures and Infrastructure Report** contains data on existing adjacent structures and major infrastructure.

2.0 PROJECT BACKGROUND

Forrestfield-Airport Link is a State Government project to deliver a rail service to the eastern suburbs. The proposed project alignment is about 8.5 km long, as presented on Figure 1, General Site Location Plan. At the time of reporting the project was planned to include two dive and portal structures, approximately 7.5 km of twin underground rail tunnels between the dive and portal structures, 13 cross passages between the two tunnels, with a permanent egress shaft to the surface at three of the cross passages, and three new railway stations at Airport West, Consolidated Airport Terminal and Forrestfield. Airport West and Consolidated Airport Terminal Stations are planned to be constructed underground. Forrestfield Station is planned to be constructed at-ground together with an associated at-grade parking area.

In preparing this report, reference was made to FAL Project chainages and cross passage and emergency egress shaft locations as shown on PTA Drawing No. 16-C-24-0044, Rev F, Reference Design Plan and Profile, dated 9 April 2015.

The proposed rail line spurs from near the existing at-ground Bayswater Station on the Midland Line, dives underground on the west side of Guildford Road, then generally follows adjacent to and on the south side of Tonkin Highway, passes under the Swan River, deviates under Tonkin Highway towards Perth Airport, runs beneath the airport estate, including both runways, and surfaces and terminates east of the freight rail main lines at Forrestfield.

The current proposed design tunnel configuration involves twin bored tunnels, each with internal diameter of 6.15 m. The separation between the two tunnel centrelines is planned to vary in the range 10 m to 15.5 m, but is typically about 13.5 m. The tunnels will be constructed using a Tunnel Boring Machine (TBM).

The Rev F Reference Design Plan and Profile includes ten cross passages between the twin bored tunnels (CP1, CP2, CP3, CP4, CP4a, CP5, CP5a, CP6, CP6a and CP6b), and a further three cross passages that are incorporated with emergency egress shafts (Emergency Egress Shaft Wright Crescent, Emergency Egress Shaft Domestic Airport Terminal and Emergency Egress Shaft Abernethy Road).

3.0 OBJECTIVES

The objectives of the groundwater conditions studies were to evaluate existing conditions and provide interpretive advice and numerical modelling of construction dewatering for various assumed construction methodologies and design assumptions, based on advice from PTA for possible scenarios, as follows:

- Report the results and interpretation of hydraulic testing carried out during the Stage 2 Geotechnical investigation.
- Provide recommended hydrogeological design parameters.
- Provide recommendations on the design parameters for disposal of stormwater by soakage at Bayswater dive structure, Airport West Station, Consolidated Airport Terminal Station, Forrestfield Station and associated car park.

- Provide advice on possible risks from seasonal and periodic variations and trends to groundwater conditions. Evaluate the maximum design groundwater level for the next 50 years and 120 years at each of the Bayswater dive structure, Airport West Station, Consolidated Airport Terminal Station, Forrestfield Station and Forrestfield car park based on review of historical records and new monitoring data.

- Provide advice on methods of groundwater control during construction, likely dewatering discharge rates, methods of pumped groundwater disposal and constraints or limitations on dewatering activities at each of the Bayswater dive structure, Airport West Station, Consolidated Terminal Station and Forrestfield dive.

- Conduct preliminary 3D groundwater drawdown and recharge modelling at each of the 4 main sites above and show steady state drawdown contours and cross-sections at each structure. Where settlement due to groundwater drawdown is predicted to cause damage that requires repair, suggest means of reducing effects of drawdown.

- Assess the requirements for drainage control measures to protect the integrity of excavations and rail formation and present design concepts, if appropriate. Any requirements for long-term drainage shall be included with appropriate advice on maintenance requirements to satisfy long term effective operation of the drainage system.

4.0 SITE DESCRIPTION

The following sections provide a brief overview of the site conditions including a brief discussion on the geology and hydrogeology. Full details and discussion on the geological model and hydrogeological model developed for the project is provided in the Geological and Hydrogeological Model report (Golder, 2015b).

4.1 Topography and Surface Features

Local topography and surface features are discussed in further detail in (Golder, 2015b). In summary there are three main topographic areas across the proposed alignment as shown on Figure 2. From west to east these include:

- Bassendean Dune System and Swan River Terraces (CH428 to CH3200) – The western end of the proposed alignment has deflated sand dunes of the Bassendean Dune System set alongside alluvial terraces of small creeks and the ancient Swan River. The resulting topography is gently rolling between the crests and troughs of the deflated dune system and eroded river terraces. Overall the elevations are between RL 20 m AHD and RL 25 m AHD at CH428 and gently decreasing to RL 0 m AHD at the Swan River (CH2700). On the eastern side of the Swan River, the elevation quickly rises to between RL 5 m AHD and RL 11 m AHD.

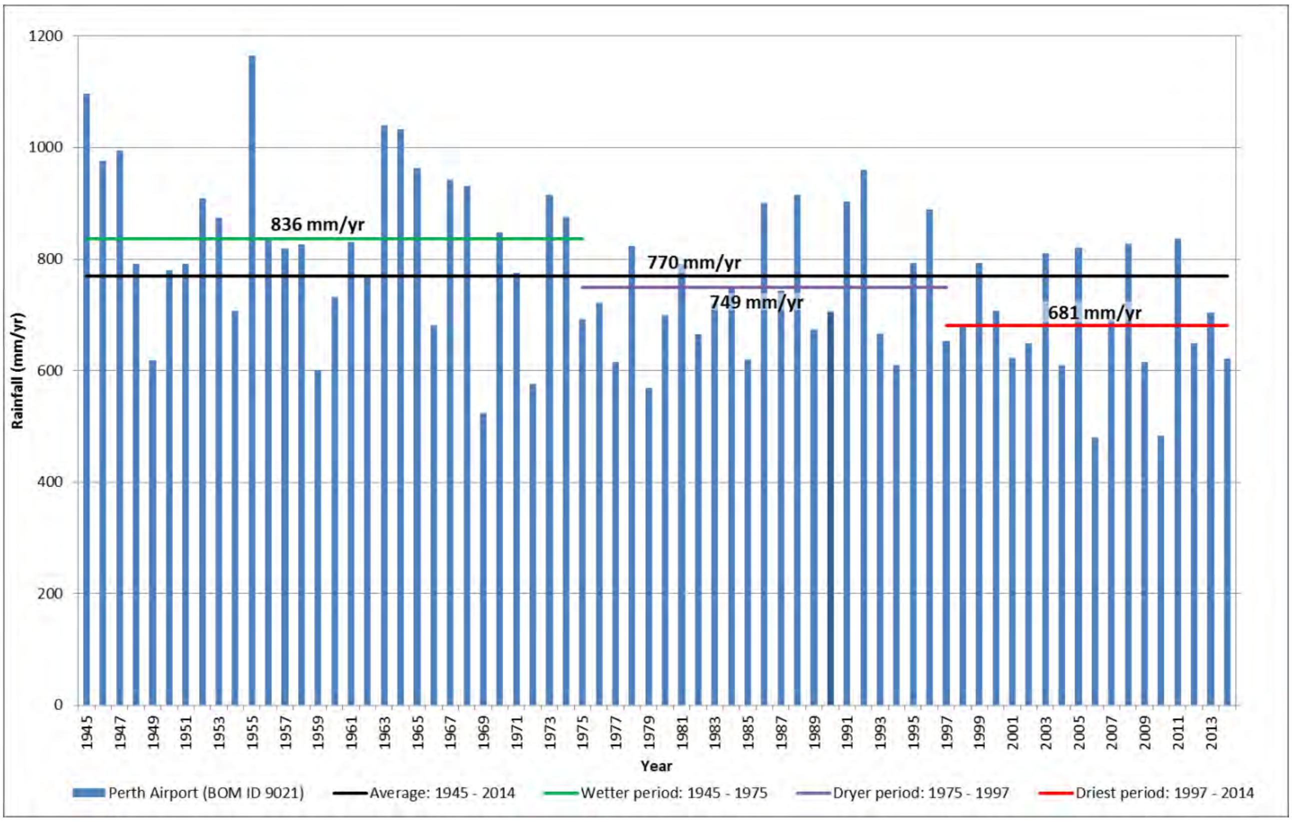
- Bassendean Dune System and Sand Plain (CH3200 to CH7700) – The middle portion of the alignment is largely comprised of sand of the Bassendean Dune System. Over much of this area interdunal depressions previously containing swamps, wetlands and damplands have been infilled during development of the area. In some instances infilling has been completed by excavating local sand for fill. Anecdotal evidence suggests infilling will have modified the current surface level by less than 5 m. Elevation gently increases from approximately RL 8 m AHD at CH3200 to approximately RL 20 m AHD at CH7700.

- Pinjarra Plain (CH7700 to CH9492) – The eastern end of the alignment is located on the Pinjarra Plain which generally comprises alluvial fan deposits extending out from the Perth Hills. Across the alignment a thin layer (1 m to 2 m thickness) of Bassendean Sand covers most the alluvial fan deposits. The terrain begins to rise from approximately RL 20 m AHD at CH 7700 up to RL 30 m AHD by CH8600. As with many geomorphological features in the Perth area, the Pinjarra Plain tends to have an overall north to south alignment. This means the portion of the proposed alignment that runs approximately north to south between CH8600 and CH9492 has a relatively constant elevation of approximately RL 30 m AHD.

4.2 Climate

Sketch B shows the annual rainfall from the Bureau of Meteorology rainfall station (BOM ID 9021) located at the Perth Airport for the period from 1945 to 2014 and indicates the following:

- The average annual rainfall from 1945 to 2014 is 770 mm/yr.
- Perth experienced a wetter period between 1945 and 1975 with an average annual rainfall of 836 mm/yr.
- Since 1975 it has experienced a drying climate with an average from 1975 to 1997 of 749 mm/yr.
- The average annual from 1997 to present is only 681 mm/yr.



Sketch B: Annual Rainfall from 1945-2014 (BOM ID 9021 – Perth Airport)

4.3 Geology

Full details of the geological model and detailed description of geological units relevant to the project are provided in the Geological and Hydrogeological Model Report (Golder, 2015b). A summary of the identified relevant geological units is provided in Table 1. A conceptual geological model along the alignment (in long section) is provided on Figure 2.

Table 1: Summary of Project Specific Geological Units

Geological Unit		Typical Description	Depositional Environment	Approximate Age	Diagenesis
Name	Unit Colour				
Fill (MG)		Primarily fine to medium grained yellow to brown sand. Also road base and other types of fill	Controlled and uncontrolled sand fill in recent history.	<200 years	Some cementation of limestone road base may have occurred.
Swan River Formation (SF)		Silty clay, clayey silt, silty sand and sand, dark grey, dark brown to black with shells and organic material, low to high plasticity fines, very soft to firm, or very loose to loose.	Palaeochannel deposits in marine, estuarine and fresh water conditions.	0 to 30 ka	Natural consolidation of this unit may have been enhanced by construction of the Redcliffe Bridge approach embankments
Perth Formation (PF)	PF / PFs	PFs: Sand to silty sand, yellow, brown and grey, fine to coarse grained, medium dense to dense. Some fine to coarse gravel, generally rounded to sub-rounded quartz, may be present.	Palaeochannel deposits in marine, estuarine and fresh water conditions.	80 to 150 ka	Some local pockets (up to approximately 2 m thick) of very weakly cemented (non-carbonate) sand may be present at the contact with the overlying Bassendean Sand.
	PF / PFc	PFc: Clay, some silt and sand, blue-grey, mottled red, yellow, brown, generally low to medium plasticity and generally stiff to hard some soft to firm materials close to the Swan River.			
Bassendean Sand (BS)		Sand, light grey, yellow, dark brown, fine to medium grained, loose to dense, fining upwards where fluvial in origin, with thin (up to 1 to 2 m) localised iron cemented layers. May contain peaty sand, silty and clay associated with wetland or dampland interdunal deposits.	Mixed fluvial and aeolian origin.	80 to 750 ka	Localised iron-cementation has occurred in this unit creating pockets and layers that can be up to approximately 2 m thick of very weakly to moderately well cemented sandstone ("coffee rock").
		transitional boundary / facies change			
Guildford Formation (GF)		Clayey sand, silty sand, sand and clay, brown, pale grey, orange, fine grained layers stiff to hard and low plasticity, coarse grained layers are medium dense to very dense. Includes potential sand deposits of the Yoganup Formation east of the RAC driving centre (~ CH7600).	Fluvial origin generally deposited as part of alluvial fan system. Yoganup formation is a littoral (coastal) deposit.	170 ka to 2 Ma	Aside from natural consolidation no other extensive diagenetic processes have been noted.
		transitional boundary / facies change			
Gnangara Sand (GS)		Sand and silty sand, blue-green, dark green, fine grained, loose to dense.	Freshwater and marine deposit in nearshore coastal environment.	170 ka to 2 Ma	Alteration of materials at contact with the underlying unit may have led to reduction in strength at the contact (e.g. decomposition of organics).
Ascot Formation (AF)		Ascot Beds (AFa): Carbonate sandy gravel, gravelly sand and sand, fine to medium grained sand, grey, yellow, medium dense to dense, some siliceous calcarenite layers.	Inner shelf, nearshore marine environment, deposited during multiple marine transgressions.	750 ka to 3 Ma	This unit appears to have undergone carbonate cementation since deposition of the original sediments. Subsequent leaching may have created small voids and cavities that have now been infilled with sand. Recementation of previously leached sand and gravel layers may still be occurring.
		Jandakot Beds (AFj): Carbonate sand, sandy gravel and gravelly sand, fine to coarse grained, grey, dark grey and blue-grey, medium dense to very dense, some siliceous calcarenite. Polished rounded black phosphatic gravel often found at the base. High strength conglomerate boulders may also be present at the base of this unit but have only been noted in the vicinity of the Perth Airport air traffic control tower to date.			
			major unconformity		
Osborne Formation (OF)	OFm	Mirrabooka Member (OFm): Sand, silty sand and clayey sand, dark green to dark grey, medium to coarse grained, dense to very dense, siliceous and glauconitic. Includes the Molecap Greensand.	Shallow-marine origin.	100 to 120 Ma	Potential secondary formation of pyrite may have occurred.
		facies change			
		Kardinya Shale Member sand dominated (OFs): Silty sandstone, fine-grained, layered, dark green and black, moderately weathered to fresh, extremely low to medium strength.			
		facies change			
		Kardinya Shale Member fines dominated (OFf): Sandy mudstone and sandy siltstone, black and dark green, moderately weathered to fresh, extremely low to medium strength.			

Notes:

- This table is intended to represent a basis for broad geological subdivision of the geology and is not the basis of engineering characterisation. Indications of consistency and relative density in the table are generally typical for the units and do not necessarily represent the full range of values encountered. Not every permutation of material grading is provided. Rock materials may exist in units that are principally soils and vice versa and not all diagenesis processes may have been identified.
- The carbonate and non-carbonate soil and rock classification systems used for this study are defined in Appendix B of (Golder, 2015a).

5.0 HYDROGEOLOGICAL CONDITIONS

5.1 Definitions

The following definitions have been adopted in this report:

- Groundwater level means the level at which the pressure in the pore water in the subsurface material is atmospheric. The terms groundwater level, phreatic surface, groundwater table and water table may be used interchangeably. If perched groundwater conditions exist there may be more than one groundwater level at any particular plan position.
- Piezometric pressure means pore water pressure measured at a point below ground level.
- Piezometric level means piezometric pressure referenced to the level in metres AHD that water would rise to in a standpipe installed with a porous tip registering the pressure at a point below ground.
- Perched groundwater means a saturated lens of water supported by a low permeability unit that occurs above the regional groundwater table (refer to Figure 3). The extent of the perched water table depends on the extent and continuity of the low permeability unit.

5.2 Assignment of Hydrogeological Units

A conceptual hydrogeological model showing the main aquifers, regional groundwater and piezometric levels and flow directions is shown on Figure 3. A summary of the hydrogeological units in the model is provided in Table 2. The hydrogeological units have been split into two zones; East and West, based on the regional geology. Figure 3 shows that the West Zone extends to east of the Swan River where the Perth Formation terminates and the East Zone extends east from this point.

Table 2: Summary of Project Specific Hydrogeological Units

Zone	Regional Unit	Hydrogeological Unit	Local Aquifer Type	Geological Units Included
West (CH428-CH3200)	Superficial Aquifer	Upper Aquifer	Unconfined	MG, BS, PFs
		Bayswater Aquitard	Aquitard	PFc
		Lower Aquifer	Confined (west of Swan River) Semi-confined (east of Swan River)	PFs
	Osborne Aquitard		Aquitard	OF (OFs)
East (CH3200-CH9493)	Superficial Aquifer	Bassendean Sand	Unconfined	MG, BS
		Guildford-Gnangara	Semi-confined	GF, GS
		Ascot Formation		AF
	Mirrabooka Aquifer		Semi-confined Aquifer	OF (OFm)
	Osborne Aquitard		Aquitard	OF (OFf)

Notes: This table is intended to represent a basis for broad hydrogeological subdivision of the geology and is not the basis of engineering characterisation.

The two main regional aquifers of relevance beneath the proposed alignment are the Superficial Aquifer (present in both the east and west zones) and the Mirrabooka Aquifer (present in the east zone only). Along the proposed alignment the Superficial Aquifer comprises all the materials overlying the Osborne Formation. In the west zone, the Superficial Aquifer comprises an Upper and Lower Aquifer separated by an aquitard (PFc). The Superficial Aquifer includes seven of the main geological units listed previously, which all have unique hydrogeological properties. The Superficial Aquifer and the Mirrabooka Aquifer is in direct hydraulic connection.

5.2.1 West Zone

Within the West Zone, groundwater of relevance to the project is largely contained within the sandy dominated materials of the Perth Formation and the overlying Bassendean Sand. However, the occurrence of fines dominated sediments within the Perth Formation (termed the Bayswater Aquitard in Table 2) separates the water bearing materials into two aquifers. Differences in groundwater levels measured within these two aquifers substantiate the presence of these two aquifers and this is discussed in more detail in Section 5.3.5. For the purpose of this report the two aquifers have been named the Upper Aquifer and Lower Aquifer. The Lower Aquifer is underlain by the Osborne Aquitard (KSc).

5.2.2 East Zone

Within the east hydrogeological zone all materials overlying the Osborne Formation are part of the regional Superficial Aquifer. However, the materials have been separated into distinct hydrogeological units (BS, GF, GS and AF) due to variations in their hydrogeological characteristics. Clayey/silty soils within the Guildford Formation and Gnangara Sands are expected to be responsible for creating semi-confined conditions. Underlying the Ascot Formation over part of the east zone is the semi-confined Mirrabooka Member (Mirrabooka Aquifer), which is in direct hydraulic connection with the Ascot Formation. All materials are underlain by the Osborne Aquitard (KSc).

5.3 Groundwater Levels

5.3.1 Published Information

The Perth Groundwater Atlas (WRC, 1997), which presents the inferred maximum historical groundwater level contours, covers the alignment between CH428 and CH4250 and at CATS (refer to Figure 4). Approximate groundwater levels from the 1997 Groundwater Atlas for each main structure are summarised below:

- Bayswater Dive Structure (at portal) – between RL 5 m AHD and RL 6 m AHD (contours suggest there has historically been a surface drain at the portal.
- Airport West Station – between RL 10 m AHD and RL 11 m AHD.
- Consolidated Airport Terminal Station – RL 19 m AHD.
- Forrestfield Dive Structure – No coverage.

It should be noted that the 1997 Groundwater Atlas in some areas presents the groundwater level prior to installation of some of the drains that are used to control groundwater levels in built-up areas. Therefore, the maximum historical groundwater levels shown in the 1997 Groundwater Atlas may not represent the possible maximum future groundwater levels.

5.3.2 Historical Trends

Historical groundwater level trends for the Superficial Aquifer were evaluated using data obtained from the Department of Water (DoW) WIN database, Perth Airport Pty Ltd (PAPL) and CSBP investigation (Parsons Brinckerhoff, 2013). Figure 4 shows the location of selected monitoring wells with available hydrographs while Appendix A presents the hydrographs. The historical groundwater level data indicates:

- A step-decline in groundwater levels occurred in the Belmont area in the late 1950’s (e.g. WIN ID 4809) and 1960’s (e.g. WIN ID 4883) which is due to installation of drains to lower the groundwater level to allow for land development.
- Steady groundwater levels between the mid 1960’s and the present day.
- The Superficial Aquifer along the alignment is full and surface drains generally constrain the maximum groundwater level in the area.

- Although annual rainfall totals indicate a drying climate (Section 4.2), rainfall (and subsequent recharge) experienced in recent years is still sufficient to fill the aquifer resulting in flow into the surface drains that constrain groundwater levels to their maximum local height. A decline in groundwater levels due to change in climate is therefore not observed in this area yet.

5.3.3 Seasonal Fluctuations

Seasonal groundwater level fluctuations along the alignment were assessed by reviewing the following hydrographs (refer to Figure 4 for location of wells):

- DoW hydrographs (data from the 1950's to present).
- PAPL hydrographs (data from 1999 to present).
- CSBP hydrographs (Parsons Brinckerhoff, 2013) (data from 2003 to 2011)
- Vibrating wire piezometer (VWP) data (Golder, 2015i) from instruments installed by GHD (GHD, 2014c) during the Stage 1 geotechnical investigation (data from one season only 2014-2015).

A summary of the seasonal fluctuation data is provided below:

- West Zone:
  - Upper Aquifer – 0.7 m to 1.1 m
  - Lower Aquifer – 1.2 m to 1.6 m (based on 2014/2015 hydrographs from BH 0-02, BH 0-03 and BH 0-08 only).
- East Zone:
  - Superficial Aquifer – General range between 0.6 and 1.6 m with an average around 1.2 m, but at BH 0-07 in Forrestfield the seasonal variation is observed to be 3.1 m (Golder, 2015i). This larger seasonal fluctuation is expected to be due to the predominance of clayey and lower permeability soils close to the ground surface that make up the Guildford Formation in this area, which is also referenced in published information (Davidson, 1995). VWP readings from BH1-02, BH1-04 and BH1-07 show similar seasonal declines as BH0-07, suggesting that the 3 m seasonal variation could exist over the whole Forrestfield Area.
  - Mirrabooka Aquifer – no seasonal data is currently available, but based on the available readings from VWPs installed in the Mirrabooka Aquifer (BH1-22 and BH1-24), the piezometric levels show similar trends to piezometers installed in the Superficial Aquifer at CATS. The seasonal variation would therefore be expected to be similar to the seasonal variations in the Superficial Aquifer (the maximum seasonal variation observed in MB14s is 1.2 m).

5.3.4 March 2015 Levels

Groundwater levels were measured in 95 monitoring wells (installed as part of the geotechnical and environmental investigations for the FAL project) on 10 March 2015. Appendix B provides the groundwater and piezometric level measurements for the monitoring wells and the VWPs while Figures 5 shows the monitoring locations and the values measured during the March 2015 groundwater level survey. The inferred approximate groundwater and piezometric levels for each dive and station location are summarised below:

- Bayswater Dive Structure, extending from the shallowest to deepest section of the proposed dive structure, respectively:
  - Upper Aquifer – RL 10 m AHD to RL 5 m AHD
  - Lower Aquifer – RL 4 m AHD to RL 1.5 m AHD (east of the Bayswater Main Drain).
- Airport West Station – RL 8.2 m AHD to RL 8.8 m AHD

- Consolidated Airport Terminal Station – RL 16.8 m AHD to RL 17.0 m AHD
- Forrestfield Dive – RL 23 m AHD.

5.3.5 Multi Aquifer System (West Zone)

Groundwater levels measured in the Bayswater Dive area indicate a significant downward vertical hydraulic gradient between the Upper and Lower Aquifers (head difference of 3.7 m at the Bayswater Dive Portal). This difference in levels indicates that the Upper Aquifer in this area is “perched” above the Bayswater Aquitard which is therefore likely to have a very low hydraulic conductivity. It is possible that the head difference between the two aquifers could be further exacerbated as a result of potential pumping from the Lower Aquifer.

Based on the current monitoring locations the difference in groundwater level between the two aquifers is most distinct along the alignment between the Bayswater Dive Structure east toward CH1800. There is a change in groundwater level of 3.8 m between CH1800 and CH2200, after which there is insignificant difference in groundwater/piezometric levels between monitoring wells screened in the shallow and deep portions of the aquifer, suggesting that there is no longer a significant multi-layered aquifer system east of this position. The reason for an apparent merging of the multi-layer aquifer system is likely associated with both a thinning of the Bassendean Sand and intersection of the groundwater table with the Perth Formation east of approximately CH1800.

5.3.6 Perched Groundwater Levels

5.3.6.1 West Zone

Perched groundwater is unlikely to be present in this zone between CH428 and CH1800 because the groundwater level in the Upper Aquifer is already close to the ground surface in many places and the unsaturated soil mainly consists of Bassendean Sand. However, although not encountered during this investigation, the presence of localised coffee rock that may cause locally perched groundwater conditions cannot be ruled out.

Between CH1800 and CH2330 (west of Swan River) and between CH2700 and CH3200 (east of Swan River) the groundwater table is located in the Perth Formation, with overlying unsaturated Bassendean Sand. It is possible that perched groundwater conditions could form during the wet season above the contact of the Bassendean Sand with the underlying clay dominated Perth Formation (PFc).

5.3.6.2 East Zone

Groundwater levels near the proposed Forrestfield Dive structure and station indicate the presence of perched groundwater conditions in the Superficial Aquifer (Guildford Formation). Insufficient groundwater level data is currently available to identify whether these perched conditions are seasonal or persistent throughout the year. A summary of groundwater levels from March 2015, which indicated perched conditions, is provided below:

- MW 3-044 (s) (RL 23.2 m AHD) and MW 3-044 (d) (22.9 m AHD) located together adjacent to the dive structure – head difference of approximately 0.3 m.
- MW 3-060 (s) (RL 23.9 m AHD) and MW 3-060 (d) (RL 22.4 m AHD) located together adjacent to Abernethy Road at CH8100 – head difference of approximately 1.5 m.
- MW3-019 (RL 26.2 m AHD) located approximately 125 m east of MW3-026 (RL 22.8 m AHD) and MW3-012 (22.9 m AHD) – head difference of approximately 3.3 m.
- MW3-004 (RL 24.3 m AHD) and MW3-009 (RL 24.5 m AHD) located in between MW3-001 (RL 23.3 m AHD) and MW1-05 (RL 23.4 m AHD) – head difference of between approximately 1.0 m and 1.2 m.

Given that the level of perching is locally highly variable, it is likely that these perched conditions are caused by localised and discontinuous bands/layers of low permeability clay or coffee rock within the Guildford Formation soils.

5.4 Groundwater Recharge

Rainfall and stormwater runoff, via soakage basins and stormwater drains, are considered to be the major contributors to groundwater recharge for all water bearing hydrogeological units of relevance to the proposed alignment. This relationship is somewhat indirect for the Ascot Formation and Mirrabooka Member as these units receive recharge via downward leakage from the overlying Bassendean Sand and Guildford Formation where direct rainfall recharge occurs.

5.5 Groundwater Discharge

5.5.1 Surface Water

The Swan River crosses the alignment at around chainage CH2700 and ultimately acts as the main surficial discharge point for the majority of groundwater of relevance to the construction of the project. Discharge to the river is evident by the observed upward gradient in monitoring wells at the Swan River as well as the observed hydraulic gradient towards the river (Figure 4).

The following summarises other surface water bodies in the vicinity of the alignment:

- Gobba Lake is located on the western side of the Swan River approximately 130 m south-west of the alignment at about chainage CH1750. This lake has existed as a swamp/wetland since before development in the area (Golder, 2015b) and exists due to a local topographic low point (< RL 4 m AHD). This surface water body is understood to be continually inundated and therefore is expected to act as a groundwater discharge point with evaporative losses occurring predominantly during the summer months and potentially recharging the aquifer locally during the winter months.
- Munday Swamp is located approximately 150 m north of the alignment at approximate chainage CH7550. The area comprises a local topographic low point (< RL18 m AHD) explaining the presence of Munday Swamp and the seasonally flooded terrain north of the Manheim vehicle auction yard and the RAC Driving Track. This area is expected to act as a discharge point for groundwater, particularly through evaporation directly from the lake surface during summer months and where the groundwater level is high enough to reach the surface and cause inundation in the surrounding damp lands. The likely presence of low permeability soils below Munday Swamp is likely to limit any recharge to the aquifer from the swamp.
- Poison Gully Creek crosses the proposed alignment at CH8550 and was realigned in the late 1960's or early 1970's during construction of the Forrestfield Rail Yard. This creek is ephemeral and discharges into a constructed drain (part of the Perth Airport drain system) after crossing beneath Dundas Road.

5.5.2 Drains

Groundwater levels across the proposed alignment are affected by the drainage network constructed for various residential and commercial developments. The two main drains along the alignment include the Bayswater Main Drain and Airport Main Drain/Belmont Main Drain, both of which empty into the Swan River. However, there is a wide network of surface and subsurface drains present that feed into both of these drains which help control groundwater levels, particularly in former wetland areas present beneath the airport estate and over the eastern zone of the proposed alignment:

- The alignment crosses the Bayswater Main Drain at approximately CH1000. Review of historical aerial photography (Golder, 2015c) shows this drain was once a small creek and a topographical low for the area that drained wetlands located to the north, west and east. Although the drain still completes this function many of the creeks and wetlands have been infilled or piped underground to facilitate development.
- The Belmont Main Drain runs parallel (approximate offset of 25 m) from about CH3375 to CH4000
- The Perth Airport drain system crosses the alignment at about CH4700, CH5860, CH6080, CH7280, CH8030 and CH8400.

5.5.3 Local Groundwater Users

Groundwater is abstracted along the alignment from all aquifers identified in this report, which is likely to be mainly for reticulation (household and business) and industrial supply. The effect of pumped abstraction on groundwater can be seen in VWP data (Golder, 2015i) as summarised below:

- The majority of the VWPs show daily to twice daily groundwater level drawdown of up to 0.5 m along most of the alignment except in the Forrestfield area (up to CH8100 only). These drawdowns only last for a few hours, suggesting that these responses are due to reticulation bores being turned on.
- The greatest drawdown from pumping is observed between CH5000 and CH6000 at Perth Airport (BH0-01, BH0-05, BH0-09 and BH0-10) where drawdown ranges between 0.5 m and 1.5 m with greatest drawdown occurring in the Ascot Formation. The drawdown pattern is more irregular and can last for up to 2 weeks followed by no pumping for weeks or months. The drawdown pattern is more regular (weekly) during the dry season and less frequent during the wet season.
- None of the monitoring locations in the Upper Aquifer at Bayswater have to date shown an effect from pumping.

The observed effect from local groundwater abstraction (other than the pumping tests carried out as part of this investigation) in the vicinity of the four main structures is as follows:

- Bayswater Dive – VWP data (BH0-02, BH2-22 and BH2-19) indicates daily groundwater level drawdown responses between 0.1 m and 0.5 m in the Lower Aquifer with a maximum response of up to 1 m in BH2-22 at the end of December 2014.
- Airport West Station – VWP data (BH0-04, BH2-05 and BH2-11) indicates daily and in some cases twice-daily drawdown response of up to approximately 0.3 m in the Guildford, Ascot and Osborne Formations.
- Consolidated Airport Terminal Station – VWP data (BH0-06, BH1-22 and BH1-24) indicates daily drawdown responses of around 0.1 m in the Guildford Formation, 0.25 m in the Ascot Formation and less than 0.05 m in the Osborne Formation.
- Forrestfield Dive – VWP data (BH0-07, BH1-04 and BH1-02) show negligible effect in response to nearby abstraction of groundwater.

Given that groundwater level monitoring along the alignment is showing temporary (daily) effects of groundwater level drawdown from reticulation wells, any groundwater abstraction for the project (e.g. construction dewatering) would also affect nearby existing wells. It is not uncommon in Perth that reticulation bores used for individual household reticulation consist of large diameter shallow liners, which would only have up to a few metres of water column in the bores during summer. Therefore there is a potential risk that some of these reticulation bores could become dry during construction dewatering, if drawdown is not carefully managed.

5.6 Groundwater Flow

The groundwater levels measured in March 2015 are consistent with the groundwater flow direction shown in the Perth Groundwater Atlas (WRC, 1997) which indicates two main regional groundwater flow components relevant to the project.

To the north of the Swan River, the regional groundwater flow direction is south to south-east, discharging into the Swan River. Groundwater flowing through this part of the alignment originates from the southern part of the Gnangara Mound which is the dominant regional groundwater head (Davidson, 1995).

South of the Swan River, the regional groundwater flow direction is north-west, discharging into the Swan River. Groundwater flowing through this part of the alignment originates from the Darling Scarp area to the east and from recharge along the alignment (Davidson, 1995).

An assessment of groundwater flow velocities across the site was not carried out within the scope of this study. We note that for ground improvement processes such as ground freezing, the groundwater flow velocity in the treatment area is an important factor. Further evaluation of groundwater flow velocity may be required in areas where ground improvement is required, depending on the level of risk at each location.

5.7 Hydraulic Properties

The following methods and tests were used and undertaken to assess the hydraulic properties of the different hydrogeological units and aquifers:

- Analysis of particle size distribution (PSD) data from 207 samples (refer to Appendix C for results) to derive hydraulic conductivity through empirical relationships.
- Single well hydraulic (slug) testing in 31 monitoring wells along the alignment (refer to Appendix D for method description and test results).
- Test pumping in four pumping test wells, one at each of the dive structures and stations (refer to Appendix E for description of tests and results).

In addition, a desktop study was undertaken to summarise hydraulic properties from previous available investigations, (Parsons Brinckerhoff, 2013), (HydroSolutions, 2004).

It is important to note that the different tests reflect different scales of the aquifer being tested. The PSD is only carried out on small and discrete soil samples and therefore the results do not represent the entire aquifer, but only the tested sample. Similarly, a slug test only affects the immediate area around the well and does not necessarily represent the wider extent of the aquifer. The results from PSD samples and slug testing should therefore be used with caution and can generally only be used to provide an indication of the order of magnitude of the hydraulic conductivity and provide a better understanding of the potential variability within the soils and the overall homogeneity of the aquifer.

The results from properly conducted pumping tests are the most important tool in hydrogeological investigations and far superior to other methods of assessing hydraulic properties and aquifer performance as the results are representative of a much larger extent of the aquifer that will require dewatering. Therefore more weight is put on the pumping test results than results from the slug testing or by derivation from the PSD data.

5.7.1 Transmissivity

The analysis of pumping test data provides an estimate of the transmissivity of the aquifer being tested, which is equal to the average hydraulic conductivity times the saturated thickness of the aquifer.

Hydrosolutions carried out a hydrogeological investigation at Perth Airport in 2004 (HydroSolutions, 2004), which included undertaking five pumping tests, of which four were completed in the Guildford Formation and one in the Mirrabooka Aquifer. The reported results indicated transmissivity ranging from 30 m^2/d to 300 m^2/d in the Guildford Formation and 80 m^2/d in the Mirrabooka Aquifer.

Mackie Martin & Associates carried out two pumping tests in the Upper Aquifer in August 1990 at the CSBP site located 200 m northeast of the Bayswater Dive Structure. The reported results indicated a transmissivity of 100 m^2/d in the Upper Aquifer. With a reported saturated thickness of 4 m (Bassendean Sand), this would correspond to a hydraulic conductivity of 25 m/d.

Table 3 presents the results from the four pumping tests carried for the Stage 2 Geotechnical Investigation, which are based on different analytical solutions, distance drawdown curves and replication of each pumping test in a numerical groundwater model (see Appendix E). The results from the groundwater modelling analysis of the pumping test data is considered to be more representative than other approaches as it includes the effects from all the different hydrogeological units and boundary conditions and has therefore been given more weight compared to analytical solutions. The distance drawdown curves were generally found to give similar results as to the numerical modelling of the pumping test.

Table 3: Transmissivity Values from the Pumping Test Analysis

Location	Aquifer	Range (m^2/d) **	Chosen Value (m^2/d)
Bayswater Dive Structure *	Lower	20–300	113
Airport West Station	Superficial	40–140	76
Consolidated Airport Terminal Station	Superficial and Mirrabooka	130–700	274
Forrestfield Dive Structure	Superficial (GF)	100–320	180

Notes: *No pumping test was carried out in the Upper Aquifer during the Stage 2 Geotechnical Investigation

** The values have been rounded to nearest 10.

5.7.2 Hydraulic Conductivity

Table 4a and Table 4b present a summary of the interpreted and adopted values of the horizontal hydraulic conductivity (in m/d and m/s, respectively) for each of the hydrogeological units and presents the range and median from the different methods used to estimate the hydraulic conductivity. The Tunnel Proximity Study (Golder, 2014c) values were collated based on a review of both published and unpublished reports. The last two columns provide range of values adopted for this study for each of the geological units.

Given the sedimentary nature of the geological units, which have been deposited in fluvial environments, it would be expected that the ratio between the vertical and horizontal hydraulic conductivity (k_v/k_h) would be less than 1 (i.e. the vertical hydraulic conductivity is smaller than the horizontal hydraulic conductivity). The general literature suggests that k_v could be several orders of magnitude smaller than k_h and it is not uncommon to assume a k_v/k_h ratio of 0.1.

The ratio between the vertical and horizontal hydraulic conductivity (k_v/k_h) was assessed during the groundwater modelling of the pumping tests and was found to generally range between 0.1 and 1. The analysis at Bayswater Dive Structure, Airport West Station and Consolidated Airport Terminal Station indicated that the ratio in the units could be around 0.1 while at Forrestfield the results did not provide a definitive conclusion regarding the ratio (use of 0.1 to 1 gave almost similar results – best fit was 0.25). Based on the composition, heterogeneity and distinct layering observed in the materials encountered in the boreholes (e.g. in OF) we would expect that the k_v/k_h ratio is smallest in the PF, GS, GF and OF. The greatest ratio is likely to be observed in the BS, but also the sandy GF encountered in the Forrestfield Area could have a higher ratio as indicated by the pumping test analysis. There was no distinct layering observed in the AF and this unit has a low percentage of fines in most areas, which would suggest that the ratio in AF could approximately be somewhere in between the ratio for PF and BS.

Based on the above, Golder judge that it is reasonable to use a k_v/k_h ratio of 0.1. However, since the installation of D-walls would result in mainly vertical flow upwards into the excavations once dewatering begins, the vertical hydraulic conductivity of the hydrogeological units would significantly influence the dewatering rates and drawdown. A sensitivity analysis was therefore carried out on the k_v/k_h ratio to assess the effect it could have on dewatering rates and drawdown (refer to Section 6.0).

5.7.3 Storage Coefficient

The estimated storage coefficients from the analytical solutions for the four pumping tests were found to range between 1×10^{-5} and 5×10^{-2} suggesting confined to semi confined conditions. The highest storage coefficient was estimated for the pumping test at the Consolidated Airport Terminal Station while the lowest was estimated for the confined Lower Aquifer at Bayswater Dive Structure.

The storage coefficients were also estimated through the numerical modelling of the pumping tests and the results indicated that the best matched shape between the modelled drawdown and observed drawdown for the tests was obtained by using confined conditions with storage coefficients of 1.5×10^{-5} (Bayswater Dive Structure) and 2.5×10^{-3} (Forrestfield Dive Structure).

Table 4a: Summary of Horizontal Hydraulic Conductivities by Hydrogeological Unit (m/d)

Geological Unit – Stage 1 (2014)	Geological Unit – Stage 2 (this study)		Tunnel Proximity Study		Stage 2							
			Range	Suggested Value	Particle Size Distribution^		Slug Testing		Test Pumping		Adopted Values	
					Range	Median	Range	Median	Range	Median	Range	Value
			m/d									
Swan River Alluvium & Alluvial Sand	Swan River Formation		0.1-10	1	3-9	6	0.2	0.2	-	-	0.001-1.0	0.001
Bassendean Sand	Bassendean Sand		10-40	15	1-25	9	***	***	-	-	10-40	15
Guildford Formation	Perth Formation	Sand	0.1-70	12	1-23	5	0.5-28	11	1-7.5	4	1-30	7.5
		Clay			-	-	**	**	-	-	0.0001-0.1	0.0001**
	Guildford Formation				1-36	2	0.2-8	2.5	6-11	8	1-10	7
	Gnangara Sand		-	-	0.4-8	2	-	-			0.5-5	1
Ascot Formation	Ascot Formation		5-100	10	3-20	4	3-50	7.5	5-30#	11	5-50	8-14##
Osborne Formation	Osborne Formation	Kardinya Shale	0.01-1	0.01	-	-	0.0002 to 0.0006	0.0005	0.0005*	-	0.0002 to 0.001	0.0005
		Mirrabooka Member			0.3-20	9	3-6	4.5	1-3*	2	1-10	1-3^^

Notes: * Values have been estimated through numerical analysis in the groundwater model.

** No monitoring wells are installed in the Perth Formation Clay (Bayswater Aquitard) - Value is based on the unit acting as an aquitard.

*** No monitoring wells are screened entirely in Bassendean Sand.

Lower part of range is from the Airport West pumping test while the upper range is from the Consolidated Airport Terminal Station pumping test.

Lower part of range is for the Airport West area while the upper range is from the Consolidated Airport Terminal Station area.

^ Estimations exclude PSD samples that have fines content greater than 20% and the values therefore represent the more permeable samples.

^^ The higher range is for the top of the Mirrabooka Aquifer with hydraulic conductivity reducing with depth.

Parameters are intended to be used for groundwater seepage analysis. Consolidation analysis may require refined values for Swan River Formation and Perth Formation (clay), refer to the GIR (Golder, 2015c).

Table 4b: Summary of Horizontal Hydraulic Conductivities by Hydrogeological Unit ($x10^{-5}$ m/s)

Geological Unit – Stage 1 (2014)	Geological Unit – Stage 2 (this study)		Tunnel Proximity Study		Stage 2							
			Range	Suggested Value	Particle Size Distribution^		Slug Testing		Test Pumping		Adopted Values	
					Range	Median	Range	Median	Range	Median	Range	Value
			$x10^{-5}$ m/s									
Swan River Alluvium & Alluvial Sand	Swan River Formation		0.12-12	1.2	3.5-10.4	6.9	0.23	0.23	-	-	0.0012-1.2	0.0012
Bassendean Sand	Bassendean Sand		11.6-46.3	17.4	1.2-28.9	10.4	***	***	-	-	11.6-46.3	17.4
Guildford Formation	Perth Formation	Sand	0.12-81	13.9	1.2-26.6	5.8	0.58-32.4	12.7	1.2-8.7	4.6	1.2-34.7	8.7
		Clay			-	-	**	**	-	-	0.00012-0.12	0.00012 **
	Guildford Formation				1.2-41.7	2.3	0.23-9.3	2.9	6.9-12.7	9.3	1.2-11.6	7
	Gnangara Sand		-	-	0.5-9.3	2.3	-	-			0.6-5.8	1
Ascot Formation	Ascot Formation		5.8-115.7	11.6	3.5-23.1	4.6	3.5-57.9	8.7	5.8-34.7#	12.7	5.8-57.9	9.3-16.2##
Osborne Formation	Osborne Formation	Kardinya Shale	0.012-1.2	0.012	-	-	0.0002 - 0.0007	0.0006	0.0006*	-	0.0002 to 0.0012	0.0006
		Mirrabooka Member			0.3-23.1	10.4	3.5-6.9	5.2	1.2-3.5*	2.3	1-10	1.2-3.5^^

Notes: * Values have been estimated through numerical analysis in the groundwater model.

** No monitoring wells are installed in the Perth Formation Clay (Bayswater Aquitard) - Value is based on the unit acting as an aquitard.

*** No monitoring wells are screened entirely in Bassendean Sand.

Lower part of range is from the Airport West pumping test while the upper range is from the Consolidated Airport Terminal Station pumping test.

Lower part of range is for the Airport West area while the upper range is from the Consolidated Airport Terminal Station area.

^ Estimations exclude PSD samples that have fines content greater than 20% and the values therefore represent the more permeable samples.

^^ The higher range is for the top of the Mirrabooka Aquifer with hydraulic conductivity reducing with depth.

Parameters are intended to be used for groundwater seepage analysis. Consolidation analysis may require refined values for Swan River Formation and Perth Formation (clay), refer to the GIR (Golder, 2015c).

5.8 Groundwater Quality

This section only provides a general overview and high level discussion on groundwater quality to assist with the hydrogeological conceptualisation and general discussion on dewatering discharge disposal options. The overview relates to groundwater samples taken at the beginning and end of the pumping tests (Appendix E) as well groundwater quality results from the Environmental Site Investigation (Golder, 2015h). Given that the results from the pumping tests represent a more average value of the aquifer tested, more emphasis has been put on the pumping test results in this report. For specific and detailed groundwater quality information along the alignment, the Environmental Site Investigation (Golder, 2015h) should be referred to.

The following summarises the general groundwater quality data along the alignment:

- pH generally ranged between 5.5 and 8.1 indicating between slightly acidic and alkaline conditions. For the pumping tests the higher pH (alkaline) was observed at the AWS and CATS, which is not surprising given that the pumping wells were pumping for the carbonate rich Ascot Formation. The lowest pH (acidic) was observed in Forrestfield where the field average pH was 5.7 while the average pH in the Lower Aquifer during the pumping test was 7.1.
- Groundwater range between fresh and brackish with highest salinity observed in the Swan River Formation in the vicinity of the Swan River. The Total Dissolved Solids (TDS) values ranged between approximately 250 mg/L (Lower Aquifer at BDS) and 750 mg/L (AWS) during the pumping tests, indicating fresh water. The salinity was generally found to remain stable during the pumping tests.
- Some metal concentrations were generally identified above detection limits at all locations. Total iron, which is one of the key parameters to dewatering discharge disposal and effectiveness of recharge wells, was found to range between 0.1 mg/L and 22 mg/L. The highest iron concentration was measured in the Lower Aquifer at the end of the Bayswater pumping test and the concentrations was found to increase by almost an order of magnitude between the start and end of the pumping test. The total iron concentration during the three other pumping tests ranged between 0.03 mg/L (Forrestfield) and 2.8 mg/L (AWS) with similar concentrations at the beginning and end of the tests.
- Nutrient (as total nitrogen), another key parameter for dewatering discharge disposal options, was found to range between 0.1 mg/L and 66 mg/L, with the highest concentrations observed in the Guildford Formation at Emergency Egress Shaft Abernethy Road. Similarly, the highest nutrient concentrations during the pumping tests were observed in Forrestfield (33 mg/L to 44 mg/L), while at the remaining pumping test locations total nitrogen ranged between 0.1 mg/L (CATS) and 0.78 mg/L (AWS).
- Total alkalinity, which indicates the buffering capacity of the water, ranged between 20 mg/L and 390 mg/L, lowest in Forrestfield and highest at AWS. The higher alkalinity concentrations were not surprisingly found in areas where Ascot Formation is present, while the lower total alkalinity was found in the Guildford Formation. The results indicate that the water in the Guildford Formation could have insufficient buffering capacity to maintain a stable pH (DEC, 2011).
- The following Contaminants of Potential Concern (CoPC) were encountered during the environmental groundwater quality sampling (Golder, 2015h):
  - Hydrocarbons (at 26 sample locations), chloroform (at 3 sample locations) and cyanide (Bayswater only) were found to be above detection levels in some groundwater samples.
  - PFOS (a fire fighting chemical) was found in the groundwater (at 5 sample locations) between AWS and Emergency Egress Shaft Domestic Airport Terminal.

The above CoPC (chloroform was not analysed) were not detected in any of the samples collected during the pumping tests except for Cyanide, which was above the detection limit in the sample taken at the beginning of the pumping test, but was subsequent below the detection limit in the sample taken at the end of the pumping test.

The groundwater quality will have an effect on the dewatering discharge treatment requirements and disposal options as discussed in Section 6.6.

The contamination monitoring undertaken as part of the CBSP investigation indicate that the groundwater quality in the Upper and Lower Aquifers at Bayswater are different, with nutrient and metal concentrations in the Upper Aquifer being up to an order of magnitude higher than in the Lower Aquifer (Australian Environmental Auditors, 2013). This large difference in groundwater quality between the aquifers suggests that the Upper Aquifer and Lower Aquifer are disconnected, which is supported by the high head difference in groundwater level (Section 5.3.5).

6.0 DEWATERING

This section discusses the construction dewatering requirements for the four main structures; Bayswater Dive Structure, Airport West Station, Consolidated Airport Terminal Station and Forrestfield Dive Structure and outlines preliminary dewatering rate estimates, dewatering methodologies and groundwater disposal options and constraints. The section is based on PTA's Reference design Rev F, a document titled Reference Design Summary Table RevB provided by PTA and assumed construction methodologies and cut-off wall elevations as outlined in this section.

6.1 Dewatering Requirements

Table 5 presents the construction details and dewatering requirements for the structures considered in this study based on the Rev F alignment and plan and profile drawings.

Table 5: Construction Details and Dewatering Requirements

Structure	Approximate Excavation Dimensions (m)			Required GWL Drawdown** (m)	Dewatering Period (weeks) ***	Geological Unit in which D-wall Terminates
	Length	Width	Depth*			
Bayswater Dive West of BMD	270	10	0.0–7.8	0.0–4.0	16	BS and PF
Bayswater Dive East of BMD	230	11–20	7.8–12	2.9–7.1 [#]		BS and PF
Bayswater Retrieval Box	20	20	12	7.1 [#]		PF
Airport West Station	156	27	12	12.1	52	OF (OFs)
Consolidated Terminal Station	160	28–46	17	16.2	52	OF (OFm)
Forrestfield Retrieval Box	20	20	10	5.5	16	GF
Forrestfield Dive Structure	300	10–24	0-10	0.0–5.5		

Notes: * Depth is below current ground surface, GWL = Groundwater Level, BMD = Bayswater Main Drain

** Estimated drawdown from groundwater level to 1 m below the base of excavation based on an estimated average seasonal groundwater level.

*** Total period during which dewatering is required.

[#] Required drawdown in the Lower Aquifer

The Reference Design Revision F indicates that D-walls are planned to form the four main structures. This approach significantly reduces the dewatering requirements because horizontal groundwater inflow to the excavation (except for any leakage through the D-wall) is essentially cut off. Accordingly, the groundwater inflow into the excavation becomes predominantly vertical where groundwater flows under the D-walls and up into the floor of the excavation.

The dewatering requirements and effect of dewatering (rates and extent of groundwater level drawdown) is dependent upon the wall depth and the geological unit in which the D-wall terminates. The analysis reported here is based on PTA's Reference Design Summary Table RevB (which is based on the Rev F Reference design):

- The D-walls on all sides will terminate 3 m into the Osborne Formation at the Airport West Station and Consolidated Airport Terminal Station (including the concourse level box).
- At the Bayswater and Forrestfield Dive Structures the D-Walls will extend to a depth that is between about 1.9 and 2.3 times the depth of excavation, respectively.

Bayswater Dive Structure

At Bayswater Dive Structure dewatering will be required from both the Upper Aquifer and Lower Aquifer as follows:

- West of the Bayswater Main Drain excavation and dewatering will only be required from the Upper Aquifer.
- East of the Bayswater Main Drain dewatering will only be required from the Lower Aquifer, because the D-walls will extend into the PFc and Lower Aquifer and thereby cut-off any horizontal groundwater inflow into the Upper Aquifer (apart from any leakage) and any flow down the open decline between the walls.
- At the deepest part of the dive and tunnel portal the D-walls will extend into the Osborne Formation, which will significantly reduce the groundwater inflow from the Lower Aquifer into the excavation. Nevertheless, the greatest dewatering is expected to be required from the Lower Aquifer at the Bayswater Retrieval Box where the piezometric level would need to be lowered by up to 7.1 m.

Airport West Station

The D-Walls will extend into the Kardinya Shale (KS) of the Osborne Formation and thereby cut off direct groundwater inflow from the Superficial Aquifer. Given the low hydraulic conductivity (0.0005 m/d) of the KS, dewatering would be required to initially remove stored water within the soils inside the excavation and thereafter remove any upward seepage through the Kardinya Shale and leakage through the D-walls. The dewatering requirements for the Airport West Station should therefore be relatively low.

Consolidated Airport Terminal Station

The same concept as for Airport West Station applies to the Consolidated Airport Terminal Station where the Superficial Aquifer is cut-off and seepage into the excavation can only occur through upward seepage from the Osborne Formation and leakage through the D-walls. However, given that the Osborne Formation below the Consolidated Airport Terminal Station consists of the Mirrabooka Member which has a hydraulic conductivity that is 4 orders of magnitude higher than the Kardinya Shale, the groundwater inflow into the excavation will be significantly higher at this station.

Forrestfield Dive Structure

The aquifer at the Forrestfield Dive Structure is comprised of the Guildford Formation within which the D-walls will terminate. Groundwater inflow into the excavation will occur from the open end of the dive unless slurry wall cut-offs are deployed and vertically upward from below the excavation between the D-walls. The most dewatering for this structure will be required at the Forrestfield Launch Box where the groundwater would need to be lowered by up to 5.5 m.

Other Structures

Construction dewatering will be required for other structures such as the emergency egress shafts. These structures have not been assessed within the scope of this current study, but will need to be addressed in the detailed design.

6.2 Dewatering Methodology

The dewatering methodology for this project will depend on the specific site and dewatering requirements, but is likely to consist of a combination of:

- **Dewatering Wells** – drilled wells with screens and associated gravel packing placed around the internal perimeter of the excavation between the D-walls.
- **Sump Pumping** – strategically placed dewatering sumps or trenches (drains) within the excavation where groundwater is removed using sump pumps.
- **Dewatering Spears (Well Points)** – shallow spears could be used to lower the groundwater level locally or where the saturated thickness of the aquifer is limited.

The use of dewatering wells and sump pumping is considered the preferred option for all four structures. However, the use of dewatering spears could be advantageous for dewatering of the Upper Aquifer at the Bayswater Dive Structure where the saturated aquifer is of limited thickness and dewatering wells will be less effective. However, dewatering wells will still be required to dewater the Lower Aquifer.

The dewatering wells must be placed inside the excavations to minimise the dewatering rates and drawdown in the aquifers. The number and spacing of the dewatering wells have not been evaluated as part of this work; this will need to be done as part of a detailed dewatering design once the methodology and sequence for the overall construction of each structure is known.

Sump pumping from inside the D-wall supported excavations is likely to be required to remove residual shallow groundwater not drained by the dewatering wells or to control surface water from rainfall events. Some local shallow dewatering may be required in the Forrestfield car park area for site preparation and/or installation of services, etc. Due to the expected limited groundwater level drawdown requirements, the dewatering methodology for this area would likely consist of a combination of sump pumps and dewatering spears.

6.3 Groundwater Modelling

6.3.1 Groundwater Modelling

The 3D groundwater modelling software Visual MODFLOW 2011.1 Premium (numerical finite difference groundwater flow modelling software used extensively throughout the world) was used to simulate existing groundwater conditions along the alignment and evaluate preliminary dewatering rates and the effect the construction dewatering could have on the groundwater level and piezometric levels. Appendix F provides details on the construction and assumptions used in the 3D numerical groundwater model.

6.3.2 Model Scenario Runs

Table 6 presents a summary of the scenarios modelled.

Table 6: Model Scenarios.

Structure	Recharge of Dewatering Discharge	Scenario	Comment
Bayswater Dive Structure	No*	1A	k_v/k_h ratio of 0.1 in Upper and Lower Aquifer
		1B	k_v/k_h ratio of 1 in the Upper and Lower Aquifer
Airport West Station	No	2A	D-walls extend into Osborne Aquitard resulting in limited dewatering (i.e. recharge wells not likely to be required or preferred disposal option)
Consolidated Airport Terminal Station	Yes	3A	k_v/k_h ratio of 0.1 in all layers
		3B	k_v/k_h ratio of 1 in Mirrabooka Aquifer
Forrestfield Dive Structure	Yes	4A	k_v/k_h ratio of 0.1 in all layers
		4B	k_v/k_h ratio to 1 in in all layers

* Estimated average dewatering rates are low and there is minimal drawdown effect in the Upper Aquifer, suggesting that recharge wells may not be required.

Given that installation of D-walls would result in mainly vertical flow upwards into the excavations once dewatering begins, the vertical hydraulic conductivity of the hydrogeological units in which the D-walls terminate will have a significant influence on the dewatering rates and extent of groundwater level drawdown outside the excavation. Sensitivity runs (scenarios with the suffix "B") were therefore carried out where the k_v/k_h ratio has been increased 10 times (i.e. vertical hydraulic conductivity is the same as horizontal hydraulic conductivity) in the hydrogeological units into which the D-walls are installed. At Airport West Station the hydraulic conductivity of the KS is so low that a change k_v/k_h ratio or a change of one order of magnitude in hydraulic conductivity would not noticeably change the dewatering rates or the groundwater level drawdown. A sensitivity run was therefore not performed for Airport West Station.

A preliminary dewatering assessment carried out by Golder in 2014 (Golder 2014) indicated that on-site recharge of the abstracted groundwater would be required to minimise and manage the groundwater level caused by the groundwater abstraction. Recharge wells were therefore installed around the excavations in the models to conceptually show the effect of the wells. However, the actual number and location of the recharge wells and distance from the excavation area will need to be assessed during the detailed design phase. The recharge wells in the models were generally screened across the whole Superficial Aquifer to a similar depth as the D-walls (wells were not modelled deeper than the D-walls as this could further promote groundwater flow back into the aquifer, resulting in increased dewatering rates).

Based on recent experience from projects where recharge wells have been used in the Perth Formation for dewatering disposal, the following assumptions were included in the model:

- The long-term recharge rate of a recharge well would not exceed 1 L/s
- Approximately 85% of the abstracted groundwater can be introduced back into the aquifer, which is considered a more realistic scenario than assuming a perfect system with 100% recharge of the abstracted water. With 85% recharge the model takes into account maintenance of recharge wells, short-term temporary shutdown, etc. However, the amount of abstracted water that is returned back into the aquifer could have an effect on the extent of the groundwater level drawdown around each excavation and it is therefore recommended that the dewatering system design and the aim during operation should be to achieve as high a recharge percentage as possible.

At Airport West Station the removal of storage inside the excavation (main dewatering requirement) would not result in a lowering of the groundwater level outside of the excavation and recharging this water back into the aquifer would therefore not be required. Given the expected low seepage rates at Airport West Station after the initial pumping of stored water, recharge wells are not likely to be the most efficient or preferred disposal option and therefore the abstracted groundwater was not recharged back into the aquifer in the Airport West Station scenario run (Scenario 2A).

At Bayswater Dive Structure the D-walls will cut-off groundwater inflow into the Upper Aquifer except for limited inflow down the open decline between the walls. The D-walls will extend into the Osborne Formation at the tunnel portal where the deepest excavation is required and therefore dewatering from the Lower Aquifer will be limited. Given that the groundwater model results indicate that the average dewatering rates will be less than 3 L/s, the abstracted groundwater was not recharged back into the aquifer in the Bayswater Dive Structure scenario runs.

6.4 Dewatering Rates

Table 7 presents the estimated dewatering rates and volume for the four main structures for the different scenarios and indicates:

- The dewatering rate at Airport West Station will be limited if the D-walls extend into the Kardinya Shale (Osborne Formation). The model run indicated that of the estimated 3 L/s, less than 1 L/s was attributed to seepage through the Kardinya Shale while the rest was due to estimated leakage through the D-walls.
- The modelled low dewatering rate for the Bayswater Dive Structure is expected, given that the pumping test (at 12 L/s) was able to lower the piezometric pressure in the Lower Aquifer by up to 9 m in the vicinity of the well (only 7 m is required during construction) and by up to 1.5 m at a distance of 500 m from the well. Given that D-walls will be used to significantly limit groundwater inflow into the excavation, the construction dewatering rates would be expected to be significantly lower than during the pumping test.
- The modelled dewatering rates at the Consolidated Airport Terminal Station are based on the D-walls on all sides terminating 3 m into the Osborne Formation, including the concourse level box. Should the D-walls surrounding the concourse level box terminate in the Ascot Formation, the dewatering rates would increase.
- The vertical hydraulic conductivity has a significant effect on the dewatering rates with an increase of the average dewatering rate of 1.5 times to 2.6 times for the Consolidated Airport Terminal Station and Forrestfield Dive Structure, respectively when k_v was increased.

Table 7: Modelled Dewatering Rates and Volume

Location	Scenarios	Dewatering Rate (L/s)		Dewatering Volume (kL)
		Initial*	Average	
Bayswater Dive Structure	1A	8	3	39,000
	1B (sensitivity analysis)	8	4	42,000
Airport West Station	2A	9	3	91,000
Consolidated Airport Terminal Station	3A	40	30	948,000
	3B (sensitivity analysis)	54	44	1,399,000
Forrestfield Dive Structure	4A	18	14	138,000
	4B (sensitivity analysis)	46	35	354,000

Notes: *Initial rate for the first 2 weeks to lower the groundwater level to required dewatering level

The depth and distance of the recharge wells would also have an effect on the dewatering rates due to the “recycling” effect of water back into the excavation from the recharge wells. The closer and deeper the recharge wells are to the excavation and bottom of the D-wall the greater the “recycling” effect and thereby dewatering rates would be greater.

6.5 Effects of Dewatering

The abstraction of groundwater during the construction dewatering will result in a lowering of the groundwater table and the piezometric pressure in the hydrogeological units. The effect will depend on the groundwater management practices and methods adopted during the dewatering operation and on the chosen disposal option.

Figures 6 to 11 show a plan and cross-sectional view of each main structure with the modelled groundwater drawdown contours at the end of the dewatering period for the different scenarios while Table 8 presents the distance to the contours of groundwater table drawdown and change in piezometric level.

Table 8: Modelled Extent of Groundwater Level Drawdown (m)

Scenarios	Groundwater Table			Piezometric Level			
	0.1 m	0.5 m	1.0 m	0.1 m	0.5 m	1 m	Geological Unit
1A *	70	-	-	2,000	380	60	PFs
1B *							
2A *	300	40	-	300	50	-	AF/OFs
3A	430	-	-	450	150	100	OFm
3B	590	-	-	590	170	110	AF/OFm
4A	210	-	-	210	60	25	GF
4B	500	170	65	490	170	70	GF/BS

Notes: *No recharge wells.
The reported distances (in metres) are from the external wall face to the groundwater level/piezometric contour

The results in Table 8 and Figures 6 to 11 indicate:

- **Groundwater table:**
  - Groundwater table drawdown of greater than 1 m does not occur in any of the modelled scenarios indicating the recharge wells are capable of reducing the groundwater table drawdown to within the SWTC requirements, except for Scenario 4B in Forrestfield where the groundwater table drawdown of 1 m extends approximately 65 m from the D-walls.
  - The groundwater table drawdown of 0.5 m is predicted in Scenario 2A (AWS) and 4B (Forrestfield Dive Structure) at a distance of 40 m and 170 m, respectively.
  - The difference in drawdown between Scenarios A and B for all structures indicates that the drawdown will extend further if the k_v/k_h ratio is 1 (compared to 0.1).
  - Groundwater mounding of up to 0.2 m is predicted around the recharge wells.
  - At Airport West Station the difference in drawdown shape between north and south (Figure 7B) is due to the presence of the Belmont Main Drain which reduces the extent of the groundwater level drawdown toward the south (i.e. Belmont Drain acts a positive flow boundary at the water table).
- **Piezometric level:**
  - The drawdown in piezometric levels extends further than the drawdown in the groundwater table. The drawdown is expectedly greatest in the hydrogeological unit where the D-walls terminate as this is the unit where the greatest groundwater inflow into the excavation occurs.

- For the Consolidated Airport Terminal Station the modelled drawdown in piezometric levels in the Mirrabooka Aquifer do not propagate to the ground surface (Figures 8B and 9B), which is due to a combination of the effect of the recharge wells and the presence of the more permeable Ascot Formation above the Mirrabooka Aquifer. The effect that Ascot Formation alone has on the shape of the piezometric level contours can be seen for the Airport West Station scenario (Figure 7) where no recharge wells are modelled.
- The difference in drawdown between Scenarios A and B for all structures except Bayswater Dive Structure indicates that the drawdown will extend further if the k_v/k_h ratio is 1 (compared to 0.1). The reason this effect is not noticeable at the Bayswater Dive Structure is that the groundwater inflow into the excavation is mainly horizontal due to the D-walls extending into the Osborne Formation along three sides of the excavation.

The results from the preliminary groundwater modelling indicate that it should be possible to design a dewatering system incorporating recharge wells that would limit the drawdown in the groundwater table outside each excavation to less than 1 m in accordance with SWTC requirements, particularly at the two Airport Stations where the D-walls extend below the Ascot Formation. At Forrestfield, the modelling indicates that greater than 85% of pumped groundwater would need to be recharged to meet the SWTC requirements.

6.5.1 Groundwater Quality

Normally the greatest concerns of the effects that construction dewatering could have on groundwater quality is related to the presence of potential ASS within the groundwater table drawdown cone of depression and mobilisation of contaminated water through the change in groundwater flow direction.

Drawdown of the groundwater table surrounding a site can lead to oxidation of ASS resulting in sulfuric acid being formed which would result in release of metals, nutrients and acidity into the soil and groundwater system (DEC, 2011). This risk can be minimised by reducing the groundwater table drawdown. However, increasing oxygen concentrations through aeration of abstracted groundwater during dewatering could potentially also cause oxidation of ASS when the groundwater is recharged back into the aquifer. This would need to be considered during the design of the dewatering and recharge system.

The results from the preliminary groundwater model indicate that it would be possible to design a dewatering system that would limit changes in groundwater flow direction and thereby limit the risk of mobilisation of contaminated water.

6.5.2 Surface Water

The results from the preliminary groundwater model indicate that it would be possible to design a dewatering system that would not affect the surface water bodies discussed in Section 5.5.1.

The model results indicate that the Belmont Main Drain will act as a positive boundary (i.e. water will flow from the drain into the water table aquifer to keep the groundwater table steady at the drain). Given that this man-made drain was constructed to lower the groundwater table, this flow is currently not considered to be an issue. It is possible that some of the Perth Airport drains could also be affected during the dewatering of the Consolidated Airport Terminal Station.

6.5.3 Means of Reducing Effects

If the piezometric level drawdown would need to be further reduced below the drawdown modelled in the current scenarios, recharge wells could be installed to a greater depth (i.e. below the D-walls), which should reduce the piezometric level drawdown outside of the D-walls. However, this deepening of recharge wells is likely to result in an increase in dewatering rates as the “recycling” effect would become greater.

If groundwater monitoring during the dewatering operation shows a greater than expected effect on the groundwater level and piezometric level, additional recharge wells could be installed between the excavation and the area of concern (e.g. a row of recharge wells could be installed adjacent to the airport control tower, if this was required).

6.6 Dewatering Disposal Options

Dewatering discharge should be disposed of so as to not cause harm to the environment or allow flooding.

The SWTC specifies that the groundwater levels in all aquifers within 500 m of the dewatering activity, unless otherwise specified, must not be elevated/lowered by more than 1 m during the project works when compared to locally recorded seasonal highs/lows in that aquifer. Golder considers that to achieve these criteria the use of onsite recharge wells is likely to be the most feasible dewatering disposal option, where dewatering is required.

Any pumped groundwater that is in excess of that required to be recharged to meet the above SWTC criteria could be disposed of by alternative methods. The following dewatering discharge disposal options (in addition to recharge wells) have been identified:

- Reuse on site
- Infiltration
- Stormwater system
- Sewer.

These options would also serve as contingency disposal options to the recharge well scheme.

6.6.1 Recharge Wells

The advantage of using recharge wells is that the abstracted water will be reintroduced back into the aquifer within the vicinity of where it is abstracted, which will result in a much lower net withdrawal of groundwater and thereby minimise the effect the dewatering will have on changes to the groundwater level and flow direction. Recharge wells can also be placed strategically between the dewatering area and sensitive structures and environments to control the groundwater levels and thereby groundwater flow direction.

The performance of the recharge wells would depend on the geological units they are screened in and the water quality of the discharged water. From experience in the Perth Metropolitan Area it is not uncommon to assume that the long-term recharge rate of a recharge well installed in the PF and GF would not exceed 1 L/s. However, the recharge well capacity would depend on the aquifer transmissivity and it is expected that higher recharge rates may be achievable for wells installed in the AF and the sandy GF in the Forrestfield area.

The dewatering discharge quality, particularly high iron concentrations, could significantly limit the long-term performance of the recharge wells and therefore water treatment and ongoing maintenance (cleaning) of the dewatering discharge system is likely to be required to minimise the risk of iron clogging of screens.

The SWTC specifies specific recharge system requirements.

6.6.2 Reuse on Site

Reuse of abstracted groundwater as a means for disposal will be dependent on the demand of the various contractors on site and the dewatering discharge quality and may include use for dust suppression or water supply to the TBM. The groundwater quality would need to be assessed at each specific site location. Site specific groundwater quality is detailed in the Environmental Site Investigation (Golder, 2015h).

6.6.3 Infiltration

The infiltration capacity of the soils at the dive and station locations is discussed in detail in Section 8.0. The viability of shallow infiltration (as opposed to deeper recharge) as a disposal option depends on the following factors:

- The area available close to the excavation where an infiltration basin can be constructed. The greater the area, the higher the achievable infiltration rate.

- The depth to groundwater table. Infiltration capacity reduces significantly where the groundwater table rises to the base of the basin in response to infiltration.
- The permeability of the subsurface profile at the infiltration basin location. The presence of layers of clay or fines can significantly reduce the infiltration capacity.

The shallow depth to groundwater at all four major structure locations is considered a significant restriction on infiltration capacity and therefore on infiltration as a disposal option. Based on infiltration testing (refer to Section 8.0), infiltration may not be a feasible option at Forrestfield and limited infiltration capacity would also be expected at the Bayswater Dive structure, Airport West Station and Consolidated Station.

6.6.4 Stormwater System

Disposal of dewatering discharge into the local stormwater drainage system will ultimately result in the dewatering effluent discharging into either the Bayswater or Belmont Main Drains and ultimately into the Swan River. The groundwater quality results indicates that some treatment of the dewatering discharge would be required prior to disposal to the stormwater system, which could include adjustment of pH and removal of some metals and nutrients to meet the Swan River Trust (SRT) guideline criteria for disposal to the Swan River.

Prior to commencement of dewatering, approval to discharge the abstracted groundwater into the stormwater system would need to be obtained from the local council (various) and asset owners (Water Corporation operates the Belmont and Bayswater Main Drains while PAPL operates the Perth Airport drain system). The asset owner is unlikely to provide access to their system before necessary regulatory approval has been obtained for discharge of water into the end environment (likely to be Department of Environment Regulation (DER) and SRT). This option is likely to require rigorous water treatment and monitoring requirements.

During the pumping tests at Forrestfield, Consolidated Airport Terminal Station and Airport West Station the abstracted groundwater was discharged into the stormwater drains at rates of up to 12 L/s after receiving approvals from Shire of Kalamunda (for Forrestfield), PAPL (Consolidated Airport Terminal Station) and City of Belmont, the Water Corporation and SRT (for Airport West Station). Given the short-term disposal duration approval was obtained without having to the treat the water for metals and nutrients. However, additional water monitoring was undertaken from the Belmont Main Drain during the pumping test at the Airport West Station as requested by the SRT. This data could be utilised for future applications if regulatory approval to discharge into the stormwater system at the Airport West Station will be sought.

It is important to note that the regulators will assess the disposal options based on a site specific risk assessment, which would require site specific water quality data as well as information on the estimated flow rates, duration of dewatering and the time of year that the dewatering is to be carried out.

6.6.5 Sewer

For discharge to sewer the following should be considered:

- Approval would be required from the Water Corporation by lodging a “one-off discharge of industrial waste”.
- Proximity to current sewer locations suitable for discharge will need to be considered and discussed with the Water Corporation.
- Disposal is normally restricted by the sewer capacity, which would need to be discussed with the Water Corporation and would therefore depend on the expected discharge rates and volumes. This could, therefore, be a limitation as dewatering rates may be higher than the available capacity.
- This option is unlikely to require on-site treatment, though it may require pH adjustment (criteria is pH 6 to pH 10) and removal of Total Suspended Solids (TSS) by installing a settling trap (mandatory requirement). To prevent escape of sewer gases to the environment, a water trap would also need to be installed between the settling trap and the sewer connection point.

There is a unit cost (per kL) for disposal to sewer, which would depend on the water quality.

7.0 DESIGN GROUNDWATER LEVELS (50 AND 120 YEAR)

This section presents the estimated maximum design groundwater level along the alignment for 50 and 120 year design periods with particular emphasis on Bayswater Dive Structure, Airport West Station, Consolidated Airport Terminal Station and Forrestfield Station.

At Bayswater where there is a dual aquifer system, the estimated design groundwater level refers to the maximum groundwater level in the Upper Aquifer.

At Forrestfield the presence of low permeability material above the regional groundwater level has been found to cause perched groundwater conditions in some areas, with the perched groundwater levels locally found to be several metres higher than the regional groundwater level following rainfall. These perched conditions may be seasonal or may occur year-round (Section 5.3.6). For Forrestfield both regional and perched design groundwater levels have been discussed.

7.1 Methodology

We have taken a pragmatic approach to the estimation of the design groundwater levels, where the present and historic groundwater levels, hydrogeological features and key parameters that would affect the groundwater level are closely considered.

The installed groundwater monitoring network along the alignment provides a comprehensive record of present-day groundwater levels for developing current groundwater level contours and allowing direct comparison with historical records.

7.1.1 Key Parameters

The identified key parameters that could have an effect on the maximum groundwater levels are:

- Change in Climate
- Geology
- Drains
- Groundwater Abstraction.

Change in Climate

As outlined in Section 4.2, Perth has experienced a drying climate over the last 40 years, which has become even more severe over the last 20 years. The reduction in rainfall is generally known to have resulted in a decline in groundwater levels over large parts of the Perth Metropolitan Area. However, the currently available groundwater level hydrographs for various locations along the alignment do not indicate any significant decreasing trend in the groundwater level, even with the drying climate, which suggests that the current lower annual rainfall is still sufficient to fill the aquifer in the study area (Section 5.2.2).

A flood modelling study was carried for the FAL project (BG&E, 2015), which included an extensive review of available information on climate change scenarios. The main overarching conclusions from the reviewed information suggests that there will be an increase in sea level (between 0.5 m and 1.1 m) and that the rainfall intensities will increase even though the annual rainfall trend in the western region of Australia could decrease (i.e. the climate could become drier, but storm events could become more severe). The rise in sea level would result in a rise in the water level in the Swan River, which would result in an increase in groundwater level in the vicinity of the Swan River. The more severe storm events could potentially increase short-term rises in groundwater levels during the wet season, particularly in areas with thicker unsaturated zones.

The climate changes are currently not expected to have a major effect on the future groundwater levels along most of the alignment except for an increase in groundwater level at the Swan River due to global sea level rise. A lower future annual rainfall could result in decreasing groundwater levels, while an increase in the rainfall to pre-1960's rainfall volumes could result in increasing groundwater levels.

Geology

Over the majority of the alignment the top soil consists of sandy soils promoting rainfall recharge. However, the geotechnical and environmental investigation results indicate that clay or low permeability material is present within less than 1 m from the ground surface in the Forrestfield area (along the tunnel alignment and in the associated car park). This low permeability material has been found to cause perched groundwater conditions in some areas with groundwater level being close to the surface. The groundwater level could possibly even reach the ground surface or cause local inundation in some local areas after large rainfall events (which could be monitored in the future during the wet season). Therefore, in the Forrestfield area the geology is causing locally perched aquifer conditions.

If climate change would result in more severe storm events, this could result in more frequent and severe inundation in the Forrestfield area.

Drains

A large network of man-made drains exists over the study area and along the alignment. The main drains are described in Section 5.5.2. The main purpose of the drainage networks is to lower the groundwater level in the full aquifer to allow for land development in the area. The drains were installed progressively from the 1950's to the 1970's (see the aerial photography review presented in (Golder, 2015c) resulting in lowering of the groundwater level.

The existing drainage networks are considered to drain the groundwater table, particularly during the wet season and thereby control the maximum groundwater level in the area. The drains are therefore currently considered to be the main parameter that determines the maximum groundwater level in the area.

Groundwater Abstraction

The main groundwater abstraction along the tunnel alignment is considered to be for reticulation (residential, public parks and Perth Airport) and for industrial purposes. No large scale groundwater abstraction has been identified in the area. The VWPs are showing temporary (daily) effects of groundwater level drawdown from reticulation wells, but no long-term decreasing trends are observed in any wells with historical groundwater level data that have been reviewed during this study (Section 5.2.2). In addition, groundwater abstraction for reticulation purposes would be highest during the dry season which is when the groundwater levels are lowest.

Groundwater abstraction is therefore currently not expected to have a major effect on the design groundwater levels.

7.1.2 Design Groundwater Level Estimation

7.1.2.1 50 Year Design Groundwater Levels

The following data was utilised to generate the 50 year design groundwater levels:

- Groundwater levels from monitoring wells and VWP's installed along the alignment during the geotechnical and environmental investigation.
- Historical hydrographs available from DoW, PAPL and the former CSBP Bayswater site (Parsons Brinckerhoff, 2013).
- Drain and wetland elevations estimated from topographic contours (1 m interval) from Landgate.
- Information on global sea level rise.

Based on the analysis of the key parameters it is considered that the existing man-made drainage network will control the maximum groundwater level over a large part of the alignment in the future. It is therefore important that the drainage network is incorporated into the estimation of the design groundwater level.

The design groundwater level contours for the study area have been estimated by contouring groundwater level interpolation points created as follows:

- **Drainage system** – The invert levels for the drainage system were obtained from 1 m topographic contours. It was assumed that the groundwater level will be up to 1.0 m above the invert levels during the wet season (i.e. 1 m was added to invert levels) based on observations at Belmont Main Drain. It has been assumed that all existing drains will remain in operation throughout the design period.
- **Wetlands and lakes** – Aerial photography was utilised together with surface contours to estimate the water levels.
- **Swan River Level Rise** – A rise in average Swan River water level due to global sea level rise of 0.4 m (from RL 0.2 m AHD to RL 0.6 m AHD).
- **Wells with historical hydrographs** – The maximum historical groundwater level was estimated for each well based on the groundwater levels measured over the period of monitoring (generally up to 15 years for PAPL wells, 8 years for CSBP wells and up to 60 years in the DoW wells).
- **Wells with no historical hydrographs (new wells installed along the alignment)** – The March 2015 measured groundwater level was used as a starting point. The groundwater level difference between the estimated maximum groundwater level and the March groundwater levels in nearby wells with historical hydrographs was then added to the March 2015 groundwater levels. This process assumes that similar historical trends would be exhibited by nearby wells. The difference between the maximum and March 2015 levels was found to vary along the alignment between +0.8 m and +4.0 m.

The interpolation points resulting from the above approach were then manually contoured. The contours are based on currently available data. If additional information (e.g. if sub-soil drains exist beneath car parks or roads, or additional monitoring wells) becomes available or if existing drains are infilled, the design groundwater level would need to be reassessed and adjusted accordingly.

7.1.2.2 120 Year Design Groundwater Levels

The derived 50 year design groundwater level was utilised as the base for generation of the 120 year design groundwater level. The following assumptions were made to develop the 120 year design groundwater level:

- The Swan River average level will rise by another 0.4 m to RL 1 m AHD
- The groundwater level would rise by 0.5 m over the whole alignment except for:
  - Where the Bayswater and Perth Airport drains cross the alignment, the level was only increased by 0.25 m
  - Along CH3400 to CH4000 the level was only increased by 0.25 m because of the presence of the Belmont Main Drain
  - In the Forrestfield area where an increase of 1 m was adopted due to the available unsaturated thickness and high seasonal variation due to the presence of lower permeability soils.

7.2 Design Groundwater Level

Table 9 summarises the design groundwater level at the stations, dive structure and Forrestfield car park while Figure 12 shows the estimated design groundwater levels over a long-section along the tunnel alignment together with the current ground surface. The results indicate:

- The depth to the design groundwater levels from the current ground surface ranges between 0 m and 5 m with the design groundwater level being within 2 m of the ground surface over the majority of the alignment.
- The groundwater level reaches the surface at several locations, which typically corresponds to where drains were previously installed.

Table 9: 50 and 120 Year Design Groundwater Levels

Location	50 Year Design Groundwater Level			120 Year Design Groundwater Level		
	Range	Average	Average Depth to Groundwater Level	Range	Average	Average Depth to Groundwater Level
	m AHD		m	m AHD		m
Bayswater Dive Portal	5.9–6.2	6.1	<1	6.4–6.7	6.6	<0.5
Airport West Station	9.3–9.9	9.6	1.3	9.5–10.2	9.9	1.0
Consolidated Airport Terminal Station	18.2–18.4	18.3	<1	18.7–18.9	18.8	<0.5
Forrestfield Dive Portal	27*	27*	3	28*	28*	2
Forrestfield Station	27*	27*	2	28*	28*	1
Forrestfield Car Park	27–34 *	NA	2-3	28–35*	NA	1–2

Notes: *Regional Aquifer – Perched groundwater level conditions exist in this area (see Section 7.2.1).
**Range refers to change in groundwater level along the length of the structure.
NA = average is not applicable due to the large area of the car park.

It should be noted that the design groundwater levels over parts of the alignment are lower than the maximum inferred groundwater level contours in the 1997 Perth Groundwater Atlas (WRC, 1997). The main reason for this difference is that the inferred maximum groundwater level contours in the 1997 Atlas include data that dates back to before some of the drains were installed.

7.2.1 Perched Aquifer at Forrestfield

Figure 5 shows the area in Forrestfield where shallow monitoring wells indicate that perched groundwater is either present or is considered likely to occur during the wet season. As described in Section 5.3.6 the differences in groundwater levels measured in shallow and deep wells have been found to vary between 0.3 m and 3.3 m, suggesting that the level of perching is locally highly variable, which is likely because of localised and discontinuous bands/layers of low permeability clay within the Guildford Formation soils. Given that the differences are based on groundwater levels measured toward the end of the dry season, these differences are likely to further increase during the wet season.

With the currently available groundwater level information it is not possible to accurately establish a 50 or 120 year design groundwater level surface for the perched groundwater. It is considered possible that perched groundwater in some areas could reach the ground surface or cause local inundation after large rainfall events. Further groundwater level monitoring would be required to establish the extent of the perched groundwater level areas and the connectivity/separation of the perched groundwater levels and the regional aquifer.

Some of the shallow environmental monitoring wells were reported to be dry during installation. It is recommended that these wells should still be part of the monitoring program in the wet season and following rainfall events to assess the possible perched groundwater level conditions in the area.

7.3 Risks Associated with Design Groundwater Levels

The following risks have been identified for the estimated maximum design groundwater levels:

- Underground structures will need to be designed to resist forces due to buoyancy (uplift) and hydrostatic pressures as well as to resist the ingress of water through walls of the structure.
- The river flood level may cause local short-term changes in groundwater level within and immediately adjacent to the Swan River flood plain. The design of any structures within this zone must consider the river flood level.
- Due to the groundwater level being within a few metres from the ground surface, the infiltration capacity for disposal of stormwater is considered to be low over majority of the alignment and at Bayswater Dive, Airport West Station and Consolidated Airport Terminal Station. Though the depth to the regional groundwater level in the Forrestfield area ranges between 3 m and 6 m, the presence of perched groundwater level conditions could also result in reduced infiltration capacity in this area.
- The presence of shallow perched groundwater and potential for groundwater inundation in the Forrestfield area could affect pavements and rail track subgrades if not managed appropriately during design and construction.
- Any facilities that will be constructed on or under the ground surface may require to be designed for moist or wet conditions (due to capillary rise).

7.4 Drainage Control

It is understood that PTA will require that all underground structures be 'tanked' which should eliminate any requirements for under-drainage systems below the base slabs.

To facilitate excavation and construction of the dive structures and stations, retaining walls will be required to be constructed around the perimeter of the structures. Reference Design Revision F indicates that the retaining structures will comprise D-walls. Depending on the depth, location and orientation in relation to groundwater flow, the installation of the D-walls could act as groundwater flow barriers, which could result in groundwater mounding behind the D-walls and may result in an increase in hydrostatic pressure against the D-walls. Therefore, permanent groundwater control in areas where groundwater mounding would occur may be required:

- ***Bayswater Dive Structure -*** The D-walls will extend through the Upper Aquifer into the Lower Aquifer, resulting in a permanent groundwater flow barrier in the Upper Aquifer where the walls are aligned obliquely or perpendicular to the groundwater flow direction:
    - East of Bayswater Main Drain – The groundwater flow is in a westerly to south-westerly direction toward the Bayswater Main drain, which could result in some groundwater mounding behind the northern D-walls.
    - West of Bayswater Main Drain – The groundwater flow is mainly in a north-easterly to easterly direction toward the Bayswater Main Drain and limited groundwater mounding could occur behind the southern D-walls.

  At the Bayswater Main Drain, the D-walls may need to be extended to below the invert level of the Bayswater Main Drain, which would require diversion of the Bayswater Main Drain. This diversion may require additional groundwater control (dewatering) during construction.

- ***Airport West Station and Consolidated Airport Terminal Station -*** The station boxes are generally located parallel to the groundwater flow direction from east to west and are therefore unlikely to significantly impede groundwater flow. However, some groundwater mounding could occur behind the eastern D-walls.

- ***Forrestfield Area –*** The D-walls associated with the Forrestfield Dive Structure will be constructed perpendicular to the groundwater flow direction. However, according to Reference Design Summary Table RevB (for Reference design Rev F) the D-walls will not extend through the full thickness of the Superficial Aquifer and it is therefore considered unlikely that the D-walls will significantly impede groundwater flow and result in significant groundwater mounding behind the up-gradient D-wall.

  The presence of perched groundwater in Forrestfield could result in some groundwater drainage control requirements at the Forrestfield Station and car park area. The required groundwater control could consist of the installation of sub-soil drains or granular drainage blankets.

It is not uncommon to have issues in the Perth Metropolitan Area with clogging of sub-soil drains due to high iron concentrations in the groundwater which precipitates out in the drain pipes and thereby reduces the efficiency of the system over time. The groundwater quality results from along the alignment indicate a large range in iron concentrations ranging between 0.1 mg/L and 22 mg/L, which is lower than compared to groundwater in other parts of Perth (e.g. up to 100 mg/L in Perth CBD). The risk of clogging would therefore depend on the site specific groundwater quality. Other reductions in efficiency of the pipes could be caused by scaling of the pipes due to calcium carbonate or gypsum, but this is normally more easily managed than iron precipitation. The design of a drainage system must consider that access is provided to the drain system to allow for periodic cleaning of the pipes and maintenance/replacement of pumps.

8.0 INFILTRATION CAPACITY

This section presents the estimated infiltration capacity based on infiltration tests carried out at Bayswater Dive Structure, Airport West Station, Consolidated Airport Terminal Station and the Forrestfield area. The development of the pumping test wells at the dive structures and two airport stations gave the opportunity for larger scale infiltration tests (infiltration in pits) and at Bayswater Dive Structure the water was also infiltrated on site using an infiltration basin during the pumping test.

The following infiltration tests were therefore carried out:

- **Inverse auger hole method** – A 75 mm diameter hole was drilled using a hand auger to install a 72 mm diameter slotted PVC casing which was filled with water and then the decline in water level was measured over time.

- **Infiltration pits** – Infiltration pits with base areas of 3 m^2 to 30 m^2 were excavated to a depth of 1 m and then filled with water from the development of the pumping wells; the declining water level was then measured over time.

- **Infiltration basin** – At Bayswater an infiltration basin with an area of approximately 250 m^2 was excavated to allow for infiltration of the abstracted water during the pumping test; the rate of pumping into the basin was used to estimate the infiltration rate.

Given that the infiltration pits and basins have significantly larger footprints and that significantly larger volumes of water are used, these methods are considered to be more representative of likely infiltration rates and more weight should therefore be given to the results from these tests. The inverse auger hole method was therefore only undertaken in the Forrestfield area (three tests) and at Consolidated Airport Terminal Station (three tests) to obtain additional information.

The results from the Inverse Auger Hole method are presented in Appendix G while the results from the infiltration pits and basin are presented in Appendix H.

A summary of the infiltration test results is provided in Table 10 and indicates that infiltration rates range from negligible to 12 m/d.

Table 10: Infiltration Test Results

Location	Geological Unit	Approximate Depth to Groundwater (m bgl)	Test Type	Infiltration Rates (m/d)
Bayswater Dive Structure	Bassendean Sand	2.0	Inverse Auger	NT
			Infiltration Pit	6* - 11
			Infiltration Basin	~2
Airport West Station	Bassendean Sand	2.2	Inverse Auger	NT
			Infiltration Pit	3
Consolidated Airport Terminal Station	Bassendean Sand	2.0	Inverse Auger	4 – 10
			Infiltration Pit	1**
Forrestfield area	Bassendean Sand	Unknown	Inverse Auger	3 – 12
		6.2	Infiltration Pit	Negligible

Notes: *The lower range is after consecutive tests in the same infiltration pit.
**Some Coffee rock encountered in the infiltration pit,
NT = No Tests.

The infiltration capacity of the ground below an infiltration area such as a drainage swale or soak well will depend on a number of factors including:

- the soil profile below the base of the infiltration area, both within the unsaturated (above the groundwater level) and the saturated zone below the groundwater level
- the depth to groundwater level below the base of the infiltration area
- a reduction in permeability caused by the build-up of any fines or other contaminants at the base of the infiltration area carried in by the water that is discharged to the infiltration area
- any compaction of the soil below the base of the infiltration area undertaken during construction.

The inverse auger hole test indicates a high permeability of the tested Bassendean Sand and Fill, which is expected given that the sand is fine to coarse grained and that the tests were short-term and carried out at a shallow depth that would generally not be influenced by the proximity to groundwater level. However, the larger area and longer duration infiltration pit and basin tests indicate lower infiltration rates. These lower infiltration rates are considered to be more representative of conditions applicable to a drainage swale since these tests would have resulted in saturation of the zone between the base of the pit/basin and the groundwater level. Once the saturation front reaches the groundwater level, the hydraulic gradient decreases significantly, which leads to a proportional decrease in infiltration rate.

Given the shallow depth to the groundwater level it is therefore estimated that short-term (less than 1 hour) infiltration rates could be about 5 to 10 m/d in the Bassendean Sand while longer term (several hours to days) infiltration rates are likely to be around 1 to 5 m/d.

Based on the infiltration test results and the presence of low permeability Guildford Formation soils at shallow depth (which are found to cause locally perched groundwater conditions), the Forrestfield area is considered to have the poorest infiltration capacity of the four areas assessed along the alignment. Therefore even though the results from the inverse auger test indicate relatively high infiltration rates, the presence of clayey material within a few metres from the ground surface would significantly reduce the infiltration capacity in this area.

The shallow depth to groundwater level over the whole alignment and the lower permeability soils in the Forrestfield area must be considered in the design of stormwater infiltration/soakage.

9.0 KEY HYDROGEOLOGICAL CHARACTERISTICS AND CONSIDERATIONS

The following sections summarise the key hydrogeological characteristics observed during the Stage 2 Geotechnical Investigation, which will need to be considered during design and construction.

9.1 Bayswater Dive Structure

For the Bayswater Dive Structure the following key points have been identified:

- A two aquifer system exists in the area with a difference in groundwater level and piezometric level in March 2015 between the Upper and Lower Aquifers of about 3.7 m and with a downward vertical gradient (i.e. groundwater level is highest in the Upper Aquifer).
- The results from the pumping test, which was carried out in the Lower Aquifer, indicated that the two aquifers are isolated from each other. This isolation is clearly illustrated by the response in two monitoring wells that were installed 5 m from the pumping well, which during the test pumping indicated no drawdown in the Upper Aquifer and 9 m of drawdown in the Lower Aquifer.
- Pumping from the Lower Aquifer resulted in a large cone of depression with a reduction in piezometric level in the Lower Aquifer observed to be approximately 8.5 m at a distance of 40 m from the pumping well and up to 1.5 m approximately 500 m away from the pumping well towards the Swan River.
- The pumping test analysis indicates that heterogeneous conditions are present in the Lower Aquifer.
- Previous investigations indicate that the groundwater quality is significantly different in the Upper and Lower Aquifers and that the Upper Aquifer is impacted from groundwater contamination from a site located to the north-east of the Bayswater Dive Structure. Careful management will therefore be required to avoid cross-contamination between the two aquifers during and post-construction and the dewatering system for the Upper and Lower Aquifers will need to be designed so that each aquifer is dewatered separately.
- The installation of the D-walls to facilitate excavation and construction of the dive structure would create a permanent groundwater flow barrier in the Upper Aquifer where the walls are aligned obliquely or perpendicular to the groundwater flow direction, which could result in groundwater mounding against the up-gradient side of the D-walls. The groundwater mounding could potentially require some groundwater control in areas where the groundwater level is close to the ground surface and may result in an increase in hydrostatic pressure against the D-walls.
- Reference Design Summary Table RevB (for Reference design Rev F) indicates that at the deeper part of the dive structure and tunnel portal the D-walls will extend into the Osborne Formation. This would also significantly reduce the groundwater inflow from the Lower Aquifer into the excavation. The estimated low dewatering rate is therefore expected given that the pumping test well was able to dewater the Lower Aquifer to below the required dewatering level (without retaining walls) during the pumping test.
- At the Bayswater Main Drain, the D-walls may need to be extended to below the invert level of the Bayswater Main Drain, which would require diversion of the Bayswater Main Drain. This diversion could require additional groundwater control (dewatering) during construction.

9.2 Airport West Station

For the Airport West Station the following key points have been identified:

- Hydraulic testing at Airport West indicates that that the hydraulic conductivity of the Kardinya Shale of the Osborne Formation is very low. According to the Reference Design Revision F the D-walls will extend into the Kardinya Shale (OFs) of the Osborne Formation and thereby cut off direct inflow from the Superficial Aquifer. Dewatering requirements will therefore only consist of emptying out the storage contained by the D-walls and any groundwater seepage through the Kardinya Shale as well as through the D-walls. Minimising seepage through the D-walls would reduce the inflow rates. Minimisation of seepage through the walls would require that water stops between panels are installed to the bottom of the D-walls (or at close as practicable).

- Given the expected low dewatering rates, a recharge well system for dewatering discharge disposal may not be required. Alternative options such as disposal to the stormwater system may be a suitable option.
- The pumping test indicates that the Belmont Main Drain will act as a positive boundary to drawdown of the groundwater table. However, a reduction in piezometric pressure was also observed in the monitoring wells on the southern side of the Belmont Drain, indicating that the cone of depression in the Ascot Formation will extend beyond the Belmont Drain to the south, should it be decided that groundwater abstraction from the Ascot Formation would be required.
- The groundwater and piezometric levels in the monitoring wells were found to be affected by local council and individual household groundwater bore reticulation systems, suggesting that any abstraction from the Superficial Aquifer could affect nearby existing wells if drawdown is not carefully managed.
- The tunnel alignment in this area and the Airport West Station are generally located parallel to the groundwater flow direction from east to west toward the Swan River. As such, construction of the tunnel and installation of D-walls for the Airport West Station is unlikely to significantly impede groundwater flow. Nevertheless, given the shallow depth to groundwater level, it is recommended that the effect of construction of the tunnel and station infrastructure be assessed during detailed design.

9.3 Consolidated Airport Terminal Station

For the Consolidated Airport Terminal Station the following key points have been identified:

- According to the Reference Design Revision F the D-walls will extend 3 m into the Mirrabooka Member of the Osborne Formation (OFm) and thereby cut off direct groundwater inflow from the Superficial Aquifer. The main groundwater inflow into the excavation will be from the Mirrabooka Aquifer. Understanding the depth, extent and hydrogeological properties of the Mirrabooka Aquifer therefore becomes the most important factor in estimating the dewatering requirements for the Consolidated Airport Terminal Station.
- The available borehole logs in the Mirrabooka Aquifer indicate that the hydraulic conductivity will reduce with depth due to the increasing influence of interbedded layers of sandy mudstone which are expected to have a significantly lower hydraulic conductivity. None of the boreholes drilled into the Mirrabooka Aquifer penetrated through it and the thickness of the Mirrabooka Aquifer is therefore not well defined.
- The analysis of the pumping test from the Consolidated Airport Terminal Station showed that the best fit when replicating the pumping test data in the groundwater model was obtained using a ratio of vertical to horizontal hydraulic conductivity of 0.1 for all the hydrogeological units. The dewatering scenarios indicate that the ratio would have a significant influence on the final dewatering rates.
- Based on the importance of the Mirrabooka Aquifer it is recommended that additional investigation is undertaken to determine the thickness and aquifer properties of the Mirrabooka Aquifer. The pumping test should include a monitoring well configuration that allows for determination of the vertical and horizontal hydraulic conductivity and to assess whether the hydraulic conductivity reduces with depth.
- The tunnel alignment in this area and the Consolidated Airport Terminal Station are generally located parallel to the groundwater flow direction from east to west toward the Swan River. As such, the construction of the tunnel and installation of D-walls for the Consolidated Airport Terminal Station is therefore unlikely to significantly impede groundwater flow. Nevertheless, given the shallow depth to

groundwater level, it is recommended that the effect of construction of the tunnel and station infrastructure be assessed during detailed design.

9.4 Forrestfield Area

For the Forrestfield area the following key points have been identified:

- The pumping test analysis at the Forrestfield Dive Structure does not provide definitive conclusion to the ratio between the vertical and horizontal hydraulic conductivity in this area (the use of 0.1 to 1 gave almost similar results – best fit was 0.25). The groundwater model scenario runs indicate that this ratio will influence the dewatering rates.
- The groundwater level measurements in the installed monitoring wells and VWPs indicate a large (approximately 3 m) seasonal variation in groundwater level as well as the presence of perched groundwater conditions in this area. Given that the Stage 2 investigation was carried out in the dry season and perched groundwater may dry out during summer in some areas, the extent and connectivity with the regional aquifer is currently unknown and can only be established through groundwater level monitoring over the wet season. It is therefore recommended that additional monitoring wells are installed and groundwater level monitoring undertaken during the wet season. It is also recommended that following a large rainfall event during the wet season a site walkover be undertaken to gain a better understanding of the potential extent of inundated areas.
- The groundwater quality during the pumping test was found to be acidic (average pH of 5.7) with limited buffering capacity, which would need to be considered during the dewatering design. The high nutrient concentrations may restrict construction dewatering and long-term drainage disposal to the stormwater system.
- Based on the infiltration test results and the presence of low permeability soils at shallow depth the Forrestfield area is considered to have the poorest infiltration capacity of the four areas assessed along the alignment.
- The D-walls associated with the Forrestfield Dive Structure will be constructed perpendicular to the groundwater flow direction. However, according to Reference Design Summary Table RevB (for Reference design Rev F) the D-walls do not extend through the full thickness of the Superficial Aquifer and it is therefore considered unlikely that the D-walls will significantly impede groundwater flow and result in significant groundwater mounding behind the up-gradient D-wall. Nevertheless, given the presence of the seasonally perched groundwater conditions, it is recommended that the effect the installation of D-walls could have on the groundwater level at the dive structure be assessed during the detailed design.

10.0 RECOMMENDATIONS FOR FURTHER WORK

Further hydrogeological investigation is recommended to allow detailed design of specific areas or to provide additional information to reduce uncertainty. In summary the following additional investigation work is currently recommended:

1) General:
   a) Establish a groundwater monitoring program along the alignment.
   b) Carry out single well hydraulic testing in future installed wells.
2) At Airport West Station:
   a) Install additional monitoring wells which are screened in the Osborne Formation at the new proposed Airport West Station location.
   b) Carry out single well hydraulic testing in the new wells to provide confirmation of the hydraulic conductivity of the Kardinya Shale Member.

3) At Consolidated Airport Terminal Station:

   a) Drill an additional geotechnical borehole to determine the thickness of the Mirrabooka Aquifer.

   b) Install a new pumping test well in the Mirrabooka Aquifer and carry out a pumping test. .

4) At Forrestfield Area:

   a) Undertake further investigation to assess the extent of the perched groundwater conditions.

   b) Undertake further assessment to enable a better understanding of the connectivity between the regional aquifer and the perched groundwater conditions.

   c) Carry out additional infiltration testing in areas where stormwater soakage may be considered.

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12.0 LIMITATIONS

Your attention is drawn to the document – “Limitations”, which is included as Appendix I to this report. This document is intended to assist you in ensuring that your expectations of this report are realistic, and that you understand the inherent limitations of a report of this nature. If you are uncertain as to whether this report is appropriate for any particular purpose please discuss this issue with us.

Report Signature Page

GOLDER ASSOCIATES PTY LTD

Michael Bartlett
Hydrogeologist

Allan Lundorf
Senior Water Resources Engineer

MJB,AL/AL,DPS/asu

A.B.N. 64 006 107 857

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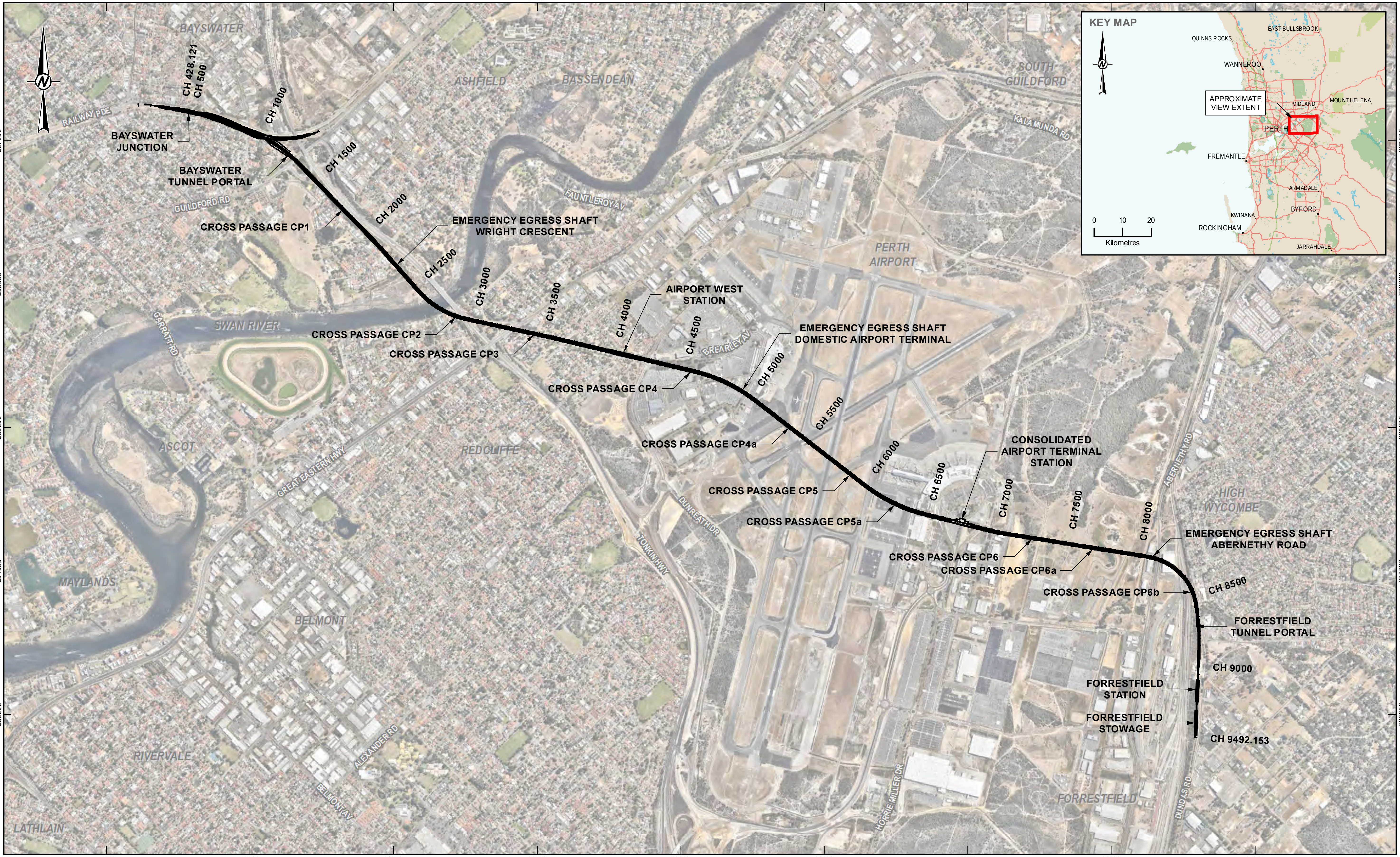

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—— PROPOSED RAIL ALIGNMENT

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

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PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.01
PREPARED	MS
DESIGN	
REVIEW	DPS
APPROVED	DPS

TITLE
GENERAL SITE LOCATION PLAN

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	1

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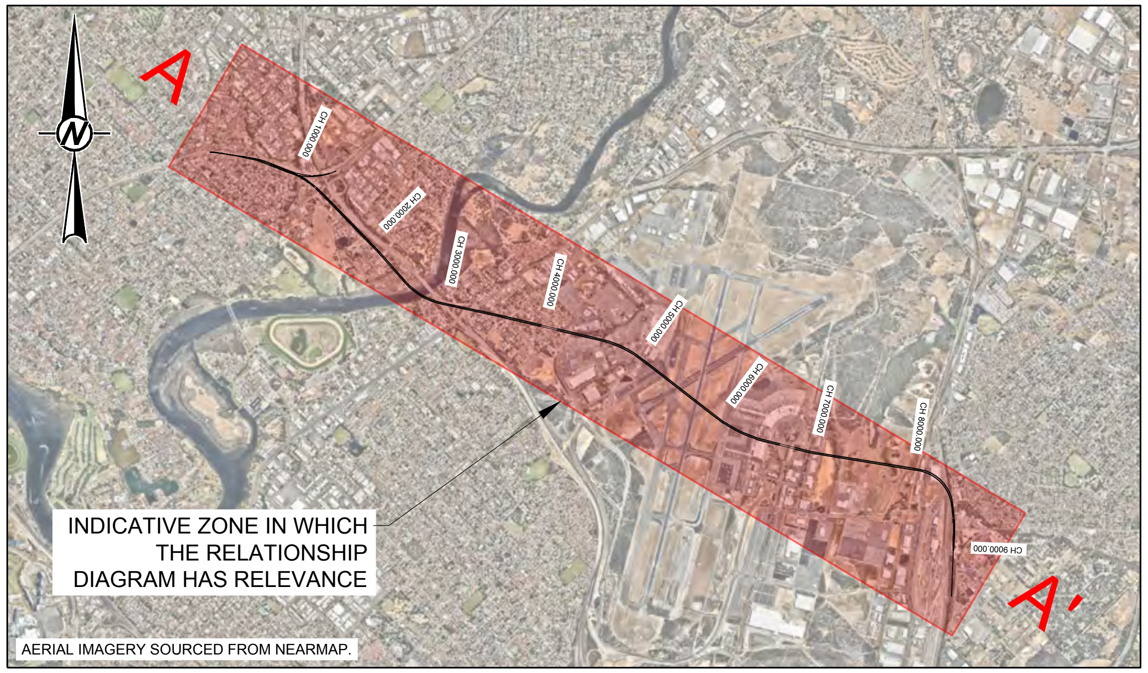
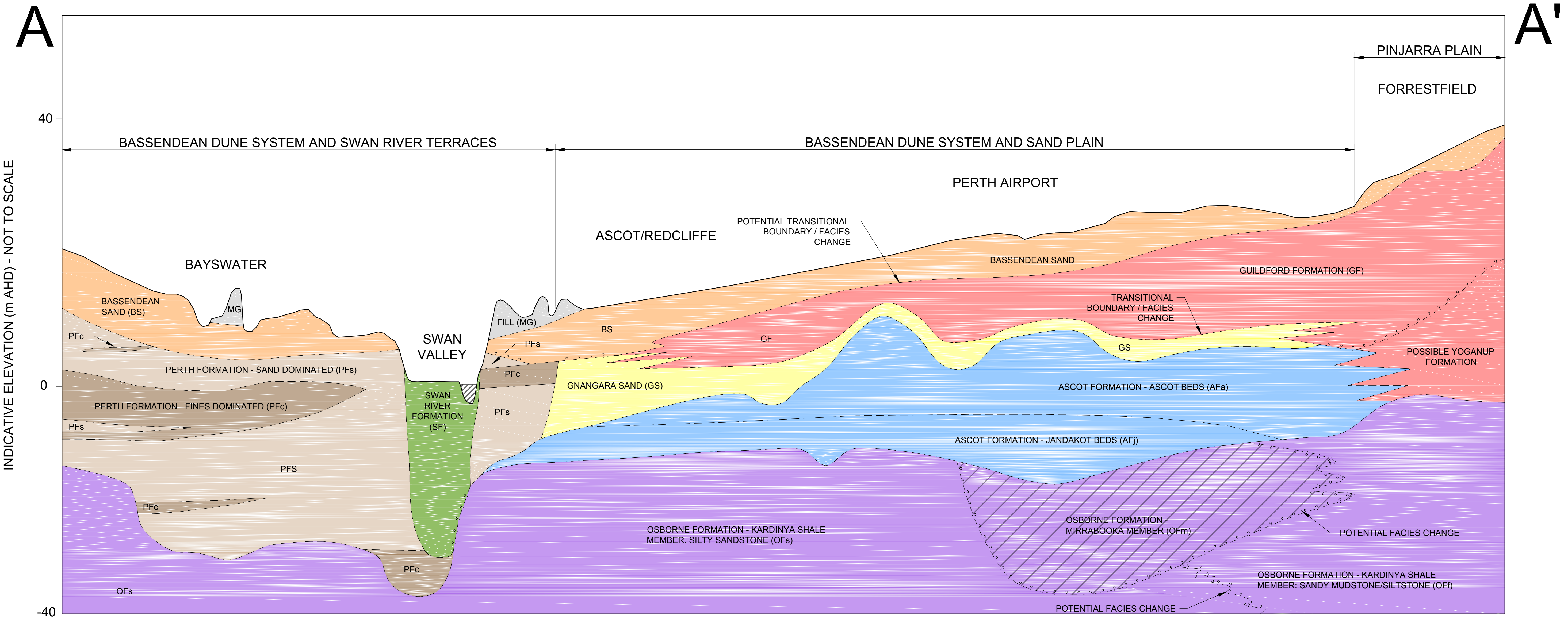
NOTES:
1. THIS FIGURE IS NOT A GEOLOGICAL CROSS SECTION BUT SIMPLY PRESENTS THE INTER-RELATIONSHIP BETWEEN THE VARIOUS GEOLOGICAL UNITS OF RELEVANCE.
2. SOME OF THE RELATIONSHIPS DISPLAYED HAVE NOT BEEN DIRECTLY OBSERVED AT INVESTIGATION LOCATIONS (EG. BS IN DIRECT CONTACT WITH GS), THE RELATIONSHIPS SHOWN BETWEEN ADJACENT UNITS AND FORMATIONS ARE KNOWN TO OCCUR WITHIN THE PERTH METRO AREA.
3. NOT EVERY POSSIBLE RELATIONSHIP IS INDICATED ON THIS DIAGRAM, MERELY THOSE THAT ARE MOST LIKELY TO OCCUR AND THAT HAVE THE MOST RELEVANCE TO THE PROJECT BASED ON THE DATA AVAILABLE.
4. ALIGNMENT LAYOUT SHOWN PROVIDED BY CLIENT, DRAWING NO. 16-C-24-0044 REV F, DATED: 09.04.2015





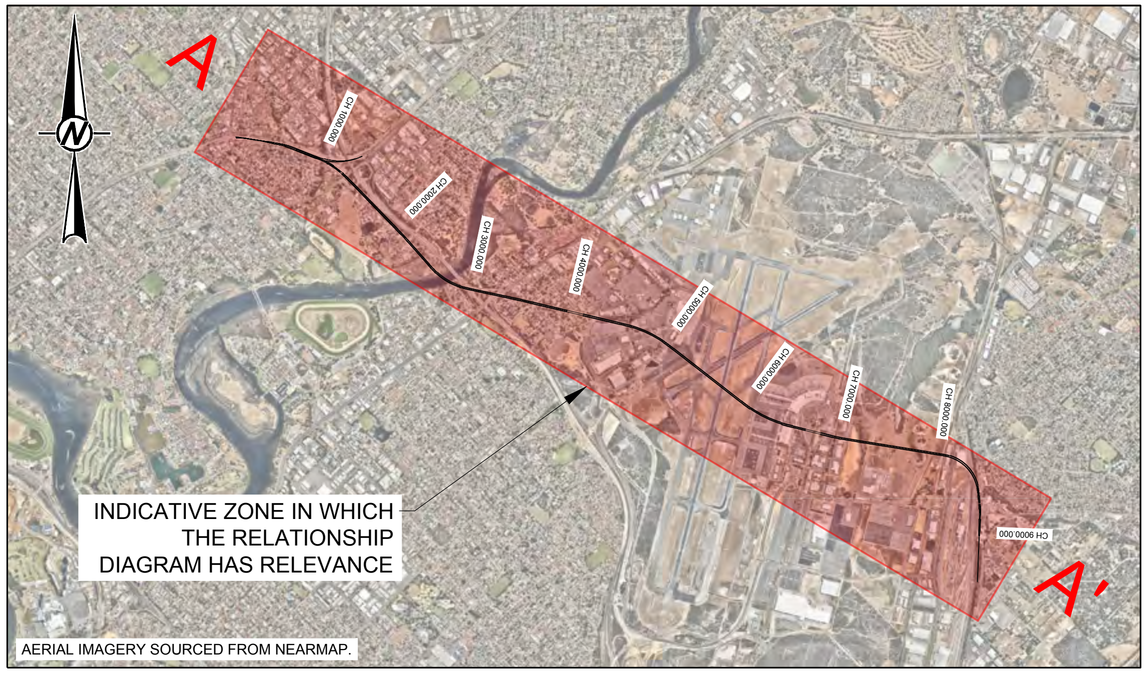
DRAWING NOT TO SCALE
INDICATIVE ONLY

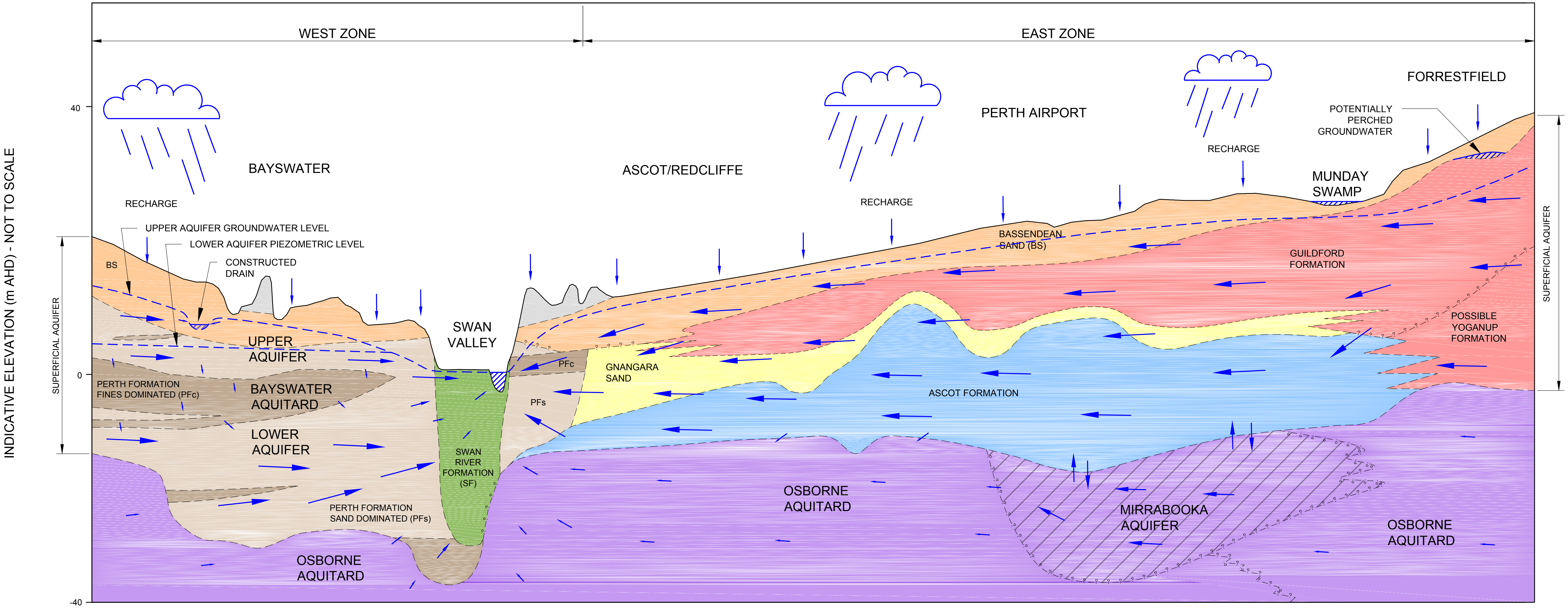
LEGEND

- MG - FILL
- BS - BASSENDEAN SAND
- PFs - PERTH FORMATION (SAND DOMINATED)
- PFc - PERTH FORMATION (FINES DOMINATED)
- SF - SWAN RIVER FORMATION
- GS - GNANGARA SAND
- GF - GUILDFORD FORMATION
- AF - ASCOT FORMATION
- OF - OSBORNE FORMATION
- –? –? – CONTACT RELATIONSHIP NOTED POSSIBLE BASED ON OBSERVED RELATIONSHIPS IN THE PERTH METRO AREA
- — — CONTACT RELATIONSHIP NOTED DURING GEOTECHNICAL INVESTIGATION

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-05-20
PREPARED	SWG/JRP
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	**CONCEPTUAL GEOLOGICAL MODEL AND RELATIONSHIP DIAGRAM**
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	2

NOTES:
1. THIS FIGURE IS NOT A HYDROGEOLOGICAL CROSS SECTION BUT SIMPLY PRESENTS THE INTER-RELATIONSHIP BETWEEN THE VARIOUS HYDROGEOLOGICAL UNITS OF RELEVANCE.
2. SOME OF THE RELATIONSHIPS DISPLAYED HAVE NOT BEEN DIRECTLY OBSERVED AT INVESTIGATION LOCATIONS (EG. BS IN DIRECT CONTACT WITH GS), THE RELATIONSHIPS SHOWN BETWEEN ADJACENT UNITS AND FORMATIONS ARE KNOWN TO OCCUR WITHIN THE PERTH METRO AREA.
3. NOT EVERY POSSIBLE RELATIONSHIP IS INDICATED ON THIS DIAGRAM, MERELY THOSE THAT ARE MOST LIKELY TO OCCUR AND THAT HAVE THE MOST RELEVANCE TO THE PROJECT BASED ON THE DATA AVAILABLE.
4. ALIGNMENT LAYOUT SHOWN PROVIDED BY CLIENT, DRAWING NO. 16-C-24-0044 REV F, DATED: 09.04.2015





LEGEND

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- PFs - PERTH FORMATION (SAND DOMINATED)
- PFc - PERTH FORMATION (FINES DOMINATED)
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- GF - GUILDFORD FORMATION
- AF - ASCOT FORMATION
- OF - OSBORNE FORMATION
- –?–?– CONTACT RELATIONSHIP NOTED POSSIBLE BASED ON OBSERVED RELATIONSHIPS IN THE PERTH METRO AREA
- – – – CONTACT RELATIONSHIP NOTED DURING GEOTECHNICAL INVESTIGATION
- → INDICATIVE GROUNDWATER FLOW LINE
- - - - APPROX. INTERPRETED GROUNDWATER LEVEL

DRAWING NOT TO SCALE INDICATIVE ONLY

CLIENT	PUBLIC TRANSPORT AUTHORITY	PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates	TITLE	**CONCEPTUAL HYDROGEOLOGICAL MODEL**
YYYY-MM-DD	2015-05-20		
PREPARED	SWG/JRP		
DESIGN	SWG		
REVIEW	AL		
APPROVED	DPS		

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	3

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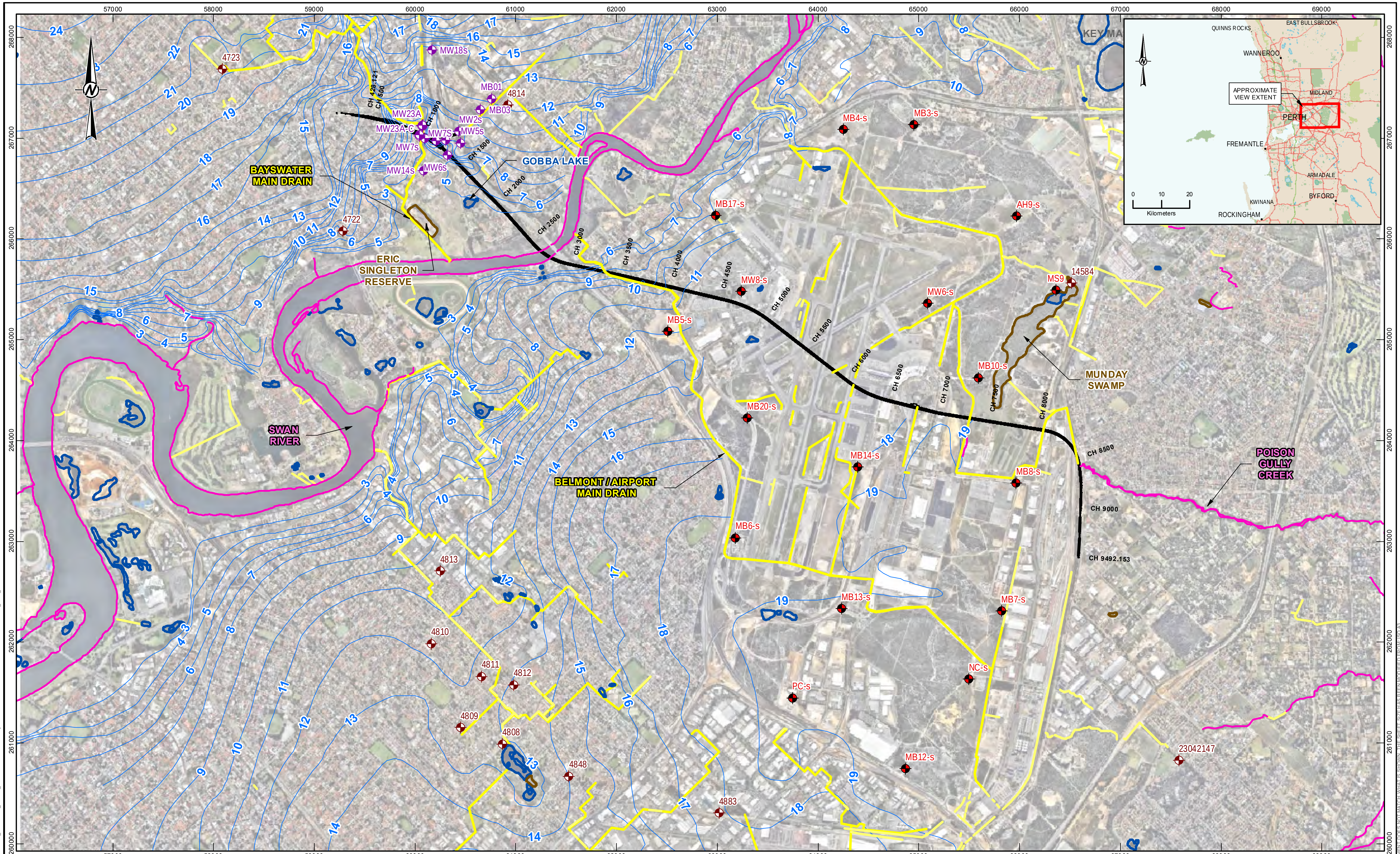

LEGEND

PROPOSED RAIL ALIGNMENT

1997 GW ATLAS CONTOURS (m

OTHER MONITORING LOCATIONS

CSBP

DEPARTMENT OF WATER (DOW)

PERTH AIRPORT PTY LTD (PAPL)

MAIN SURFACE WATER FEAUTRES

(Information Provided by DoW, WaterCorp and PAPL)

MAJOR DRAINS

LAKE

SWAMP

WATERCOURSE

NOTES

1. COORDINATE SYSTEM: PCG94

REFERENCE

PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)
WATER DATA OBSTAINED FROM PAPL, DER AND DOW
INSET BASE DATA/ROADS SOURCED FROM STREET PRO DATA 2009

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CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT

Golder Associates

YYYY-MM-DD	2015.05.22
PREPARED	SWG/MS
DESIGN	
REVIEW	DPS
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
PUBLICLY AVAILABLE WATER DATA

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	4

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
- LG = LANDFILL GAS MONITORING WELL
- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

0 20 40 60 80 100 m
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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS
SHEET 1 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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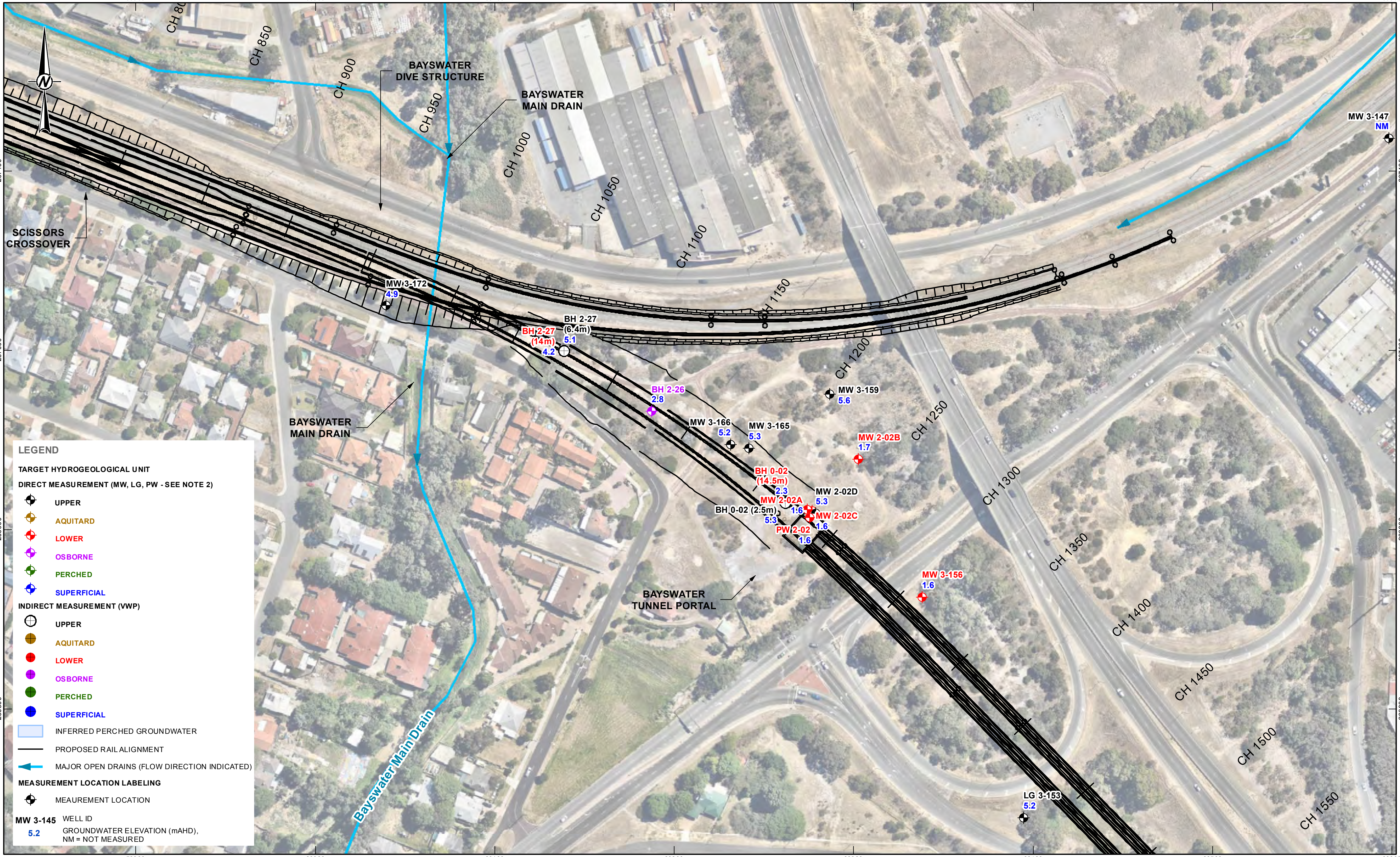

NOTES

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 2 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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

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NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

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GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 3 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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

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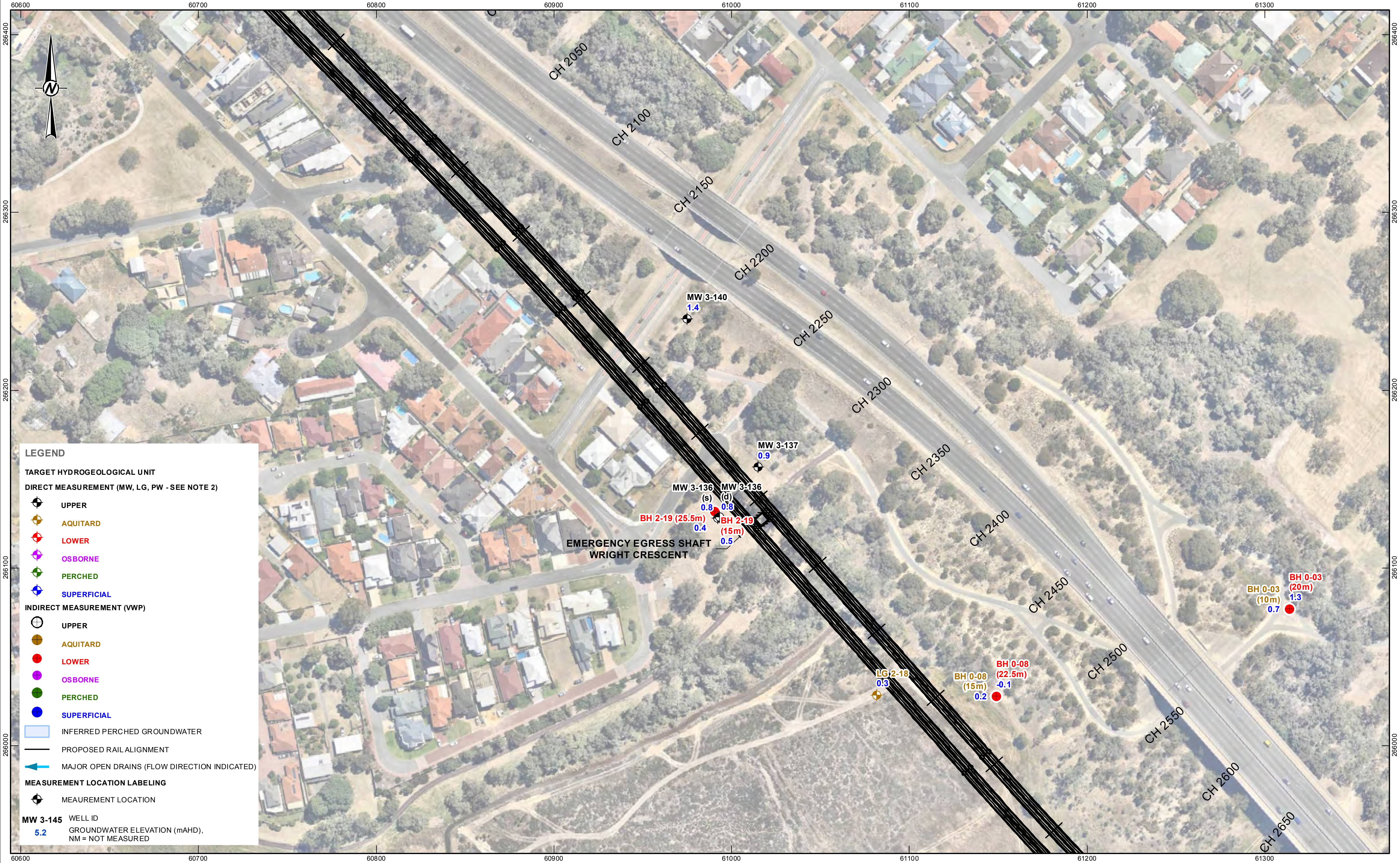

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT PUBLIC TRANSPORT AUTHORITY		PROJECT FORRESTFIELD - AIRPORT LINK CONTAMINATION AND ASS INVESTIGATION	
CONSULTANT Golder Associates	YYYY-MM-DD: 2015.05.20 PREPARED: JRP/SWG DESIGN: REVIEW: AL APPROVED: DPS	TITLE GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 4 OF 17	
		PROJECT No. 147642129 / CONTROL 077R / Rev. 0	FIGURE 5

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NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS
SHEET 5 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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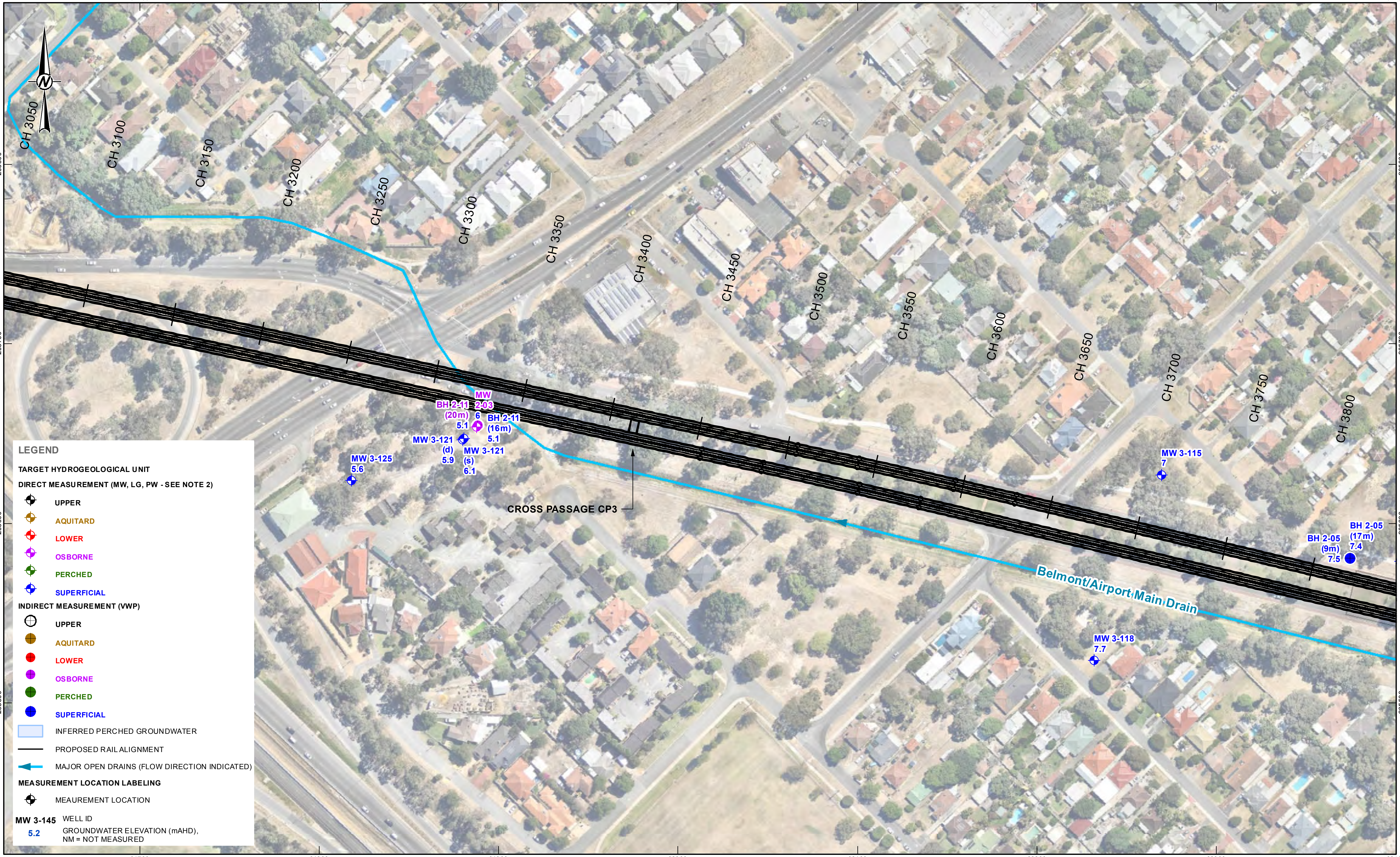

NOTES

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 6 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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

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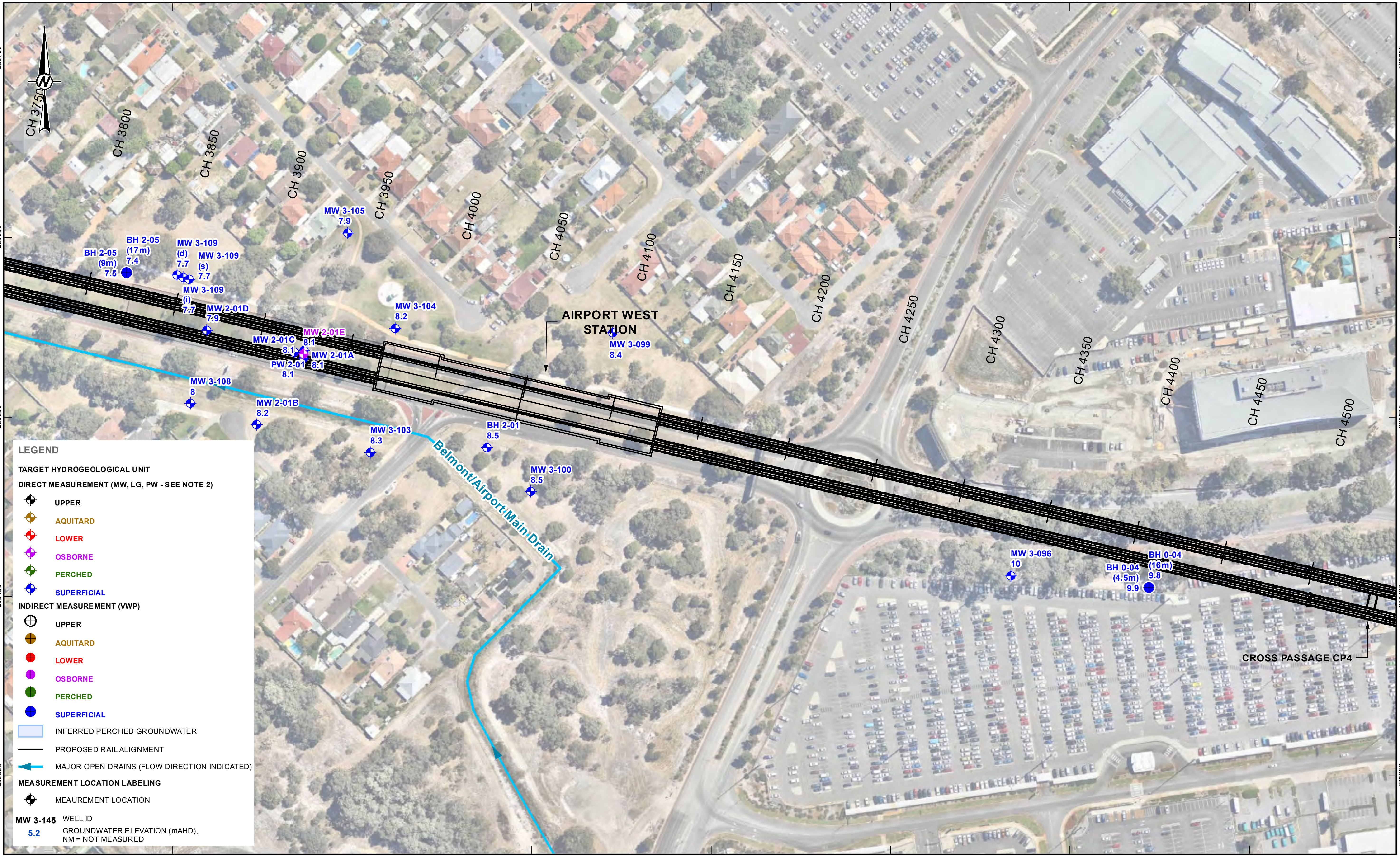

NOTES

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD - AIRPORT LINK CONTAMINATION AND ASS INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 7 OF 17
PROJECT No.	147642129
CONTROL	077R
Rev.	0
FIGURE	5

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

NOTES

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

0 20 40 60 80 100 m

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CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT

Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS
SHEET 8 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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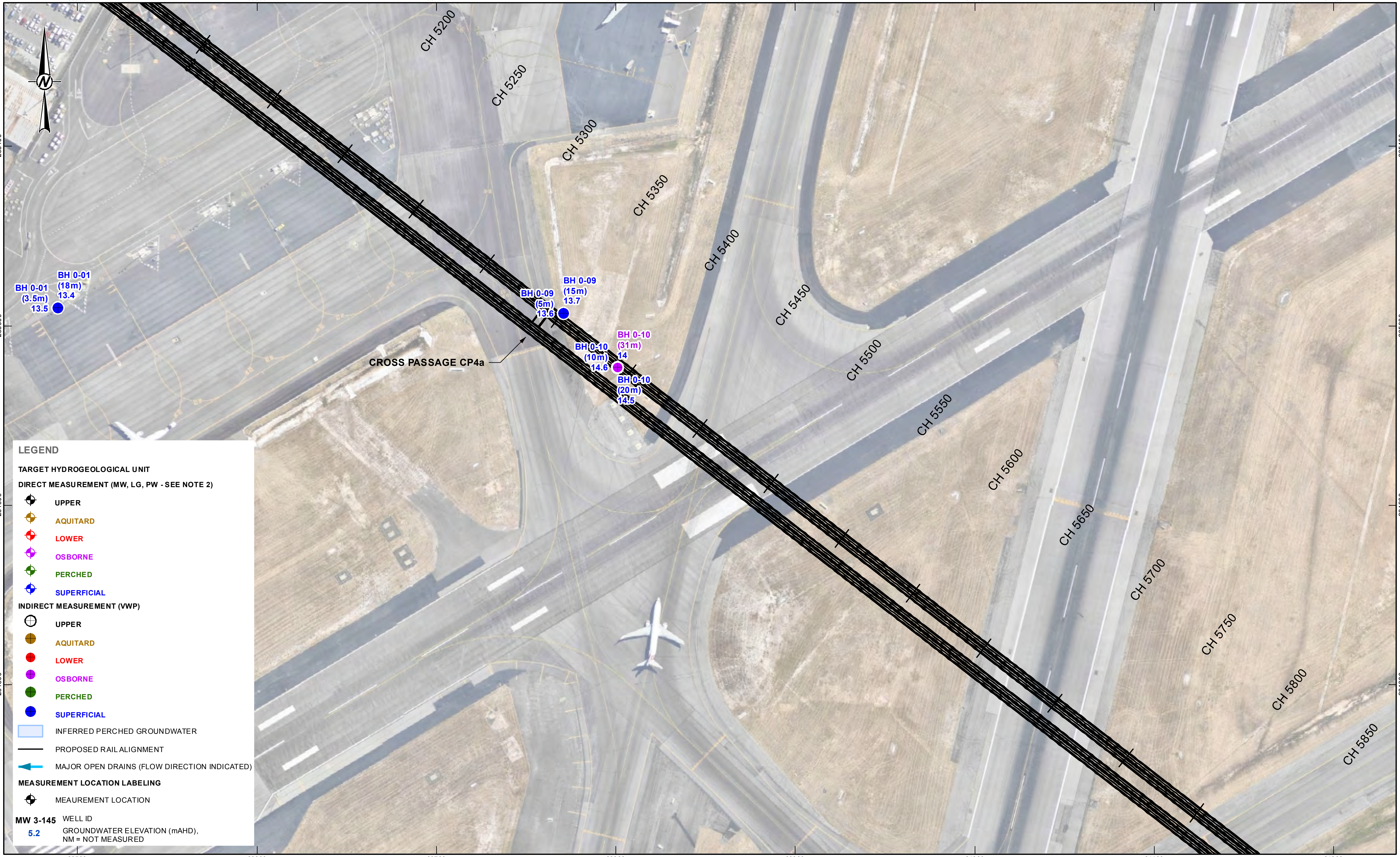

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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD - AIRPORT LINK CONTAMINATION AND ASS INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 9 OF 17
PROJECT No.	147642129
CONTROL	077R
Rev.	0
FIGURE	5

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

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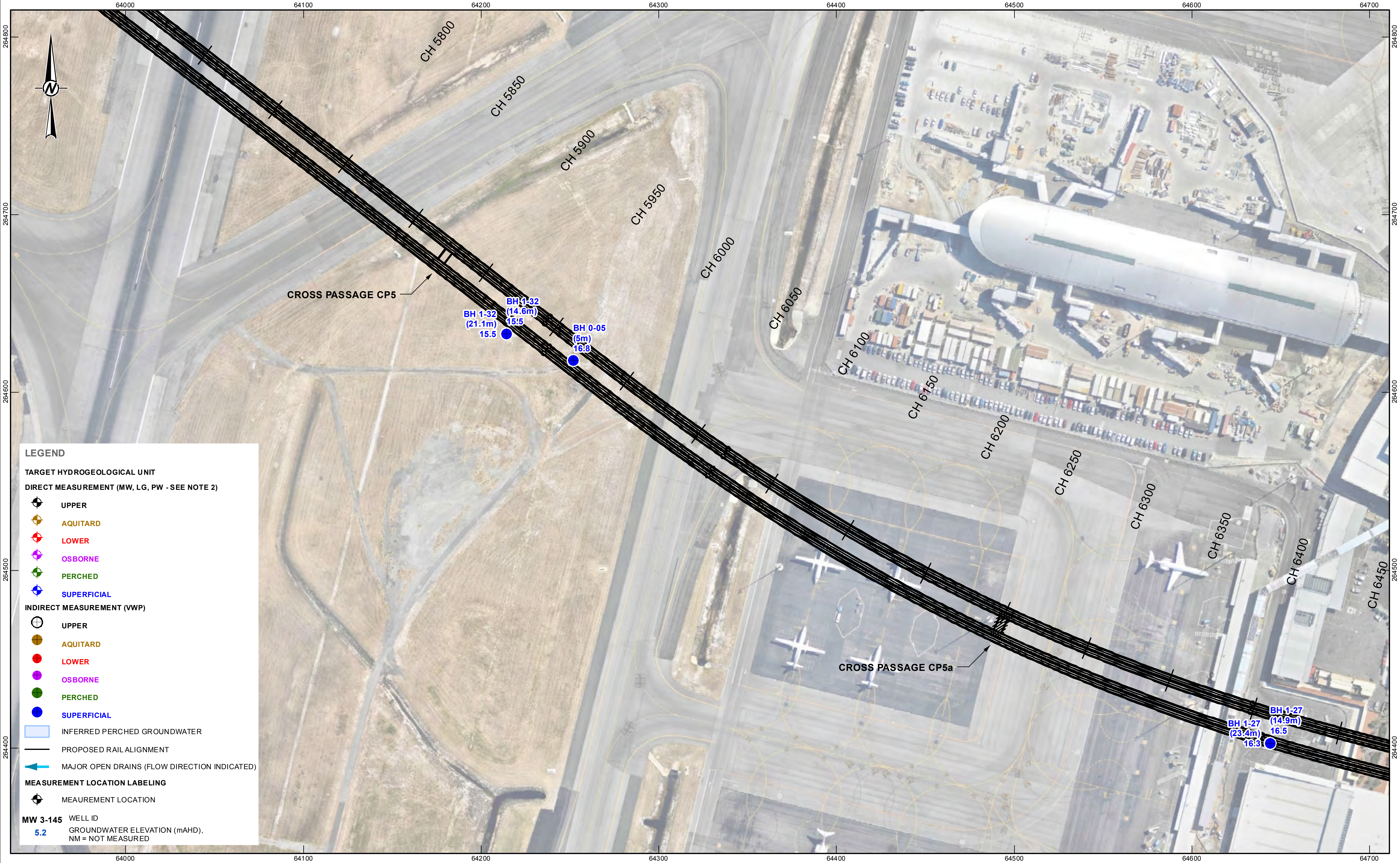


NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
- LG = LANDFILL GAS MONITORING WELL
- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

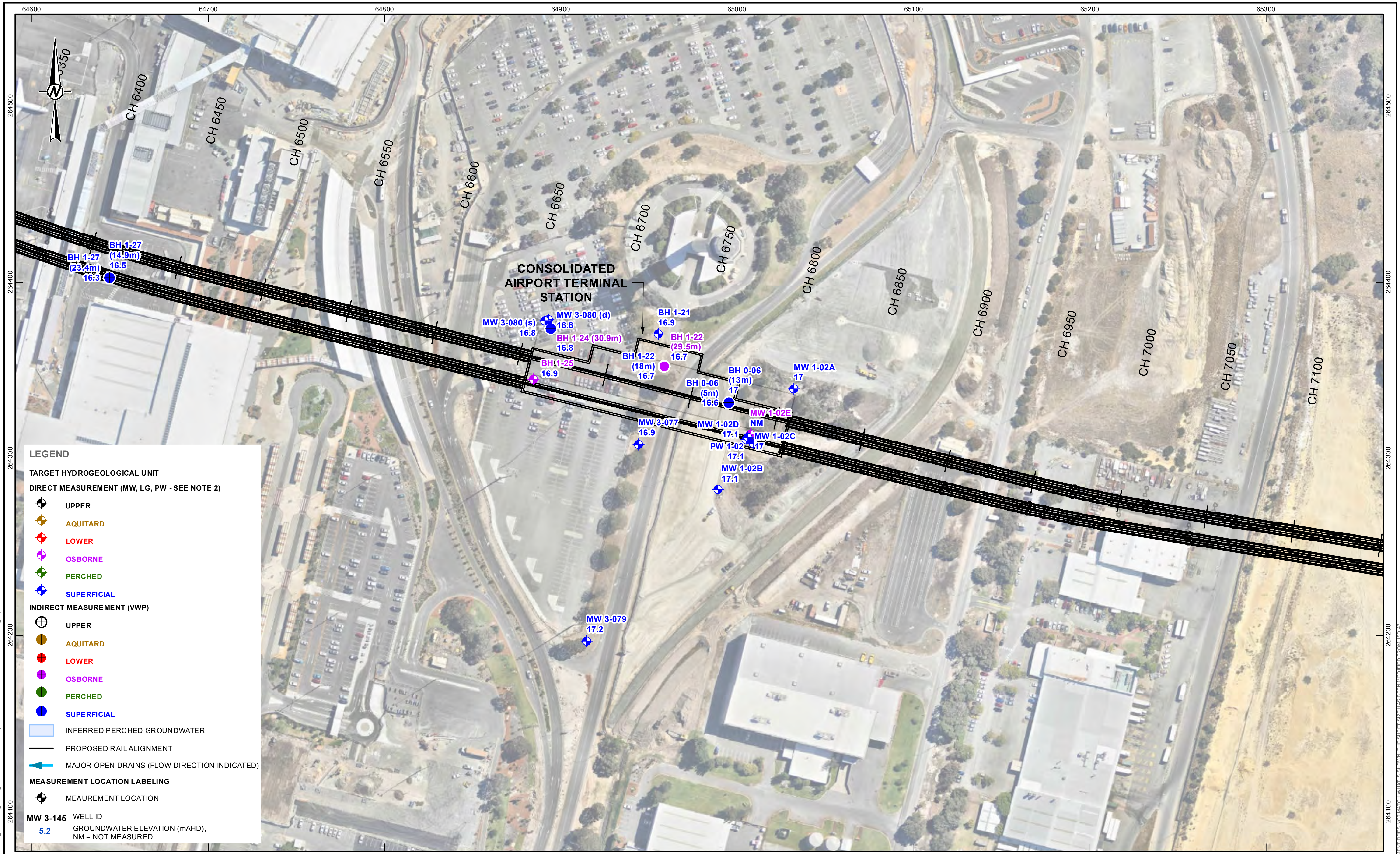
CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 10 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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



NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
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- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

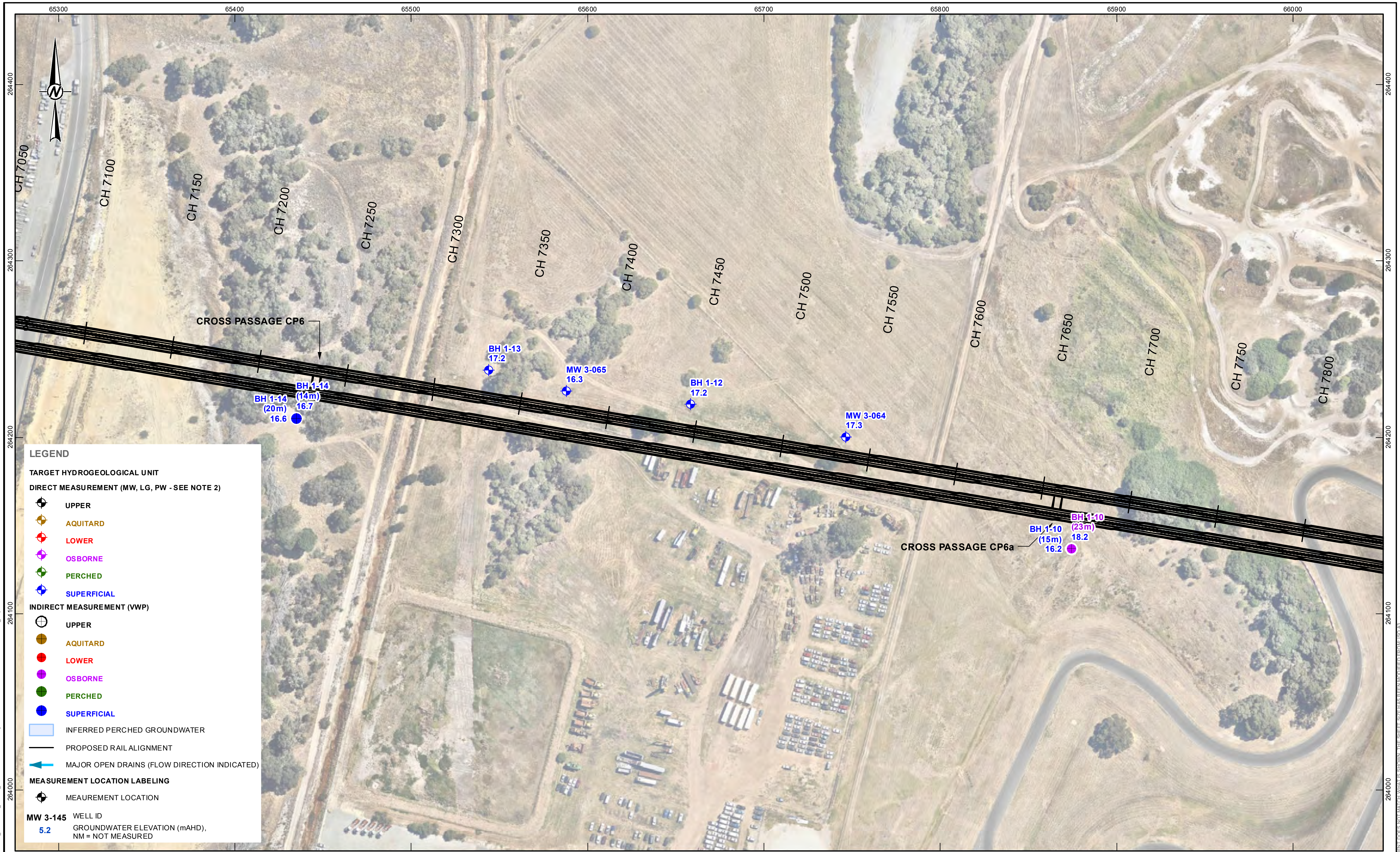
PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 11 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5



NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
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- MW = MONITORING WELL
- LG = LANDFILL GAS MONITORING WELL
- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 12 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
- LG = LANDFILL GAS MONITORING WELL
- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

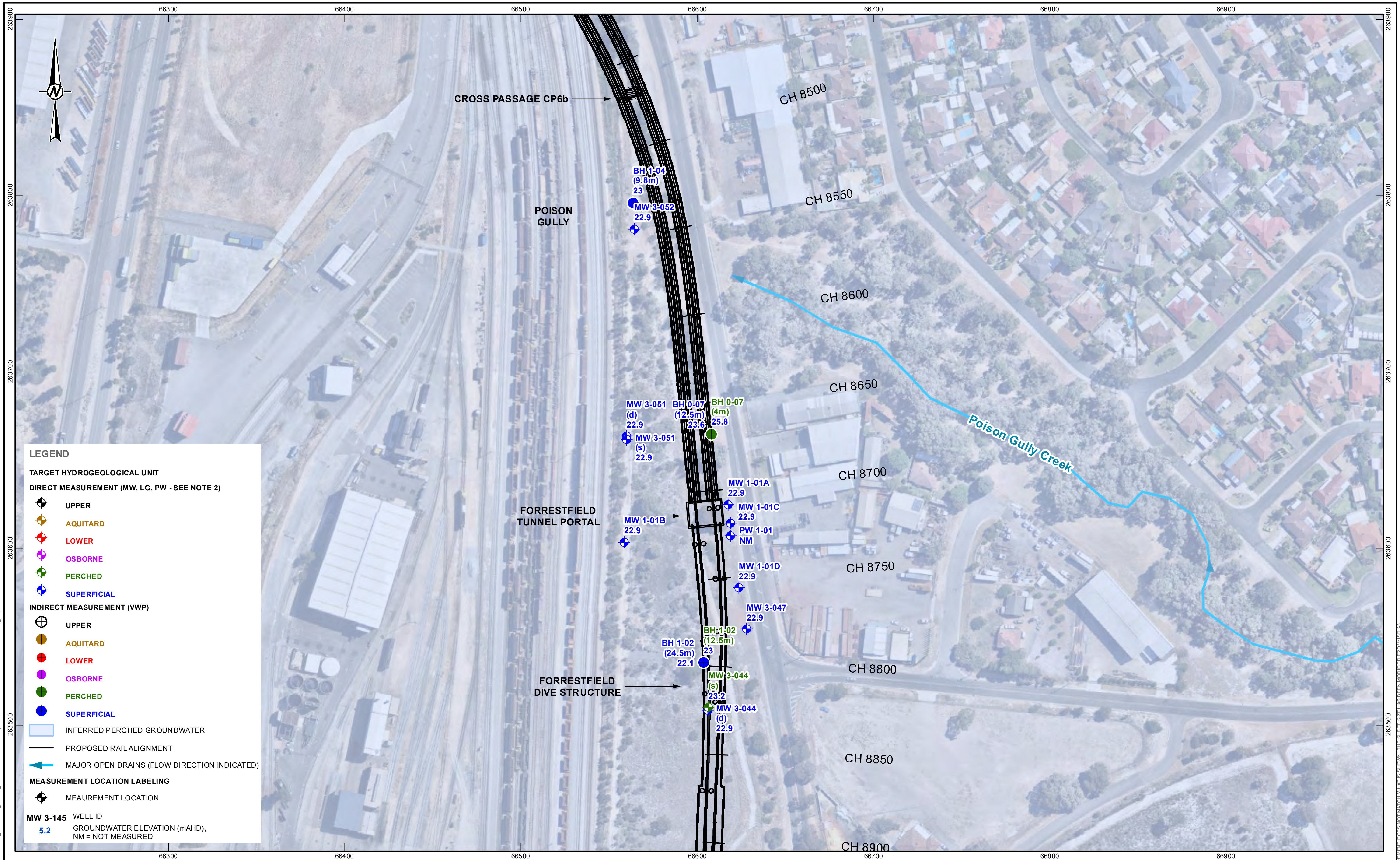
CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 13 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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



NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
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- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

0 20 40 60 80 100 m

1:2,000

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT

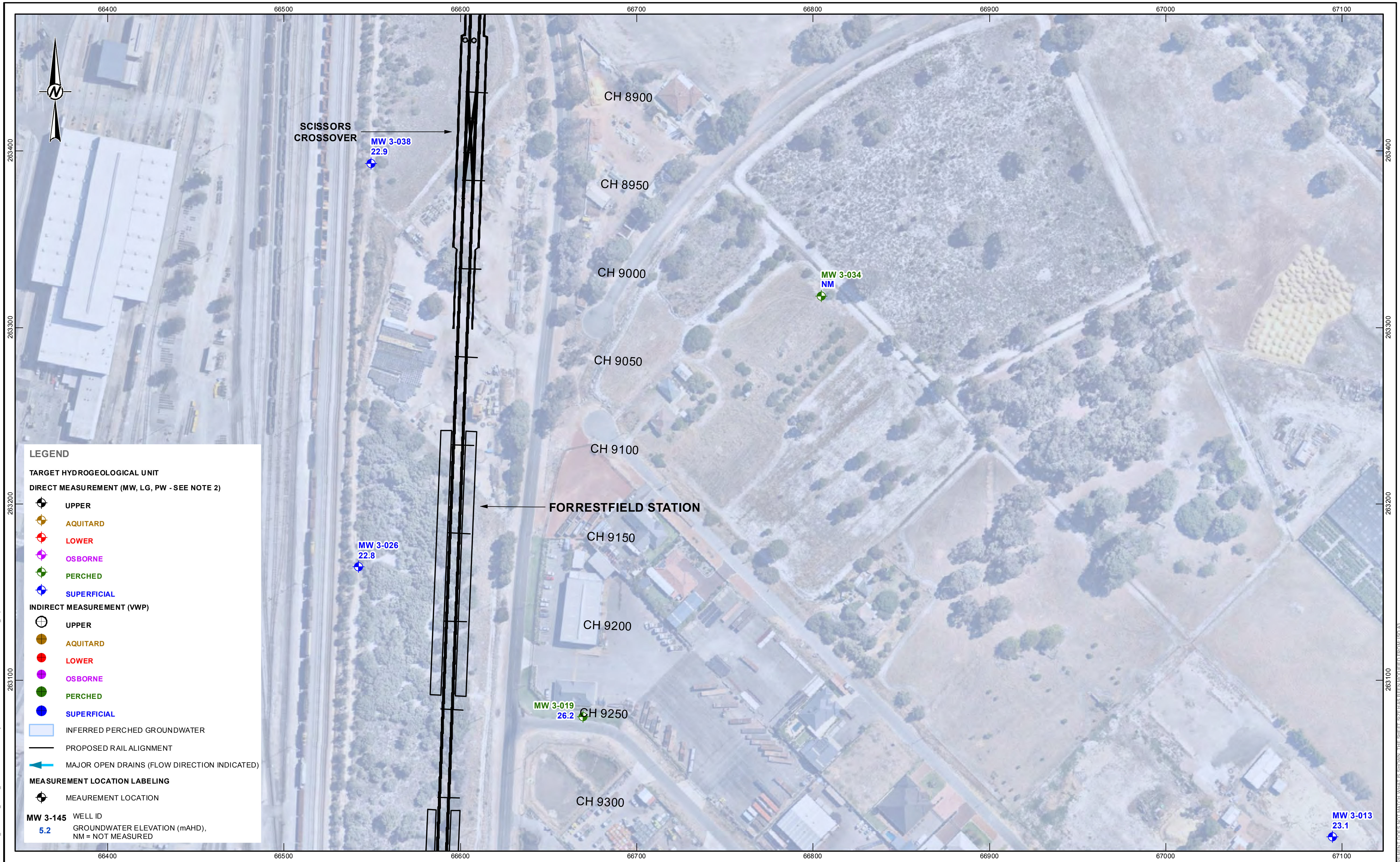
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS
SHEET 14 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

25mm



NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
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- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 15 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
- MW = MONITORING WELL
- LG = LANDFILL GAS MONITORING WELL
- PW = PUMPING WELL

REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 16 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

2. GROUNDWATER MONITORING LOCATION TYPES
- BH = BOREHOLE
- BH WITH (X.XM) = VIBRATING WIRE PIEZOMETER (VWP) LOCATION SHOWING DEPTH OF SENSOR
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REFERENCE

GROUNDWATER LEVELS SHOWN ARE THOSE MEASURED 0N 10 MARCH 2015.
PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD - AIRPORT LINK
CONTAMINATION AND ASS INVESTIGATION

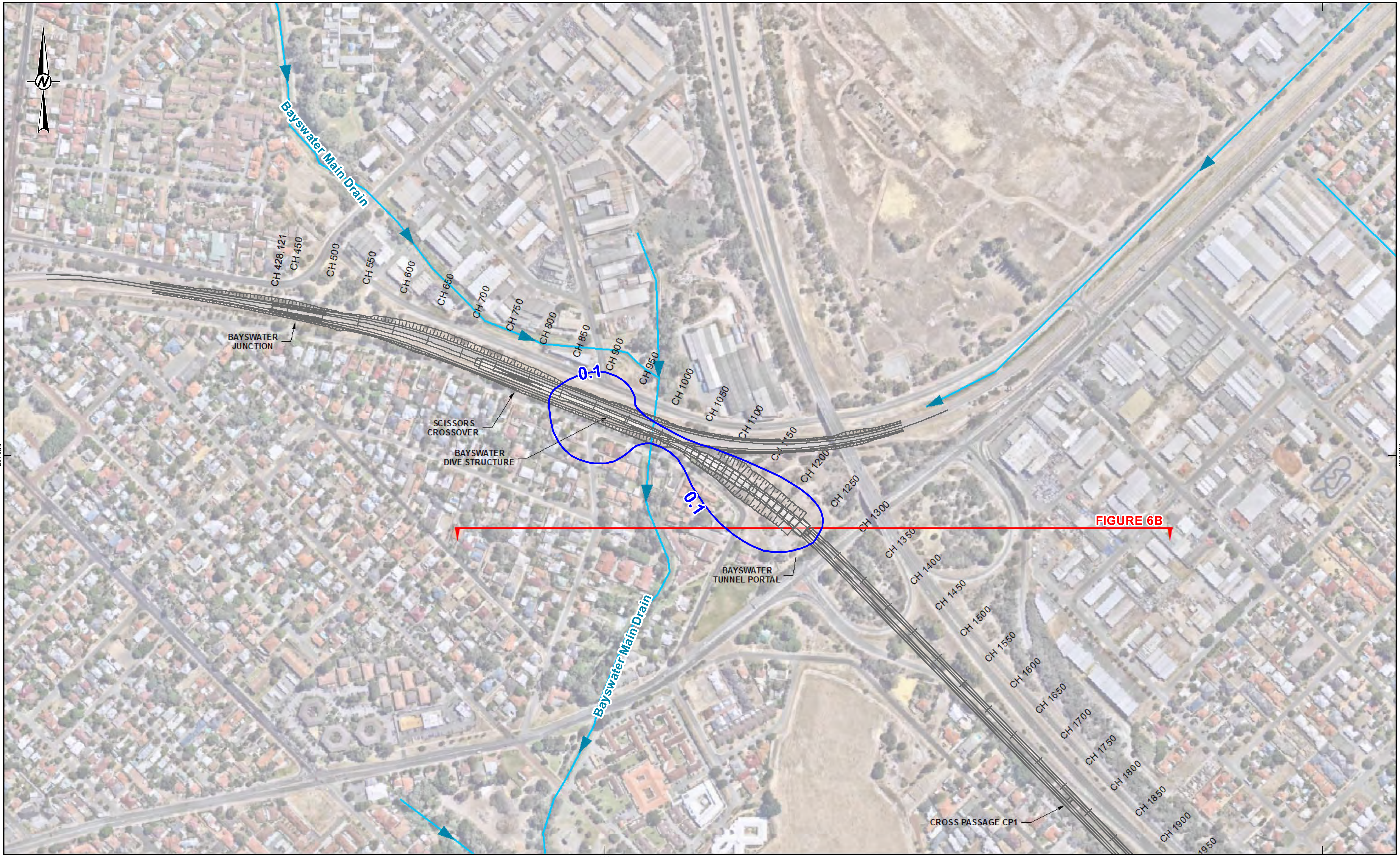
CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	JRP/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER MONTIROING LOCATIONS SHOWING MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVELS SHEET 17 OF 17

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077R	0	5

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



LEGEND

GROUNDWATER LEVEL CHANGE CONTOUR (m)

PROPOSED RAIL ALIGNMENT

APPROXIMATE CROSS SECTION POSITION

MAJOR OPEN DRAINS (FLOW DIRECTION INDICATED)

0 40 80 120 160 200 m

1:5,000

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

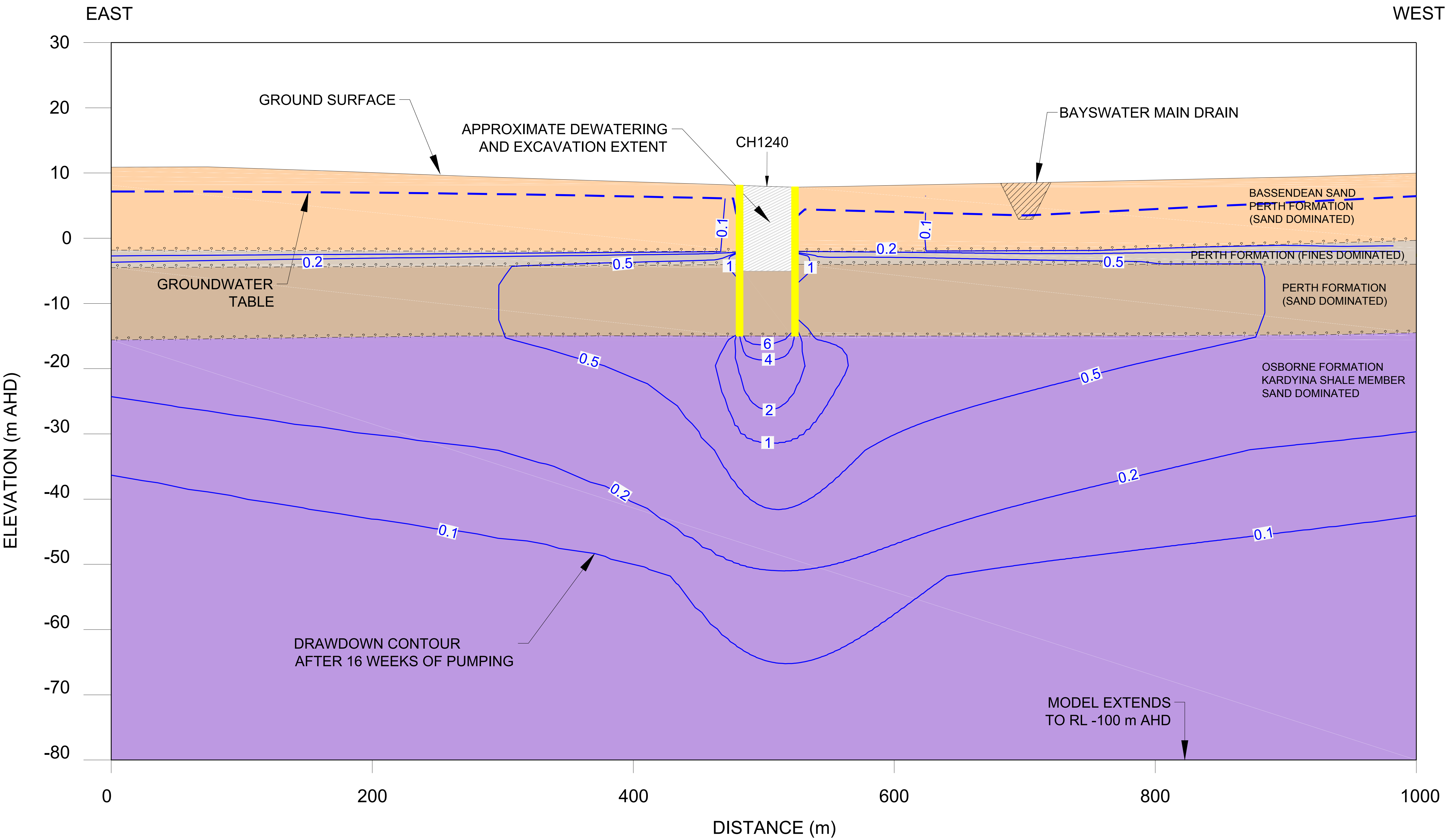
CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.21
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
GROUNDWATER TABLE DRAWDOWN CONTOURS SCENARIO 1A: BAYSWATER TUNNEL PORTAL AND DIVE STRUCTURE (16 WEEKS) Kv:Kh = 0.1

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	6A



LEGEND

- BASSENDEAN SAND, PERTH FORMATION (SAND DOMINATED)
- PERTH FORMATION (FINES DOMINATED)
- PERTH FORMATION (SAND DOMINATED)
- OSBORNE FORMATION - KARDINYA SHALE MEMBER
- APPROXIMATE DEWATERING AND EXCAVATION EXTENT
- DIAPHRAGM WALLS
- 1 — DRAWDOWN CONTOUR (M) AFTER 16 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT
PUBLIC TRANSPORT AUTHORITY

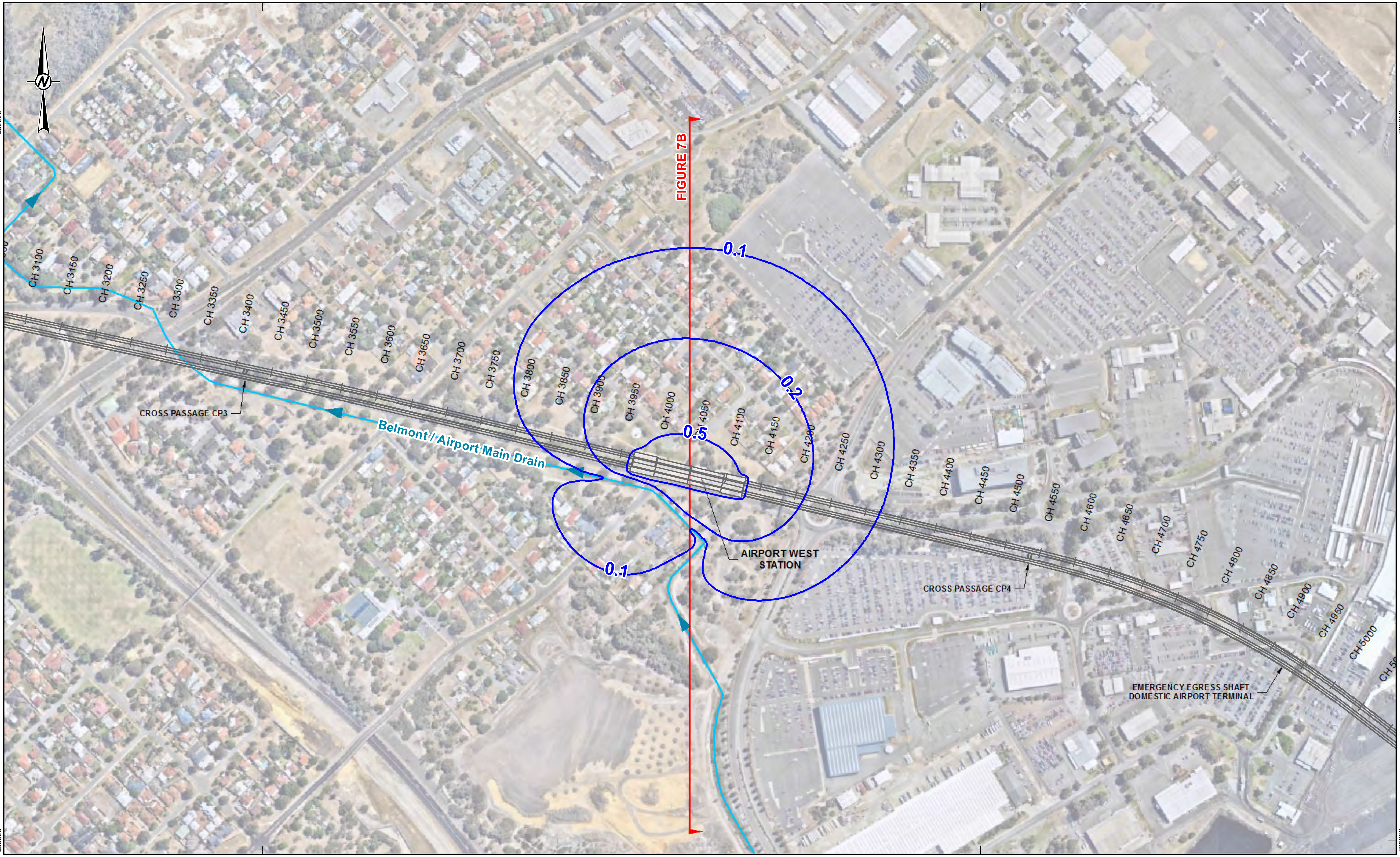
PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION SCENARIO 1A - BAYSWATER TUNNEL PORTAL (16 WEEKS) Kv:Kh = 0.1

PROJECT No.	CONTROL	Rev.	FIGURE
		----	6B



LEGEND

- GROUNDWATER LEVEL CHANGE CONTOUR (m)
- PROPOSED RAIL ALIGNMENT
- APPROXIMATE CROSS SECTION POSITION
- MAJOR OPEN DRAINS (FLOW DIRECTION INDICATED)

0 40 80 120 160 200 m

1:5,000

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT
Golder Associates

YYYY-MM-DD	2015.05.20
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

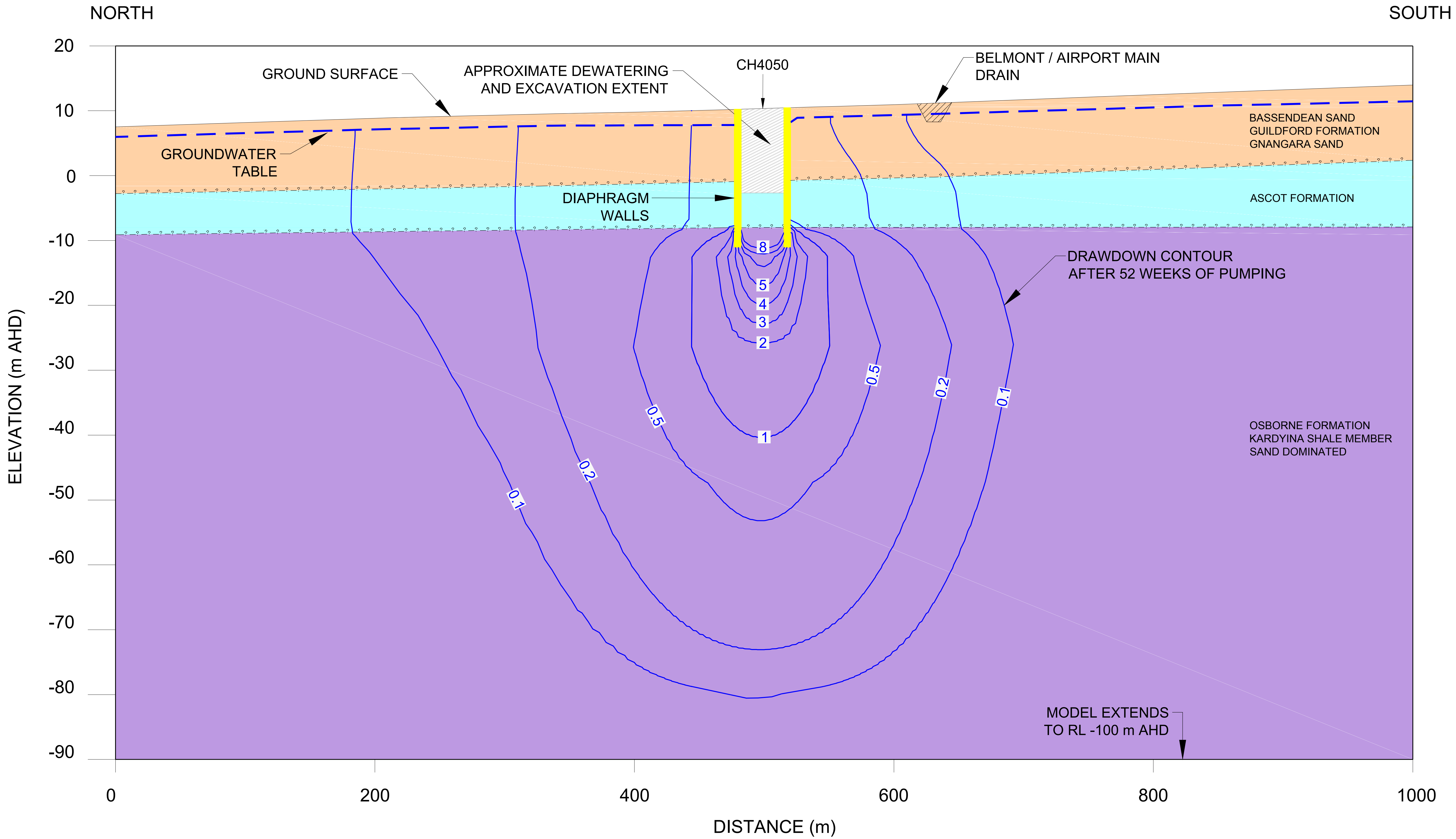
PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
GROUNDWATER TABLE DRAWDOWN CONTOURS
SCENARIO 2A: AIRPORT WEST STATION (52 WEEKS)
Kv:Kh = 0.1

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	**7A**

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

25mm



LEGEND

BASSENDEAN SAND, GUILDFORD FORMATION, GNANGARA SAND

ASCOT FORMATION

OSBORNE FORMATION KARDINYA SHALE MEMBER

APPROXIMATE DEWATERING AND EXCAVATION EXTENT

DIAPHRAGM WALLS

DRAWDOWN CONTOUR (M) AFTER 52 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT
PUBLIC TRANSPORT AUTHORITY

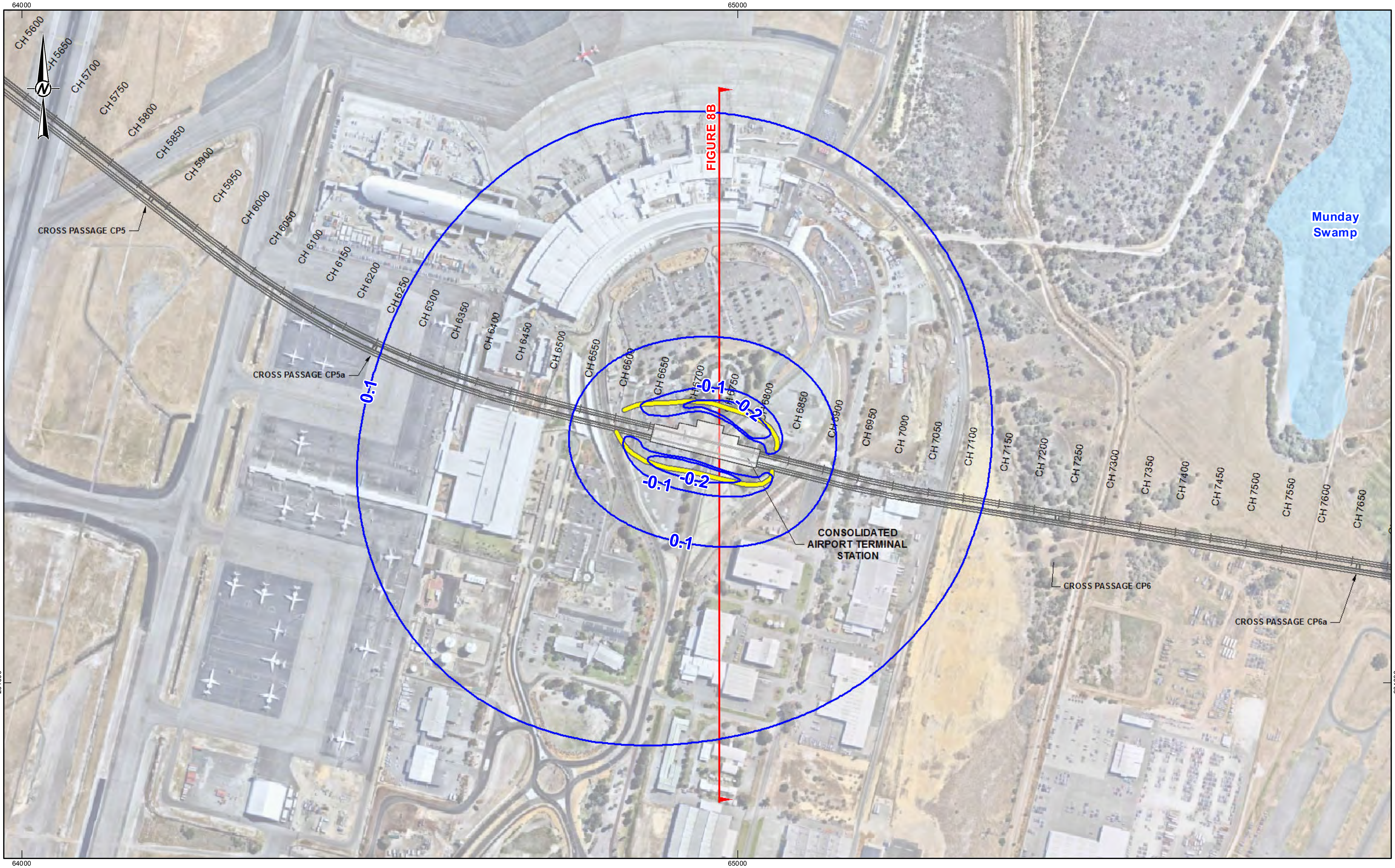
PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT

YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION
SCENARIO 2A: AIRPORT WEST STATION (52 WEEKS)
Kv:Kh = 0.1

PROJECT No.	CONTROL	Rev.	FIGURE
176742129	077R	0	7B



LEGEND

- GROUNDWATER LEVEL CHANGE CONTOUR (m)
- PROPOSED RAIL ALIGNMENT
- AREA OF MODEL RECHARGE WELLS
- APPROXIMATE CROSS SECTION POSITION

0 40 80 120 160 200 m

1:5,000

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

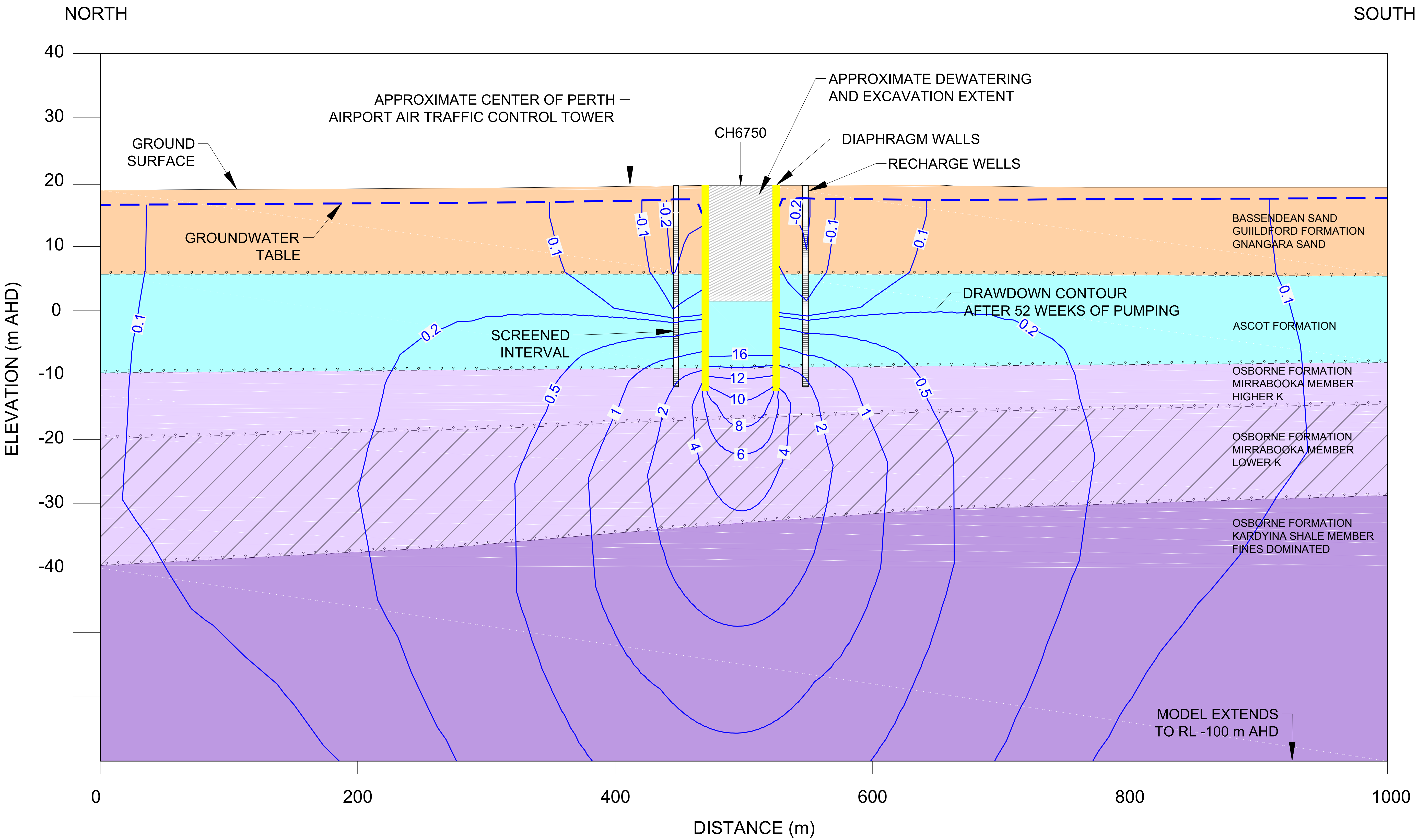
REFERENCE

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

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.20
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER TABLE DRAWDOWN CONTOURS SCENARIO 3A: CONSOLIDATED AIRPORT TERMINAL STATION (52 WEEKS) Kv:Kh = 0.1
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	8A

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

25mm

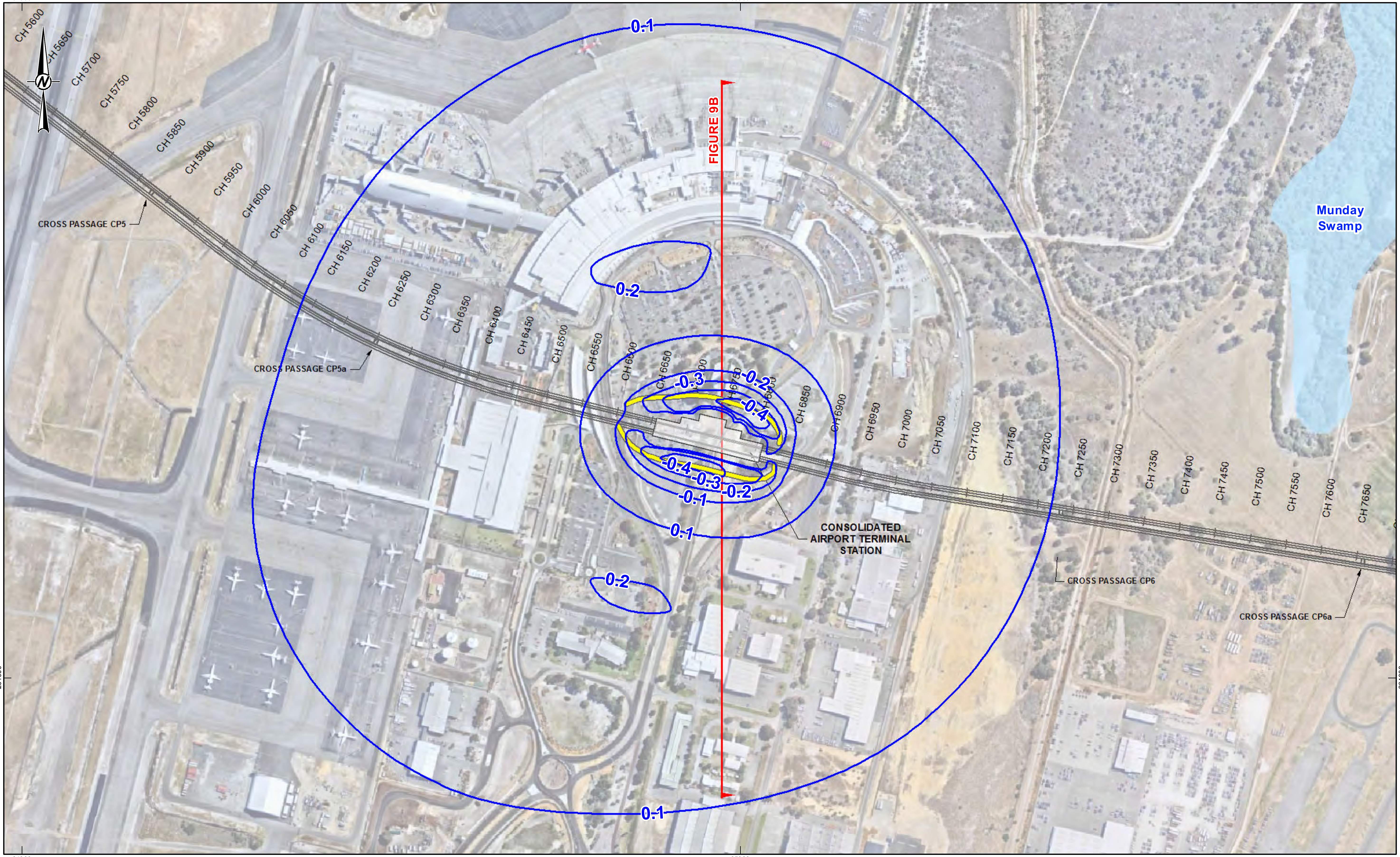


LEGEND

- BASSENDEAN SAND, GUILDFORD FORMATION, GNANGARA SAND
- ASCOTFORMATION
- OSBORNE FORMATION MIRRABOOKA MEMBER (HIGHER K)
- OSBORNE FORMATION MIRRABOOKA MEMBER (LOWER K)
- OSBORNE FORMATION KARDINYA SHALE MEMBER
- APPROXIMATE DEWATERING AND EXCAVATION EXTENT
- DIAPHRAGM WALLS
- DRAWDOWN CONTOUR (M) AFTER 52 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION SCENARIO 3A : CONSOLIDATED AIRPORT TERMINAL STATION (52 WEEKS) Kv:Kh = 0.1
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	8B



LEGEND

- GROUNDWATER LEVEL CHANGE CONTOUR (m)
- PROPOSED RAIL ALIGNMENT
- AREA OF MODEL RECHARGE WELLS
- APPROXIMATE CROSS SECTION POSITION

0 40 80 120 160 200 m

1:5,000

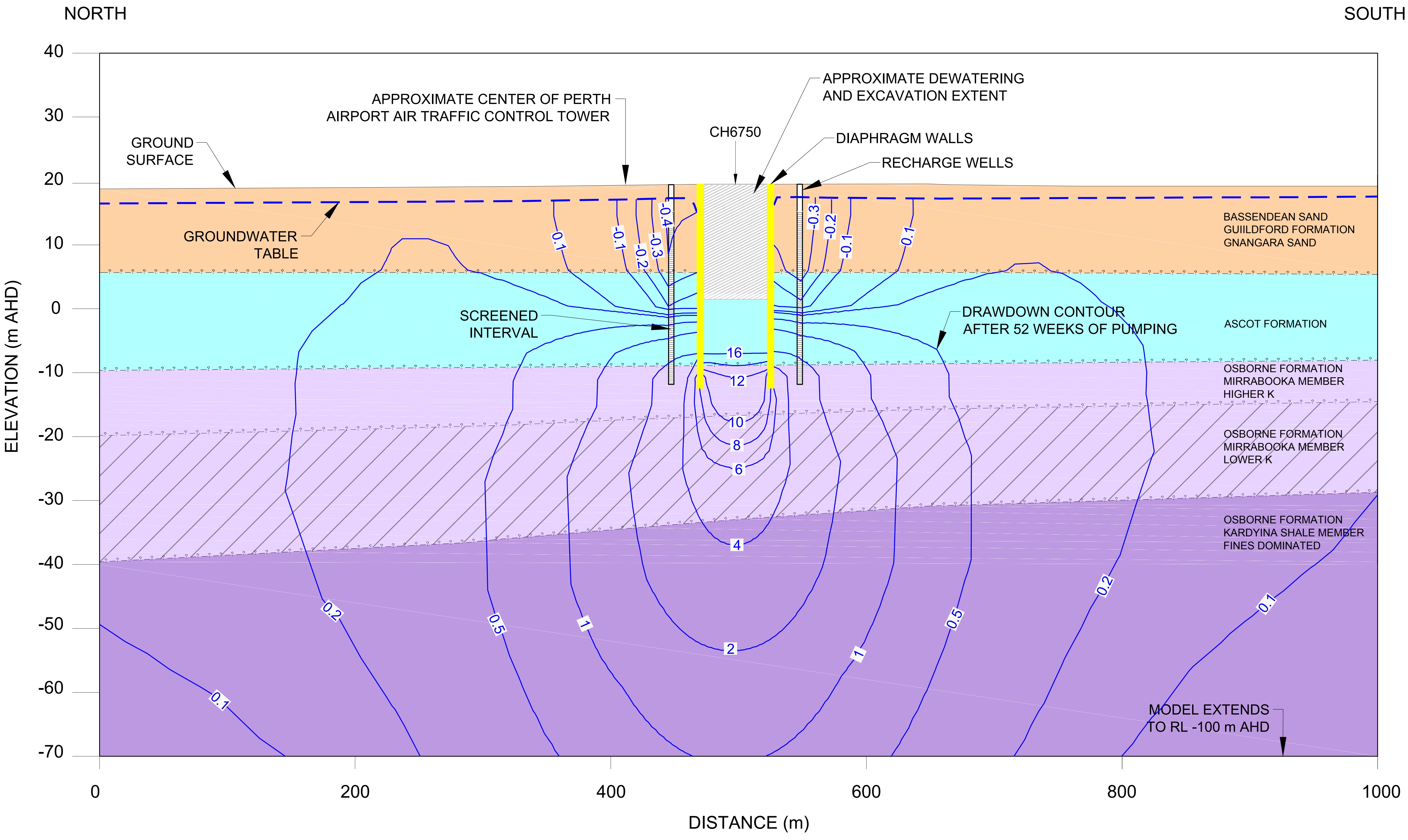
NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

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

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.20
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER TABLE DRAWDOWN CONTOURS SCENARIO 3B: CONSOLIDATED AIRPORT TERMINAL STATION (52 WEEKS) Kv:Kh = 1
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	9A



LEGEND

BASSENDEAN SAND, GUILDFORD FORMATION, GNANGARA SAND	OSBORNE FORMATION MIRRABOOKA MEMBER (LOWER K)
ASCOTFORMATION	OSBORNE FORMATION KARDINYA SHALE MEMBER
OSBORNE FORMATION MIRRABOOKA MEMBER (HIGHER K)	APPROXIMATE DEWATERING AND EXCAVATION EXTENT
DIAPHRAGM WALLS	DRAWDOWN CONTOUR (M) AFTER 52 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT
PUIBLIC TRANSPORT AUTHORITY

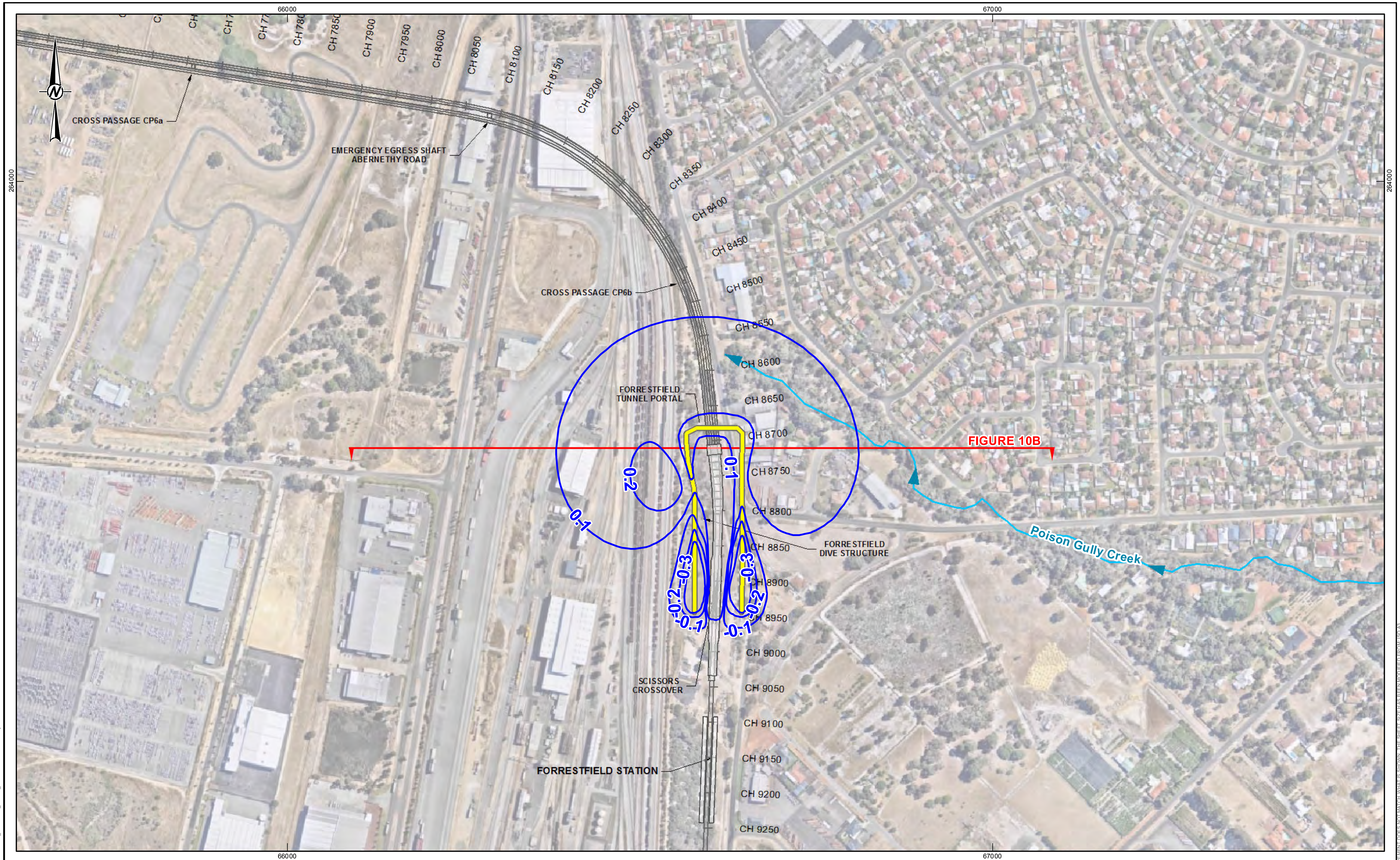
PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION SCENARIO 3B: CONSOLIDATED AIRPORT TERMINAL STATION (52 WEEKS) Kv:Kh = 1

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	9B



LEGEND

- GROUNDWATER LEVEL CHANGE CONTOUR (m)
- PROPOSED RAIL ALIGNMENT
- AREA OF MODEL RECHARGE WELLS
- APPROXIMATE CROSS SECTION POSITION
- MAJOR OPEN DRAINS (FLOW DIRECTION INDICATED)

0 40 80 120 160 200 m

1:5,000

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

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

CLIENT
PUBLIC TRANSPORT AUTHORITY

CONSULTANT
Golder Associates

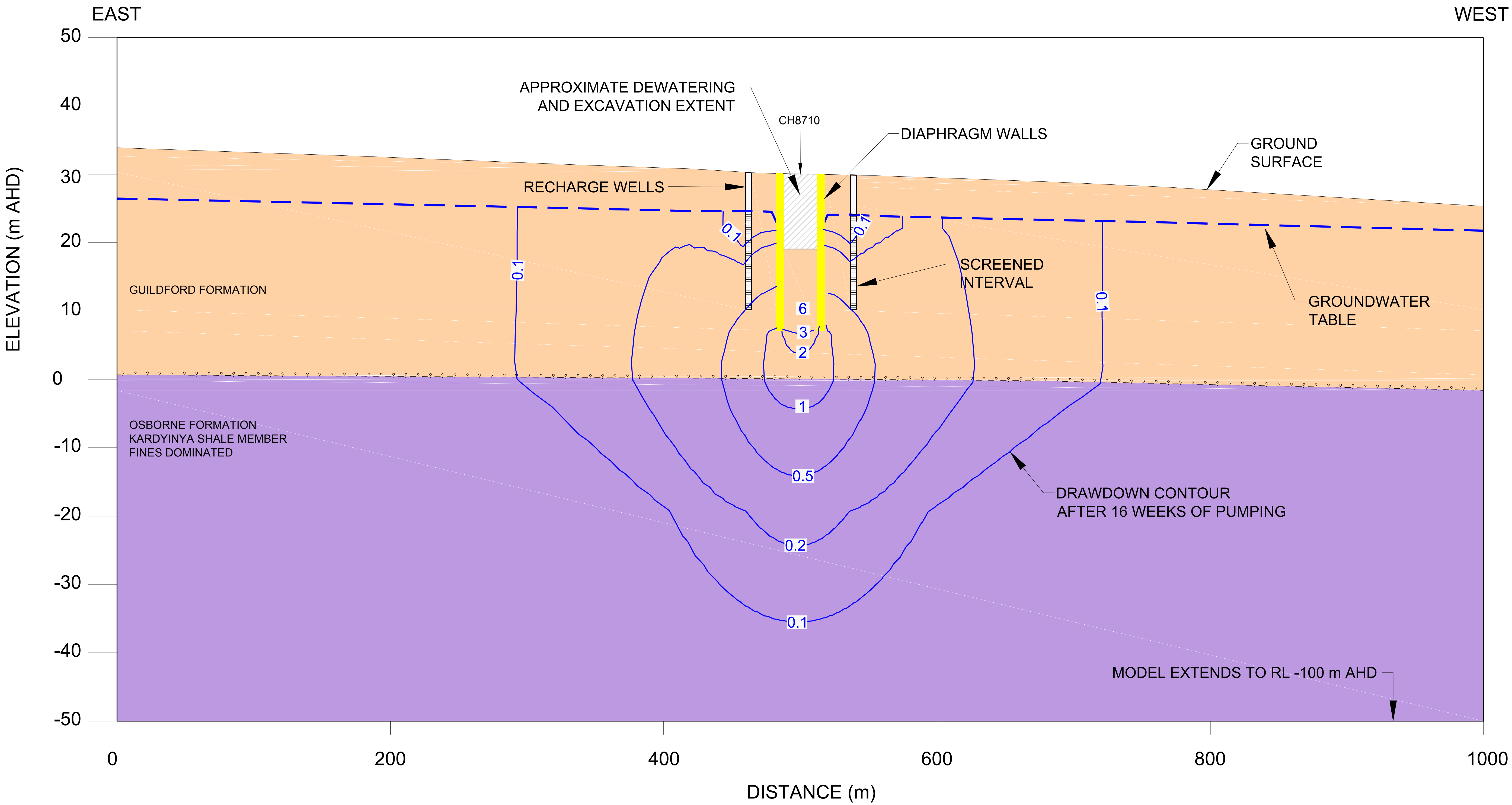
YYYY-MM-DD	2015.05.21
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
GROUNDWATER TABLE DRAWDOWN CONTOURS SCENARIO 4A: FORRESTFIELD TUNNEL PORTAL AND DIVE STRUCTURE (16 WEEKS) Kv:Kh = 0.1

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	10A

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

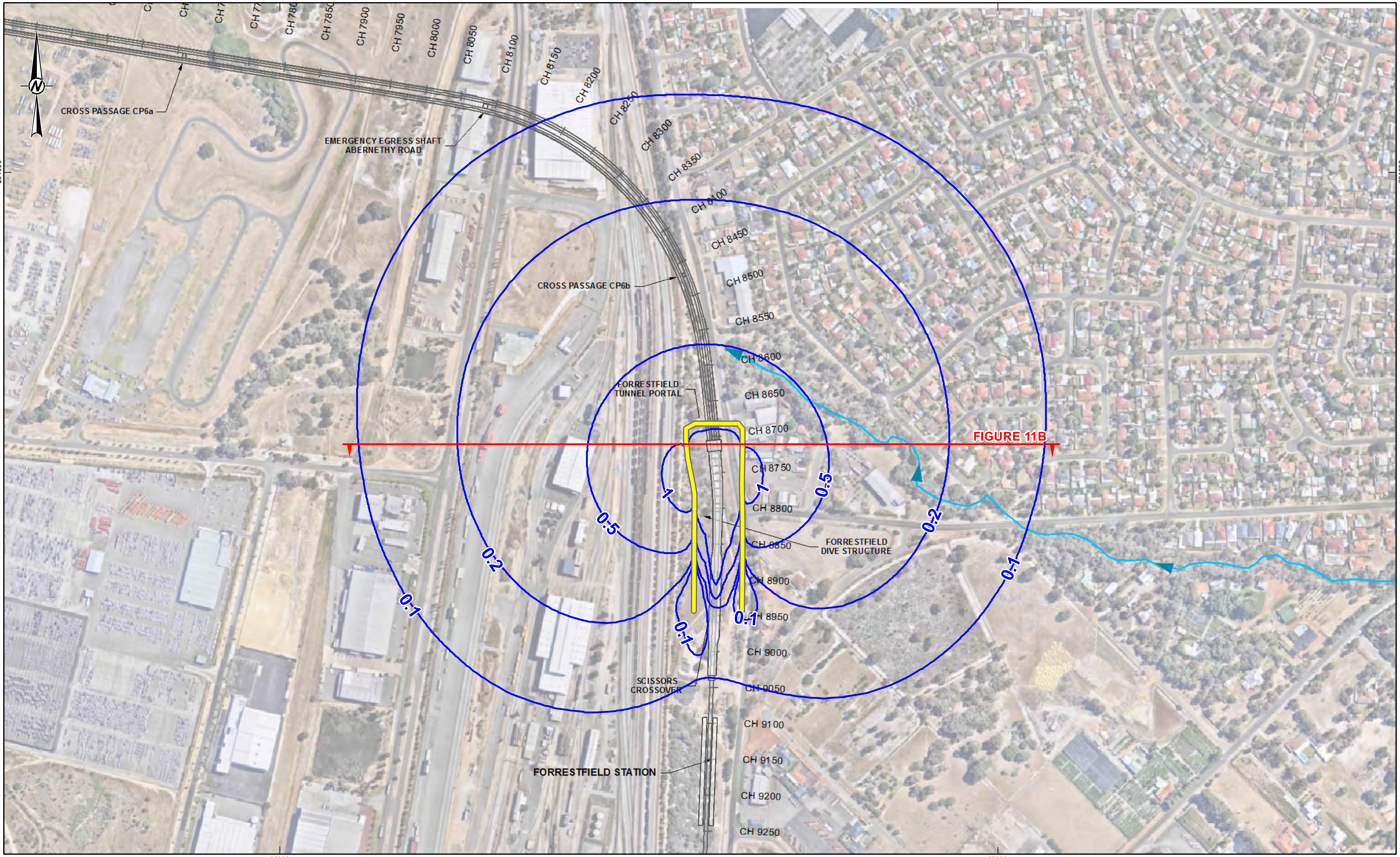


LEGEND

- BASSENDEAN SAND, GUILDFORD FORMATION, GNANGARA SAND
- OSBORNE FORMATION KARDYINA SHALE MEMBER
- APPROXIMATE DEWATERING AND EXCAVATION EXTENT
- DIAPHRAGM WALLS
- DRAWDOWN CONTOUR (M) AFTER 16 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	**GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION SCENARIO 4A: FORRESTFIELD TUNNEL PORTAL (16 WEEKS) Kv:Kh = 0.1**
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	10B



LEGEND

- GROUNDWATER LEVEL CHANGE CONTOUR (m)
- PROPOSED RAIL ALIGNMENT
- AREA OF MODEL RECHARGE WELLS
- APPROXIMATE CROSS SECTION POSITION
- MAJOR OPEN DRAINS (FLOW DIRECTION INDICATED)

0 40 80 120 160 200 m

1:5,000

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

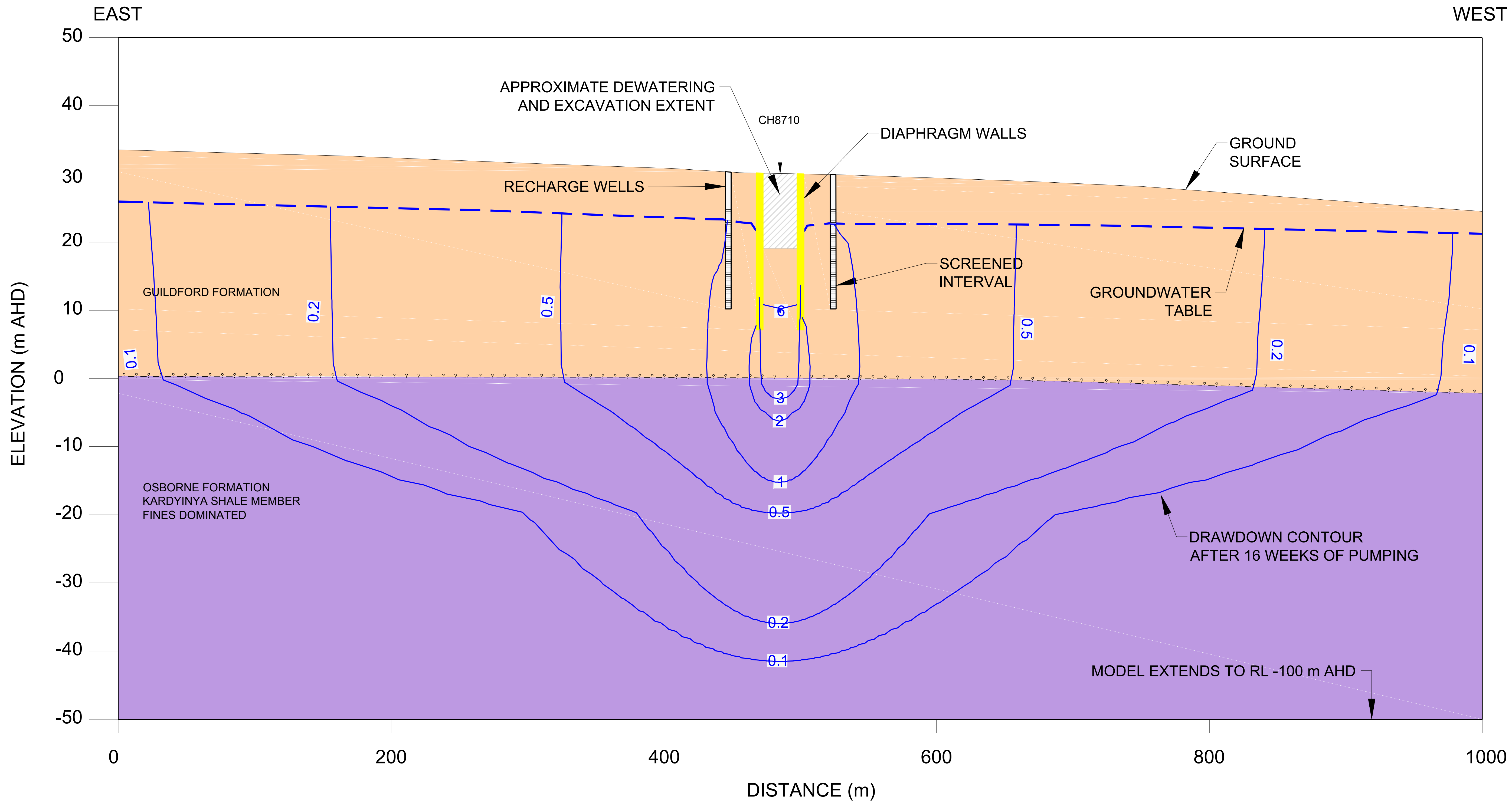
REFERENCE

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

CLIENT	PUBLIC TRANSPORT AUTHORITY
PROJECT	FORRESTFIELD-AIRPORT LINK STAGE 2 GEOTECHNICAL INVESTIGATION
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.21
PREPARED	MS/SWG
DESIGN	
REVIEW	AL
APPROVED	DPS
TITLE	GROUNDWATER TABLE DRAWDOWN CONTOURS SCENARIO 4B: FORRESTFIELD TUNNEL PORTAL AND DIVE STRUCTURE (16 WEEKS) Kv:Kh = 1
PROJECT No.	147642129
CONTROL	077 R
Rev.	0
FIGURE	11A

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

25mm



LEGEND

- BASSENDEAN SAND, GUILDFORD FORMATION, GNANGARA SAND
- OSBORNE FORMATION KARDYINA SHALE MEMBER
- APPROXIMATE DEWATERING AND EXCAVATION EXTENT
- DIAPHRAGM WALLS
- — 1 — DRAWDOWN CONTOUR (M) AFTER 16 WEEKS OF PUMPING

SCALE AS SHOWN

CLIENT
PUBLIC TRANSPORT AUTHORITY

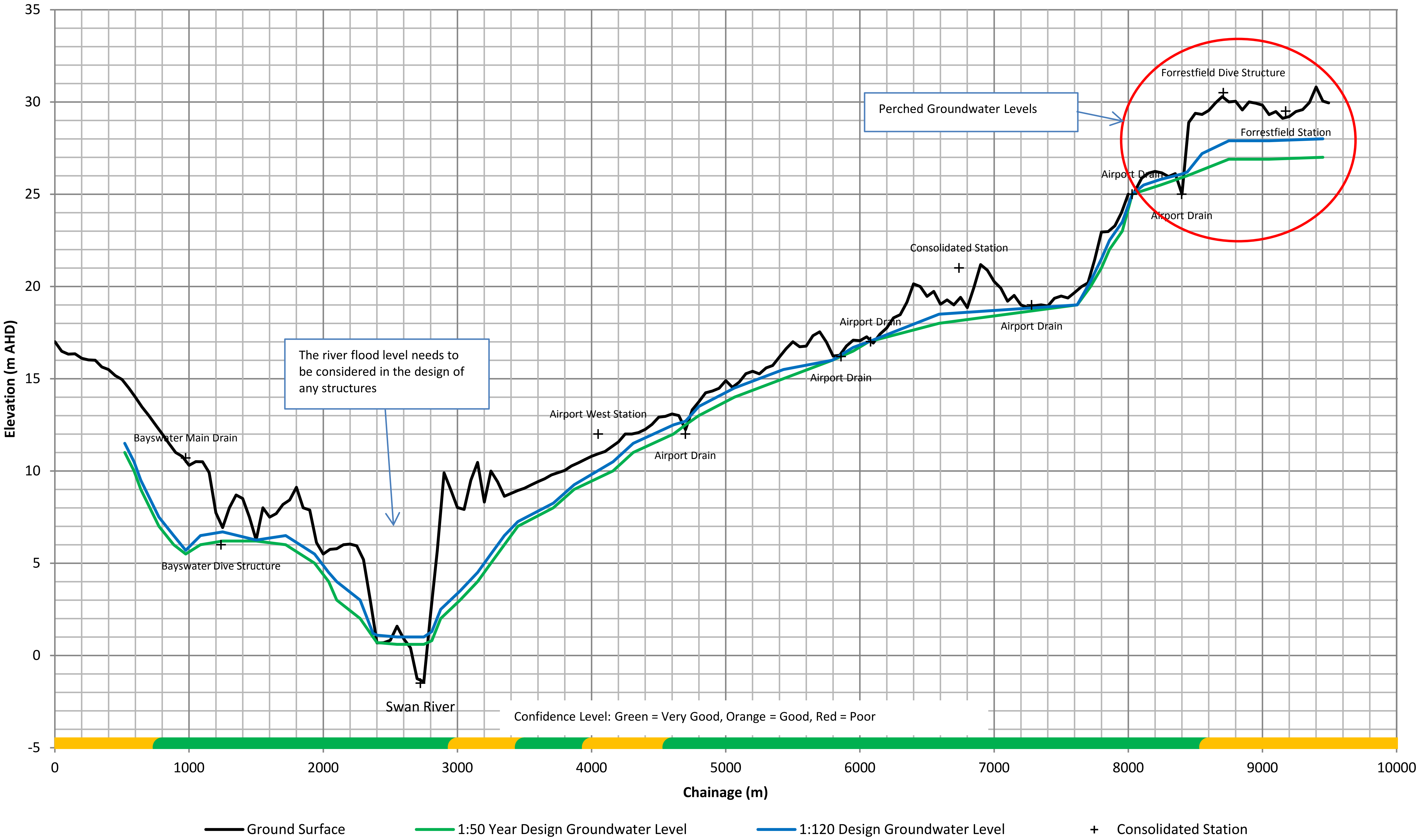
PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
GROUNDWATER DRAWDOWN CONTOURS - CROSS SECTION SCENARIO 4B: FORRESTFIELD TUNNEL PORTAL (16 WEEKS) Kv:Kh = 1

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	11B



CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT

Golder Associates

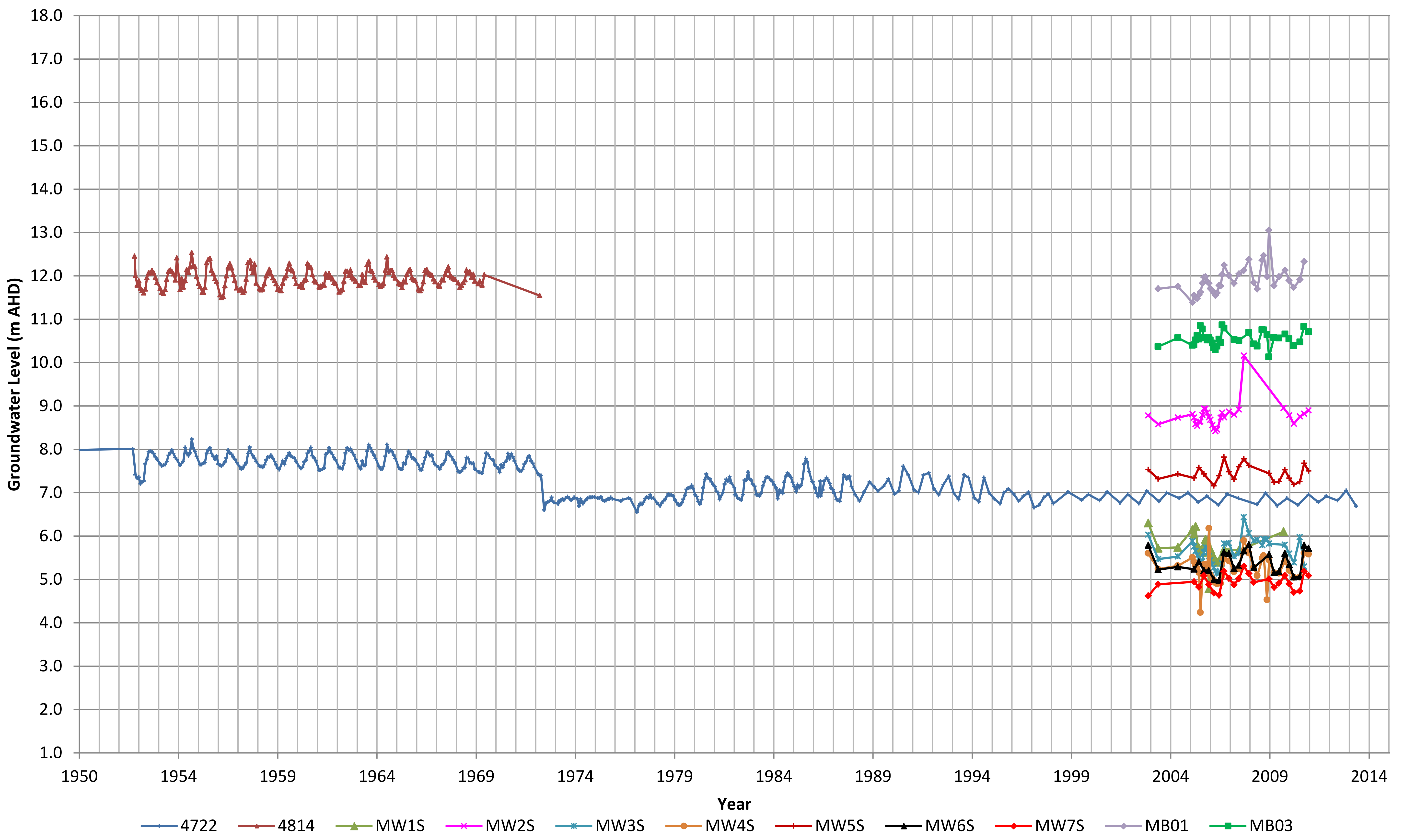
YYY/MM/DD	2015-05-22
PREPARED	AL
DESIGN	AL
REVIEW	DPS
APPROVED	DPS

TITLE
50 AND 120 DESIGN GROUNDWATER LEVEL

PROJECT No.	Control	Rev.	FIGURE
147642129	077	0	12

APPENDIX A

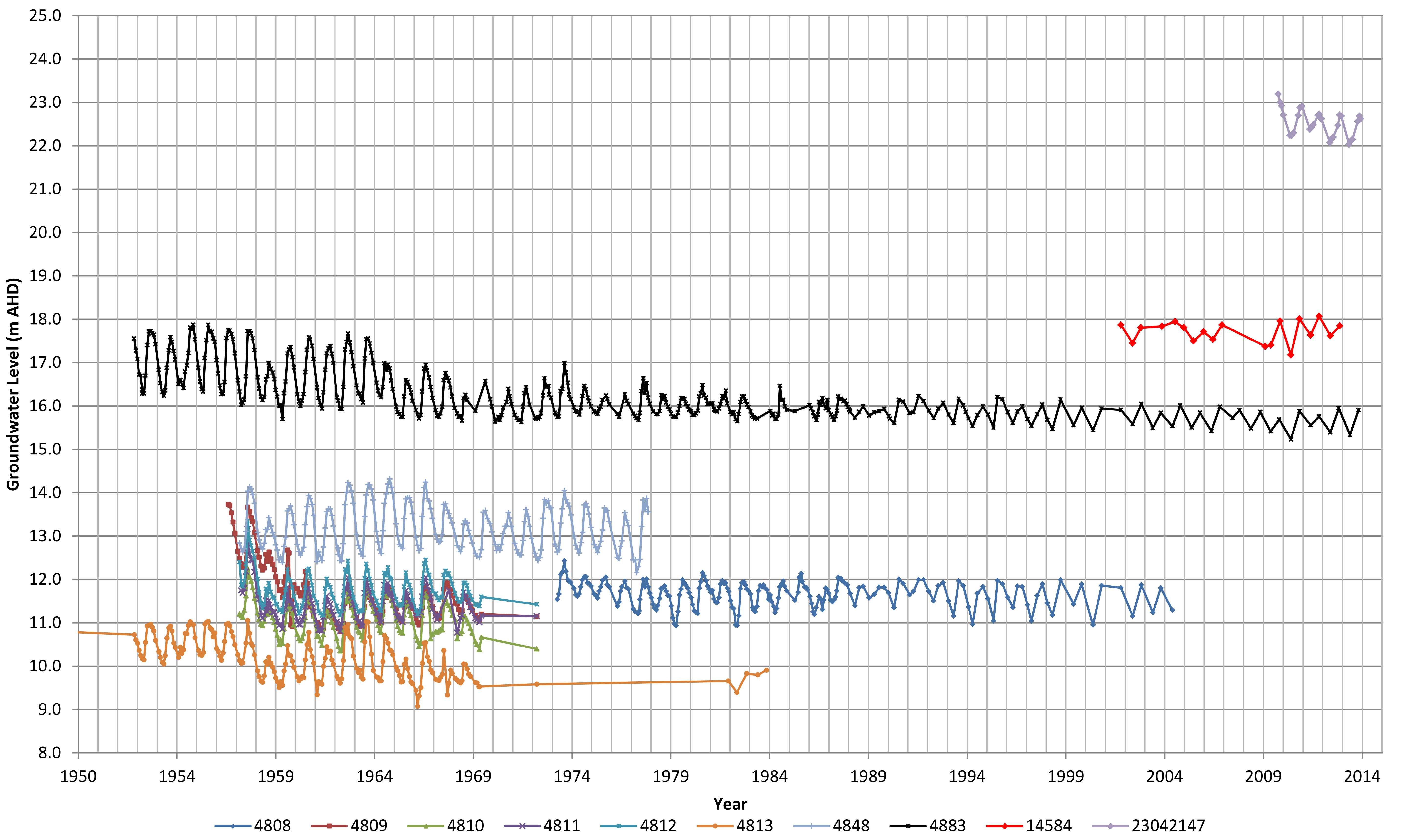
Historical Hydrographs



Dow Wells (4722 and 4814) obtained from DoW WIN database

All other wells obtained from PB2013

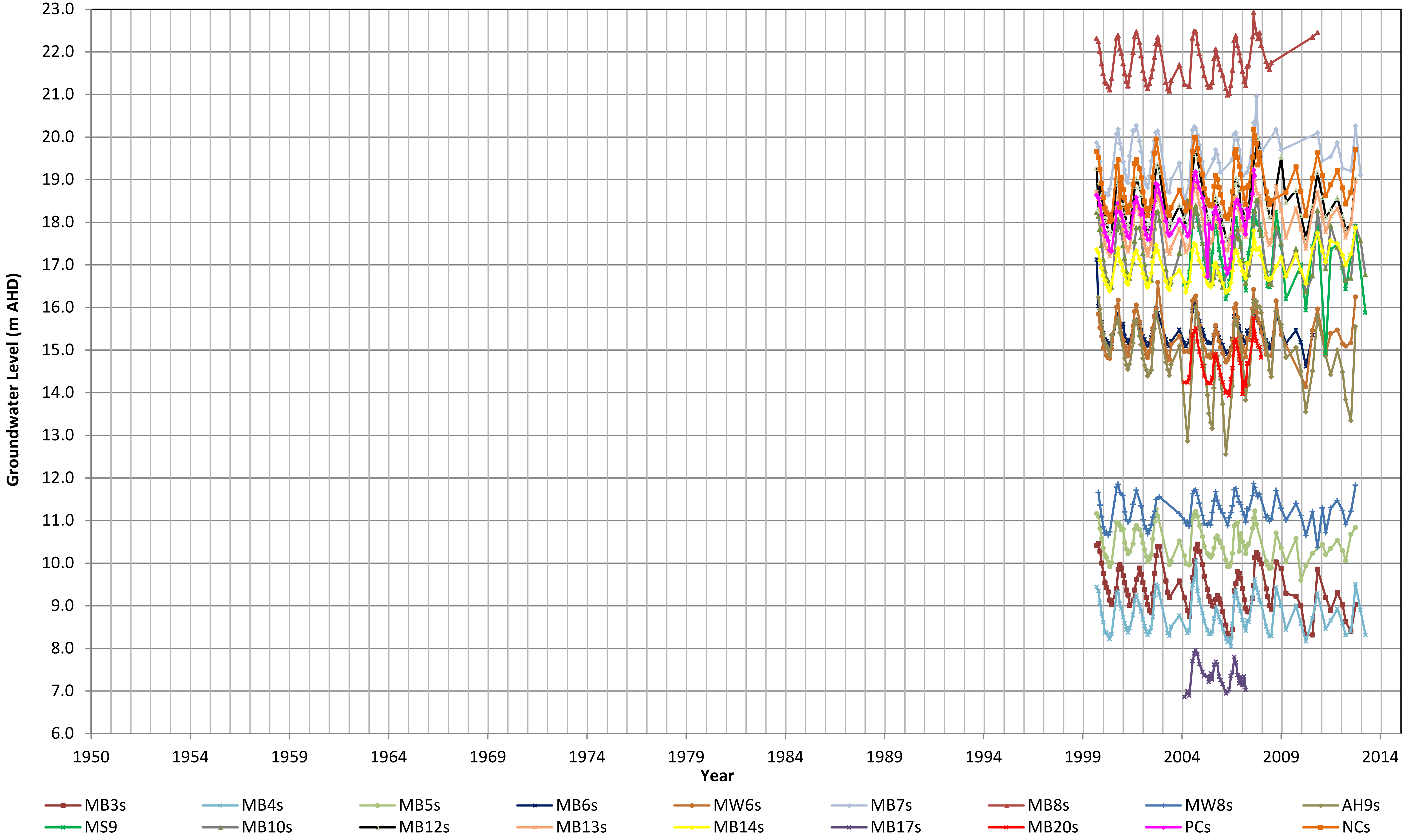
CLIENT	Public Transport Authority		PROJECT	Forrestfield-Airport Link Stage 2 Geotechnical Investigation
DRAWN	AL	DATE May 2015	TITLE	**Hydrographs - West Zone Upper Aquifer**
CHECK	DPS	DATE May 2015		
SCALE	Not To Scale	A3	PROJECT No. 147642129-077-Rev0	**APPENDIX A1**



Information obtained from DoW WIN Database

Golder Associates

CLIENT	Public Transport Authority			PROJECT	Forrestfield-Airport Link Stage 2 Geotechnical Investigation
DRAWN	AL	DATE	May 2015	TITLE	**Hydrographs - East Zone DoW Wells**
CHECK	DPS	DATE	May 2015		
SCALE	Not To Scale	A3		PROJECT No.	147642129-077-Rev0 **APPENDIX A2**



Information obtained from PAPL

CLIENT	Public Transport Authority		PROJECT	Forrestfield-Airport Link Stage 2 Geotechnical Investigation
DRAWN	AL	DATE May 2015	TITLE	**Hydrographs - East Zone PAPL Wells**
CHECK	DPS	DATE May 2015		
SCALE	Not To Scale	A3	PROJECT No. 147642129-077-Rev0	**APPENDIX A3**

J:\Geo\2014\147642129 - PTA FAL Stage 2 Geotechnical Investigation\03 Correspondence & Report\077-R Groundwater Conditions Report\Rev0\Appendix A - Hydrographs\147642129-077-R-Rev0 - Appendix A - Hydrographs.xlsx

APPENDIX B

March 2015 Groundwater Level Measurements

10 MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVEL MEASUREMENTS																
Well ID	Chainage *	Offset (m) **	Type	Easting (PCG94)	Northing (PCG94)	Surface Elevation (m AHD)	Top of Casing Elevation (m AHD)	Monument Type	Borehole Depth (m)	Well or VWP Sensor Depth (m)	Screen (m bgl)		Material Screened	Aquifer	Groundwater or Piezometric Level	
											from	to			m b TOC	m AHD
LG 3-153	1435	-30	LG	60,395	266,740	9.17	9.80	Riser	20.0	13.0	6.0	13.0	Bassendean Sand	Upper	4.59	5.21
LG 3-149	1575	-20	LG	60,500	266,647	8.83	9.49	Riser	18.0	18.0	11.0	18.0	Perth Formation Clay Dominated	Aquitard	6.86	2.63
LG 2-18	2425	-18	LG	61,082	266,029	0.62	0.55	Riser	39.0	21.5	15.5	21.5	Swan River Alluvium	Aquitard	0.30	0.25
LG 3-131	2600	-19	LG	61,200	265,899	0.55	0.43	Gatic	19.5	19.5	15.5	19.5	Swan River Formation	Aquitard	0.26	0.17
LG 2-14	2825	35	LG	61,415	265,822	2.58	2.44	Gatic	35.0	31.9	16.9	31.9	Osborne Formation	Osborne	1.85	0.59
MW 3-180	70	0	MW	59,182	267,262	16.38	16.29	Gatic	6.5	6.5	3.5	6.5	Bassendean Sand	Upper	4.88	11.41
MW 3-175	500	-25	MW	59,650	267,164	15.06	14.98	Gatic	7.5	7.3	4.3	7.3	Bassendean Sand	Upper	5.17	9.81
MW 3-172	970	-20	MW	60,040	267,025	7.08	6.98	Gatic	4.5	2.7	1.2	2.7	Bassendean Sand	Upper	2.10	4.88
BH 2-26	1130	0	MW	60,187	266,966	10.14	10.73	Riser	35.0	35.0	26.0	35.0	Osborne Formation	Osborne	7.98	2.75
MW 3-165	1175	10	MW	60,242	266,946	8.54	9.12	Riser	17.0	5.0	2.0	5.0	Bassendean Sand	Upper	3.85	5.27
MW 3-166	1185	15	MW	60,232	266,948	9.23	9.85	Riser	20.0	5.5	2.5	5.5	Bassendean Sand	Upper	4.62	5.23
MW 3-159	1195	67	MW	60,287	266,976	9.86	10.56	Riser	6.2	5.2	2.2	5.2	Bassendean Sand	Upper	4.96	5.60
MW 2-02C	1230	8	MW	60,274	266,911	6.92	7.62	Riser	20.0	19.0	11.5	19.0	Perth Formation	Lower	6.05	1.57
MW 2-02A	1233	8	MW	60,277	266,911	6.90	7.67	Riser	26.0	26.0	22.0	26.0	Perth Formation	Lower	6.10	1.57
MW 2-02B	1235	48	MW	60,303	266,939	7.90	8.67	Riser	26.0	26.0	10.5	26.0	Perth Formation	Lower	6.98	1.69
MW 2-02D	1236	8	MW	60,279	266,909	6.87	7.63	Riser	6.9	6.7	0.7	6.7	Bassendean Sand	Upper	2.36	5.27
MW 3-156	1325	17	MW	60,338	266,863	7.89	8.56	Riser	17.0	17.0	15.0	17.0	Perth Formation Sand Dominated	Lower	6.96	1.60
MW 3-145	1805	-18	MW	60,660	266,483	9.77	9.69	Gatic	6.5	5.2	3.2	5.2	Bassendean Sand	Upper	4.47	5.22
MW 3-140	2195	43	MW	60,975	266,240	6.37	6.27	Gatic	6.0	6.0	3.5	6.0	Bassendean Sand	Upper	4.90	1.37
MW 3-137	2285	18	MW	61,015	266,157	5.28	5.22	Gatic	6.0	6.0	3.0	6.0	Perth Formation Sand Dominated	Upper	4.36	0.86
MW 3-136 (d)	2295	-18	MW	60,992	266,128	5.25	5.21	Gatic	28.5	15.5	12.5	15.5	Perth Formation Clay Dominated	Upper	4.38	0.83
MW 3-136 (s)	2295	-18	MW	60,993	266,129	5.25	5.22	Gatic	5.0	5.0	1.0	5.0	Perth Formation Sand Dominated	Upper	4.38	0.84
MW 3-132	2620	19	MW	61,237	265,914	0.83	0.79	Gatic	27.0	4.0	1.0	4.0	Swan River Formation	Superficial	0.46	0.33
MW 3-128	2815	30	MW	61,402	265,821	2.26	2.24	Gatic	37.0	4.0	1.0	4.0	Perth Formation Sand Dominated	Superficial	2.02	0.22
MW 3-125	3270	-64	MW	61,818	265,624	8.60	8.50	Gatic	5.3	5.3	2.3	5.3	Perth Formation Sand Dominated	Superficial	2.86	5.64
MW 3-121 (d)	3320	-28	MW	61,880	265,647	8.75	8.69	Gatic	27.1	22.0	19.5	23.7	Ascot Formation	Superficial	2.75	5.94
MW 3-121 (s)	3320	-28	MW	61,881	265,647	8.72	8.65	Gatic	6.0	5.5	1.0	5.5	Bassendean Sand	Superficial	2.59	6.06
MW 2-03	3330	-19	MW	61,888	265,654	8.75	8.68	Gatic	21.0	21.0	18.0	21.0	Osborne Formation	Osborne	2.69	5.99
MW 3-118	3695	-71	MW	62,232	265,524	9.66	9.57	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.89	7.68
MW 3-115	3705	39	MW	62,269	265,627	8.20	8.09	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.06	7.03
MW 3-109 (d)	3845	22	MW	62,403	265,579	9.84	9.75	Gatic	14.5	14.5	12.0	14.5	Ascot Formation	Superficial	2.09	7.66
MW 3-109 (i)	3850	22	MW	62,406	265,578	9.82	9.74	Gatic	10.0	10.0	8.0	10.0	Gnangara Sand	Superficial	2.06	7.68
MW 3-109 (s)	3855	22	MW	62,409	265,577	9.92	9.82	Gatic	4.5	4.5	1.5	4.5	Bassendean Sand	Superficial	2.14	7.68
MW 2-01D	3870	-3	MW	62,419	265,548	10.08	10.05	Gatic	18.0	17.0	11.0	17.0	Ascot Formation	Superficial	2.17	7.88
MW 3-108	3870	-44	MW	62,410	265,508	10.00	9.91	Gatic	20.0	17.5	14.5	17.5	Ascot Formation	Superficial	1.90	8.01
MW 2-01B	3910	-48	MW	62,447	265,496	10.12	10.05	Gatic	8.0	8.0	2.0	8.0	Bassendean Sand	Superficial	1.88	8.17
MW 2-01A	3925	-6	MW	62,473	265,533	10.32	10.28	Gatic	8.9	8.0	2.0	8.0	Bassendean Sand	Superficial	2.16	8.12
MW 2-01C	3925	-2	MW	62,473	265,537	10.33	10.29	Gatic	19.5	17.0	10.5	17.0	Ascot Formation	Superficial	2.19	8.10
MW 2-01E	3925	-4	MW	62,473	265,535	10.29	10.26	Gatic	25.0	23.0	20.0	23.0	Osborne Formation	Osborne	2.19	8.07
MW 3-105	3935	68	MW	62,498	265,603	10.12	10.02	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	2.08	7.94
MW 3-104	3970	23	MW	62,524	265,550	10.02	9.92	Gatic	18.1	17.1	14.1	17.1	Ascot Formation	Superficial	1.75	8.17
MW 3-103	3975	-49	MW	62,510	265,480	10.26	10.17	Gatic	14.0	4.5	1.5	4.5	Bassendean Sand	Superficial	1.83	8.34
BH 2-01	4035	-30	MW	62,575	265,483	10.44	11.01	Riser	28.0	18.5	11.0	18.5	Ascot Formation	Superficial	2.51	8.50
MW 3-100	4070	-48	MW	62,600	265,459	10.41	11.11	Riser	4.5	4.5	1.5	4.5	Bassendean Sand	Superficial	2.65	8.46
MW 3-099	4090	50	MW	62,645	265,547	10.29	10.19	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.83	8.36
MW 3-096	4335	-34	MW	62,867	265,412	11.96	11.86	Gatic	18.5	3.8	0.8	3.8	Bassendean Sand	Superficial	1.84	10.02
MW 3-094	4590	18	MW	63,125	265,402	12.96	12.98	Gatic	23.0	4.0	1.0	4.0	Bassendean Sand	Superficial	2.19	10.79
MW 3-093	4665	-46	MW	63,178	265,320	13.44	13.36	Gatic	4.5	4.5	1.5	4.5	Bassendean Sand	Superficial	2.15	11.21
MW 3-092	4675	42	MW	63,214	265,400	12.88	12.79	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.72	11.07
MW 3-089	4775	40	MW	63,309	265,362	13.50	13.42	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.77	11.65
MW 3-090	4825	-21	MW	63,330	265,284	14.00	13.88	Gatic	4.0	4.0	1.0	4.0	Bassendean Sand	Superficial	1.63	12.25
MW 3-087	4970	-27	MW	63,445	265,208	14.81	14.71	Gatic	3.5	3.5	0.9	3.5	Bassendean Sand	Superficial	1.00	13.71
MW 1-03	5030	17	MW	63,522	265,208	14.68	14.59	Gatic	14.5	14.5	11.5	14.5	Ascot Formation	Superficial	1.89	12.70
MW 3-086 (d)	5035	15	MW	63,522	265,205	14.72	14.66	Gatic	28.0	22.0	20.0	22.0	Osborne Formation	Osborne	1.96	12.70
BH 1-25	6660	-5	MW	64,884	264,345	19.23	19.16	Gatic	48.0	42.0	29.0	42.0	Osborne Formation (Mirrabooka)	Osborne	2.28	16.88
MW 3-080 (d)	6660	30	MW	64,893	264,379	19.14	19.04	Gatic	20.0	20.0	17.0	20.0	Ascot Formation	Superficial	2.26	16.78
MW 3-080 (s)	6660	30	MW	64,891	264,378	19.17	19.08	Gatic	20.0	4.5	1.0	4.5	Bassendean Sand	Superficial	2.32	16.76
BH 1-21	6725	37	MW	64,955	264,371	19.03	19.54	Riser	36.0	24.9	15.9	24.9	Ascot Formation	Superficial	2.64	16.90
MW 3-077	6730	-27	MW	64,944	264,308	19.40	19.29	Gatic	14.0	5.0	1.5	5.0	Bassendean Sand	Superficial	2.38	16.91
MW 3-079	6730	-140	MW	64,915	264,197	20.38	20.32	Gatic	5.0	5.0	1.5	5.0	Bassendean Sand	Superficial	3.16	17.16
MW 1-02B	6780	-40	MW	64,989	264,283	19.45	20.08	Riser	28.5	26.0	14.0	26.0	Ascot Formation	Superficial	2.97	17.11
MW 1-02C	6785	-9	MW	65,005	264,311	18.63	19.32	Riser	11.0	11.0	5.0	11.0	Bassendean Sand	Superficial	2.30	17.02
MW 1-02D	6785	-6	MW	65,006	264,312	18.55	19.26	Riser	26.0	25.8	13.8	25.8	Ascot Formation	Superficial	2.17	17.09
MW 1-02A	6805	25	MW	65,032	264,340	18.56	19.05	Riser	36.0	26.0	14.0	26.0	Ascot Formation	Superficial	2.00	17.05
BH 1-13	7330	22	MW	65,544	264,238	18.90	19.55	Riser	36.0	16.5	15.5	16.5	Ascot Formation	Superficial	2.32	17.23
MW 3-065	7375	18	MW	65,588	264,226	18.72	19.22	Gatic	26.0	4.0	1.0	4.0	Bassendean Sand	Superficial	2.92	16.30
BH 1-12	7445	22	MW	65,658	264,219	18.94	19.60	Riser	35.0	23.5	15.5	23.5	Ascot Formation	Superficial	2.37	17.23
MW 3-064	7535	16	MW	65,746	264,200	19.09	19.56	Gatic	26.0	4.0	1.0	4.0	Bassendean Sand	Superficial	2.30	17.26

10 MARCH 2015 GROUNDWATER AND PIEZOMETRIC LEVEL MEASUREMENTS

Well ID	Chainage *	Offset (m) **	Type	Easting (PCG94)	Northing (PCG94)	Surface Elevation (m AHD)	Top of Casing Elevation (m AHD)	Monument Type	Borehole Depth (m)	Well or VWP Sensor Depth (m)	Screen (m bgl)		Material Screened	Aquifer	Groundwater or Piezometric Level	
											from	to			m b TOC	m AHD
MW 1-04	8110	15	MW	66,311	264,103	26.30	26.27	Gatic	31.5	31.5	28.5	31.5	Osborne Formation	Osborne	3.87	22.40
MW 3-060 (d)	8110	0	MW	66,308	264,087	26.33	26.29	Gatic	27.0	17.5	15.5	17.5	Guildford Formation	Superficial	3.86	22.43
MW 3-060 (s)	8110	0	MW	66,308	264,088	26.33	26.29	Gatic	4.5	4.0	1.0	4.0	Bassendean Sand	Perched	2.40	23.89
MW 3-059	8130	-33	MW	66,303	264,054	26.39	26.28	Gatic	4.0	3.5	1.0	3.5	Bassendean Sand	Perched	2.36	23.92
MW 3-055	8360	112	MW	66,599	264,019	28.81	28.71	Gatic	7.0	7.0	4.0	7.0	Guildford Formation	Superficial	5.95	22.76
MW 3-052	8545	-21	MW	66,564	263,781	28.35	28.97	Riser	17.0	10.0	7.0	10.0	Guildford Formation	Superficial	6.11	22.86
MW 3-051 (d)	8665	-40	MW	66,560	263,664	29.41	30.05	Riser	17.5	17.5	15.5	17.5	Guildford Formation	Superficial	7.18	22.87
MW 3-051 (s)	8665	-40	MW	66,560	263,662	29.39	30.01	Riser	17.5	7.0	4.0	7.0	Guildford Formation	Superficial	7.13	22.88
MW 1-01A	8710	13	MW	66,617	263,625	30.47	30.37	Gatic	46.2	32.0	8.0	32.0	Guildford Formation	Superficial	7.45	22.92
MW 1-01C	8720	12	MW	66,619	263,615	30.47	30.40	Gatic	45.0	32.3	7.0	32.3	Guildford Formation	Superficial	7.49	22.91
MW 1-01B	8725	-48	MW	66,558	263,604	29.33	29.26	Gatic	32.5	32.5	8.5	32.5	Guildford Formation	Superficial	6.37	22.89
MW 1-01D	8755	15	MW	66,624	263,578	30.19	30.07	Gatic	33.0	32.0	7.0	32.0	Guildford Formation	Superficial	7.15	22.92
MW 3-047	8780	18	MW	66,628	263,555	30.36	30.27	Riser	17.0	12.0	9.0	12.0	Guildford Formation	Superficial	7.32	22.95
MW 3-044 (d)	8825	-3	MW	66,606	263,509	29.54	30.27	Riser	14.0	14.0	11.0	14.0	Guildford Formation	Superficial	7.35	22.92
MW 3-044 (s)	8825	-3	MW	66,606	263,510	29.50	30.17	Riser	7.0	6.3	3.3	6.3	Guildford Formation	Perched	6.95	23.22
MW 3-038	8940	-57	MW	66,549	263,393	29.33	29.95	Riser	7.5	7.5	4.5	7.5	Guildford Formation	Superficial	7.07	22.88
MW 3-034	9010	200	MW	66,805	263,318	31.23	31.89	Riser	7.7	7.0	4.0	7.0	Guildford Formation	Perched	DRY	
MW 3-026	9170	-55	MW	66,542	263,164	28.39	29.02	Gatic	8.0	8.0	5.0	8.0	Guildford Formation	Superficial	6.22	22.80
MW 3-019	9250	75	MW	66,670	263,080	30.61	30.52	Gatic	6.5	6.5	3.5	6.5	Guildford Formation	Perched	4.32	26.20
MW 3-013	9315	506	MW	67,095	263,011	34.68	34.57	Gatic	17.5	17.3	16.3	17.3	Guildford Formation	Superficial	11.50	23.07
MW 3-012	9360	-58	MW	66,531	262,979	29.24	29.86	Riser	10.5	10.5	7.5	10.5	Guildford Formation	Superficial	6.97	22.89
MW 1-05	9595	-34	MW	66,548	262,742	28.42	28.42	Gatic	10.0	10.0	7.0	10.0	Guildford Formation	Superficial	5.01	23.41
MW 3-009	9630	6	MW	66,587	262,706	30.20	30.10	Gatic	8.0	6.9	3.9	5.9	Guildford Formation	Perched	5.56	24.54
MW 3-004	9755	-14	MW	66,561	262,579	30.00	29.89	Gatic	8.0	8.0	5.0	8.0	Guildford Formation	Perched	5.55	24.34
MW 3-001	9985	-32	MW	66,533	262,353	27.78	27.70	Gatic	6.0	6.0	3.0	6.0	Guildford Formation	Superficial	4.45	23.25
PW 2-02	1235	5	PW	60,275	266,907	6.91	7.40	Riser	27.0	26.0	10.5	26.0	Perth Formation	Lower	5.81	1.59
PW 2-01	3920	-4	PW	62,468	265,536	10.24	10.69	Riser	19.0	17.8	10.5	17.8	Ascot Formation	Superficial	2.57	8.12
PW 1-02	6790	-10	PW	65,009	264,309	18.60	18.99	Riser	28.5	26.0	12.0	26.0	Ascot Formation	Superficial	1.85	17.14

* Transposed perpendicular to alignment (approximate to nearest 5 m)

** Distance is measured to project centreline (between tunnels). Negative value is when monitoring point is located south or west of alignment. Positive value is when the monitoring point is located north or east of alignment

MW = Monitoring Well

VWP = Vibrating Wire Piezometer

LG = Gas Monitoring Well

PW = Pumping Well

NA = Not Applicable

NM = Not Measured

APPENDIX C

Summary of Analysis of PSD Samples

The hydraulic conductivity was calculated using Hazen's formula, shown below, which is an empirical method that uses data from the particle size distribution of a sample.

$$k = C_1 \times f(n) \times D_e^2 \times 975124$$

Where:

$C_1 = 0.0047$

$f(n) = 1$

$D_e = D_{10}$ in m

Hazen's method is usually used for samples with low fines content. Therefore samples with fines content greater than 10% were generally not analysed except for some samples from the Guildford and Perth Formation where samples with a fines content of up to 20% were analysed. It is therefore important to note that the derived hydraulic conductivities will be skewed toward giving higher hydraulic conductivity (i.e. the samples with large fines content which would result in low hydraulic conductivity have been excluded from analysis due to the limitation of the method).

The hydraulic conductivity was estimated for a total of 207 PSD test results. Table 1 presents a summary of the derived hydraulic conductivities.

Table 1: Hydraulic Conductivities Derived from Particle Size Distribution Analysis (m/d)

Geological Unit	CH0 to CH2800			CH2800 to CH4850			CH4850 to CH7600			CH7600 to CH9492			All			Number of Tests
	Range		Median	Range		Median	Range		Median	Range		Median	Range		Median	
Swan River Formation	3	9	6	-	-	-	-	-	-	-	-	-	3	9	6	4
Bassendean Sand	9	22	16	4	23	9	1	25	5	3	5	3	1	37	9	43
Perth Formation	1	23	2	5	14	9	-	-	-	-	-	-	1	23	5	25
Guildford Formation	-	-	-	1	16	3	1	36	3	1	25	2	1	36	2	79
Gnangara Sand	-	-	-	1	8	3	0.4	3	1	-	-	-	0.4	8	2	12
Ascot Formation	-	-	-	3	16	3	3	20	4	-	-	-	3	20	4	27
Osborne Formation Mirrabooka Member	-	-	-	-	-	-	0.3	20	9	-	-	-	0.3	20	9	17

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APPENDIX D

Summary of Slug Test Analysis

Single well hydraulic testing (slug testing) was carried out in 31 selected groundwater monitoring wells in March 2015.

The testing involved installing an automatic water level logger into the test well and introducing or removing a slug of PVC or water of known volume while measuring the resulting displacement in groundwater level at 1 second intervals. The groundwater level displacement data was then analysed using AQTESOLV Pro to provide an estimate of hydraulic conductivity (k) adjacent to the well screen.

Several tests were carried out at each well dependent on the time required for complete recovery of the initiated change in groundwater level. In most cases this comprised of three falling and three rising head tests.

Table 1 provides a summary of the estimated hydraulic conductivity for each well and for each hydrogeological unit. Table 1 only provides results for 29 of the 31 tests as the data collected at two of the wells was not suitable to estimate hydraulic conductivity.

Attachment D1 provides selected output files from AQTESOLV Pro of analysis of different groundwater displacement responses as examples:

- BH1-12 (Slug In, High k, Fast Response)
- MW1-03 (Slug Out, High k, Fast Response)
- MW1-02D (High k, Falling Head, Oscillatory Response)
- MW1-04 (Low k, Falling Head, Slow response)
- MW1-05 (Low k, Slug In, Moderate Response).

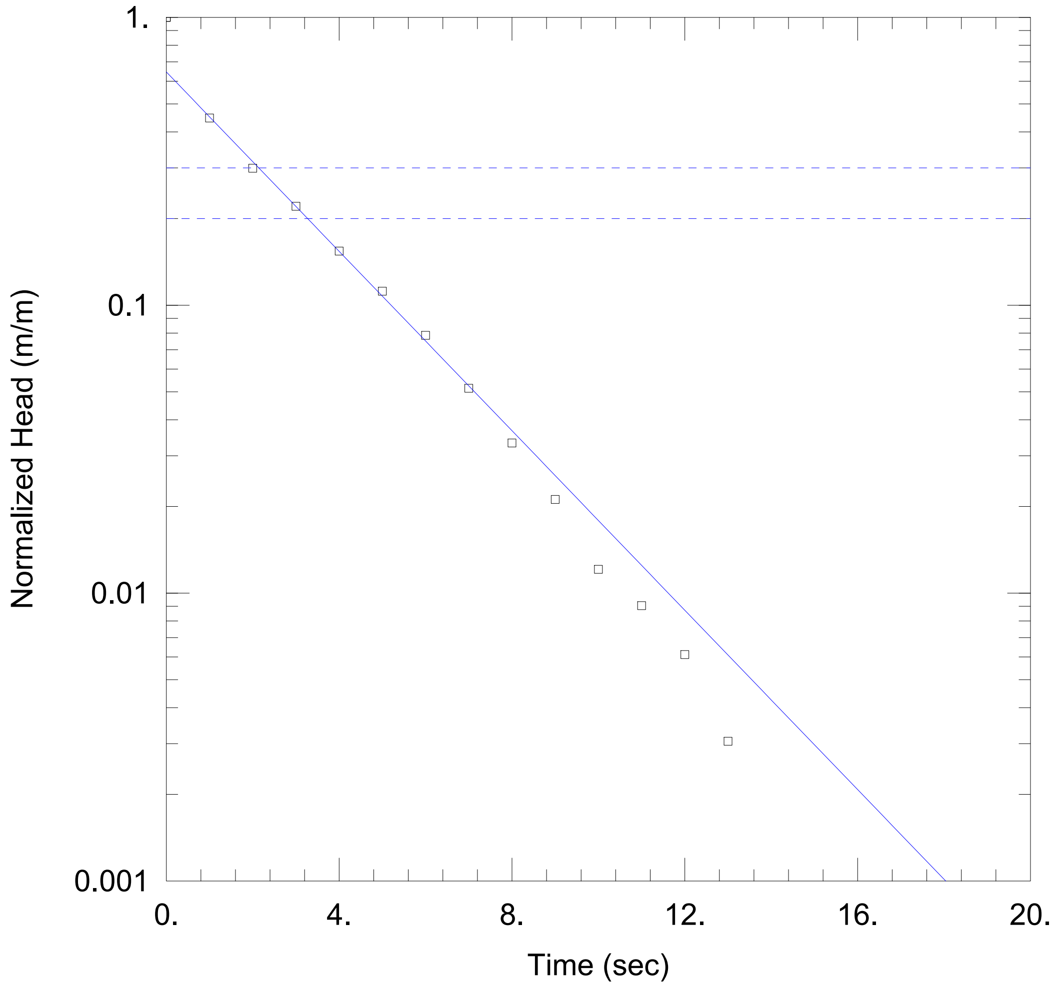
Table 1: Results of Slug Testing

Well ID	Location	Material Description at Well Screen	Well Screen Interval (m bgl)	Geological Unit (Formation)	Aquifer	Hydraulic Conductivity (m/d)			
						Individual Well		Hydrogeological Unit	
						Range	Median	Range	Median
MW2-02D	Bayswater	Sand (*f-c*)	0.7 – 6.7	Perth	Upper	5 – 6	6	0.3 – 35	11
MW2-02C	Bayswater	Sand (*c*)	11.5 – 19.0		Lower	10 – 32	27		
MW2-02A	Bayswater	Sandy clay/gravelly sand (*c*)	22.0 – 26.0			8 – 35	16		
MW2-02B	Bayswater	Sand (*f-m*),clayey sand(*f*), gravelly sand (*f-c*)	10.5 – 26.0			0.3 – 0.6	0.5		
LG2-18	Swan River	Clayey silt	15.5 – 21.5	Swan River	Aquitard	0.2 – 0.2	0.2	0.2	0.2
MW2-01A	Airport West	Sand (*m-c*), trace clay	2.0 – 8.0	Guildford	Superficial	1.1 – 2.2	2	0.1 – 12	2.5
MW2-01B	Airport West	Sand (*f-c*), trace clay	2.0 – 8.0			2.9 – 3.8	3		
MW1-02C	Consolidated	Sand (*f-c*)/clayey sand (*m-c*)	5.0 – 11.0			5 – 12	8		
MW1-01A	Forrestfield	Sand (*f-c*),silty sand (*f-m*)	8.0 – 32.0			0.1 – 0.3	0.2		
MW1-01B	Forrestfield	Sand (*f-c*), silty sand *(f-m)*, clayey sand (*f-m*)	8.5 – 32.5			0.1 – 1.5	0.4		
MW1-01C	Forrestfield	Clayey sand (*f-m*), sand (*f-c*), silty sand (*f-m*)	7.0 – 32.3			0.3 – 0.4	0.4		
MW1-01D	Forrestfield	Clayey sand (*f-m*), sand (*f-c*), clayey gravelly sand (*f*)	7.0 – 32.0			0.5 – 5.1	4		
MW1-05	Forrestfield	Sand (*f-m*), clayey sand (*f-m*)	7.0 – 10.0			0.1 – 0.2	0.2		

Well ID	Location	Material Description at Well Screen	Well Screen Interval (m bgl)	Geological Unit (Formation)	Aquifer	Hydraulic Conductivity (m/d)			
						Individual Well		Hydrogeological Unit	
						Range	Median	Range	Median
MW2-01D	Airport West	Silty gravelly sand (*f-c*)	11.0 – 17.0	Ascot	Superficial	2 – 26	6	1 – 75	7.5
MW2-01C	Airport West	Calcarenite (*m-c*)	10.5 – 17.0			3 – 23	18		
BH2-01	Airport West	Silty sand (*f*), sand (*f-m*), gravel (*f-c*)	11.0 – 18.5			2 – 3	3		
MW1-03	Airport	Silty sand Gravel (*f*)	11.5 – 14.5			5 – 8	7		
BH1-21	Consolidated	Silty sandy gravel (*f-c*), sand (*f-m*)	15.9 – 24.9			1 – 4	3		
MW1-02A	Consolidated	Gravelly silty sand (*f*), calcarenite (*f*)	14.0 – 26.0			2 – 8	5		
MW1-02D	Consolidated	Gravelly sand (*m-c*), calcarenite	13.8 – 25.8			15 – 21	17		
MW1-02B	Consolidated	Sandy gravel (*f*), gravelly sand (*f-c*)	14.0 – 26.0			3 – 12	12		
BH1-12	Consolidated	Sand (*f-c*), gravel (*f-c*), calcarenite (*f-c*)	15.5 – 23.5			5 – 12	8		
BH1-13	Consolidated	Sandy gravel (*f-c*)	15.5 – 16.5			20 – 75	50		
LG2-14	Swan River	Silty sandstone (*f*)	16.9 – 31.9	Osborne Formation (Kardinya Shale)	Osborne Aquitard	0.0002	0.0002	0.0002 – 0.008	0.0005
MW3-121 (d)	Airport West	Sandstone (*f*)	19.5 – 23.7			0.0005	0.0005		
MW2-01E	Airport West	Siltstone, claystone	20.0 – 23.0			0.0006	0.0006		
MW1-04	EE4	Sandy clay	28.5 – 31.5			0.008	0.008		
BH1-25	Consolidated	Sand (*f-c*), gravelly clayey sand (*f-c*)	29.0 – 42.0	Osborne Formation	Mirrabooka	1 – 4	3	1 – 7	4.5
MW1-02E	Consolidated	Sandy Gravel (*f-c*), calcarenite	27.0 – 34.0			4 – 7	6		

f,- fine grained, *m* – medium grained, *c* – coarse grained, m bgl – meters below ground level

ATTACHMENT D1
Selected AQTESOLV Solutions from Slug Testing



WELL TEST ANALYSIS

Data Set: J:\...\BH1-12 slug in 2_AL.aqt
Date: 04/08/15
Time: 09:15:44

PROJECT INFORMATION

Test Well: BH1-12

AQUIFER DATA

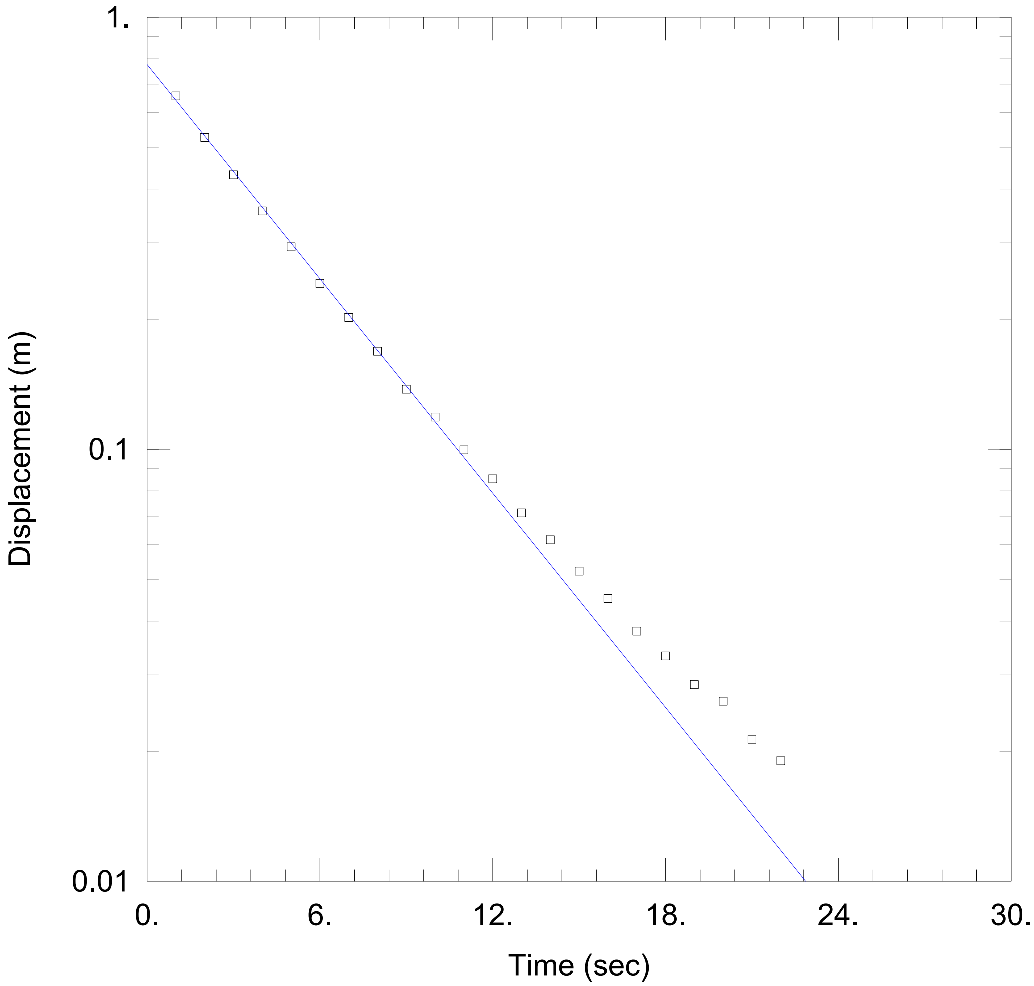
Saturated Thickness: 21.81 m
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (BH1-12)

Initial Displacement: 0.7852 m
Static Water Column Height: 21.81 m
Total Well Penetration Depth: 21.81 m
Screen Length: 9. m
Casing Radius: 0.0253 m
Well Radius: 0.06 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined
Solution Method: Bouwer-Rice
K = 6.427 m/day
y0 = 0.5072 m



WELL TEST ANALYSIS

Data Set: J:\...\MW1-03 slug out 1.aqt
Date: 04/08/15 Time: 09:27:58

PROJECT INFORMATION

Test Well: MW1-03

AQUIFER DATA

Saturated Thickness: 11.74 m Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MW1-03)

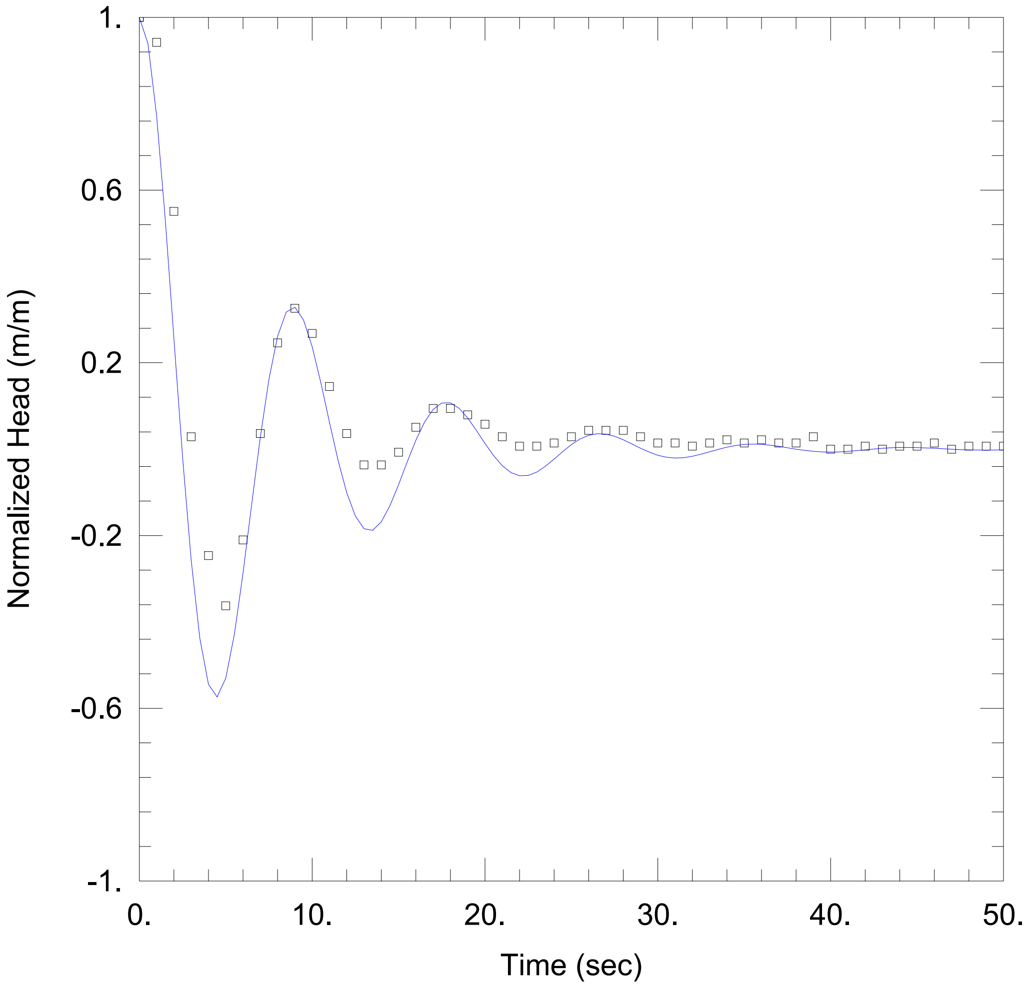
Initial Displacement: 1.233 m
Total Well Penetration Depth: 11.74 m
Casing Radius: 0.0253 m

Static Water Column Height: 11.74 m
Screen Length: 3.5 m
Well Radius: 0.0253 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Bouwer-Rice

K = 6.883 m/day y0 = 0.7768 m



WELL TEST ANALYSIS

Data Set: J:\...\MW1-02D - Falling Head 1_AL.aqt
Date: 04/08/15 Time: 09:29:14

PROJECT INFORMATION

Test Well: MW1-02D

AQUIFER DATA

Saturated Thickness: 29.78 m Anisotropy Ratio (Kz/Kr): 0.1

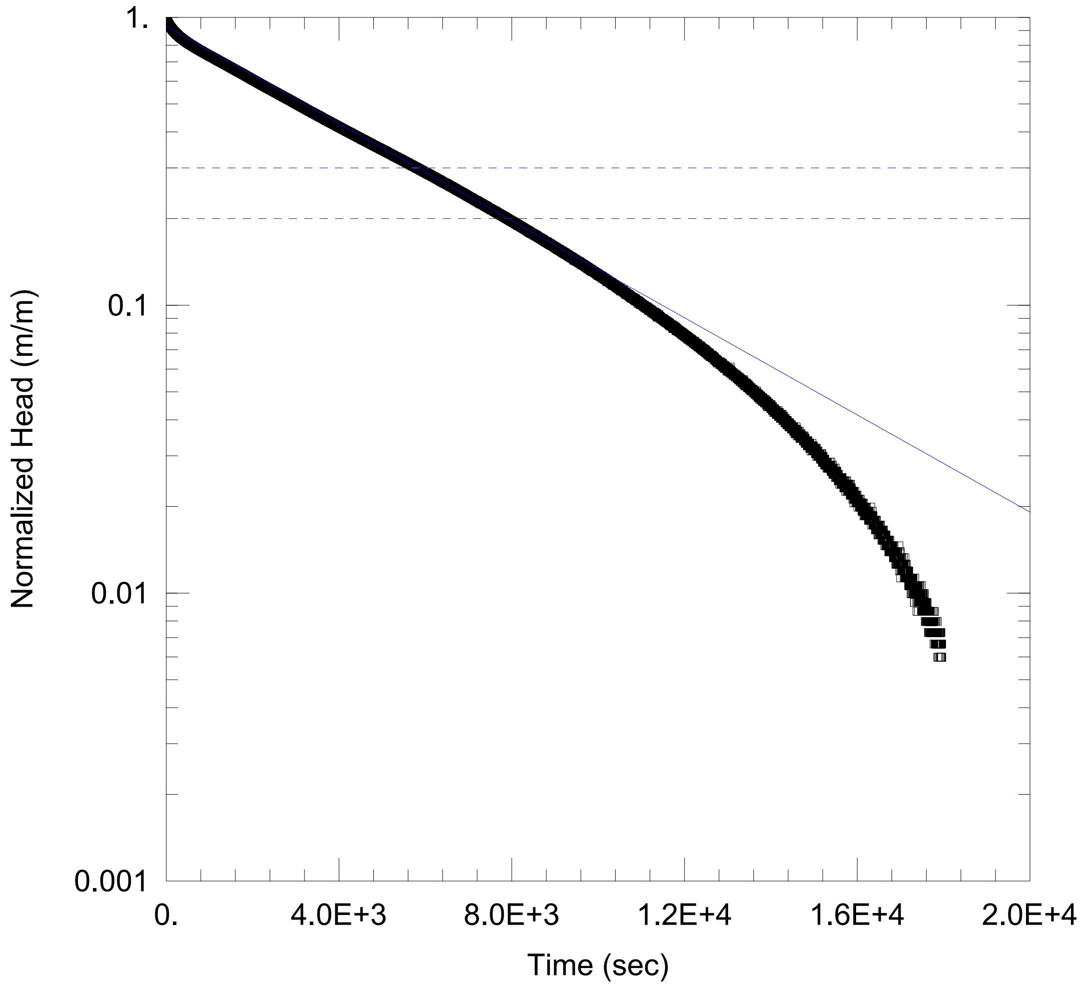
WELL DATA (MW1-02D)

Initial Displacement: 0.3273 m
Total Well Penetration Depth: 23.78 m
Casing Radius: 0.0253 m
Static Water Column Height: 23.78 m
Screen Length: 12. m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Unconfined Solution Method: Springer-Gelhar

K = 20.53 m/day Le = 19. m



WELL TEST ANALYSIS

Data Set: J:\...\MW1-04-Confined.aqt
Date: 04/08/15 Time: 09:20:55

PROJECT INFORMATION

Test Well: MW1-04

AQUIFER DATA

Saturated Thickness: 4.5 m
Anisotropy Ratio (Kz/Kr): 0.1

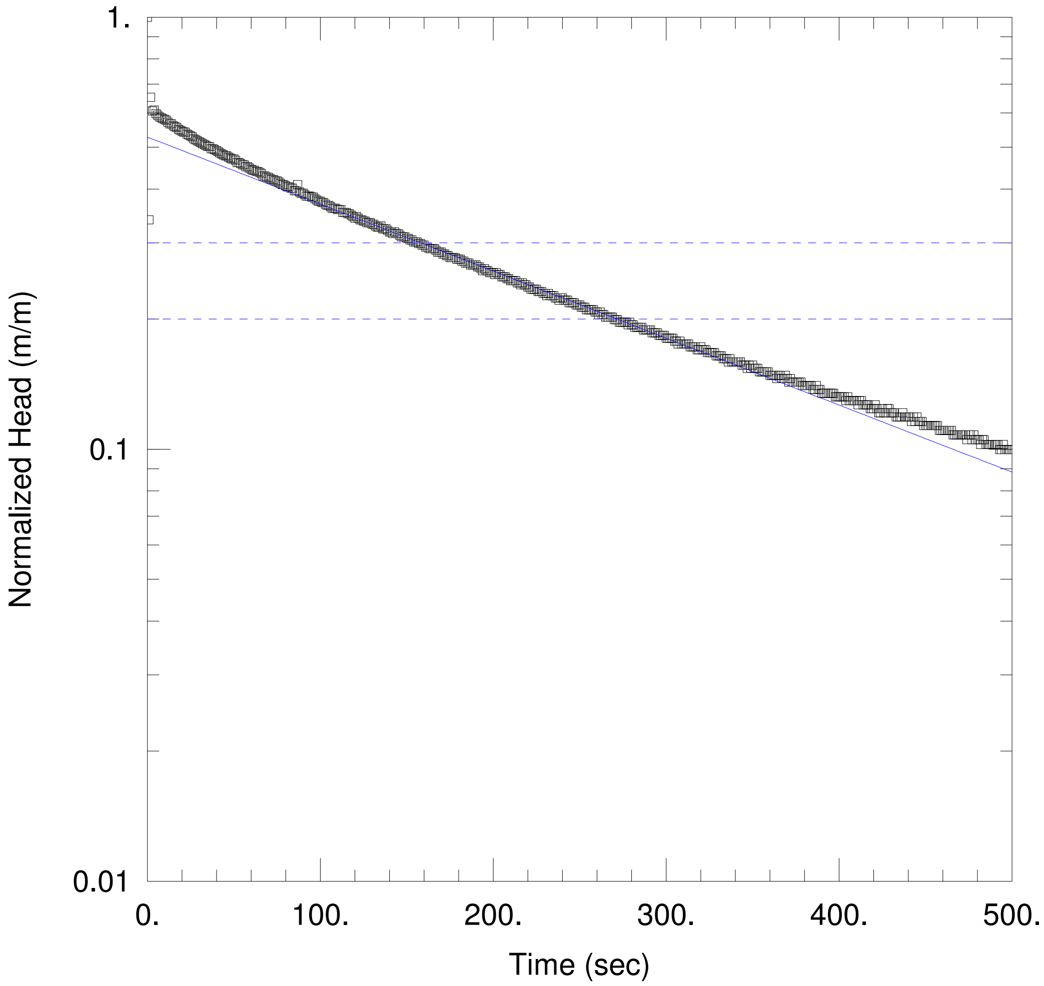
WELL DATA (MW1-04)

Initial Displacement: 3.578 m
Static Water Column Height: 27.89 m
Total Well Penetration Depth: 27.89 m
Screen Length: 3.5 m
Casing Radius: 0.0253 m
Well Radius: 0.06 m

SOLUTION

Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 0.006694 m/day
y0 = 3.333 m



WELL TEST ANALYSIS

Data Set: J:\...\MW1-05- Slug In_AL.aqt
Date: 05/16/15 — Time: 16:56:23

PROJECT INFORMATION

Test Well: MW1-05

AQUIFER DATA

Saturated Thickness: 4.87 m — Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA (MW1-05)

Initial Displacement: 0.8801 m
Total Well Penetration Depth: 4.87 m
Casing Radius: 0.0253 m
Static Water Column Height: 4.87 m
Screen Length: 3. m
Well Radius: 0.06 m
Gravel Pack Porosity: 0.

SOLUTION

Aquifer Model: Unconfined — Solution Method: Bouwer-Rice

K = 0.1633 m/day — y0 = 0.4643 m

APPENDIX E

Summary of Test Pumping Analysis

1.0 INTRODUCTION

This Appendix describes and presents the results from the four pumping tests carried out as part of the Stage 2 Geotechnical Investigation.

The following pumping tests were completed at the following sites:

- PW1-01 at Forrestfield Dive Structure – 8 to 12 December 2014
- PW1-02 at Consolidated Airport Station – 5 to 9 January 2015
- PW2-01 at Airport West Station – 19 to 22 January 2015
- PW2-02 at Bayswater Dive Structure – 2 to 6 February 2015.

A 26D licence under the Rights in Water and Irrigation Act 1914 was obtained to install all the pumping test wells and to carry out all the pumping tests. This licence was issued by the Department of Water (DoW) and allowed for the installation, development and testing of the pumping test wells. Additional approvals were obtained for disposal of the groundwater abstracted during the pumping tests. The required disposal approvals are site specific and are discussed specifically for each site in the sections below.

2.0 GENERAL METHODOLOGY

2.1 Pumping Tests

The pumping tests were completed by McArthur Drilling and Pumping (MDP) under the supervision of Golder in general accordance with AS 2368-1990 – "Test pumping of water wells". The following tests were carried out at each of the four sites:

- Step-Rate – The test involved pumping the test well at four different pumping rates (with the rate constant during each step, but increasing between steps) with each step lasting around one hour. The purpose of this test is to assess the pumping rate for the constant rate test.
- Constant Rate – This test involved pumping the test well at a constant rate for up to 72 hours depending on the response observed in the pumping and monitoring wells during the test.
- Recovery – The recovery occurred immediately following the cessation of the constant rate test (i.e. the start of the test is when the pump is turned off for the constant rate test) and was continued until approximately 95% recovery had occurred.

Some changes to the methodology did occur at each site due to site specific conditions and logistics. The design of each pumping test focused on maximising the return of information from each of the four pumping test locations.

2.2 Monitoring

Monitoring of both groundwater level and quality was carried out as part of the pumping tests in accordance with AS 2368-1990. In summary, the groundwater monitoring consisted of:

- Background barometric pressure and groundwater levels in monitoring and pumping wells were monitored prior to the start of each pumping test using automated barometric and groundwater level loggers.
- Groundwater level monitoring in the pumping well and at least four monitoring wells was completed during each pumping test using time-synchronised, automated groundwater level loggers logging at 1 minute intervals.

- Manual measurement of groundwater level in the pumping wells and the monitoring wells closest to the pumping well was undertaken at the intervals outlined in AS 2368-1990 as a quality assurance control and to verify automated water level logger information during each pumping test. In addition, groundwater levels in other monitoring wells with automated loggers was manually measured during the pumping tests as time permitted.
- Barometric pressure was measured for the duration of the pumping tests using an automated pressure logger that was synchronised with the groundwater level loggers to allow for barometric correction of the groundwater level logger data.
- Flow volume and discharge rate from the pumping well was measured using a digital flow meter at the wellhead.
- Water quality field monitoring of pH, electrical conductivity (EC), and temperature was carried out on the abstracted groundwater.
- Sampling of discharge water for laboratory water quality analysis for major ions, metals, nutrients, TPH, BTEX, PAH, MAH and pesticides was undertaken as a minimum at the beginning of each pumping test and at the end of each pumping test. A sample was also taken halfway through the test at Airport West (PW2-01) at the request of Swan River Trust (SRT).

Some variations in the monitoring at each site did occur due to site specific conditions and logistics.

2.3 Groundwater Disposal

The groundwater abstracted during pumping well development was either reinfiltrated on site (Bayswater), pumped to a turkeys nest for construction use by others (Consolidated Airport Terminal Station) or pumped to the stormwater drain (Forrestfield and Airport West). The method of disposal was evaluated on a case by case basis. Approval from the relevant asset owner and regulators was obtained before proceeding with each pumping test.

2.4 Analysis

The pumping test data was analysed analytically [1, 2] using multiple analytical solutions and type curves and numerically using Visual MODFLOW. A basic numerical 3D groundwater model developed using Visual MODFLOW for the area around each pumping well was used to match the pumping test data by manually changing hydraulic conductivity and storage.

3.0 PW 1-01 (FORRESTFIELD DIVE STRUCTURE)

The results from the Stage 2 Geotechnical Investigation indicate that the regional Superficial Aquifer at the Forrestfield Dive Structure is comprised of Guildford Formation with a depth of approximately 32 m from current ground surface. The pumping well and associated monitoring wells were installed to the bottom of the Guildford Formation and screened across the whole aquifer (screen lengths of approximately 24 m to 27 m).

3.1 Site and Pumping Test Layout

Pumping tests were carried out at PW 1-01 between 8 and 12 December 2014 and included:

- A step test with pumping rates set at 6, 8, 10 and 12 L/s. The first three steps lasted for 60 minutes each, while the fourth step was stopped after 8 minutes due to the groundwater level drawdown reaching the pump.

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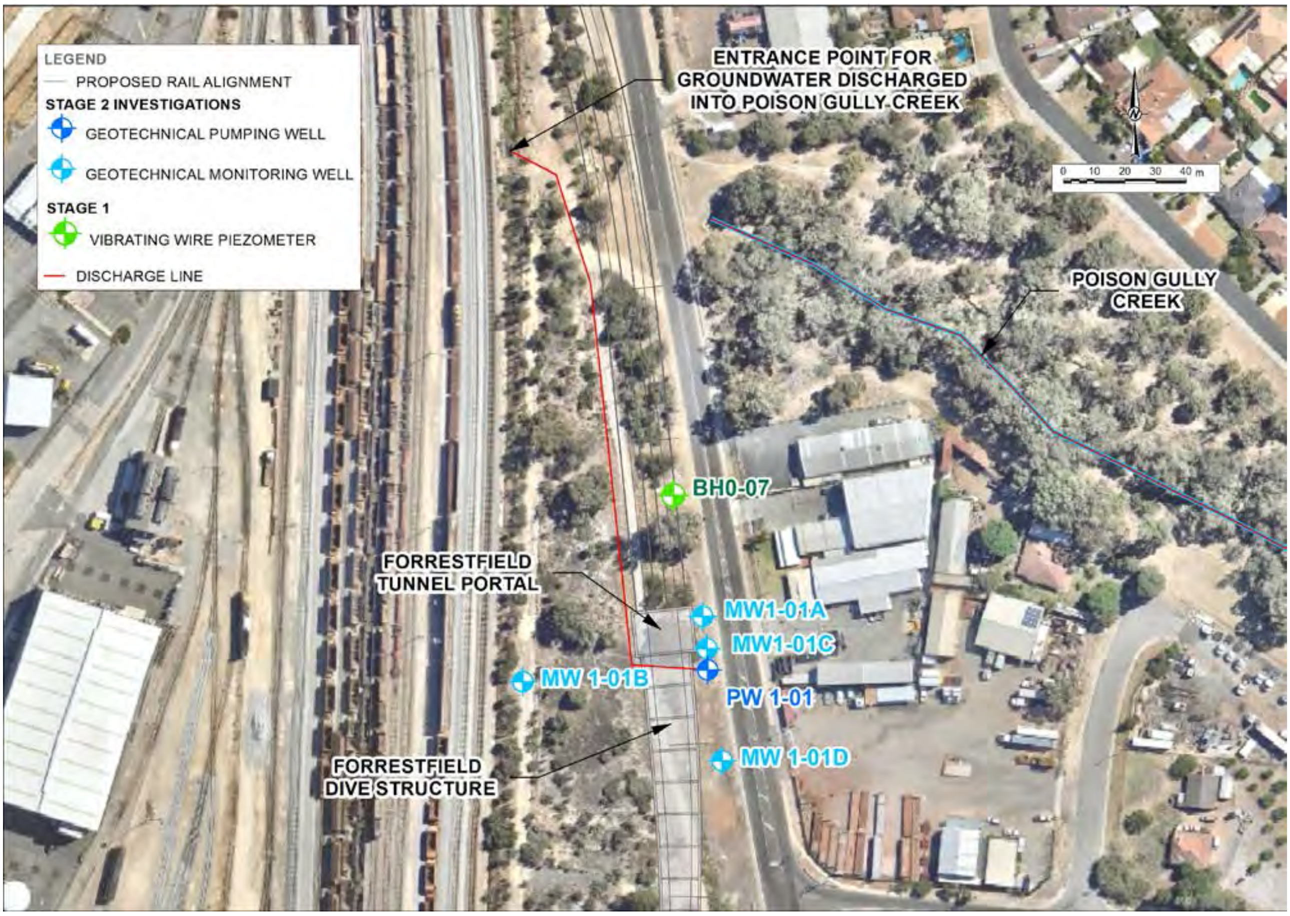
[1] Kruseman, G.P. and N.A. de Ridder, 1994. Analysis and Evaluation of Pumping Test Data. Second Edition. Publication 47. International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands, 1994.

[2] Cooper, H.H. and C.E. Jacob, 1946. A generalized graphical method for evaluating formation constants and summarizing well field history. Am. Geophys. Union Trans. 27: 526-534.

- A 72-hour constant rate test with a discharge rate of approximately 10 L/s; followed by
- A 9-hour recovery test.

Sketch 1 shows the site layout of the pumping test well (PW1-01), four dedicated monitoring wells (MW1-01A to MW1-01D) and Vibrating Wire Piezometers (VWPs) (BH0-07) while Table 1 presents the distances and directions of the different monitoring locations from the pumping test well.



Sketch 1: Site Layout for pumping test at (PW 1-01)

Table 1: Distance and Direction from the Pumping Test Well to the Monitoring Locations

Well ID	Type	Distance to Pumping Well (m)	General Direction to Pumping Well	Screened Geological Unit
PW1-01	Pumping Well	-	-	GF
MW1-01-A	Dedicated Monitoring Well	18	North	GF
MW1-01-B	Dedicated Monitoring Well	61	West	GF
MW1-01-C	Dedicated Monitoring Well	7	North	GF
MW1-01-D	Dedicated Monitoring Well	30	South	GF
BH0-07	Vibrating Wire Piezometer	58	North	GF
BH1-02	Vibrating Wire Piezometer	74	South	GF
BH1-04	Vibrating Wire Piezometer	197	North	GF

* Location of BH1-02 and BH1-04 are not shown on Sketch 1 due to the distance from PW1-01. Refer to Figure 5 in the main report for location of these VWPs.

3.2 Discharge Location

The abstracted groundwater during the pumping test was discharged to Poison Gully Creek at the confluence just before it becomes a man-made drain and enters part of the Perth Airport Drain system (Sketch 1). Discharge approval was obtained from the Shire of Kalamunda.

3.3 Analysis and Results

Figures E1–1 to E1–2 summarise the pumping test results while Table 2 presents the estimated hydraulic properties from the different analysis methods.

Table 2: Results from Pumping Test Analysis – Forrestfield Dive Structure

Method	Transmissivity (m^2/d)	Storage Coefficient	Figures
Distance Drawdown	180	6.0×10^{-3}	E1-3
Groundwater Model	104	2.5×10^{-3}	E1–4 to E1–5
Analytical Type Curves	94–316	-	E1–6 to E1–15 *

* Selected type curves only

The results indicate:

- The groundwater level drawdown in the pumping well reached almost 16 m toward the end of the test and the groundwater level almost reached steady-state conditions at the end of the pumping test
- The groundwater level drawdown in the monitoring wells ranged between 0.9 m and 3.2 m, depending on their distance from the pumping well.
- Four hours after starting the Constant Rate test the flow rate was adjusted as it was decreasing. The increase in flow rate resulted in a step change in the groundwater level within the test well. However, the groundwater level decline was similar before and after the step change, suggesting that the step change in level within the pumping well was due to removal of bore storage when the pumping rate was increased.
- The distance drawdown curve (Figure E1–3) indicates that
  - There is a relatively good correlation between distance (from the pumping well) and drawdown, which suggests generally homogenous conditions.
  - The expected groundwater level drawdown in the aquifer just outside the pumping well is around 6.5 m, indicating that 9.5 m of the 16 m of drawdown in the well was caused by well loss.
- There is a reasonably good match between observed and modelled groundwater level drawdown (E1–4 and E1–5). There was found to be only a small difference when varying the vertical hydraulic conductivity in the model, which is likely due to the wells being screened over the full aquifer thickness and the presence of relatively homogenous conditions.
- The estimated range in the derived storage coefficient suggests semi-confined to confined conditions.

3.4 Groundwater Quality

Figure E1–16 shows the field monitoring results of pH and Electrical Conductivity (EC) from the Constant Rate Test while Table E1 presents the groundwater quality laboratory results from samples taken at the beginning and end of the pumping test. The results indicate:

- pH is acidic and ranged between 5.5 and 6.0 during the pumping test with no particular trend, excluding one outlier.

- EC was generally steady throughout the pumping test at around 1000 uS/cm, indicating slightly brackish water.
- Total Nitrogen was 44 mg/L and 33 mg/L at the beginning and end of test respectively, indicating high nutrient concentrations.
- Total iron increased from below detection limit at the beginning of the test to 0.018 mg/L at the end of the test, which is well below SRT criterion of 1 mg/L.
- BTEX, MAH, PAH, hydrocarbons and pesticides were not detected in either of the two samples.

4.0 PW1-02 (CONSOLIDATED AIRPORT TERMINAL STATION)

The results from the Stage 2 Geotechnical Investigation indicated that the Superficial Aquifer at this location consists of the Bassendean Sand, Guildford Formation and Ascot Formation, overlying the Mirrabooka Member of the Osborne Formation. The Superficial Aquifer is approximately 24 m thick at the Consolidated Airport Terminal Station, of which approximately 12 m consists of the Ascot Formation.

The pumping test well was installed and screened across the full thickness of the Ascot Formation with two of the dedicated monitoring wells (MW1-02B and MW1-02D) installed in the Ascot Formation, one monitoring well in the Bassendean Sand and Guildford Formation (MW1-02C) and one well (MW1-02E) in the Mirrabooka Aquifer.

4.1 Site and Pumping Test Layout

Pumping tests were carried out at PW 1-02 between 5 and 9 January 2015 and included:

- A step test with pumping rates set at 6, 8, 10, 12 and 13.5 L/s. The first four steps lasted for 60 minutes each, while the fifth step was stopped after 3 minutes due to excessive drawdown and the pump sucking in air.
- CRT 1 - A 52-hour constant rate test with a discharge rate of approximately 12.0 L/s followed by an 18.5-hour recovery test.
- CRT 2 - A 6-hour constant rate test with a discharge rate of approximately 9.5 L/s followed by a 1.5 hour recovery test.

CRT 1 was found to pump some air during the pumping test which resulted in some fluctuations in the groundwater level inside the pumping well. Following the completion of the recovery after CRT 1 it was therefore decided to run a short second test (CRT2) at a lower pumping rate to see if less groundwater level fluctuation would be observed in the pumping well.

Sketch 2 shows the site layout of the pumping test well (PW1-02), monitoring wells and VWPs while Table 3 presents the distances and directions of the different monitoring locations from the pumping test well.

Sketch 2: Site Layout for pumping test at PW 1-02

Table 3: Distance and Direction from the Pumping Test Well to the Monitoring Locations

Well ID	Type	Distance to Pumping Well (m)	General Direction to Pumping Well	Screened Geological Unit
PW1-02	Pumping Well	-	-	AF
MW1-02-A	Dedicated Monitoring Well	39	Northeast	AF
MW1-02-B	Dedicated Monitoring Well	33	Southwest	AF
MW1-02-C	Dedicated Monitoring Well	5	West	BS, GF, GS
MW1-02-D	Dedicated Monitoring Well	5	West	AF
MW1-02-E	Dedicated Monitoring Well	4	Northwest	OFm
BH1-21	Monitoring Well	82	Northwest	AF
BH1-25	Monitoring Well	130	West	OFm
BH0-06	Vibrating Wire Piezometer (two sensors)	27	Northwest	GF and AF
BH1-22	Vibrating Wire Piezometer (two sensors	67	Northwest	AF and OFm
BH1-24	Vibrating Wire Piezometer (three sensors)	132	West	GF, AF and OFm

4.2 Discharge Location

The abstracted groundwater during the pumping test was discharged into a turkeys nest located approximately 30 m west PW1-02 (Sketch 2). The water from the turkeys nest was used during the day by Densford Civil for dust suppression. Normally Densford Civil obtained their construction water from a reticulation bore located approximately 50 m north of the site. However, the pumping rate from PW1-02 was sufficient to supply Densford Civil with their water demand and therefore the reticulation bore could be turned off during the test. While the pump test was being carried out, the turkeys nest overflowed into the Perth Airport Drain (Sketch 2) during the night when the water was not being used by Densford Civil. Discharge approval into the Perth Airport Drain was obtained from PAPL.

4.3 Analysis and Results

Figures E2–1 to E2–3 summarise the pumping test results while Table 4 presents the estimated hydraulic properties from the different analysis methods.

Table 4: Results from Pumping Test Analysis – Consolidated Airport Terminal Station

Method	Transmissivity (m^2/d)	Storage Coefficient	Figures
Distance Drawdown	271–281	1×10^{-2} - 5×10^{-2}	E2–4 to E2–5
Groundwater Model	274	6×10^{-4}	E2–6
Analytical Type Curves	136–690 *	-	E2–7 to E2–20 *

* Selected type curves only

The results indicate:

- The drawdown in piezometric level in the pumping well reached approximately 17 m and 9 m during Test 1 and Test 2, respectively, and the groundwater level reached steady-state within only a few hours of pumping.
- The groundwater and piezometric level drawdown in the monitoring wells ranged between 0.1 m and 2.3 m, depending on the distance of the monitoring well from the pumping well. This suggests that there is a large well loss in the pumping well (according to the distance drawdown curves the expected groundwater level drawdown in the aquifer just outside the pumping well is estimated to be around 4.5 m and 3.5 m instead of the observed 17 m and 9 m, for the two tests respectively).
- MW1-02E and BH1-25, both screened in the underlying Osborne Formation, show significant hydraulic connection with the Ascot Formation. MW1-02E shows a very similar response to pumping when compared with MW1-02D which is screened in the Ascot Formation and located next to MW1-02E.
- BH1-25 shows a small response to pumping at a distance of 130 m from the test well. The hydraulic connection between the Osborne Formation and the Ascot Formation is supported by the distance drawdown plot where the measurements for both formations plot on a straight line.
- The drawdown in piezometric level at BH1-21 (located closest to the Perth Airport control tower) was approximately 0.5 m at the end of the test.
- MW1-02C, screened in the overlying Bassendean Sand, Guildford Formation and Gnangara Sand, shows a similar but reduced response to pumping when compared with MW1-02D and MW2-01E. This response indicates some connection with the Ascot Formation, semi-confined conditions and a lower vertical hydraulic conductivity.
- A good match between observed and modelled groundwater level drawdown (Figure E2–6) was obtained. The Ascot Formation was found to have the greatest hydraulic conductivity. The best match was obtained when using a vertical to horizontal hydraulic conductivity ratio of 0.1 (= k_v/k_h).

- The estimated range in storage coefficient suggests semi-confined to confined conditions.

4.3.1 Groundwater Quality

Figure E2–21 shows the field monitoring results of pH and Electrical Conductivity (EC) from the Constant Rate tests while Table E1 presents the groundwater quality laboratory results from samples taken at the beginning and end of the pumping test. The results indicate:

- pH was stable throughout the pumping tests ranging between 7.5 and 8.0, indicating slightly alkaline conditions, excluding one outlier.
- EC was stable throughout the pumping tests ranging between ranging between 600 and 800 uS/cm, indicating fresh water.
- Total Nitrogen was between 0.16 mg/L and 0.1 mg/L at the beginning and end of each test respectively, which is below the SRT criterion for disposal to Swan River (1 mg/L). However, total phosphorous (0.2 mg/L and 0.13 mg/L) was above the SRT criterion (0.1 mg/L).
- Total iron was low and ranged between 0.57 mg/L and 0.87 mg/L, which is below the SRT criterion of 1 mg/L.
- BTEX, MAH, PAH, hydrocarbons and pesticides were not detected in either of the two samples.

5.0 PW 2-01 (AIRPORT WEST STATION)

The results from the Stage 2 Geotechnical Investigation indicated that the Superficial Aquifer at Airport West Station consists of Bassendean Sand, Guildford Formation, Gnangara Sand and Ascot Formation, overlying the Kardinya Shale of the Osborne Formation. The Superficial Aquifer is approximately 16 m thick at the Airport West Station, of which approximately 8 m consists of the Ascot Formation. The Osborne Formation below the Airport West Station consists of Kardinya Shale which was tested to have a very low hydraulic conductivity. A pumping test in the Osborne Formation at this location was therefore considered to be not necessary. The most permeable unit at the Airport West Station is the Ascot Formation and it was therefore decided to undertake the pumping test in a pumping well screened across the Ascot Formation. The pumping test well was installed and screened across the full thickness of the Ascot Formation with two of the dedicated monitoring wells (MW2-01C and MW2-01D) installed in the Ascot Formation, one monitoring well in the Kardinya Shale (MW2-01E) and two wells in the Bassendean Sand (MW2-01A and MW2-01B). MW2-01B was located on the other side of Belmont Main Drain to assess the effect the drain had on the pumping test results.

5.1 Site and Pumping Test Layout

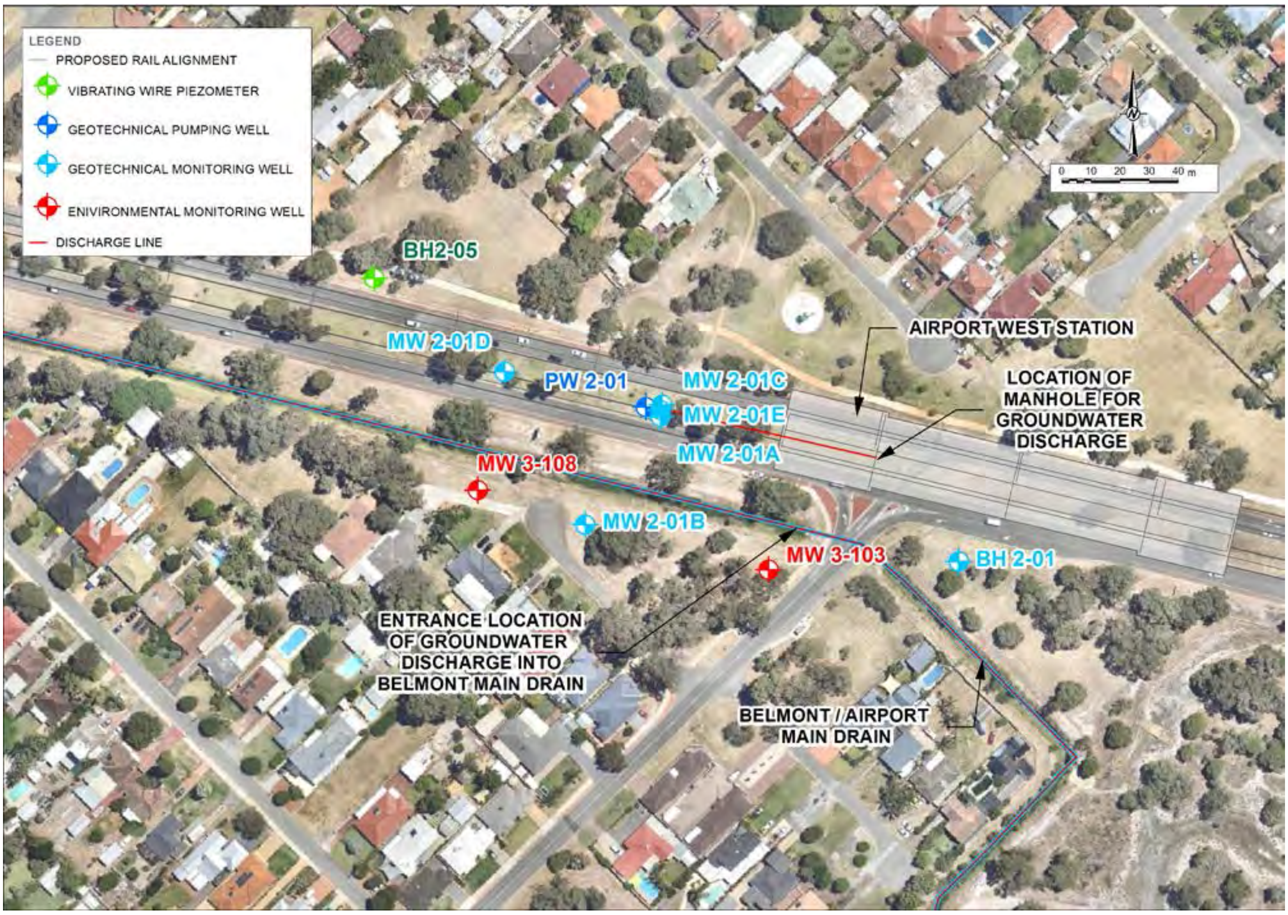
Pumping tests were carried out at PW 2-01 between 19 and 22 January 2015 and included:

- A step-test with pumping rates set at 2, 3, 4, 5 and 5.5 L/s. The steps lasted for 60 minutes each.
- Constant Rate Test 1 (CRT 1) - A 26-hour constant rate test with a discharge rate of approximately 5.0 L/s followed by a 5-hour recovery test.
- Constant Rate Test 1 (CRT 2) - A 22-hour constant rate test with a discharge rate of approximately 6.1 L/s followed by a 3.5-hour recovery test.

During CRT 1 reticulation systems from garden bores in adjacent properties and parks were found to affect the groundwater levels in the monitoring wells and VWPs. In addition the groundwater levels reached steady state within a short period of time indicating that the aquifer system could be pumped at a higher pumping rate. The short period of time to reach steady state may also be due to a recharge boundary associated with the nearby drain.

CRT 2 was carried out after it was arranged with the City of Belmont to turn off their reticulation systems and the test was started in the middle of the morning when the household reticulation bores were no longer pumping. A higher pumping rate was chosen based on the results of the first test.

Sketch 3 shows the site layout of the pumping test well (PW1-02), monitoring wells and VWPs while Table 5 presents the distances and directions of the different monitoring locations from the pumping test well.



Sketch 3: Site Layout for pumping test at PW 2-01.

Table 5: Distance and Direction from the Pumping Test Well to the Monitoring Locations

Well ID	Type	Distance to Pumping Well (m)	General Direction to Pumping Well	Screened Geological Unit
PW2-01	Pumping Well	-	-	AF
MW2-01A	Dedicated Monitoring Well	6	East	BS, GF, GS
MW2-01B	Dedicated Monitoring Well	45	South	BS, GF, GS
MW2-01C	Dedicated Monitoring Well	6	East	AF
MW2-01D	Dedicated Monitoring Well	50	West	AF
MW2-01E	Dedicated Monitoring Well	6	East	OFs
BH2-01	Monitoring Well	120	Southeast	AF
MW3-108	Monitoring Well	64	Southwest	AF
MW3-103	Monitoring Well	70	Southeast	BS
BH2-05	Vibrating Wire Piezometer	103	Northwest	GS and AF

5.2 Discharge Location

The abstracted groundwater during the pumping test was discharged into the Belmont Main Drain via a man hole located on the road island where the pumping well was installed (Sketch 3). Approval for the discharge of the groundwater was given by the Water Corporation, the City of Belmont and Swan River Trust on the condition that water quality monitoring and sampling was also undertaken in the Belmont Main Drain. pH and EC was therefore measured in the morning and evening in the Belmont Drain during the CRT at two locations:

- Corner of Brearley Ave and Second Street, approximately 5 m downstream of the discharge point into the drain.
- Corner of Brearley Ave and First Street, approximately 365 m downstream of the discharge point into the drain.

Three water samples were collected at the corner of Brearley Ave and Second Street, at the beginning, halfway through and at the end of the pumping tests.

5.3 Analysis and Results

Figures E3–1 to E3–3 summarise the pumping test results while Table 6 presents the estimated hydraulic properties from the different analysis methods.

Table 6: Results from Pumping Test Analysis – Airport West Station

Method	Transmissivity (m^2/d)	Storage Coefficient	Figures
Distance Drawdown	74–76	6×10^{-3}	E3–4 to E3–5
Groundwater Model	76	2×10^{-4}	E3–6
Analytical Type Curves	39–180 *	-	E3–7 to E3–15 *

* Selected type curves only

The results indicate:

- The drawdown in piezometric level in the pumping well reached approximately 8.5 m and 11 m during Test 1 and Test 2, respectively, and the groundwater level reached steady-state within only one hour of pumping.
- The groundwater and piezometric level drawdown in the monitoring wells ranged between 0.1 m and 4.0 m, depending on the distance of the monitoring well from the pumping well.
- According to the distance drawdown curves the expected groundwater level drawdown in the aquifer just outside the pumping well is estimated to be 7 m and 8 m instead of the observed 8.5 m and 11 m, in the two CRT respectively.
- The monitoring wells, particularly MW3-108 and MW2-01B showed a clear effect from pumping of nearby household reticulation bores, resulting in temporary drawdown of up to 0.5 m in these wells.
- MW2-01E (screened in the underlying Osborne Formation) showed a different response to any of the other monitoring locations with a steady decrease in piezometric pressure throughout the tests. At the end of the tests the piezometric head in the Osborne Formation had been reduced by approximately 2 m. After the pumping ceased only a very small recovery (<0.1 m) occurred suggesting a very low hydraulic conductivity and slow or limited recharge of the Osborne Formation.

- MW3-103 which is shallow (4.5 m deep) and located south of Belmont Main Drain showed no noticeable response to the pumping, suggesting that the Belmont Main Drain acts a positive head boundary to the groundwater table. MW3-108 and MW2-01B, which are also located south of the Belmont Main Drain but installed deeper in the Ascot Formation, showed a reduction in piezometric level of up to approximately 1.2 m, indicating that a piezometric pressure reduction occured below the Belmont Main drain and that the radius of influence extended beyond the drain.
- MW2-01A, screened in the overlying Bassendean Sand, Guildford Formation and Gnangara Sand, shows a similar but reduced response to pumping when compared with MW2-01C. This response indicates some connection with the Ascot Formation, semi-confined conditions and a lower vertical hydraulic conductivity.
- A reasonable match between observed and modelled groundwater level drawdown (Figure E3-6) was obtained in the groundwater model. The Ascot Formation was found to have the greatest hydraulic conductivity. The best match was obtained when using a vertical to horizontal hydraulic conductivity ratio of 0.1 (= k_v/k_h).
- The groundwater model indicates that water inflow from the Belmont Main Drain into the aquifer during the pumping tests could have been up to 0.4 L/s.
- The estimated range in storage coefficient suggests confined conditions.

5.4 Groundwater Quality

Figure E3–16 and E3–17 show the field monitoring results of pH and Electrical Conductivity (EC) from the Constant Rate Test while Table E1 presents the groundwater quality laboratory results from samples taken at the beginning and end of the pumping test. The results indicate:

- pH was generally steady through the pumping test with the following ranges, excluding outliers:
  - 6.9 to 7.4 in PW 2-01 (average of 7.25)
  - 6.7 to 7.4 in Belmont Drain at Second Street (average of 7.19)
  - 7.6 to 7.3 in Belmont Drain at First Street (average of 7.43)
  - pH was within the upper and lower bounds of the Swan River Trust criteria.
  - pH of the discharge water remained within one pH unit of the receiving environment.
- EC was brackish in the both the discharge water and the drain with the following ranges:
  - 1191 to 1339 uS/cm in PW2-01 (average of 1313 uS/cm)
  - 628 to 969 uS/cm in Belmont Drain at Second Street (average of 820 uS/cm)
  - 608 to 955 uS/cm in Belmont Drain at First Street (average of 820 uS/cm)
  - EC was higher in the discharge water than in the drain
  - The EC increased in the drain from around 600 uS/cm prior to discharge to approximately 900 to 950 uS/cm during discharge into the drain
  - The EC decreased at the discharge to pre-discharge concentrations within 0.5 hour of ceasing the discharge into the drain.
- Total Nitrogen ranged between 0.31 mg/L and 0.13 mg/L at the beginning and end of test respectively, which is below the SRT criteria for disposal to Swan River (1 mg/L).

- Total iron remained stable throughout the pumping and ranged between 2.5 mg/L and 2.8 mg/L.
- BTEX, MAH, PAH, hydrocarbons and pesticides were not detected in either of the two samples.

The results indicated that discharge to Belmont Main Drain did not have a detrimental effect on the receiving environment.

6.0 PW 2-02 (BAYSWATER DIVE STRUCTURE)

The results from the Stage 2 Geotechnical Investigation indicated that the Superficial Aquifer at the Bayswater Dive Structure consists of two aquifers (Upper and Lower Aquifer), separated by a 5 m thick impermeable aquitard. The Superficial Aquifer is approximately 25 m thick (including the aquitard) and is underlain by the Kardinya Shale of the Osborne Formation. The Upper Aquifer consists mainly of Bassendean Sand while the Lower Aquifer consists of Perth Formation. The Lower Aquifer is approximately 15 m thick at the Bayswater Dive Structure portal.

The pumping test well was installed and screened across the full thickness of the Lower Aquifer with three of the dedicated monitoring wells (MW2-02A, MW2-02B and MW2-02C) installed in the Lower Aquifer and one monitoring well (MW2-02D) in the Upper Aquifer. Two other environmental monitoring wells (MW3-165 and MW3-166) were installed in the Upper Aquifer while one geotechnical borehole drilled into the Kardinya Shale was converted to a monitoring well (BH2-26).

6.1 Site and Pumping Test Layout

Pumping tests were carried out at PW 2-02 between 2 and 6 February 2015 and included:

- A step test with pumping rates set at 10, 14, 16 and 18 L/s. The first three steps lasted 60 minutes, while the fourth step was stopped after 4 minutes due to excessive drawdown.
- A 32-hour constant rate test with a discharge rate of approximately 12 L/s followed by a 46-hour recovery test.

Sketch 4 shows the site layout of the pumping test well (PW2-02), monitoring wells and VWPs while Table 7 presents the distances and directions of the different monitoring locations from the pumping test well.

Sketch 4: Site Layout for pumping test at PW 2-02

Table 7: Distance and Direction from the Pumping Test Well to the Monitoring Locations

Well ID	Type	Distance to Pumping Well (m)	General Direction to Pumping Well	Screened Geological Unit	Aquifer
PW2-02	Pumping Well	-	-	PF	Lower
MW2-02A	Dedicated Monitoring Well	4	North	PF	Lower
MW2-02B	Dedicated Monitoring Well	42	Northeast	PF	Lower
MW2-02C	Dedicated Monitoring Well	5	North	PF	Lower
MW2-02D	Dedicated Monitoring Well	4	Northeast	BS	Upper
BH2-26	Monitoring Well	106	Northwest	OFf	Osborne Aquitard
MW3-156	Monitoring Well	77	Southeast	PF	Lower
MW3-165	Monitoring Well	51	Northwest	BS	Upper
MW3-166	Monitoring Well	60	Northwest	BS	Upper
BH0-02	Vibrating Wire Piezometer#	16	Northwest	BS, PF	Upper and Lower
BH2-27	Vibrating Wire Piezometer#	165	Northwest	BS, PF	Upper and Aquitard
BH2-22 *	Vibrating Wire Piezometer#	501	Southeast	PF, OFf	Lower and Osborne Aquitard
BH2-19 *	Vibrating Wire Piezometer#	1054	Southeast	PF, PF	Lower

* Locations of BH2-19 and BH2-22 are not shown on Sketch 1 due to the distance from PW2-02. Refer to Figure 5 in the main report for location of these VWPs. # Each VWP has two sensors installed.

6.2 Discharge Location

Originally the plan was to discharge the pumped groundwater into the Bayswater Main Drain via a stormwater drain located to the south of the site. However, approval could not be obtained from the City of Bayswater and Swan River Trust due to the known groundwater contamination in the area from the CSBP site (located to the northeast of the Bayswater Dive structure). Therefore, arrangements were instead made with the Water Corporation to discharge the pumped water to the sewer (approval to discharge up to 15 L/s to the sewer was granted by the Water Corporation). However, on the day of the connection to the sewer discharge point (manhole), it was found that it had been covered and that it would take several months before access could be obtained.

Approval to infiltrate on site was then sought and obtained from the City of Bayswater and the site owner (Western Power) and the groundwater abstracted during the pumping tests was therefore re-infiltrated on site (Sketch 4). The water was infiltrated into two infiltration basins with discharge being alternated between the basins when they had filled. The capacity of the infiltration basins was found to be insufficient as the pumping test progressed and it was therefore decided to start alternating the discharge between the infiltration basins and a natural low depression south of the main infiltration basin. After 32 hours of pumping it was considered that the pumping test data was sufficient for analysis and the pumping test was therefore terminated due to issues with the available infiltration capacity.

6.3 Analysis and Results

Figures E4–1 to E4–2 summarise the pumping test results while Table 8 presents the estimated hydraulic properties from the different analysis methods.

Table 8: Results from Pumping Test Analysis – Bayswater Dive Structure

Method	Transmissivity (m^2/d)	Storage Coefficient	Figures
Distance Drawdown	120	7.0×10^{-5}	E4–3
Groundwater Model	60–113	1.5×10^{-5} - 7.5×10^{-5}	E4–4 and E4–5
Analytical Type Curves	21–300 *	-	E4–6 to E4–13 *

* Selected type curves only

The results indicate:

- The drawdown in piezometric level in the pumping well reached almost 14 m toward the end of the test and the piezometric level almost reached steady-state conditions at the end of the pumping test. The drawdown in the monitoring wells and VWPs ranged between 0.1 m and 9.2 m.
- There was no groundwater level drawdown response in the Upper Aquifer due to the pumping of the Lower Aquifer. Instead groundwater level rose in some of the wells due to the infiltration of the water back into the Upper Aquifer. This indicates that there is no noticeable connection between the two aquifers.
- BH2-26 (screened in the Osborne Formation), showed a small delayed response to the pumping, indicating limited connection of the Lower Aquifer with the Osborne Formation.
- The recovery of the piezometric level after pumping ceased took a much longer time than for the other pumping tests described in this Appendix, suggesting that there is limited direct recharge to the Lower Aquifer.
- The distance drawdown curve (Figure E4–3) indicates that there is a medium correlation between distance (from the pumping well) and drawdown, suggesting heterogeneous conditions. MW2-02B falls far from the curve, which is also the well that showed a significantly lower hydraulic conductivity during slug testing than the other wells.

- The groundwater model was not able to provide a good match for all observed piezometric levels by using a homogenous aquifer approach. The closer wells (MW2-01C and BH0-02) showed a better match with a higher transmissivity, while the wells and VWPs located further away (BH2-19, BH2-22 and MW2-02B) showed a better match with a lower transmissivity (E4–4 and E4–5). There was found to be only a small difference in the calculated values when varying the vertical hydraulic conductivity in the model, which is likely due to the wells being screened over the full aquifer thickness.

- The type curve analysis provided larger transmissivity for the pumping curves and lower transmissivity for the recovery curves, again indicating slow or limited recharge to the Lower Aquifer. MW2-02C reached steady-state more quickly than any other well, suggesting that the hydraulic conductivity could be higher in the upper part of the Lower Aquifer.

6.4 Groundwater Quality

Figure E4–14 shows the field monitoring results of pH and Electrical Conductivity (EC) from the Constant Rate Test while Table E1 presents the groundwater quality laboratory results from samples taken at the beginning and end of the pumping test. The results indicate:

- pH decreased from 7.5 to 7.0 within the first 400 minutes of the pumping test after which it remained stable at about 7.0, suggesting neutral conditions.

- EC ranged between 500 and 700 uS/cm during the test indicating fresh water. There was a slight increasing trend from the beginning of the test to 1600 minutes into the test, after which EC decreased again.

- Total Nitrogen was 0.33 mg/L and 0.49 mg/L at the beginning and end of test, respectively, which is below the SRT criterion for disposal to Swan River (1 mg/L).

- Total iron increased from 3 mg/L at the beginning of the test to 22 mg/L at the end of the test.

- BTEX, MAH, PAH, hydrocarbons and pesticides were not detected in either of the collected samples.

TABLE E1 - SUMMARY OF WATER QUALITY RESULTS

			Area	Forrestfield		Airport West									Consolidated		Bayswater Dive Structure		
			Well ID	PW1-01	PW1-01	PW2-01	SW08	PW2-01	Drain	PW2-01	Drain	PW2-01	PW2-01 DUP	Drain	PW1-02	PW1-02	MW2-02A	MW2-02C	PW2-02
			Test Time	Beginning	End	Before		Beginning		Mid		End			Beginning	End	Before		End
			Sample Date	8/12/2014	11/12/2014	5/12/2014		19/1/2015		21/1/2015		22/1/2015			6/1/2015	8/1/2015	5/12/2014		4/2/2015
			Matrix	Groundwater		Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater		Water	Groundwater		Groundwater		
pH	pH Units	6.0-8.5	0	6.3	6.5	9.1	8.0	7.9	7.7	7.7	7.7	7.8		7.6	8.0	8.1	7.1	7.4	7.0
Total Dissolved Solids Dried at 175-185°C	mg/L		10	540	520	770	360	720	390	740	540	740		460	410	420	250	380	420
Conductivity @ 25 C	µS/cm		2	930	930			1300	670	1300	920	1300		660	720	750			670
Salinity	mg/L		2	610	610			860	440	860	600	850		430	470	490			440
Total Suspended Solids Dried at 103-105°C	mg/L		5			7	<5										<5	9	
Turbidity	NTU		0.5			5.7	3.5										4.1	15	
Hydroxide Alkalinity as OH	mg/L		5	<5	<5	<5	<5	<5	<5	<5	<5	<5		<5	<5	<5	<5	<5	<5
Carbonate Alkalinity as CO3	mg/L		1	<1	<1	57	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1
Bicarbonate Alkalinity as HCO3	mg/L		5	25	22	170	110	340	110	330	200	330		110	180	180	100	150	93
Total Alkalinity as CaCO3	mg/L		5	21	18	240	90	280	88	270	160	270		90	150	150	84	120	76
Acidity to pH 8.3	mg CaCO3/L	>40	5	39	33	<5	<5	16	10	18	10	17		9	7	<5	16	19	50
Chloride, Cl	mg/L		1	130	120	260	130	260	140	260	180	260		140	110	120	91	110	92
Sulphate, SO4	mg/L		1	69	65	24	30	<1	18	<1	20	<1		29	58	58	6	20	110
Sulphide	mg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		0	<0.1	<0.1			<0.1
Sodium, Na	mg/L		0.5	110	100	150	67	140	76	130	92	140		63	67	66	55	110	59
Calcium, Ca	mg/L		0.2	10.0	10.0	95	28	94.0	29	86.0	51	87.0		27	57.0	53.0	14	8.7	30.0
Magnesium, Mg	mg/L		0.1	28.0	28.0	11	12	18.0	14	16.0	14	16.0		12	11.0	12.0	7.5	5.5	14.0
Potassium, K	mg/L		0.1	4.7	4.7	9.7	5.0	6.1	4.8	5.5	5.0	6.3		4.9	4.0	4.0	4.3	3.5	5.5
Total Hardness by Calculation	mg CaCO3/L		1	140	140	280	120	310	130	280	180	290		120	190	180	66	45	130
Total Organic Carbon	mg/L		0.2			21	24										4.1	7.2	
Total Cyanide	mg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	0.1	<0.004			<0.004
Thiocyanate	mg/L		0.1	<0.1	<0.1			<0.1	0	0.4	1	0.3		1	<0.1	<0.1			<0.1
Chlorophyll a	mg/L		0.0005			<0.0005	0.0010										0.0031	<0.0005	
NUTRIENTS																			
Nitrite, NO_2 as NO_2	mg/L		0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate, NO_3 as NO_3	mg/L		0.2	190	150	<0.2	0.4	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate/Nitrite Nitrogen, NOx as N	v		0.05	44	33			<0.05	0.1	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05			<0.05
Ammonia, NH_3	mg/L		0.05	0.07	0.25	0.17	<0.05	0.52	<0.05	0.54	0.19	0.55	0.54	<0.05	<0.05	0.05	0.15	0.13	0.32
Total Kjeldahl Nitrogen	mg/L		0.05	<0.05	<0.05	0.82	0.85	0.70	<0.05	0.76	0.76	0.77	0.82	0.89	0.13	0.10	0.30	0.33	0.47
Total Nitrogen (calc)	mg/L	1	0.05	44.00	33.00	0.83	0.94	0.72	0.06	0.77	0.76	0.78	0.82	0.89	0.16	0.10	0.30	0.33	0.49
Total Phosphorus (Kjeldahl Digestion)	mg/L	0.1	0.01	0.09	0.07	1.10	<0.01	0.31	<0.01	0.12	0.06	0.13	0.12	0.01	0.20	0.13	0.76	0.12	0.07
Filterable Reactive Phosphorus	mg/L		0.00	0.09	0.06			0.04	0.01	0.09	0.05	0.09	0.09	0.004	0.08	0.07			<0.002
DISSOLVED METALS																			
Aluminium, Al	mg/L	0.15	0.02	0.01	<0.005	<0.02	0.10	0.01	0.12	<0.005	0.07	<0.005		0.08	0.04	<0.005	<0.02	0.03	<0.005
Arsenic, As	mg/L		0.02	<0.001	<0.001	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.002	0.002	<0.02	<0.02	0.003
Boron, B	mg/L		0.05	0.05	0.06	0.09	0.07	0.03	0.03	0.02	0.02	0.03		0.04	0.02	0.02	<0.05	0.07	0.02
Cadmium, Cd	mg/L		0.001	<0.0001	<0.0001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.0001
Chromium, Cr	mg/L		0.005	<0.001	<0.001	<0.005	<0.005	0.002	0.001	0.002	0.002	0.002		<0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Copper, Cu	mg/L		0.005	0.001	0.008	<0.005	<0.005	<0.001	0.001	<0.001	<0.001	<0.001		0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Iron, Fe	mg/L		0.02	0.02	0.03	<0.02	0.23	2.10	0.33	2.70	1.10	1.10		0.18	0.13	0.51	2.90	0.25	20.00
Manganese, Mn	mg/L		0.005	0.031	0.002	0.026	0.007	0.093	0.007	0.028	0.014	0.027		<0.001	0.038	0.034	0.44	0.094	0.064
Molybdenum, Mo	mg/L		0.01	<0.001	<0.001	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.01	<0.01	<0.001
Lead, Pb	mg/L		0.02	0.001	0.002	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.02	<0.02	<0.001
Nickel, Ni	mg/L		0.005	0.001	<0.001	<0.005	<0.005	<0.001	0.001	<0.001	<0.001	<0.001		0.002	<0.001	<0.001	<0.005	<0.005	0.001
Selenium, Se	mg/L		0.05	<0.002	<0.002	<0.05	<0.05	<0.002	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.05	<0.05	<0.002
Tin, Sn	mg/L		0.05	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.05	<0.05	<0.001
Zinc, Zn	mg/L		0.01	0.009	0.065	<0.01	0.01	<0.005	<0.005	<0.005	0.01	<0.005		<0.005	<0.005	<0.005	<0.01	<0.01	0.008
Mercury	mg/L		0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005		<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
TOTAL METALS																			
Total Aluminium	mg/L	1	0.02	0.08	0.01	0.18	0.27	0.26	0.13	0.02	0.09	0.01		0.11	0.08	0.02	0.03	1.50	0.01
Total Arsenic	mg/L		0.02	<0.001	<0.001	<0.02	<0.02	0.001	<0.001	<0.001	<0.001	<0.001		<0.001	0.002	0.002	<0.02	<0.02	0.003
Total Boron	mg/L		0.05	0.07	0.08	0.09	0.07	0.03	0.03	0.03	0.04	0.03		0.04	0.03	0.03	<0.05	0.07	0.03
Total Cadmium	mg/L		0.001	<0.0001	<0.0001	<0.001	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.001	<0.001	<0.0001
Total Chromium	mg/L		0.005	<0.001	<0.001	0.008	<0.005	0.007	0.001	0.003	0.002	0.002		0.001	<0.001	<0.001	<0.005	<0.005	<0.001
Total Copper	mg/L		0.005	0.002	0.003	<0.005	<0.005	<0.001	0.001	<0.001	<0.001	<0.001		0.001	<0.001	<0.001	<0.005	0.006	<0.001
Ferrous Iron, Fe2+	mg/L		0.05	<0.05	<0.05			2.50	0.37	2.70	0.99	2.80		0.33	0.51	0.49			22.00
Ferric Iron, Fe3+	mg/L		0.05	<0.05	0.018			<0.05	<0.05	<0.05	0.32	<0.05		<0.05	0.06	0.38			1.00
Total Iron	mg/L	1	0.02	0.03	0.02	0.10	0.43	2.50	0.41	2.70	1.30	2.80		0.33	0.57	0.87	3.00	1.20	22.00
Total Manganese	mg/L		0.005	0.033	0.002	0.032	0.008	0.096	0.008	0.028	0.016	0.028		0.008	0.042	0.037	0.46	0.099	0.071
Total Molybdenum	mg/L		0.01	<0.001	<0.001	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.01	<0.01	<0.001
Total Lead	mg/L		0.02	0.002	<0.001	<0.02	<0.02	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.02	<0.02	<0.001
Total Nickel	mg/L		0.005	0.001	<0.001	0.005	<0.005	0.001	0.001	<0.001	<0.001	<0.001		0.002	0.001	<0.001	<0.005	<0.005	0.001
Total Selenium	mg/L		0.05	<0.002	<0.002	<0.05	<0.05	<0.002	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.05	<0.05	<0.002
Total Tin	mg/L		0.05	<0.001	<0.001	<0.05	<0.05	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.05	<0.05	<0.001
Total Zinc	mg/L		0.01	0.012	0.008	<0.01	<0.01	<0.005	0.007	<0.005	0.01	<0.005		0.009	<0.005	0.029	<0.01	<0.01	0.011
Total Mercury	mg/L		0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

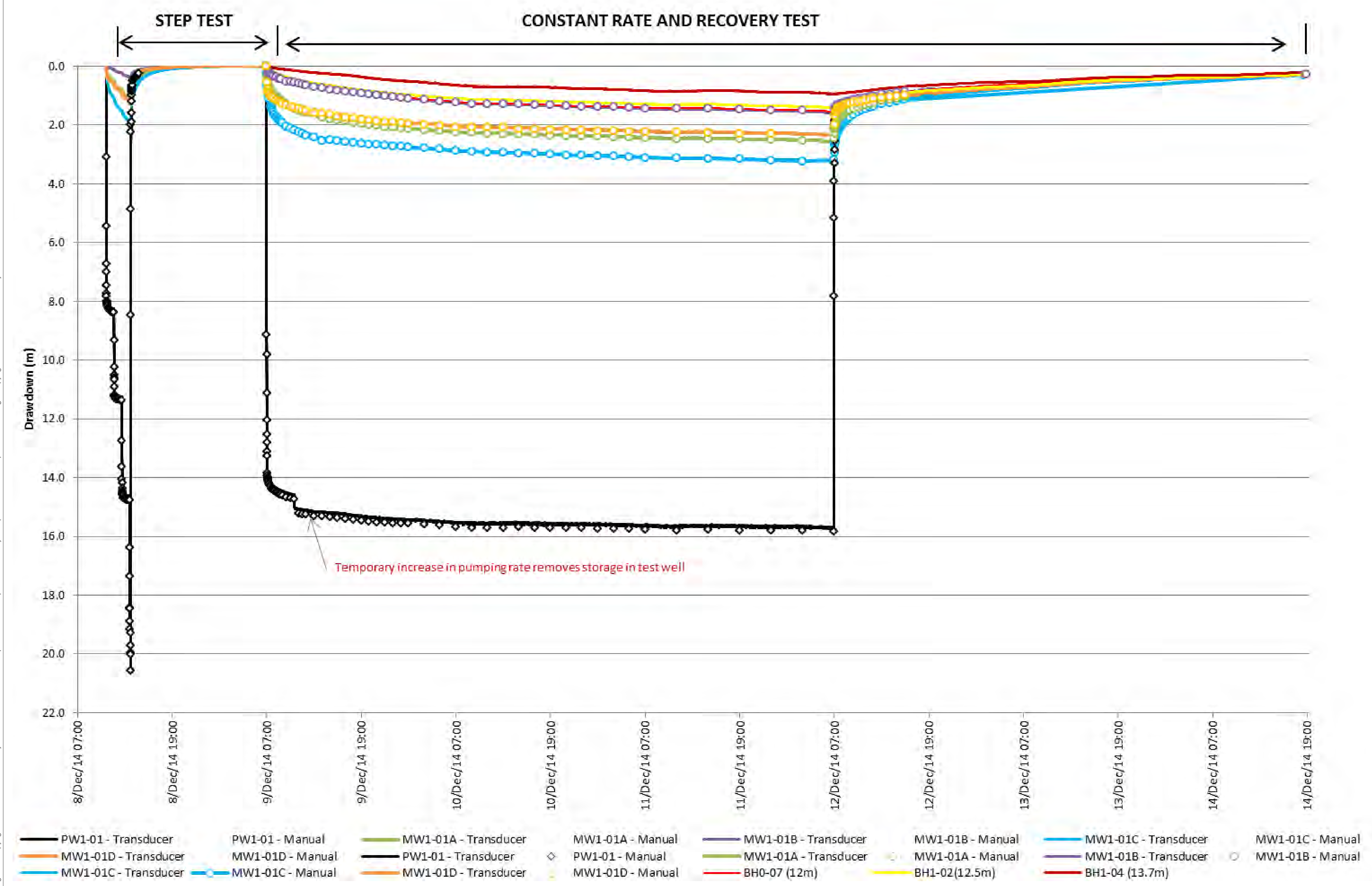
TABLE E1 - SUMMARY OF WATER QUALITY RESULTS

			Area	Forrestfield		Airport West									Consolidated		Bayswater Dive Structure		
			Well ID	PW1-01	PW1-01	PW2-01	SW08	PW2-01	Drain	PW2-01	Drain	PW2-01	PW2-01 DUP	Drain	PW1-02	PW1-02	MW2-02A	MW2-02C	PW2-02
			Test Time	Beginning	End	Before		Beginning		Mid		End			Beginning	End	Before		End
			Sample Date	8/12/2014	11/12/2014	5/12/2014		19/1/2015		21/1/2015		22/1/2015			6/1/2015	8/1/2015	5/12/2014		4/2/2015
			Matrix	Groundwater		Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater		Water	Groundwater		Groundwater		
HYDROCARBONS																			
Benzene (F0)	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
TRH C6-C9	µg/L		40	<40	<40	71	<40	<40	<40	<40	<40	<40		<40	<40	<40	<40	<40	<40
TRH C6-C10	µg/L		50	<50	<50			<50	<50	<50	<50	<50		<50	<50				<50
TRH C6-C10 minus BTEX (F1)	µg/L		50	<50	<50	79	<50	<50	<50	<50	<50	<50		<50	<50	<50	<50	<50	<50
TRH C10-C14	µg/L		50	55	<50	<50	<50	<50	<50	<50	<50	<50		<50	<50	<50	<50	<50	<50
TRH C15-C28	µg/L		200	<200	<200	<200	<200	<200	<200	<200	<200	<200		<200	<200	<200	<200	<200	<200
TRH C29-C36	µg/L		200	<200	<200	<200	<200	<200	<200	<200	<200	<200		<200	<200	<200	<200	<200	<200
TRH >C10-C16 (F2)	µg/L		60	<60	<60	<60	<60	<60	<60	<60	<60	<60		<60	<60	<60	<60	<60	<60
TRH >C16-C34 (F3)	µg/L		500	<500	<500	<500	<500	<500	<500	<500	<500	<500		<500	<500	<500	<500	<500	<500
TRH >C34-C40 (F4)	µg/L		500	<500	<500	<500	<500	<500	<500	<500	<500	<500		<500	<500	<500	<500	<500	<500
VOLATILES																			
Benzene	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Toluene	µg/L		0.5	<0.5	<0.5	1.3	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Ethylbenzene	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
m/p-xylene	µg/L		1	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	<1	<1	<1	<1	<1
o-xylene	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total Xylenes			1.5	<1.5	<1.5			<1.5	<1.5	<1.5	<1.5	<1.5		<1.5	<1.5	<1.5			<1.5
Styrene (Vinyl benzene)			0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Naphthalene	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
MtBE (Methyl-tert-butyl ether)				<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
PESTICIDES																			
Hexachlorobenzene (HCB)	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Alpha BHC	µg/L			<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
Lindane (gamma BHC)	µg/L		0.002	<0.05	<0.05	<0.002	<0.002	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.002	<0.002	<0.05
Beta BHC	µg/L			<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
Heptachlor	µg/L		0.002	<0.02	<0.02	<0.002	<0.002	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.002	<0.002	<0.02
Delta BHC	µg/L			<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
Aldrin	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Isodrin	µg/L			<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			<0.02
Heptachlor epoxide	µg/L		0.002	<0.02	<0.02	<0.002	<0.002	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.002	<0.002	<0.02
Gamma Chlordane	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Alpha Chlordane	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Alpha Endosulfan	µg/L		0.005	<0.02	<0.02	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.005	<0.005	<0.02
p,p'-DDE	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Dieldrin	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Endrin	µg/L		0.004	<0.02	<0.02	<0.004	<0.004	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.004	<0.004	<0.02
p,p'-DDD	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Beta Endosulfan	µg/L		0.005	<0.02	<0.02	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.005	<0.005	<0.02
p,p'-DDT	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Endrin Aldehyde	µg/L			<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			<0.02
Endosulfan sulphate	µg/L		0.005	<0.02	<0.02	<0.005	<0.005	<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.005	<0.005	<0.02
Methoxychlor	µg/L		0.100	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
Mirex	µg/L		0.010	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Endrin Ketone	µg/L		0.010	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Oxychlordane	µg/L		0.002	<0.01	<0.01	<0.002	<0.002	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.002	<0.002	<0.01
Azinphos-methyl (Guthion)	µg/L		0.050	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Bromophos Ethyl	µg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Chlorpyrifos (Chlorpyrifos Ethyl)	µg/L		0.009	<0.01	<0.01	<0.009	<0.009	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.009	<0.009	<0.01
Diazinon (Dimpylate)	µg/L		0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Dichlorvos	µg/L		0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Dimethoate	µg/L		0.1	<0.15	<0.15	<0.1	<0.1	<0.15	<0.15	<0.15	<0.15	<0.15		<0.15	<0.15	<0.15	<0.1	<0.1	<0.15
Ethion	µg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Fenitrothion	µg/L		0.1	<0.2	<0.2	<0.1	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2		<0.2	<0.2	<0.2	<0.1	<0.1	<0.2
Malathion	µg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Methidathion	µg/L		0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Parathion-ethyl (Parathion)	µg/L		0.004	<0.01	<0.01	<0.004	<0.004	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.004	<0.004	<0.01
PCBs																			
PCB Congener C28	µg/L		0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			<0.02
PCB Congener C52	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
PCB Congener C101	µg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004			<0.004
PCB Congener C118	µg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004			<0.004
PCB Congener C153	µg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004			<0.004
PCB Congener C138	µg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004			<0.004
PCB Congener C180	µg/L		0.004	<0.004	<0.004			<0.004	<0.004	<0.004	<0.004	<0.004		<0.004	<0.004	<0.004			<0.004

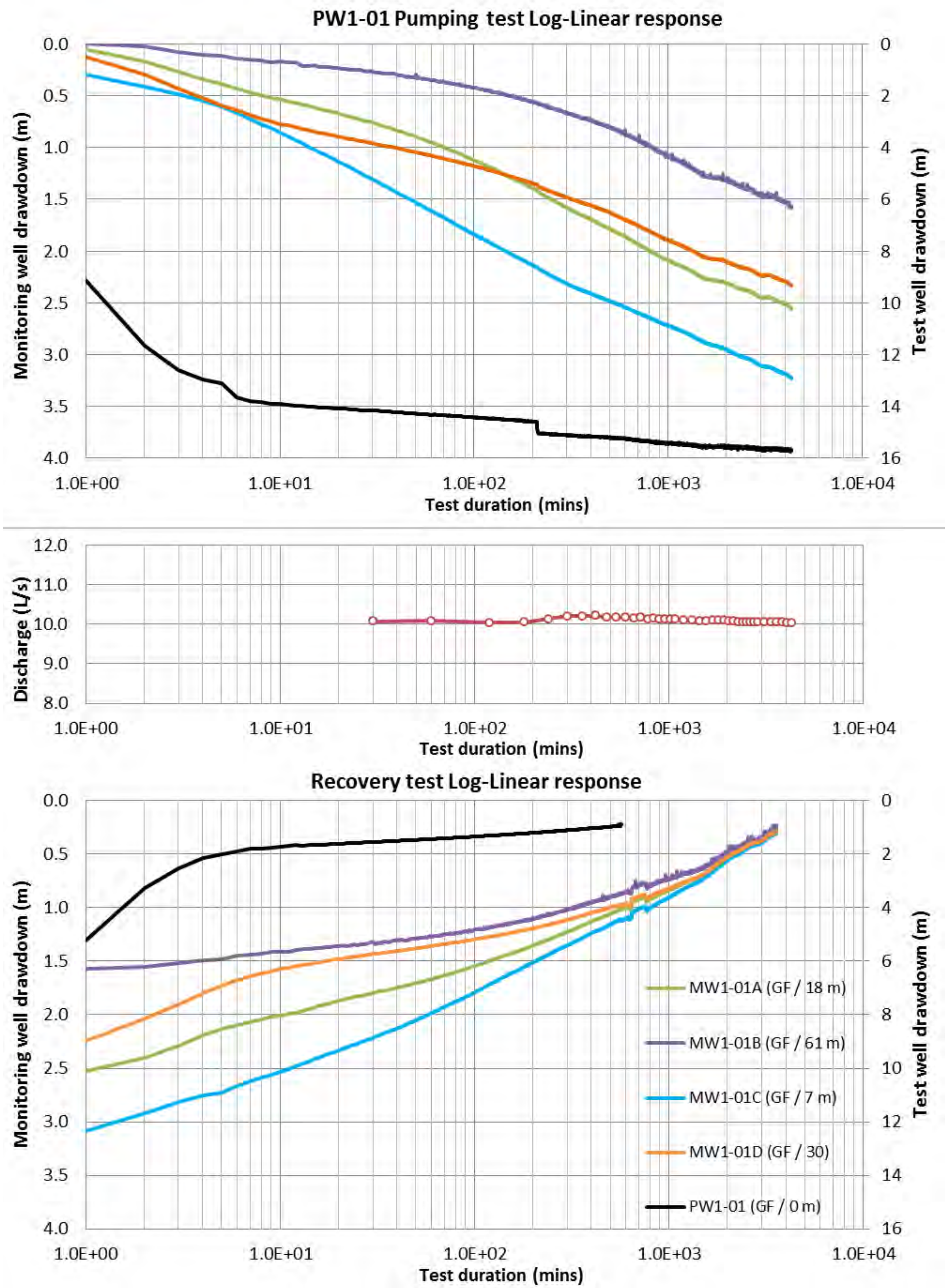
TABLE E1 - SUMMARY OF WATER QUALITY RESULTS

			Area	Forrestfield		Airport West									Consolidated		Bayswater Dive Structure		
			Well ID	PW1-01	PW1-01	PW2-01	SW08	PW2-01	Drain	PW2-01	Drain	PW2-01	PW2-01 DUP	Drain	PW1-02	PW1-02	MW2-02A	MW2-02C	PW2-02
			Test Time	Beginning	End	Before		Beginning		Mid		End			Beginning	End	Before		End
			Sample Date	8/12/2014	11/12/2014	5/12/2014		19/1/2015		21/1/2015		22/1/2015			6/1/2015	8/1/2015	5/12/2014		4/2/2015
			Matrix	Groundwater		Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater	Surfacewater	Groundwater		Water	Groundwater		Groundwater		
PAH																			
Naphthalene	µg/L		0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			0.03
2-methylnaphthalene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
1-methylnaphthalene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Acenaphthylene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Acenaphthene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Fluorene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Phenanthrene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Anthracene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Fluoranthene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Pyrene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(a)anthracene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Chrysene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(k)fluoranthene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(b&j)fluoranthene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(a)pyrene	µg/L		0.005	<0.005	<0.005			<0.005	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005			<0.005
Indeno(1,2,3-cd)pyrene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Dibenzo(a&h)anthracene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(ghi)perylene	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Benzo(b&j&k)fluoranthene	µg/L		0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			<0.02
Total PAH (18)	µg/L		0.1					<0.1	<0.1	<0.1	<0.1	<0.1		<0.1					<0.1
Phenols																			
4-chloro-3-methylphenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
2-chlorophenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
2,4-dichlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
2,6-dichlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Pentachlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
2,5-dichlorophenol	µg/L		0.05	<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
2,3,4,5-tetrachlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
2,3,4,6/2,3,5,6-tetrachlorophenol	µg/L		0.02	<0.02	<0.02			<0.02	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02			<0.02
2,4,5-trichlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
2,4,6-trichlorophenol	µg/L		0.01	<0.01	<0.01			<0.01	<0.01	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01			<0.01
Phenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	0.1	<0.1	<0.1		<0.1	0.1	<0.1			0.3
2-methyl phenol (o-cresol)	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
3/4-methyl phenol (m/p-cresol)	µg/L		0.2	<0.2	<0.2			<0.2	<0.2	<0.2	<0.2	<0.2		<0.2	<0.2	<0.2			<0.2
2,4-dimethylphenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
2,4-dinitrophenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
2-methyl-4,6-dinitrophenol	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
2-nitrophenol	µg/L		0.05	<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
4-nitrophenol	µg/L		0.05	<0.05	<0.05			<0.05	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05			<0.05
Dinex (2-cyclohexyl-4,6-dinitrophenol)	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
Dinoseb	µg/L		0.1	<0.1	<0.1			<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1			<0.1
Carbamates																			
Carbofuran	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Carbaryl	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Triazines																			
Simazine	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Atrazine	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Propazine	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Terbuthylazine	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Metribuzin	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Prometryn	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Terbutryn	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Cyanazine	µg/L		0.5	<0.5	<0.5			<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5			<0.5
Hexazinone	µg/L		1	<1	<1			<1	<1	<1	<1	<1		<1	<1	<1			<1
E.coli & Coliforms																			
E. coli	CFU/100mL		1	<1	<1			<1	490	<1	170	<1		500	<1	<1			<1
Thermotolerant Coliforms	CFU/100mL		1	<1	<1			<1	720	<1	250	<1		500	<1	<1			<1

ATTACHMENT E1
Constant Rate Test – Forrestfield Dive Structure (PW1-01)



CLIENT	Public Transport Authority	PROJECT	FAL-Stage 2 Geotechnical Investigation
DRAWN	AL	DATE	MAY 2015
CHECKED	DPS		MAY 2015
TITLE	Pumping Test Data PW1-01-Data (Forrestfield)		
SCALE	NOT TO SCALE	A3	
PROJECT No	147642129-077-R-Rev0	FIGURE No	Figure E1-1



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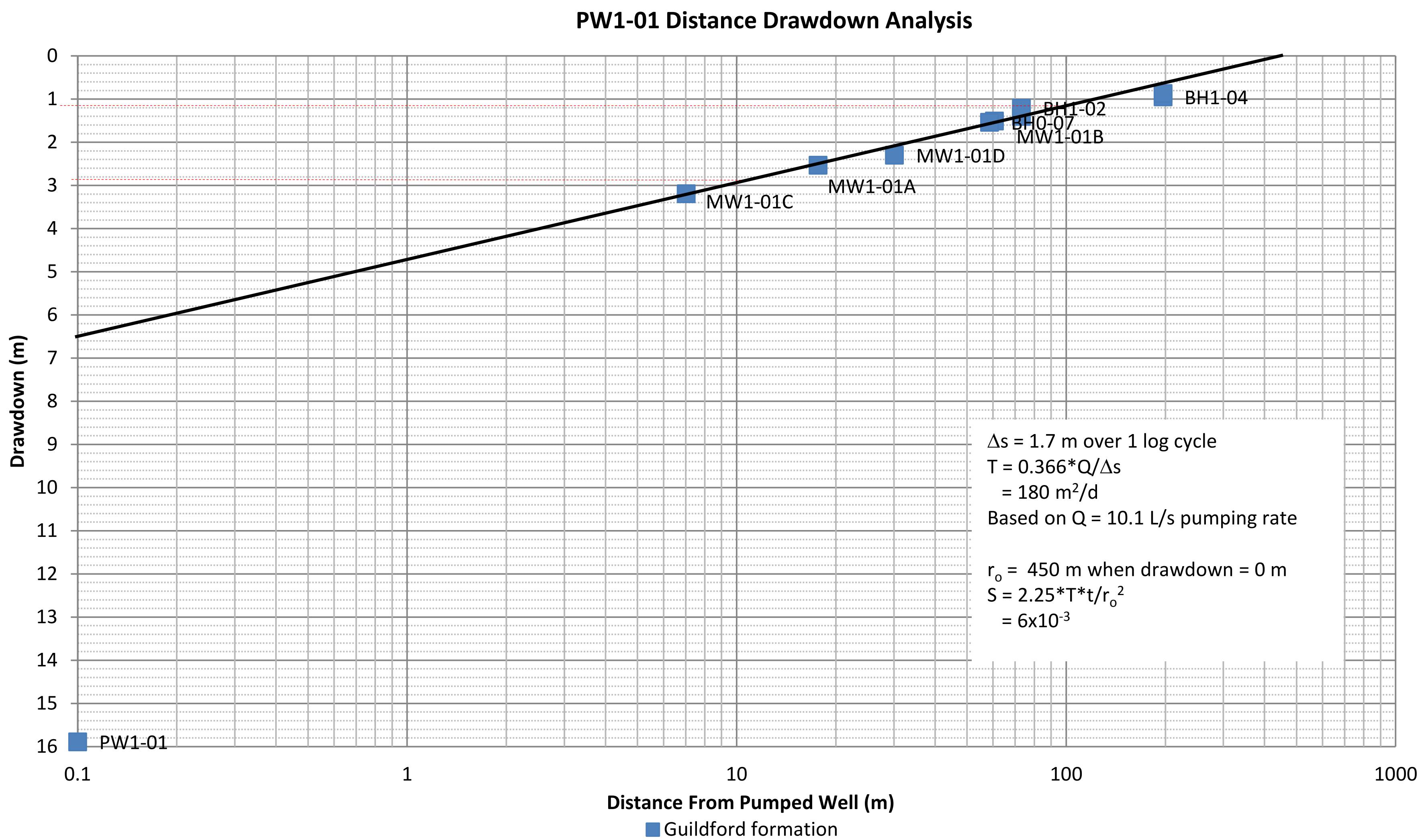
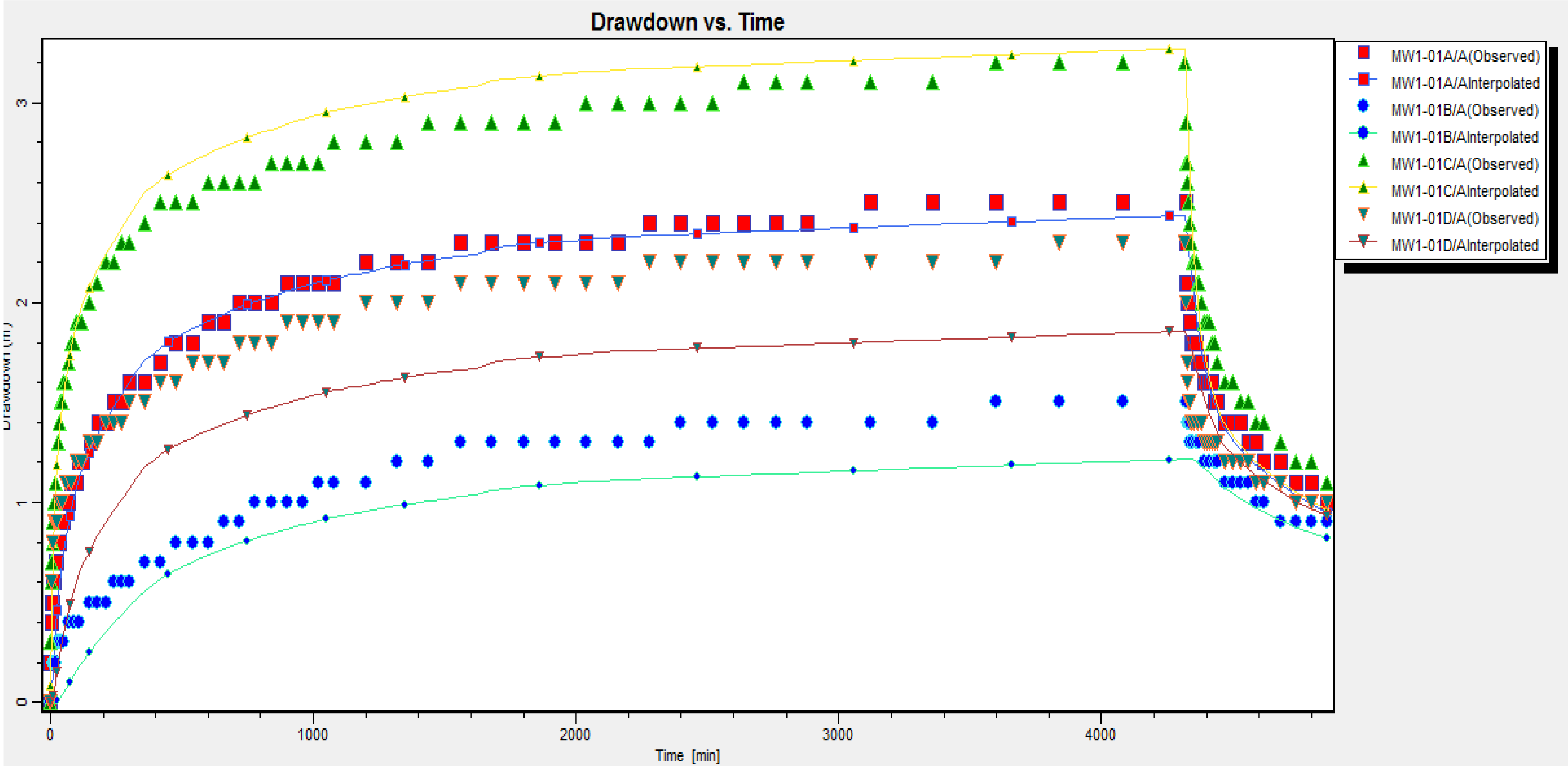
CLIENT: Public Transport Authority		PROJECT: FAL-Stage 2 Geotechnical Investigation	
DRAWN: SDB	DATE: 23/05/2015	TITLE: **Pumping Test Data PW1-01 (Forrestfield Dive Structure)**	
CHECKED: AL	DATE: 23/05/2015		
SCALE: NOT TO SCALE	A4	PROJECT No: 147642129-077-R-Rev0	FIGURE No: **Figure E1-2**



Golder Associates	CLIENT: Public Transport Authority		PROJECT: FAL-Stage 2 Geotechnical Investigation
	DRAWN: SDB	DATE: 24/05/2015	TITLE: **DISTANCE DRAWDOWN ANALYSIS PW1-01 (Forrestfield Dive Structure)**
	APPROVED: AL	24/05/2015	
	NOT TO SCALE	A4	PROJECT No: 147642129-077-R-Rev0 — **Figure E1-3**

Specific Storage = 1.00E-04 1/m
Transmissivity = 104 m2/d
Hydraulic Conductivity
K(GF)h 4 m/d
K(GF)v 4 m/d



Screenshot from MODFLOW output

CLIENT	Public Transport authority	PROJECT	FAL - Stage 2 Geotechnical Investigation
DRAWN AL	DATE 25-May-15	TITLE	**Modelled Groundwater Level Drawdown PW1-01 Pumping Test (Forrestfield) Forrestfield Dive Structure**
CHECK DPS	DATE 25-May-15		
SCALE Not To Scale	A4	PROJECT No. 147642129-077-R-Rev0	FIGURE No. E1-4

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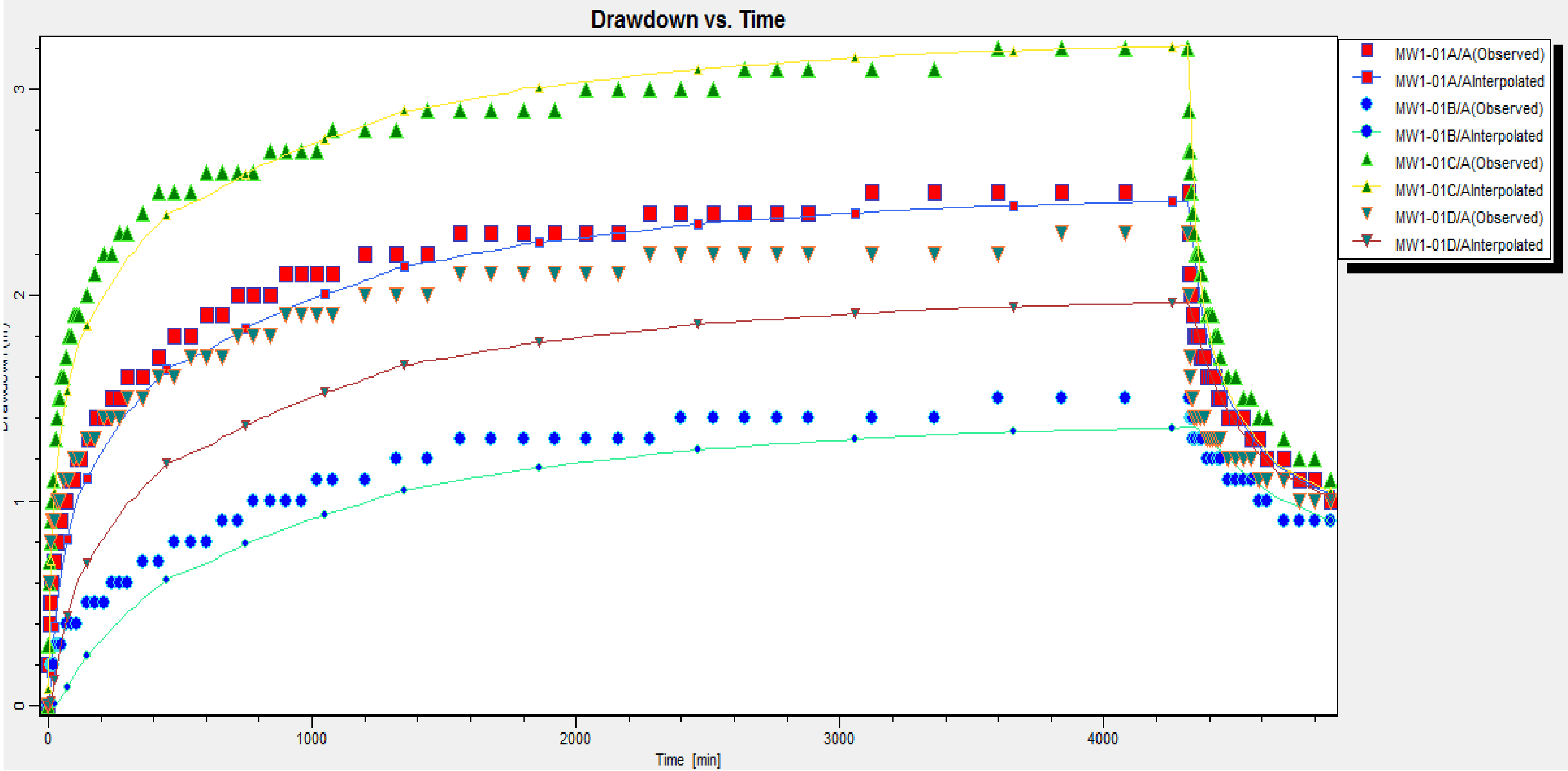
Specific Storage = 1.00E-04 1/m
Transmissivity = 104 m2/d
Hydraulic Conductivity
K(GF)h 4 m/d
K(GF)v 1 m/d



Screenshot from MODFLOW output

CLIENT	Public Transport authority		PROJECT	FAL - Stage 2 Geotechnical Investigation	
DRAWN	AL	DATE 25-May-15	TITLE	Modelled Groundwater Level Drawdown PW1-01 Pumping Test (Forrestfield) Forrestfield Dive Structure	
CHECK	DPS	DATE 25-May-15			
SCALE	Not To Scale	A4	PROJECT No. 147642129-077-R-Rev0	FIGURE No.	E1-5

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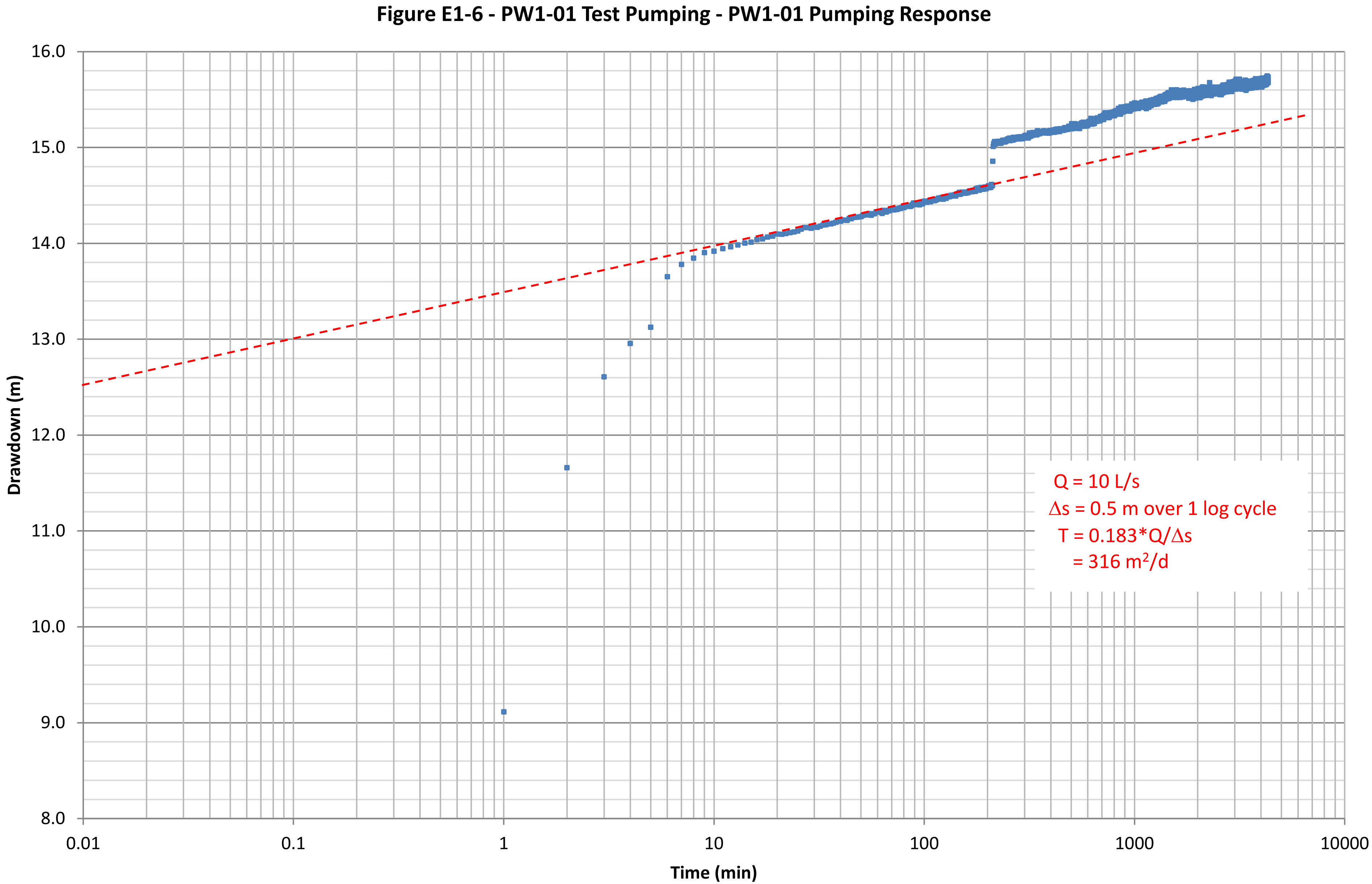


Figure E1-6 - PW1-01 Test Pumping - PW1-01 Pumping Response
16.0
15.0
14.0
13.0
12.0
11.0
10.0
9.0
8.0
Drawdown (m)
0.01
0.1
1
10
100
1000
10000
Time (min)
Q = 10 L/s
Δs = 0.5 m over 1 log cycle
T = 0.183*Q/Δs
= 316 m²/d

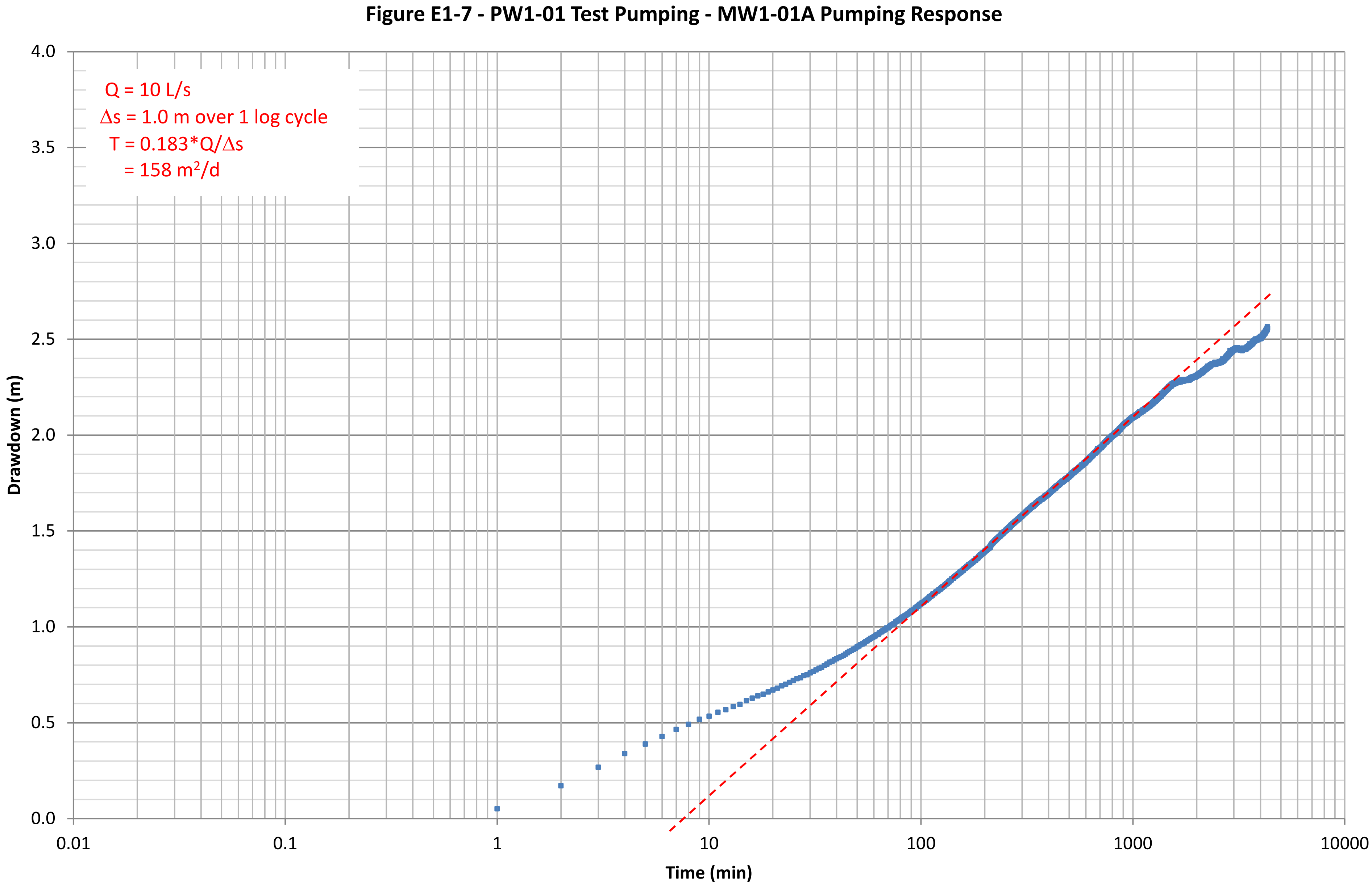
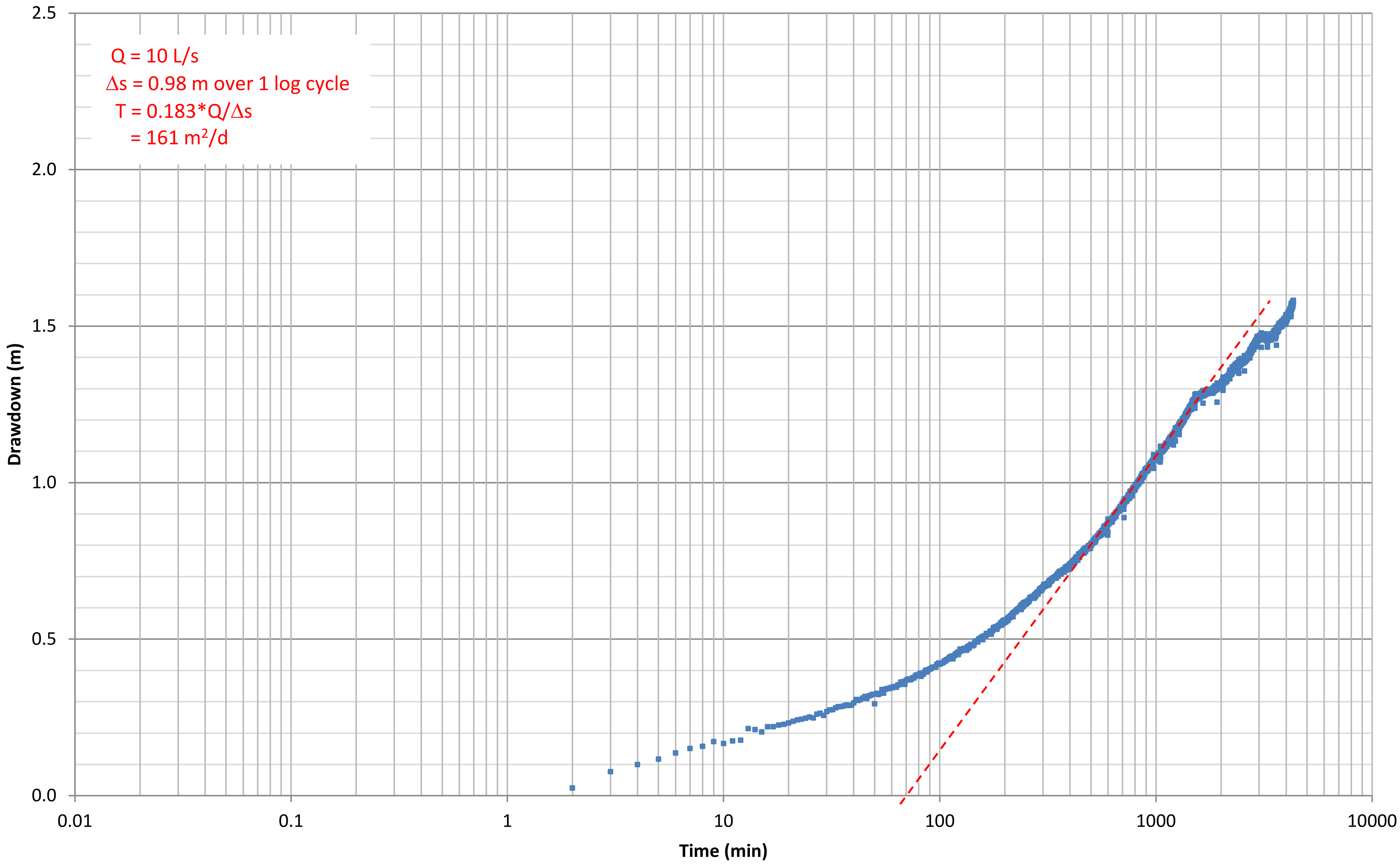


Figure E1-7 - PW1-01 Test Pumping - MW1-01A Pumping Response
Q = 10 L/s
Δs = 1.0 m over 1 log cycle
T = 0.183*Q/Δs
= 158 m²/d
Drawdown (m)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.01
0.1
1
10
100
1000
10000
Time (min)

Figure E1-8 - PW1-01 Test Pumping - MW1-01B Pumping Response



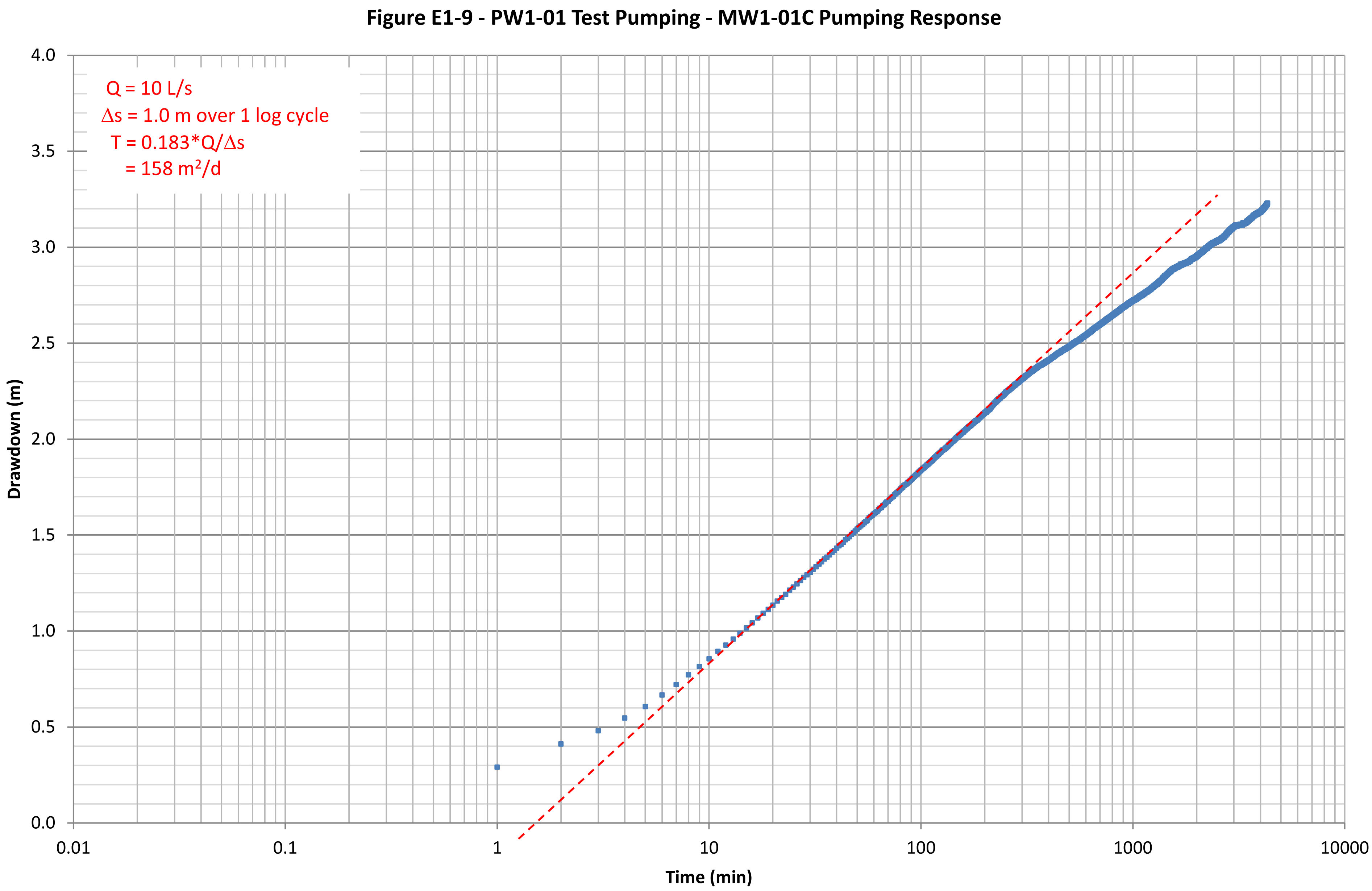


Figure E1-9 - PW1-01 Test Pumping - MW1-01C Pumping Response
Q = 10 L/s
Δs = 1.0 m over 1 log cycle
T = 0.183*Q/Δs
= 158 m²/d
Drawdown (m)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.01
0.1
1
10
100
1000
10000
Time (min)

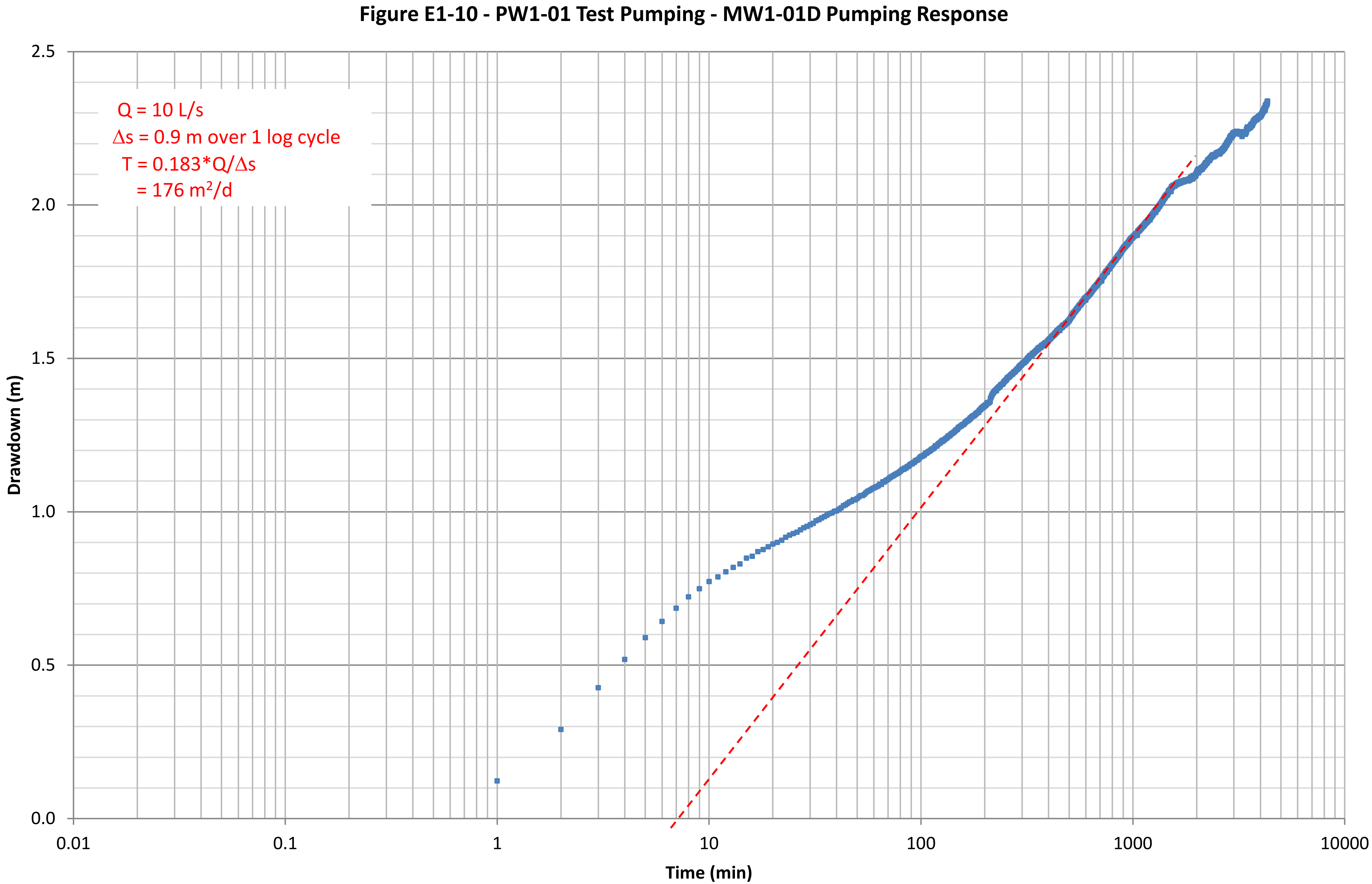


Figure E1-10 - PW1-01 Test Pumping - MW1-01D Pumping Response
Q = 10 L/s
Δs = 0.9 m over 1 log cycle
T = 0.183*Q/Δs
= 176 m2/d
Drawdown (m)
Time (min)
2.5
2.0
1.5
1.0
0.5
0.0
0.01
0.1
1
10
100
1000
10000

Figure E1-11: PW1-01 Test Pumping - PW1-01 Recovery Response

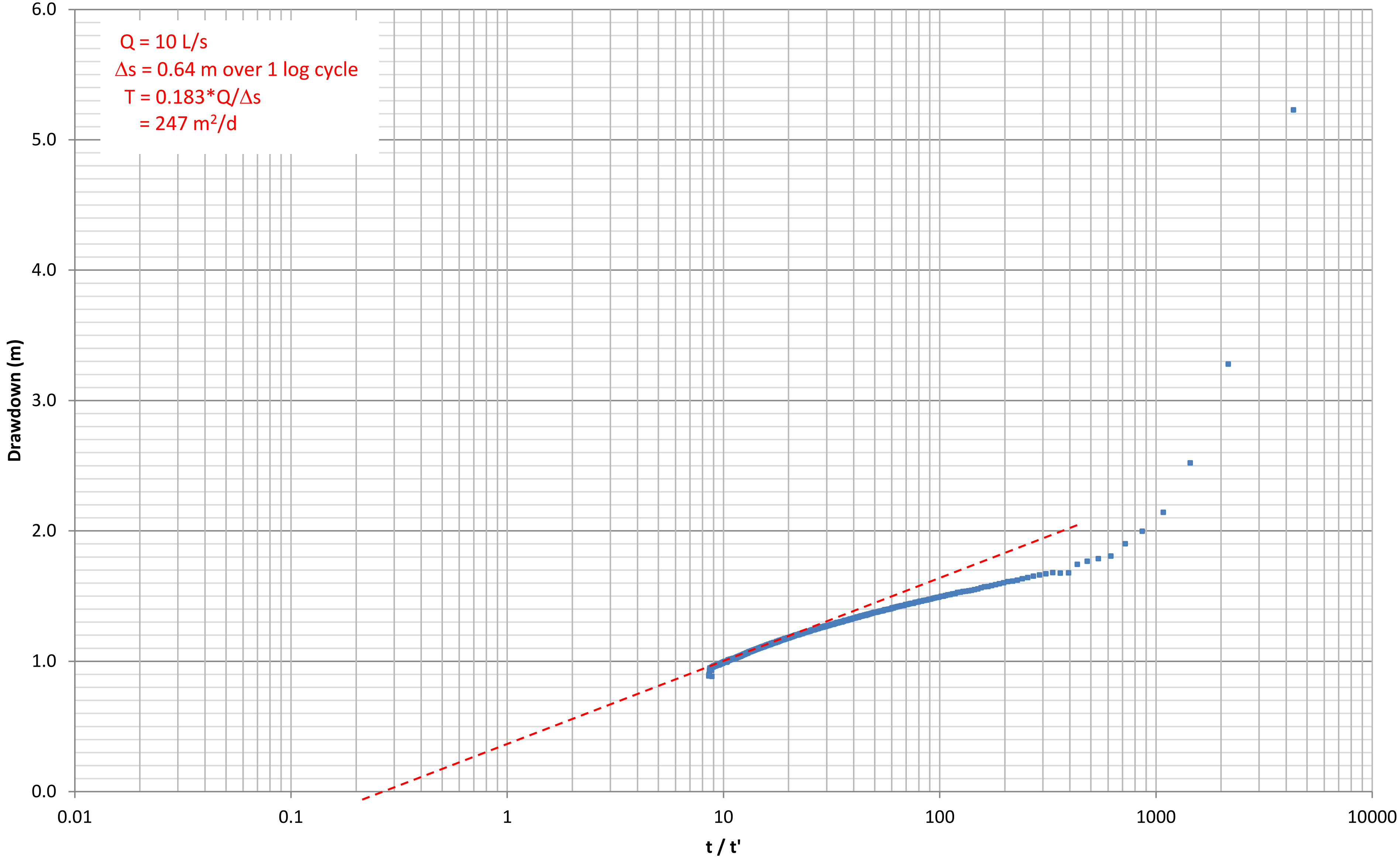


Figure E1-12: PW1-01 Test Pumping - MW1-01A Recovery Response

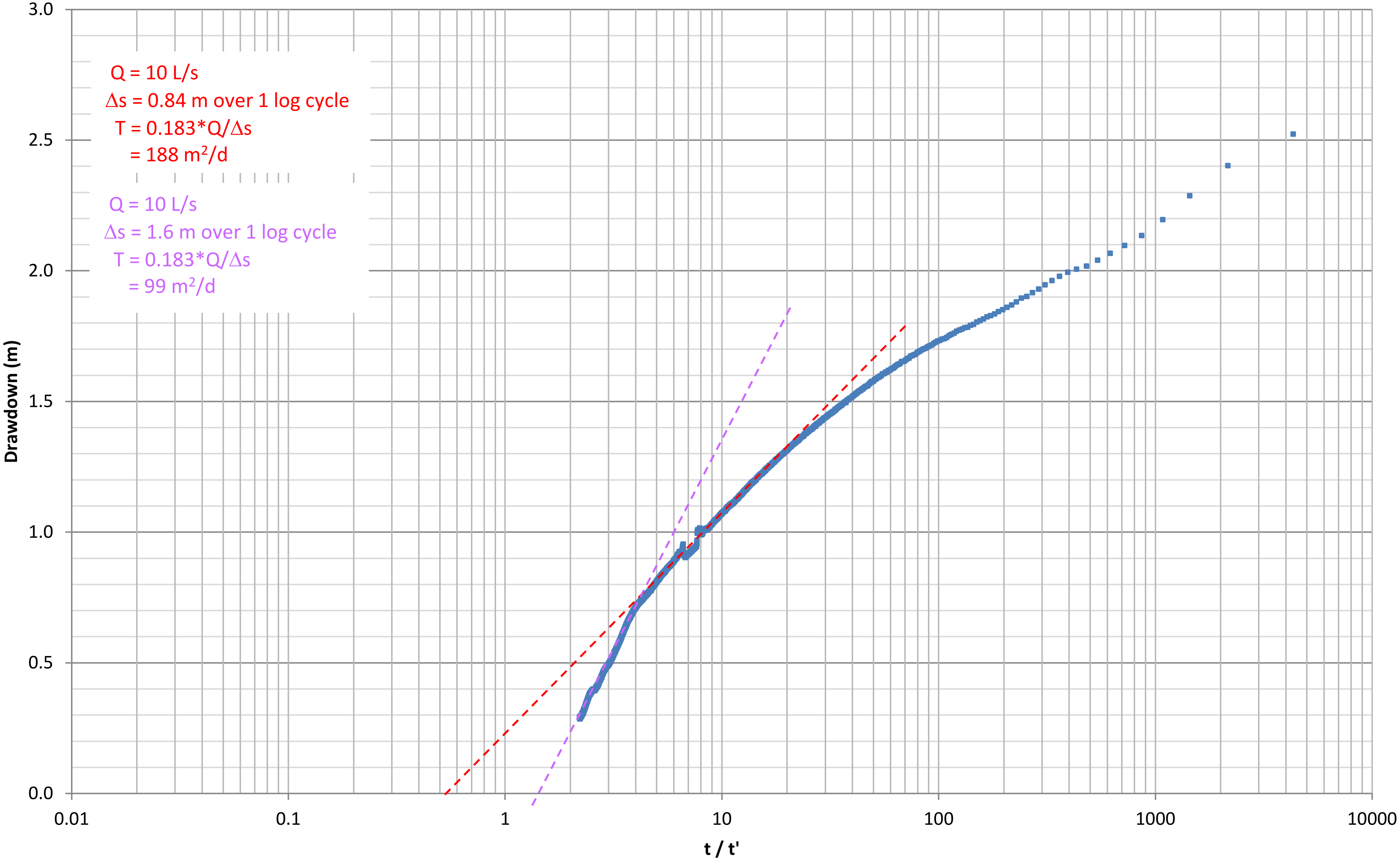


Figure E1-13: PW1-01 Test Pumping - MW1-01B Recovery Response

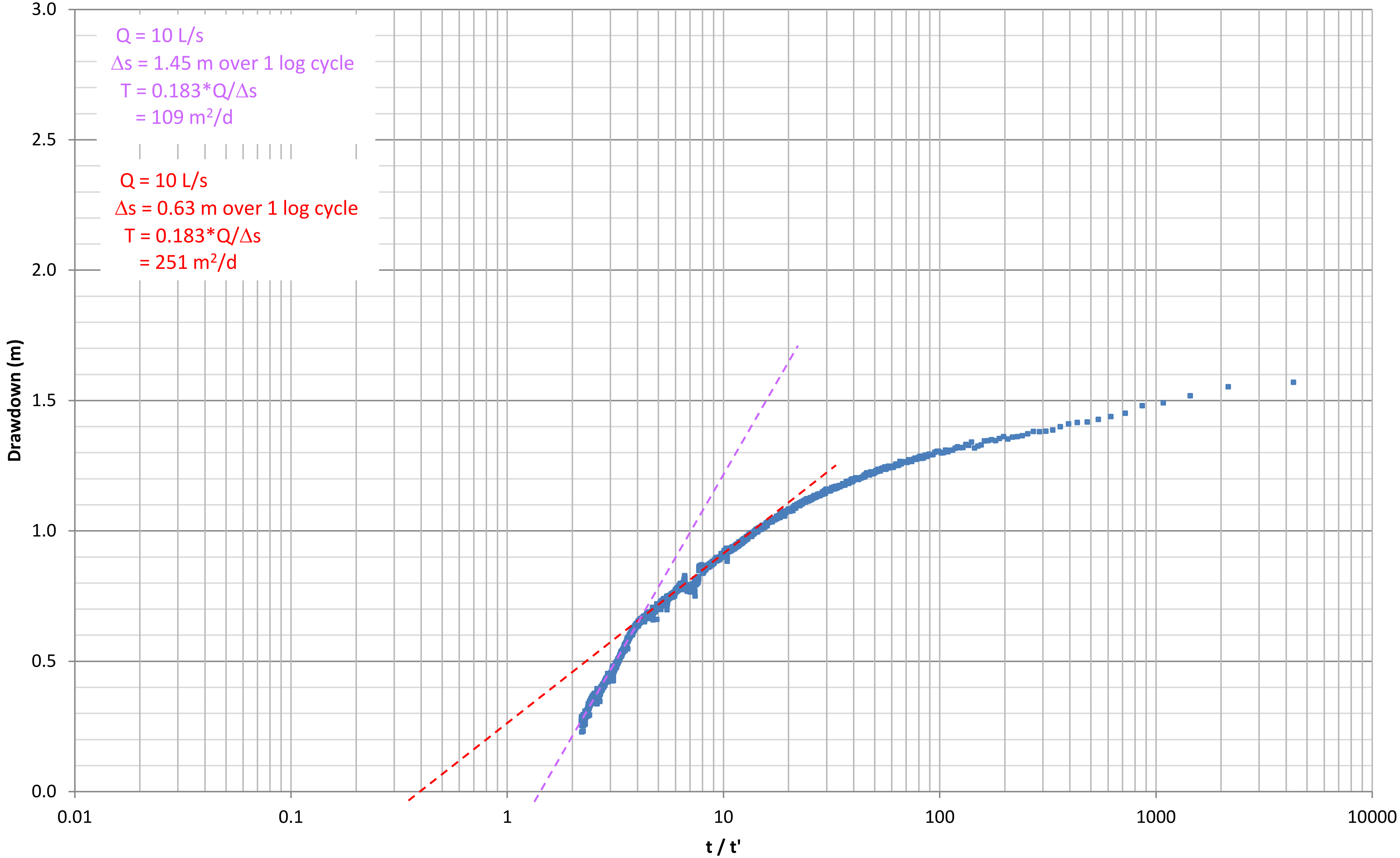


Figure E1-14: PW1-01 Test Pumping - MW1-01C Recovery Response

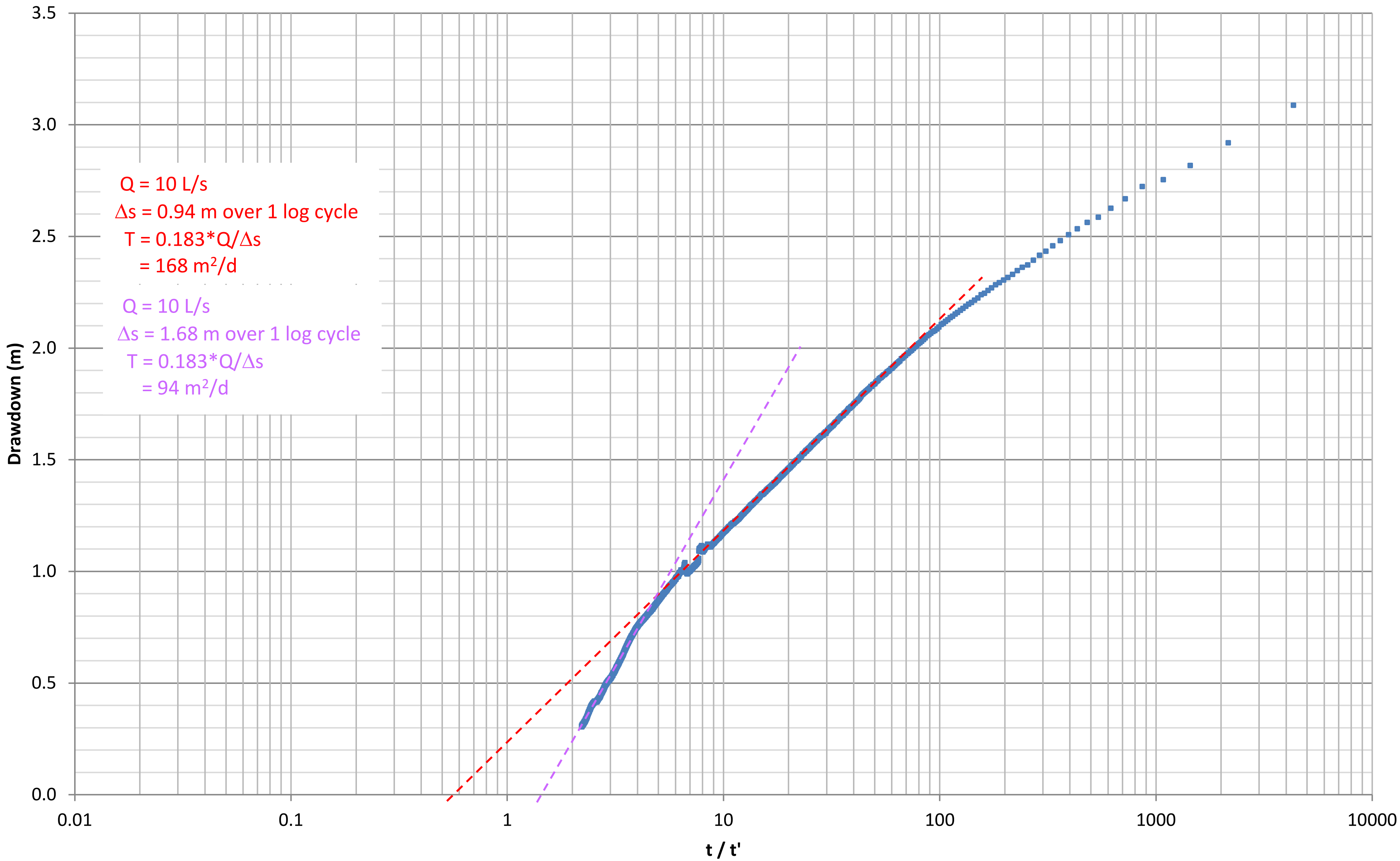
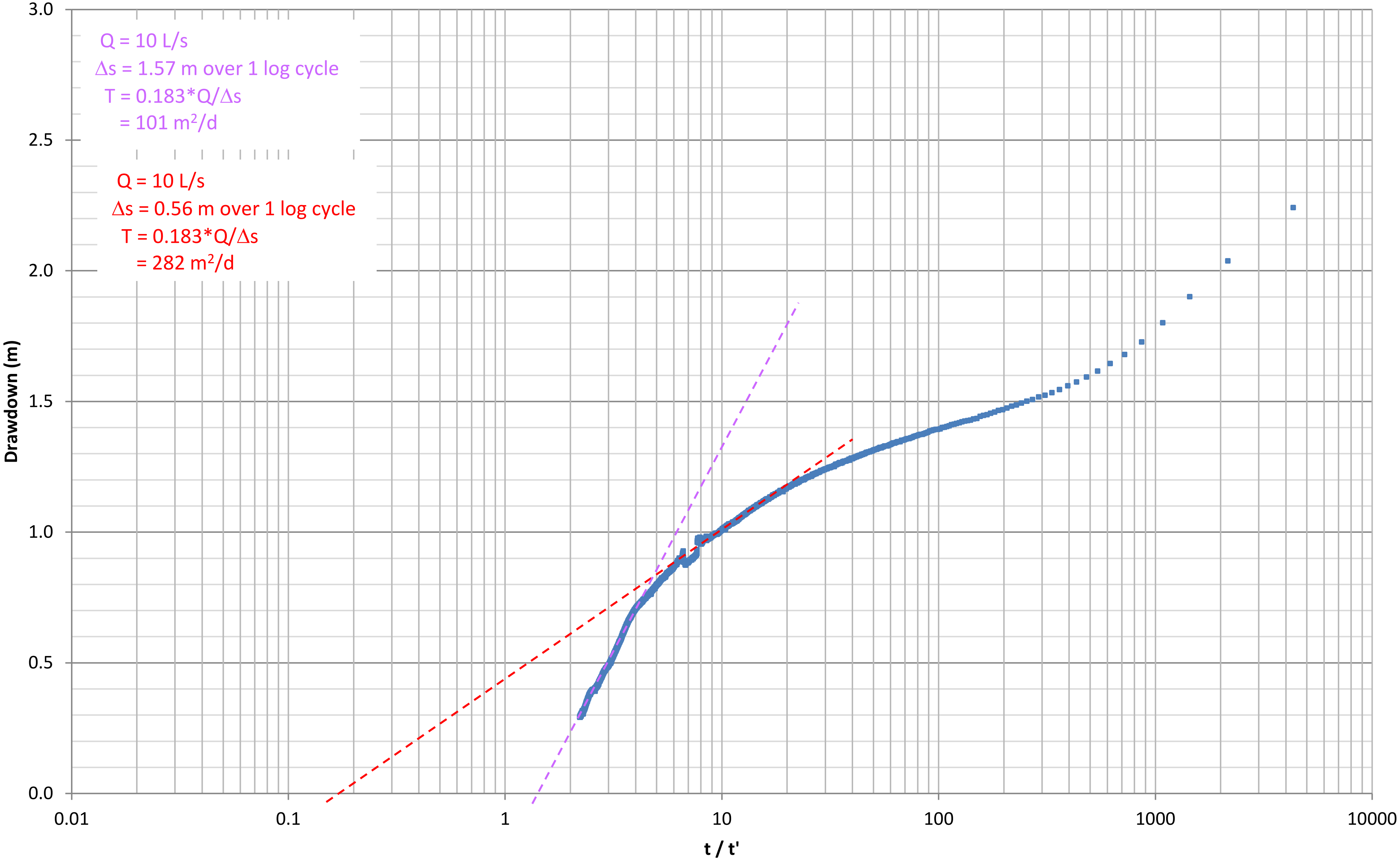


Figure E1-15: PW1-01 Test Pumping - MW1-01D Recovery Response



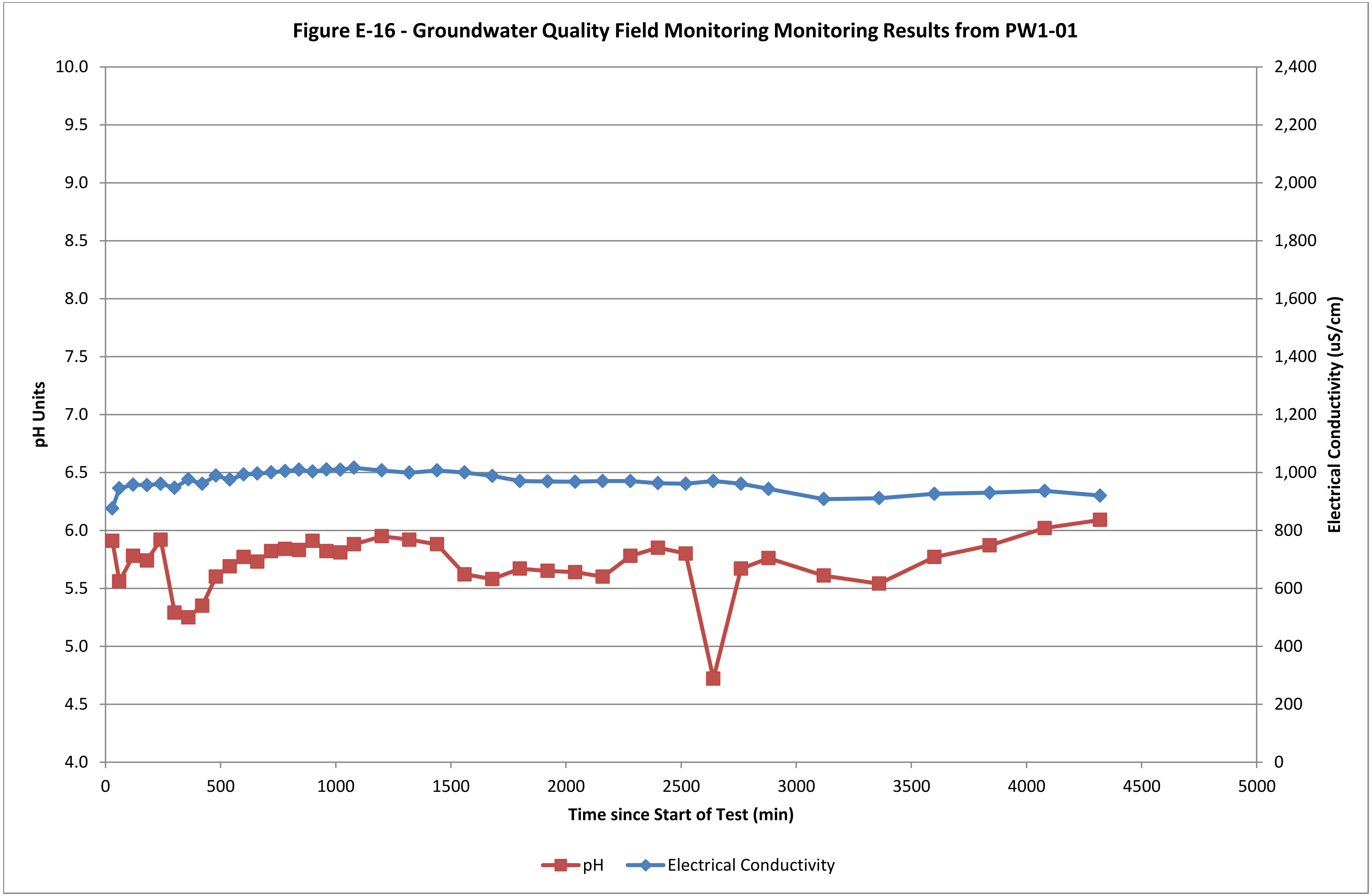
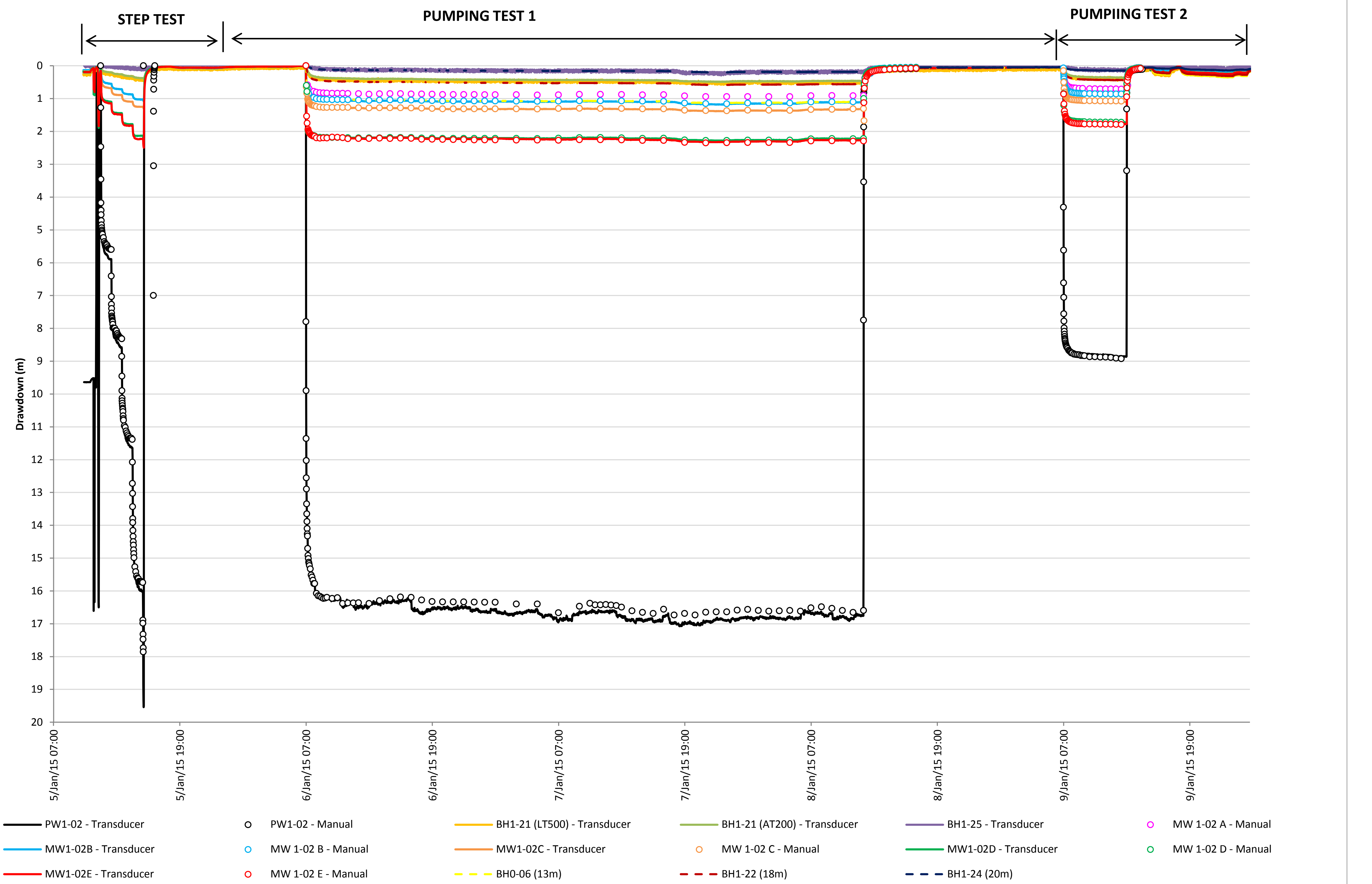


Figure E-16 - Groundwater Quality Field Monitoring Monitoring Results from PW1-01
pH Units
Electrical Conductivity (uS/cm)
Time since Start of Test (min)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
pH
Electrical Conductivity

ATTACHMENT E2
Constant Rate Test – Consolidated Terminal Station (PW1-02)



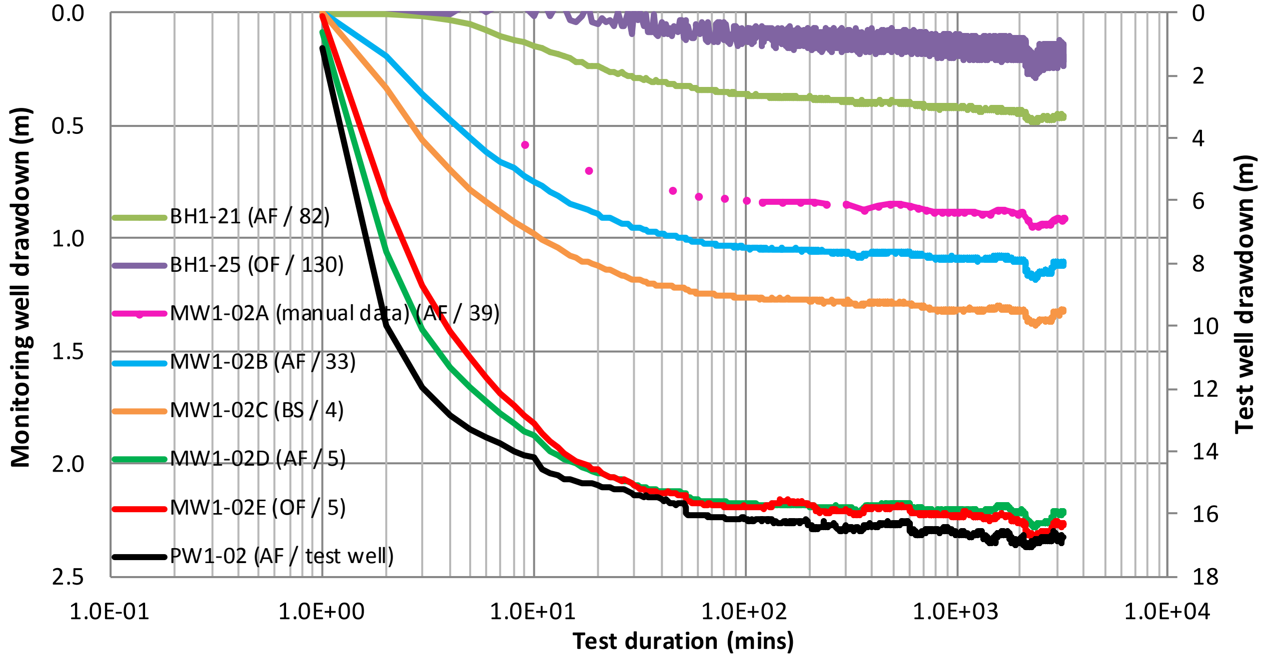
DRAFT

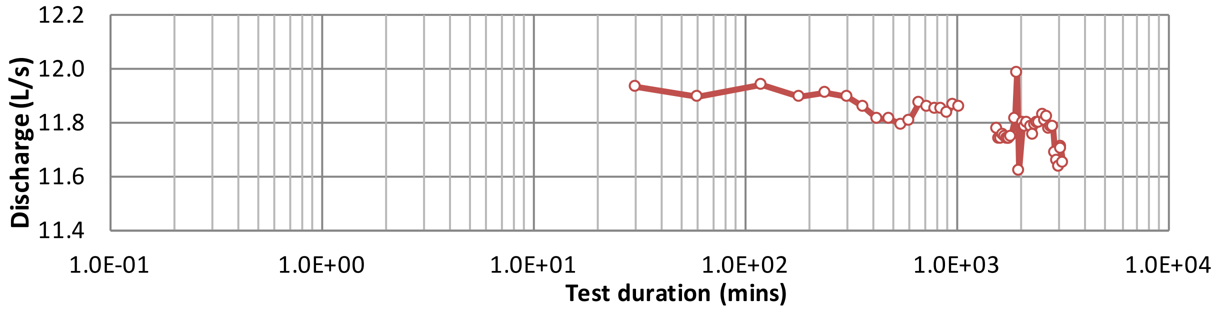
Golder Associates

CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 09/04/2015	TITLE **Pumping Test Data PW1-02-Data (CATS)**	
CHECKED AL	24/05/2015		
SCALE NOT TO SCALE	A3	PROJECT No 147642129-077-R-Rev0	FIGURE No **Figure E2-1**

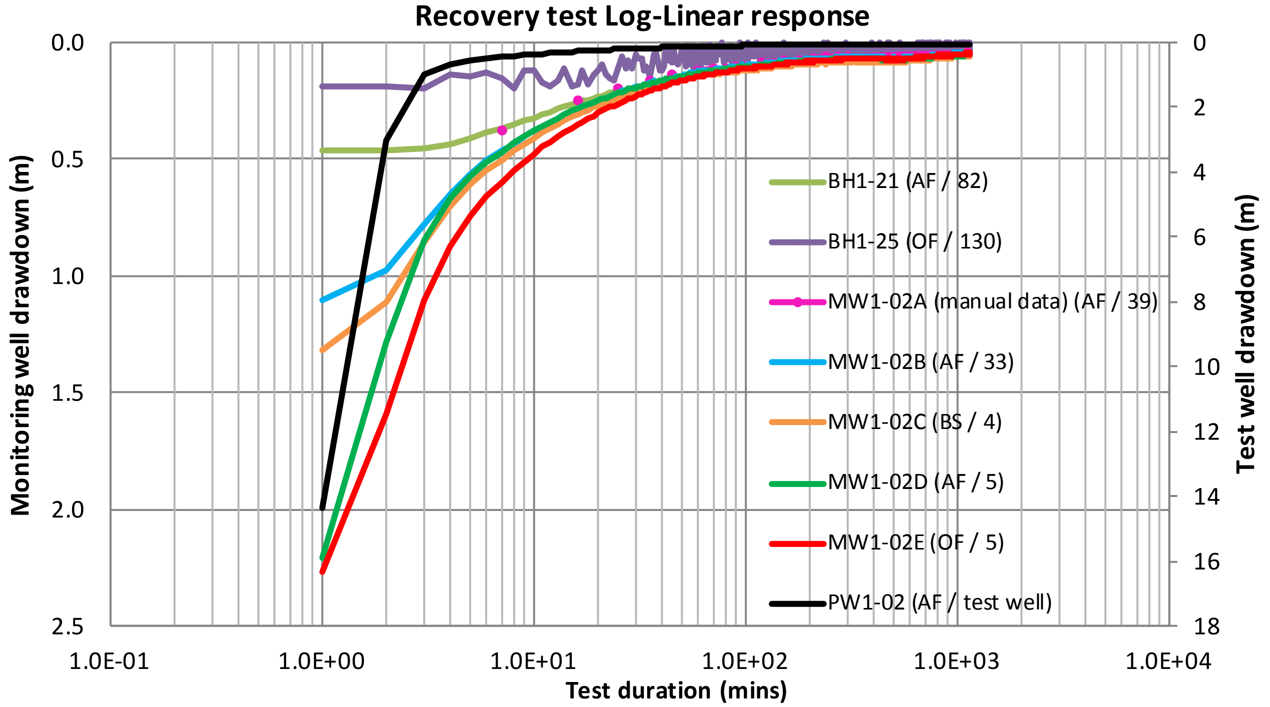
File Location: t:\powerpoint\golder_a3_landscape.pptm

PW1-02 Pumping test Log-Linear response





Recovery test Log-Linear response



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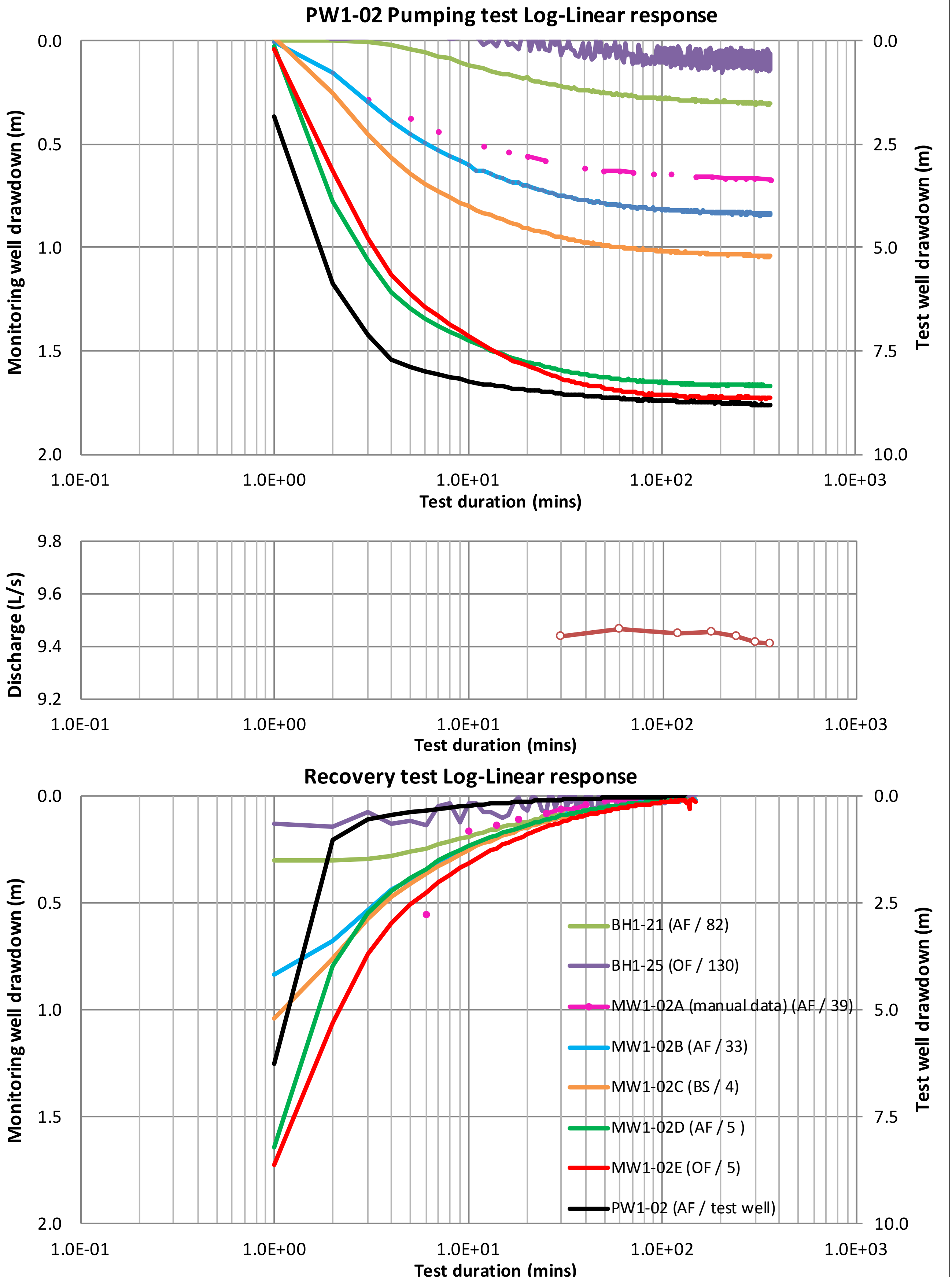
CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 24/05/2015	TITLE **Pumping Test Data PW1-02-Test 1 (Consolidated Station)**	
CHECKED AL	DATE 24/05/2015		
SCALE NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	FIGURE No **Figure E2-2**

File Location:



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CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 24/05/2015	TITLE **Pumping Test Data PW1-02-Test 2 (Consolidated Station)**	
CHECKED AL	DATE 24/05/2015		
SCALE NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	FIGURE No **Figure E2-3**

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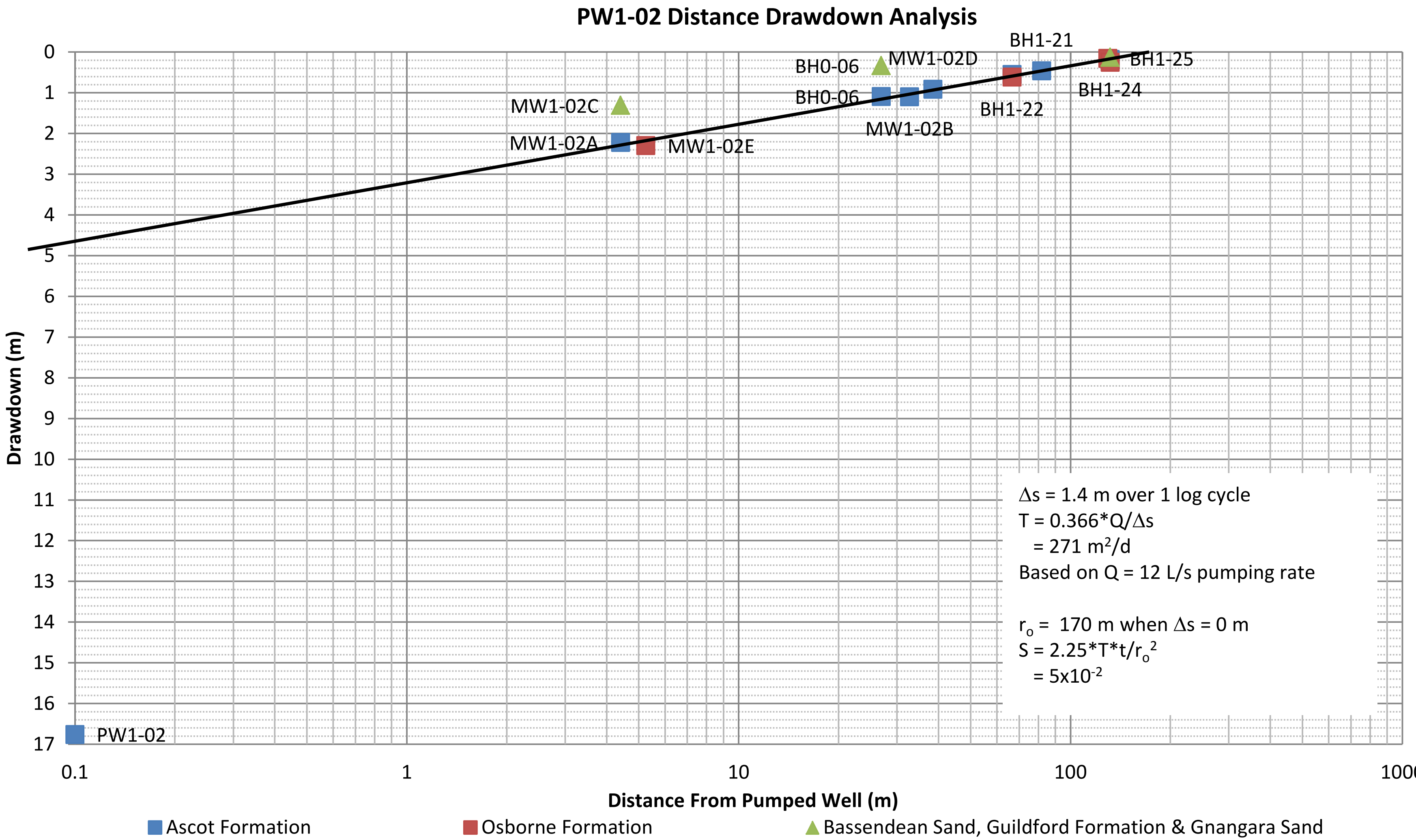
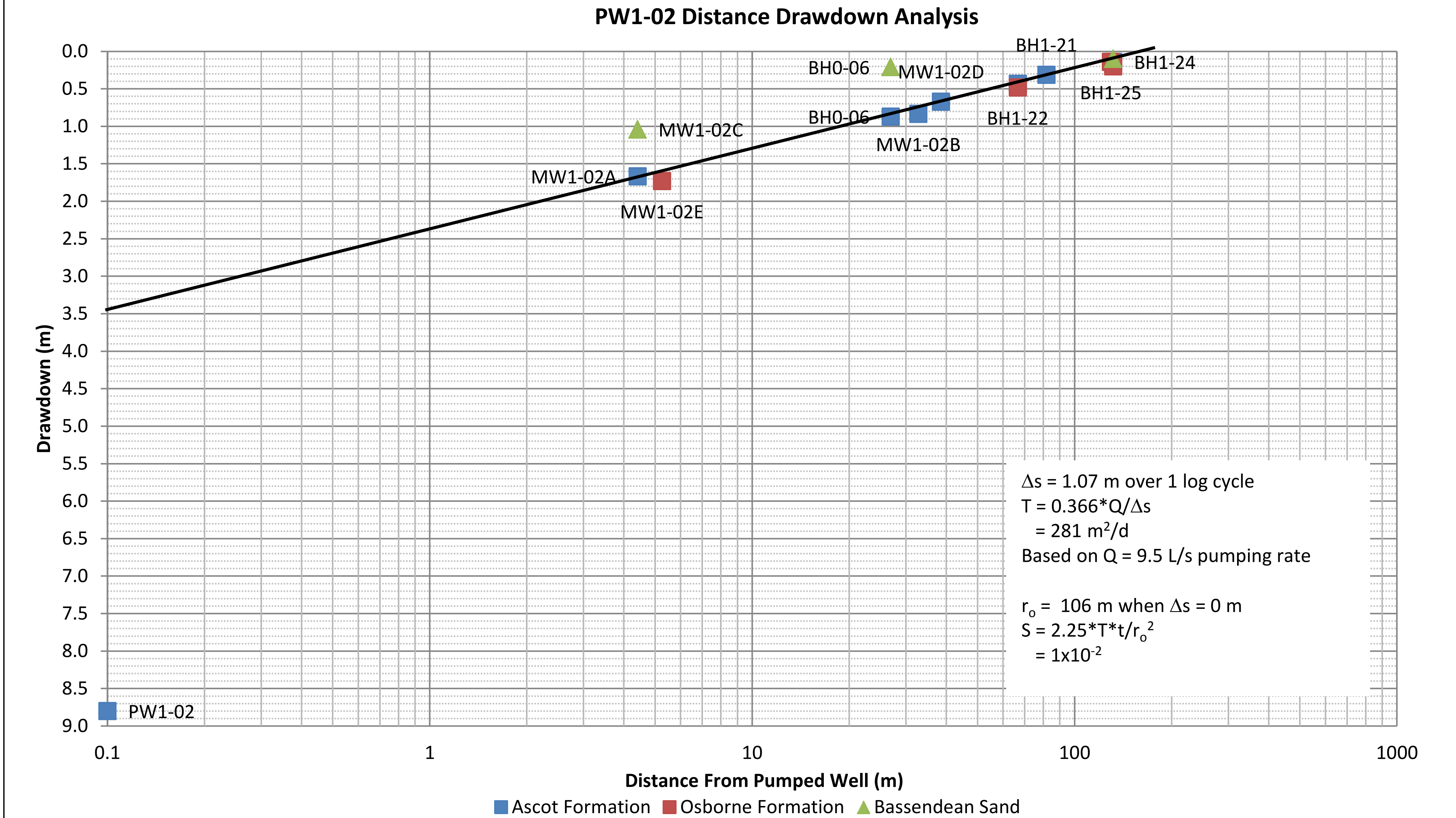


Golder Associates	CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation
	DRAWN SDB	DATE 24/05/2015	TITLE **DISTANCE DRAWDOWN ANALYSIS PW1-02-Test 1 (CATS)**
	APPROVED AL	24/05/2015	
	NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0 — **Figure E2-4**

File Location: J:\Hydro\2013\137646044 - Yandi W6 and E7 drilling\Analysis\E7 Hydraulic Testing\HYE0127P test results\Step test\Hantush Bierschenk



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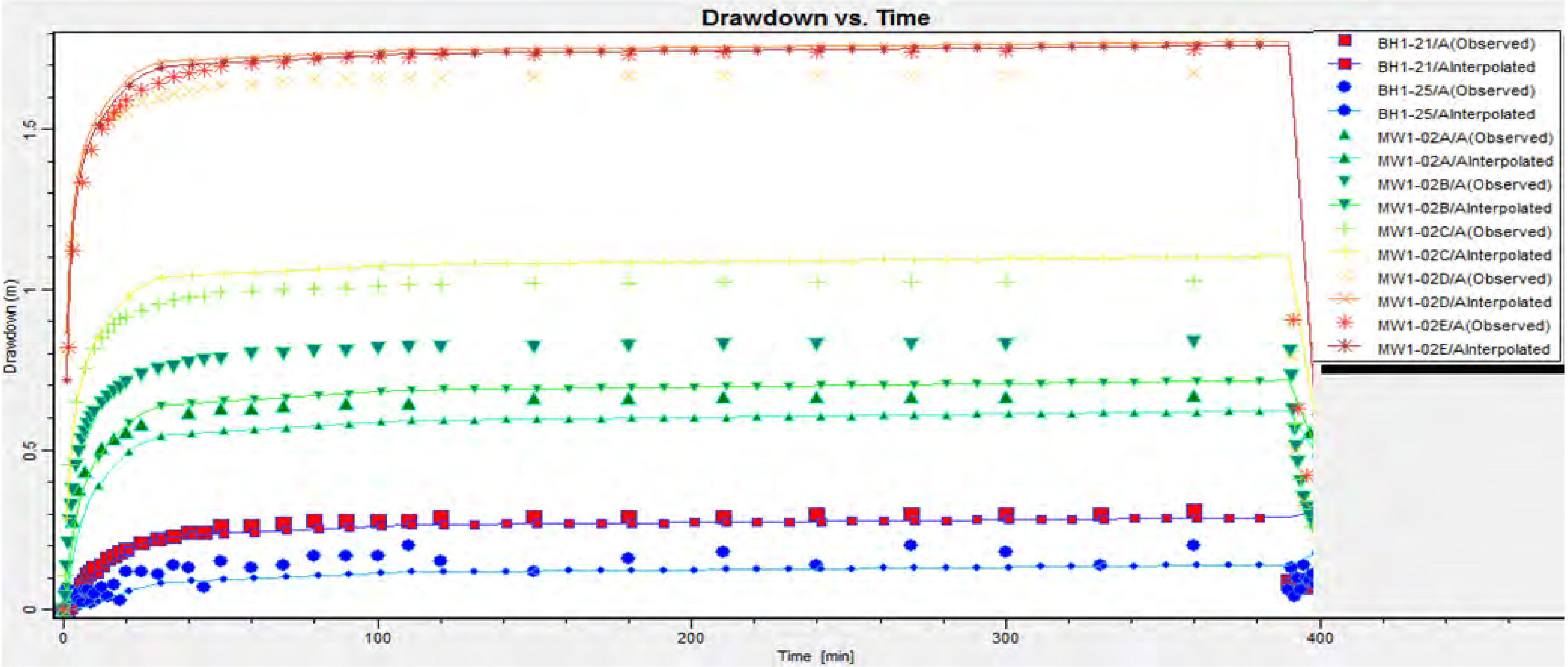
CLIENT	Public Transport Authority	PROJECT	FAL-Stage 2 Geotechnical Investigation
DRAWN SDB	DATE 24/05/2015	TITLE	**DISTANCE DRAWDOWN ANALYSIS PW1-02-Test 2 (CATS)**
APPROVED AL	24/05/2015		
NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	**Figure E2-5**

File Location: J:\Hydro\2013\137646044 - Yandi W6 and E7 drilling\Analysis\E7 Hydraulic Testing\HYE0127P test results\Step test\Hantush Bierschenk

Specific Storage =	2.50E-05 1/m
Transmissivity =	274 m2/d
Hydraulic Conductivity	
K(BS,GF,GS)h	5 m/d
K(BS,GF,GS)v	0.5 m/d
K(AF)h	14 m/d
K(AF)v	1.4 m/d
K(OF)h	3 m/d
K(OF)v	0.3 m/d



Screenshot from MODFLOW output Note: Other combinations in hydraulic conductivity and storage may also be possible	Golder Associates	CLIENT Public Transport authority		PROJECT FAL - Stage 2 Geotechnical Investigation	
		DRAWN AL	DATE 24-May-15	TITLE **Analysis of Pumping Test 2 using Numerical Groundwater Model Airport West Station**	
		CHECK DPS	DATE 24-May-15		
		SCALE Not To Scale	A4	PROJECT No. 147642129-077-R-Rev0	FIGURE No. E2-6

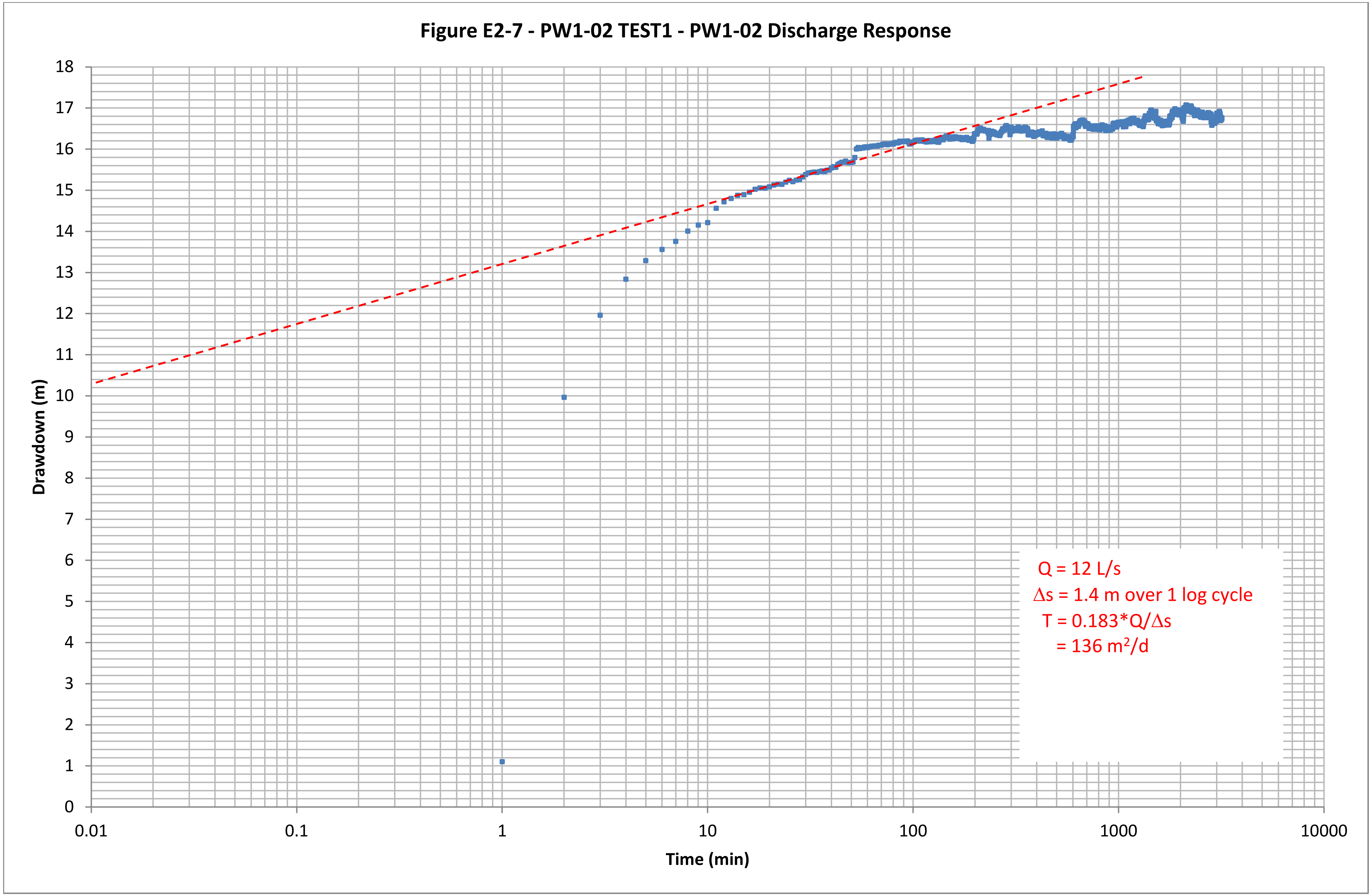


Figure E2-7 - PW1-02 TEST1 - PW1-02 Discharge Response
Drawdown (m)
Time (min)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0.01
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 1.4 m over 1 log cycle
T = 0.183*Q/Δs
= 136 m²/d

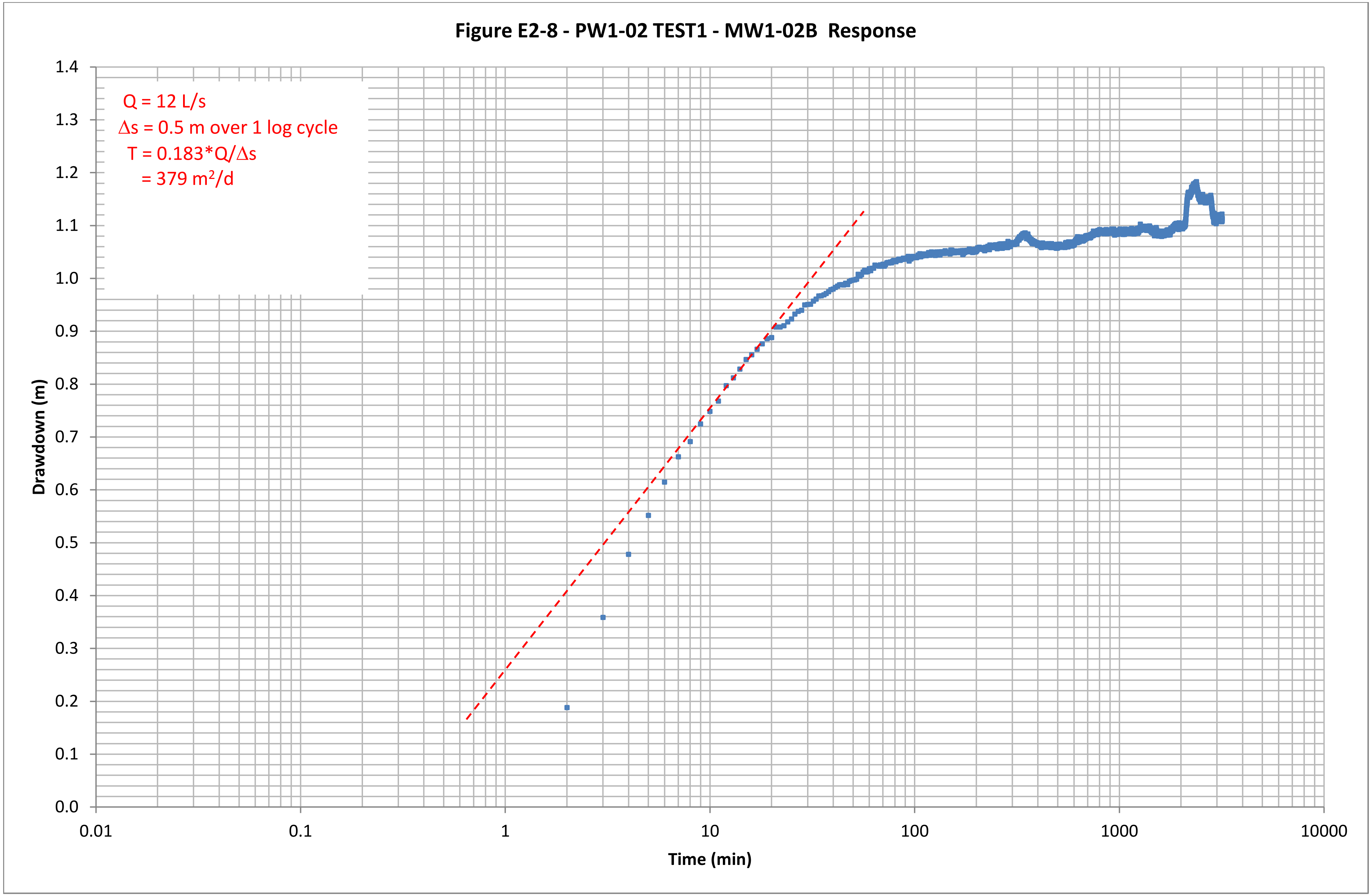


Figure E2-8 - PW1-02 TEST1 - MW1-02B Response
Q = 12 L/s
Δs = 0.5 m over 1 log cycle
T = 0.183*Q/Δs
= 379 m²/d
Drawdown (m)
Time (min)
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.01
0.1
1
10
100
1000
10000

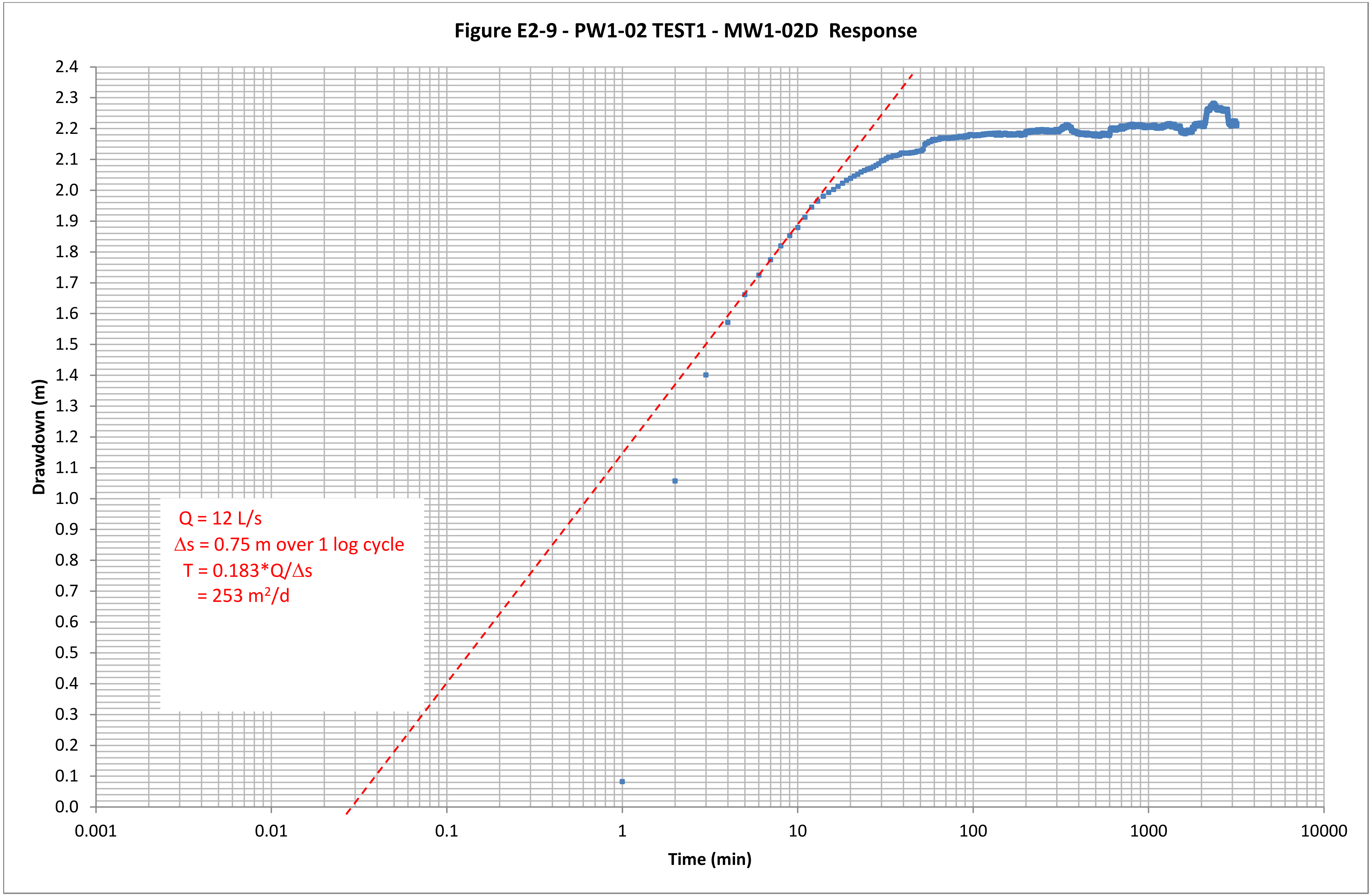


Figure E2-9 - PW1-02 TEST1 - MW1-02D Response
Drawdown (m)
Time (min)
2.4
2.3
2.2
2.1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.001
0.01
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 0.75 m over 1 log cycle
T = 0.183*Q/Δs
= 253 m²/d

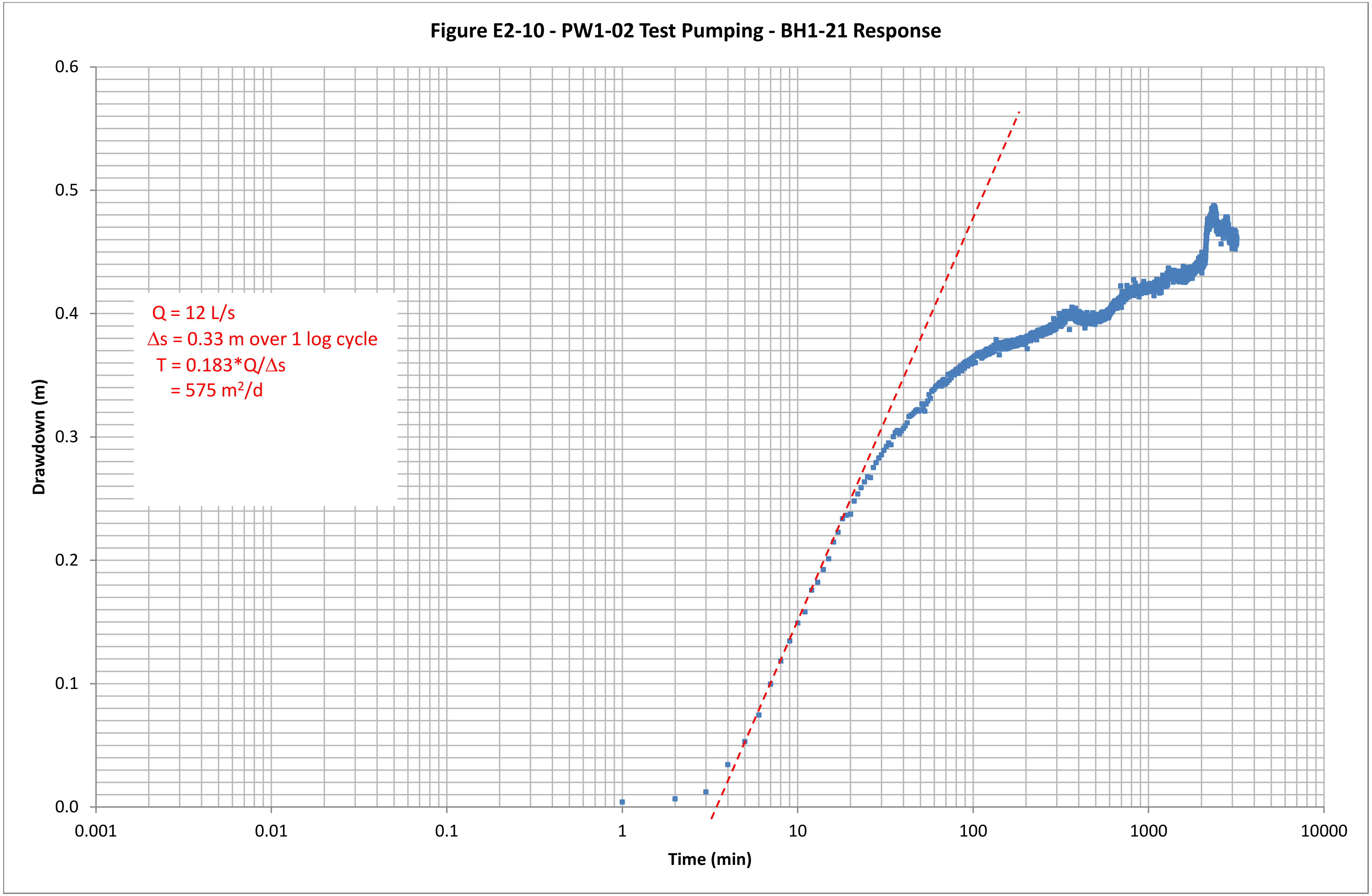


Figure E2-10 - PW1-02 Test Pumping - BH1-21 Response
Q = 12 L/s
Δs = 0.33 m over 1 log cycle
T = 0.183*Q/Δs
= 575 m²/d
Drawdown (m)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.001
0.01
0.1
1
10
100
1000
10000
Time (min)

Figure E2-11 - PW1-02 TEST1 - PW1-02 Recovery

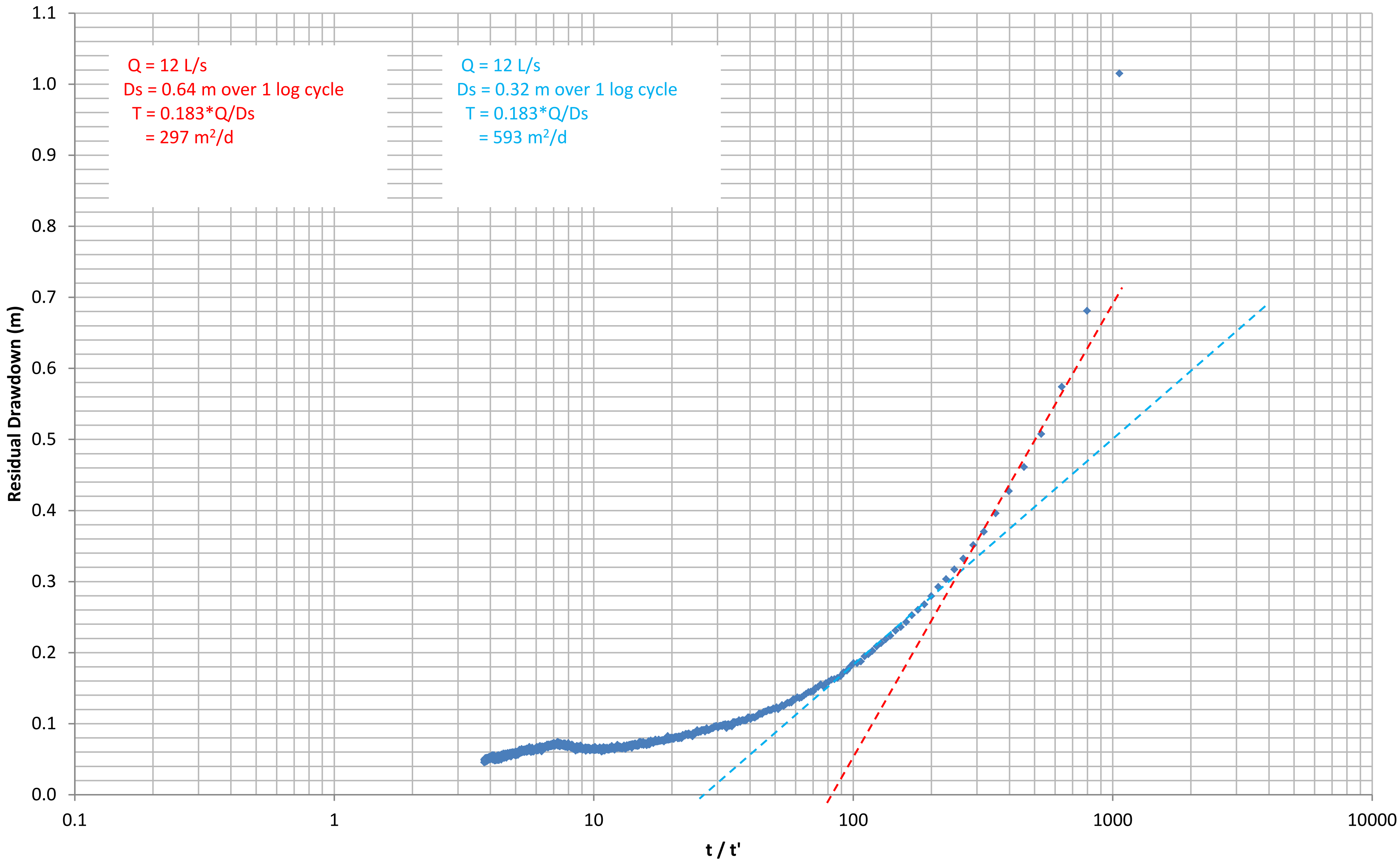
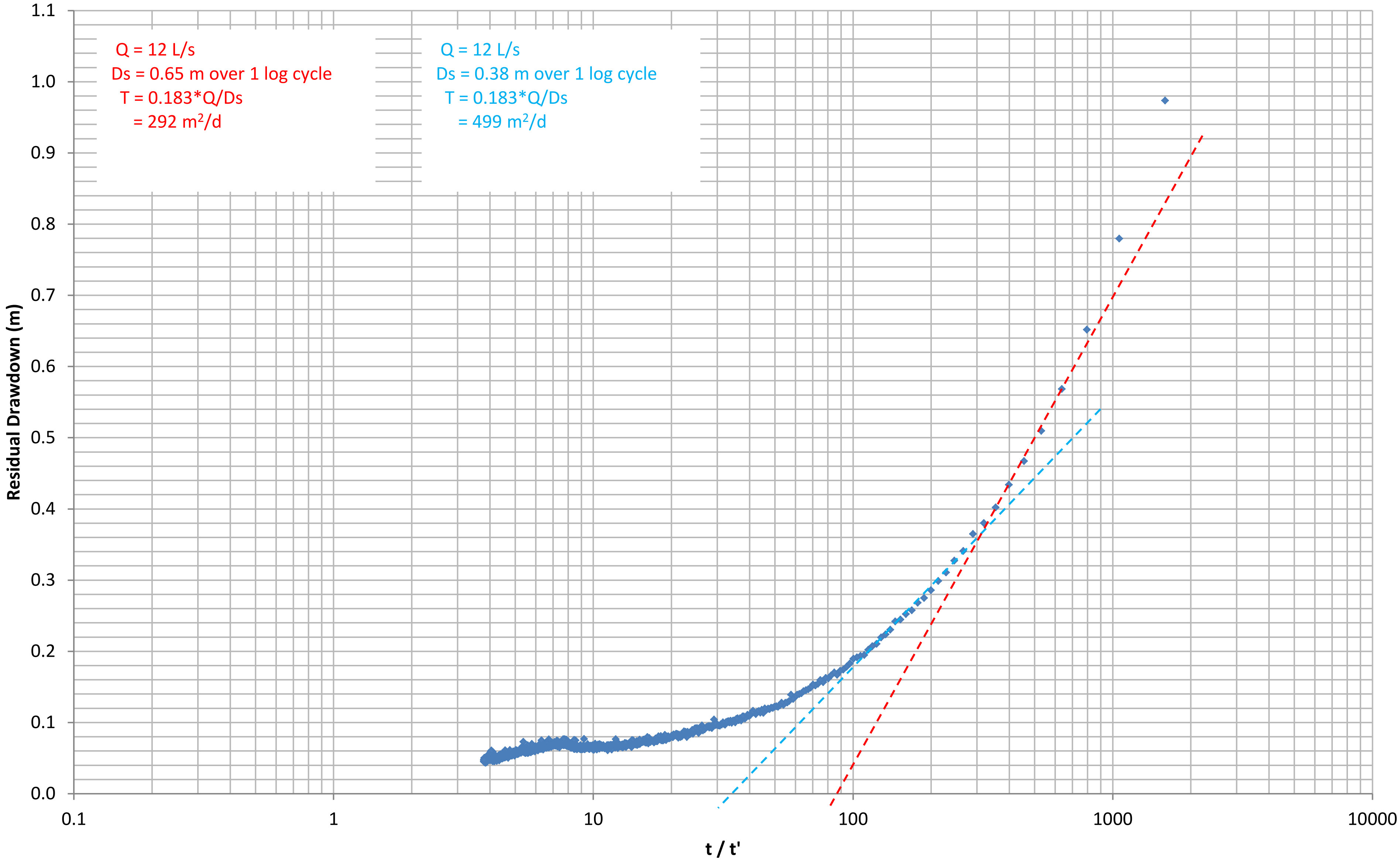


Figure E2-12 - PW1-02 TEST1 - MW1-02B Recovery



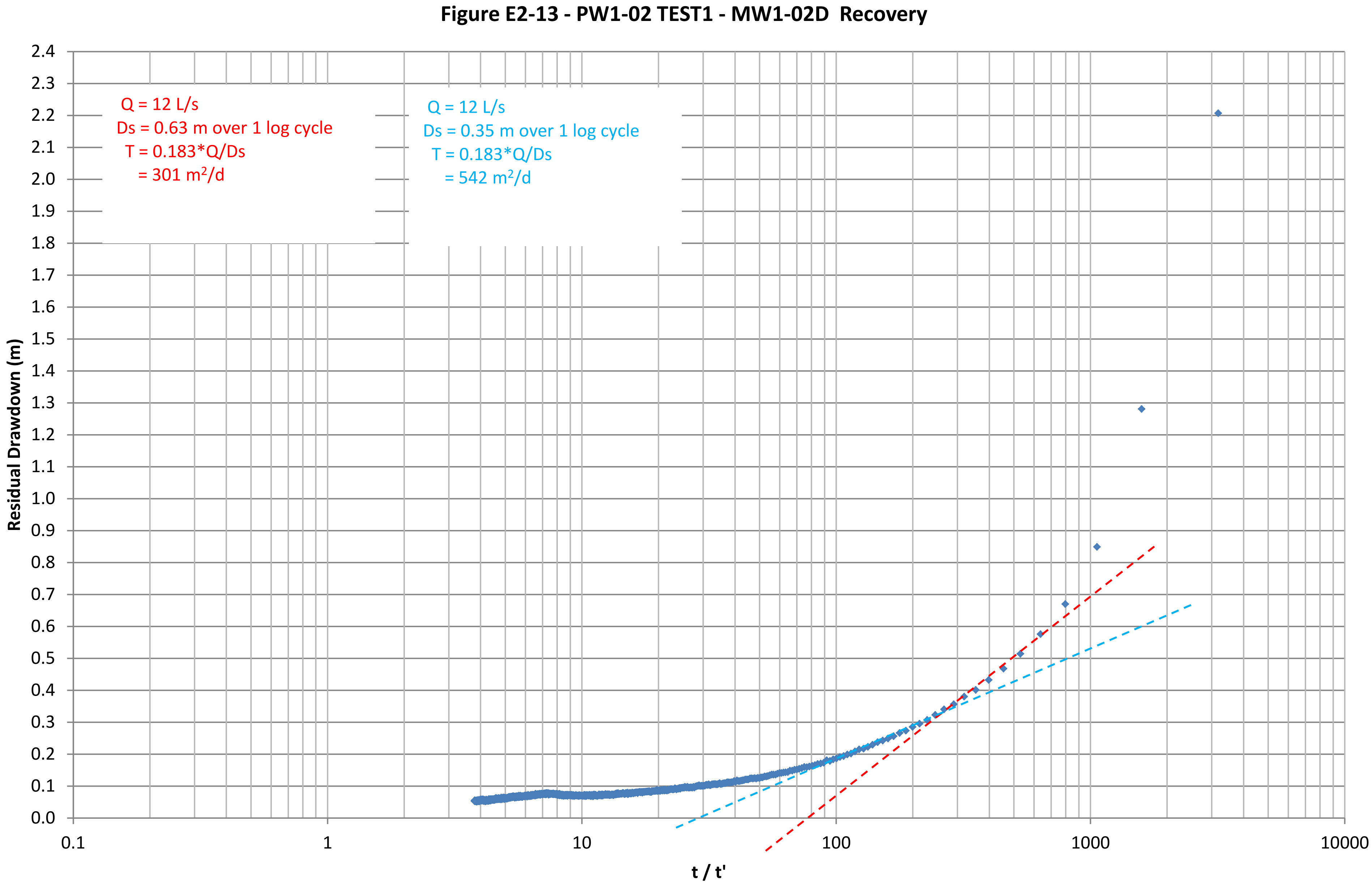


Figure E2-13 - PW1-02 TEST1 - MW1-02D Recovery
Q = 12 L/s
Ds = 0.63 m over 1 log cycle
T = 0.183*Q/Ds
= 301 m²/d
Q = 12 L/s
Ds = 0.35 m over 1 log cycle
T = 0.183*Q/Ds
= 542 m²/d
Residual Drawdown (m)
t / t'
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
0.1
1
10
100
1000
10000

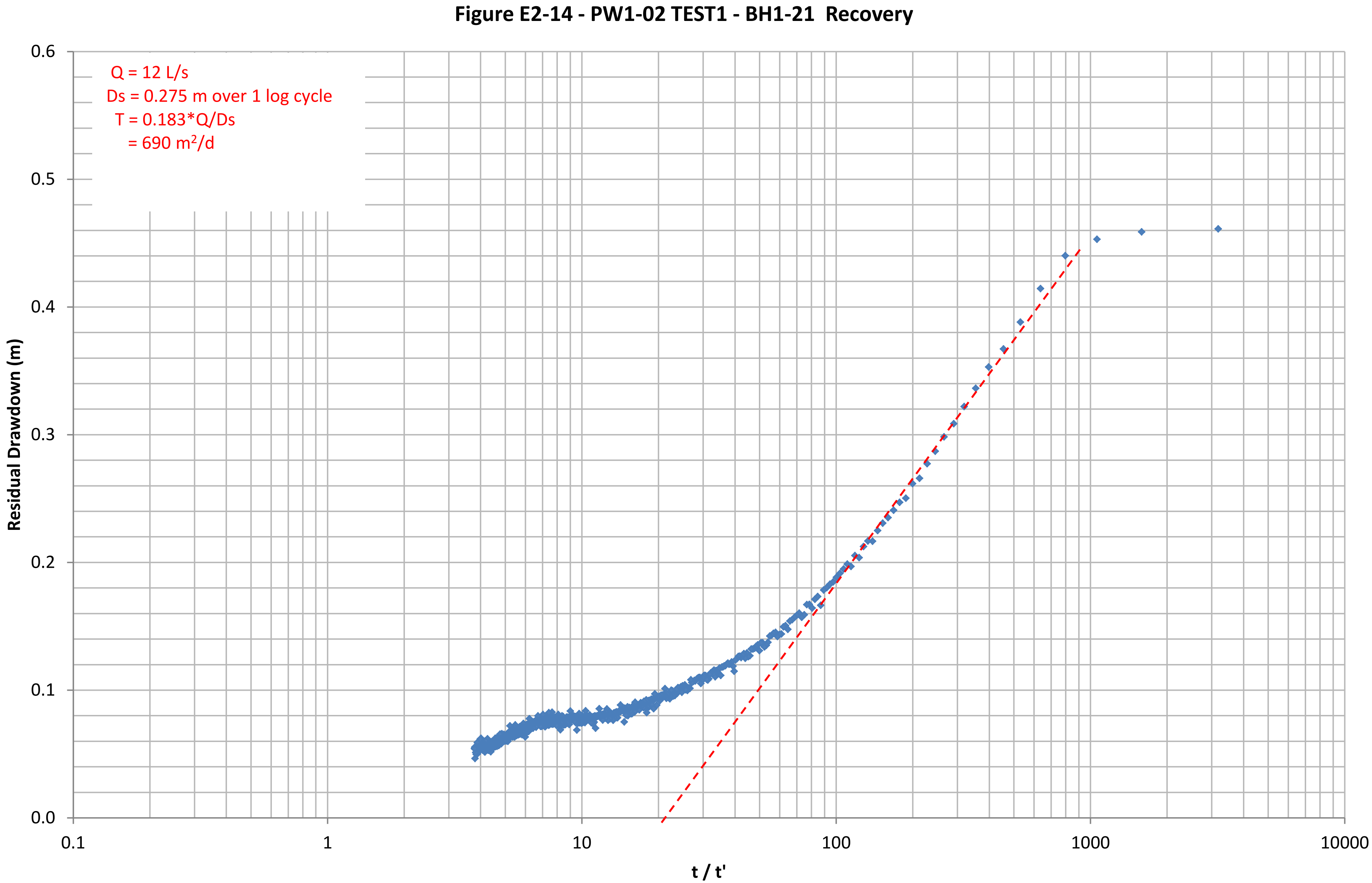


Figure E2-14 - PW1-02 TEST1 - BH1-21 Recovery
Q = 12 L/s
Ds = 0.275 m over 1 log cycle
T = 0.183*Q/Ds
= 690 m²/d
Residual Drawdown (m)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
1000
10000
t / t'

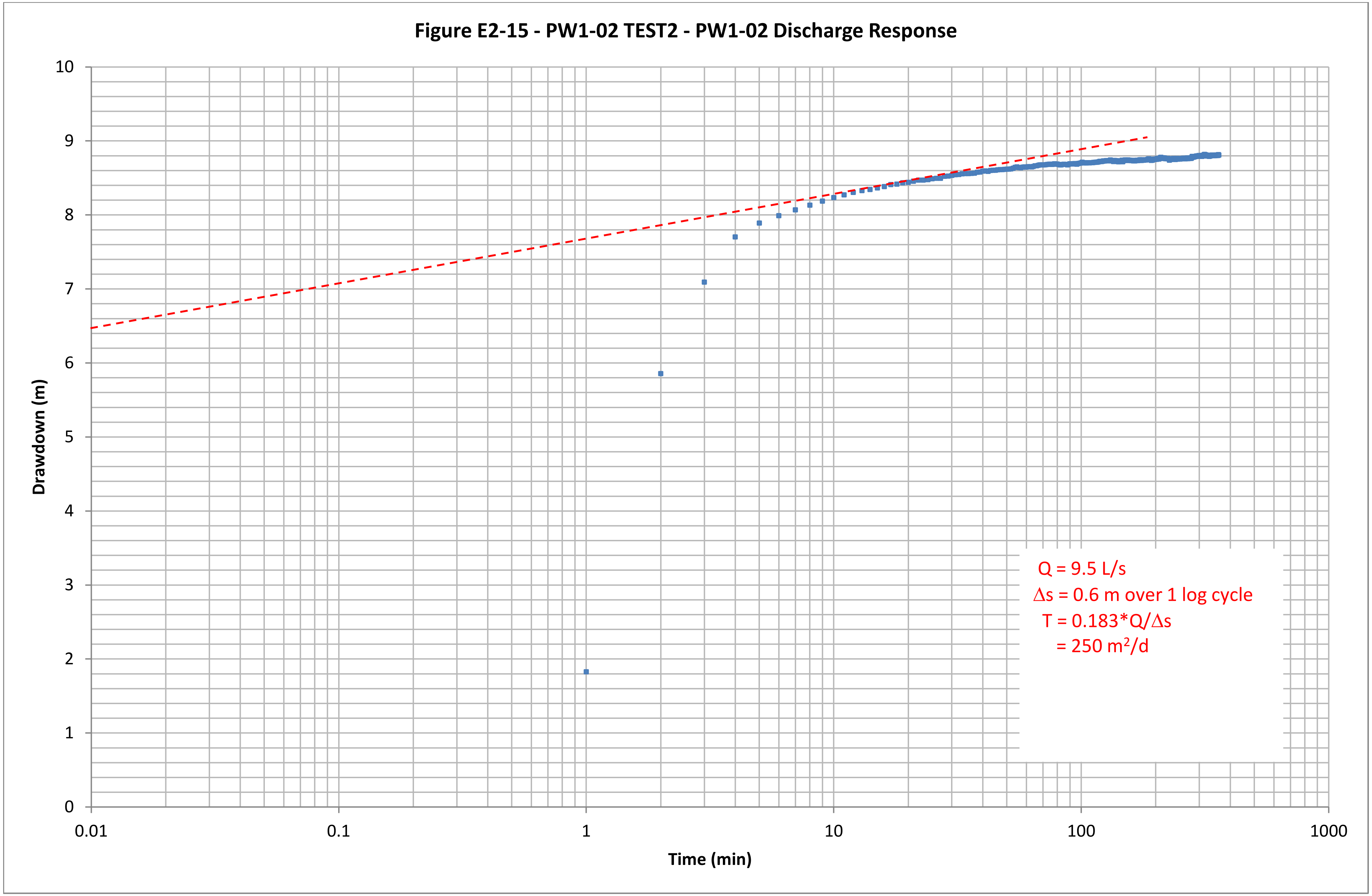


Figure E2-15 - PW1-02 TEST2 - PW1-02 Discharge Response
Drawdown (m)
Time (min)
0
1
2
3
4
5
6
7
8
9
10
0.01
0.1
1
10
100
1000
Q = 9.5 L/s
Δs = 0.6 m over 1 log cycle
T = 0.183*Q/Δs
= 250 m²/d

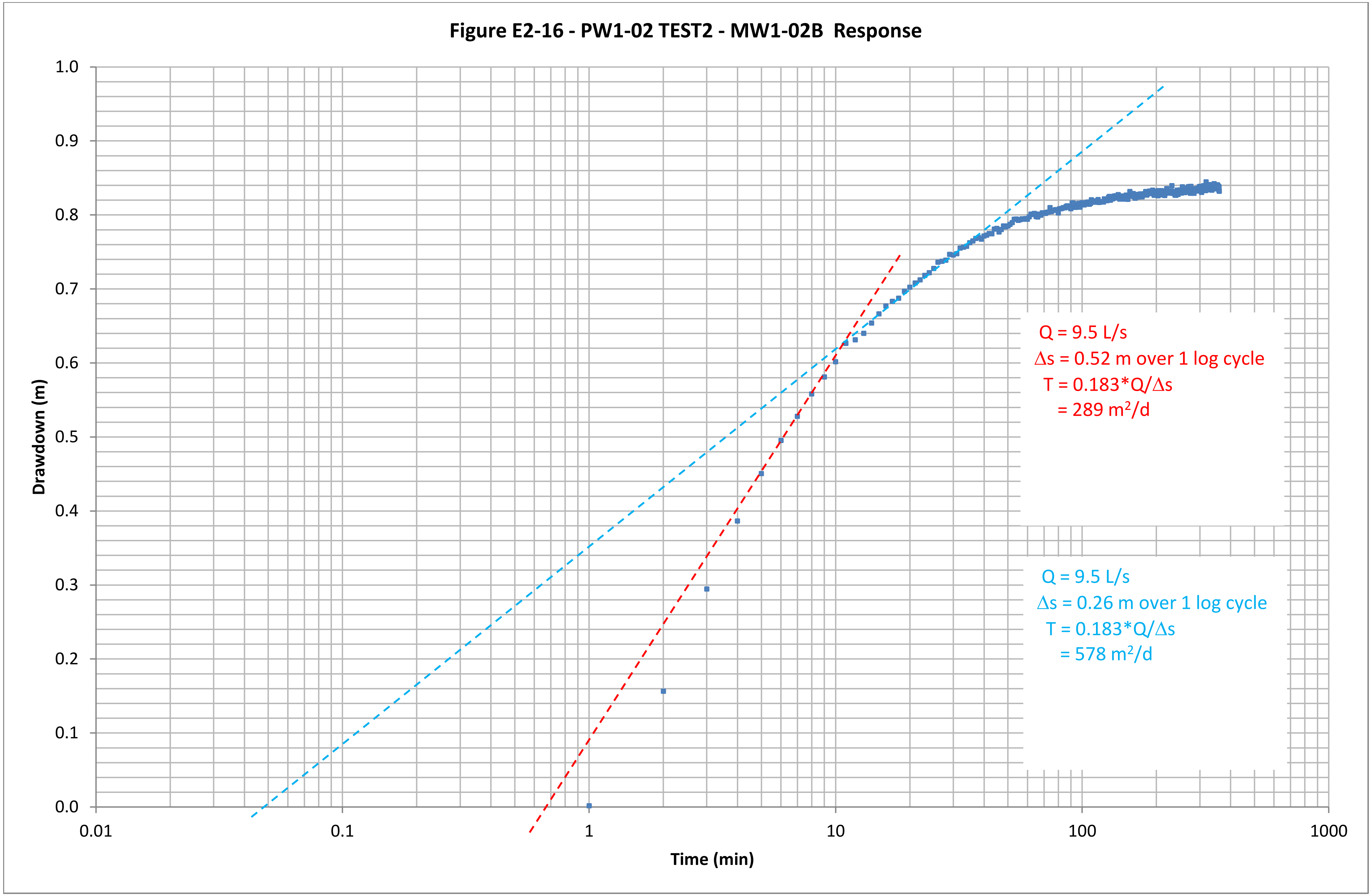


Figure E2-16 - PW1-02 TEST2 - MW1-02B Response
Drawdown (m)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.01
0.1
1
10
100
1000
Time (min)
Q = 9.5 L/s
Δs = 0.52 m over 1 log cycle
T = 0.183*Q/Δs
= 289 m²/d
Q = 9.5 L/s
Δs = 0.26 m over 1 log cycle
T = 0.183*Q/Δs
= 578 m²/d

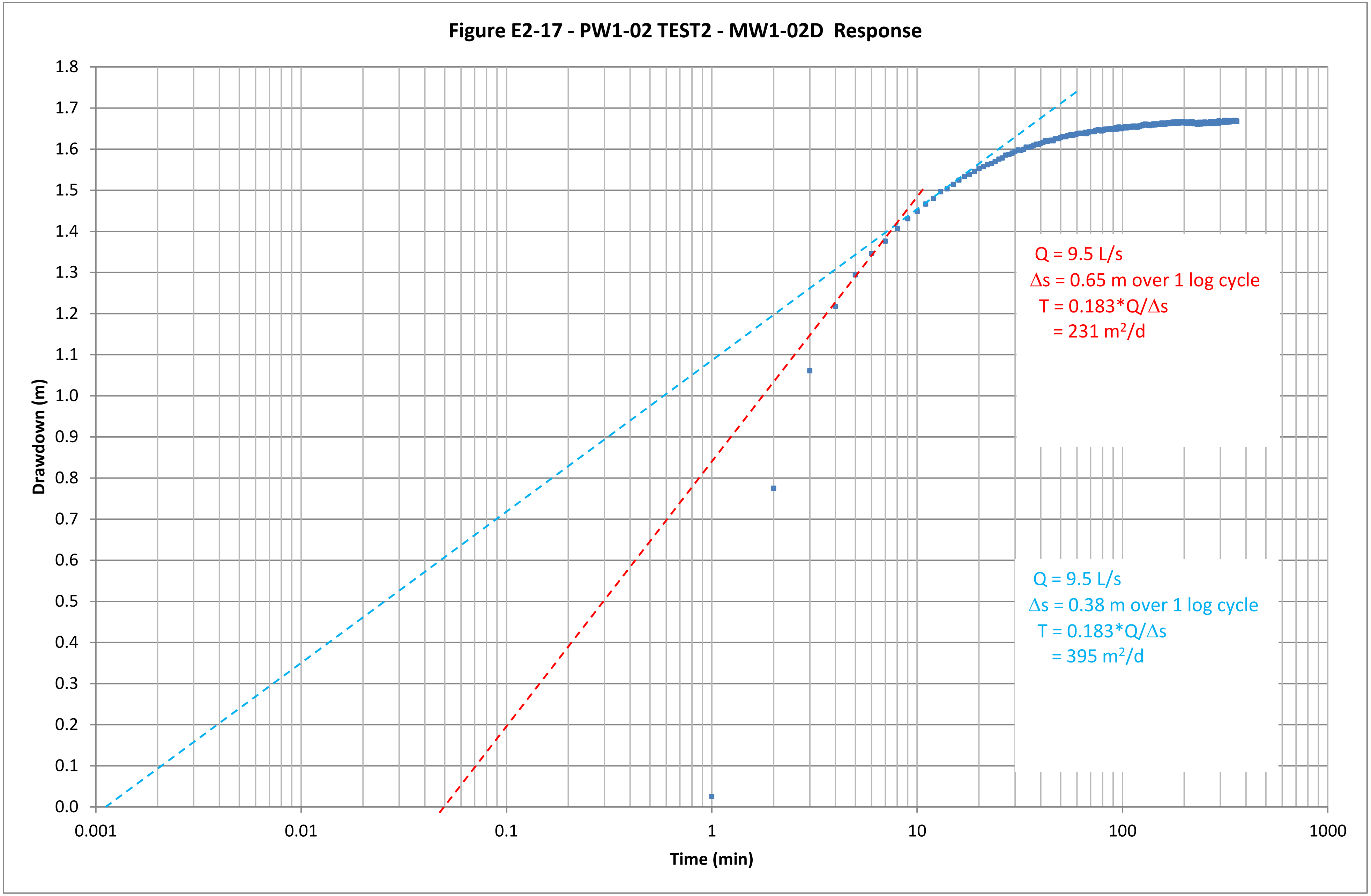


Figure E2-17 - PW1-02 TEST2 - MW1-02D Response
Drawdown (m)
Time (min)
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.001
0.01
0.1
1
10
100
1000
Q = 9.5 L/s
Δs = 0.65 m over 1 log cycle
T = 0.183*Q/Δs
= 231 m²/d
Q = 9.5 L/s
Δs = 0.38 m over 1 log cycle
T = 0.183*Q/Δs
= 395 m²/d

Figure E2-18 - PW1-02 TEST2 - PW1-02 Recovery

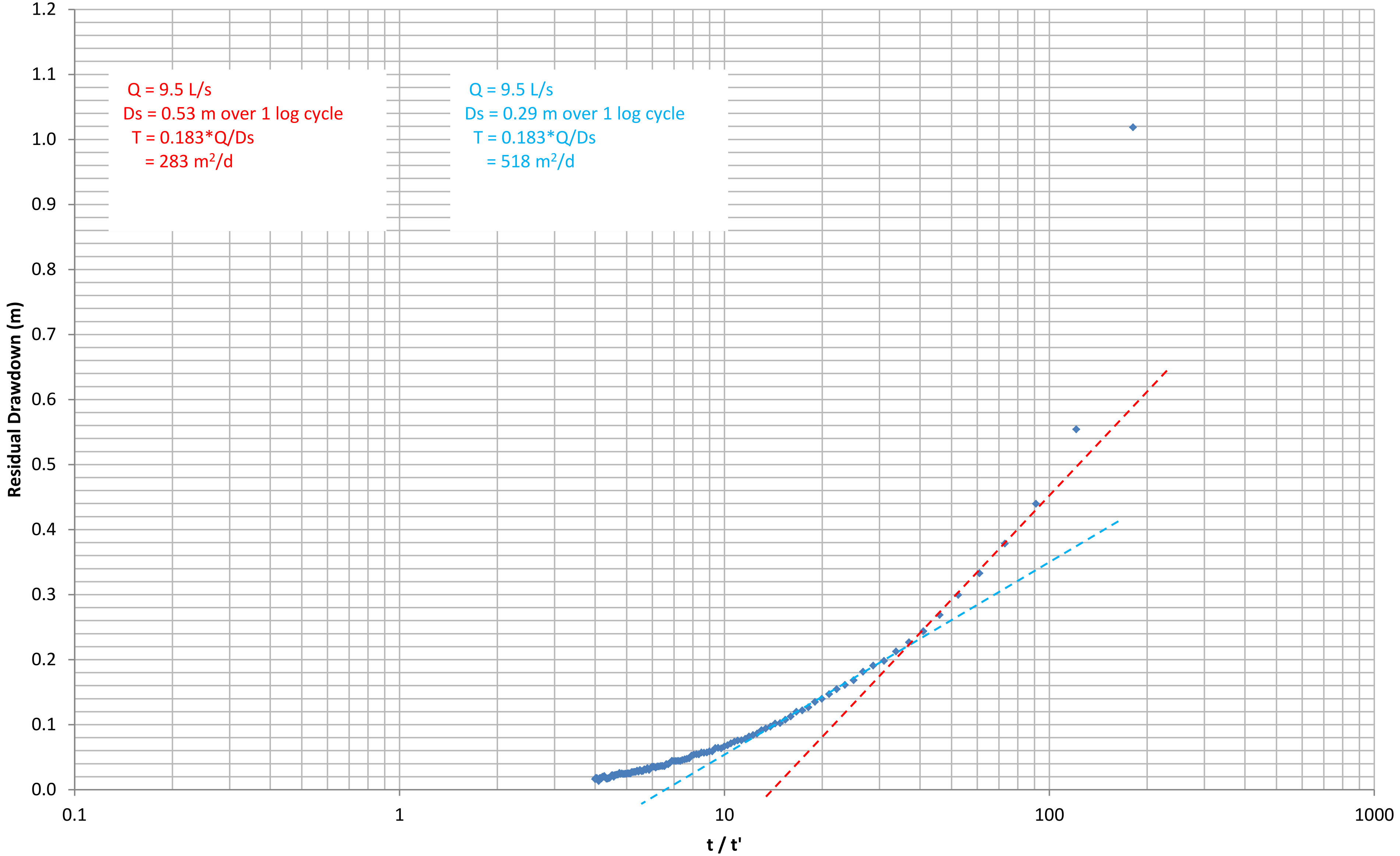
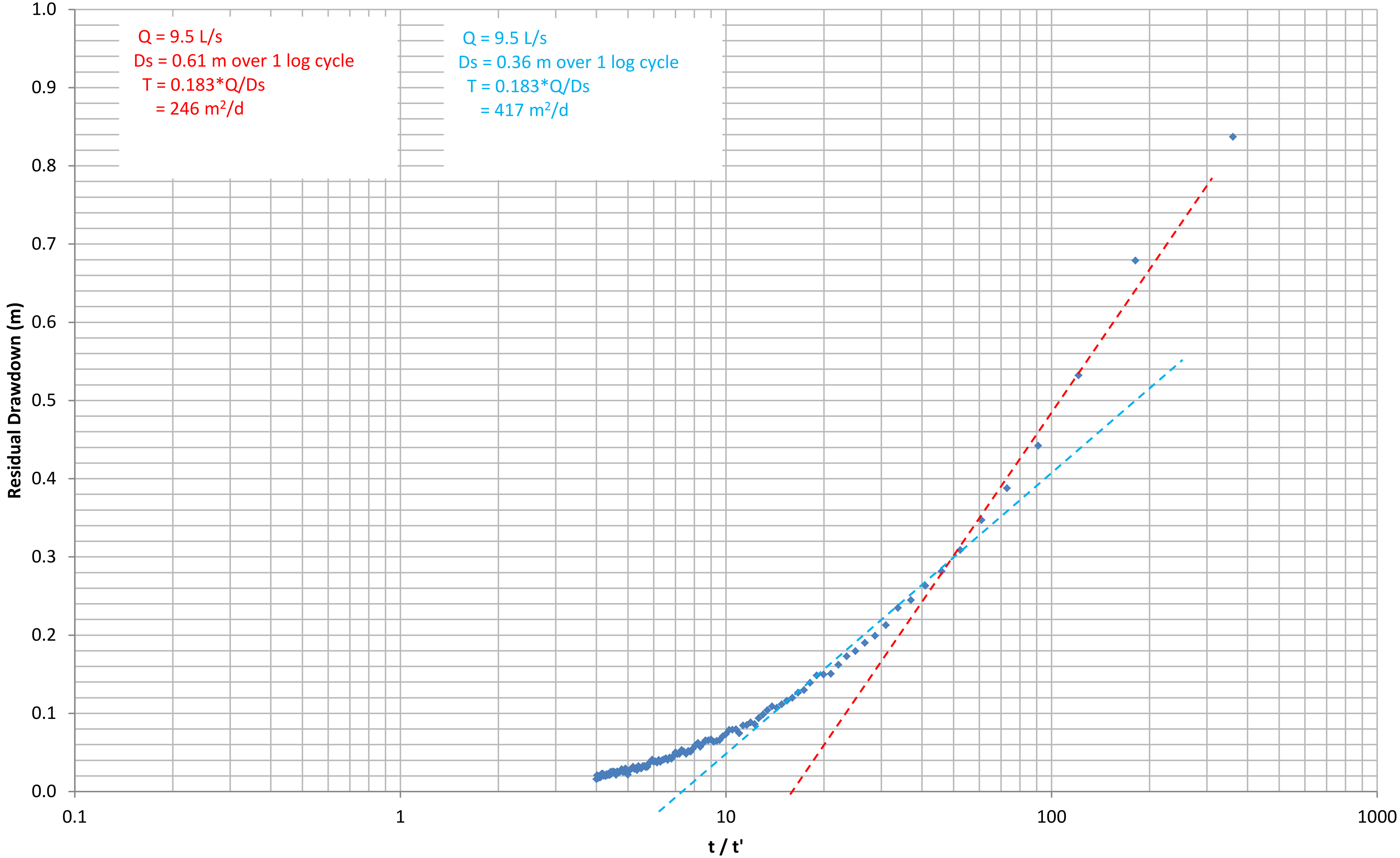


Figure E2-19 - PW1-02 TEST2 - MW1-02B Recovery



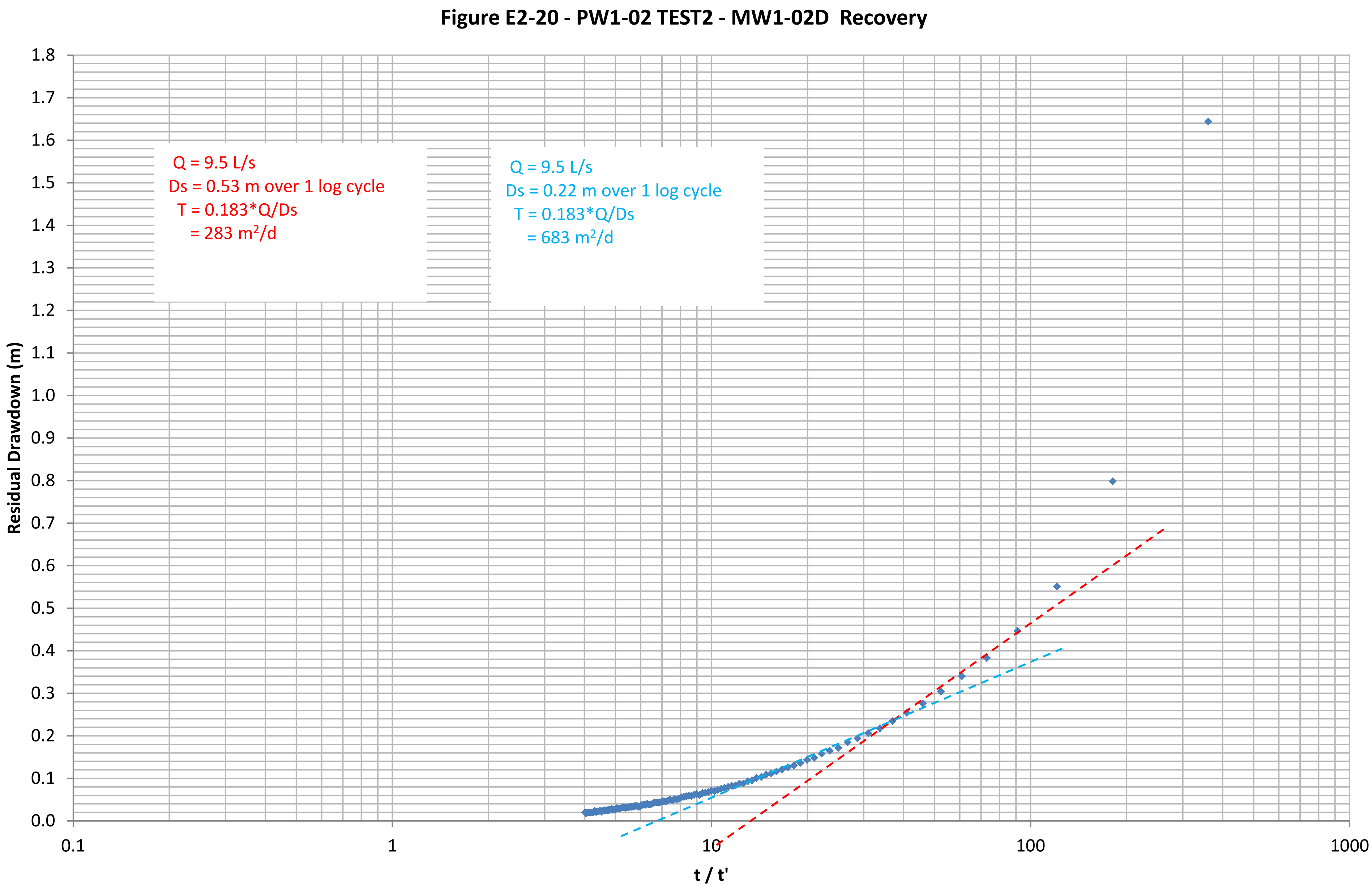


Figure E2-20 - PW1-02 TEST2 - MW1-02D Recovery
Q = 9.5 L/s
Ds = 0.53 m over 1 log cycle
T = 0.183*Q/Ds
= 283 m²/d
Q = 9.5 L/s
Ds = 0.22 m over 1 log cycle
T = 0.183*Q/Ds
= 683 m²/d
Residual Drawdown (m)
t / t'
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.1
1
10
100
1000

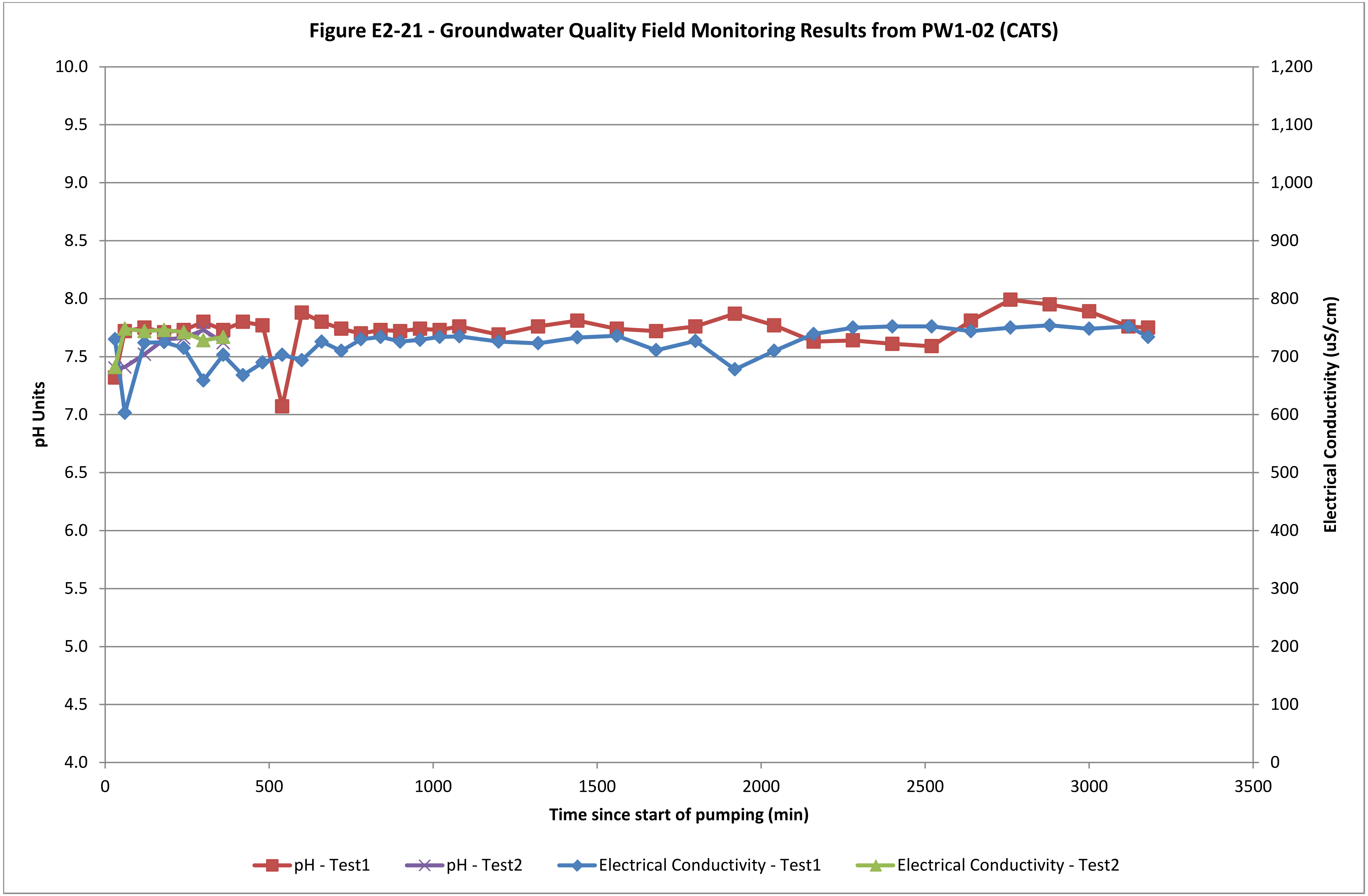
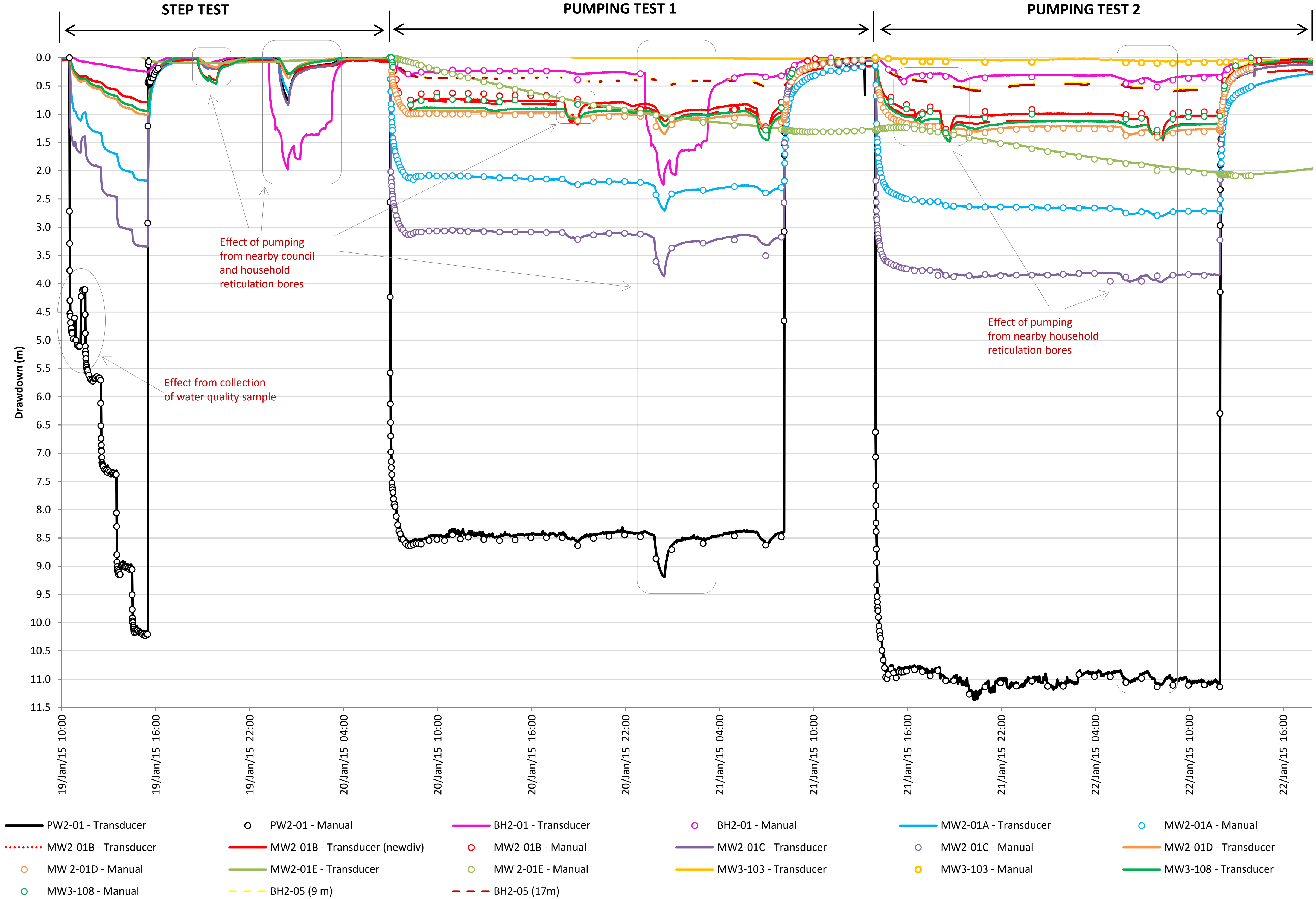


Figure E2-21 - Groundwater Quality Field Monitoring Results from PW1-02 (CATS)
pH Units
Electrical Conductivity (uS/cm)
Time since start of pumping (min)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
pH - Test1
pH - Test2
Electrical Conductivity - Test1
Electrical Conductivity - Test2

ATTACHMENT E3
Constant Rate Test – Airport West Station (PW2-01)



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	DRAWN SDB	DATE 09/04/2015	TITLE **Pumping Test Data PW2-01-Data (Airport West Station)**
	CHECKED AL	24/05/2015	
	SCALE NOT TO SCALE	A3	PROJECT No 147642129-077-R-Rev0 / FIGURE No **Figure E3-1**

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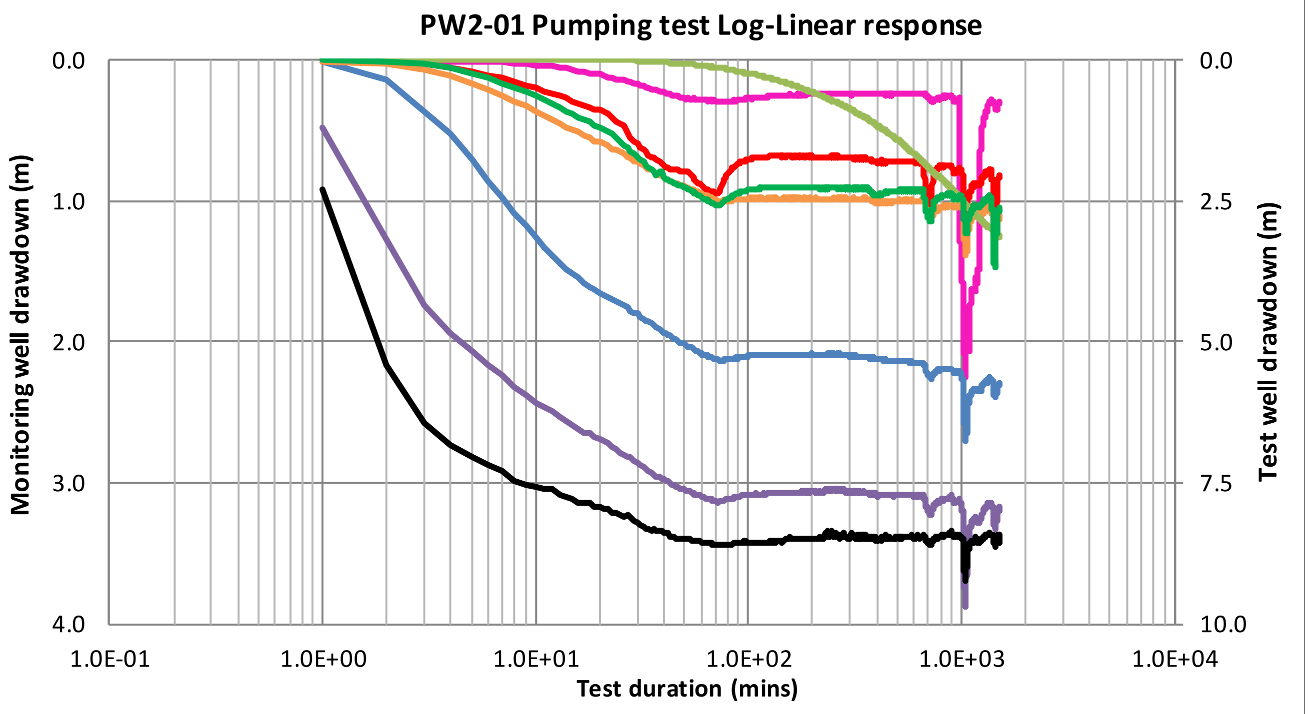

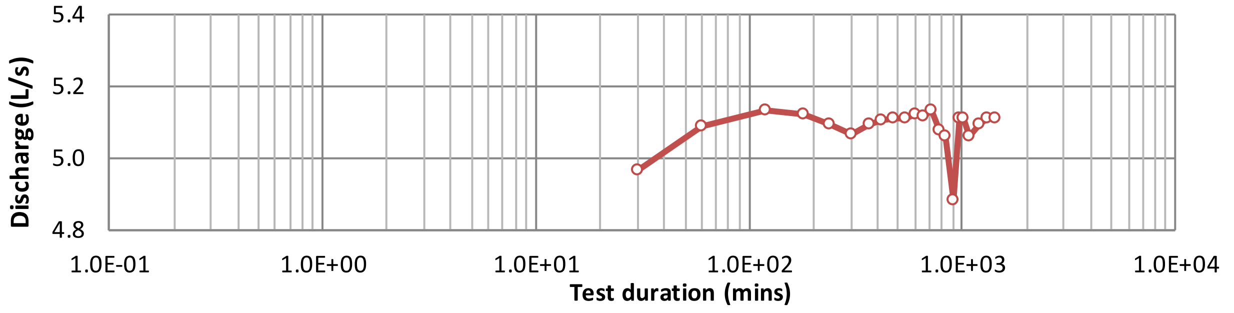

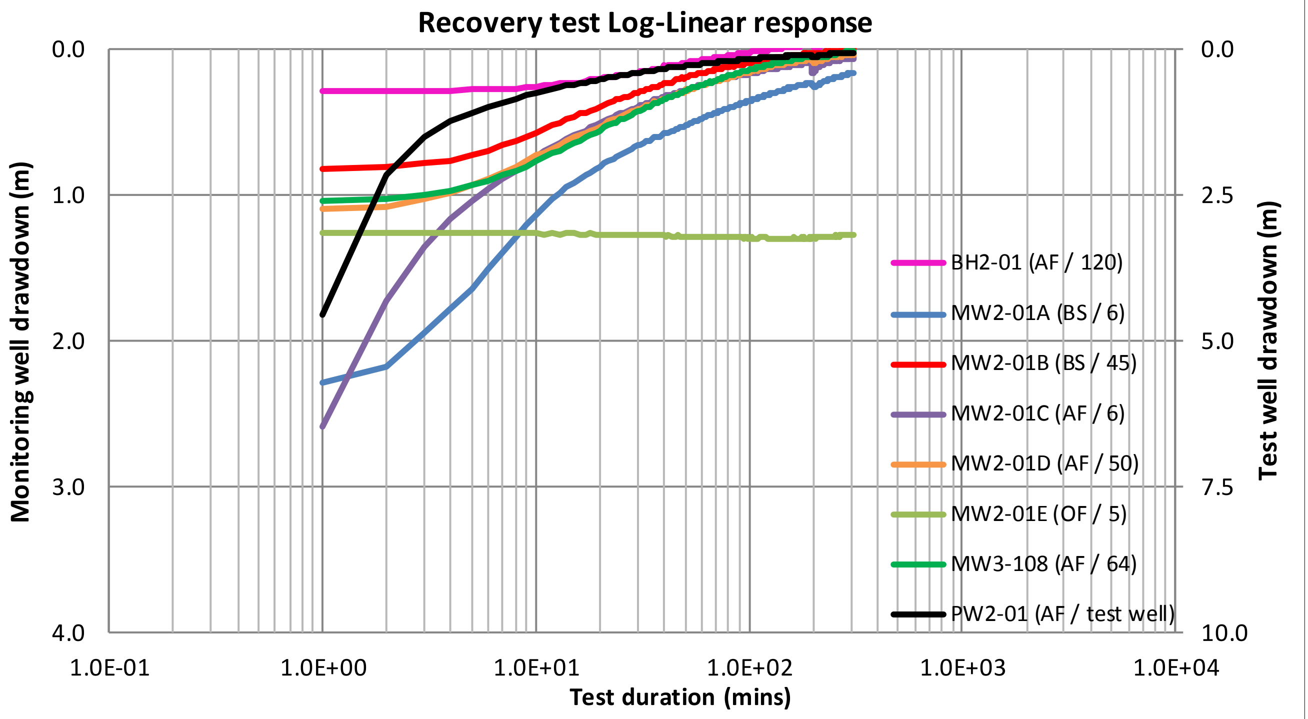

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CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 24/05/2015	TITLE **Pumping Test Data PW2-01-Test 1 (Airport West Station)**	
CHECKED AL	DATE 24/05/2015		
SCALE NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	FIGURE No **Figure E3-2**

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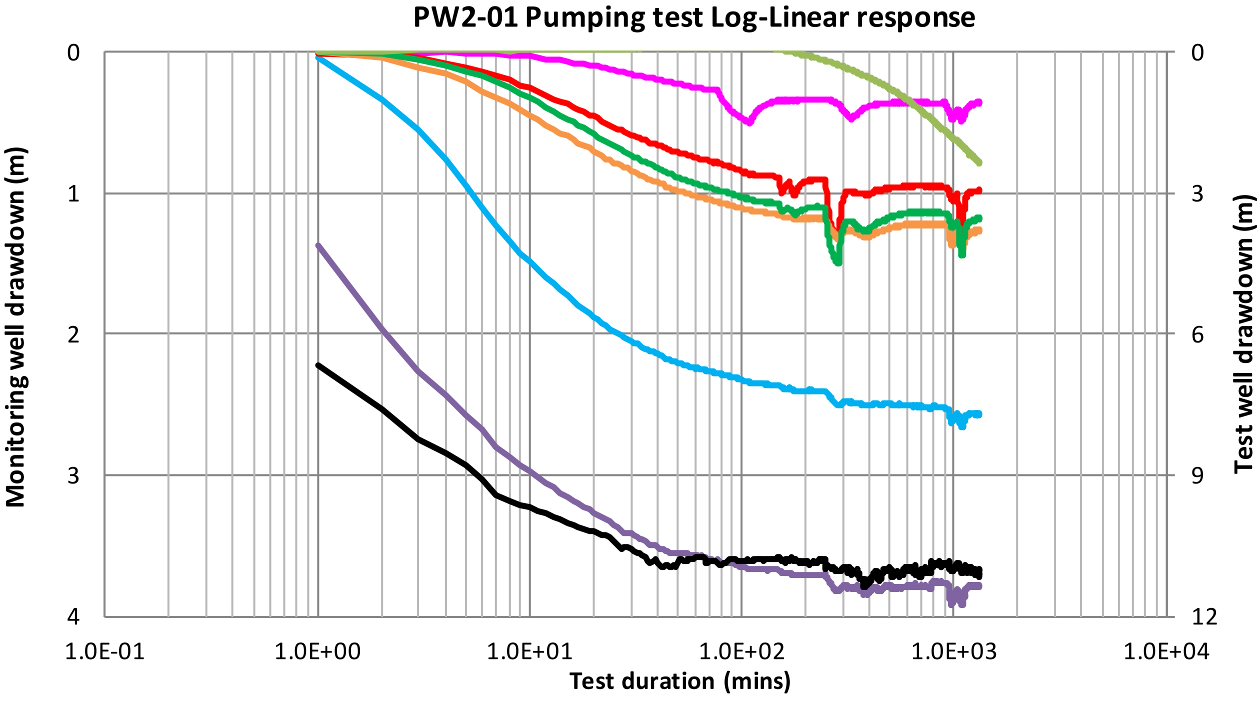

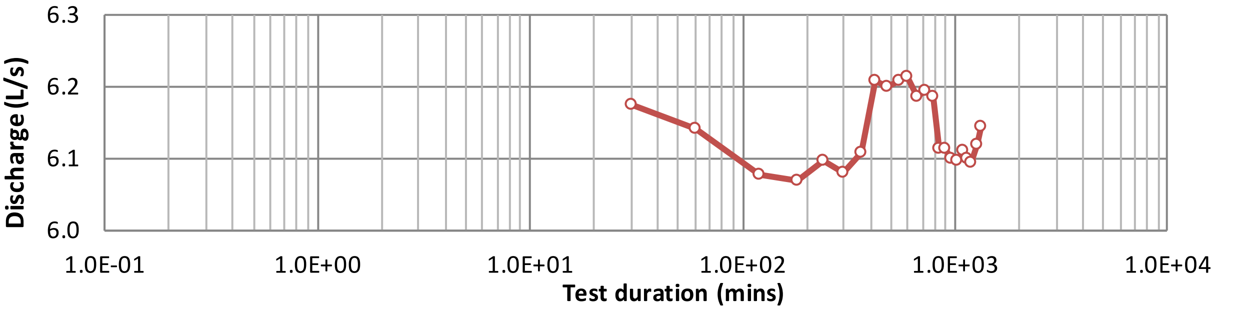

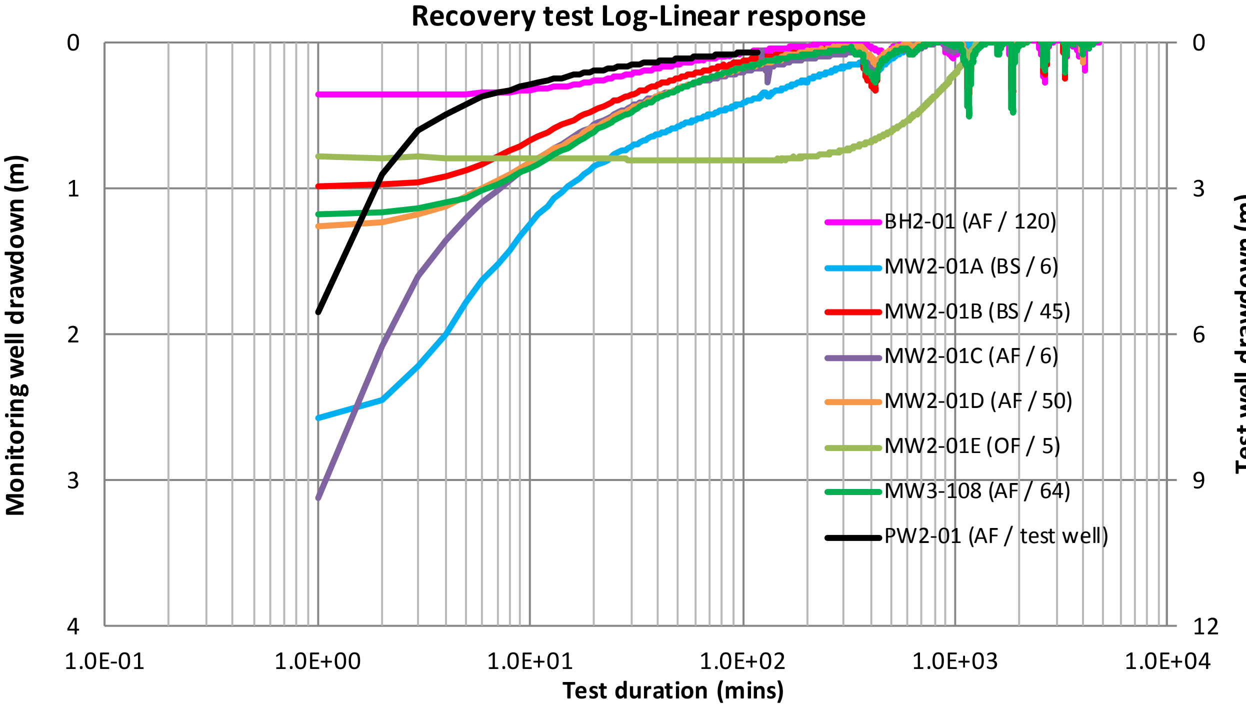

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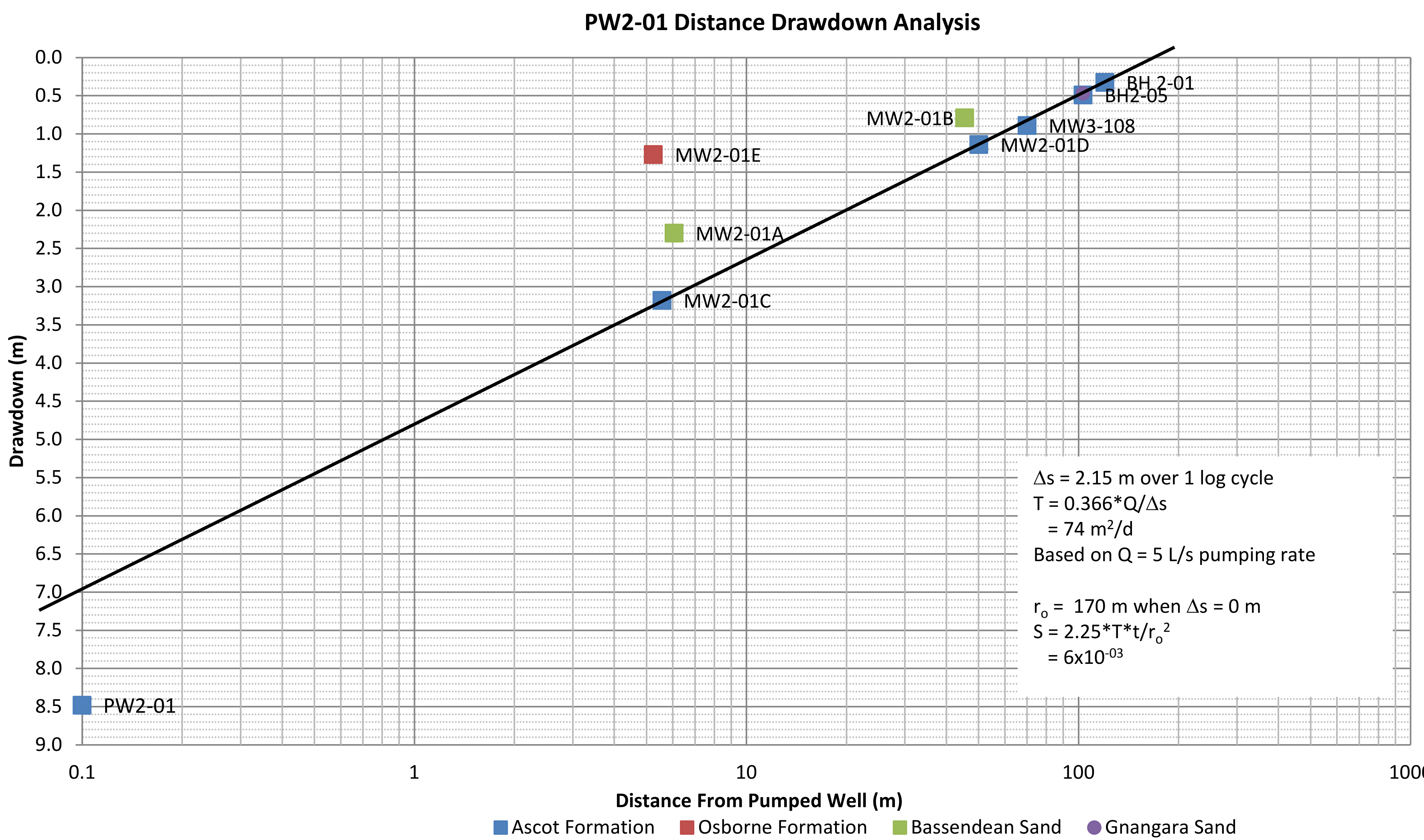
CLIENT: Public Transport Authority		PROJECT: FAL-Stage 2 Geotechnical Investigation	
DRAWN: SDB	DATE: 24/05/2015	TITLE: **Pumping Test Data PW2-01-Test 2 (Airport West Station)**	
CHECKED: AL	DATE: 24/05/2015		
SCALE: NOT TO SCALE	A4	PROJECT No: 147642129-077-R-Rev0	FIGURE No: **Figure E3-3**

File Location:



CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 24/05/2015	TITLE **DISTANCE DRAWDOWN ANALYSIS PW2-01-Test 1 (Airport West Station)**	
APPROVED AL	24/05/2015		
NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	**Figure E3-4**

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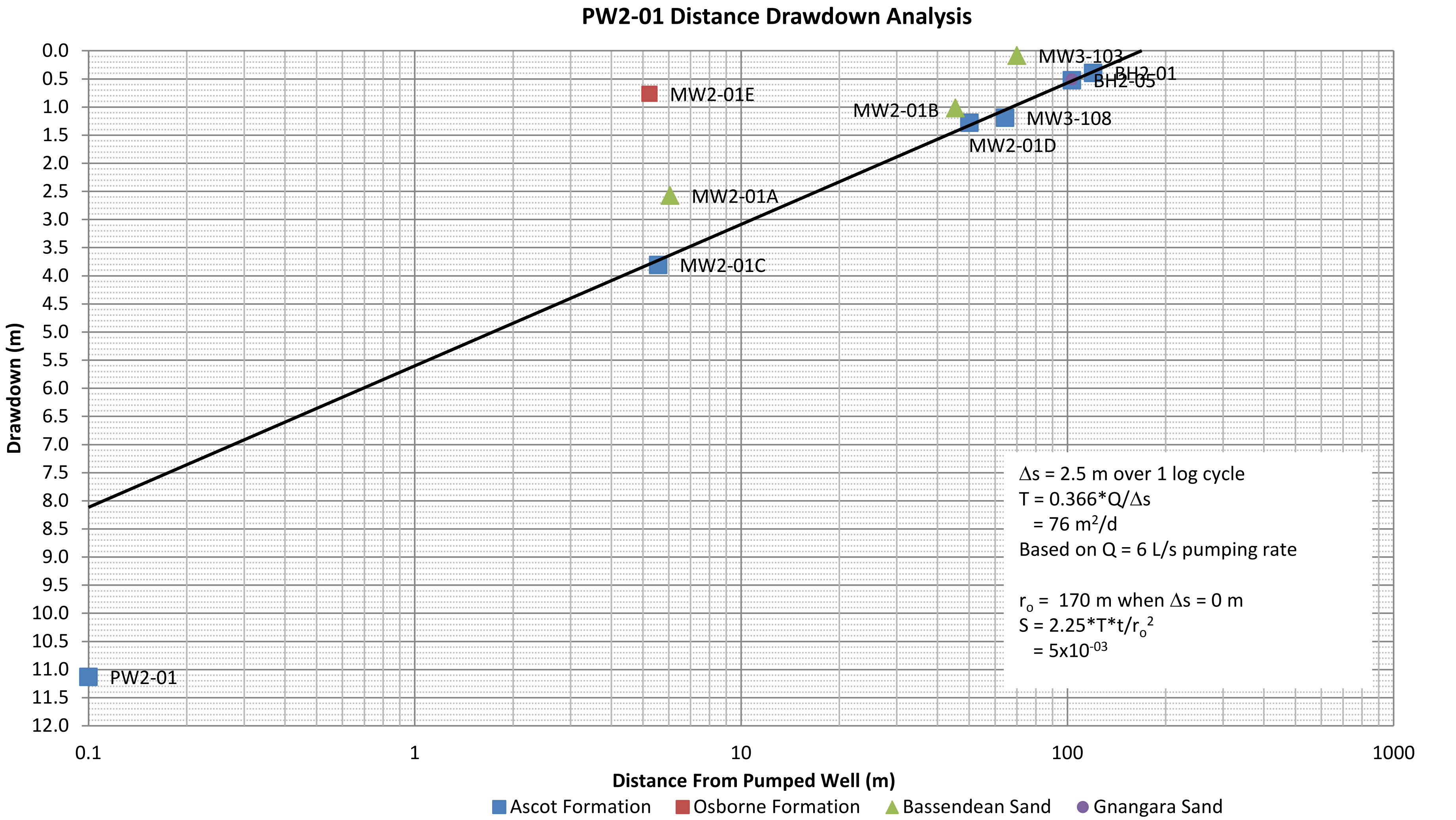
File Location: J:\Hydro\2013\137646044 - Yandi W6 and E7 drilling\Analysis\E7 Hydraulic Testing\HYE0127P test results\Step test\Hantush Bierschenk



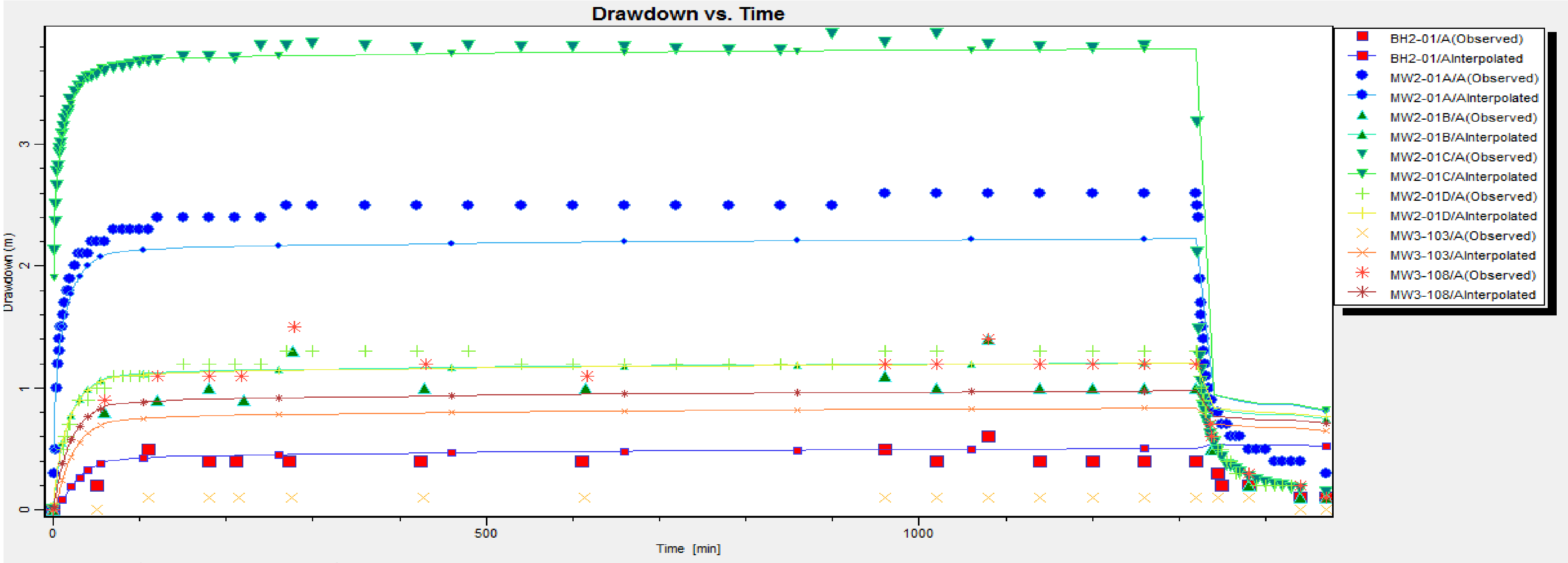
Golder Associates	CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation
	DRAWN SDB	DATE 24/05/2015	TITLE **DISTANCE DRAWDOWN ANALYSIS PW2-01-Test 2 (Airport West Station)**
	APPROVED AL	24/05/2015	
	NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0 — **Figure E3-5**

File Location: J:\Hydro\2013\137646044 - Yandi W6 and E7 drilling\Analysis\E7 Hydraulic Testing\HYE0127P test results\Step test\Hantush Bierschenk

Specific Storage =	1.00E-05 1/m
Transmissivity =	76 m2/d
Hydraulic Conductivity	
K(BS,GF,GS)h	3 m/d
K(BS,GF,GS)v	0.3 m/d
K(AF)h	8 m/d
K(AF)v	0.8 m/d
K(OF)h	0.0005 m/d
K(OF)v	0.00005 m/d
River Conductance =	9 m2/d

River Leakage

Time (min)	Rate (L/S)
10	0.1
20	0.2
30	0.3
40	0.3
50	0.3
120	0.4
320	0.4
520	0.4
920	0.4
1120	0.4
1320	0.4
1470	0.4



Screenshot from MODFLOW output	CLIENT	Public Transport authority		PROJECT	FAL - Stage 2 Geotechnical Investigation
	DRAWN	AL	DATE 24-May-15	TITLE	**Analysis of Pumping Test 2 using Numerical Groundwater Model Airport West Station**
	CHECK	DPS	DATE 24-May-15		
Note: Other combinations in hydraulic conductivity and storage could may be possible	SCALE	Not To Scale	A4	PROJECT No. 147642129-077-R-Rev0	FIGURE No. E3-6

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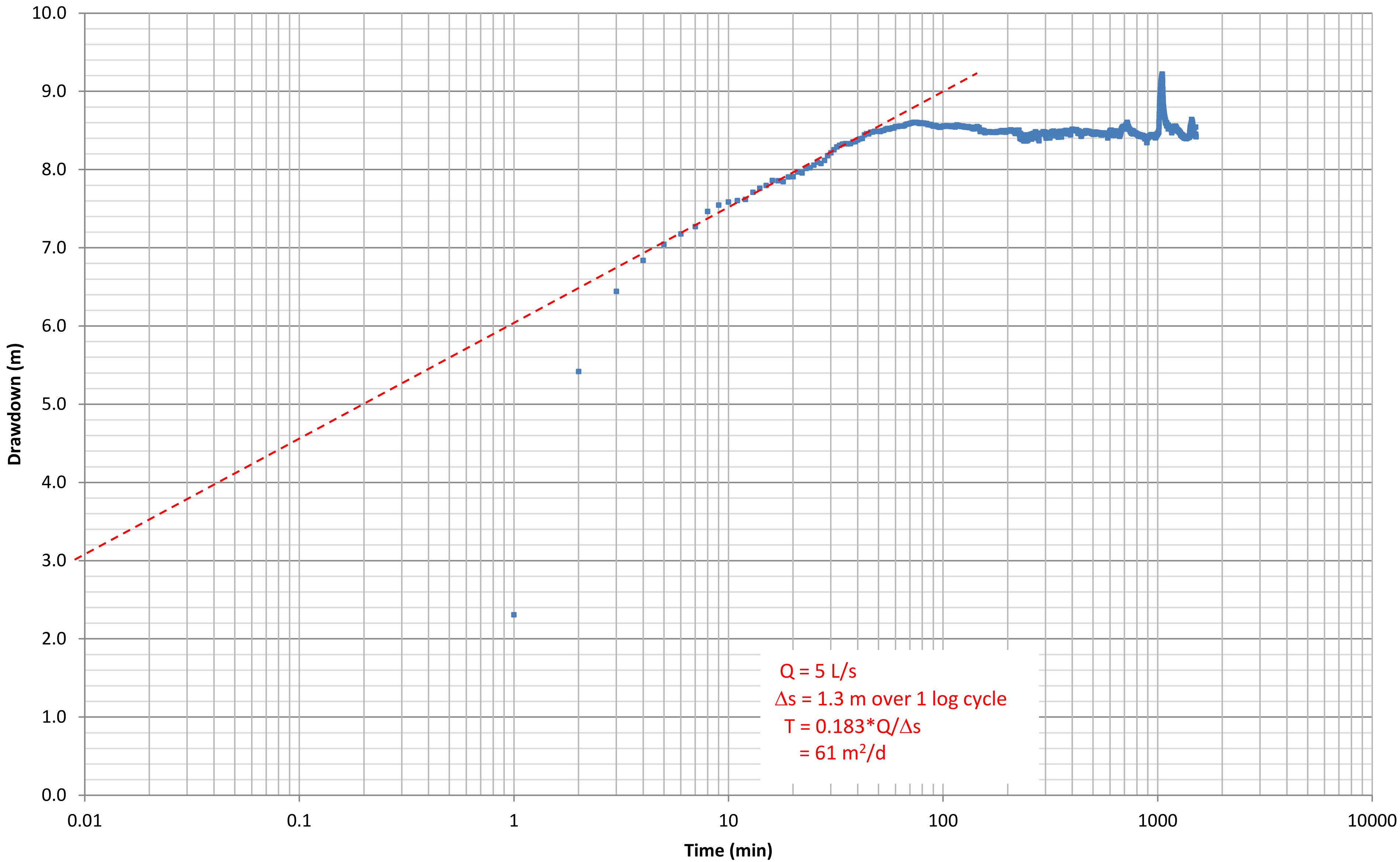
C:\Users\alundorf\Desktop\FAL\APPENDIX E\Appendix E - Test Pumping Results\Attachment E3\Figure E3-6.xlsx

Figure E3-7 - PW2-01 TEST1 - PW2-01 Pumping Response



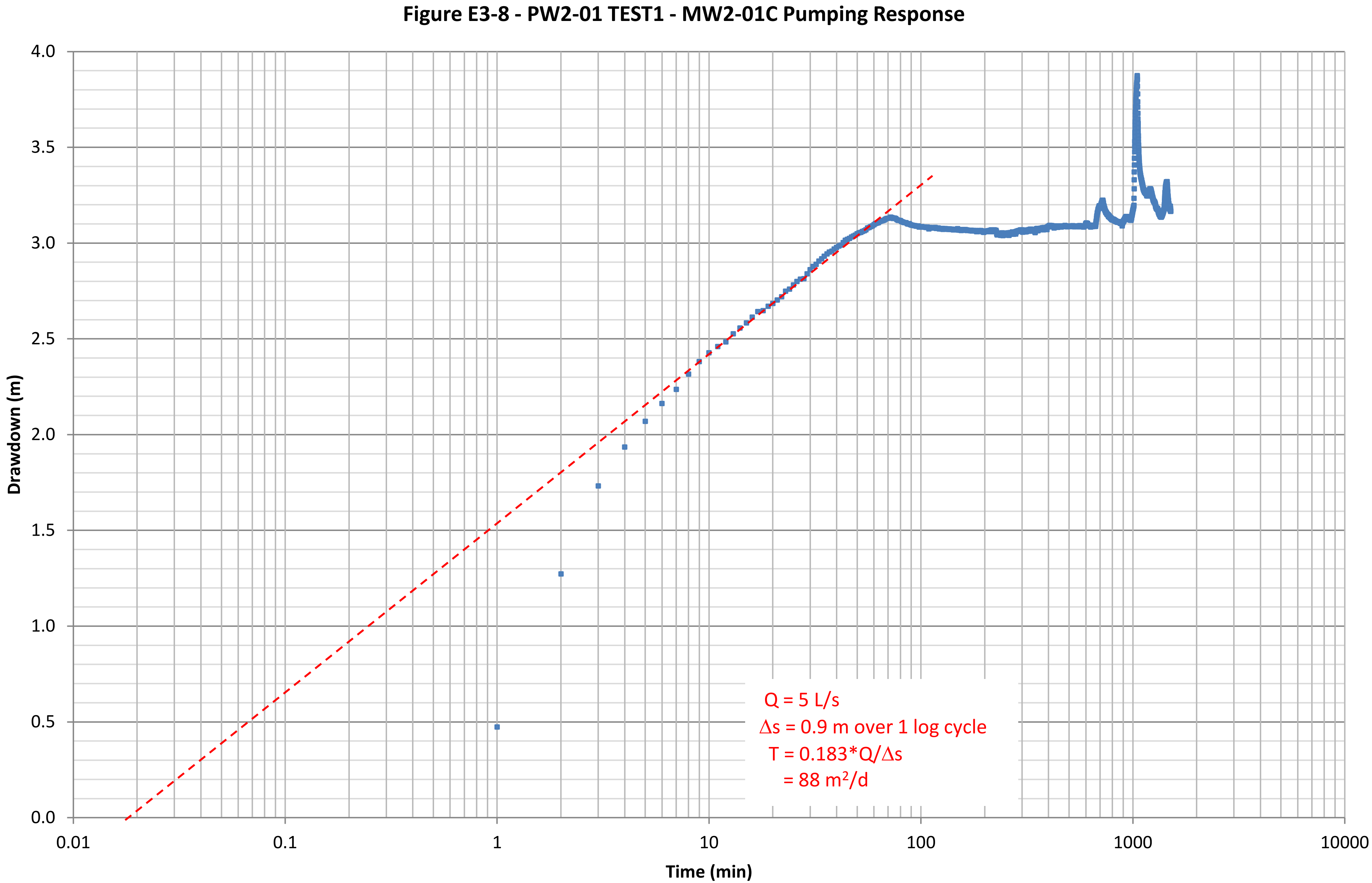


Figure E3-8 - PW2-01 TEST1 - MW2-01C Pumping Response
Drawdown (m)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.01
0.1
1
10
100
1000
10000
Time (min)
Q = 5 L/s
Δs = 0.9 m over 1 log cycle
T = 0.183*Q/Δs
= 88 m2/d

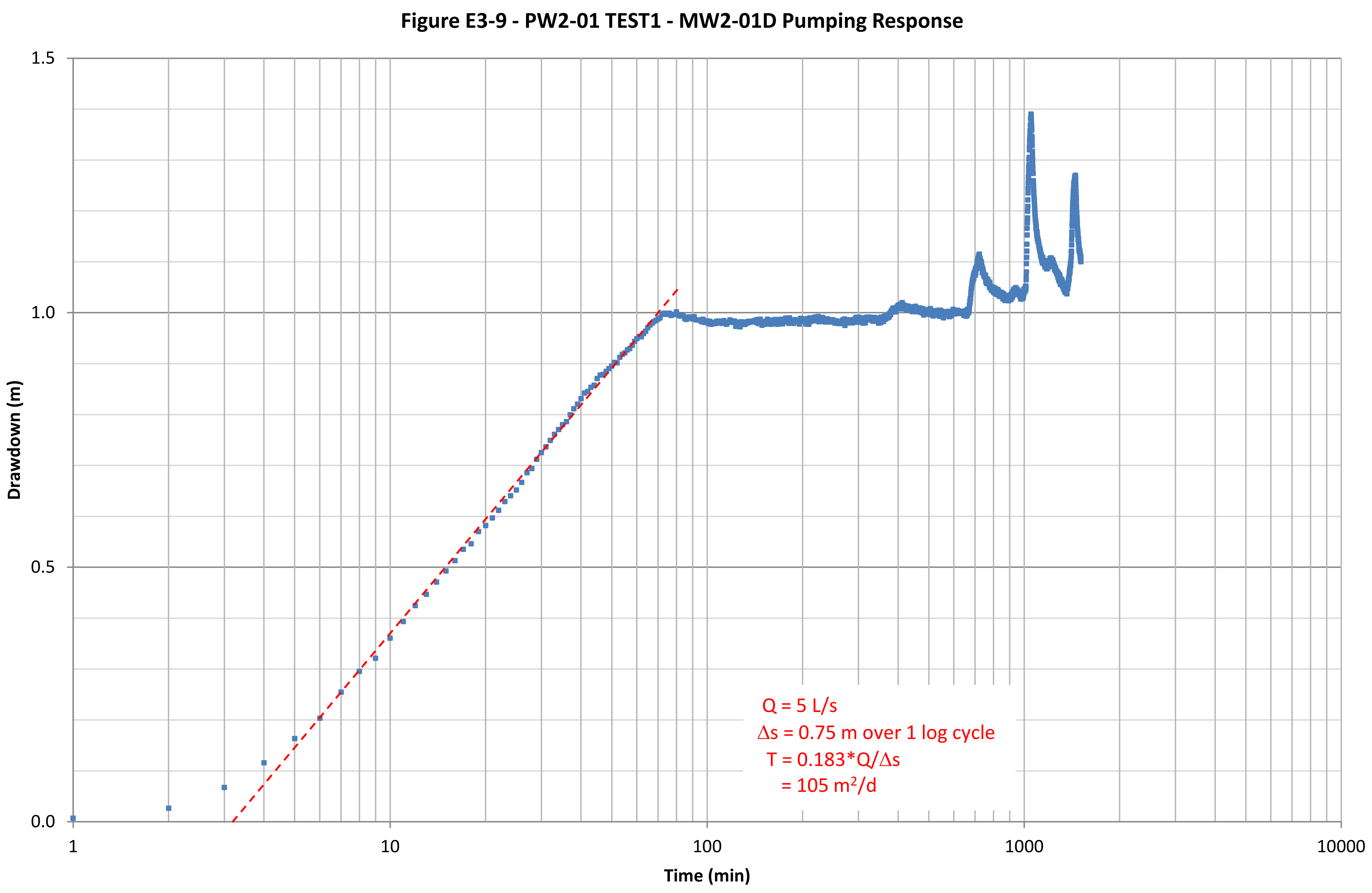


Figure E3-9 - PW2-01 TEST1 - MW2-01D Pumping Response
Drawdown (m)
1.5
1.0
0.5
0.0
1
10
100
1000
10000
Time (min)
Q = 5 L/s
Δs = 0.75 m over 1 log cycle
T = 0.183*Q/Δs
= 105 m²/d

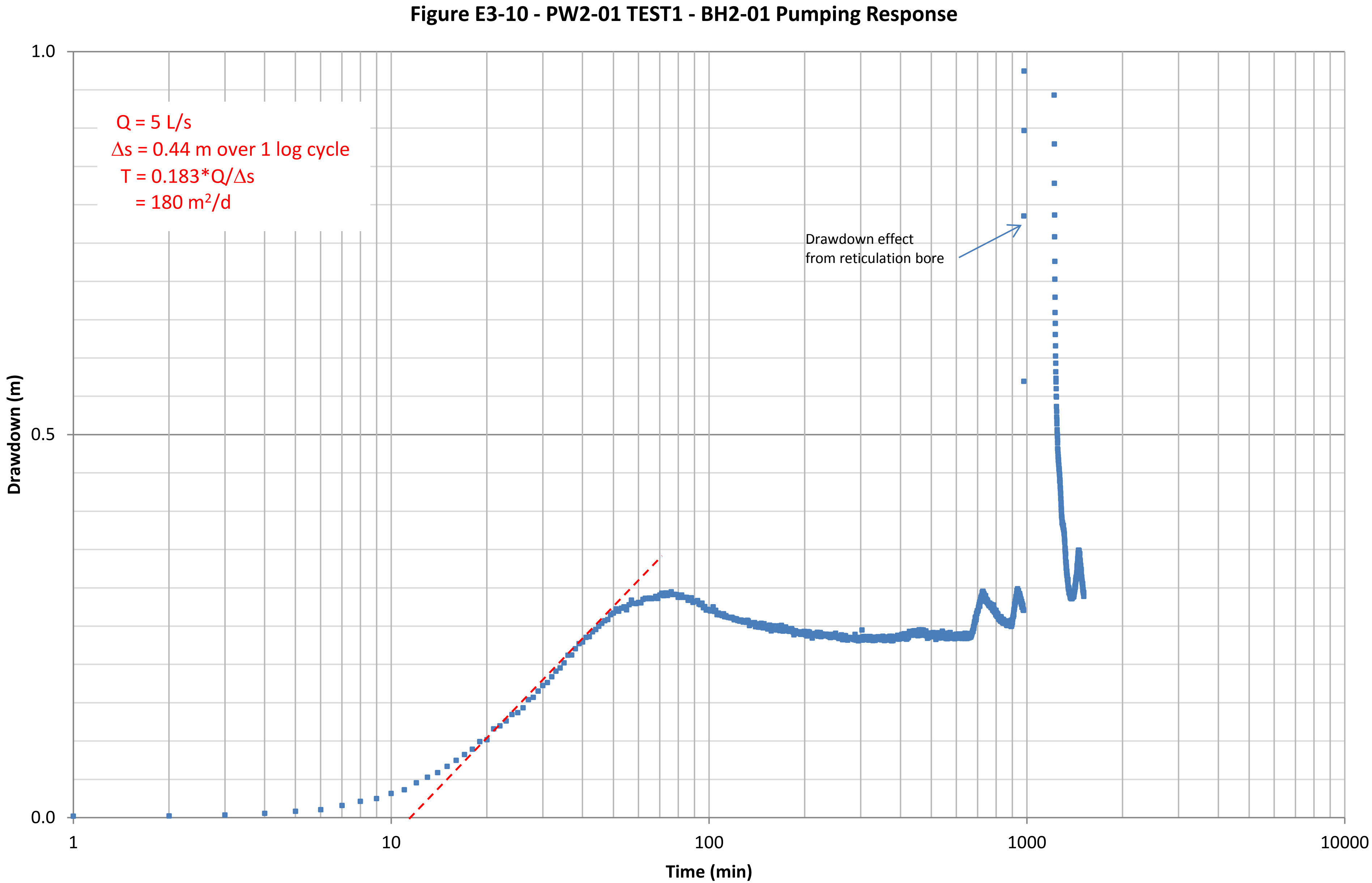
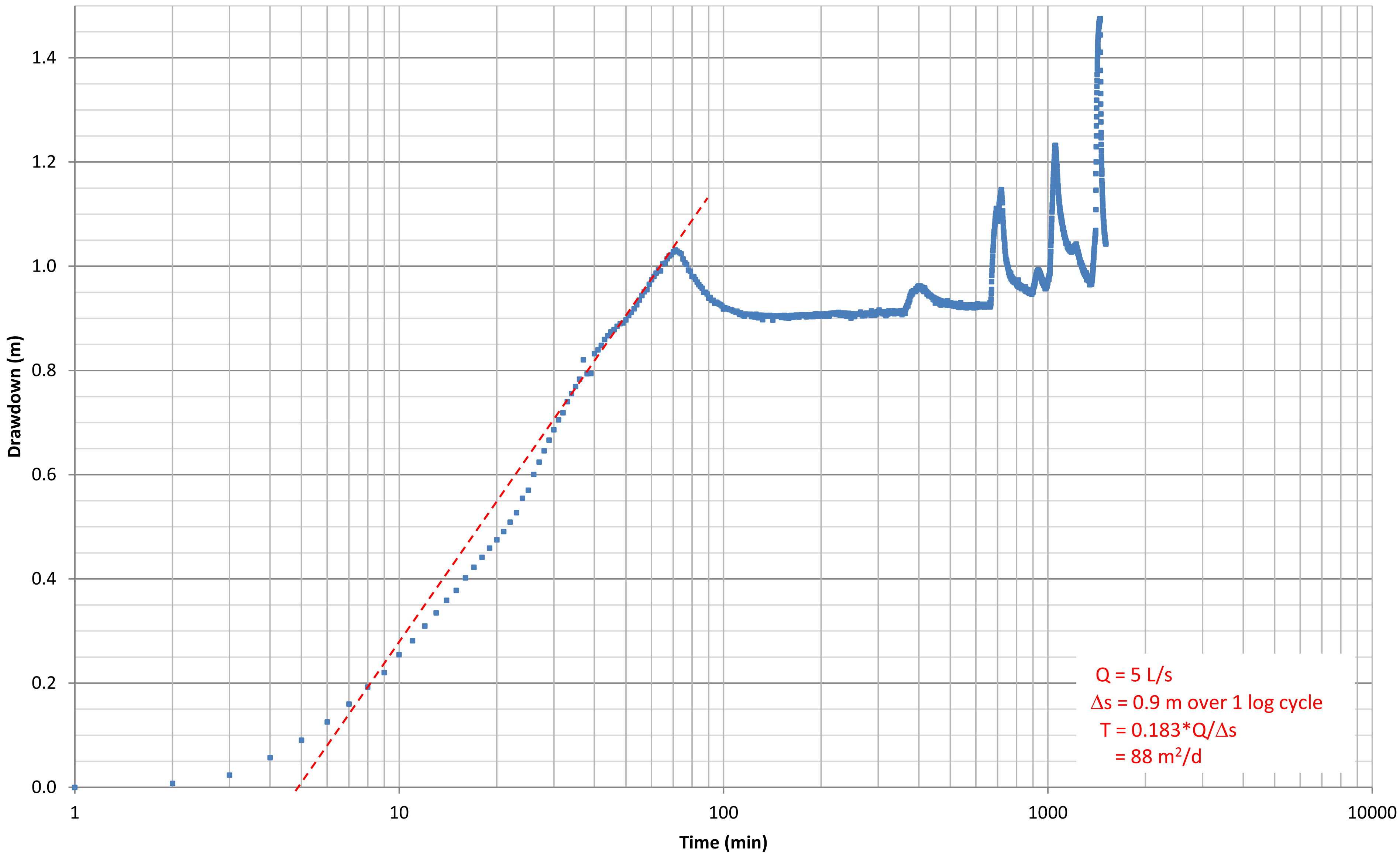


Figure E3-10 - PW2-01 TEST1 - BH2-01 Pumping Response
Q = 5 L/s
Δs = 0.44 m over 1 log cycle
T = 0.183*Q/Δs
= 180 m2/d
Drawdown effect
from reticulation bore
Drawdown (m)
Time (min)
1.0
0.5
0.0
1
10
100
1000
10000

Figure E3-11 - PW2-01 TEST1 - MW3-08 Pumping Response



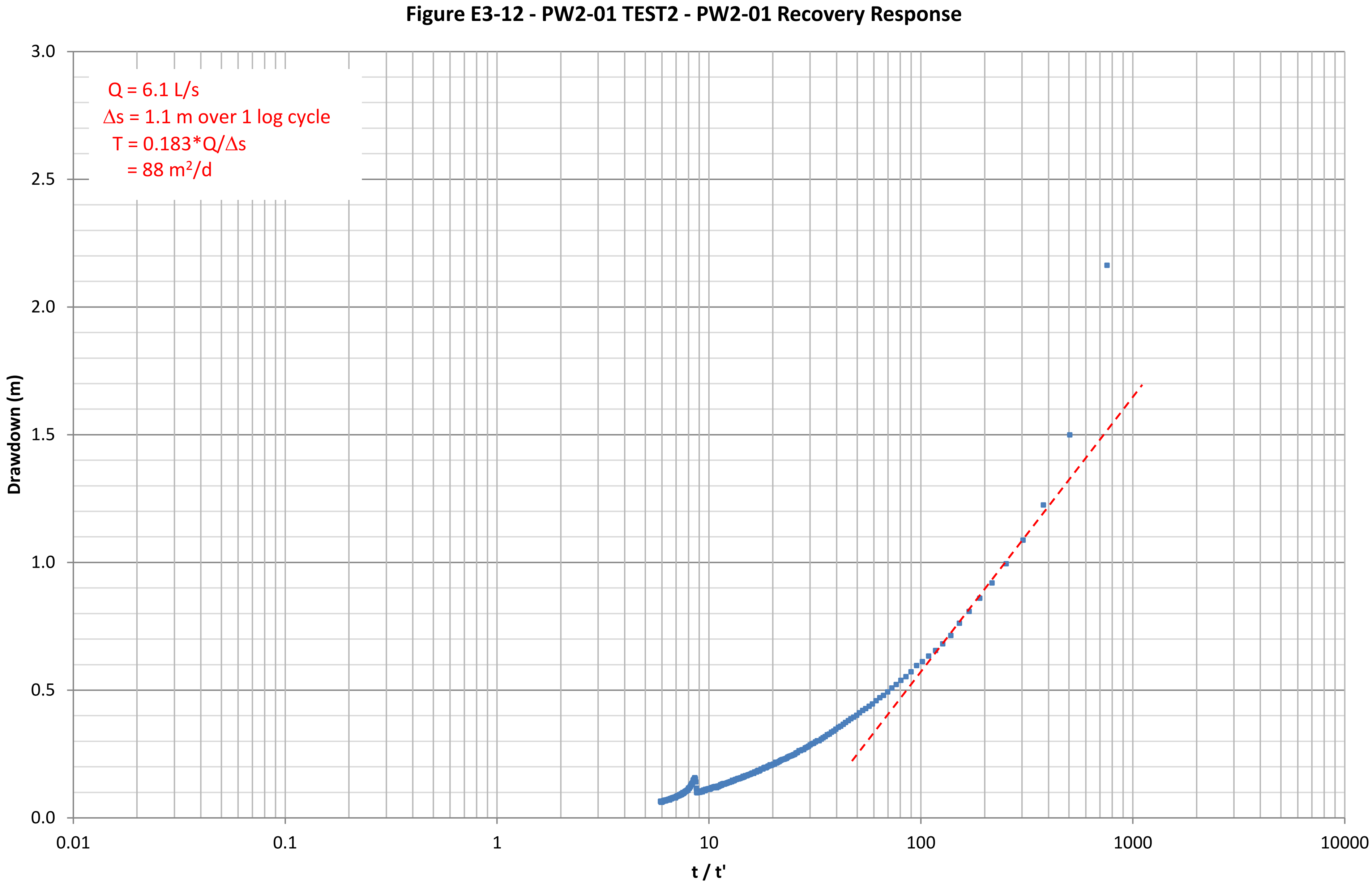
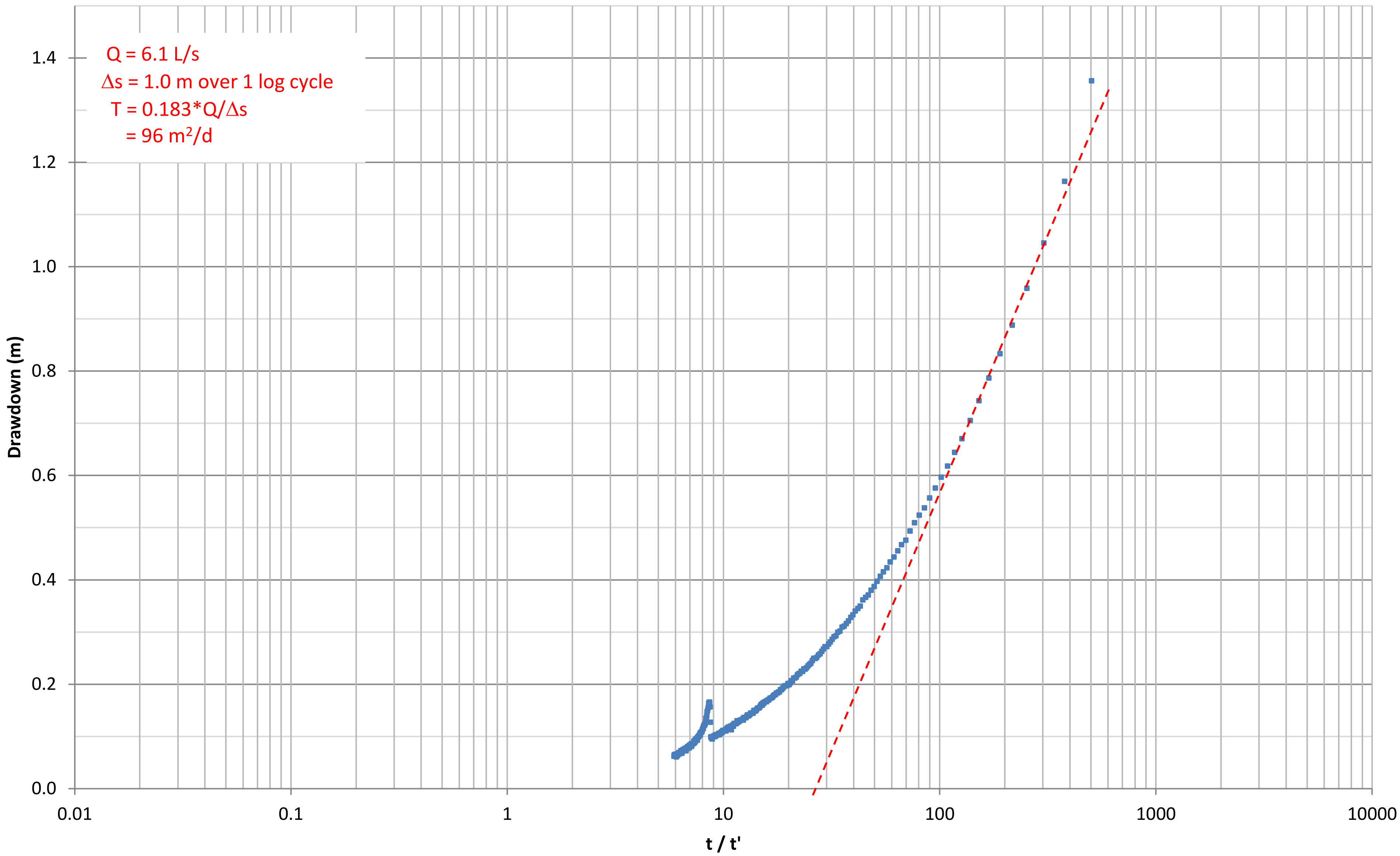


Figure E3-12 - PW2-01 TEST2 - PW2-01 Recovery Response
Q = 6.1 L/s
Δs = 1.1 m over 1 log cycle
T = 0.183*Q/Δs
= 88 m2/d
Drawdown (m)
t / t'
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.01
0.1
1
10
100
1000
10000

Figure E3-13 - PW2-01 TEST2 - MW2-01C Recovery Response



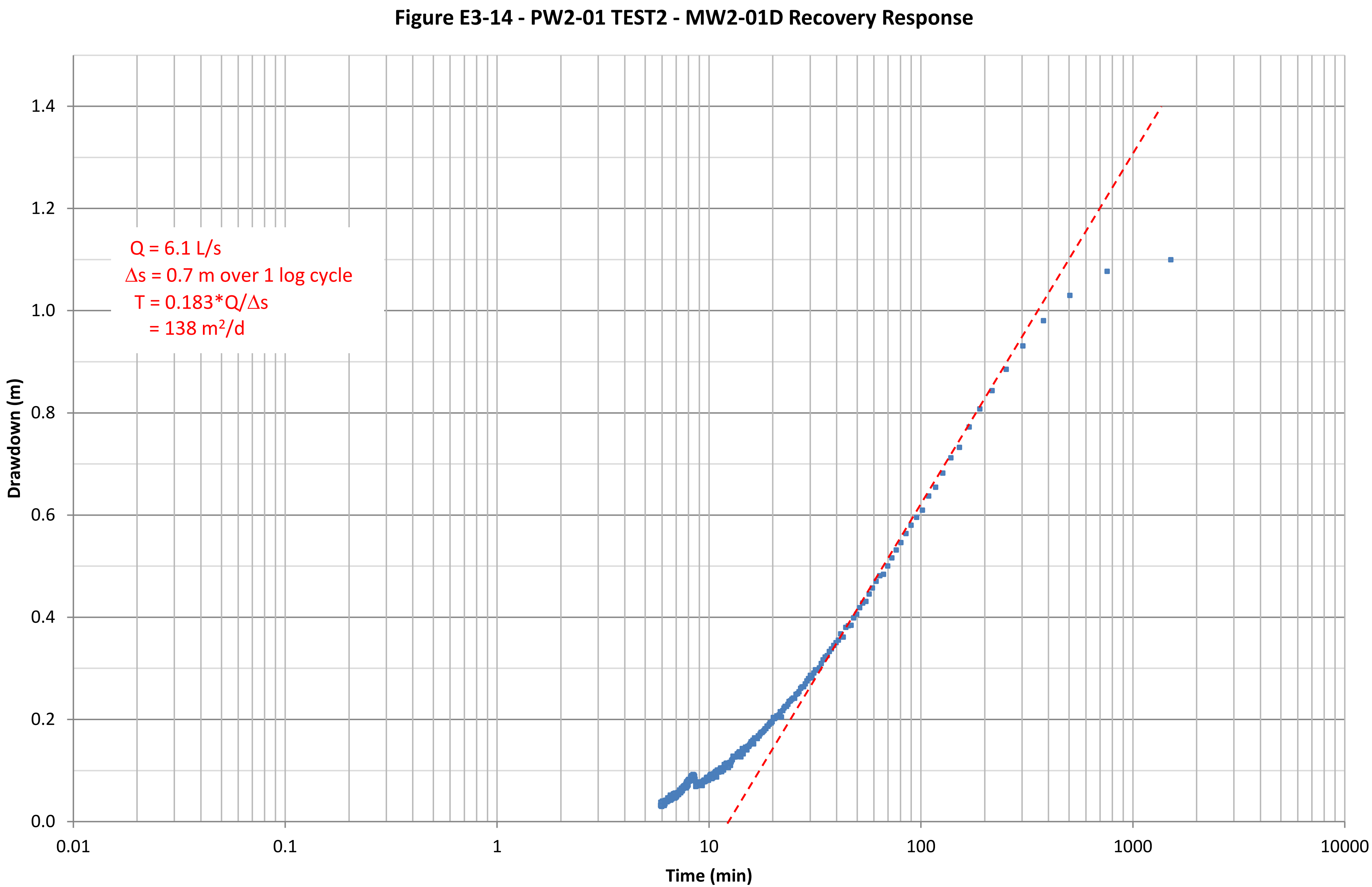
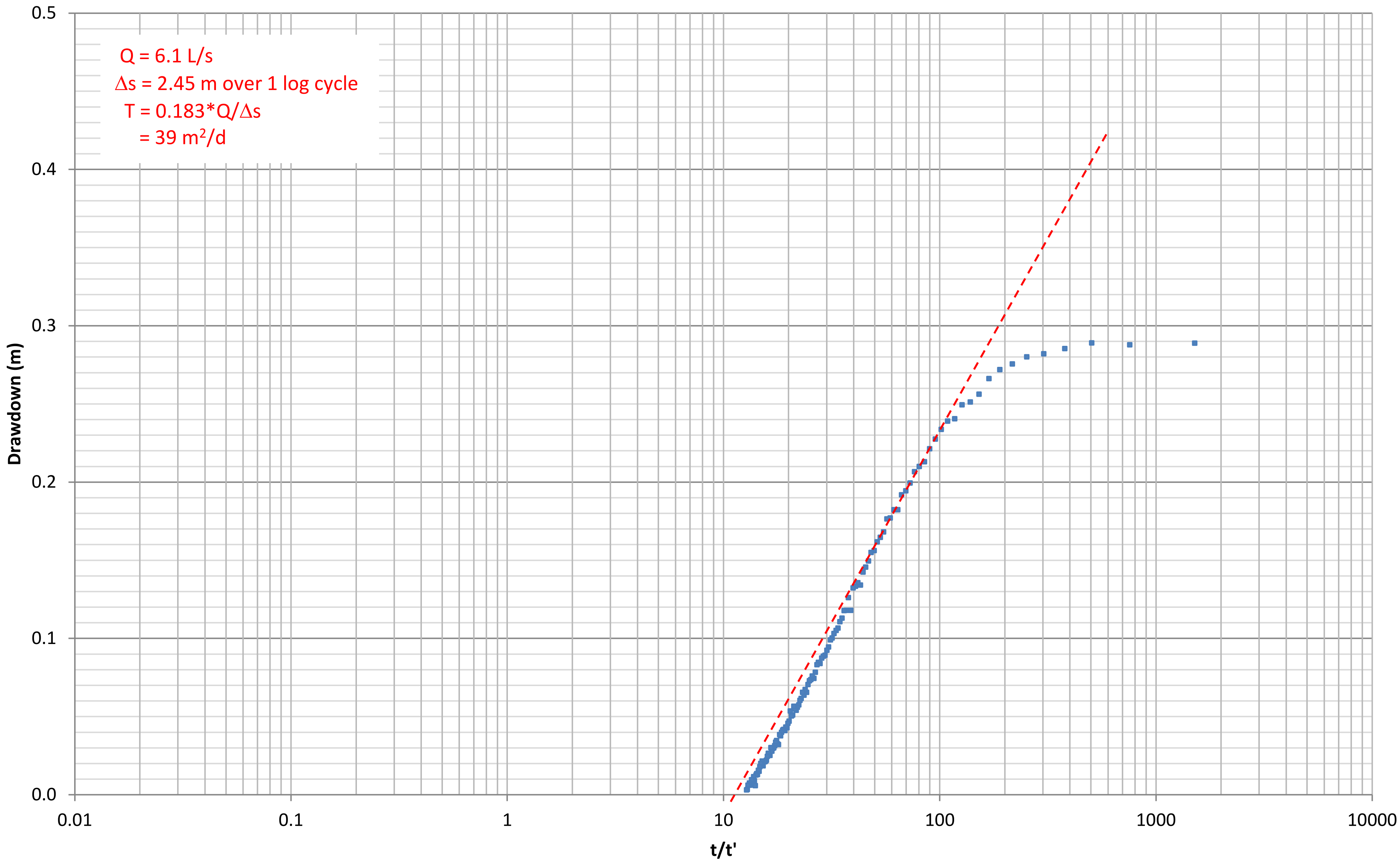


Figure E3-14 - PW2-01 TEST2 - MW2-01D Recovery Response
Q = 6.1 L/s
Δs = 0.7 m over 1 log cycle
T = 0.183*Q/Δs
= 138 m²/d
Drawdown (m)
Time (min)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0.01
0.1
1
10
100
1000
10000

Figure E3-15 - PW2-01 TEST2 - BH2-01 Recovery Response



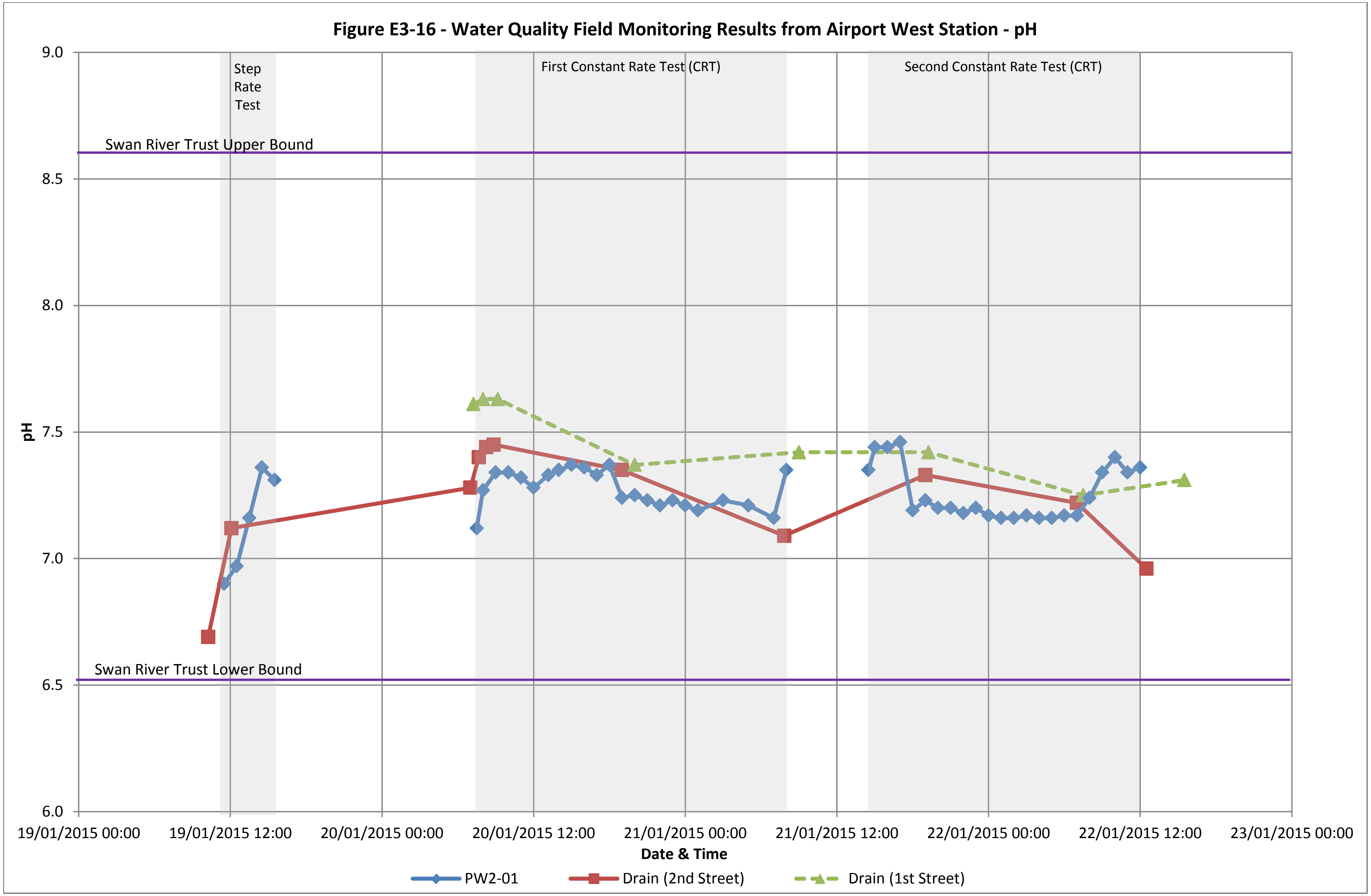


Figure E3-16 - Water Quality Field Monitoring Results from Airport West Station - pH
Step Rate Test
First Constant Rate Test (CRT)
Second Constant Rate Test (CRT)
Swan River Trust Upper Bound
Swan River Trust Lower Bound
pH
9.0
8.5
8.0
7.5
7.0
6.5
6.0
19/01/2015 00:00
19/01/2015 12:00
20/01/2015 00:00
20/01/2015 12:00
21/01/2015 00:00
21/01/2015 12:00
22/01/2015 00:00
22/01/2015 12:00
23/01/2015 00:00
Date & Time
PW2-01
Drain (2nd Street)
Drain (1st Street)

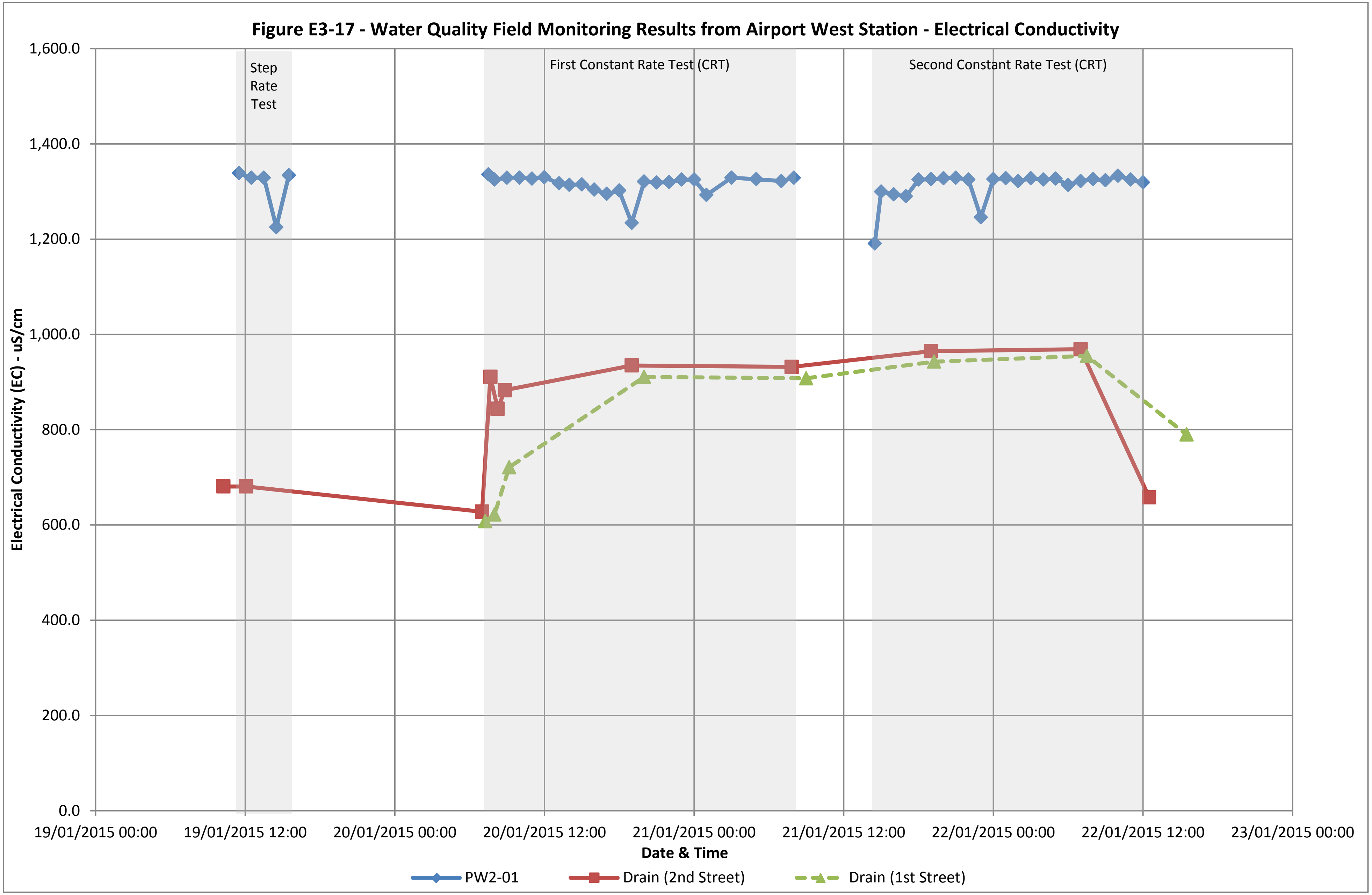
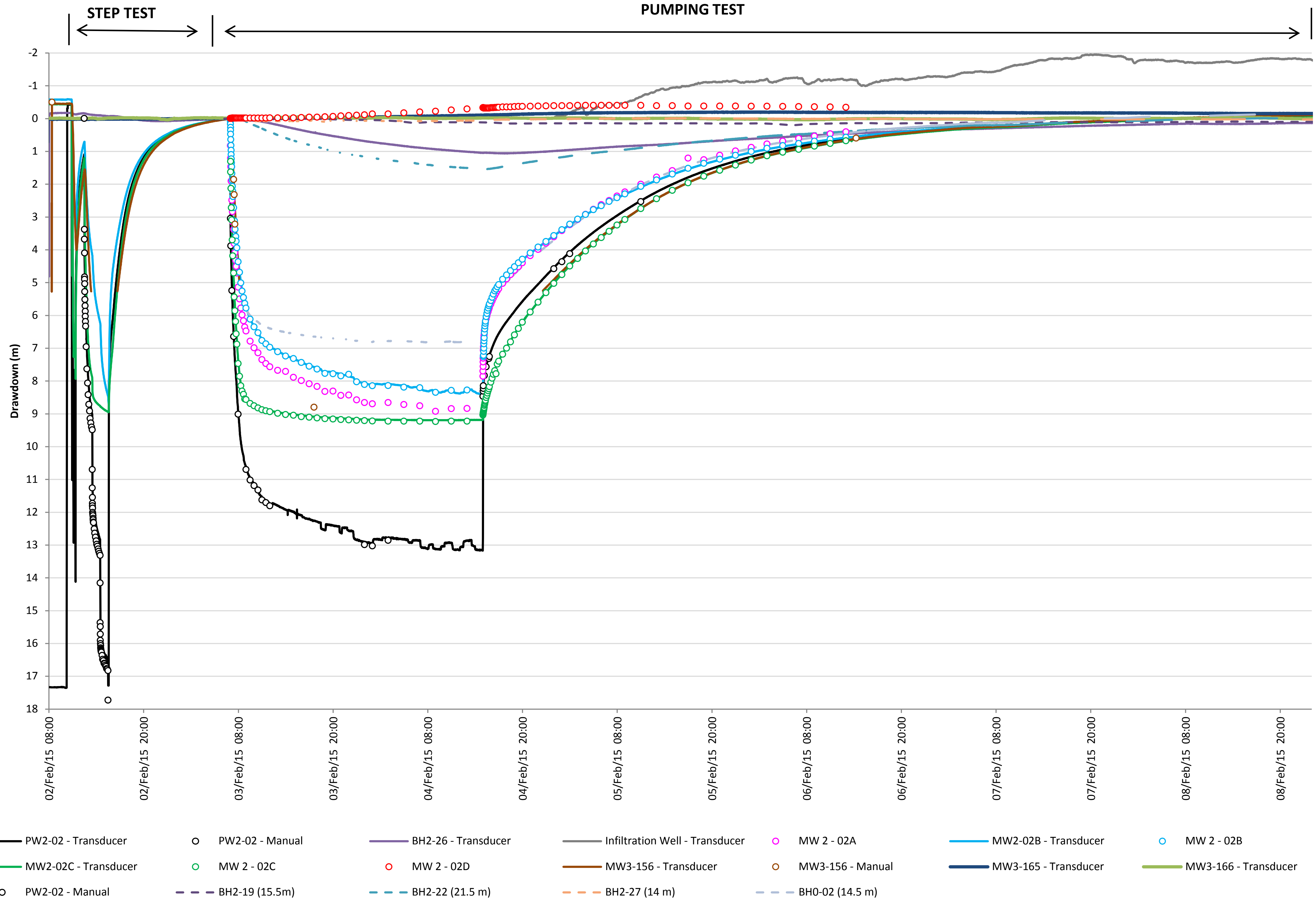
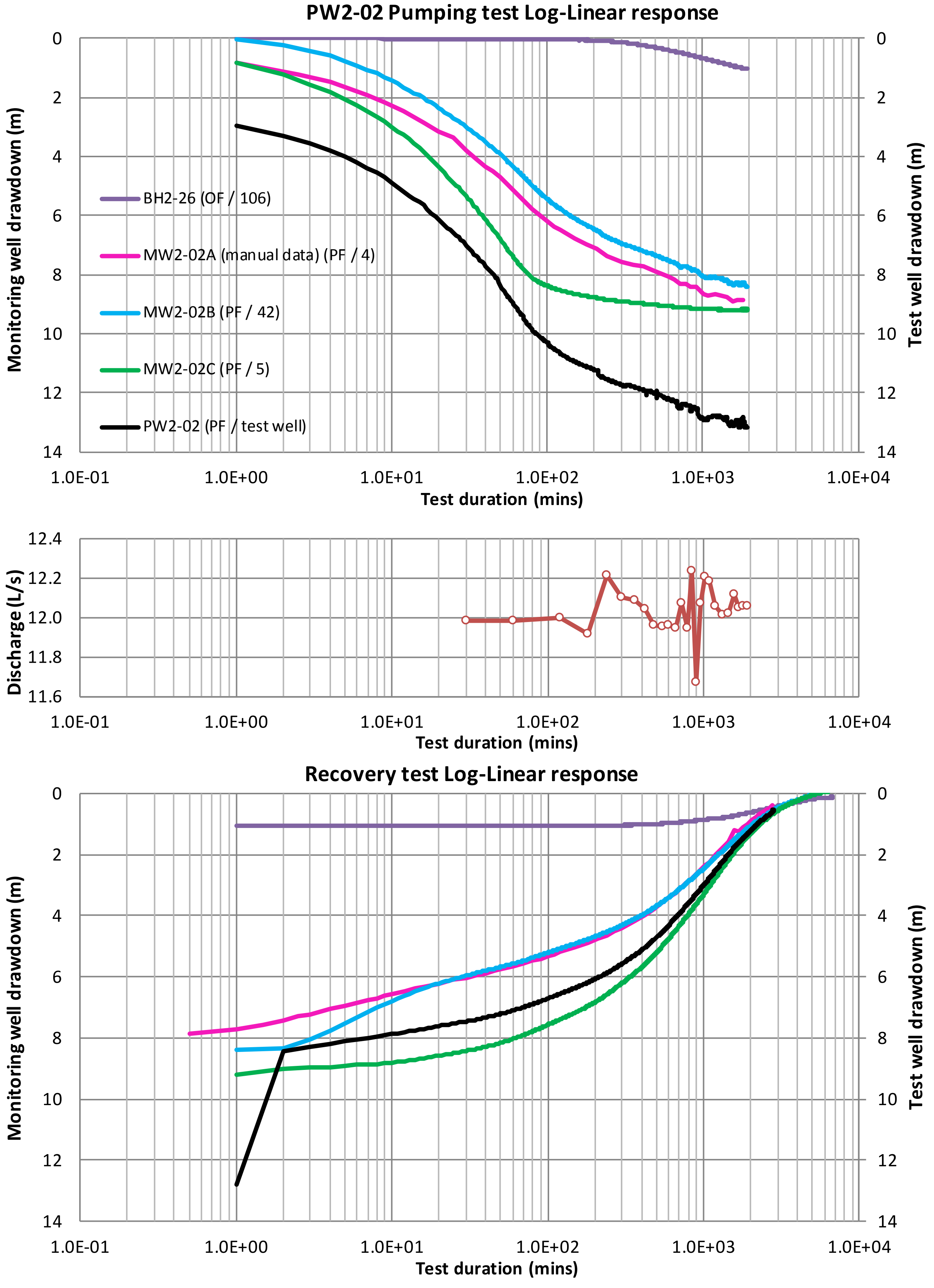


Figure E3-17 - Water Quality Field Monitoring Results from Airport West Station - Electrical Conductivity
Step
Rate
Test
First Constant Rate Test (CRT)
Second Constant Rate Test (CRT)
Electrical Conductivity (EC) - uS/cm
1,600.0
1,400.0
1,200.0
1,000.0
800.0
600.0
400.0
200.0
0.0
19/01/2015 00:00
19/01/2015 12:00
20/01/2015 00:00
20/01/2015 12:00
21/01/2015 00:00
21/01/2015 12:00
22/01/2015 00:00
22/01/2015 12:00
23/01/2015 00:00
Date & Time
PW2-01
Drain (2nd Street)
Drain (1st Street)

ATTACHMENT E4
Constant Rate Test – Bayswater Dive Structure (PW2-02)



Golder Associates	CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation
	DRAWN SDB	DATE 09/04/2015	TITLE **Pumping Test Data PW2-02-Data (Bayswater Dive)**
	CHECKED AL	24/05/2015	
	SCALE NOT TO SCALE	A3	PROJECT No 147642129-077-R-Rev0 / FIGURE No **Figure E4-1**



Golder Associates
Level 3, 1 Havelock St West Perth WA 6005
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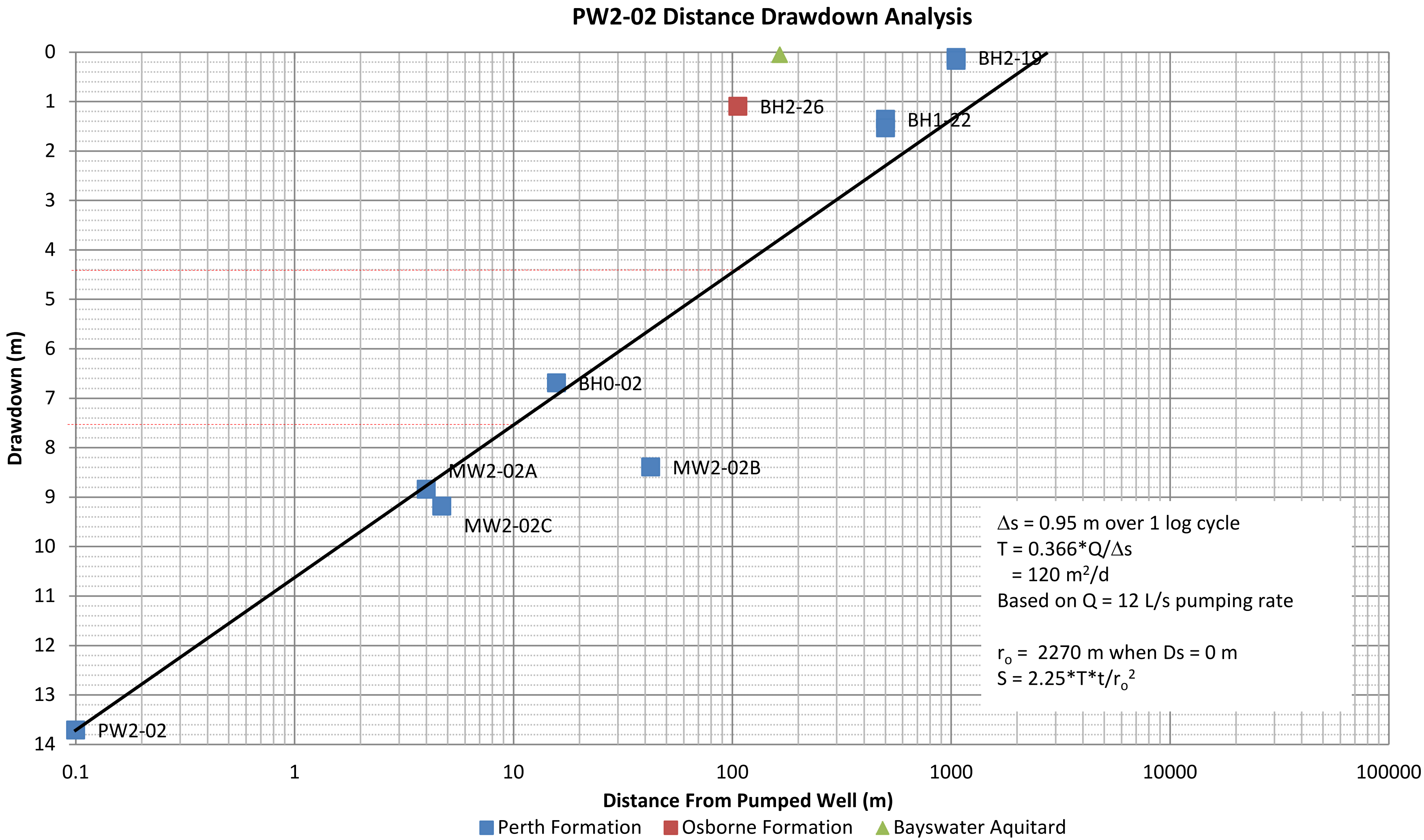
CLIENT Public Transport Authority		PROJECT FAL-Stage 2 Geotechnical Investigation	
DRAWN SDB	DATE 24/05/2015	TITLE **Pumping Test Data PW2-02 (Bayswater Dive Structure)**	
CHECKED AL	DATE 24/05/2015		
SCALE NOT TO SCALE	A4	PROJECT No 147642129-077-R-Rev0	FIGURE No **Figure E4-2**

File Location:



CLIENT: Public Transport Authority		PROJECT: FAL-Stage 2 Geotechnical Investigation
DRAWN: SDB	DATE: 24/05/2015	TITLE: **DISTANCE DRAWDOWN ANALYSIS PW2-02 (Bayswater Dive Structure)**
APPROVED: AL	24/05/2015	
NOT TO SCALE	A4	PROJECT No: 147642129-077-R-Rev0 — **Figure E4-3**

File Location: J:\Hydro\2013\137646044 - Yandi W6 and E7 drilling\Analysis\E7 Hydraulic Testing\HYE0127P test results\Step test\Hantush Bierschenk

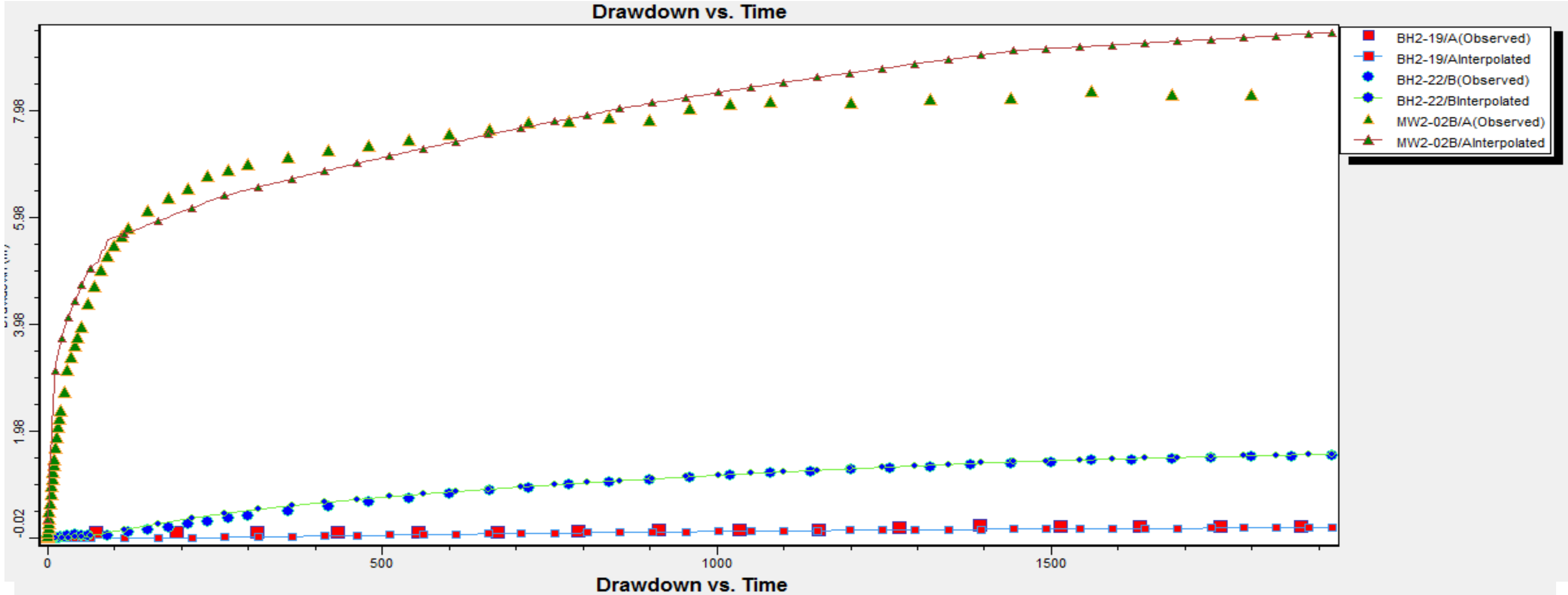
Specific Storage = 1.00E-06 1/m

Transmissivity = 60 m2/d

Hydraulic Conductivity

K(GF)h 4 m/d

K(GF)v 0.4 m/d



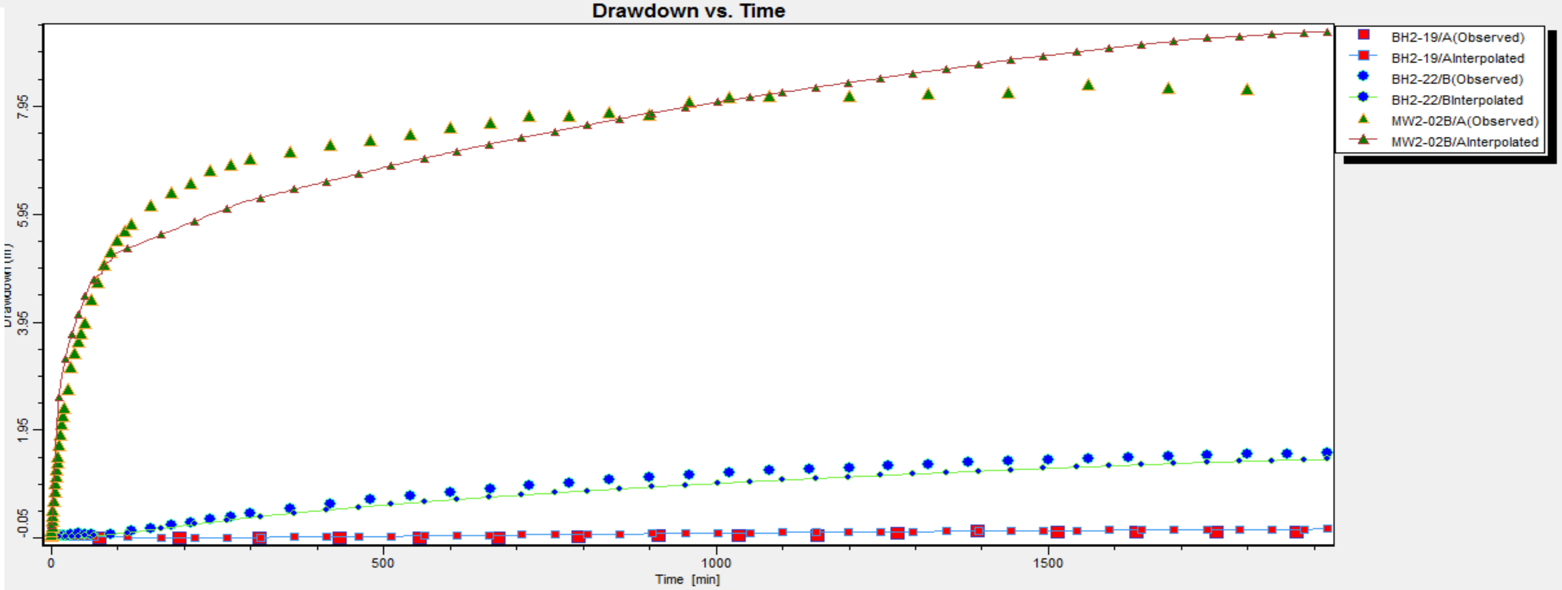
Specific Storage = 5.00E-06 1/m

Transmissivity = 60 m2/d

Hydraulic Conductivity

K(GF)h 4 m/d

K(GF)v 4 m/d



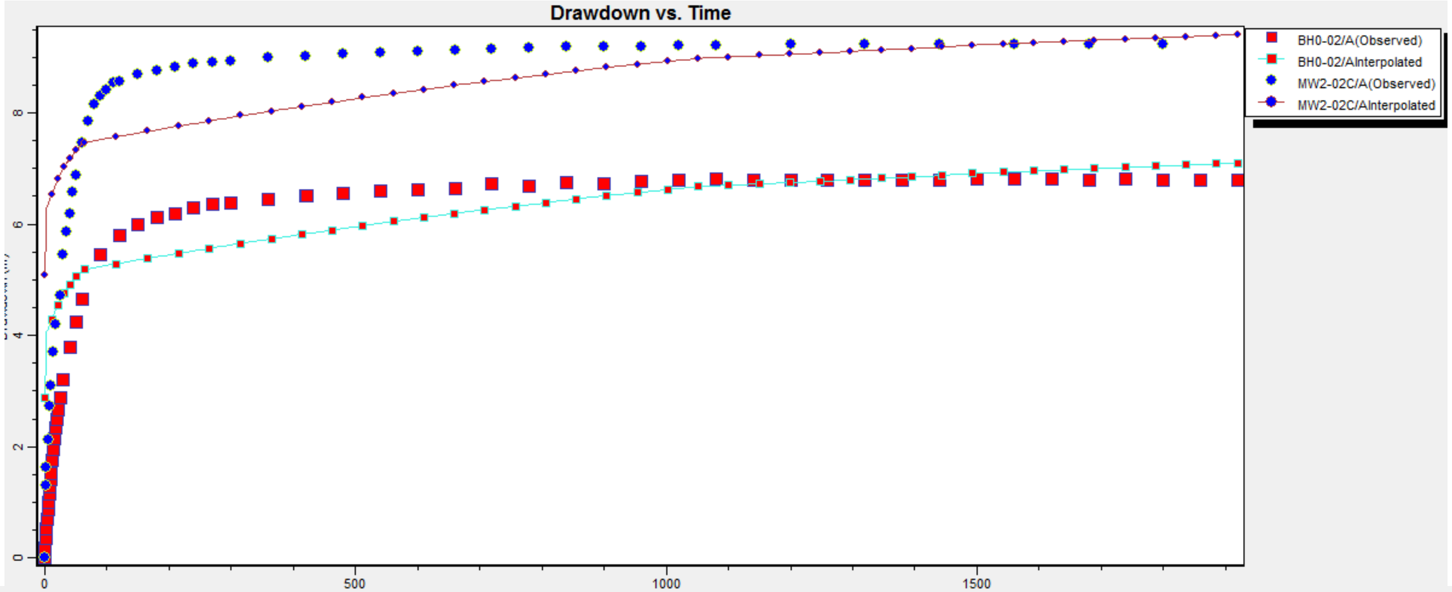
Screenshot from MODFLOW output

Graphs for BH2-19, BH2-22 and MW2-02B (further from PW2-02)

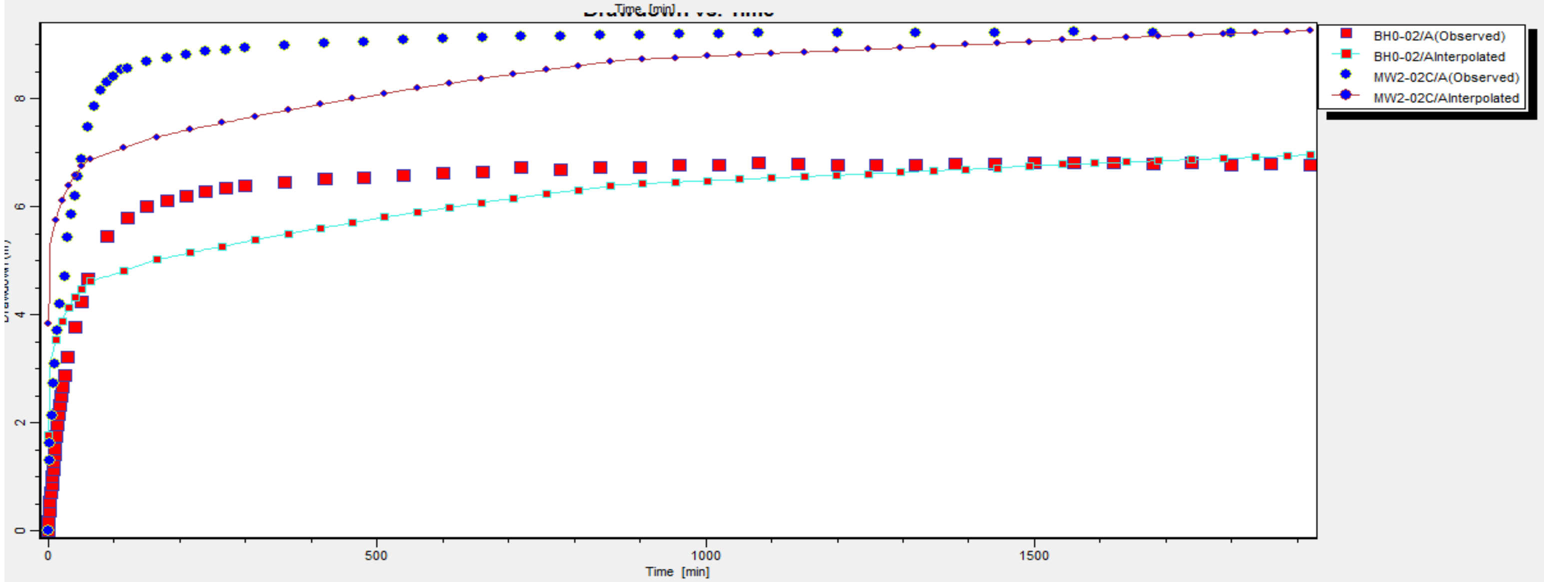
Golder Associates

CLIENT	Public Transport authority	PROJECT	FAL - Stage 2 Geotechnical Investigation
DRAWN AL	DATE 24-May-15	TITLE	**Modelled Groundwater Level Drawdown PW2-02 Pumping Test (Bayswater) Forrestfield Dive Structure**
CHECK DPS	DATE 24-May-15		
SCALE Not To Scale	A4	PROJECT No. 147642129-077-R-Rev0	FIGURE No. E4-4

Specific Storage = 1.00E-06 1/m
Transmissivity = 113 m2/d
Hydraulic Conductivity
K(GF)h 7.5 m/d
K(GF)v 0.75 m/d



Specific Storage = 5.00E-06 1/m
Transmissivity = 113 m2/d
Hydraulic Conductivity
K(GF)h 7.5 m/d
K(GF)v 7.5 m/d



Screenshot from MODFLOW output

Graphs for BH0-02 and MW2-02C (Closer to PW2-02)

Golder Associates

CLIENT	Public Transport authority			PROJECT	FAL - Stage 2 Geotechnical Investigation
DRAWN	AL	DATE	24-May-15	TITLE	**Modelled Groundwater Level Drawdown PW2-02 Pumping Test (Bayswater) Forestfield Dive Structure**
CHECK	DPS	DATE	24-May-15		
SCALE	Not To Scale		A4	PROJECT No.	147642129-077-R-Rev0
				FIGURE No.	E4-5

C:\Users\alundorf\Desktop\FAL\APPENDIX E\Appendix E - Test Pumping Results\Attachment E4\Figure E4-4&E4-5.xlsx

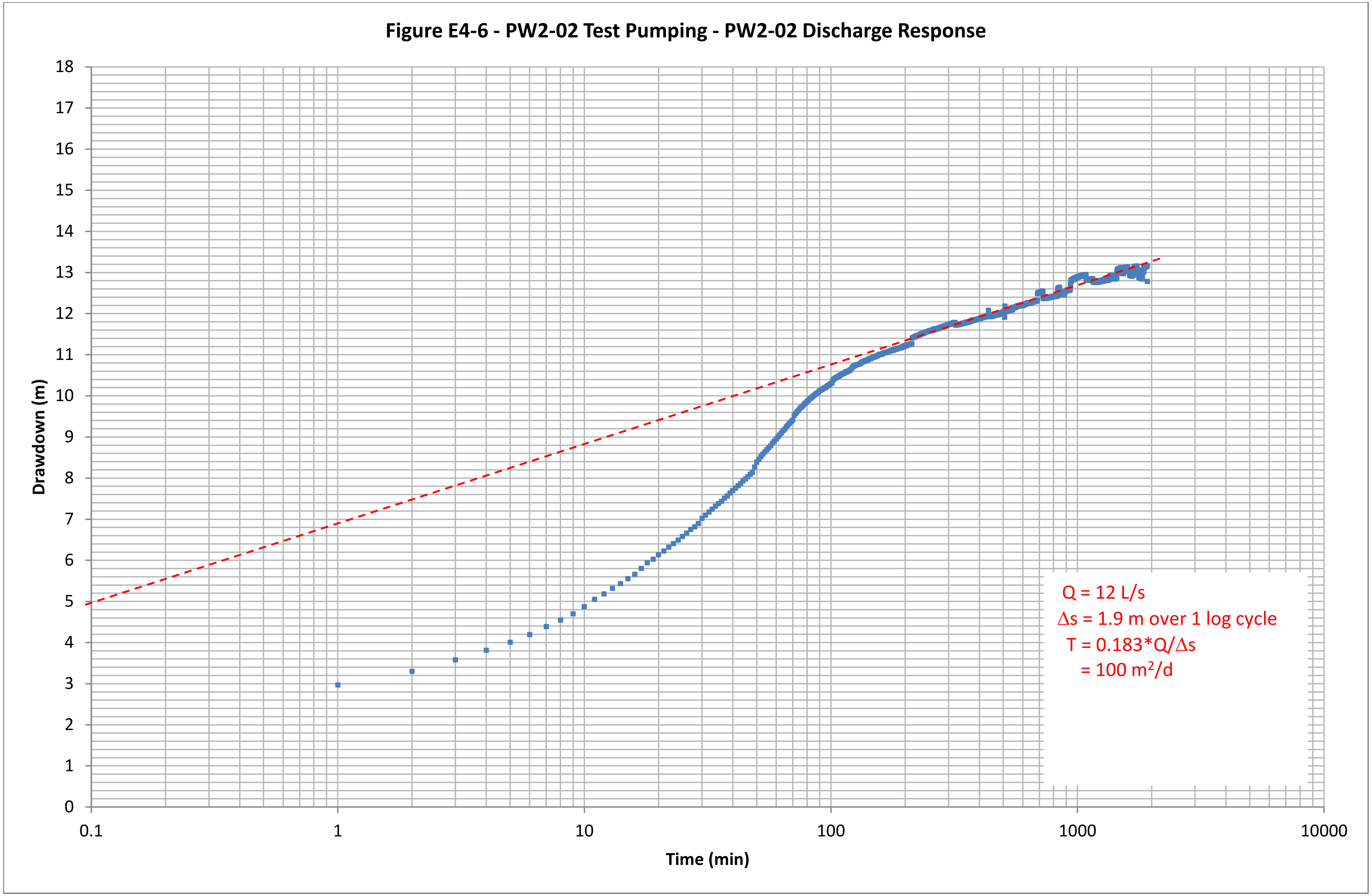


Figure E4-6 - PW2-02 Test Pumping - PW2-02 Discharge Response
Drawdown (m)
Time (min)
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 1.9 m over 1 log cycle
T = 0.183*Q/Δs
= 100 m²/d

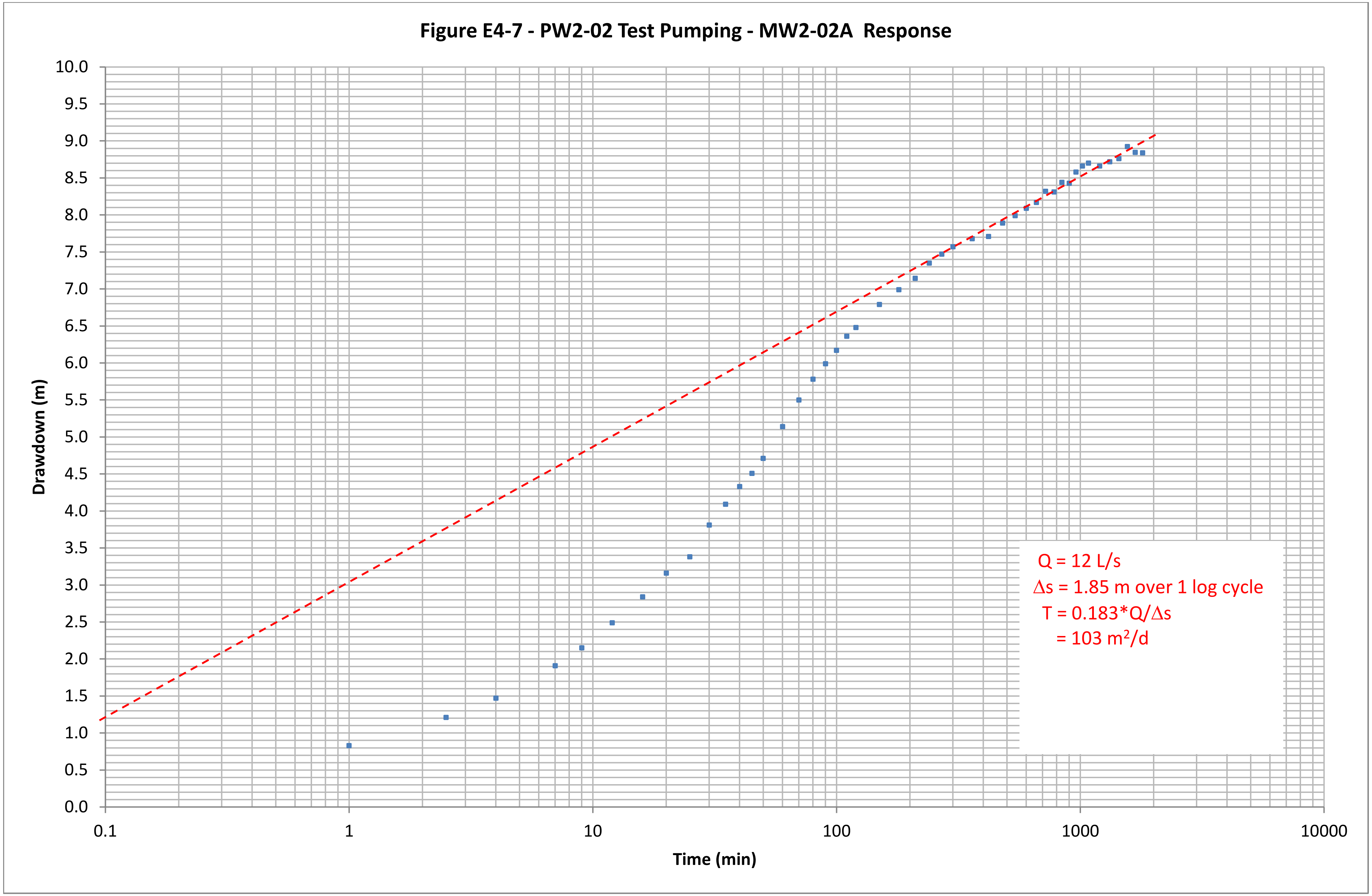


Figure E4-7 - PW2-02 Test Pumping - MW2-02A Response
Drawdown (m)
Time (min)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 1.85 m over 1 log cycle
T = 0.183*Q/Δs
= 103 m²/d

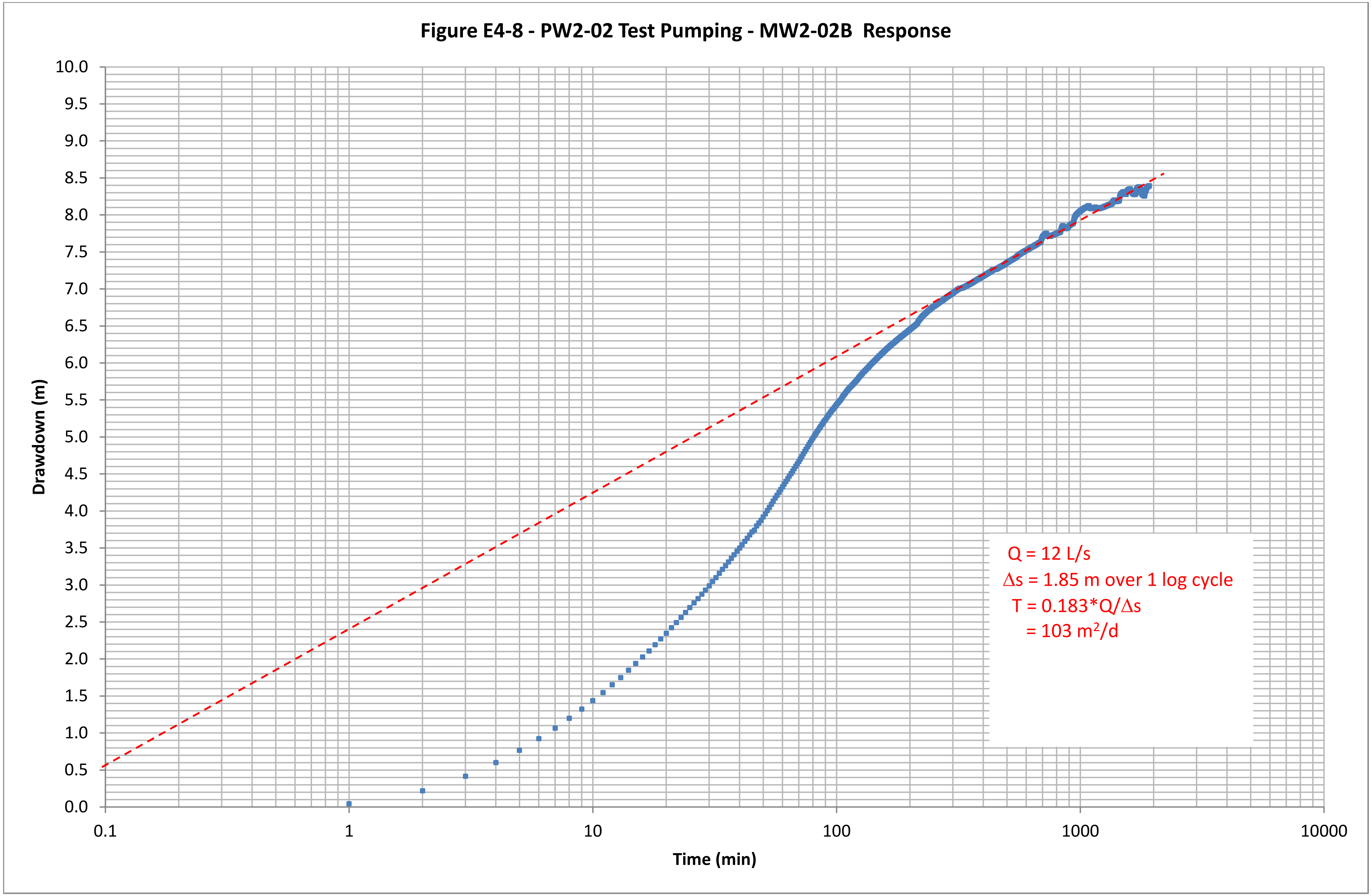


Figure E4-8 - PW2-02 Test Pumping - MW2-02B Response
Drawdown (m)
Time (min)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 1.85 m over 1 log cycle
T = 0.183*Q/Δs
= 103 m²/d

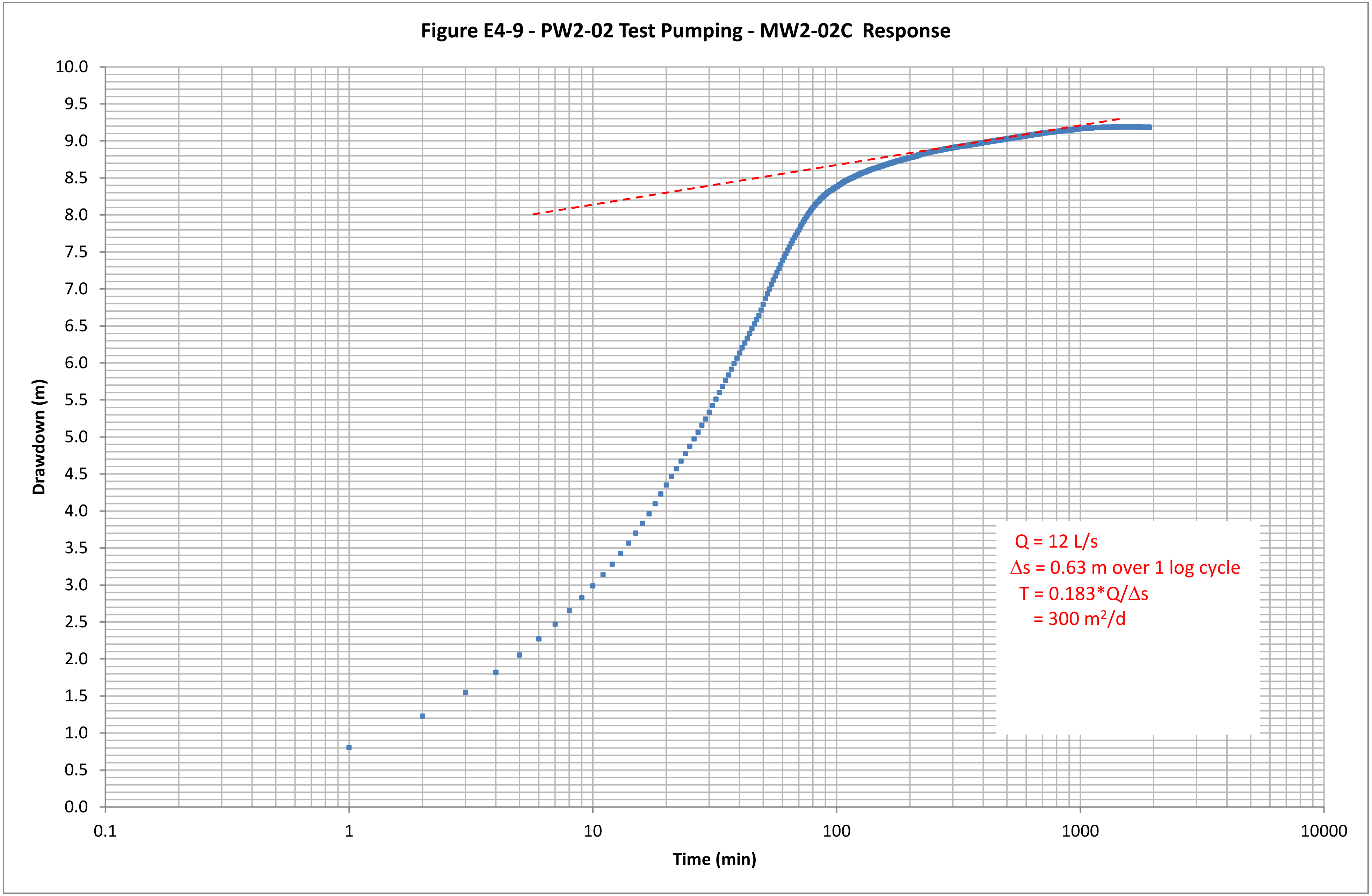


Figure E4-9 - PW2-02 Test Pumping - MW2-02C Response
Drawdown (m)
Time (min)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
1
10
100
1000
10000
Q = 12 L/s
Δs = 0.63 m over 1 log cycle
T = 0.183*Q/Δs
= 300 m²/d

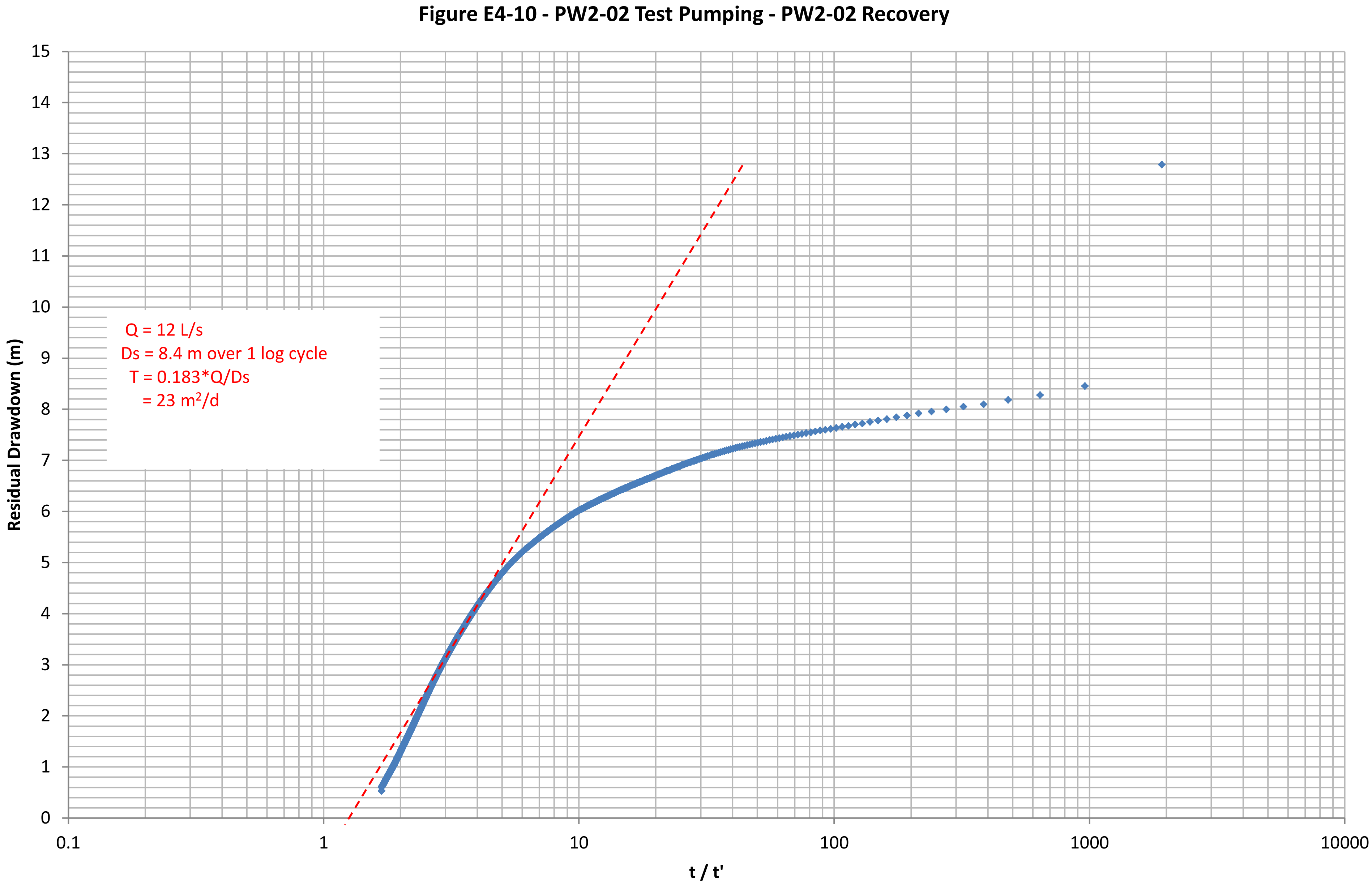


Figure E4-10 - PW2-02 Test Pumping - PW2-02 Recovery
Q = 12 L/s
Ds = 8.4 m over 1 log cycle
T = 0.183*Q/Ds
= 23 m²/d
Residual Drawdown (m)
t / t'
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0.1
1
10
100
1000
10000

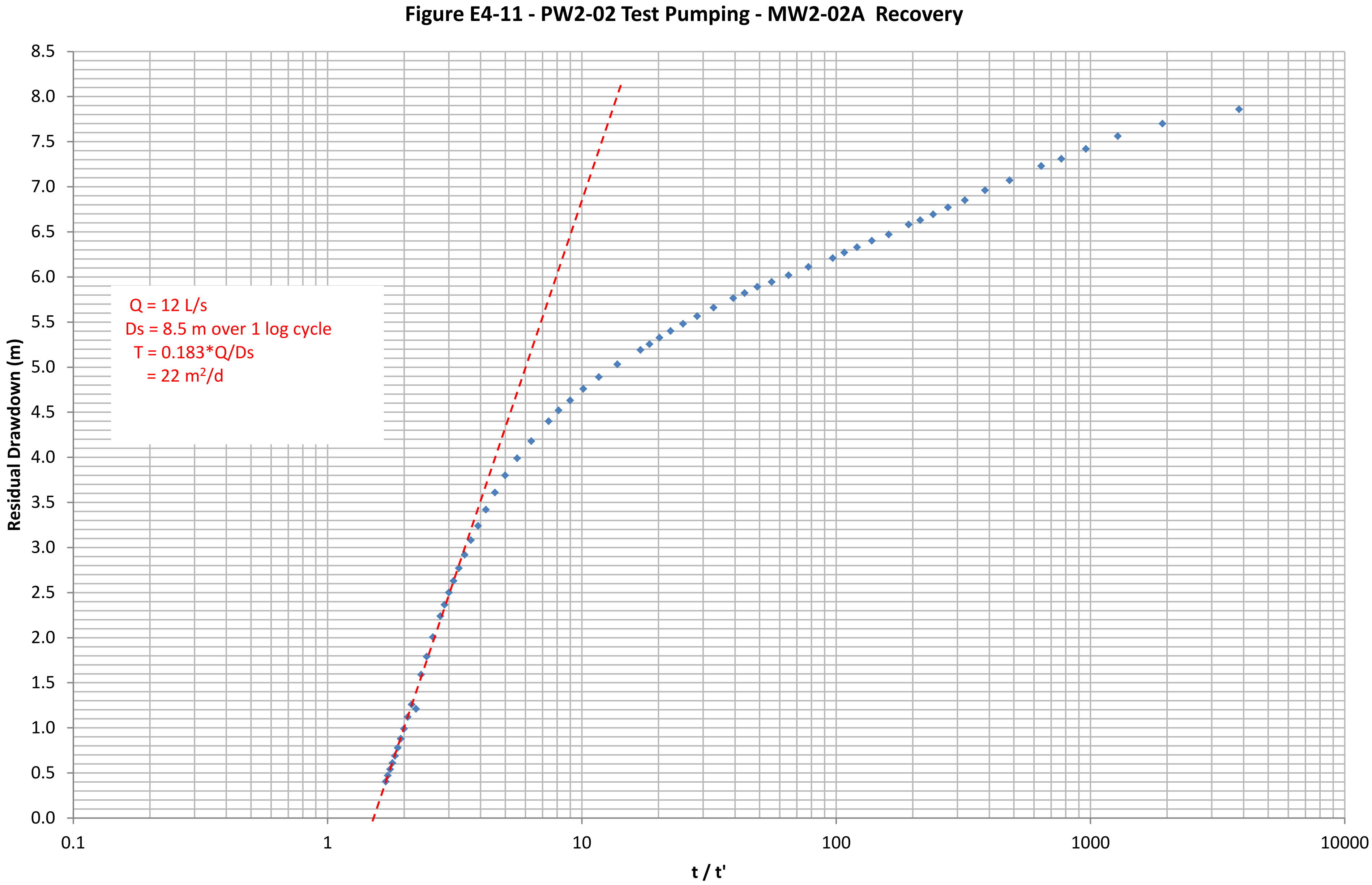


Figure E4-11 - PW2-02 Test Pumping - MW2-02A Recovery
Q = 12 L/s
Ds = 8.5 m over 1 log cycle
T = 0.183*Q/Ds
= 22 m²/d
Residual Drawdown (m)
t / t'
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
1
10
100
1000
10000

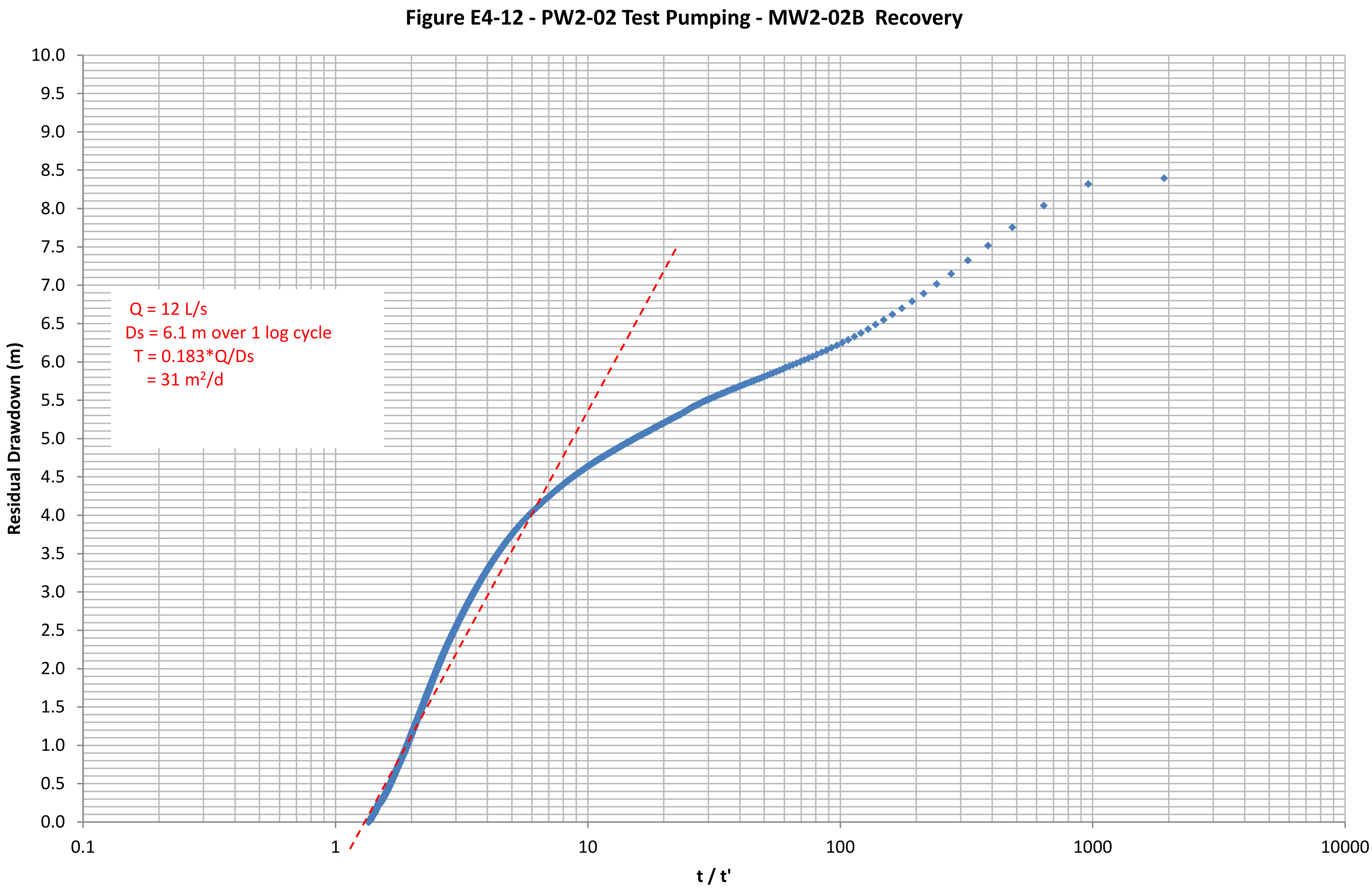


Figure E4-12 - PW2-02 Test Pumping - MW2-02B Recovery
Q = 12 L/s
Ds = 6.1 m over 1 log cycle
T = 0.183*Q/Ds
= 31 m²/d
Residual Drawdown (m)
t / t'
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.1
1
10
100
1000
10000

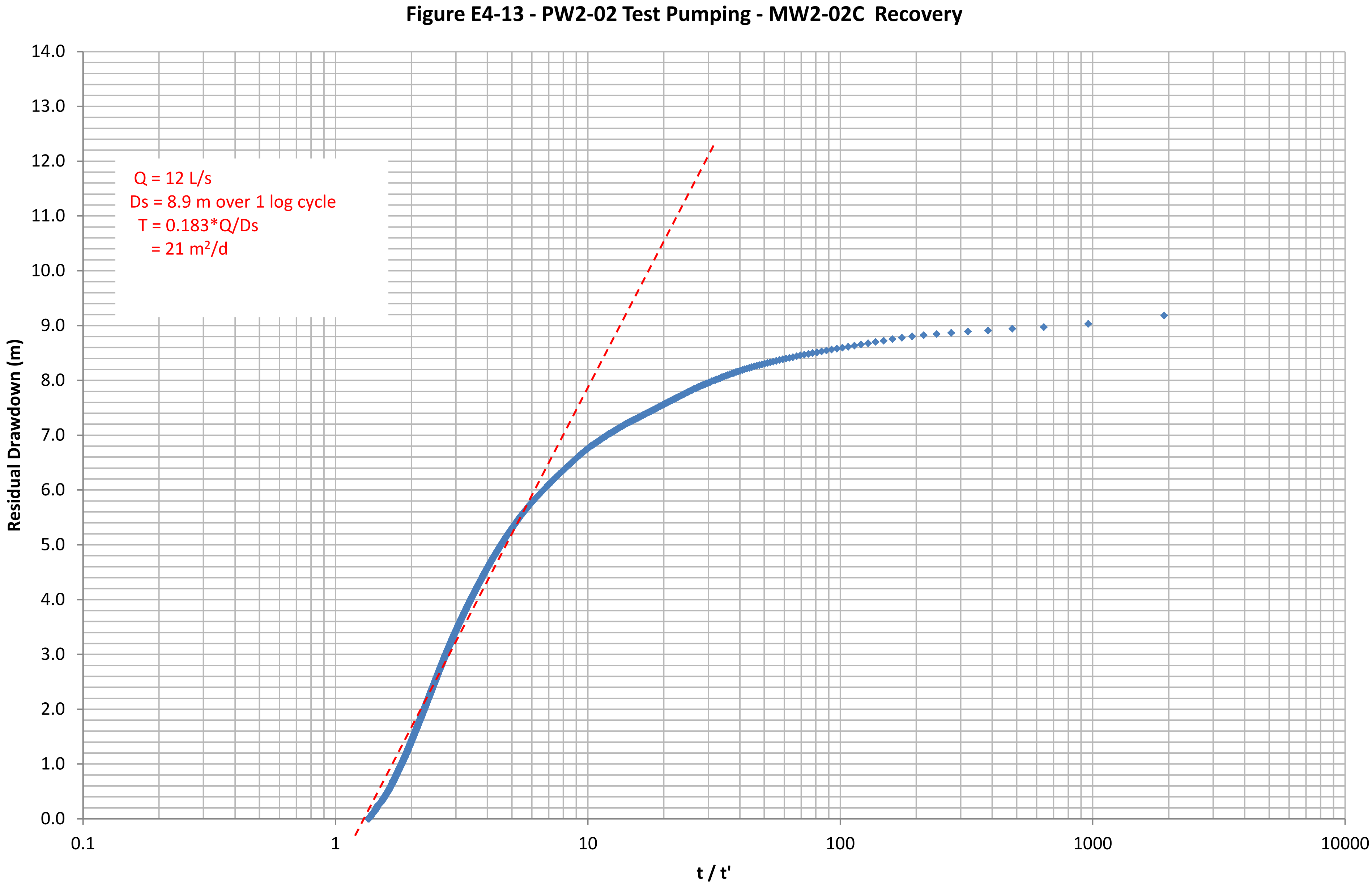


Figure E4-13 - PW2-02 Test Pumping - MW2-02C Recovery
Q = 12 L/s
Ds = 8.9 m over 1 log cycle
T = 0.183*Q/Ds
= 21 m2/d
Residual Drawdown (m)
t / t'
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.1
1
10
100
1000
10000

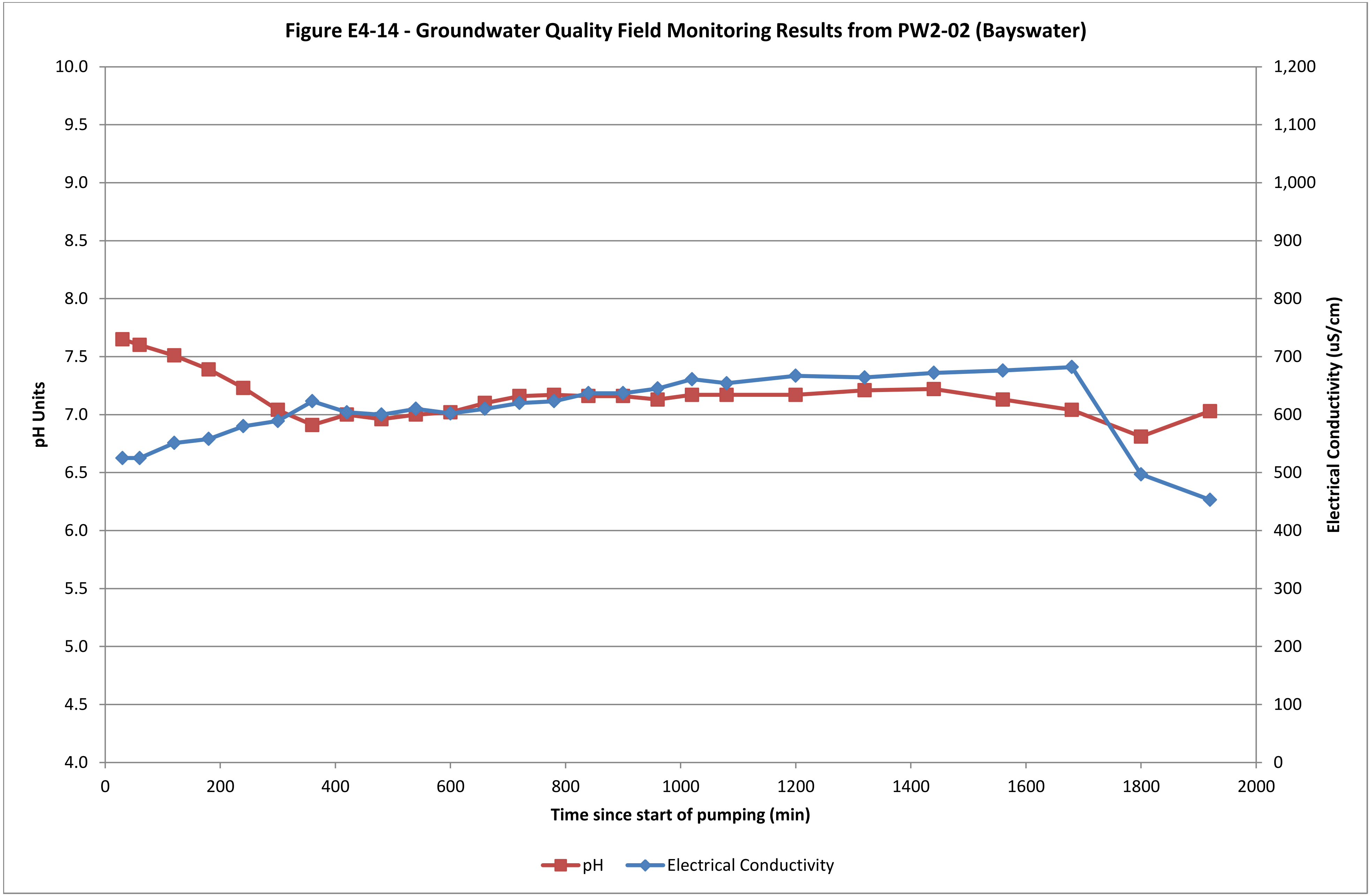


Figure E4-14 - Groundwater Quality Field Monitoring Results from PW2-02 (Bayswater)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
pH Units
1,200
1,100
1,000
900
800
700
600
500
400
300
200
100
0
Electrical Conductivity (uS/cm)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Time since start of pumping (min)
pH
Electrical Conductivity

APPENDIX F

Description of Preliminary Groundwater Model Setup

1.0 INTRODUCTION

This appendix provides details on the construction and assumptions used in the 3D numerical groundwater model. Golder prepared a basic groundwater model in 2014 (Golder, 2014b). This model was used as the platform and updated to include more detailed information on the geology and hydrogeological properties.

The modelling development of the groundwater has been carried out in general accordance with the guiding principles in the Australian Groundwater Modelling Guidelines (NWC, 2012).

The objective of the preliminary groundwater model is to estimate the effect the construction dewatering could have on the groundwater level and piezometric levels and to provide preliminary dewatering rates by modelling conceptual dewatering designs. The model is still considered preliminary (Class 1 according to NWC, 2012) and further detailing of the groundwater model could be required during the dewatering design (Class 2 according to NWC, 2012).

2.0 MODEL ASSUMPTIONS

The following is a list of assumptions used in the design of the preliminary 3D groundwater model:

- Geology beneath the proposed alignment is representative of the geology to the north and south of the alignment and is relatively consistent across the modelled area. Publicly available information, where available, has been utilised to assist with creating the geological surfaces within the model domain outside of the tunnel alignment (e.g. extent and depth of the Mirrabooka Aquifer). However, this data can only be considered approximate.
- Each geological unit is homogenous and isotropic in terms of hydraulic properties with the exception of:
  - The ratio of vertical to horizontal hydraulic conductivity ranges between 1:1 and 1:10 (i.e. $k_v/k_h = 1$ to $k_v/k_h = 0.1$). These ratios were considered appropriate because:
    - The majority of the geological units represented in the model are sedimentary and have been deposited in fluvial environments.
    - Our professional experience on other projects in the Perth Metropolitan area indicates similar ratios.
    - Calibration of pumping test data indicated a best fit using such ratios.
  - Ascot Formation was divided into two areas of different hydraulic conductivity based on the results of the pumping tests which indicate higher hydraulic conductivity in the eastern part of this unit.
  - The Mirrabooka Member was divided into two layers of different hydraulic conductivity to simulate an interpreted decrease in hydraulic conductivity with depth based on bore logs and results from the pumping test.
- Diaphragm walls (D-walls) will be constructed around the perimeter (except for the entrance to the dive structures) of the excavations prior to the start of any excavation and dewatering. The proposed D-walls have been simulated using a low hydraulic conductivity, which allows for simulation of some seepage through the walls.
- Recharge and evapotranspiration are uniform spatially and temporally across the model. Seasonal variation has not been included in the model during transient model runs as this would mask the objective of assessing the changes in groundwater level and piezometric level caused by the construction dewatering. There is no recharge within the D-walls during the dewatering operation as it is assumed that any rainfall over the site will be pumped off site immediately.
- The model does not consider off-site influences, such as groundwater abstraction from other sites, which could affect the groundwater behaviour within the model.

2.1 Model Setup

The model setup and main input parameters are described in the sections below.

2.1.1 Extent and Grid Sizing

The model domain is 10.8 km long and 8.7 km wide (Figure F1). The model extent was selected so that the boundaries would be set at distances outside the influence of groundwater drawdown caused by the dewatering.

The grid sizing within the model ranges from 50 m by 50 m (mainly at the model peripheral boundaries) to 5 m by 5 m around the main structures where dewatering is required. This variation in grid size allows for greater resolution near the proposed structures. The model consists of a total of 438 rows and 493 columns.

2.1.2 Layers

The model has been divided into 13 layers to represent the main geological units. The geological surfaces have been obtained from the geological long section (Golder, 2015b) and geological control points away from the tunnel alignment. The reason for the additional model layers is to allow for the termination of the D-walls within a geological unit and to model variability of hydraulic conductivity with depth. Figure F2 shows a cross-section of the model along Row 111 (refer to Section A – A' on Figure F1 for alignment - given the orientation of the model the software does not allow for a cross-sectional representation along the alignment). Table F1 presents the different geological units per layer.

Table F1: Summary of Groundwater Model Layers.

<table>
<tr><th>Layers</th><th colspan="3">West Zone</th><th colspan="4">East Zone</th></tr>
<tr><td>1</td><td rowspan="2">Bassendean Sand/Perth Formation Sand</td><td rowspan="2">Swan River Formation</td><td rowspan="2"></td><td colspan="3" rowspan="5">Bassendean Sand, Guildford Formation, Gnangara Sand</td><td rowspan="7">Guildford Formation</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td colspan="3" rowspan="3">Perth Formation Clay</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td></tr>
<tr><td>6</td><td colspan="3" rowspan="2">Perth Formation Sand</td><td colspan="3" rowspan="2">Ascot Formation</td></tr>
<tr><td>7</td></tr>
<tr><td>8</td><td colspan="4" rowspan="6">Kardinya Shale (Osborne Formation)</td><td rowspan="2">Mirrabooka Member (Osborne Formation)</td><td colspan="2" rowspan="6">Kardinya Shale (Osborne Formation)</td></tr>
<tr><td>9</td></tr>
<tr><td>10</td><td rowspan="4">Kardinya Shale (Osborne Formation)</td></tr>
<tr><td>11</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
</table>

The elevation of the Layer 1 is based on the current smoothed topography ranging from approximately RL 0 m AHD at the Swan River to RL 50 m AHD at the eastern boundary of the model towards the Darling Scarp. The bottom of Layer 13 is flat with an elevation of RL -100 m AHD, based on the inferred depth of the Kardinya Shale in Davidson (1995).

2.2 Steady-State Model Boundaries

Boundary conditions are assigned in the model to control how water will flow into and out of the model. It is preferable that natural boundaries are used where they exist, otherwise boundaries should be set far enough away that they do not influence what is occurring within the model. Figure F1 shows the assigned boundary locations.

2.2.1 General Head Boundaries

General head boundaries (GHB) were assigned at the north-western and south-eastern boundaries of the model in all layers. The boundaries were set using off-set groundwater level contours estimated from both the Perth Groundwater Atlas (WRC, 1997) and observed groundwater levels.

2.2.2 Constant Head Boundaries

A constant head boundary at an elevation of RL 0.2 m AHD was assigned to the portions of the model representing the Swan River.

2.2.3 Drain Boundaries

A river function was applied to represent the Bayswater Main Drain and the Belmont Main Drain; the locations of these drains are shown in Figure F1. River functions were used in preference to drain functions as the two drains modelled contain a phreatic surface for a significant proportion of the year. In the event that dewatering results in drawdown which extends to these drains, the use of a river function will allow water to flow from the drain into the aquifer (i.e. the drains could start giving water to the aquifer rather than draining it from the aquifer).

2.2.4 No-flow Boundaries

Inactive cells or no-flow boundaries were assigned to large portions of the north-eastern and south-western portions of the model because of the model geometry relative to the alignment. The areas within these inactive cells are unlikely to experience any influence from the proposed dewatering and are roughly perpendicular to groundwater flow direction. Assigning inactive flow to these large areas helps to improve accuracy and increase speed of computation. The bottom of the model was also considered a no flow boundary.

2.2.5 Recharge and Evapotranspiration

A spatially and temporally uniform recharge value of 100 mm/year (approximately 12% of Mean Annual Rainfall) was applied across the whole model. Evapotranspiration was applied to the model with an extinction depth of 1.5 m (i.e. the evapotranspiration function will only be active when the groundwater level comes within 1.5 m of the model surface, which mainly occurs in the Perth Airport area. Given that the whole of Perth Airport contains a large network of closely spaced drains to control the groundwater level at the airport estate (the Perth Airport area used to be a wetland area), the evapotranspiration function was used to simulate the dense network of drains rather than incorporating all the drains in the model using drain functions.

2.3 Transient Model (Non-steady State) Boundaries

The following input parameters are assigned for transient modelling components of the groundwater model.

2.3.1 Diaphragm Walls (D-walls)

D-walls were introduced into the model at varying depths for each dive structure and at the two stations and were based on the Rev F alignment plan and Reference Design Summary Table RevB:

- The D-walls will terminate 3 m into the Osborne Formation at the Airport West Station and Consolidated Airport Terminal Station.
- At the Bayswater and Forrestfield Dive Structures the D-Walls will extend to a depth that is about 1.9 and 2.3 times the depth of excavation, respectively.

The D-walls are introduced around the structures as cells with a low hydraulic conductivity. The hydraulic conductivity of the walls was varied between 0.001 m/d and 0.01 m/d to simulate some leakage through the D-walls.

2.3.2 Dewatering Method

Dewatering will likely be undertaken using a combination of dewatering wells, dewatering spears and sump pumping. The dewatering in the groundwater model was simulated by using drain cells assigned a particular drain elevation equivalent to 1m below the excavation base. For dive structures the drain elevation was inserted along a linear gradient from the surface (no dewatering) to the maximum dewatering elevation at the portal of the dive structure.

2.3.3 Recharge Wells

To simulate water being re-injected back into the aquifer, the water was introduced back into the groundwater model using the well function. The recharge wells were generally screened across the whole Superficial Aquifer to a similar depth as the D-walls. It was assumed in the model that the long-term recharge rate of a recharge well would not exceed 1 L/s.

3.0 MODEL CALIBRATION

3.1 Steady-State Calibration

The steady state model was run to simulate the estimated average seasonal groundwater level contours and groundwater flow direction based on the March 2015 groundwater level survey. The groundwater level results from the steady state calibration were then used as input into the transient (non-steady state) simulation.

The model boundaries and hydraulic conductivities were changed until groundwater and piezometric level contours across the model were approximately equal to the estimated average seasonal groundwater levels along the alignment (main focus was given to the groundwater and piezometric levels at the four main structures) and the observed hydraulic gradients and flow direction from the March 2015 groundwater level survey and Perth Groundwater Atlas (WRC, 1997).

Table F2 presents a comparison between estimated average seasonal groundwater and piezometric levels and modelled groundwater and piezometric levels at the four main structures along the alignment based on the March 2015 groundwater level survey and the 2014/2015 seasonal variation from the closest VWPs. The modelled groundwater levels were consistently 0.6 m to 0.7 m higher than the groundwater levels observed in March 2015, which is considered a reasonable representation of the average seasonal groundwater level, given that the March 2015 groundwater levels represent close to the seasonal low levels and that seasonal fluctuations have been observed to range between 0.7 m and 1.2 m over majority of the alignment and 3.0 m in the Forrestfield area.

Table F2: Comparison of Modelled Groundwater and Piezometric Levels (m AHD).

Structure	March 2015 Measure Groundwater and Piezometric Level	Estimated Average Seasonal Groundwater and Piezometric Level	Modelled Groundwater and Piezometric Level
Bayswater Structures – Upper Aquifer	5.3	5.9	6.0
Bayswater Structures – Lower Aquifer	1.6	2.0	2.0
Airport West Station and Structure	8.1	9.1	8.9
Consolidated Terminal Station	17.1	17.6	17.5
Forrestfield Structures	23.0	24.5	24.4

3.2 Transient Calibration

There is currently insufficient data to carry out a transient calibration on a regional scale. Instead the groundwater model was used to simulate the short-term pumping tests carried out at the four main structures by using the regional groundwater model structure and layers in four sub-models, one for each structure, with a greater discretisation (minimum cell size of 0.5 m) to better simulate the pumping tests. The results from modelling of the pumping tests are discussed in detail in Appendix E, but the main conclusions were:

- The hydrogeological units below Bassendean Sand were found to be semi-confined to confined, likely caused by the lower permeability layers in the Guildford Formation and Perth Formation.
- The vertical to horizontal hydraulic conductivity ratio (k_v/k_h) was found to range between 0.1 and 1 for all hydrogeological layers with the ratio of 0.1 generally providing the best fit with the monitoring data from the pumping tests.

Based on the favourable comparison between estimated average seasonal and modelled groundwater levels, similar hydraulic gradients and good comparison between the observed and modelled pumping test data (in the sub-models), Golder judge that the preliminary groundwater model is an adequate representation of actual groundwater conditions for the purposes of the study reported here. We therefore conclude that the preliminary groundwater model can be used for predictive purposes of dewatering design concepts to assess the effect the construction dewatering could have on the groundwater level and piezometric levels and to provide preliminary dewatering rates for the assumed design and construction methodology.

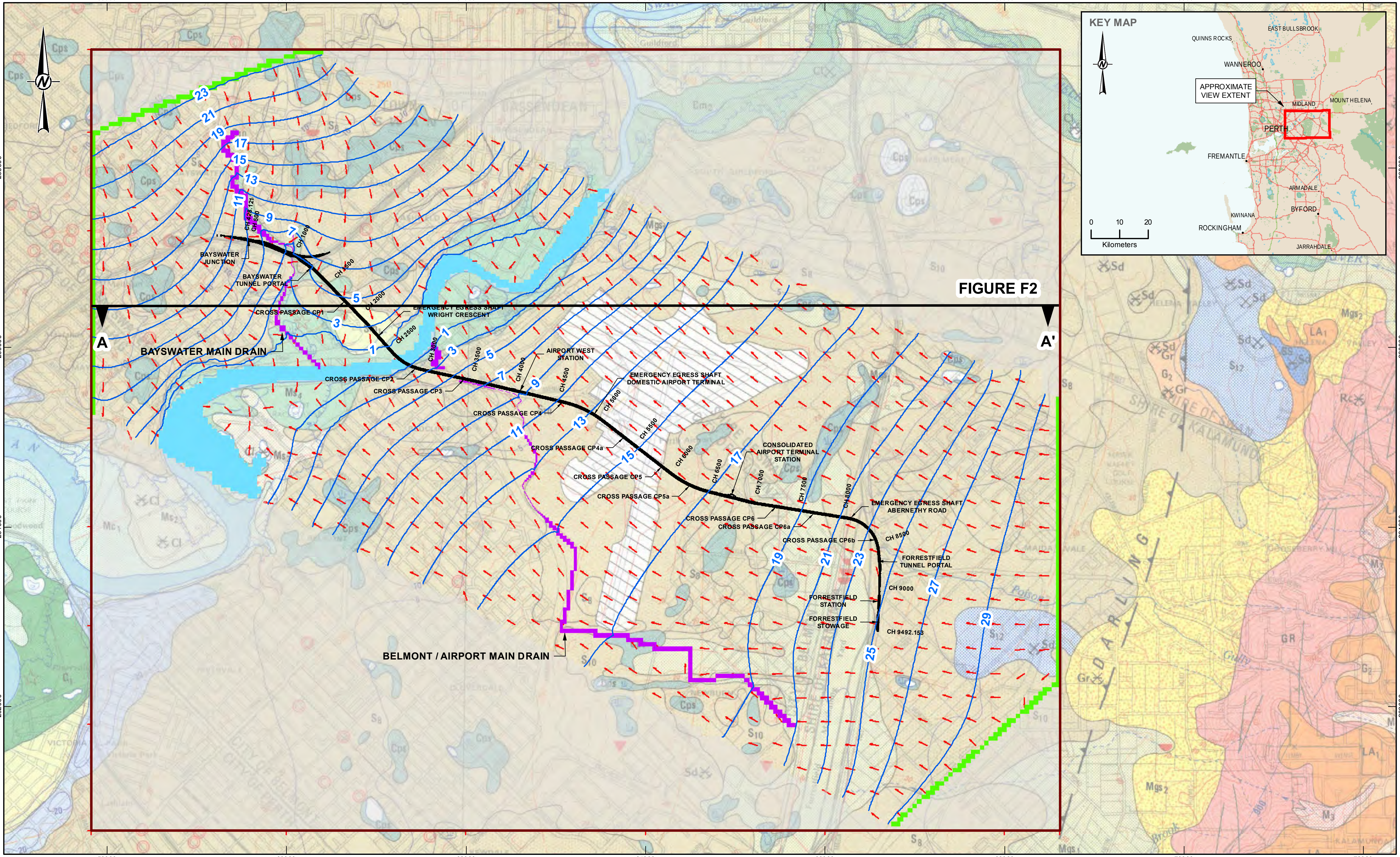
3.3 Hydraulic Parameters Used in the Calibrated Model

Table 1 presents the hydraulic input parameters of the calibrated preliminary groundwater steady-state model which was used for the transient scenario model runs.

Table 1: Summary of Hydraulic Parameters Used in the Groundwater Model

Unit	Horizontal Hydraulic Conductivity (k_h) (m/d)	Vertical Hydraulic Conductivity (k_v) (m/d)	Specific Yield	Specific Storage (1/m)
Swan River Formation	1	0.1	0.05	2×10^{-5}
Combined Bassendean Sand, Guildford Formation and Gnangara Sand	5	0.5	0.1	2×10^{-5}
Perth Formation – sandy unit	7.5	0.75 *	0.1	5×10^{-6}
Perth Formation – clay unit	0.0001	0.00001	0.02	2×10^{-5}
Guildford Formation	5	0.5 *	0.1	1×10^{-4}
Ascot Formation	8 – 14	0.8 – 1.4	0.15	2×10^{-5}
Mirrabooka Member (Osborne Formation)	1 – 3	0.1 – 0.3 *	0.1	2×10^{-5}
Kardinya Shale (Osborne Formation)	0.0005	0.00005	0.02	2×10^{-5}

* Sensitivity runs were carried out for the parameters by increasing the vertical hydraulic conductivity values 10 times (giving a K_v/K_h ratio of 1).



LEGEND

- PROPOSED RAIL ALIGNMENT
- GROUNDWATER ELEVATION CONOUR (M AHD)
- GROUNDWATER FLOW DIRECTION
- MODEL EXTENT
- INACTIVE MODEL CELLS (NO FLOW)

MODEL BOUNDARIES

- CONSTANT HEAD (SWAN RIVER)
- GENERAL HEAD (FLOW)
- RIVER FUNCTION (REPRESENTING MAIN DRAINS)

NOTES

1. COORDINATE SYSTEM: PERTH COASTAL GRID (PCG94)

REFERENCE

PLAN AND PROFILE LAYOUT PROVIDED BY CLIENT
PTA DRG NO. 16-C-24-0044 REV F, DATED: 09.04.2015
AERIAL IMAGERY 2015.03.07 © NEARMAP (2015)
ROADS © WESTERN AUSTRALIAN LAND INFORMATION AUTHORITY TRADING AS LANDGATE (2015)
GEOLOGY MAP, PERTH SHEET 2034 II AND PART OF 2034 III AND 2134 III © WESTERN AUSTRALIA 1986
INSET BASE DATA/ROADS SOURCED FROM STREET PRO DATA 2009

0 500 1,000 1,500 2,000 2,500 m

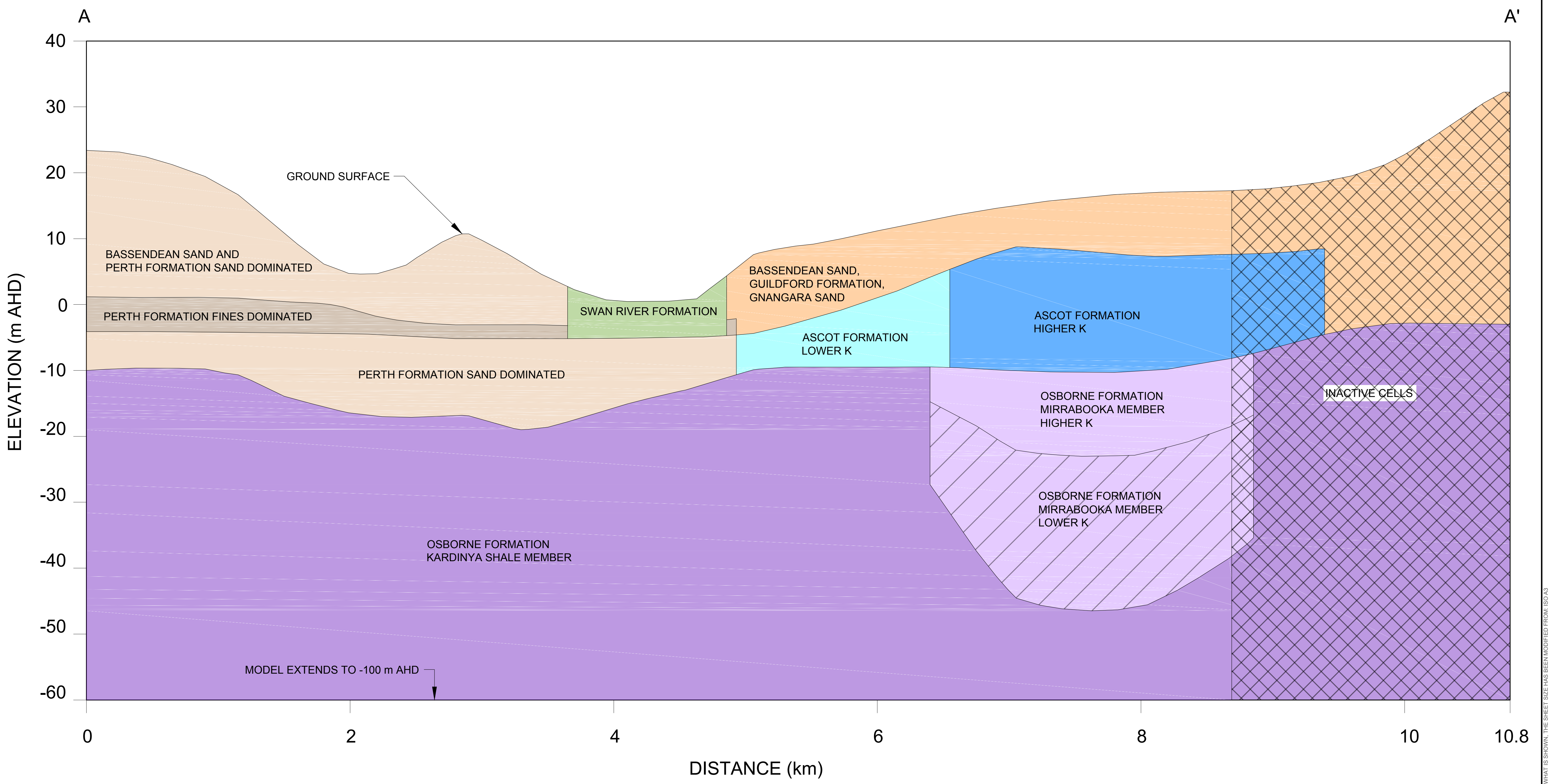
1:40,000

CLIENT	PUBLIC TRANSPORT AUTHORITY
CONSULTANT	Golder Associates
YYYY-MM-DD	2015.05.20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

PROJECT
FORRESTFIELD-AIRPORT LINK
STAGE 2 GEOTECHNICAL INVESTIGATION

TITLE
GROUNDWATER STEADY STATE MODEL (LAYER 1)

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	F1



SCALE AS SHOWN

CLIENT
PUBLIC TRANSPORT AUTHORITY

PROJECT
FORRESTFIELD-AIRPORT LINK STAGE 2
GEOTECHNICAL INVESTIGATION

CONSULTANT
Golder Associates

YYYY-MM-DD	2015-05-20
PREPARED	SWG
DESIGN	
REVIEW	AL
APPROVED	DPS

TITLE
MODEL CROSS SECTION:ROW 111

PROJECT No.	CONTROL	Rev.	FIGURE
147642129	077 R	0	F2

Path: \\GOLDER.GDS\GAP\PERTH\JOBS\Geo\2014\147642129 - PTA FAL Stage 2 Geotechnical Investigation\05 CADD\FIGURES\ | File Name: 147642129-077-R-0F2_Cross Section Row 111.dwg

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

25 mm

APPENDIX G

Summary of Analysis of Inverse Auger Hole Testing

Shallow infiltration testing using the “inverse auger hole method” (Cocks, 2007) was carried out at six locations I1-01, I1-02, I1-03 (Forrestfield Area) and I1-04, I1-05 and I1-06 (Consolidated Airport Terminal Station). Attachment G1 shows the infiltration locations. All tests were carried out in Bassendean Sand except for I1-05 which was carried out in Fill.

The inverse auger hole method uses a machine slotted PVC casing sealed into an open auger hole followed by numerous falling head tests carried out by introducing water into the PVC casing. The decline in head inside the PVC casing is recorded at regular intervals and used to calculate the permeability as described by Cocks (2007).

The permeability values calculated from each test are summarised in Table 1 and the analysis sheets are presented in Attachment G2.

Table 1: Infiltration Tests Results

Test ID	Location	Soil Description*	Average Calculated Permeability (m/d)
I1–01	Forrestfield	Sand (*f-m*), some clay	12
I1–02		Sand (*f-m*), trace silt and clayey gravelly sand (*f-c*)	3
I1–03		Sand (*f-m*) and sandy gravel (*f-m*)	10
I1–04	Consolidated Airport	Sand (*f-m*)	10
I1–05		Fill/Topsoils: Sand (*f-m*)	5
I1–06		Sand (*f-m*)	4

*Material description based on upper 1 metre of soil profile encountered in closest test pit or borehole, *f*,- fine grained, *m* – medium grained, *c* – coarse grained,

ATTACHMENT G1
Infiltration Test Locations

Infiltration Test Locations at Consolidated Airport Terminal Station

Infiltration Test Locations in Forrestfield

ATTACHMENT G2
Inverse Auger Hole Permeability Testing Analysis

Permeability Calculation - Inverse Auger Hole Method

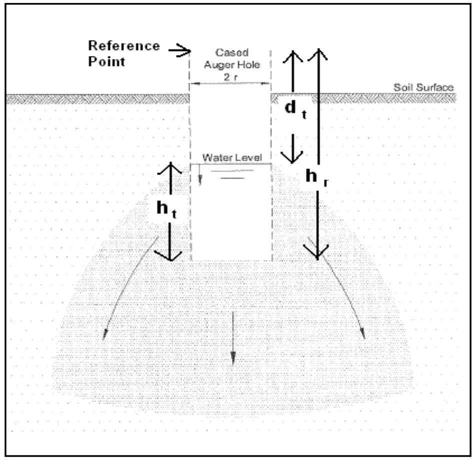
Golder Associates

Spreadsheet author: 4-Jun-08

Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-01

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

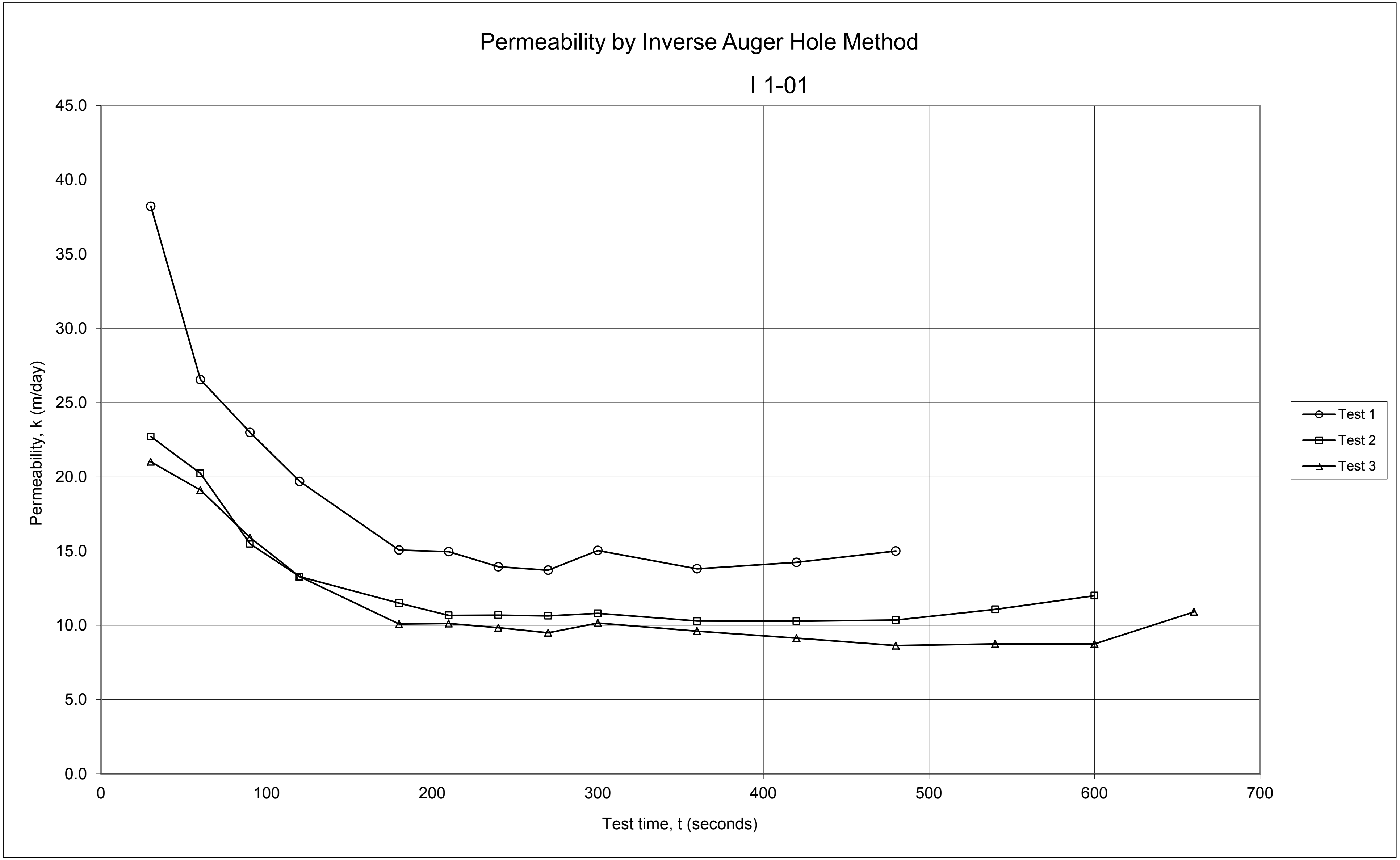
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.48	0.54	4.4E-04	38.2
60	0.6	0.42	3.1E-04	26.5
90	0.7	0.32	2.7E-04	23.0
120	0.75	0.27	2.3E-04	19.7
180	0.8	0.22	1.7E-04	15.1
210	0.85	0.17	1.7E-04	15.0
240	0.87	0.15	1.6E-04	13.9
270	0.9	0.12	1.6E-04	13.7
300	0.95	0.07	1.7E-04	15.0
360	0.97	0.05	1.6E-04	13.8
420	1	0.02	1.6E-04	14.2
480	1.02	0	1.7E-04	15.0
		AVERAGE	2.2E-04	18.6

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.32	0.7	2.6E-04	22.7
60	0.5	0.52	2.3E-04	20.2
90	0.55	0.47	1.8E-04	15.5
120	0.6	0.42	1.5E-04	13.3
180	0.7	0.32	1.3E-04	11.5
210	0.73	0.29	1.2E-04	10.7
240	0.78	0.24	1.2E-04	10.7
270	0.82	0.2	1.2E-04	10.6
300	0.86	0.16	1.3E-04	10.8
360	0.9	0.12	1.2E-04	10.3
420	0.94	0.08	1.2E-04	10.3
480	0.97	0.05	1.2E-04	10.4
540	1	0.02	1.3E-04	11.1
600	1.02	0	1.4E-04	12.0
		AVERAGE	1.5E-04	12.9

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.3	0.72	2.4E-04	21.0
60	0.48	0.54	2.2E-04	19.1
90	0.56	0.46	1.8E-04	15.9
120	0.6	0.42	1.5E-04	13.3
180	0.65	0.37	1.2E-04	10.1
210	0.71	0.31	1.2E-04	10.1
240	0.75	0.27	1.1E-04	9.8
270	0.78	0.24	1.1E-04	9.5
300	0.84	0.18	1.2E-04	10.2
360	0.88	0.14	1.1E-04	9.6
420	0.91	0.11	1.1E-04	9.1
480	0.93	0.09	1.0E-04	8.6
540	0.96	0.06	1.0E-04	8.8
600	0.98	0.04	1.0E-04	8.7
660	1.02	0	1.3E-04	10.9
		AVERAGE	1.3E-04	11.7


Permeability by Inverse Auger Hole Method
I 1-01
Permeability, k (m/day)
Test time, t (seconds)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
0
100
200
300
400
500
600
700
Test 1
Test 2
Test 3

Permeability Calculation - Inverse Auger Hole Method

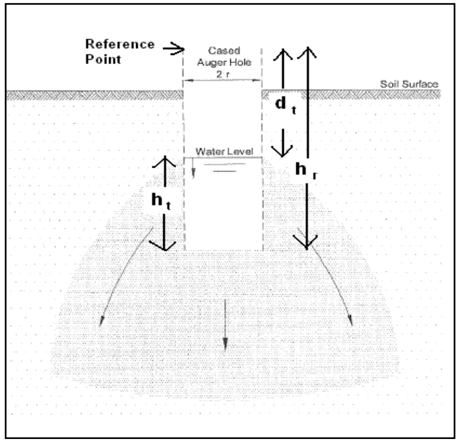
Golder Associates

Spreadsheet author: 4-Jun-08

Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-02

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



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(yellow)	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

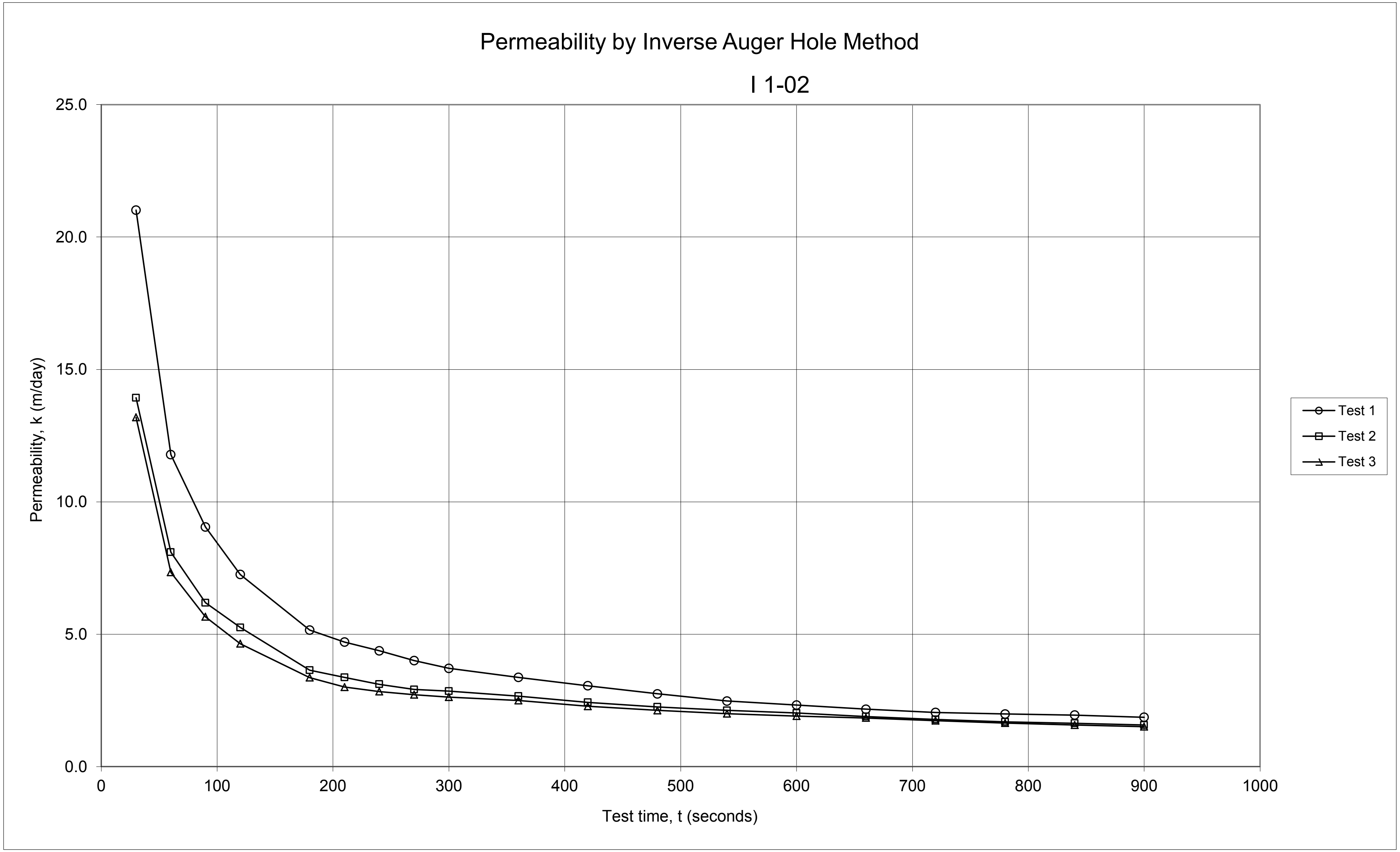
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.3	0.72	2.4E-04	21.0
60	0.33	0.69	1.4E-04	11.8
90	0.37	0.65	1.0E-04	9.0
120	0.39	0.63	8.4E-05	7.3
180	0.41	0.61	6.0E-05	5.2
210	0.43	0.59	5.4E-05	4.7
240	0.45	0.57	5.1E-05	4.4
270	0.46	0.56	4.6E-05	4.0
300	0.47	0.55	4.3E-05	3.7
360	0.5	0.52	3.9E-05	3.4
420	0.52	0.5	3.5E-05	3.1
480	0.53	0.49	3.2E-05	2.7
540	0.535	0.485	2.9E-05	2.5
600	0.55	0.47	2.7E-05	2.3
660	0.56	0.46	2.5E-05	2.2
720	0.57	0.45	2.4E-05	2.0
780	0.59	0.43	2.3E-05	2.0
840	0.61	0.41	2.3E-05	1.9
900	0.62	0.4	2.2E-05	1.9
		AVERAGE	5.8E-05	5.0

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.21	0.81	1.6E-04	13.9
60	0.24	0.78	9.4E-05	8.1
90	0.27	0.75	7.2E-05	6.2
120	0.3	0.72	6.1E-05	5.3
180	0.31	0.71	4.2E-05	3.6
210	0.33	0.69	3.9E-05	3.4
240	0.345	0.675	3.6E-05	3.1
270	0.36	0.66	3.4E-05	2.9
300	0.385	0.635	3.3E-05	2.9
360	0.42	0.6	3.1E-05	2.7
420	0.44	0.58	2.8E-05	2.4
480	0.46	0.56	2.6E-05	2.3
540	0.48	0.54	2.5E-05	2.1
600	0.5	0.52	2.3E-05	2.0
660	0.51	0.51	2.2E-05	1.9
720	0.52	0.5	2.1E-05	1.8
780	0.53	0.49	2.0E-05	1.7
840	0.545	0.475	1.9E-05	1.6
900	0.555	0.465	1.8E-05	1.6
		AVERAGE	4.2E-05	3.7

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.2	0.82	1.5E-04	13.2
60	0.22	0.8	8.5E-05	7.3
90	0.25	0.77	6.5E-05	5.7
120	0.27	0.75	5.4E-05	4.6
180	0.29	0.73	3.9E-05	3.4
210	0.3	0.72	3.5E-05	3.0
240	0.32	0.7	3.3E-05	2.8
270	0.34	0.68	3.1E-05	2.7
300	0.36	0.66	3.0E-05	2.6
360	0.4	0.62	2.9E-05	2.5
420	0.42	0.6	2.6E-05	2.3
480	0.44	0.58	2.5E-05	2.1
540	0.46	0.56	2.3E-05	2.0
600	0.48	0.54	2.2E-05	1.9
660	0.5	0.52	2.1E-05	1.8
720	0.51	0.51	2.0E-05	1.7
780	0.52	0.5	1.9E-05	1.6
840	0.53	0.49	1.8E-05	1.6
900	0.54	0.48	1.7E-05	1.5
1200	0.6	0.42	1.5E-05	1.3
1500	0.65	0.37	1.4E-05	1.2
1800	0.7	0.32	1.3E-05	1.1
		AVERAGE	3.6E-05	3.1



\\Golder.gds\gap\Perth\Jobs\Geo\2014\147642129 - PTA FAL Stage 2 Geotechnical Investigation\08 Analysis\Permeability\Permeability Inverse Auger Hole Method.xls

Permeability Calculation - Inverse Auger Hole Method

Golder Associates

Spreadsheet author: 4-Jun-08

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114

Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-03

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

Spreadsheet Legend

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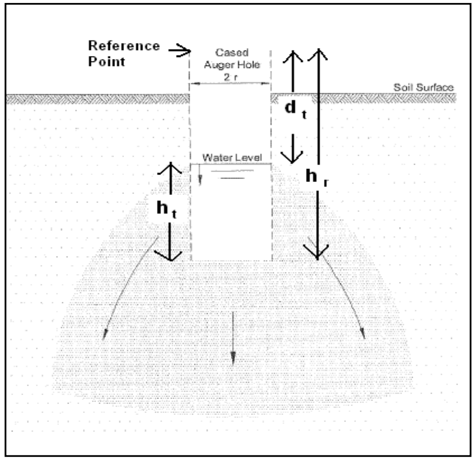
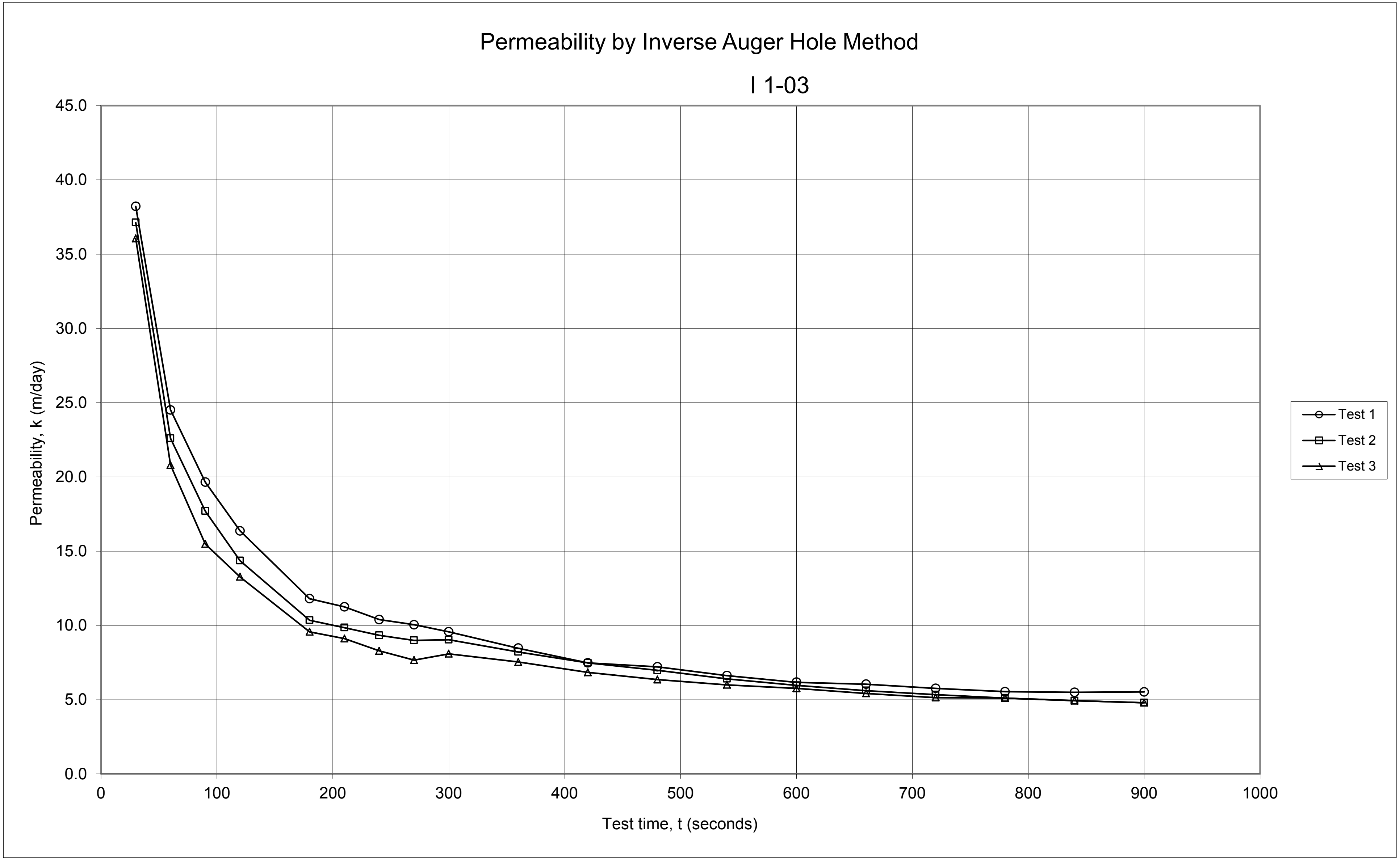
(green)	Calculated field
(orange)	Comment field
(crossed)	Field not used
(yellow)	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m



Test 1 / **Test 2** / **Test 3**

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)	t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)	t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02			0	0	1.02			0	0	1.02		
30	0.48	0.54	4.4E-04	38.2	30	0.47	0.55	4.3E-04	37.1	30	0.46	0.56	4.2E-04	36.0
60	0.57	0.45	2.8E-04	24.5	60	0.54	0.48	2.6E-04	22.6	60	0.51	0.51	2.4E-04	20.8
90	0.64	0.38	2.3E-04	19.7	90	0.6	0.42	2.0E-04	17.7	90	0.55	0.47	1.8E-04	15.5
120	0.68	0.34	1.9E-04	16.4	120	0.63	0.39	1.7E-04	14.4	120	0.6	0.42	1.5E-04	13.3
180	0.71	0.31	1.4E-04	11.8	180	0.66	0.36	1.2E-04	10.4	180	0.63	0.39	1.1E-04	9.6
210	0.75	0.27	1.3E-04	11.3	210	0.7	0.32	1.1E-04	9.9	210	0.67	0.35	1.1E-04	9.1
240	0.77	0.25	1.2E-04	10.4	240	0.73	0.29	1.1E-04	9.3	240	0.685	0.335	9.6E-05	8.3
270	0.8	0.22	1.2E-04	10.0	270	0.76	0.26	1.0E-04	9.0	270	0.7	0.32	8.9E-05	7.7
300	0.82	0.2	1.1E-04	9.6	300	0.8	0.22	1.0E-04	9.0	300	0.76	0.26	9.4E-05	8.1
360	0.84	0.18	9.8E-05	8.5	360	0.83	0.19	9.5E-05	8.2	360	0.8	0.22	8.7E-05	7.5
420	0.85	0.17	8.7E-05	7.5	420	0.85	0.17	8.7E-05	7.5	420	0.82	0.2	7.9E-05	6.8
480	0.88	0.14	8.3E-05	7.2	480	0.87	0.15	8.1E-05	7.0	480	0.84	0.18	7.3E-05	6.3
540	0.89	0.13	7.7E-05	6.6	540	0.88	0.14	7.4E-05	6.4	540	0.86	0.16	6.9E-05	6.0
600	0.9	0.12	7.1E-05	6.2	600	0.89	0.13	6.9E-05	6.0	600	0.88	0.14	6.7E-05	5.8
660	0.92	0.1	7.0E-05	6.0	660	0.9	0.12	6.5E-05	5.6	660	0.89	0.13	6.3E-05	5.4
720	0.93	0.09	6.7E-05	5.8	720	0.91	0.11	6.2E-05	5.3	720	0.9	0.12	6.0E-05	5.1
780	0.94	0.08	6.4E-05	5.5	780	0.92	0.1	5.9E-05	5.1	780	0.92	0.1	5.9E-05	5.1
840	0.955	0.065	6.4E-05	5.5	840	0.93	0.09	5.7E-05	4.9	840	0.93	0.09	5.7E-05	4.9
900	0.97	0.05	6.4E-05	5.5	900	0.94	0.08	5.6E-05	4.8	900	0.94	0.08	5.6E-05	4.8
		AVERAGE	1.3E-04	11.4			AVERAGE	1.2E-04	10.5			AVERAGE	1.1E-04	9.8



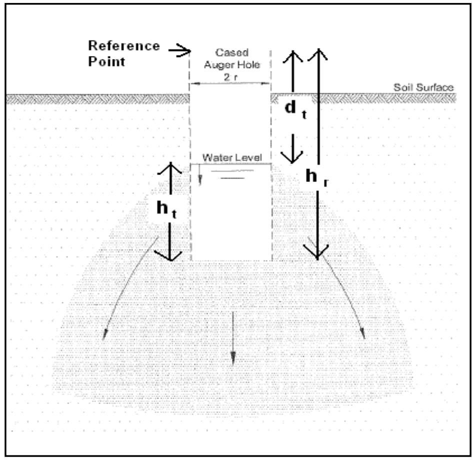
\\Golder.gds\gap\Perth\Jobs\Geo\2014\147642129 - PTA FAL Stage 2 Geotechnical Investigation\08 Analysis\Permeability\Permeability Inverse Auger Hole Method.xls

Permeability Calculation - Inverse Auger Hole Method

Golder Associates

Spreadsheet author: 4-Jun-08

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-04

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

Spreadsheet Legend

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	Calculated field
	Comment field
	Field not used
	Fixed field

Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

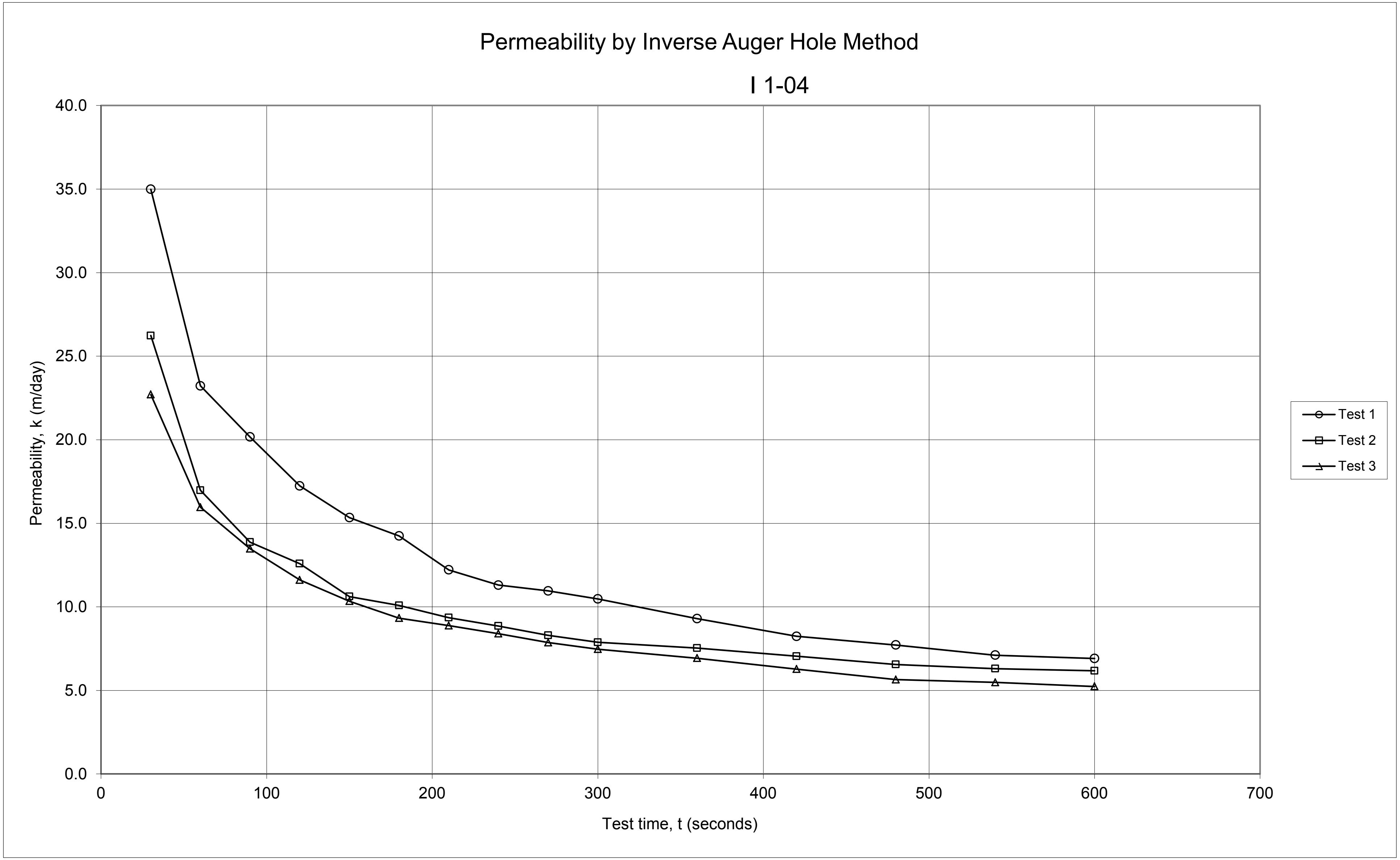
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.45	0.57	4.1E-04	35.0
60	0.55	0.47	2.7E-04	23.2
90	0.65	0.37	2.3E-04	20.2
120	0.7	0.32	2.0E-04	17.2
150	0.74	0.28	1.8E-04	15.3
180	0.78	0.24	1.6E-04	14.2
210	0.8	0.24	1.4E-04	12.2
240	0.83	0.22	1.3E-04	11.3
270	0.85	0.19	1.3E-04	11.0
300	0.87	0.17	1.2E-04	10.5
360	0.88	0.15	1.1E-04	9.3
420	0.9	0.14	9.5E-05	8.2
480	0.91	0.12	8.9E-05	7.7
540	0.93	0.11	8.2E-05	7.1
600	0.95	0.09	8.0E-05	6.9
		AVERAGE	1.6E-04	14.0

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.36	0.66	3.0E-04	26.2
60	0.44	0.58	2.0E-04	17.0
90	0.51	0.51	1.6E-04	13.9
120	0.58	0.44	1.5E-04	12.6
150	0.6	0.42	1.2E-04	10.6
180	0.65	0.37	1.2E-04	10.1
210	0.68	0.34	1.1E-04	9.3
240	0.71	0.31	1.0E-04	8.9
270	0.73	0.29	9.6E-05	8.3
300	0.75	0.27	9.1E-05	7.9
360	0.8	0.22	8.7E-05	7.5
420	0.83	0.19	8.2E-05	7.0
480	0.85	0.17	7.6E-05	6.5
540	0.875	0.145	7.3E-05	6.3
600	0.9	0.12	7.1E-05	6.2
		AVERAGE	1.2E-04	10.6

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.32	0.7	2.6E-04	22.7
60	0.42	0.6	1.8E-04	16.0
90	0.5	0.52	1.6E-04	13.5
120	0.55	0.47	1.3E-04	11.6
150	0.59	0.43	1.2E-04	10.3
180	0.62	0.4	1.1E-04	9.3
210	0.66	0.36	1.0E-04	8.9
240	0.69	0.33	9.7E-05	8.4
270	0.71	0.31	9.1E-05	7.9
300	0.73	0.29	8.6E-05	7.5
360	0.77	0.25	8.0E-05	6.9
420	0.79	0.23	7.3E-05	6.3
480	0.8	0.22	6.5E-05	5.6
540	0.83	0.19	6.3E-05	5.5
600	0.85	0.17	6.1E-05	5.2
		AVERAGE	1.1E-04	9.7



Permeability by Inverse Auger Hole Method
I 1-04
Permeability, k (m/day)
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0
100
200
300
400
500
600
700
Test time, t (seconds)
Test 1
Test 2
Test 3

Permeability Calculation - Inverse Auger Hole Method

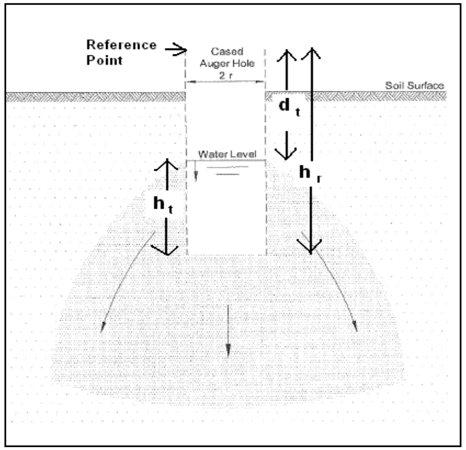
Golder Associates

Spreadsheet author:	4-Jun-08

Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-05

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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	Comment field
	Field not used
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Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

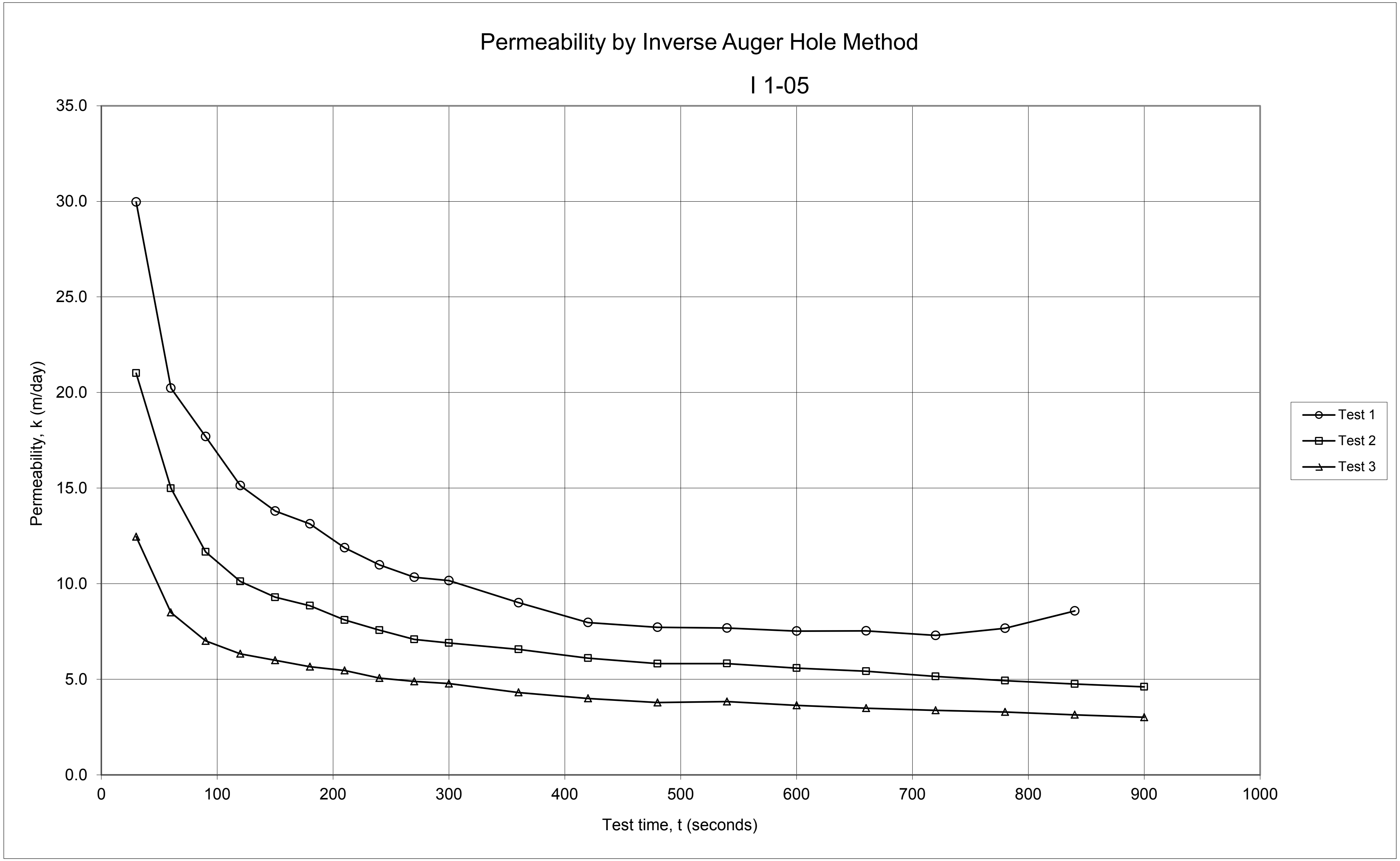
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.4	0.62	3.5E-04	30.0
60	0.5	0.52	2.3E-04	20.2
90	0.6	0.42	2.0E-04	17.7
120	0.65	0.37	1.8E-04	15.1
150	0.7	0.32	1.6E-04	13.8
180	0.75	0.27	1.5E-04	13.1
210	0.77	0.25	1.4E-04	11.9
240	0.79	0.23	1.3E-04	11.0
270	0.81	0.21	1.2E-04	10.3
300	0.84	0.18	1.2E-04	10.2
360	0.86	0.16	1.0E-04	9.0
420	0.87	0.15	9.2E-05	8.0
480	0.9	0.12	8.9E-05	7.7
540	0.93	0.09	8.9E-05	7.7
600	0.95	0.07	8.7E-05	7.5
660	0.97	0.05	8.7E-05	7.5
720	0.98	0.04	8.4E-05	7.3
780	1	0.02	8.9E-05	7.7
840	1.02	0	9.9E-05	8.6
		AVERAGE	1.4E-04	11.8

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.3	0.72	2.4E-04	21.0
60	0.4	0.62	1.7E-04	15.0
90	0.45	0.57	1.4E-04	11.7
120	0.5	0.52	1.2E-04	10.1
150	0.55	0.47	1.1E-04	9.3
180	0.6	0.42	1.0E-04	8.8
210	0.625	0.395	9.4E-05	8.1
240	0.65	0.37	8.8E-05	7.6
270	0.67	0.35	8.2E-05	7.1
300	0.7	0.32	8.0E-05	6.9
360	0.75	0.27	7.6E-05	6.6
420	0.78	0.24	7.1E-05	6.1
480	0.81	0.21	6.7E-05	5.8
540	0.85	0.17	6.7E-05	5.8
600	0.87	0.15	6.5E-05	5.6
660	0.89	0.13	6.3E-05	5.4
720	0.9	0.12	6.0E-05	5.1
780	0.91	0.11	5.7E-05	4.9
840	0.92	0.1	5.5E-05	4.7
900	0.93	0.09	5.3E-05	4.6
		AVERAGE	9.3E-05	8.0

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.19	0.83	1.4E-04	12.5
60	0.25	0.77	9.8E-05	8.5
90	0.3	0.72	8.1E-05	7.0
120	0.35	0.67	7.3E-05	6.3
150	0.4	0.62	6.9E-05	6.0
180	0.44	0.58	6.6E-05	5.7
210	0.48	0.54	6.3E-05	5.5
240	0.5	0.52	5.9E-05	5.1
270	0.53	0.49	5.7E-05	4.9
300	0.56	0.46	5.5E-05	4.8
360	0.59	0.43	5.0E-05	4.3
420	0.62	0.4	4.6E-05	4.0
480	0.65	0.37	4.4E-05	3.8
540	0.7	0.32	4.4E-05	3.8
600	0.72	0.3	4.2E-05	3.6
660	0.74	0.28	4.0E-05	3.5
720	0.76	0.26	3.9E-05	3.4
780	0.78	0.24	3.8E-05	3.3
840	0.79	0.23	3.6E-05	3.1
900	0.8	0.22	3.5E-05	3.0
		AVERAGE	5.9E-05	5.1



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Permeability Calculation - Inverse Auger Hole Method

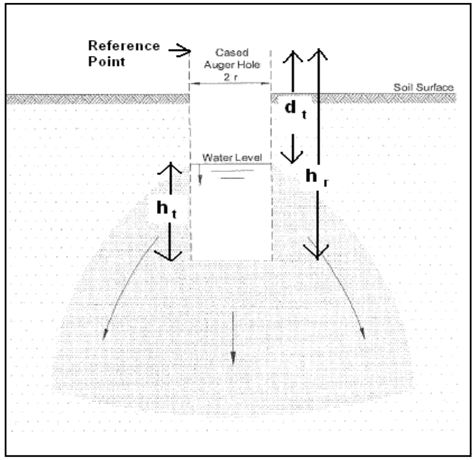
Golder Associates

Spreadsheet author: 4-Jun-08

Job No:	147642129
Client:	PTA
Site:	STAGE 2 FAL PROJECT
Location:	Forrestfield to Perth Airport
Calc by:	PSM 17-Mar-15
BH Name:	I 1-06

$$K = 1.15r \frac{\log_{10}(h_0 + \frac{1}{2}r) - \log_{10}}{t - t_0}$$

REFERENCE: Cocks, G. *Disposal of Stormwater Runoff by Soakage in Perth Western Australia*, Journal and News of the Australian Geomechanics Society, Volume 42 No 3 September 2007, pp101-114



Spreadsheet Legend

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	Calculated field
	Comment field
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Parameter	Description	Value	Units
K	Permeability		m/s
r	radius of test hole	0.043	m
t	time since start of measurement		s
h_r	reference point height above base	1.02	m
d_t	depth from reference point to water at time t		m
h_t	Water column height at time t		m
h_0	h_t at t=0		m

Test 1

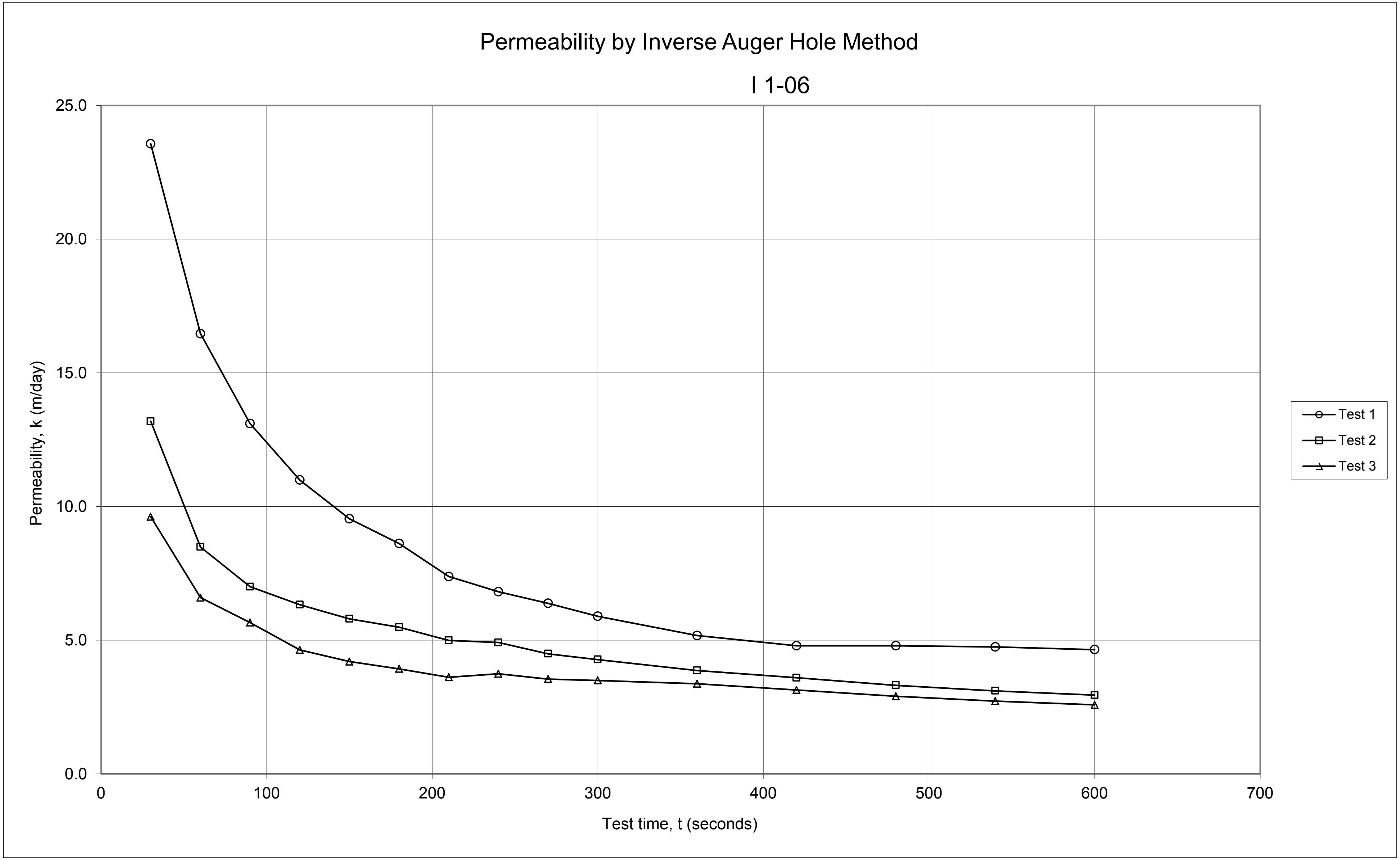
t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.33	0.69	2.7E-04	23.6
60	0.43	0.59	1.9E-04	16.5
90	0.49	0.53	1.5E-04	13.1
120	0.53	0.49	1.3E-04	11.0
150	0.56	0.46	1.1E-04	9.5
180	0.59	0.43	1.0E-04	8.6
210	0.61	0.43	8.5E-05	7.4
240	0.63	0.41	7.9E-05	6.8
270	0.64	0.39	7.4E-05	6.4
300	0.66	0.38	6.8E-05	5.9
360	0.69	0.36	6.0E-05	5.2
420	0.74	0.33	5.6E-05	4.8
480	0.78	0.28	5.5E-05	4.8
540	0.81	0.24	5.5E-05	4.7
600	0.85	0.21	5.4E-05	4.7
		AVERAGE	1.0E-04	8.9

Test 2

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.2	0.82	1.5E-04	13.2
60	0.25	0.77	9.8E-05	8.5
90	0.3	0.72	8.1E-05	7.0
120	0.35	0.67	7.3E-05	6.3
150	0.39	0.63	6.7E-05	5.8
180	0.43	0.59	6.4E-05	5.5
210	0.45	0.57	5.8E-05	5.0
240	0.49	0.53	5.7E-05	4.9
270	0.5	0.52	5.2E-05	4.5
300	0.52	0.5	5.0E-05	4.3
360	0.55	0.47	4.5E-05	3.9
420	0.58	0.44	4.2E-05	3.6
480	0.6	0.42	3.8E-05	3.3
540	0.62	0.4	3.6E-05	3.1
600	0.64	0.38	3.4E-05	2.9
		AVERAGE	6.3E-05	5.5

Test 3

t (s)	d_w (m)	h_t (m)	K (m/s)	K (m/day)
0	0	1.02		
30	0.15	0.87	1.1E-04	9.6
60	0.2	0.82	7.6E-05	6.6
90	0.25	0.77	6.5E-05	5.7
120	0.27	0.75	5.4E-05	4.6
150	0.3	0.72	4.9E-05	4.2
180	0.33	0.69	4.5E-05	3.9
210	0.35	0.67	4.2E-05	3.6
240	0.4	0.62	4.3E-05	3.7
270	0.42	0.6	4.1E-05	3.5
300	0.45	0.57	4.1E-05	3.5
360	0.5	0.52	3.9E-05	3.4
420	0.53	0.49	3.6E-05	3.1
480	0.55	0.47	3.4E-05	2.9
540	0.57	0.45	3.2E-05	2.7
600	0.59	0.43	3.0E-05	2.6
		AVERAGE	4.9E-05	4.3


Permeability by Inverse Auger Hole Method
I 1-06
Permeability, k (m/day)
25.0
20.0
15.0
10.0
5.0
0.0
0
100
200
300
400
500
600
700
Test time, t (seconds)
Test 1
Test 2
Test 3

APPENDIX H

Summary of Analysis of Infiltration Testing

1.0 INTRODUCTION

This appendix presents the results from the infiltration testing carried out during the development of the pumping test wells at Bayswater Dive Structure, Airport West Station, Consolidated Airport Terminal Station and Forrestfield Dive Structure. In addition the results from monitoring the infiltration basin at the Bayswater Dive Structure during the pumping test are described.

2.0 BAYSWATER DIVE STRUCTURE

2.1 Infiltration Test During Well Development

The pumping test well (PW2-02) at Bayswater Dive Structure was developed on 4 and 5 November 2014. The groundwater from the development was pumped into two different infiltration pits excavated with a backhoe. Attachment H1 shows the location of the infiltration basins while Figure H1 shows photos of the two infiltration pits.

Figure H1: Infiltration Testing at Bayswater Dive Structure (Pit 1 left, Pit 2 right)

The dimensions of the two infiltration pits were approximately 5 m long by 5 m wide and 1 m deep, giving a volume of 25 kL. Given the loose sandy conditions it was not possible to form steep batter slopes and the pits kept collapsing during excavation. The dimensions are therefore approximate only.

PW2-02 was developed at a rate of approximately 4 L/s for a total period of 12 hours (over 2 days). Generally, it was found that the infiltration pits were able to infiltrate all of the discharged water by alternating the pumping into the pits.

The infiltration test consisted of filling the infiltration pit with water from the well development process and then measuring the water level decline in the pit over time. Infiltration Pit 1 was tested three times while Infiltration Pit 2 was only tested once.

Figure H2 shows the resulting water level decline while Table H1 presents the estimated infiltration rate for each test.

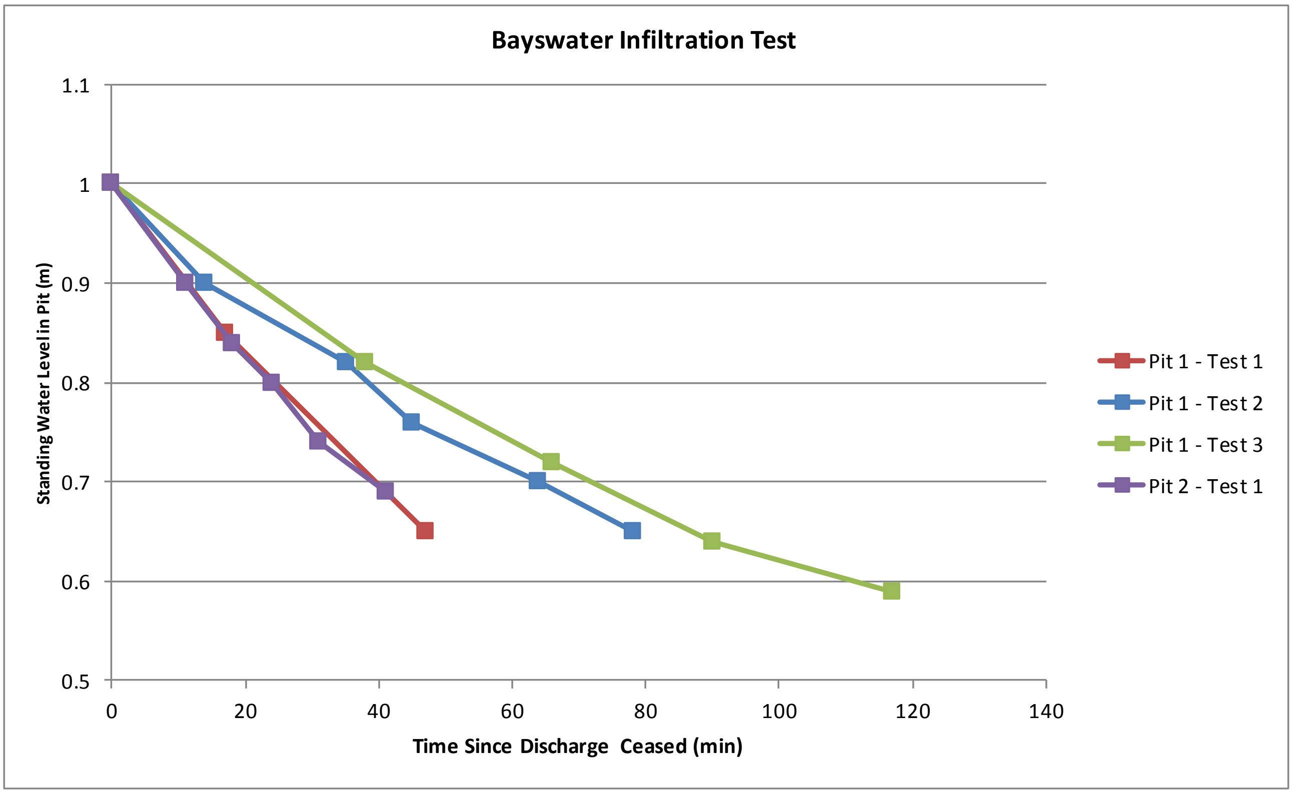


Figure H2: Infiltration Testing Data at Bayswater Dive Structure

Table H1: Estimated Infiltration Rate at Bayswater Dive Structure

Test	Approximate Infiltration Rate	
	L/s	m/d *
Pit 1 – Test 1	3.1	11
Pit 1 – Test 2	1.9	7
Pit 1 – Test 3	1.6	6
Pit 2 – Test 1	3.1	11

* Assuming all water is infiltrating through the base of the Infiltration Pit, which is a conservative assumption.

The results indicate:

- The derived infiltration rate ranges from 6 to 11 m/d assuming that all water infiltrated through the 25 m^2 base of the pits.
- Similar water level decline was observed in both pits for Test 1, resulting in similar infiltration rate at the two locations.
- The infiltration rates for Infiltration Pit 1 was found to decrease in Test 2 and Test 3, which is likely due to progressive saturation of the soil profile and fines being deposited at the bottom of the pit during the development (the development water contained some fines from the well).

2.2 Infiltration During Pumping Test

Due to restrictions on the groundwater discharge disposal, the pumped groundwater was also infiltrated on site during the pumping test carried out from 3 to 6 February 2015. Attachment H1 shows the location of the main infiltration basin and a contingency infiltration basin. The footprints of the basins were approximately 250 m^2 and 25 m^2. The main basin was only excavated to approximately 1 m depth at the periphery of the basin to create the bund walls while the central area was not excavated. The estimated volume of the main basin is approximately 115 kL.

A monitoring well (unknown construction details but with a depth of 4.5 m) existed inside the main infiltration basin. The groundwater level was measured to be 1.8 m below ground surface prior to start of the infiltration. A groundwater level logger was installed in the well to measure the change in groundwater level during the infiltration. The results from the groundwater level logger indicate that the groundwater level rose to the surface, indicating that fully saturated conditions occurred below the infiltration basin.

The discharge rate from the pumping test was approximately 12 L/s, but after 6 hours the basin was full and the discharge was therefore diverted into the contingency basin. The total volume of water pumped to the main basin within the first 6 hours was approximately 260 kL. With a storage volume of 115 kL, a total of 145 kL would have infiltrated over the 6 hour period, which corresponds to an average infiltration rate of approximately 2 m/d.

3.0 AIRPORT WEST STATION

The pumping test well (PW2-01) at Airport West Station was developed on 25 November 2014. The groundwater from the development was pumped into an infiltration pit excavated with a backhoe. Attachment H2 shows the location of the infiltration pit while Figure H3 shows a photo of the infiltration pit.

Figure H3: Infiltration Pit at Airport West Station

The dimensions of the infiltration pit were measured to be 10.3 m long by 2.9 m wide and 1.1 m deep, giving a volume of 33 kL. The ground was fairly consolidated and steep batter slopes were therefore achievable.

PW2-01 was developed at a rate of approximately 4 L/s. Generally, it was found that the infiltration pit would fill up and that well development had to cease until the water had infiltrated in the infiltration pit. This indicates that the infiltration rate is less than 10 m/d.

The infiltration tests consisted of pumping water into the pits until the standing water level in the pit was approximately 0.8 m. The pumping was then ceased and the decline in water level in the infiltration pit was measured over time.

It took approximately 110 minutes of pumping at 4 L/s (total volume of 26 kL) to fill the infiltration pit to 0.8 m (total volume in pit of 20 kL), indicating that approximately 6 kL infiltrated during the 110 minutes, corresponding to an average infiltration rate of 0.9 L/s or approximately 2.6 m/d during the time of filling.

Figure H4 shows the resulting water level decline and indicates that the groundwater declined by approximately 0.13 m over a period of 55 minutes, corresponding to an infiltration rate of 1.2 L/s or approximately 3.4 m/d (assuming that all water is infiltrating through the base of the Infiltration Pit, which is a conservative assumption).

It is noted that the calculated infiltration rate for the emptying of the pit is more precise than for filling due to the accumulation of potential measurement errors.

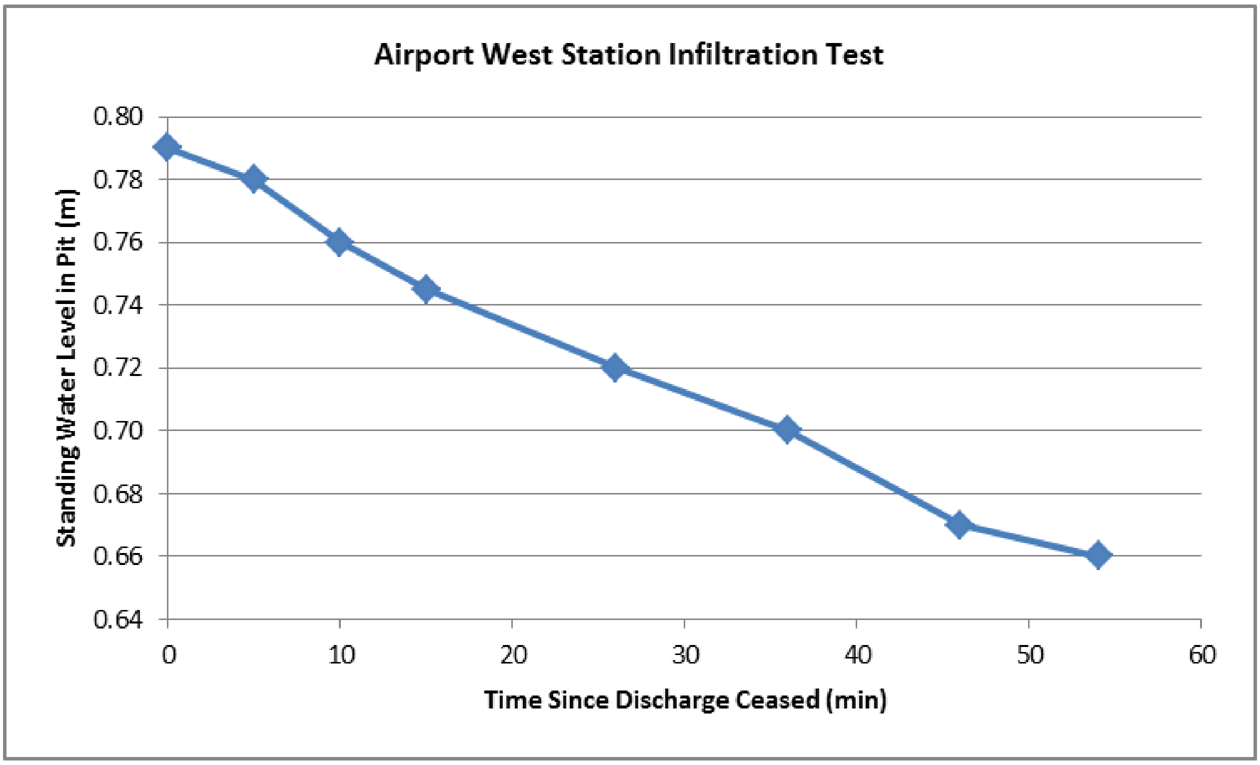


Figure H4: Infiltration Test Data at Airport West Station

4.0 CONSOLIDATED AIRPORT TERMINAL STATION

The pumping test well (PW1-02) at Consolidated Airport Terminal Station was developed on 25 November 2014. The groundwater from the development was pumped into an infiltration pit excavated with a backhoe. Attachment H3 shows the location of the infiltration pit while Figure H5 shows a photo of the infiltration pit.

Figure H5: Infiltration Pit at Consolidated Station (left before discharge, right after start of discharge)

The dimensions of the infiltration pit were approximately 6 m long by 2 m wide and 1 m deep, giving a volume of 12 kL. The ground was fairly consolidated and steep batter slopes were therefore achievable. The red colour on the left photo in Figure H5 indicates that coffee rock was present at approximately 1 m depth at the infiltration pit location.

PW1-02 was developed at a rate of approximately 8 L/s. The infiltration test consisted of filling the infiltration pit with water from the development process and then measuring the water level decline in the pit over time.

It took approximately 27 minutes of pumping at approximately 8 L/s (total volume of 13 kL) to fill the infiltration basin, indicating that approximately 1 kL infiltrated during the 27 minutes, corresponding to an average infiltration rate of 0.6 L/s or approximately 4 m/d during the time of filling.

Figure H6 shows the resulting water level decline and indicates that the groundwater declined by approximately 0.03 m over a period of 33 minutes, corresponding to an infiltration rate of 0.2 L/s or approximately 1 m/d (assuming that all water is infiltrating through the base of the Infiltration Pit, which is a conservative assumption).

It is noted that the calculated infiltration rate for the emptying of the pit is more precise than for filling due to the accumulation of potential measurement errors.

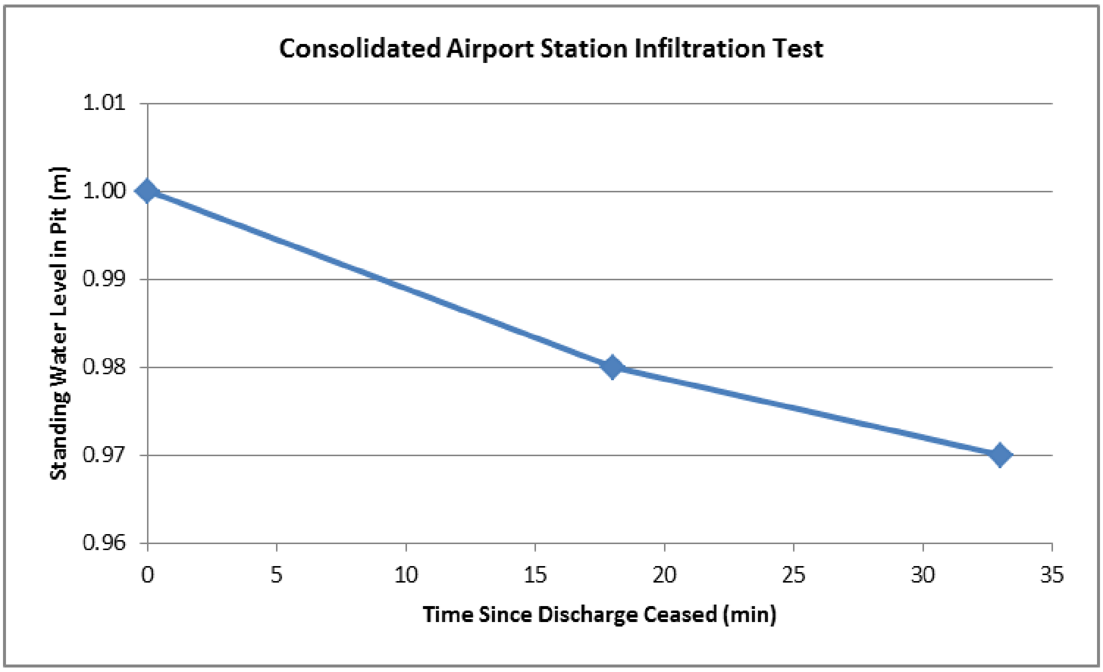


Figure H6: Infiltration Test Data at Consolidated Airport Terminal Station

5.0 FORRESTFIELD DIVE STRUCTURE

The pumping test well (PW1-01) at Forrestfield Dive Structure was developed on 7 November 2014. Some of the groundwater from the well development was pumped into an infiltration pit excavated with a backhoe. Attachment H4 shows the location of the infiltration pit while Figure H7 shows a photo of the infiltration pit.

Figure H7: Infiltration Pit at Forrestfield Dive Structure

The dimensions of the infiltration pit were approximately 3 m long by 1 m wide and 0.5 m deep, giving a volume of 1.5 kL. The ground was hard and steep batter slopes were therefore achievable.

PW1-01 was developed at a rate of approximately 6 to 10 L/s. The infiltration test consisted of filling the infiltration pit with water from the well development and then measuring the water level decline in the pit over time.

The capacity of the pit was reached within five minutes of the commencement of development of PW1-01. The change in water level in the pit was found to negligible between ceasing pumping into the pit and the end of the day (approximately 6 hours). The water level in the test pit was observed again the following day and the water level had not declined noticeably, indicating that the infiltration capacity of the soil at the infiltration location is negligible.

ATTACHMENT H1
Bayswater Infiltration Test Locations


Properties
Infiltration Pit 1
Infiltration Pit 2
PW2-02
Contingency Infiltration Basin
Main Infiltration Basin

ATTACHMENT H2
Airport West Infiltration Test Locations


Infiltration Pit
PW2-02

ATTACHMENT H3

Consolidated Infiltration Test Locations


I1-06
I1-04
PW1-02
Infiltration Pit
I1-05

ATTACHMENT H4
Forrestfield Infiltration Test Locations


Infiltration Pit 1
PW1-01
I1-03
I1-02
I1-01
Abernethy Rd
Avonside Crescent
Dundas Rd
Maida Vale Rd
Ibis Pl
Palmer Crescent
Durrant Way
Mack Pl
Imperial St
Eureka St
Milner Rd
Raven St
55

APPENDIX I

Limitations

LIMITATIONS

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