Cannington Swamp Threatened Ecological Community

Hydrological Study and Preliminary Management Plan

Prepared for the City of Canning

By Urbaqua

December 2019

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1 INTRODUCTION

The Cannington Swamp Threatened Ecological Community Hydrological Study and Preliminary Management Plan has been prepared for the City of Canning to support the construction of the proposed Southern Link Road Stage 3 between Grey Street and the Lake Street / Gerard Street / Jameson Street roundabout in Cannington. The proposed road will traverse through the corner of the Cannington Swamp and will require clearing of native vegetation within the swamp. Cannington Swamp is recognised for its conservation values, containing a threatened ecological community (TEC) and a conservation category wetland (CCW).

A hydrological study has been undertaken to assess the existing condition of the TEC and supporting wetland, and to determine the potential impacts of construction of the proposed road and other infrastructure. The preliminary management plan has been developed to identify the ongoing management requirements for the TEC and surrounding land and to facilitate allocation of appropriate management roles and responsibilities.

1.1 Site background

Undertaking planning studies that aim to improve amenity and facilitate intensification of land use, the City of Canning prepared the City Centre Structure Plan to guide implementation of town planning instruments. The Structure Plan has proposed new roads and other infrastructure to be constructed around Cannington Swamp and these have the potential to impact the wetland and threatened ecological community (TEC).

Cannington Swamp was previously the subject of soil and hydrogeological investigations by Parsons Brinckerhoff in 2005, and flora and fauna investigations undertaken by Woodman Environmental Consulting in 2005, Natural Area Consulting in 2016 and Ecoscape in 2018.

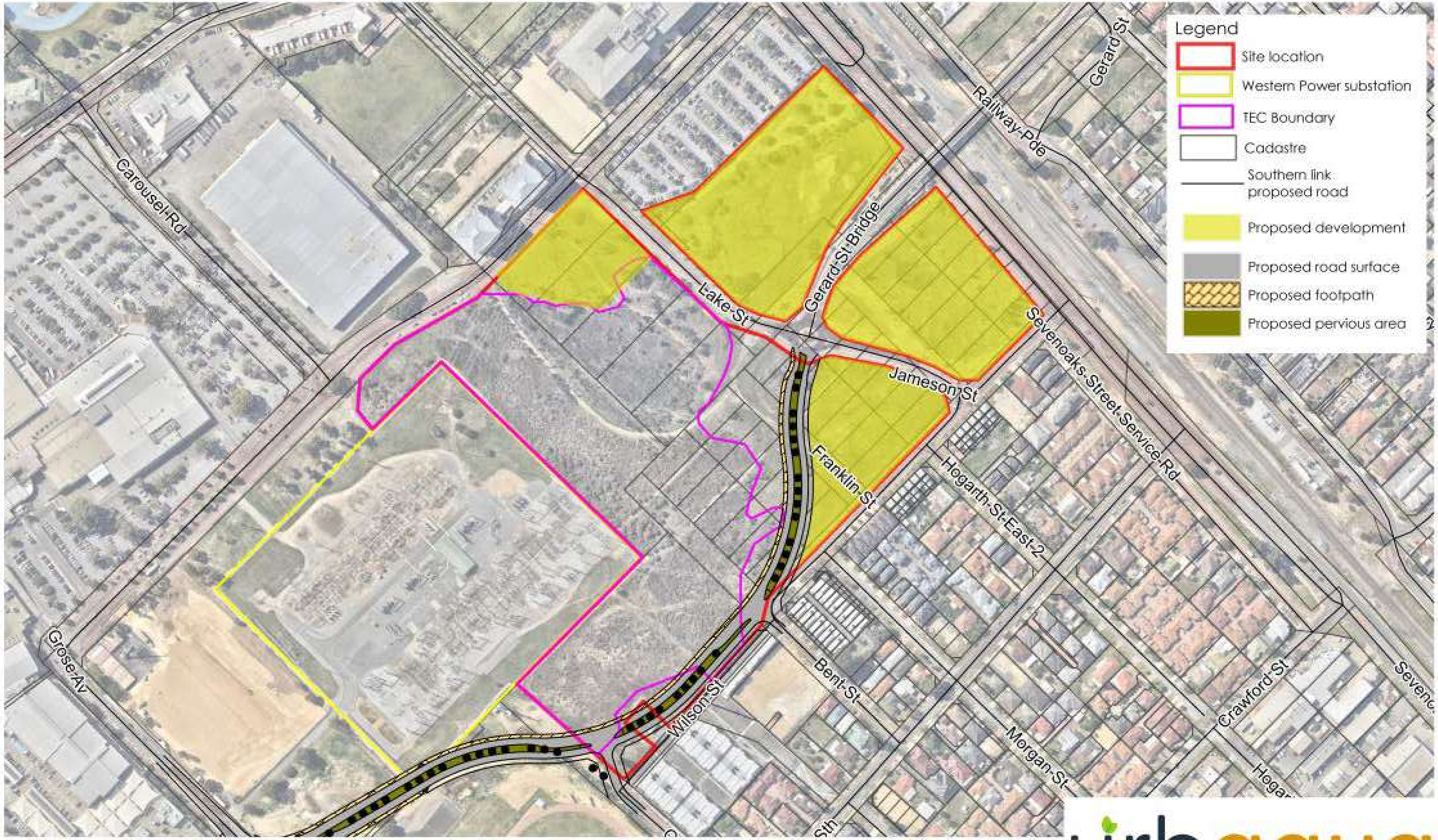
As part of the City's planning studies mentioned above, a detailed hydrologic and hydraulic model of the drainage system and surrounding catchments were previously developed by Urbaqua in 2016. This work provided a thorough understanding of the Cannington TEC site and surrounds that will enable a thorough and technically robust water balance to be developed for the site that will inform the development of the management plan to meet the requirements.

Having previously developed a detailed hydrologic and hydraulic model of the drainage system and surrounding catchments, there is no need to develop further surface water modelling for the surrounding area. The interaction between the surrounding drainage system and catchment is limited to high level infrequent events and the TEC is therefore predominantly supported by locally shallow groundwater and direct rainfall onto the site. It will therefore only be necessary to develop an annual water balance model for the site to establish the interdependencies between the TEC and the wetlands.

1.2 Location

Cannington Swamp is located approximately 11km southeast of Perth on Western Power land (behind the Cannington substation) and private land. The Cannington TEC has been identified as: Shrublands and woodlands on Muchea Limestone (endangered). The Southern Link Road construction has the potential to impact the wetland and threatened ecological community. The site location and the proposed Southern Link Road Stage 3 are illustrated in Figure 1.

Western Power - Cannington Swamp Hydrological Study
Figure 1 - Site location and proposed road layout



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2 SITE CHARACTERISTICS

The following review provides relevant information on the site characteristics sourced from available data and potential environmental issues.

2.1 Climate

The sites Mediterranean climate is typical of the Perth Metropolitan region, with warm dry summers and cooler wetter winters. The closest Bureau of Meteorology (BoM) weather station is Gosnells City located at approximately 6 km away from the site. This station has been in operation continuously since 1961.

As demonstrated in Figure 2a, there is a variation in the annual totals, ranging between 499.6mm (2010) and 1,184mm (1965). The data indicates a decreasing trend in annual and winter rainfall totals, particularly since 2000 where the annual average rainfall has decreased from 820.3mm to 729.4mm (approximately 11.1% decrease).

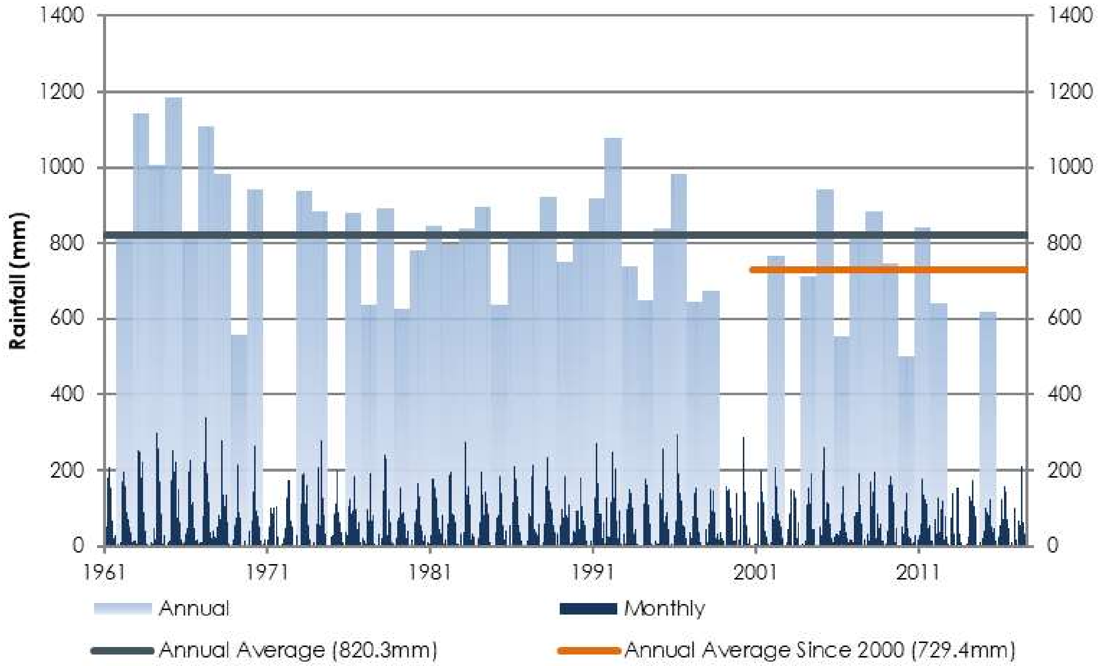

Figure 2a: Average annual and monthly climate data (station no. 9106) (BoM, 2018)

Evaporation data was obtained from Armadale Station given it was not recorded at Gosnells City and is the next closest BoM station recording this data. Evaporation is shown in Figure 2b. with the highest levels occurring between November and March. A comparison of the mean monthly rainfall and evaporation totals demonstrates that the region is water limited between September and April. Between May and August rainfall exceeds evaporation.

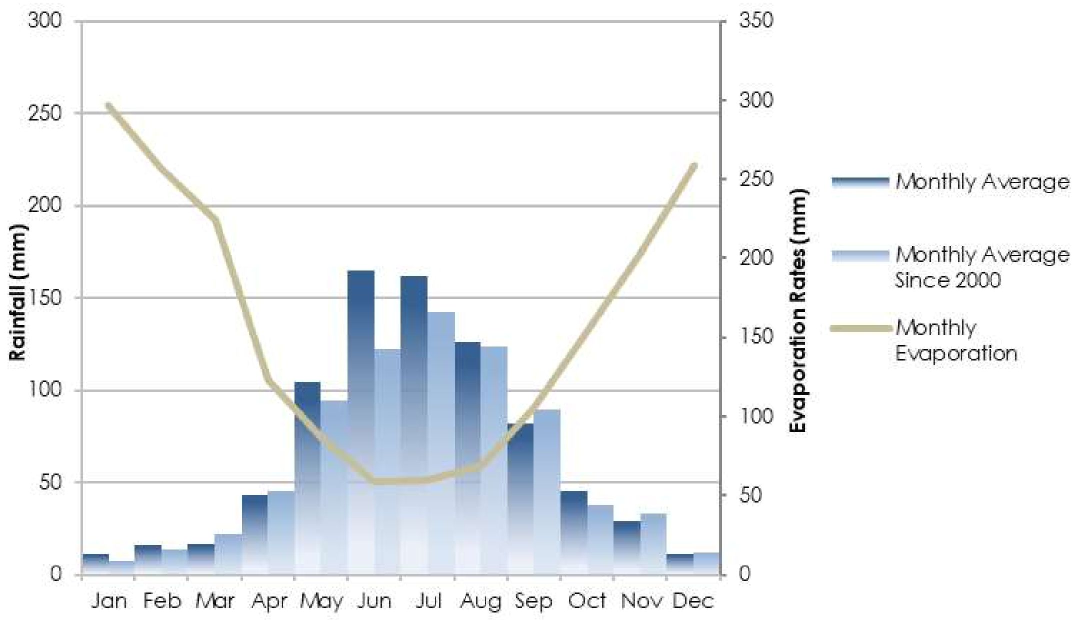

Figure 2b: Average Monthly Rainfall and Evaporation Data

2.2 Topography and geology

The topography of Cannington Swamp varies from 3.2 mAHD to 5.3 mAHD (Figure 3). The elevations within the larger portion of the swamp (main area), which includes the CCW and TEC immediately adjacent to the Western Power Sub Station, varies between 3.5 mAHD and 5.1 mAHD. The other portions of the swamp located in the north east and east will be filled and developed as part of the Canning City Centre Activity Centre Plan. Existing roads and developed land surrounding the site has generally been filled with imported sand material to approximately 0.5m above natural surface.

The Perth Metropolitan Region 1:50,000 Environmental Geology Mapping (Jordan J. E., 1986 Armadale part sheets 2033 I and 2133 IV) defines the materials as S10, thin Bassendean Sand over Sandy Clay to Clayey Sand of the Guildford Formation of eolian origin.

The Guildford formation has a low hydraulic conductivity of less than 0.1m/day although some basal sandy lenses may have a horizontal hydraulic conductivity of up to 10m/day.

Site-specific soil and hydrogeological investigations were undertaken in 2005 by Parsons Brinkerhoff (See Appendix A for the full report). The soil profile was summarised as follows:

- Sandy Clay (depth of 0 – 5.5m): underlain by sand and clay layers, the clay is brown above the sandy layers and changing to dull green with depth, representing a change from oxidising to reducing condition;
- Limestone Gravel (depth of 1.5 – 4.5m): Gravel clasts are sub-angular to rounded and contain minor quartz sand fraction;
- Chalky Clay (depth of 3.5 – 5.5m): Contains coarse sand to granule cementations, occasionally range to gravel and cobble size;
- Interlayered Sand and Sandy Clay (depth of 3 – 12): sandy lenses are generally medium to coarse grained and yielded small volumes of water during air-core drilling;
- Black Clay (depth of 12 – 13m): underlain by a grey sandy unit containing some limestone cobbles and shelly material; and
- Sand with Calcareous Gravel and Shells (depth of 13 – 15m).

Western Power - Cannington Swamp Hydrological Study
Figure 3 - Topography

Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

Scale 1: 4,000 @ A4

0 80 m

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2.3 Biodiversity

2.3.1 Vegetation description

A Flora, Vegetation and Fauna Survey undertaken (Natural Area, 2016) onsite identified the presence of nine vegetation types within the swamp:

- Open *Casuarina obesa* Woodland;
- *Viminaria juncea* and *Melaleuca lateritia* Shrubland;
- Open *Hakea prostrata* Shrubland;
- *Melaleuca lateritia* Heathland;
- *Meeboldina* Sedgeland;
- *Baumea juncea* Sedgeland;
- Open *Bolboschoenus caldwellii* Sedgeland;
- *Verticordia densiflora* var. *densiflora* Heathland; and
- *Melaleuca rhaphiophylla* Woodland.

The vegetation condition of the swamp was assessed in spring and ranged from Completely Degraded to Very Good, with the majority of the site (51.2%) recorded as Completely Degraded (Natural Area, 2016). The condition of the area considered by DBCA to represent the Muchea Limestone TEC ranged from Very Good to Degraded (Ecoscape, 2019).

2.3.2 Flora

A total of 111 flora species were recorded from 43 families within the swamp, of which 42 were monocotyledons (21 native species, 21 introduced species) and 69 were dicotyledons (36 native species, 33 introduced species). The threatened species *Eremophila glabra subsp. chlorella*, and the Priority 4 species *Ornduffia submersa* were observed during the site survey activities (Natural Area, 2016).

During a more recent environmental investigation conducted on 22 November 2018, 54 species were recorded, including 18 introduced species (weeds) none of which were Declared Pest plants or Weeds of National Significance (Ecoscape, 2019). The investigation's survey area was restricted to the proposed road alignment (between the Lake Street / Gerard Street / Jameson Street roundabout and Bent Street) and 20 m buffer and did not include the entire wetland.

2.3.3 Fauna

The fauna surveys identified the presence of three mammals (including the *European Red Fox (Vulpes Vulpes)* and the *European Rabbit (Oryctolagus cuniculus)* which are listed as C3 declared pests on the Western Australian Organism List (WAOL) under the Biosecurity Agriculture Management Act 2007 (WA)), 15 birds, five reptiles, four amphibians and 42 invertebrate species.

A native Bee of conservation significance, *Leioproctus douglasiellus* (a short-tongued bee) is listed by the Department of Biodiversity, Conservation and Attractions as having been recorded within the survey boundary. According to the Threatened Species Scientific Committee (2013), the Bee is closely associated with the presence of flora species *Goodenia filiformis* (Thread-leaved Goodenia) and *Anthotium junciforme*, neither of which were recorded at the site during the surveys undertaken by Natural Area in 2016. However, this does not necessarily preclude the presence of bees in the swamp area. No threatened or priority listed fauna was found during this survey activities.

Bee surveys were conducted on 23 November, 20 December 2018, and 5 January, 16 January and 26 January 2019 under warm, sunny conditions with low wind speed and cloud cover (Ecoscape, 2019). Host plants for the target bee species (*Goodenia pulchella*) were in bloom throughout the survey periods; prolifically during November and December and declining in January. 44 species from four families were recorded in total. Many were undescribed and were given a morphospecies identifier. Neither of the target short-tongued native bee species (*Leioproctus douglasiellus* and *Neopasiphae simplicior*) were recorded during five survey periods that corresponded with optimal timing to find them i.e. suitable season, suitable weather and prolific flowering of suitable host species.

2.3.4 *Potential biodiversity impacts*

Direct impacts

Physical disturbance within vegetated areas has the potential to impact on the biodiversity values and as such should be minimised. These impacts include clearing, introduction of Phytophthora dieback and/or weeds and shading caused by construction of surrounding buildings.

Phytophthora Dieback is a plant disease that can kill native vegetation. It is caused by the introduced pathogen *Phytophthora cinnamomi* and is a particularly significant pressure in Perth and the south west of Western Australia because this region is defined a world 'biodiversity hotspot', and the climate and soils of the area suit the pathogen's spread and survival (DWG, 2008). Dieback is spread easily by transfer of contaminated vegetation, soil and water, as well as via vehicles and footwear of users walking through an uncontaminated area of wetland.

Weeds are a threat to native vegetation as they often out-compete existing native species, resulting in the degradation of vegetation communities and the loss of native habitat for native fauna. This is a particularly significant pressure at Cannington Swamp due to the presence of the Threatened Ecological Communities and declared native flora and fauna.

Weed invasion is thought to have occurred at the swamp due to:

- transfer by recreational users; and
- introduction of non-native species in surrounding facilities and gardens.

Development of tall buildings in the surrounding area have potential to cast shade over areas of the wetland and TEC. Shade modelling should be required for design approvals to understand how the reduced sunlight may impact the wetland and TEC.

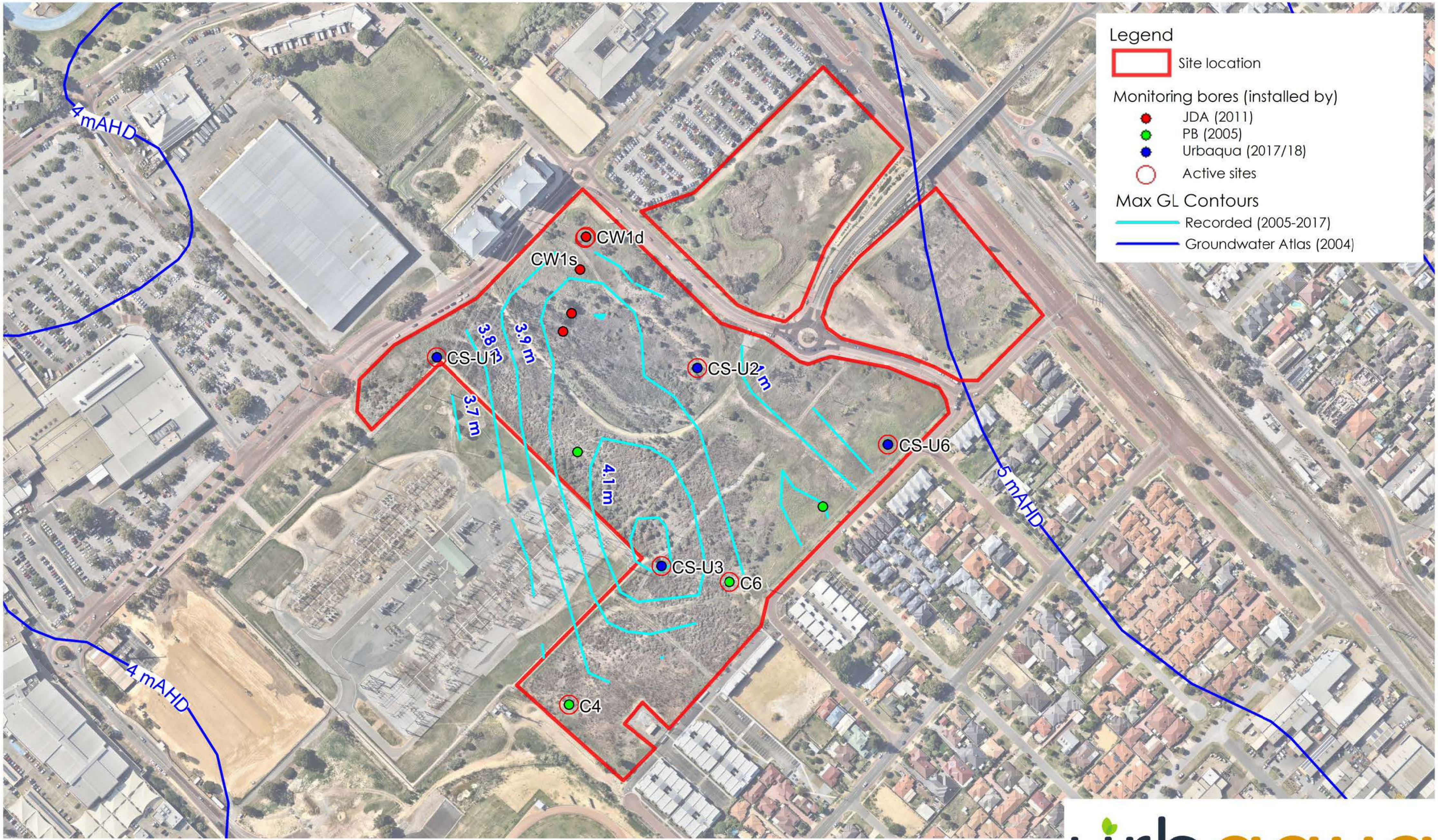
Indirect impacts

Any changes to the hydrological regime that supports the TEC and CCW has the potential to impact on its biodiversity values and as such should be minimised. These potential impacts are dealt with in more detail in sections 2.4 and 2.5 below.

2.4 Groundwater

Figure 4 presents a summary of groundwater information for the site including a comparison between maximum groundwater levels reported in the Perth Groundwater Atlas (DWER, 2017) and maxima recorded in site specific monitoring. Maximum recorded groundwater levels at the site vary between 3.7 and 4.3mAHD or from 0.5m below ground level to 0.5m above ground level.

Western Power - Cannington Swamp Hydrological Study
Figure 4 - Groundwater



Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

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2.4.1 Groundwater monitoring

Groundwater monitoring has previously been undertaken on the site in 2005 by Parsons Brinkerhoff and in 2011 by JDA. Parsons Brinkerhoff recorded a single round of groundwater levels at four monitoring bores only. JDA recorded twelve groundwater levels over seven months (May-Dec 2011) at twelve monitoring bores including those previously installed by Parsons Brinkerhoff. Monthly groundwater levels recorded by JDA are shown in Figure 5. In 2017, Urbaqua were only able to find four of these bores remaining.

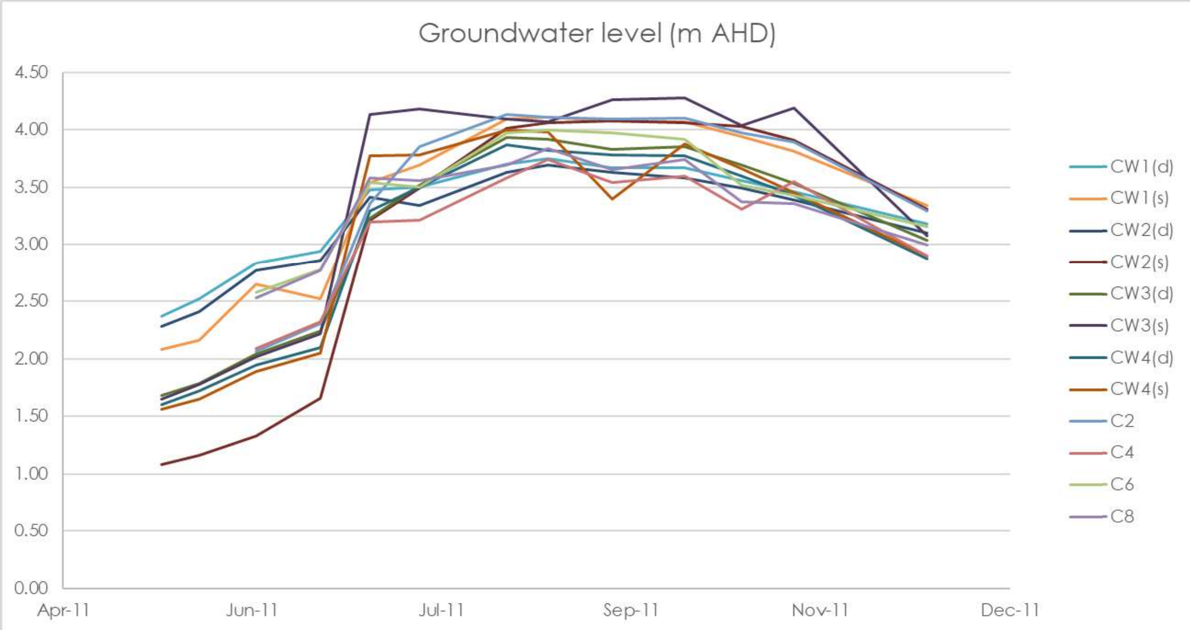


Figure 5: Groundwater levels recorded by JDA in 2011

As part of the Cannington Swamp Hydrological Study, a groundwater monitoring program was undertaken by Urbaqua between July 2017 and June 2018. Monitoring included monthly measurement of groundwater levels from four existing bores and four newly installed bores. Groundwater samples were also taken from each bore in July and October 2017 for water quality analysis as per Australian Standards (AS/NZS 5667.4:1998 and AS/NZS 5667.11.1998).

Monthly groundwater levels (July 2017-June 2018) and depths to groundwater recorded by Urbaqua at the monitoring bores across the Cannington Swamp are provided in Table 1 and Table 2 and monthly groundwater levels are also shown in Figure 6. Bore locations are illustrated in Figure 4 and bore logs are provided in Appendix B.

Spatial analysis of maximum recorded groundwater levels (2005-2017) presented in Figure 4 indicates the presence of slight mounding in the local groundwater system coinciding with the TEC area which is most likely reflective of local seasonal recharge patterns. The gradient of groundwater associated with this mounding is approximately 1:200.

The Perth Groundwater Atlas (DWER, 2017) indicates that the long-term Maximum Groundwater Level (MGL) is approximately between 4 and 5 mAHD across the Cannington Swamp. The regional groundwater gradient indicated by these contours is quite flat (approximately 1:700) and sloped to the west as can be observed in Figure 4. This indicates that groundwater in the area flows slowly towards the Canning River.

Table 1: Local monthly groundwater levels (mAHD)

Month	Urbaqua Bores (2017)				JDA Bores (2012)		PB Bores (2005)	
	CS-U1	CS-U2	CS-U3	CS-U6	CW1(s)	CW1(d)	C4	C6
Jul 2017	2.45	2.65	2.94	3.92	3.57	3.44	3.31	3.40
Aug 2017	3.46	3.50	4.14	4.06	4.10	3.79	3.77	3.83
Sep 2017	3.30	3.56	4.13	3.91	3.99	3.62	3.35	3.61
Oct 2017	3.08	3.36	3.99	3.74	3.85	3.54	3.21	3.48
Nov 2017	2.67	3.00	3.21	3.27	3.38	3.33	3.01	3.19
Dec 2017	2.35	2.52	2.62	3.03	2.97	3.13	2.79	2.98
Jan 2018	2.36	2.45	2.28	3.19	2.85	3.21	2.99	3.08
Feb 2018	2.09	2.02	2.05	2.93	2.69	2.91	2.57	2.86
Mar 2018	1.90	1.56	1.77	2.84	2.55	2.83	2.49	2.74
Apr 2018	1.85	1.67	1.59	2.98	2.43	2.88	2.49	2.77
May 2018	1.75	1.35	NA*	2.96	2.38	2.84	2.39	2.69
Jun 2018	2.28	2.26	N/A	3.73	3.32	3.31	3.13	N/A

*N/A: NO ACCESS to the bore

Table 2: Local monthly depth to groundwater (mBGL)

Month	Urbaqua Bores (2017)				JDA Bores (2012)		PB Bores (2005)	
	CS-U1	CS-U2	CS-U3	CS-U6	CW1(s)	CW1(d)	C4	C6
Jul 2017	1.74	1.43	0.96	0.41	0.71	0.84	0.85	0.72
Aug 2017	0.72	0.58	-0.24	0.27	0.19	0.49	0.39	0.29
Sep 2017	0.89	0.52	-0.23	0.42	0.29	0.67	0.81	0.51
Oct 2017	1.11	0.72	-0.09	0.59	0.43	0.74	0.95	0.64
Nov 2017	1.52	1.08	0.69	1.06	0.91	0.95	1.15	0.94
Dec 2017	1.84	1.56	1.28	1.30	1.32	1.15	1.37	1.14
Jan 2018	1.83	1.63	1.62	1.14	1.45	1.08	1.17	1.05
Feb 2018	2.10	2.06	1.85	1.40	1.59	1.37	1.59	1.26
Mar 2018	2.29	2.52	2.13	1.49	1.74	1.46	1.68	1.38
Apr 2018	2.33	2.41	2.32	1.35	1.85	1.41	1.67	1.35
May 2018	2.44	2.73	N/A*	1.37	1.90	1.45	1.77	1.43
Jun 2018	1.91	1.82	N/A	0.60	0.96	0.97	1.03	N/A

*N/A: NO ACCESS to the bore

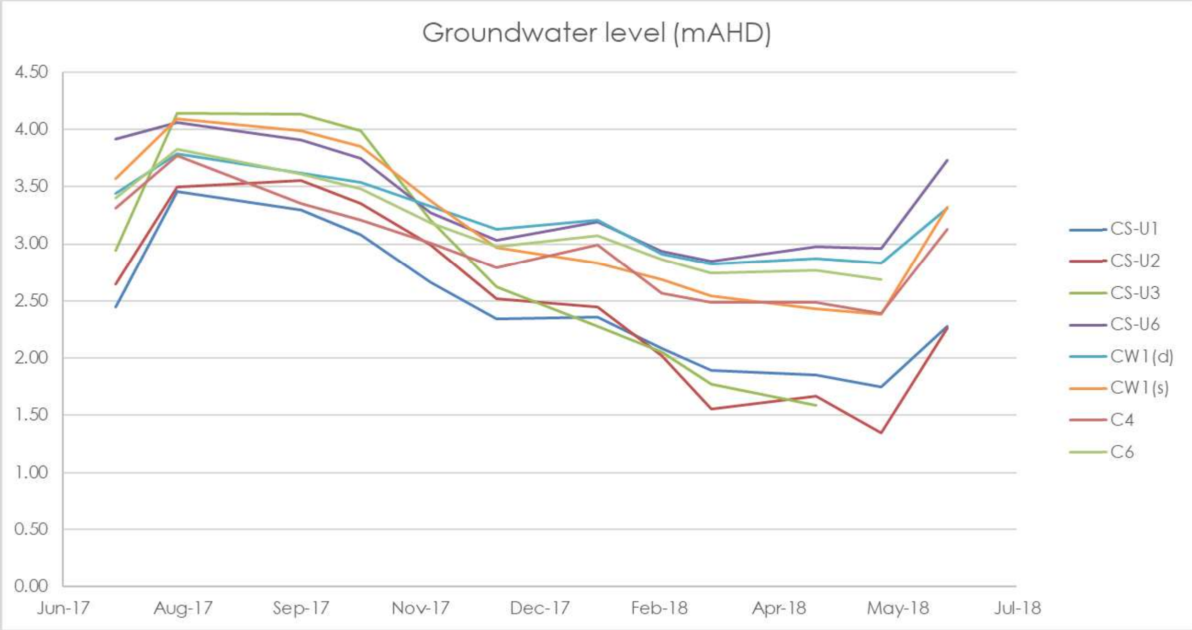


Figure 6: Groundwater levels recorded by Urbaqua in 2017/18

2.4.2 Groundwater quality

Groundwater quality testing was undertaken from all the bores onsite in July and October 2017. The results of groundwater quality within the superficial aquifer are provided in Table 3.

pH levels were typically recorded within the guideline range for the wetlands (ANZECC & ARMCANZ, 2000) with levels slightly below 7 only at Bores CS-U1 and CS-U6. The superficial groundwater at the site is considered as Fresh with the average salinity of 3.68mg/L.

Nitrogen levels in groundwater were found to be relatively low across the site, elevated total nitrogen concentrations were identified at CS-U1 and CW1(S) (north and north west of the site). Total Phosphorus and Ammonia levels exceeded the wetland criteria in All bores.

2.4.3 Potential groundwater impacts

The proposed road construction and future development of surrounding sites has the potential to change the local water balance reducing local recharge and impacting on groundwater levels. On-site infiltration of small rainfall events consistent with the requirements of DWER and the City of Canning will be required to prevent this impact.

As shown in Figure 4, regional groundwater flow within the Project Area is generally in a south westerly direction. Development of north east and eastern portions of Cannington Swamp and construction of the road extension will also include compaction of the soil layers. This has the potential to make a barrier to the groundwater flow and impact groundwater flows and levels.

Construction of the proposed road and future development of surrounding sites also has the potential to impact the quality of groundwater. Treatment of infiltrated runoff generated within the proposed road and future developments may be required to minimise the export of pollutants to groundwater.

Table 3: Local groundwater quality (July & October 2017)

		Sampling location																
	ANZECC	CS-U1		CS-U2		CS-U3		CS-U6		CW1(s)		CW1(d)		C4		C6	
		6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17	6/07/17	18/10/17
Temperature	-	19.60	19.90	20.80	20.90	17.60	23.30	17.20	18.50	16.90	19.50	19.10	19.80	21.20	21.00	21.30	21.70
Electrical Conductivity @ 25°C	300-1500	7787	12269	6657	8145	6730	7710	8411	16033	2575	8295	5270	5110	3016	2869	2581	2353
Dissolved Oxygen	90 -120	0.16	1.33	0.11	0.06	0.60	7.07	0.02	1.04	1.10	0.26	0.58	0.16	0.31	0.30	0.37	0.04
pH Value	7.0 - 8.5	6.99	6.26	7.22	7.15	7.32	7.43	7.29	6.98	7.78	7.25	7.20	7.18	7.19	7.22	7.34	7.28
Total Dissolved Solids @180°C	-	5064	7976	4329	5304	4374	4998	5473	10419	1658	5408	3425	3328	1956	1859	1677	1541
Salinity	-	4.33	7.05	3.65	4.55	3.71	4.27	4.71	9.42	1.32	4.64	2.85	2.76	1.57	1.49	1.34	1.21
Total Nitrogen as N	1.5	0.20	2.80	0.20	0.40	0.80	0.50	0.30	0.60	0.90	1.80	0.20	0.40	0.20	1.20	0.20	0.40
Total Phosphorus as P	0.06	0.14	0.18	0.11	0.15	0.12	0.10	0.34	0.29	0.24	0.57	0.20	0.11	1.30	0.63	0.21	0.21
Filterable Reactive Phosphorus	0.03	0.02	0.04	0.02	0.03	0.02	0.03	0.03	0.05	0.01	0.02	0.03	0.02	0.09	0.08	0.01	0.05
Nitrite + Nitrate as N	0.1	0.01	2.00	0.01	0.15	0.25	0.16	0.06	0.01	0.01	0.01	0.02	0.01	0.09	1.10	0.03	0.01
Ammonia	0.04	0.06	0.11	0.13	0.08	0.32	0.08	0.03	0.12	0.02	0.06	0.02	0.06	0.03	0.05	0.13	0.10
Total Kjeldahl Nitrogen as N	-	0.20	0.80	0.20	0.30	0.60	0.40	0.20	0.60	0.90	1.80	0.20	0.40	0.20	0.20	0.20	0.40

2.5 Surface water hydrology

The Cannington Swamp has been classified as Conservation Category (main area) and Multiple Use Wetlands (corner of the main area and the other two portions in the north east) by the Department of Biodiversity, Conservation and Attractions in its Swan Coastal Plain geomorphic wetlands database as shown in Figure 7.

2.5.1 Local drainage

In order to provide technical analysis that quantifies infrastructure flooding issues and assist with the Canning City Centre Activity Centre Plan, a Local Drainage Plan has been prepared by Urbaqua in 2016. The study indicates that the Cannington Swamp is located within a Water Corporation drainage catchment named as Cockram Street Main Drain which ultimately discharges to the Liege Street constructed wetlands.

Cannington Swamp is bounded on all sides by roads, which are typically constructed on fill to sit at approximately 0.5m above the natural surface level. Subcatchment delineation for the wetland site based on LiDAR information is shown on Figure 7 and demonstrates that the site is internally draining with virtually no external catchment except for portions of the Western Power site. The drainage system underlying the swamp is comprised of an underground pipe network which may surcharge via raised manholes during major storm events (>20% AEP). However, this surcharge is not expected to have a significant impact on overall hydrology of the swamp as it occurs only during large storm events and therefore has no influence on the annual hydrological cycle of the swamp (Urbaqua, 2016a). With virtually no upstream catchment, surface water inflow to the swamp occurs via direct rainfall recharge and outflow is via infiltration, evaporation and evapotranspiration.

2.5.2 Water balance model development

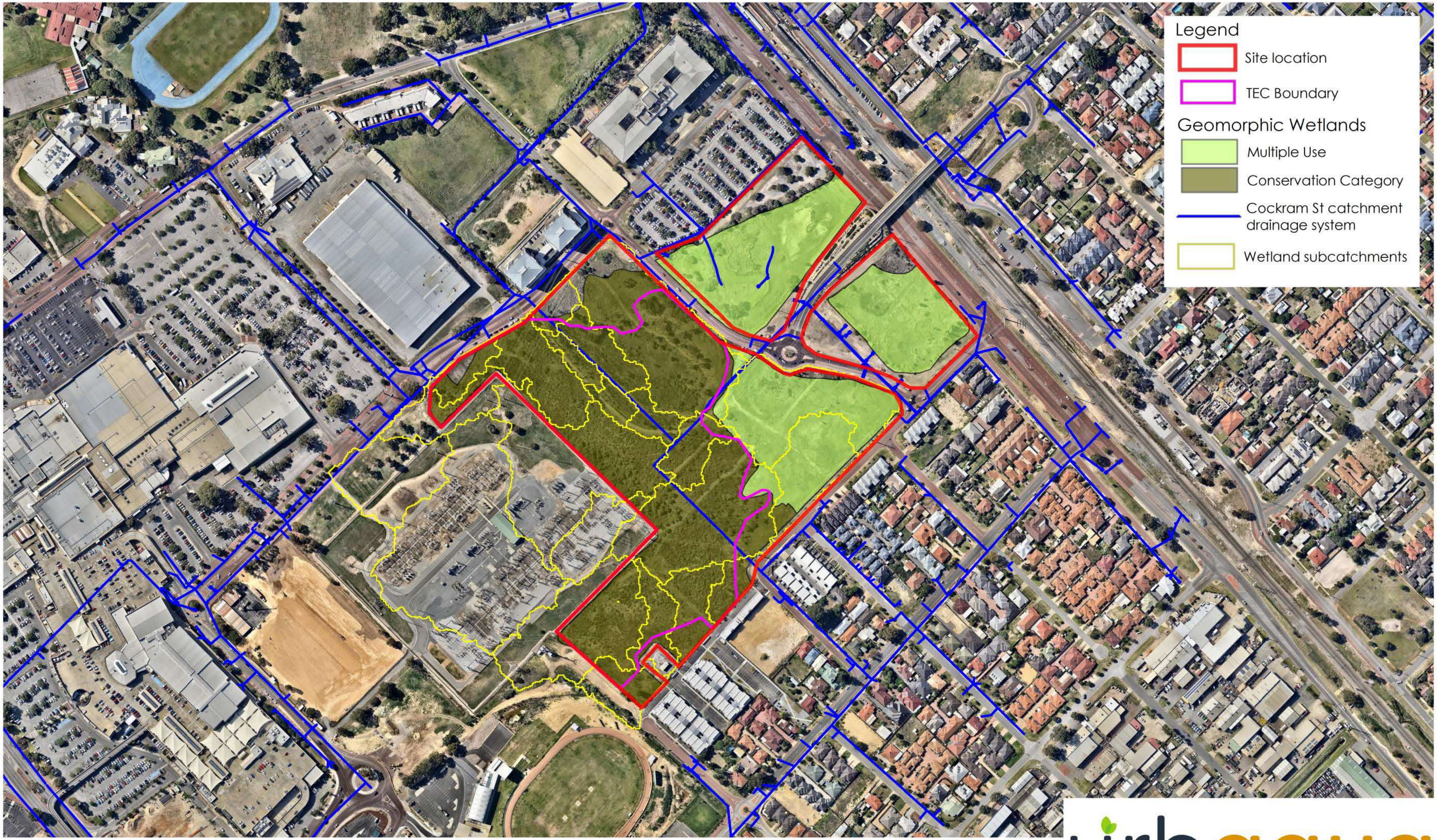
A simple bucket type water balance model of the site has been constructed to facilitate assessment of the extent, depth and duration of surface inundation in the site. The model considers direct and indirect rainfall into the wetland from the contributing catchment. Rainfall to inundated portions of the catchment entirely (100%) contributes to the wetland model while portions of the catchment that are not inundated are assumed to contribute to groundwater recharge or evapotranspirate (80% combined) and into the wetland model (20%). The most recent 10 years of rainfall record (2008-2017) from BoM Gosnells City station (ref: 9106) have been selected for modelling.

Evaporation from the wetland waterbody is accounted with monthly local pan evaporation rates from BoM Perth Airport station (ref: 9021) adjusted by the open water body correction factor of 0.75.

Hydraulic conductivity controls leakage from the wetland into the underlying groundwater system and has been set at 0.1m/day to reflect typical vertical hydraulic conductivities for the Guildford formation (Xu et al. 2008 and DWER, 2010).

The wetland is assumed to be connected to the superficial aquifer and some forcing by average (from all available monitoring data 2005-2018) seasonal groundwater levels is allowed, to reflect horizontal and underlying boundary conditions. This forcing of the water balance means that recharge and evapotranspiration from portions of the site that are not inundated can be effectively ignored as they are accounted for in the local groundwater level adopted in the model.

Western Power - Cannington Swamp Hydrological Study
Figure 7 - Existing hydrology and drainage



Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

Scale 1: 5,000 @ A4

0 100 m

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Table 4 presents the dimensions and key parameters used in the water balance model.

Table 4: Existing site water balance inputs

Swamp invert (mAHD)	Base Area (ha)	Overflow level (mAHD)	Total Storage (ML)	Max GW only level (mAHD)	Hydraulic conductivity (m/day)
3.75	0.08	4.75	54.5	3.83	0.1

It is recognised that this model is a significant simplification of the natural systems being represented. Therefore, a review of historic aerial imagery has been undertaken to provide a level of calibration and to increase confidence in the model's predictions.

2.5.3 Water balance model calibration

A review of aerial imagery 2008-2017 was undertaken to correspond with the model simulation duration. Available images were reviewed from Nearmap and Landgate to identify years where an estimate of hydroperiod could be determined. Table 5 presents the findings of this review and Figure 8 presents a selection of the images reviewed.

It is noted that inundation in the wetland is often only observable in certain locations in aerial imagery such as cleared maintenance tracks and other more sparsely vegetated areas. Because these do not correspond to the lowest points on the site, inundation at levels lower than approximately 3.8mAHD cannot be observed by this method. Therefore, the observable hydroperiod is likely to be shorter than the actual hydroperiod. Observations of maximum water level are considered more reliable as it is generally possible to observe high water marks on exposed portions of the site that can be easily compared to LiDAR elevations.

Table 5: Aerial imagery review

Year	Annual rainfall (mm)	Approx. top water level	Approx. observable hydroperiod
2011	840.6	4.2m AHD	6 months (Jul-Dec)
2012	640.0	3.9m AHD	3 months (Jul-Sep)
2017	730.7	4.1m AHD	4 months (Jul-Oct)

This information has been used to review the extent and hydroperiod predicted by the model in these years and the results of this comparison are presented in Table 6. In general, the model predicts a longer hydroperiod than was observed, however this is expected given the difficulties associated with the observation method. The observed top water level is reproduced by the model reasonably accurately in all three years.

Table 6: Model calibration results

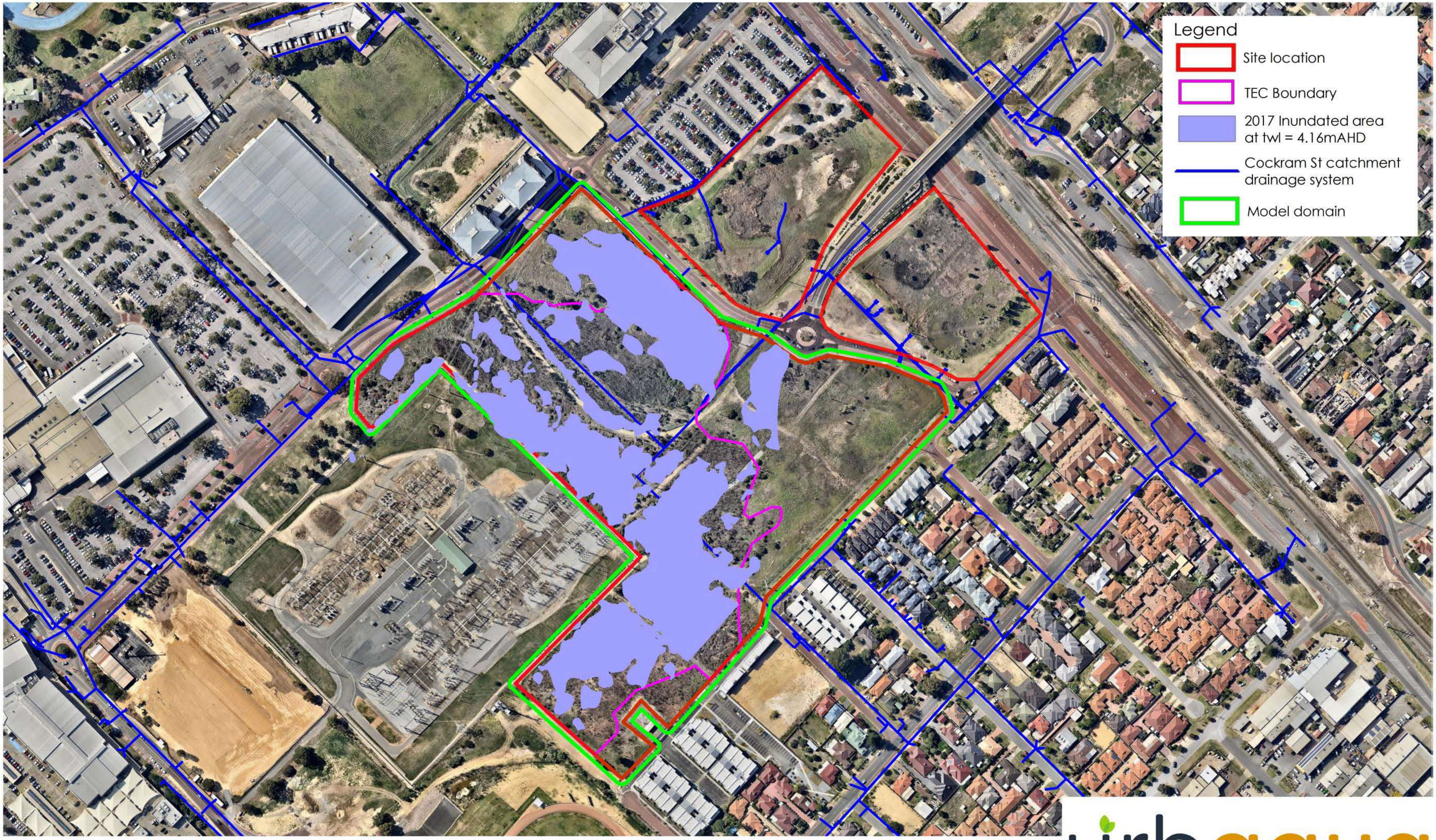
Year	Modelled maximum inundation level	Approx. observed top water level	Modelled hydroperiod	Approx. observable hydroperiod
2011	4.17m AHD	4.2m AHD	7 months (Jun-Dec)	6 months (Jul-Dec)
2012	3.91m AHD	3.9m AHD	5 months (Jul-Nov)	3 months (Jul-Sep)
2017	4.16m AHD	4.1m AHD	6 months (Jun-Nov)	4 months (Jul-Oct)

Modelled inundation in August 2017, which experienced close to average rainfall for the duration modelled and resulted in close to average inundation, is presented in Figure 9.

Figure 8: Aerial imagery review – observable inundation in selected years

Western Power - Cannington Swamp Hydrological Study

Figure 9 - Modelled maximum water level and extent in 2017



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Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

Scale 1: 4,000 @ A4

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2.5.4 Model sensitivity

Analysis of the model's sensitivity to various parameter changes revealed the following results:

- Hydraulic conductivity ±0.05m/d: Maximum TWL (over 10 years) ±5cm
- Pan evaporation factor ±10%: Maximum TWL (over 10 years) ±3cm
- Catchment % runoff ±10%: Maximum TWL (over 10 years) ±12cm

2.5.5 Existing water balance

The modelled water balance for the existing site is presented in Table 7. Detailed results from the model including all input parameters, seasonal groundwater levels and seasonal surface water results (tabulated and graphed) are provided in Appendix C.

Table 7: Existing site water balance

Inputs	10-year total (ML)	Average annual (ML)
Direct rainfall	93.0	9.3
Catchment runoff	37.2	3.7
Total inputs	130.2	13.0
Outputs		
Evaporation	98.9	9.9
Net seepage to groundwater	31.3	3.1
Overflow	0.0	0.0
Total outputs	130.2	13.0

2.5.6 Potential surface water impacts

The proposed road construction and future development of surrounding sites includes localised excavation/filling within parts of the swamp which has the potential to reduce the storage capacity and change the natural hydrology and runoff generation across the swamp.

Construction of the proposed road and future development of surrounding sites also has the potential to impact the quality of stormwater runoff. Treatment of any additional runoff generated within the proposed road and future developments may be required to minimise the export of pollutants to the swamp.

2.6 Summary of potential impacts

Cannington Swamp and the TEC may be affected by a number of potential impacts associated with the road construction and future development of surrounding sites. Actions need to be undertaken to manage these appropriately. Identified potential impacts to Cannington TEC are:

- Excavation and filling works – impact on wetland hydrology and water levels;
- Road and development drainage discharge treatment – impacts to downstream groundwater and surface water quality;
- Road and building compaction – impacts to groundwater flows/levels;
- Clearing and physical disturbance – impact on flora/fauna and biodiversity values;
- Introduction of Phytophthera dieback and/or weeds – impact on flora/fauna and biodiversity values; and
- Overshadowing - impact on flora/fauna and biodiversity values.

3 PRELIMINARY REVIEW AND SITE INSPECTIONS

The following is a summary of the findings of the site inspections and the desktop review of the proposed road design.

It is understood that all portions of the swamp are separated by the roads and there is no surface water interaction between them. The proposed construction at the smaller portions will have minimal impact on the water levels within the main area. The assessments will only be undertaken on the main area of the swamp, which includes the TEC.

3.1 Onsite groundwater monitoring

As discussed in Section 2.4, a groundwater monitoring program and site inspection was undertaken by Urbaqua staff between July 2017 and June 2018. During August, September and October 2017, inundation was observed at some areas of the Swamp. Figure 10 illustrates the inundation around bore CS-U3 at the corner of the Western Power Sub Station in October 2017. The groundwater has been below the ground level at the other sampling bores during the monitoring period.

Figure 10: Inundation around bore CS-U3 (looking north-west)

3.2 Review of the proposed construction

This study considers two elements of proposed construction which are relevant to the TEC site. These are:

- Construction of the proposed Southern Link Road by the City of Canning
- Future development of sites surrounding the TEC by others

The proposed Southern Link Road (extension of Liege Street) will consist of two asphalt sealed carriageways with a footpath proposed at the northern side. Details of the road design are shown in Appendix D.

Approximately 380m of the proposed road section is bordering the swamp. The potential impacts of the construction are explained in the sections below. Based on the City of Canning Structure Plan, a mixed landuse of office, community and/or high-density residential is proposed at the north east and eastern portions of the swamp.

3.2.1 Post development drainage system

A local water management strategy (Urbaqua, 2016a) and Local Drainage Plan (Urbaqua 2016b) have been previously prepared and approved by DWER to support the Canning Activity Centre Structure Plan. This included the proposed development to the north east and east of the Cannington Swamp located within Cockram Street Main Drain catchment. These plans provide guidance for development to manage water quality and quantity utilising the City of Canning and Water Corporation existing drainage system and preventing impacts to the Cannington swamp and TEC. Therefore, there will be no new drainage discharges from developing lots into the Cannington Swamp and TEC.

Approximately 380m of the proposed road passes through the swamp. In order to maintain the existing hydrology within the swamp, it is not recommended to direct any of the proposed road runoff to the swamp. A mix of formal and informal drainage system should be installed for the proposed road to direct its runoff to the existing drainage systems. Based on the local topography, the road surface can be divided into three catchments as shown in Figure 11.

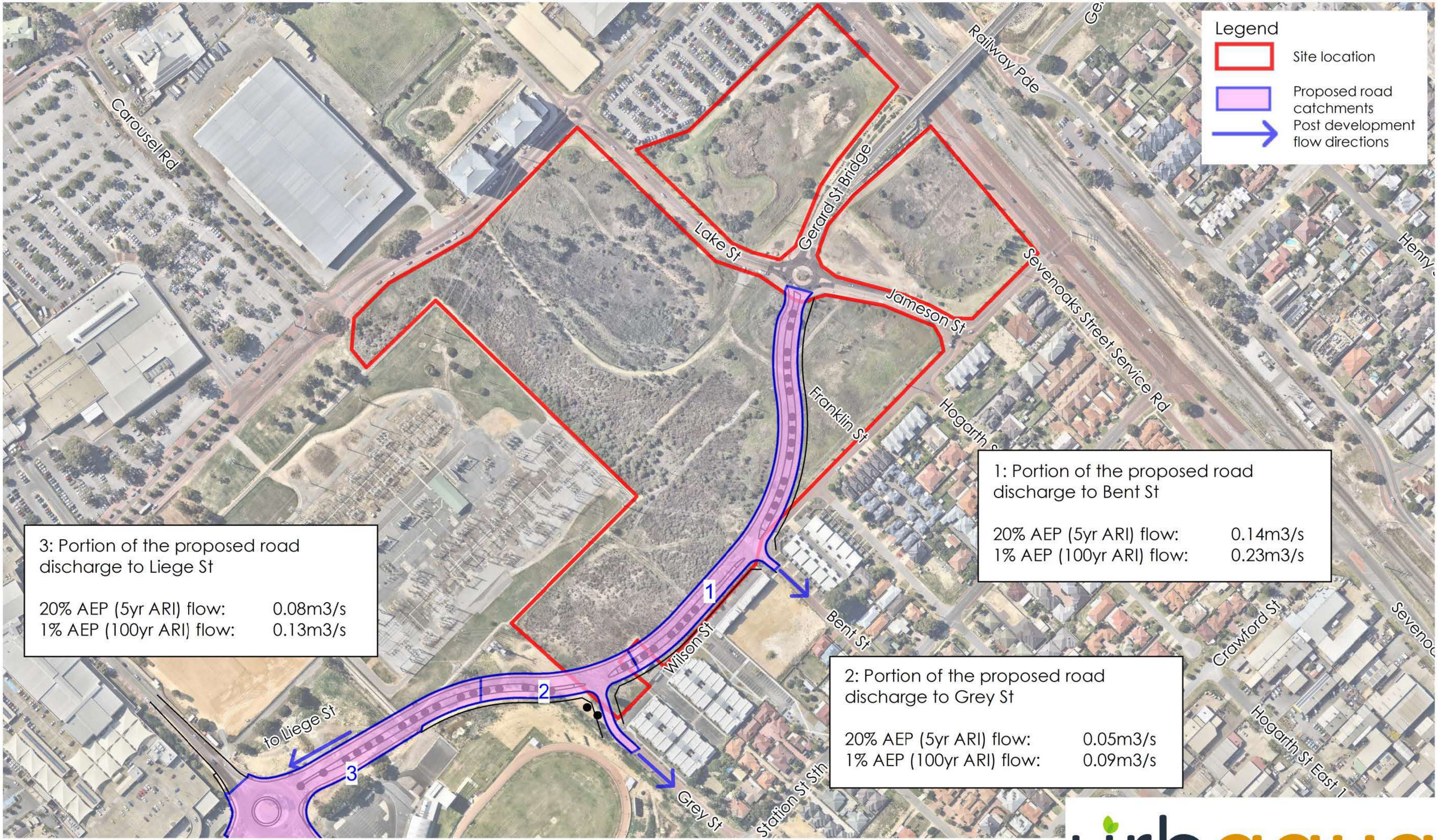
In order to determine post development flows from the proposed road, hydrologic and hydraulic modelling was undertaken with the model XP-Storm. A multi-storm analysis was conducted to determine the critical duration event that produces the largest peak discharge from the modelled catchments. The rainfall used for the modelling is based on 2016 IFD data (BoM,2017b). The peak flows discharging from each section of the road are provided in Figure 11 and Table 8. There is no external catchment draining to the road.

Table 8: Proposed Southern Link Road post development flows

Discharge location	Catchment Area (ha)	20% AEP (5yr ARI)		1% AEP (100yr ARI)	
		Flow Rate (m^3/s)	Critical Duration	Flow Rate (m^3/s)	Critical Duration
1 (to Bent St drainage system)	0.71	0.14	15 min	0.23	15 min
2 (to Grey St drainage system)	0.27	0.05	15 min	0.09	10 min
3 (to Liege St drainage system)	0.41	0.08	15 min	0.13	10 min

The modelling results indicate that post development flow rates from the proposed road are relatively small and are not expected to cause substantial erosion effects. Underground pipes can be designed to convey runoff from up to the 20% AEP event downstream to provide for appropriate serviceability. Extreme flooding events (up to the 1% AEP event) that exceed the capacity of pipes will be directed through overland flow on the road.

Western Power - Cannington Swamp Hydrological Study
Figure 11 - Proposed road extension drainage



Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

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3.2.2 Post development water balance for the swamp

Developing lots surrounding the Cannington swamp and TEC are physically separated from the swamp and TEC by previously constructed roads. This physical separation has removed all surface hydrological connectivity and therefore development of these lots will not modify the catchment of the site or the area available for surface water storage.

The water balance model of the site (discussed in section 2.5.3) was amended to consider the response of the swamp water levels to the road construction. The post development details of the swamp are provided in Table 9.

Table 9: Post development site water balance inputs

Swamp invert (mAHD)	Base Area (ha)	Overflow level (mAHD)	Total Storage (ML)	Max GW only level (mAHD)	Hydraulic conductivity (m/day)
3.75	0.001	4.75	41.3	3.83	0.1

A comparison of the existing and post-development modelled water balance over the model period (10-years) is provided in Table 10. The post development inundation area based on 2017 rainfall is illustrated in Figure 12 and the detailed model output is provided in Appendix E.

Table 10: Water balance for the site following construction of the road

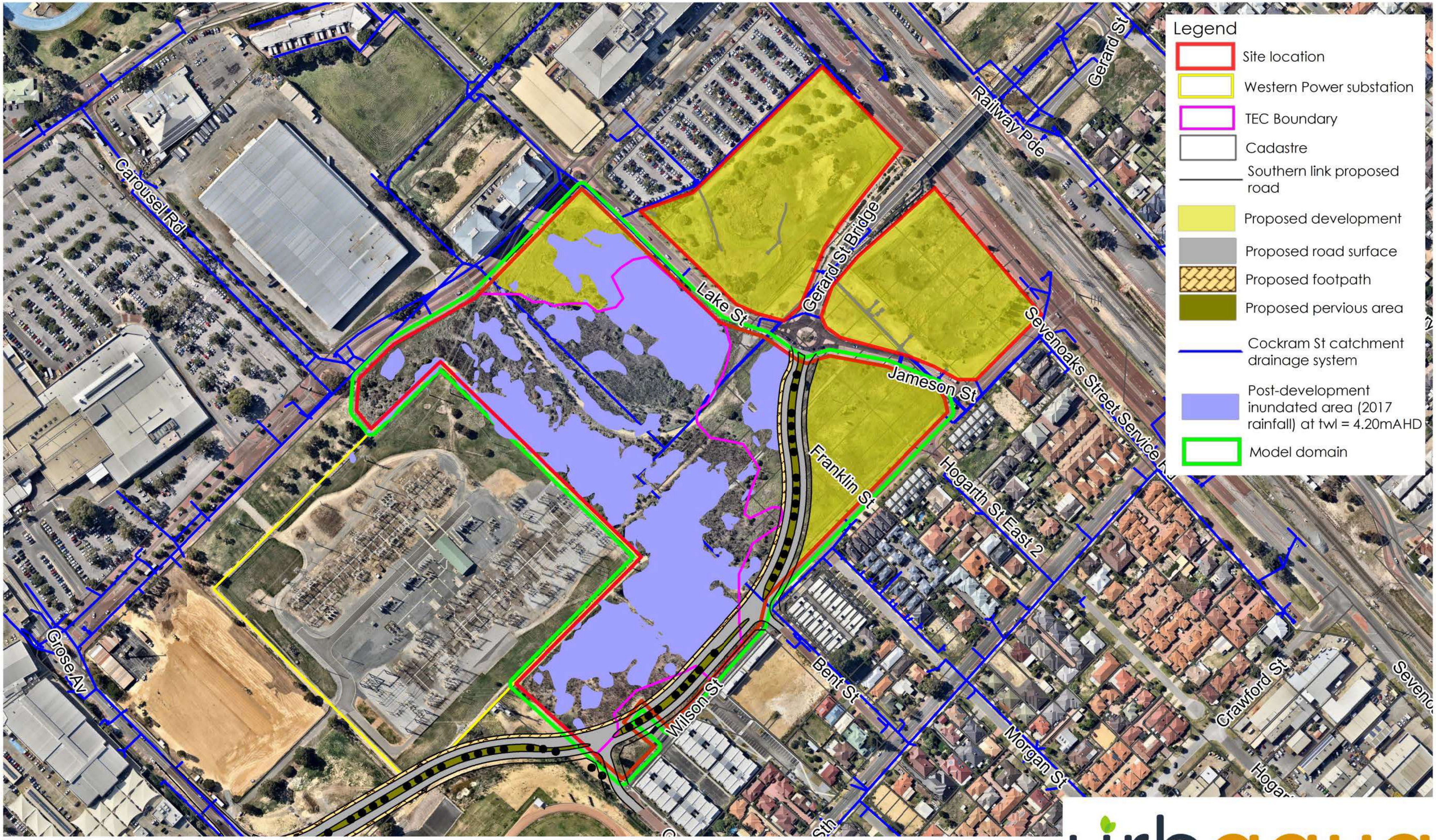
Inputs	Existing 10-year total (ML)	Post-road construction 10-year total (ML)
Direct rainfall	93.0 (71%)	70.0 (72%)
Catchment runoff	37.2 (29%)	29.5 (28%)
Total inputs	130.2	99.4
Outputs		
Evaporation	98.9 (76%)	70.7 (71%)
Net seepage to groundwater	31.3 (24%)	28.7 (29%)
Overflow	0.0	0.0
Total outputs	130.2	99.4
Top water level (10-year max)	4.22	4.25 (+0.03m)
Average winter top water level	4.14	4.16 (+0.02m)
Average hydroperiod	203 days	215 days (+ 12 days)

The comparison presented in Table 10 illustrates that changes in water level and hydroperiod are relatively small and comparable to the existing condition. The average winter water depth increased by two centimetres and the maximum (10 year) top water level increased by three centimetres in post development modelling. The average hydroperiod increased by 12 days.

Consistent with the existing conditions, there will be no upstream catchment discharging to the Cannington Swamp. Runoff from the new road will be directed to the existing drainage systems within the Cockram Street Main Drain catchment. The swamp area and storage capacity will be decreased slightly as a result of the road construction but importantly, the depth and duration of inundation has not changed substantially.

Western Power - Cannington Swamp Hydrological Study

Figure 12 - Modelled post-development maximum water level and extent (2017 rainfall)



Data source: Landgate, DoP. Created by: AT. Projection: MGA: zone 50.

3.2.3 Groundwater flows/levels

The Cannington Swamp proposed construction is in an area where the regional groundwater gradient is quite flat (approximately 1:700) and angled to the south-west, as can be observed in Figure 4. This indicates that groundwater in the area flows sluggishly towards the Canning River and suggests that the proposed construction would not likely have a significant influence on groundwater throughflow at the swamp. However, to consider the potential for any impact, the proposed development has been considered as discussed below.

The proposed development at north east and eastern portions of Cannington Swamp will have minimal effect on the groundwater at the CCW. The finished level of any construction at this area is expected to be above and have sufficient clearance from the local Maximum Groundwater Level (MGL).

For the proposed road, it is recommended to use imported fill where necessary to achieve a minimum 600 mm clearance from MGL to the design surface. A typical pavement cross section of the road is shown in Figure 13 which provides a typical pavement thickness of 200mm base course with an underlying subbase of 200mm thickness (total of 400mm).

The Institute of Public Works Engineering Australasia Western Australia Incorporated Subdivisional Guidelines Edition No.2.3, 2016 specifies that the sub-base should have a minimum compacted thickness of 150mm. However, it is not unusual for the compacted subbase to extend to 400mm thickness to provide stability to the pavement. Conservatively, assuming compaction of the sub-base to 400mm and a pavement thickness of 200mm the depth of the compacted layer would be approximately 600mm from the design surface. Given the minimum of 600mm clearance from MGL to the design surface recommended, compaction would not extend below the MGL and would not influence groundwater levels and/or flow.

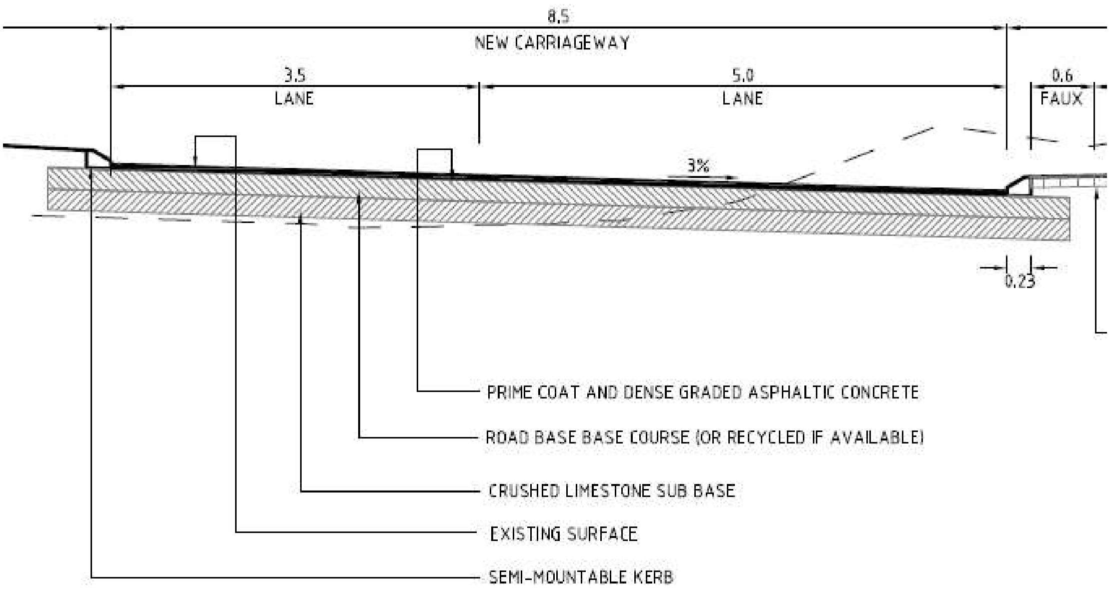


Figure 13: Typical pavement cross-section

3.2.4 Post development water quality

Runoff generated by frequent rainfall events has the potential to mobilise pollutants within the catchment. The first 15mm of rainfall from developing lots, which is anticipated to contribute minimal nutrients, will be managed at-source, preferably on-lot using various approaches such as soakwells, permeable pavements or rainwater tanks.

It is proposed that runoff generated by the first 15mm of rainfall onto the new road reserve will be managed in median swales within the road reserve (see example in Figure 14) while runoff from larger events will be conveyed directly into the existing downstream drainage system.

By directing the runoff from the constructed road to the existing drainage systems, as demonstrated in Figure 11, no contaminants of heavy metals or hydrocarbons would be transferred to the swamp and the existing water quality would be maintained.

Figure 14: Example median swale arrangement

4 ASSESSMENT OF POTENTIAL IMPACTS AND RECOMMENDED MITIGATION STRATEGIES

Modelling has been undertaken to evaluate the potential impacts of the proposed construction and identify recommended strategies for mitigation.

4.1 Wetland hydrology and water level impacts

4.1.1 Post development drainage system

As shown in Section 3.2, a formal drainage system including underground pipes and overland flow on the road will direct all the runoff from the proposed road to existing drainage systems and no stormwater from the proposed road will flow to the swamp.

Runoff from surrounding developing lots will similarly be directed to existing drainage systems and no stormwater from the proposed lots will flow to the swamp.

4.1.2 Post development water balance for the swamp

A water balance model was developed to consider the response of the swamp water levels to the road construction. The post development inundation area is illustrated in Figure 12.

A comparison of the estimated water balance for the proposed and existing systems indicates very little change in winter water depth, inundation extent or hydroperiod of the swamp. The proposed road construction will not interfere with the Cannington Swamp catchment and none of the runoff from the proposed road will be directed to the swamp, as such, the post development water balance at the swamp will be consistent with the existing condition.

Construction of the proposed road will result in no change to surface water levels in the TEC and CCW when compared to existing conditions.

4.2 Water quality impacts

Runoff from the proposed road will not discharge into the Cannington Swamp area. Therefore, any change in downstream water quality will not affect the TEC or CCW.

4.3 Groundwater impacts

The groundwater gradient across the site is quite flat (approximately 1:700) and sloped to the west as can be observed in Figure 4. This indicates that groundwater in the area flows slowly towards the Canning River. Additionally, compaction related to road and development construction is expected to be minimal as discussed in section 3.2. It is therefore considered highly unlikely that compaction related to the proposed mixed use developments and road will present any obstruction to these flows.

4.4 Flora/fauna and biodiversity impacts

Based on the City of Canning Structure Plan, land proposed for mixed use development is located outside of the boundaries of the Cannington swamp CCW and TEC.

Based on the flora and fauna investigations (Natural Area, 2016), the proposed Southern Link Road layout will impact 0.16 ha of the 5.8 ha threatened ecological community and 0.44 ha of the 6.71 ha conservation category wetland (Figure 7). These areas have been further reviewed by Ecoscape (2019) which found that the proposed works area contains:

- 0.12ha (8.81%) *Melaleuca lateritia*, *Astartea affinis* and *Viminaria juncea* mid shrubland over *Leptocarpus canus* and *Watsonia meriana* mid rushland/forbland
- 0.25ha (18.62%) *Viminaria juncea* tall shrubland over *Watsonia meriana* mid dense forbland

Vegetation (assessed as Completely Degraded, 'not native vegetation', 'rehab – Geraldton Wax' and 'not assessed' as it was not close to the mapped TEC) occupied the remaining 1.03ha (75.57%) of the works area as shown in Figure 15 (Ecoscape 2019).

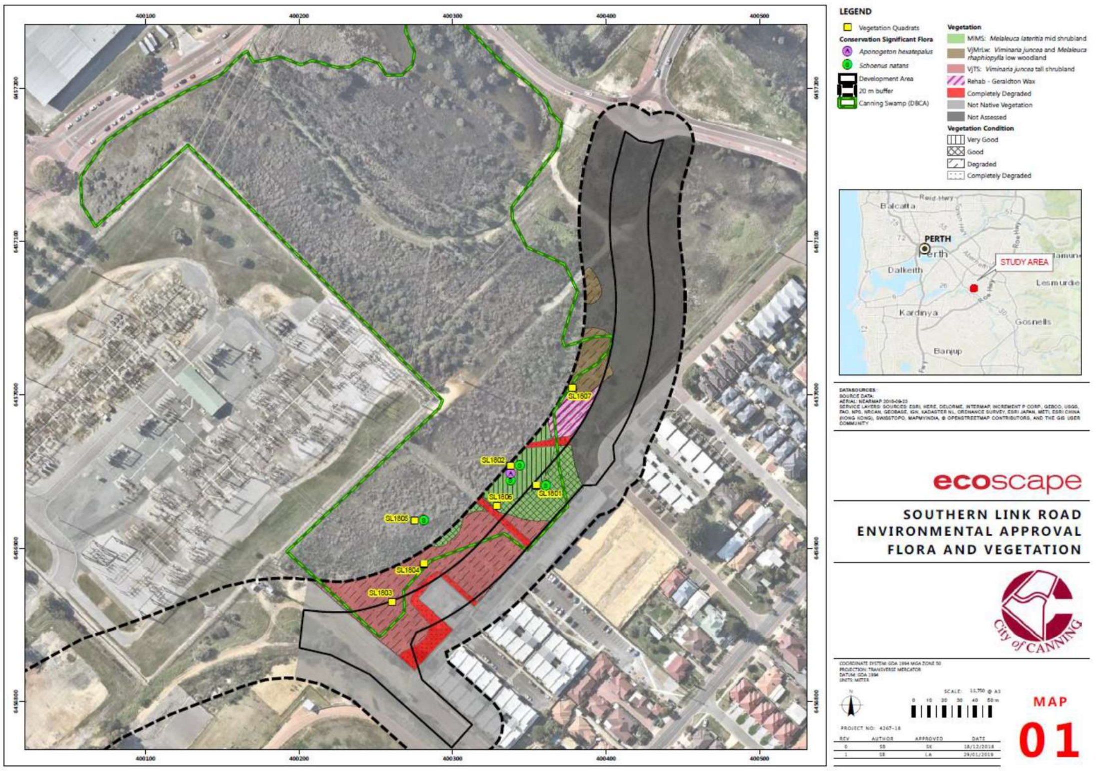


Figure 15: Flora and vegetation impact assessment (Ecoscape 2019)

Construction of the road has the potential to result in introduction of *Phytophthera Dieback* and weeds conveyed via construction vehicles and equipment. It will be necessary to manage this risk appropriately during construction.

Development of tall buildings in the surrounding area have potential to cast shade over areas of the wetland and TEC. Shade modelling should be required for design approvals to understand how the reduced sunlight may impact the wetland and TEC.

4.5 Risk of potential impacts

Table 11 provides the risk of potential impacts from the construction of the Southern Link Road and surrounding developments.

Table 11: Relative risk of impacts for construction of the Southern Link Road Stage 2

Potential impact	Relative risk
Excavation and filling works – impact on wetland hydrology and water levels	Low
Road and development drainage discharge treatment – impacts to downstream water quality	Low
Road and building compaction – impacts to groundwater flows/levels	Low
Clearing and physical disturbance – impact on flora/fauna and biodiversity values	Moderate
Introduction of *Phytophthera dieback* and/or weeds – impact on flora/fauna and biodiversity values;	Moderate
Overshadowing - impact on flora/fauna and biodiversity values	Low

4.5.1 Summary of recommendations

The following strategies are recommended to minimise the impact of the proposed road extension and development and have been considered as a part of the management plan:

- Retain the existing water quality at the swamp by at-source treatment of the first 15mm of rainfall from the additional developments and road reserves;
- Direct the runoff from the proposed road to the existing downstream drainage systems within the Cockram Street Main Drain catchment to maintain predevelopment hydrology and water levels. This will also minimise clearing and compaction extent within the wetland;
- Revegetation of the proposed road fill batters and streetscapes with selected locally native plants to ensure minimal impact to the swamp biodiversity values will reduce the impact of clearing on biodiversity values;
- Undertake weed and dieback controls and monitoring programs (if required) to maintain the existing and newly planted native species; and
- Implement development planning controls for drainage and water quality management and overshadowing.

4.6 Management of construction phase impacts

In addition to the long-term risks to the wetland previously discussed in this report, it is important to consider the short-term risks presented by construction activity at the wetland boundary. The following strategies are recommended for consideration in developing an appropriate construction environmental management plan:

- The proposed road alignment must be fenced to ensure all the construction traffic is restricted only within the road footprint with no disturbance to the wetland;
- Construction during periods of low groundwater is preferred to avoid requirements for any dewatering;
- Sediment fencing should be provided along the edge of the construction area to provide protection from wind and water borne sediment and construction materials;
- Construction during periods of low rainfall is preferred to avoid dispersal of sediment and construction materials into the wetland; and
- Temporary stockpiles should be located outside the wetland boundaries and contained by sediment fencing.

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APPENDIX A – CANNINGTON SWAMP SOIL AND HYDROGEOLOGICAL INVESTIGATIONS

Cannington Swamp Soil and Hydrogeological Investigations

July 2005

Woodman Environmental Consulting Pty Ltd

PARSONS BRINCKERHOFF

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Appendices

1. Introduction

Parsons Brinckerhoff (PB) was commissioned by Woodman Environmental Consulting Pty Ltd (Woodman Environmental) to carry out a hydrogeological and soil distribution investigation at Cannington Swamp, Cannington. The Cannington Swamp, owned by Western Power, is the site of the Cannington Substation which supplies power to Perth's South Eastern suburbs. Western Power wish to upgrade the linework associated with Cannington substation, requiring excavation into the swamp surface. This report details the hydrogeological and soil investigations at the swamp and the likely impact of the lineworks upgrade on the hydrogeological regime.

1.1 Scope of Works

The scope of works for field investigations at Cannington Swamp involved the excavation of bores and installation of temporary piezometers to enable:

- Mapping of the soil profile and distribution;
- Determination of the presence and extent of any Muchea Limestone soils;
- Determination of the presence and extent of any ironstone or ferricrete soils;
- Characterisation of the hydrogeological support mechanisms maintaining Cannington Swamp, particularly low permeability soils that may perch groundwater;
- Assessment of the likelihood of site works to compromise any low permeability soils present and identification of any potential impacts to groundwater dependent ecosystems that may result from site works; and,
- Consultation and agreement with relevant government authorities regarding the development (if required).

2. Field Investigations

2.1 Phase 1

The first phase of investigations carried out by PB included a shallow soil investigation in the northwest area of Cannington Swamp in February 2005, to:

- determine the presence and nature of silts and clays in the swamp that may potentially perch groundwater; and
- assess the hydrogeological impact, if any, of installation of power poles and stays into the swamp.

Field investigations included the following:

- Drilling of 8 boreholes in the vicinity of proposed pole installation sites.
- Logging the soil profile with particular emphasis on soil unit hydrogeological properties.
- Installation of temporary piezometers, slotted between 1.5 and 3.0 m below ground level.

Soil bores were drilled using a 76 mm diameter air core, truck-mounted drill rig. All bores were drilled to 3.0 m below ground level (the maximum depth of pole installation) and logged for geological and hydrogeological soil parameters. Water injection was used during air core drilling to assist penetration of the clay layers.

2.2 Phase 2

Phase 2 field investigations were carried out on May 11th and 12th, 2005. A site walkover revealed some ferricrete exposure along a drainage feature in the northwest part of the swamp, and some limestone gravel in spoil piles next to two power poles in the southwest. A soil bore was hand augured near C01 beside a power pole with limestone clasts in the spoil pile. Limestone gravel was encountered at a depth of approximately 1.5 m, suggesting that the limestone in the spoil pile originated from on-site excavations.

Eleven bores were drilled using air-core methods to characterise the thickness of the clay layer and assist in creating a generalised map of the sites soils, geology and hydrogeology. Drilling was carried out using a truck-mounted air-core drill rig. Every effort was made to minimise vegetation disturbance and drill sites were located on access tracks and cleared areas. Soil bore cuttings were removed from undisturbed sites and piezometers were installed as temporary completions that can be removed by hand once the investigation and monitoring has been completed. Bore locations are shown in Figure 1.

3. Investigation Results

3.1 Soil Profile and Distribution

The generalised soil profile is presented in Table 3.1 below and the lithological details are discussed in the following sections. A description of soil units encountered in each bore is presented in Table 3.2. Water levels, pH and electrical conductivity (EC) measured in piezometers are summarised in Table 3.3. Bore logs and piezometer construction details are included as Appendix A.

Table 3.1: Generalised Soil Profile

Depth Range	Lithology
0 - 5.5	Sandy Clay
1.5 - 4.5	Limestone Gravel
3.5 - 5.5	Chalky Clay
3 - 12	Interlayered Sand and Sandy-Clay
12 - 13	Black Clay
13 - 15	Sand with Calcareous Gravel and Shells

A map of the inferred surface distribution of soil units of interest is presented in Figure 2.

3.1.1 Sandy Clay

The general soil profile encountered in all bores at Cannington Swamp comprises 3.0 to 5.5 m thick sandy clay, underlain by sand and clay layers. The sandy clay is generally dry between 0.5 and 3.0 m, and is occasionally weakly cemented. A colour change is present in clays within the top 1.5 m of the interlayered sand – clay units; the clay is brown above the sandy layers and changing to dull green with depth, representing a change from oxidising to reducing conditions.

3.1.2 Limestone Gravels

Occasional limestone gravels were encountered in a sandy clay matrix in bores C01, 2, 6 and 7, between 1.0 and 4.5 mbgl. The gravel clasts are sub-angular to rounded and contain minor quartz sand fraction. The textural maturity, sparse occurrence, and differing composition from the sandy clay matrix suggest the limestone gravel was not formed in-situ but may have been deposited during flood events.

Table 3.2: Summary of Soil Profiles

		C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
Location (GDA)	Easting	400295	400238	400186	400231	400342	400363	400312	400440	400516	400453	400392
	Northing	6457081	6457089	6457137	6456881	6457148	6456982	6456932	6457044	6457123	6457158	6457080
		(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)	(mbgl)
Brown Sandy Clay		0.0-1.0	0.0-3.0	0.0-4.3	0.0-3.0	0.0-5.5	0.0-1.5	0.0-4.0	0.0-3.0	0.0-2.0	0.0-1.0	0.0-4.0
Calcareous gravel/grit horizon		1.0-3.5	3.0-4.0				1.5-4.5	4.0-4.5				
Chalky Clay		3.5-4.5		4.3-5.5						2.0-4.5	1.0-3.5	
Brown/orange Sandy Clay & Sand Lenses		4.5-5.0			3.0-8.0	5.5-7.4	4.5-6.0	4.5-6.0	3.0-6.0	4.5-6.0	3.5-4.5	4.0- >5.0
Dull green/blue Sandy Clay & Sand Lenses		5.0- >10.0	4.0- >5.5	5.5-12.0	8.0-10.5	7.4- >10.5	6.0- >10.5	6.0- >7.5	6.0- >7.5	6.0- >7.5	4.5- >6.0	
Black Clay				12.0-13.0								
Sand with some shells				13.0- >15.0								
Total Depth		10.0	5.5	15.0	15.0	10.5	10.5	7.5	7.5	7.5	6.0	5.0
Screened Section		5.5-9.5	3.5-5.5	8.0-12.0	5.2-9.2	4.0-8.0	6.5-10.5	3.5-7.5	3.5-7.5	3.5-7.5	2.0-6.0	3.0-5.0

Table 3.3: Bore Water Levels and Groundwater Chemistry

Bore	C01	C02	C03	C04	C05	C06	C07	C08	C09	C10	C11
Static Water Level*	1.37	1.83	1.57	1.93	2.27	1.75	1.98	1.85	1.71	1.02	1.23
pH*	7.45	7.29	7.17	7.98	7.56	7.91	7.92	7.30	8.25	7.68	7.16
EC (mS/cm)*	2.94	8.75	5.12	3.05	5.59	2.51	11.61	3.66	2.94	24.1	2.86

* Static Water Level, pH and EC were measured on the 10th of February 2005

3.1.3 Chalky Clays

A 1.0 to 2.5 m thick, soft chalky clay unit was intersected below 3.5 m in bores C01, 3, 9 and 10, and also encountered in bores BH3, 4, 5 and 6, excavated during Phase 1 investigations. The chalky clay contains coarse sand to granule cementations, which occasionally range to gravel and cobble size. It is considered that these cementations have formed in-situ, given the lack of detrital material in the clay matrix. It is inferred that the chalky clays were eroded from areas up-gradient and deposited at the site as over-bank fines or under waning current conditions, and may represent a former drainage course for tributaries to the Canning River.

3.1.4 Interlayered Sand/Sandy-Clays

The near surface sandy clay is underlain by a sequence of interlayered sand and sandy-clay and lenses, which increase in sand content with depth. The sandy lenses are generally medium to coarse grained and yielded small volumes of water during air-core drilling. The sandy-clay changes colour from brown or grey to dull green below 4.0 to 8.0 m.

3.1.5 Black Clay

Bores C03 and C04 were the only two bores drilled to 15.0 m during field investigations. C03 was the only soil bore that intersected units below the interlayered sand/dull-green clay. Black clay is present from 12.0 to 13.0 m, which in turn is underlain by a grey sandy unit containing some limestone cobbles and shelly material. It is anticipated that this soil type is laterally extensive and that black clay and sand is likely to underlie most of the study area.

3.2 Other Soil Units

3.2.1 Ferricrete/Ironstone

The extent of surficial ferricrete is inferred from the exposure identified along a drainage channel in the western part of the study area. Thin lenses of iron cemented sands in a sandy-clay matrix were present between 5.0 and 8.0 mbgl in bores C01, 4 and 5. Laterally extensive ferricrete layers were not encountered during drilling investigations.

Ferricrete hard-pan layers typically form in the zone of water table fluctuation through the accumulation and cementation of interstitial iron oxide silt and clays. The lithologies overlying the ferricrete, possibly Bassendean Sand, may have been eroded by alluvial or aeolian processes to leave the ferricrete exposed at the surface in the northwest of the site.

3.2.2 Muchea Limestone

A soil unit known as 'Muchea Limestone' is inferred to occur at the site. The distribution and nature of Muchea Limestone on the Swan Coastal Plain was researched to assist in identifying this unit at the site.

GSWA (1990) describes the Muchea Limestone as follows:

- marly limestone; in places algal laminated;
- overlies Guildford Formation;
- non-marine molluscs; Quaternary;
- lacustrine; and,
- some kankar development.

English and Blyth (2000) describes the Muchea Limestone as:

- frequently mounded up above the surrounding area and are likely to reflect areas of spring activity in the past, where carbonates have precipitated out of solution; and
- sandy black clay, or sandy clay soils are present on the limestone.

Two soil units containing limestone and/or calcareous material were encountered at the site:

- chalky clays; and,
- limestone gravels.

The limestone gravels appear to have a marly texture, consistent with the description of Muchea Limestone, but evidence of transportation, such as rounding and sorting, suggests that they have not formed in-situ. Black sandy-clay and sands containing molluscs were found approximately 8m beneath the limestone gravel horizon, although this is inconsistent with the description of English and Blyth (2000), which states that the black sandy clays are often found overlying the limestone.

The chalky clay contains small calcareous cementations within the clay matrix, which may have formed in-situ. Cementation within the clay is discontinuous and the soft chalky clay does not represent a calcrete or similar hard pan layer and there is no apparent evidence of mounding or carbonate precipitation from spring activity. Therefore, although containing significant calcareous material, the soft chalky clay is not considered to represent the Muchea Limestone, as described by GSWA (1990) or English and Blyth (2000).

The calcareous deposits intersected during drilling investigations at the Cannington Swamp are not consistent with the in-situ formation of Muchea Limestone, and it is apparent that the limestone gravels and chalky clays have been transported and deposited at the site through alluvial processes.

3.3 Site Hydrogeology

The Cannington Swamp wetland system is supported by a perched surficial water table. The site is bound on all sides by roads, with no surface runoff features to the swamp identified. Perching of rainfall occurs on the near surface sandy clay layer during the winter months. Areas of standing surface water were present at the site on May 12th due to overnight rainfall. It was observed that surface clays previously showing summer desiccation cracks had hydrated and swelled considerably after rainfall on May 11th.

The presence of a dry section of the soil profile between 0.5 and 3.0mbgl in bores C01, 3, 4, 6, and 7 demonstrates the hydraulic isolation of surface water from groundwater. A schematic diagram of the Cannington Swamp hydrogeology is presented in Figure 3.

Groundwater is present in discontinuous sandy lenses between 3.0 to 5.5m, forming confined to semi/confined aquifer conditions with residual pressure; groundwater levels in piezometers screened in the sand lenses are up to 5m above the top of the sands. The degree of hydraulic connectivity between the sand lenses is not apparent, however the thickness of sand intersected in some bores suggest that sand horizons may be laterally extensive.

The electrical conductivity (EC) of groundwater is brackish, ranging from 2.9 to 24.1mS/cm, which also suggests a limited hydraulic connection between sandy lenses. The hydraulic conductivity of the clays and silts is very low and it is likely that the EC of shallow groundwater has been elevated over time by concentration of salts in near surface clays through evaporation, combined with limited aquifer throughflow.

Regional groundwater throughflow is from northeast to southwest towards the Canning River, located approximately 700m to the southwest. Regional groundwater levels are inferred to be at or near ground surface at approximately 4mAHD, although development of the area for urban landuse by installation of drainage and importation of construction fill is considered to have increased the depth to groundwater.

A significant thickness of clay and silt perches surface water and groundwater at the site, and it is considered that site works involving excavation into the swamp surface will result in minimal impact to the hydrodynamics of the wetland. However, excavation that intersects sandy lenses may require dewatering and sealing to prevent upwelling of groundwater with elevated salinity.

4. Conclusions

The following conclusions have been drawn from site investigations at the Cannington Swamp;

- soils matching the description of Muchea Limestone were not intersected during this investigation;
- the calcareous deposits intersected during drilling investigations at the Cannington Swamp are not consistent with the in-situ formation of Muchea Limestone, and it is apparent that the limestone gravels and chalky clays have been transported and deposited at the site through alluvial processes;
- sandy clay encountered within the top 1.5m of all bores extended to the maximum depth of excavation of 3.0m in all bores;
- the general soil profile encountered in all bores at Cannington Swamp was 3.0 to 5.5 m of sandy clay, underlain by sand and clay layers;
- calcareous deposits encountered at the site include a sparse limestone gravel horizon between 1.0 and 4.5mbgl in a northwest - southeast band across the site, and a 1.0 to 2.5m thick chalky clay is present between 1.0 and 4.5mbgl in the eastern part of the swamp;
- some iron cemented clasts were identified, but no extensive ferricrete layers were encountered during drilling. A localised ferricrete layer is exposed at the surface in the northwest of the site;
- the wetland is maintained by perching of groundwater and surface water on a 3.0 – 5.5 m thick sandy clay layer;
- surface water inflow to the wetland is via direct rainfall recharge, and outflow is via surface drainage, evaporation and evapotranspiration;
- groundwater encountered at the site is generally brackish due to concentration of salts in near surface clays by evaporation;
- it is considered that site works involving excavation into the swamp surface will result in minimal impact to the hydrodynamics of the wetland. However, excavation that intersects sandy lenses may require dewatering and sealing to prevent upwelling of groundwater with elevated salinity.
- the installation of poles to a maximum depth of 3.0m in locations defined for the purpose of this investigation will not perforate the clay layer encountered on site and impacts to the hydrogeology of the swamp are considered to be negligible.

5. References

English. V, and Blyth. J, 2000. *Shrubland and Woodlands on Muchea Limestone. Interim Recovery Plan.*

Geological Survey of Western Australia, 1990. *Geology and Mineral Resources of Western Australia*

Legend

- Hand Auger Site
- Phase 1 Soil Bore
- Phase 2 Soil Bore

DRN: A.R May 2005 CHKD: G.F May 2005 DATUM: - SCALE: Not shown	Cannington Swamp Investigations Site Layout		PB 100 YEARS ® Figure 1 2142125A
	CLIENT: Woodman Environmental Consulting Pty Ltd.	REF: 2142125A\drawings\Site Layout.cdr	

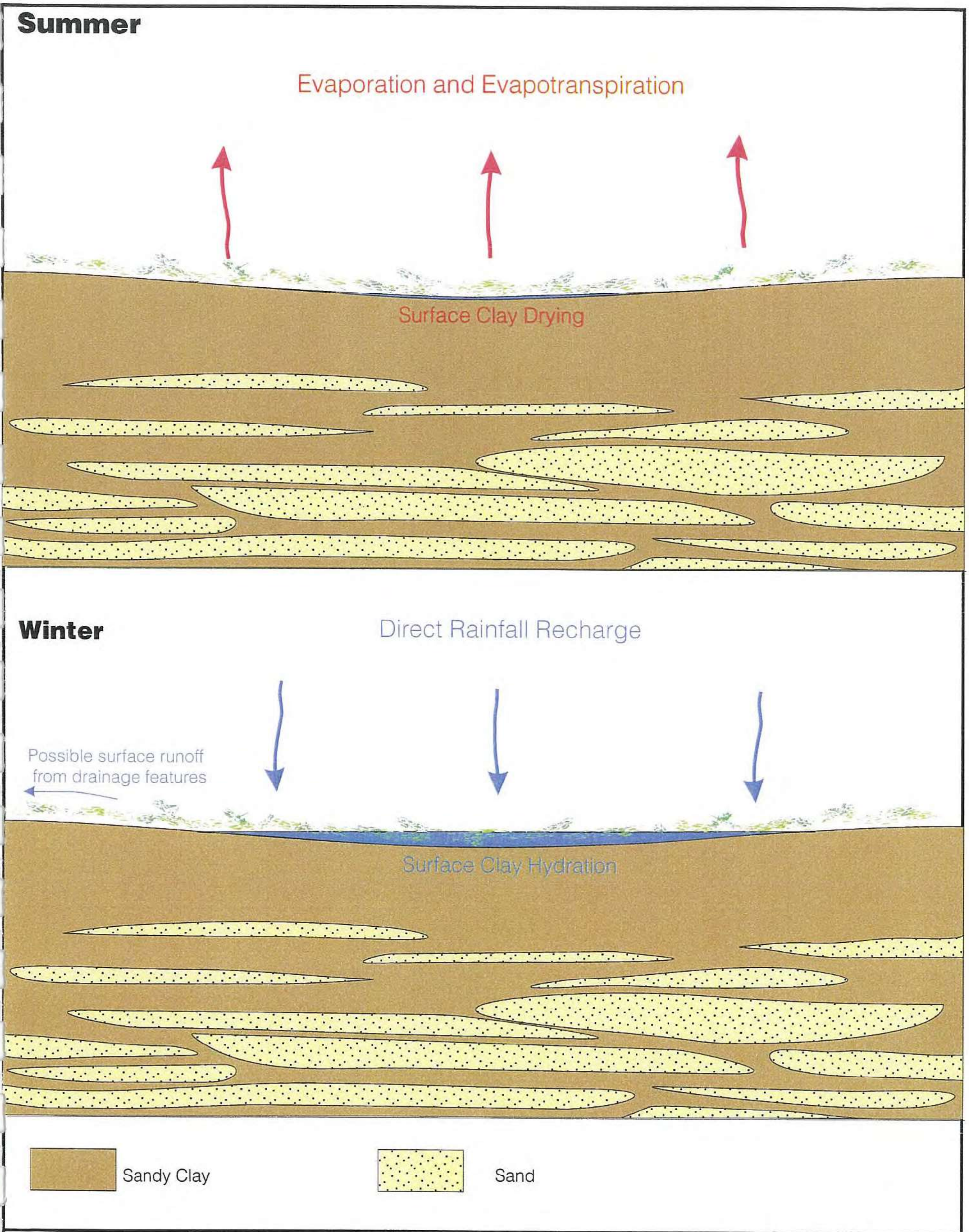
Legend

- Hand Auger Site
- Phase 1 Soil Bore
- Phase 2 Soil Bore

Inferred Distribution of:

- Calcareous Gravel
- Chalky-Clay Horizon
- Near-Surface Ferricrete

DRN: A.R May 2005 CHKD: G.F May 2005 DATUM: - SCALE: Not shown	Cannington Swamp Investigations Inferred Soil Distribution		PB 100 YEARS ® Figure 2 2142125A
	CLIENT: Woodman Environmental Consulting Pty Ltd.	REF: 2142125A\drawings\Soil Distribution.cdr	



DRN: A.R May 2005 CHKD: G.F May 2005 DATUM: - SCALE: Not shown	Carousel Swamp Investigations Schematic Hydrogeologic Mechanism for Carousel Swamp CLIENT: Woodman Environmental Consulting Pty Ltd. REF: 2142125A\drawings\Schematic.cdr	PB 100 YEARS Figure 3 2142125A

Appendix A

Test Pit Soil Bore Logs and
Piezometer Construction

PB 100 YEARS

TEST PIT ENVIRONMENTAL LOG

TEST PIT NO. **BH01**

SHEET 1 OF 1

Client:	**Woodman Environmental Consulting Pty Ltd**	Date Commenced:	**10/02/05**
Project:	**Carousel Swamp Investigations**	Date Completed:	**10/02/05**
Test Pit Location:	**Cannington**	Recorded By:	**GF**
Project Number:	**2142125A**	Log Checked By:	**GF**
Excavation Method:	**Air Core**	Surface RL:	
		Co-ords:	**E 400295 N 6457005 GDA**

Test Pit Information					Field Material Description						
1	2		3	4	5	6	7	8	9	10	11
WATER	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (KPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
		0.00–0.30					SAND: Surface Bassendean Sand.	D			
		0.30–1.50					SANDY CLAY: Dry hard clay, stiff sandy brown-orange with medium to high plasticity in clay fraction.				
		1.50–2.50					SANDY CLAY: Brown-grey, very stiff, poorly sorted sandy clay/clayey sands. Sand fraction is quartz and rock fragments, with minor quartz angular pebbles.	M (W from 2)			
		2.50–3.00					SANDY CLAY: As above, becoming brown-orange with large angular quartz and feldspar.				
		3					END OF TEST PIT AT 3.00 m				

Depth scale: 1, 2, 3

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH02

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	10/02/05
Project:	Carousel Swamp Investigations	Date Completed:	10/02/05
Test Pit Location:	Cannington	Recorded By:	GF
Project Number:	2142125A	Log Checked By:	GF

Excavation Method: Air Core

Surface RL:

Co-ords: E 400466 N 6457229 GDA

Test Pit Information				Field Material Description						
1	2	3	4	5	6	7	8	9	10	11
WATER	RL(m) DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
	0.00–1.50					GRAVELLY SAND: Road base / fill	D			
	1.50–3.00					SILTY CLAY: Soft grey with moderate plasticity, grading to light grey/brown and increasing in sand content with depth	M			
	3.00					END OF TEST PIT AT 3.00 m				

Depth scale: 1, 1.50, 2, 3

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

BH03

TEST PIT ENVIRONMENTAL LOG

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	10/02/05
Project:	Carousel Swamp Investigations	Date Completed:	10/02/05
Test Pit Location:	Cannington	Recorded By:	GF
Project Number:	2142125A	Log Checked By:	GF
Excavation Method:	Air Core	Surface RL:	
		Co-ords:	E 400492 N 6457199 GDA

Test Pit Information				Field Material Description						
1	2	3	4	5	6	7	8	9	10	11
WATER	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
							GRAVELLY SAND: Road base / fill				
	1.00	1					SANDY CLAY: Firm silty dark grey clay with minor sand				
	1.50						SANDY CLAY: Sandy base				
	2.00	2					GRAVELLY CLAY: Brown/ tan soft clay with some angular feldspar/quartz gravel				
		3					END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH04

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	10/02/05
Project:	Carousel Swamp Investigations	Date Completed:	10/02/05
Test Pit Location:	Cannington	Recorded By:	GF
Project Number:	2142125A	Log Checked By:	GF

Excavation Method:	Air Core	Surface RL:	
		Co-ords:	E 400509 N 6457187 GDA

Test Pit Information					Field Material Description					
1	2	3	4	5	6	7	8	9	10	11
WATER	RL(m) DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S FB F VL L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
	0.00 – 0.50					CLAYEY SAND: Organic content.				
	0.50 – 1.50					SANDY CLAY: Orange firm clays with some coarse sand grains.				
	1.50 – 3					SANDY CLAY: Very soft cream gritty clay with angular very coarse grains present.				
	3					END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH05

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	10/02/05
Project:	Carousel Swamp Investigations	Date Completed:	10/02/05
Test Pit Location:	Cannington	Recorded By:	GF
Project Number:	2142125A	Log Checked By:	GF
Excavation Method:	Air Core	Surface RL:	
		Co-ords:	E 400577 N 6457251 GDA

Test Pit Information				Field Material Description						
1	2		3	4	5	6	7	8	9	10	11
WATER	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
		0.00					FILL: Sandy/ gravelly.				
	1.00	1					SANDY CLAY: Soft cream clay with sand as in BH4.				
	1.50						SANDY CLAY: Soft cream to pale brown clay with sand as in BH4.				
		3					END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH06

SHEET 1 OF 1

Client:	**Woodman Environmental Consulting Pty Ltd**	Date Commenced:	**10/02/05**
Project:	**Carousel Swamp Investigations**	Date Completed:	**10/02/05**
Test Pit Location:	**Cannington**	Recorded By:	**GF**
Project Number:	**2142125A**	Log Checked By:	**GF**

Excavation Method: **Air Core**

Surface RL:

Co-ords: **E 400595 N 6457184 GDA**

Test Pit Information				Field Material Description						
1	2		3	4	5	6	7	8	9	10	11
WATER	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
		0.10					SAND: Medium to coarse brown sand with organics.				
		1.30					SANDY CLAY: Cream to pale brown soft gritty clay.				
	2.00	2					SANDY CLAY: Dark grey/ blue, stiff clay with some sand content.				
		3					SANDY CLAY: Pale brown sand with some clay. Moderately stiff.				
							END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH07

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	10/02/05
Project:	Carousel Swamp Investigations	Date Completed:	10/02/05
Test Pit Location:	Cannington	Recorded By:	GF
Project Number:	2142125A	Log Checked By:	GF

Excavation Method: Air Core

Surface RL:

Co-ords: E 400436 N 6457260 GDA

Test Pit Information				Field Material Description						
1	2	3	4	5	6	7	8	9	10	11
WATER	RL(m) DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
	0–1.00					SANDY CLAY: Brown clay with sand. Moderately firm.				
	1.00 1 – 2					SANDY CLAY: Sandy matrix with high clay content increasing with depth.				
	2.00 2 – 3					CLAY: Pale brown moderately soft clay.				
	3					END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

TEST PIT NO.

TEST PIT ENVIRONMENTAL LOG

BH08

SHEET 1 OF 1

Client:	**Woodman Environmental Consulting Pty Ltd**	Date Commenced:	**10/02/05**
Project:	**Carousel Swamp Investigations**	Date Completed:	**10/02/05**
Test Pit Location:	**Cannington**	Recorded By:	**GF**
Project Number:	**2142125A**	Log Checked By:	**GF**

Excavation Method: **Air Core**

Surface RL:

Co-ords: **E 400316 N 6457119 GDA**

Test Pit Information				Field Material Description						
1	2		3	4	5	6	7	8	9	10	11

1 WATER	2 RL(m)	2 DEPTH(m)	3 FIELD TEST	4 SAMPLE	5 GRAPHIC LOG	6 USC SYMBOL	7 SOIL/ROCK MATERIAL FIELD DESCRIPTION (SOIL NAME; plasticity/grain size, colour, particle shape, secondary components, minor constituents, moisture, relative density/consistency) (ROCK NAME; grain size, colour, weathering, strength, minor constituents)	8 MOISTURE	9 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H FB VL L MD D VD	10 HAND PENETROMETER (kPa)	11 STRUCTURE AND ADDITIONAL OBSERVATIONS (Defects - depth, type, orientation, spacing, planarity, roughness, thickness, coating)
							SANDY CLAY: Orange clay with sand.				
	0.50						SANDY CLAY: Orange clay with sand. Moderately firm.				
	1.00	1					SANDY CLAY: Very firm pale brown/ orange clay with sand.				
	2.00	2					SANDY CLAY: Moderately soft, pale brown clay with sand.				
	2.50						CLAY: Gritty soft pale brown clay.				
		3					END OF TEST PIT AT 3.00 m				

This test pit log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C01**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	11/05/05
Project:	Carousel Swamp Investigations	Date Completed:	11/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400295 N 6457081 GDA

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE) — **Field Material Description** (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY: VS S F ST VST H / FB VL L MD D VD, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water: ▼ 10/02/05 (at approx. 1.40 m)

Depth (m)	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE
0.00–1.00	Sandy Clay; Dull brown, stiff sandy clay. Sand is fine to medium grained quartz.	M / D
1.00–1.40	Sandy Clay; Pale yellow/brown, stiff sandy clay with some rare calcareous granule sized chips.	D
1.40–3.50	Sandy clay as above with occasional calcareaous gravel. Clay is softer and gravel pieces are up to cobble size.	M
3.50–4.50	Clay; Cream, soft, highly plastic clay with medium grained sand. Some rare marly calcareous chips and hard dry cobbles. Slightly green colour.	
4.50–5.00	Sandy Clay; Navy grey, soft clay with fine to medium grained sand. Dry clay and wet sand suggest lenses of sand within the clay.	W
5.00–8.00	Sandy Clay; Grey-dull green mottled stiff clay with sandy lenses. Occasional quartz granules present.	
8.00–9.00	Partially Cemented Sand; Pale brown sand, iron cemented in places, with interstitial silt/clay.	
9.00–10.00	Sand; Pale brown silty sand. Some cacareous cemented clasts up to 4cm.	
10.00	END OF BOREHOLE AT 10.00 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C02**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	11/05/05
Project:	Carousel Swamp Investigations	Date Completed:	11/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: **Air Core** Driller: **Proline Drilling** Surface RL:

Borehole Diameter: **76 mm** Driller Lic No: Co-ords: **E 400238 N 6457089 GDA**

Water level: 10/02/0

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–0.50	Sandy Clay; Dull brown, stiff sandy clay. Sand is fine to medium grained quartz.	M
0.50–2.50	Clay with Sand; Cream/yellow clay with medium to fine grained sand. Gravelly hard dry clasts. Some orange mottling.	
2.50–3.00	Clay with Sand; Grey, stiff clay with some sand content.	
3.00–4.00	Clay with Sand; Brown, soft clay with some medium grained sand. Some calcareous gravel pieces.	
4.00–4.50	Clay with Sand; Dull green clay with some medium grained sand.	
4.50–5.50	Clay with Sand; Dull green-brown mottled clay with sandy lenses.	W
5.50	END OF BOREHOLE AT 5.50 m	

Columns: 1 Method, 2 Support, 3 Water, 4 Well Construction, 5 RL(m) / Depth(m), 6 Field Test, 7 Sample, 8 Graphic Log, 9 USC Symbol, 10 Soil/Rock Material Field Description, 11 Moisture, 12 Relative Density/Consistency (VS, S, F, ST, VST, H / VL, L, MD, D, VD, FB), 13 Structure and Additional Observations

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C03**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	11/05/05
Project:	Carousel Swamp Investigations	Date Completed:	11/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400186 N 6457137 GDA

Water level: 10/02/05

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–0.50	Sandy Clay; Brown stiff sandy clay.	M
0.50–2.00	Clay with Sand; Pale brown clay with some medium grained sand. Sometimes weakly indurated.	D
2.00–3.50	Clay with Sand; Orange/brown soft clay with some sand.	M
3.50–4.30	Clay with Sand; Brown clay with some sand.	
4.30–5.50	Chalky Clay; White calcareaous clay, with medium grained sand. Sometimes weakly indurated.	W
5.50–7.00	Clay with Sand; Dull green clay with some fine grained sand. Lenses of medium to coarse grained, sub angular to sub rounded sand present.	
7.00–9.00	Clay with Sand; Dull brown clay with sand lenses as above.	
9.00–12.00	Clay with Sand; Dull green-brown mottled clay with some fine sand and quartz granules. Some sandy lenses present. Dull green/blue clay, some fine sand. Medium to coarse grained sandy layers with clay lenses as above.	
12.00–13.00	Clay; Black, stiff clay of low plasticity.	
13.00–14.50	Sand; Pale grey fine to coarse grained quartz sand with occasional limestone cobbles.	
14.50–15.00	Sand; Pale grey fine to granule grainsize quartz sand with shell fragments up to 1.0cm.	
15.00	END OF BOREHOLE AT 15.00 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C04**

SHEET 1 OF 1

Client:	**Woodman Environmental Consulting Pty Ltd**	Date Commenced:	**11/05/05**
Project:	**Carousel Swamp Investigations**	Date Completed:	**11/05/05**
Borehole Location:	**Cannington**	Recorded By:	**AR**
Project Number:	**2142125a**	Log Checked By:	**GF**

Drill Model/Mounting: **Air Core** Driller: **Proline Drilling** Surface RL:

Borehole Diameter: **76 mm** Driller Lic No: Co-ords: **E 400231 N 6456881 GDA**

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE) — **Field Material Description** (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H FB VL L MD D VD, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water level: 10/02/05 (approx. 1.8 m)

DEPTH(m)	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE
0.00–1.00	Clayey Sand; Brown clayey sand, sometimes weakly indurated.	M
1.00–2.50	Sandy Clay; Pale brown sandy clay, sometimes weakly indurated. Some iron staining.	D
2.50–5.00	Sandy Clay; Red-grey mottled sandy clay. Sometimes weakly indurated. Some white mottling from 3.0 to 3.5m.	M / W
5.00–6.50	Sandy Clay; Red-grey mottled sandy clay with gritty iron cementations.	
6.50–7.50	Clay with Sand; Yellow/brown clay with some red/brown sand lenses.	
7.50–8.00	Sand with Clay; Pale brown medium to coarse grained quartz and iron oxide sand with some pale grey/blue stiff sandy clay layers.	
8.00–10.50	Sandy Clay; Dull grey/green sandy clay with some sandy lenses. Clay has a high fine sand content.	
10.50–11.00	Sand; Yellow/brown, fine to medium, sub angular to sub rounded sand with some iron cemented gravel up to 2.0cm and some minor silt.	
11.00–12.00	Sand with Clay; Brown/red fine grained quartz and iron oxide sand with some iron cemented gravel and clay content.	
12.00–15.00	Sand; Brown, fine to coarse grained sand with some silt. Coarser grainsize with depth and greener colour.	
15.00	END OF BOREHOLE AT 15.00 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C05**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400508 N 6457115 GDA

Borehole Information / Field Material Description

Columns: 1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) DEPTH(m), 6 FIELD TEST, 7 SAMPLE, 8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY (VS S F ST VST H / FB VL L MD D VD), 13 STRUCTURE AND ADDITIONAL OBSERVATIONS

Water level: 10/02/0

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00	Sandy clayey fill material.	M
1.00	Clay with Sand; Pale grey clay with some medium grained sand. Sometimes weakly indurated.	
3.00	Clay with Sand; Very pale grey, soft clay with some orange, medium to coarse grained sandy lenses. Greater sand content with depth.	
5.50	Sand with Clay; As above, dominantly sand with minor clay.	W
6.50	Clay; Brown clay with minor sand. Sometimes weakly indurated.	
7.40	Clay with Sand; Dull green sandy clay with some medium to corase grained sandy lenses and angular iron cementations up to 3cm.	
8.00	Sand; Pale brown, medium to coarse grained sand with minor clay/silt.	
10.50	END OF BOREHOLE AT 10.50 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C06**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core   Driller: Proline Drilling   Surface RL:

Borehole Diameter: 76 mm   Driller Lic No: Co-ords: E 400363 N 6456982 GDA

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–1.50	Sand; Brown, fine to coarse grained sand with some clay.	M
1.50–2.50	Sandy Clay; Brown-red mottled stiff sandy clay with some iron cementation. Occasional calcareaous white gravel pieces.	D
2.50–3.50	Clay with Sand; Grey-brown, stiff clay with some sand content.	M
3.50–6.00	Sandy Clay; Grey-brown sandy clay as above with limestone pieces up to 5cm. No limestone present.	
6.00–7.00	Clay with Sand; Layers of blue-brown mottled clay and sand.	W
7.00–8.50	Clay with Sand; Layers of blue/green stiff clay and medium to coarse grained sand.	
8.50–9.00	Sand; Brown/green, medium to coarse grained sand with some thin greenish clay layers.	
9.00–10.50	Sand and Indurated Clay; Brown, medium to coarse grained sand and weakly indurated dark grey clay layers.	
10.50	END OF BOREHOLE AT 10.50 m	

Water level: 10/02/05

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C07**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core | Driller: Proline Drilling | Surface RL:

Borehole Diameter: 76 mm | Driller Lic No: | Co-ords: E 400312 N 6456932 GDA

RL(m)	DEPTH(m)	WATER	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE
	0		Fill; Brown sandy, clayey fill.	M
1.00	1		Clay; Pale brown clay, sometimes weakly indurated.	D
	2	10/02/0		
	3		Some red mottling.	W
4.00	4		Clay; Pale brown clay, sometimes weakly indurated, occasional pieces of calcareous gravel.	
4.50			Clay with Sand; Brown-pale grey mottled clay layers and some fine to medium grained sand layers.	
6.00	6		Clay with Sand; Dull green clay with sand, darker colour with depth.	
7.50			END OF BOREHOLE AT 7.50 m	

Columns: 1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE, 8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY (VS S F ST VST H / FB VL L MD D VD), 13 STRUCTURE AND ADDITIONAL OBSERVATIONS

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO.
C08
SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core — Driller: Proline Drilling — Surface RL:
Borehole Diameter: 76 mm — Driller Lic No: — Co-ords: E 400440 N 6457044 GDA

Borehole Information							Field Material Description					
1	2	3	4	5		6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	WELL CONSTRUCTION	RL(m)	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / FB VL L MD D VD	STRUCTURE AND ADDITIONAL OBSERVATIONS
				0.50						Fill; Brown sandy, clayey fill.	M		
				1.00	1					Clay; Brown, stiff clay with some sand.			
		10/02/05		1.50						Clayey Sand; Brown clayey sand, some iron cementation.			
					2					Clay with Sand; Pale brown/pink clay, sometimes weakly indurated. Some fine to medium grained sand lenses.			
				3.00	3					Sandy Clay; Pale grey, stiff clay. Orange, medium to coarse grained sand lenses.			
				6.00	6					Sandy Clay; Dull blue green clay and orange sand lenses.	W		
				7.50						END OF BOREHOLE AT 7.50 m			

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C09**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core — Driller: Proline Drilling — Surface RL:

Borehole Diameter: 76 mm — Driller Lic No: — Co-ords: E 400516 N 6457123 GDA

RL(m)	Depth (m)	Water	Moisture	Soil/Rock Material Field Description	Structure and Additional Observations
	0.00–2.00	Water level 10/02/05	M	Sandy Clay; Dark brown, to pale brown soft sandy clay. Sand is fine to medium grained sand.	
2.00	2.00–4.00			Chalky Clay; Cream calcareous clay. Sometimes moderately indurated. Pale brown colour.	
4.00	4.00–4.50			Chalky Clay; Pale brown calcareous clay with some fine grained orange sand.	
4.50	4.50–6.00		W	Sand with Clay; Brown, fine to medium grained sand with some clay.	
6.00	6.00–7.50			Clay with Sand; Dull green/blue, stiff clay with sandy lenses.	
7.50	7.50			END OF BOREHOLE AT 7.50 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C10**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core | Driller: Proline Drilling | Surface RL:
Borehole Diameter: 76 mm | Driller Lic No: | Co-ords: E 400453 N 6457158 GDA

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE)

Field Material Description (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H FB VL L MD D VD, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water	Depth (m)	Soil/Rock Material Field Description	Moisture
	0.00–1.00	Clay; Brown, soft clay with minor fine to medium grained sand.	M
10/02/0	1.00–2.50	Chalky Sandy Clay; Cream calcareous clay. Sometimes moderately indurated.	
	2.50–3.50	Chalky Sandy Clay; Pale brown calcareous clay. Somtetimes moderately indurated. Some fine grained sand.	
	3.50–5.50	Sand; Pale brown, fine to coarse grained sand with some clay.	W
	5.50–6.00	Sand; Pale brown, fine to coarse grained sand with some dull green clay.	
	6.00	END OF BOREHOLE AT 6.00 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C11**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core — Driller: Proline Drilling — Surface RL:

Borehole Diameter: 76 mm — Driller Lic No: — Co-ords: E 400392 N 6457080 GDA

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–2.00	Sandy Clay; Brown-orange mottled, stiff sandy clay.	M
2.00–2.50	Sandy Clay; Red-grey, sometimes white mottled, stiff sandy clay.	
2.50–3.00	Sandy Clay; Pale brown, stiff sandy clay. Sometimes weakly indurated.	
3.00–4.00	Sandy Clay; Red-brown-grey mottled, stiff sandy clay.	
4.00–4.50	Clayey Sand; Grey, clayey fine grained sand.	
4.50–5.00	Caly with Sand; Pale grey, stiff clay with some sand.	W
5.00	END OF BOREHOLE AT 5.00 m	

Water level: 10/02/0

Column headings: 1 Method; 2 Support; 3 Water; 4 Well Construction; 5 RL(m), Depth(m); 6 Field Test; 7 Sample; 8 Graphic Log; 9 USC Symbol; 10 Soil/Rock Material Field Description; 11 Moisture; 12 Relative Density /Consistency (VS S F ST VST H / FB VL L MD D VD); 13 Structure and Additional Observations

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

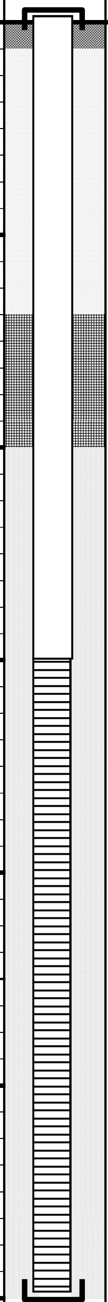
APPENDIX B – MONITORING BORE LOGS

BOREHOLE LOG

Bore ID: CS-U1

CLIENT: Western Power/CoC
PROJECT: Cannington TEC
LOCATION: Canning
CONTRACTOR: eDrill
DATE COMMENCED: 16/06/2017
DATE COMPLETED: 16/06/2017
LOGGED BY: AT
INSTALLATION METHOD: Rotary drill

HORIZONTAL DATUM: GDA94 Zone 50
EASTING:
NORTHING:
R.L. SURFACE (m AHD):
TOTAL DEPTH (m): 6
DIAMETER (mm): 50



Depth BGL (m)	Sample Taken	Water	Graphic log	Lithology	Observations
				0-0.5 mBGL: Sandy Clay, brown/black, Medium grained, damp	
				0.5-1 mBGL: Clay, red/brown, Medium grained, moderately sorted, damp	
1.0				1-2.5 mBGL: Silty Sand, Yellow/brown, fine grained, well sorted, damp	
2.0					
				2.5-4.5 mBGL: Sandy clay, brown/grey, fine grained, moderately sorted, damp/wet	
3.0					
4.0		▽			
				4.5-6 mBGL: Sandy clay, yellow, fine, well sorted, wet	
5.0					
6.0					

NOTE:

- Monitor Well Screen
- Gravel Pack
- Bentonite Layer
- Sand Fill
- Cement Grout
- ▽ Water encountered

BOREHOLE LOG

Bore ID: CS-U2

CLIENT: Western Power/CoC
PROJECT: Cannington TEC
LOCATION: Canning
CONTRACTOR: eDrill
HORIZONTAL DATUM: GDA94 Zone 50
EASTING:
NORTHING:

DATE COMMENCED: 16/06/2017
DATE COMPLETED: 16/06/2017
LOGGED BY: AT
INSTALLATION METHOD: Rotary drill
R.L. SURFACE (m AHD):
TOTAL DEPTH (m): 6
DIAMETER (mm): 50

Depth BGL (m)	Sample Taken	Water	Graphic log	Lithology	Observations
				0-0.5 mBGL: Clay, red/yellow/brown, fine grained, well sorted, damp	
				0.5-1 mBGL: gravelly clay, red, fine grained, moderately sorted, dry	
1.0				1-2 mBGL: clay, brown, fine grained, well sorted, damp	
2.0				2-3.5 mBGL: Clay, red/brown, fine grained, well sorted, wet	
3.0					
		▽		3.5-5.5 mBGL: clayey sand, brown/grey, fine grained, moderately sorted, wet	
4.0					
5.0					
				5.5-6 mBGL: clayey sand, grey, medium grained, moderately sorted, saturated	
6.0					

NOTE:

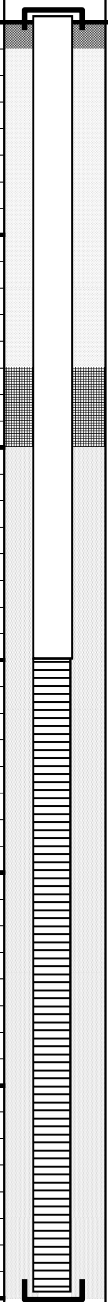
- Monitor Well Screen
- Gravel Pack
- Bentonite Layer
- Sand Fill
- Cement Grout
- ▽ Water encountered

BOREHOLE LOG

Bore ID: CS-U3

CLIENT: Western Power/CoC
PROJECT: Cannington TEC
LOCATION: Canning
CONTRACTOR: eDrill
DATE COMMENCED: 16/06/2017
DATE COMPLETED: 16/06/2017
LOGGED BY: AT
INSTALLATION METHOD: Rotary drill

HORIZONTAL DATUM: GDA94 Zone 50
EASTING:
NORTHING:
R.L. SURFACE (m AHD):
TOTAL DEPTH (m): 6
DIAMETER (mm): 50

Depth BGL (m)	Sample Taken	Water	Graphic log	Lithology	Observations
				0-1 mBGL: sandy clay, grey, medium grained, moderately sorted, damp	
1.0				1-4 mBGL: Silty clay, yellow, medium grained, moderately sorted, damp	
2.0					
3.0					
4.0		▽		4-6 mBGL: Silty clay, yellow, fine grained, well sorted, wet	Solid rocky layer encountered at ~ 4m
5.0					
6.0					

NOTE:

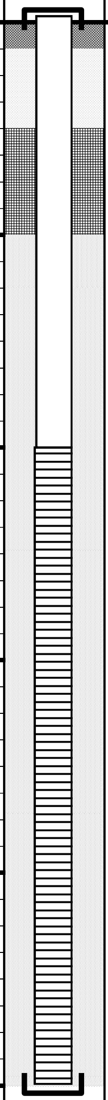
- Monitor Well Screen
- Gravel Pack
- Bentonite Layer
- Sand Fill
- Cement Grout
- ▽ Water encountered

BOREHOLE LOG

Bore ID: CS-U6

CLIENT: Western Power/CoC
PROJECT: Cannington TEC
LOCATION: Canning
CONTRACTOR: eDrill
HORIZONTAL DATUM: GDA94 Zone 50
EASTING:
NORTHING:

DATE COMMENCED: 16/06/2017
DATE COMPLETED: 16/06/2017
LOGGED BY: AT
INSTALLATION METHOD: Rotary drill
R.L. SURFACE (m AHD):
TOTAL DEPTH (m): 5
DIAMETER (mm): 50

Depth BGL (m)	Sample Taken	Water	Graphic log	Lithology	Observations
				0-0.5 mBGL: Sand. Brown/grey, medium grained, moderately sorted, damp	
				0.5-1 mBGL: sandy clay, grey, medium grained, moderately sorted, damp	
1.0				1-3 mBGL: Clay, yellow/brown, fine grained, well sorted, wet	
2.0					
3.0		▽		3-5 mBGL: silty sand, yellow, medium grained, moderately sorted, saturated	
4.0					
5.0					
6.0					

NOTE:

- Monitor Well Screen
- Gravel Pack
- Bentonite Layer
- Sand Fill
- Cement Grout
- ▽ Water encountered

LITHOLOGICAL LOG

JDA

Client:	Hurlingham Estates Pty Ltd	Job No:	J4906
Project:	Cannington: Lake St Wetland, 2011	Hole commenced:	6/05/2011
Bore location:	400245mE 6457266mN	Hole completed:	6/05/2011
Datum:	GDA94 MGA50	Logged by:	CAB
Bore Name:	CW1 (S & D)	Total Depth:	7.5mbNS(D) 3.7mbNS(S)
Drill type:	Hollow Auger	R.L. TOC:	4.88mAHD(D) 4.88mAHD(S)
Hole diameter:	150mm	Natural Surface:	4.28mAHD(D) 4.28mAHD(S)

LITHOLOGICAL LOG

Depth (m)	BORE CONSTRUCTION	GRAPHICAL LOG	LITHOLOGY	COLOUR	GRAIN SIZE	SORTING	GRAIN SHAPE	OTHER
0.5m	Bentonite seal		sandy clay	grey	fine-medium	well-moderate	rounded	
1.0m			clay	grey	fine			
1.5m			sandy clay	light brown	medium	well	rounded	with small limestone fragments <5mm
2.0m			sandy clay	light brown [light grey CW1(S)]	fine-medium [medium CW1(S)]	well-moderate	rounded	
2.5m	Gravel pack		sandy clay	light brown-grey	fine-medium	well-moderate	rounded	
3.0m	50mm PVC slotted							
3.5m	CW1(S)		sandy "clay"	light brown	fine-medium	well-moderate	rounded	softer to drill moist
4.0m			sandy clay	light brown	fine	well-moderate	rounded	moist
4.5m								
5.0m								
5.5m								
6.0m	Gravel pack							thin hard layer?
			sandy clay	light brown	fine	well-moderate	rounded	not confining
6.5m	50mm PVC slotted							
7.0m								
7.5m	CW1(D)							EOH

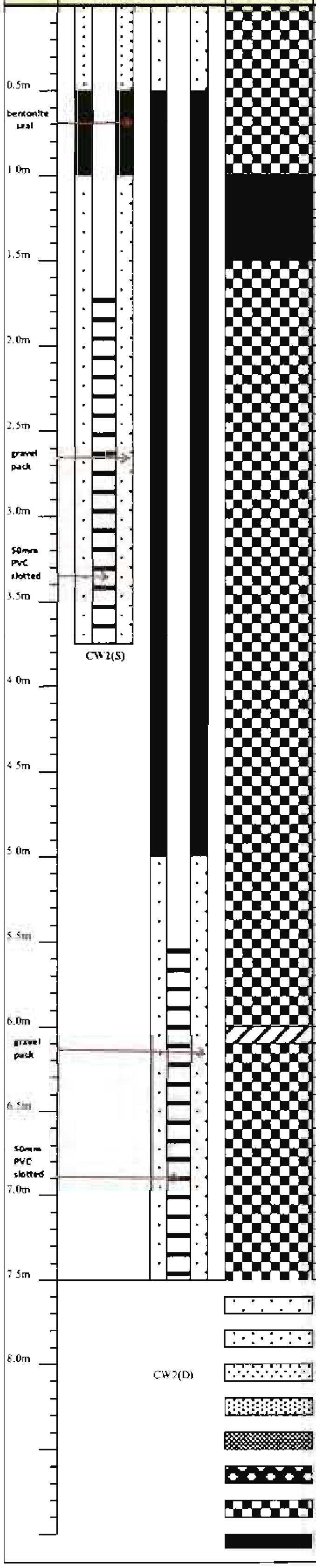
Sand
Loamy sand
Sandy Loam
Loam
Sandy Clay Loam
Clay Loam
Sandy Clay
Clay

Grain Size	Sorting	Grain
f - fine	p - poorly	a - angular
m - medium	m - moderately	suba - subangular
c course	w - well	subr - subrounded
v.c - very course		r - rounded
g - gravel		wr - well rounded

JDA Consultant Hydrologists
Suite 1, 27 York Street
Subiaco WA 6008
Tel: [illegible]
Fax: [illegible]

LITHOLOGICAL LOG

Client:	Hurlingham Estates Pty Ltd	Job No:	J4906
Project:	Cannington: Lake St Wetland, 2011	Hole commenced:	6/05/2011
Bore location:	400240mE 6457239mN	Hole completed:	6/05/2011
Datum:	GDA94 MGA50	Logged by:	CAB
Bore Name:	CW2 (S & D)	Total Depth:	8.0mbNS(D) 3.7mbNS(S)
Drill type:	Hollow Auger	R.L. TOC:	4.80mAHD(D) 4.71mAHD(S)
Hole diameter:	150mm	Natural Surface:	4.20mAHD(D) 4.11mAHD(S)



Depth (m)	LITHOLOGY	COLOUR	GRAIN SIZE	SORTING	GRAIN SHAPE	OTHER
0.0	sandy clay	light grey	fine-medium	well	rounded	
1.0	clay	light grey	fine			with small [illegible] present
1.5	sandy clay	light grey	fine - medium	well	rounded	
2.0	sandy clay	light brown	fine-medium	well	rounded	soft/moderately moist
2.5	sandy clay	light brown	fine-medium	well	rounded	moist
3.0	sandy clay	green	fine	well	rounded	moist
4.5	sandy clay	light brown	fine	well-moderate	rounded	moist
5.0	sandy clay	light brown	fine	well-moderate	rounded	thin hard layer? not confining
6.0	sandy clay	light brown	fine	well - moderately	rounded - subrounded	
8.0						EOH

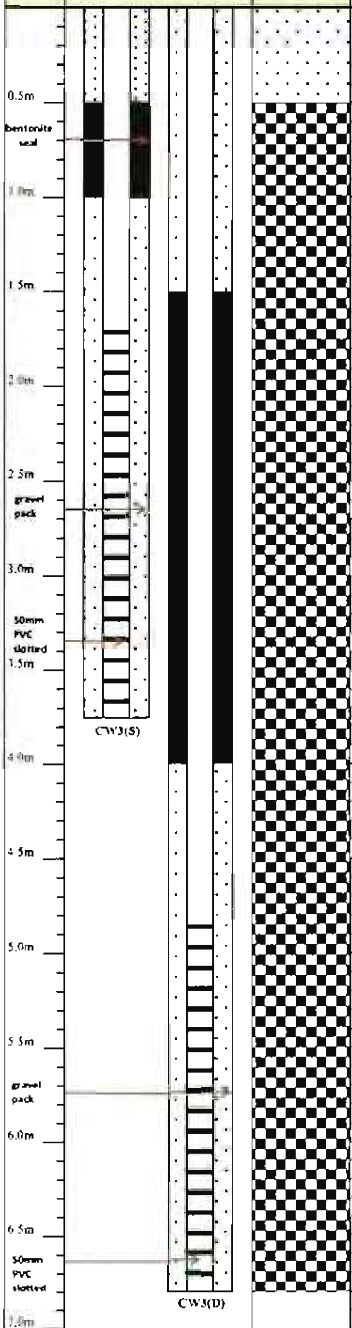
Sand
Loamy sand
Sandy Loam
Loam
Sandy Clay Loam
Clay Loam
Sandy Clay
Clay

Grain Size	Sorting	Grain Shape
f - fine	p - poorly	a - angular
m - medium	m - moderately	suba - subangular
c - coarse	w - well	subr - subrounded
v.c - very coarse		r - rounded
g - gravel		wr - well rounded

JDA Consultant Hydrologists

LITHOLOGICAL LOG

Client:	Hurlingham Estates Pty Ltd	Job No:	J4906
Project:	Cannington: Lake St Wetland, 2011	Hole commenced:	6/05/2011
Bore location:	400233mE 6457203mN	Hole completed:	6/05/2011
Datum:	GDA94 MGA50	Logged by:	CAB
Bore Name:	CW3 (S & D)	Total Depth:	6.8mbNS(D) 3.7mbNS(S)
Drill type:	Hollow Auger	R.L. TOC:	4.89mAHD(D) 4.91mAHD(S)
Hole diameter:	150mm	Natural Surface:	4.29mAHD(D) 4.31mAHD(S)



LITHOLOGICAL LOG

Depth (m)	LITHOLOGY	COLOUR	GRAIN SIZE	SORTING	GRAIN SHAPE	OTHER
0.0m	sand	yellow/orange	fine	well	rounded	
0.5m	Clayey sand	orange/brown	fine - course	moderately	rounded	lateric profile
1.0m	Clayey sand	orange/brown	fine-course	moderately	rounded	with small gravelly chunks <0.5cm
1.5m						
2.0m						
2.5m						
2.7m	Sandy Clay	red/brown	fine	well	rounded	moist
3.0m						
3.5m						
4.0m	sandy clay	grey	fine	well	rounded	moist
4.5m	sandy clay	grey/green	fine	well	rounded	moist
5.0m	sandy clay	grey	fine - medium	well - moderately	rounded	saturated
5.5m						
6.0m						
6.5m						
6.8m						EOH
7.0m						
7.5m						

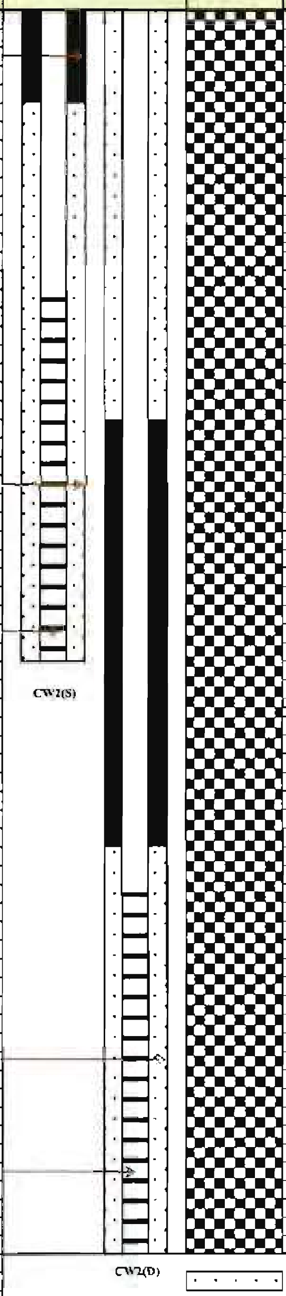
Legend: Sand; Loamy sand; Sandy Loam; Loam; Sandy Clay Loam; Clay Loam; Sandy Clay; Clay

Grain Size	Sorting	Grain
f - fine	p - poorly	a - angular
m - medium	m - moderately	suba - subangular
c course	w - well	subr - subrounded
v c - very course		r - rounded
g - gravel		wr - well rounded

JDA Consultant Hydrologists
Suite 1, 27 York Street
Subiaco WA 6008
Tel: 9388 2436
Fax: 9381 9279

LITHOLOGICAL LOG

Client:	Hurlingham Estates Pty Ltd	Job No:	J4906
Project:	Cannington: Lake St Wetland, 2011	Hole commenced:	6/05/2011
Bore location:	400226mE 6457188mN	Hole completed:	6/05/2011
Datum:	GDA94 MGA50	Logged by:	CAB
Bore Name:	CW4 (S & D)	Total Depth:	6.7mbNS(D) 3.5mbNS(S)
Drill type:	Hollow Auger	R.L. TOC:	4.90mAHD(D) 4.90mAHD(S)
Hole diameter:	150mm	Natural Surface:	4.30mAHD(D) 4.30mAHD(S)



LITHOLOGICAL LOG

Depth (m)	LITHOLOGY	COLOUR	GRAIN SIZE	SORTING	GRAIN SHAPE	OTHER
0	sandy clay	brown	fine	well	rounded	
0.5m	sandy clay	yellow brown	fine - medium	well - moderately	rounded	
1.0m	sandy clay	orange brown	fine - medium	well	rounded	
1.5m	sandy clay	light brown	fine - medium	well	rounded	soil - moist
2.0m	sandy clay	light brown	fine-medium	well	rounded	moist
2.5m						
3.0m	sandy clay	brown	fine - medium	well	rounded	moist
3.5m						
4.0m	sandy clay	red/brown	fine - medium	well	rounded	saturated
4.5m						
5.0m	sandy clay	light brown	medium - coarse	well - moderately	rounded	saturated water added
5.5m						
6.0m						
6.5m						EOH
7.0m						
7.5m						
8.0m						

Legend:
- Sand
- Loamy sand
- Sandy Loam
- Loam
- Sandy Clay Loam
- Clay Loam
- Sandy Clay
- Clay

Grain Size	Sorting	Grain
f - fine	p - poorly	a - angular
m - medium	m - moderately	suba - subangular
c - coarse	w - well	subr - subrounded
v.c - very coarse		r - rounded
g - gravel		wr - well rounded

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C02**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	11/05/05
Project:	Carousel Swamp Investigations	Date Completed:	11/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400238 N 6457089 GDA

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE)

Field Material Description (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY: VS S F ST VST H / FB VL L MD D VD, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water level: 10/02/0

DEPTH(m)	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE
0.00–0.50	Sandy Clay; Dull brown, stiff sandy clay. Sand is fine to medium grained quartz.	M
0.50–2.50	Clay with Sand; Cream/yellow clay with medium to fine grained sand. Gravelly hard dry clasts. Some orange mottling.	
2.50–3.00	Clay with Sand; Grey, stiff clay with some sand content.	
3.00–4.00	Clay with Sand; Brown, soft clay with some medium grained sand. Some calcareous gravel pieces.	
4.00–4.50	Clay with Sand; Dull green clay with some medium grained sand.	
4.50–5.50	Clay with Sand; Dull green-brown mottled clay with sandy lenses.	W
5.50	END OF BOREHOLE AT 5.50 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C04**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	11/05/05
Project:	Carousel Swamp Investigations	Date Completed:	11/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400231 N 6456881 GDA

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE) — **Field Material Description** (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / FB VL L MD D VD, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water level: 10/02/05 (approx. 1.8 m)

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–1.00	Clayey Sand; Brown clayey sand, sometimes weakly indurated.	M
1.00–2.50	Sandy Clay; Pale brown sandy clay, sometimes weakly indurated. Some iron staining.	D
2.50–5.00	Sandy Clay; Red-grey mottled sandy clay. Sometimes weakly indurated. Some white mottling from 3.0 to 3.5m.	M / W
5.00–6.50	Sandy Clay; Red-grey mottled sandy clay with gritty iron cementations.	
6.50–7.50	Clay with Sand; Yellow/brown clay with some red/brown sand lenses.	
7.50–8.00	Sand with Clay; Pale brown medium to coarse grained quartz and iron oxide sand with some pale grey/blue stiff sandy clay layers.	
8.00–10.50	Sandy Clay; Dull grey/green sandy clay with some sandy lenses. Clay has a high fine sand content.	
10.50–11.00	Sand; Yellow/brown, fine to medium, sub angular to sub rounded sand with some iron cemented gravel up to 2.0cm and some minor silt.	
11.00–12.00	Sand with Clay; Brown/red fine grained quartz and iron oxide sand with some iron cemented gravel and clay content.	
12.00–15.00	Sand; Brown, fine to coarse grained sand with some silt. Coarser grainsize with depth and greener colour.	
15.00	END OF BOREHOLE AT 15.00 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO.
C06
SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting: Air Core | Driller: Proline Drilling | Surface RL:
Borehole Diameter: 76 mm | Driller Lic No: | Co-ords: E 400363 N 6456982 GDA

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00–1.50	Sand; Brown, fine to coarse grained sand with some clay.	M
1.50–2.50	Sandy Clay; Brown-red mottled stiff sandy clay with some iron cementation. Occasional calcareaous white gravel pieces.	D
2.50–3.50	Clay with Sand; Grey-brown, stiff clay with some sand content.	M
3.50–6.00	Sandy Clay; Grey-brown sandy clay as above with limestone pieces up to 5cm. No limestone present.	
6.00–7.00	Clay with Sand; Layers of blue-brown mottled clay and sand.	W
7.00–8.50	Clay with Sand; Layers of blue/green stiff clay and medium to coarse grained sand.	
8.50–9.00	Sand; Brown/green, medium to coarse grained sand with some thin greenish clay layers.	
9.00–10.50	Sand and Indurated Clay; Brown, medium to coarse grained sand and weakly indurated dark grey clay layers.	
10.50	END OF BOREHOLE AT 10.50 m	

Water level: 10/02/05 (approx. 1.7 m)

Column headings: 1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE, 8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY/CONSISTENCY (VS S F ST VST H / VL L MD D VD), 13 STRUCTURE AND ADDITIONAL OBSERVATIONS

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

MONITORING BORE COMPLETION LOG

BOREHOLE NO. **C08**

SHEET 1 OF 1

Client:	Woodman Environmental Consulting Pty Ltd	Date Commenced:	12/05/05
Project:	Carousel Swamp Investigations	Date Completed:	12/05/05
Borehole Location:	Cannington	Recorded By:	AR
Project Number:	2142125a	Log Checked By:	GF

Drill Model/Mounting:	Air Core	Driller:	Proline Drilling	Surface RL:	
Borehole Diameter:	76 mm	Driller Lic No:		Co-ords:	E 400440 N 6457044 GDA

Borehole Information (1 METHOD, 2 SUPPORT, 3 WATER, 4 WELL CONSTRUCTION, 5 RL(m) / DEPTH(m), 6 FIELD TEST, 7 SAMPLE)

Field Material Description (8 GRAPHIC LOG, 9 USC SYMBOL, 10 SOIL/ROCK MATERIAL FIELD DESCRIPTION, 11 MOISTURE, 12 RELATIVE DENSITY /CONSISTENCY VS S F ST VST H / VL L MD D VD FB, 13 STRUCTURE AND ADDITIONAL OBSERVATIONS)

Water level: 10/02/05

Depth (m)	Soil/Rock Material Field Description	Moisture
0.00 – 0.50	Fill; Brown sandy, clayey fill.	M
0.50 – 1.00	Clay; Brown, stiff clay with some sand.	
1.00 – 1.50	Clayey Sand; Brown clayey sand, some iron cementation.	
1.50 – 3.00	Clay with Sand; Pale brown/pink clay, sometimes weakly indurated. Some fine to medium grained sand lenses.	
3.00 – 6.00	Sandy Clay; Pale grey, stiff clay. Orange, medium to coarse grained sand lenses.	
6.00 – 7.50	Sandy Clay; Dull blue green clay and orange sand lenses.	W
7.50	END OF BOREHOLE AT 7.50 m	

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

APPENDIX C – WATER BALANCE MODEL RESULTS – EXISTING

WATER BALANCE CALCULATIONS
Lagoon Water Balance - Options Analysis

Calculation Sheet 1

Scenario	Existing Condition
Inf Model	Aquifer connected
Rainfall Data	
Source	
Reference	9106

Date	Rainfall mm
1/01/2008	0
2/01/2008	0
3/01/2008	0
4/01/2008	0
5/01/2008	0
6/01/2008	0
7/01/2008	0
8/01/2008	0
9/01/2008	0
10/01/2008	0
11/01/2008	0
12/01/2008	0
13/01/2008	0
14/01/2008	0
15/01/2008	0
16/01/2008	0
17/01/2008	0
18/01/2008	0
19/01/2008	0
20/01/2008	0
21/01/2008	0
22/01/2008	0
23/01/2008	0
24/01/2008	0
25/01/2008	0
26/01/2008	0
27/01/2008	0
28/01/2008	0
29/01/2008	0
30/01/2008	0
25/02/2008	0
26/02/2008	0
27/02/2008	0
28/02/2008	0
29/02/2008	0
1/03/2008	0
2/03/2008	0
3/03/2008	0
4/03/2008	0
5/03/2008	0
6/03/2008	0
7/03/2008	0.8
8/03/2008	2
9/03/2008	0.1
10/03/2008	0
11/03/2008	0
12/03/2008	0

Climate Data

Month	Pan Evap mm/month	mm/day	Surr GWL m AHD
Jan	297	9.6	2.80
Feb	257	8.9	2.52
Mar	224	7.2	2.33
Apr	123	4.1	2.33
May	87	2.8	2.30
Jun	59	2.0	2.95
Jul	60	1.9	3.21
Aug	69	2.2	3.83
Sep	106	3.5	3.68
Oct	154	5.0	3.53
Nov	203	6.8	3.13
Dec	259	8.4	2.80
Jan	297	9.6	2.80125

Lake Surface Area Contours

Level	Area (m2)	Perimeter	Storage
3.5	0	0	0
3.75	799.7	375	100
4	13197.4	2972	1850
4.25	45857.6	5104	9231
4.5	91675.1	5554	26423
4.75	133000	2988	54507

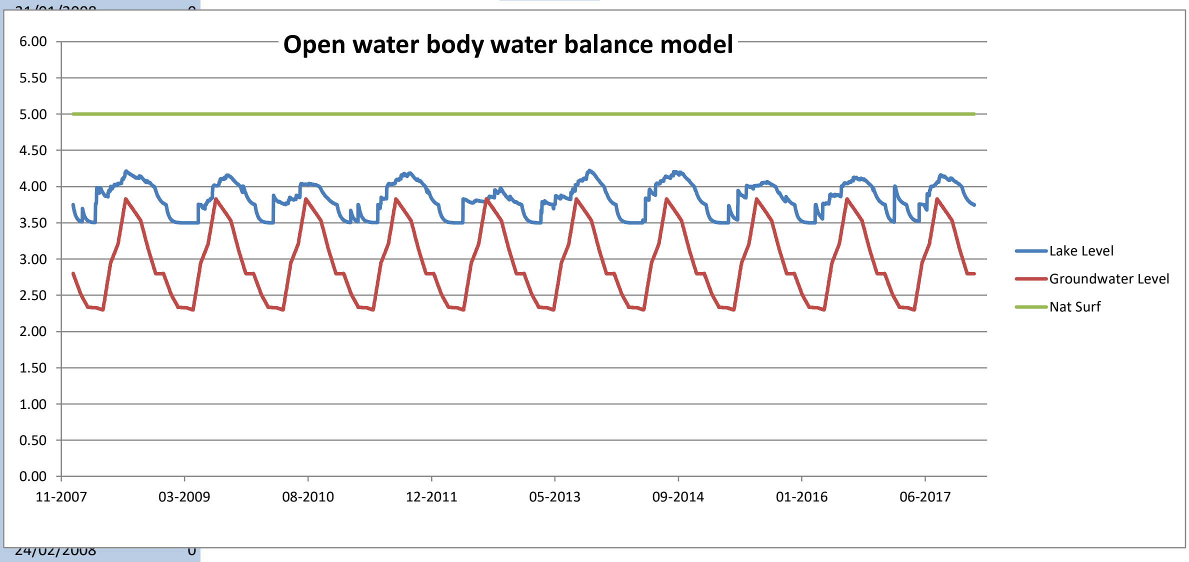
Model Results	Total (ML)
Change in Storage	0.0

Model Inputs

initial water level	3.75	mAHD
pan evaporation factor	0.75	El/Ep
aquifer conductivity - 10^		m/s
aquifer conductivity	0.1	m/day
distance of influence	150	m
base of aquifer	-8	m
base of lake	3.75	mAHD
depression storage	15	mm
natural surface level	5	mAHD
site area draining to lake	13.3	ha
overflow level	4.75	mAHD
max volume	54507.45	m3
Runoff parameter	20.00%	
Low flow discharge rate		L/s
Drain invert		mAHD

INPUTS		Peak Annual
Direct Rainfall	93.0	14.2
Catchment Runoff	37.2	5.0
net inflow/outflow	0.0	0.0
	130.2	19.2
OUTPUTS		
Evaporation	98.9	14.0
Net seepage to GW	31.3	48.3
Overflow as Stormwater	0.0	0.0
Low flow discharge	0.0	0.0
	130.2	62.3

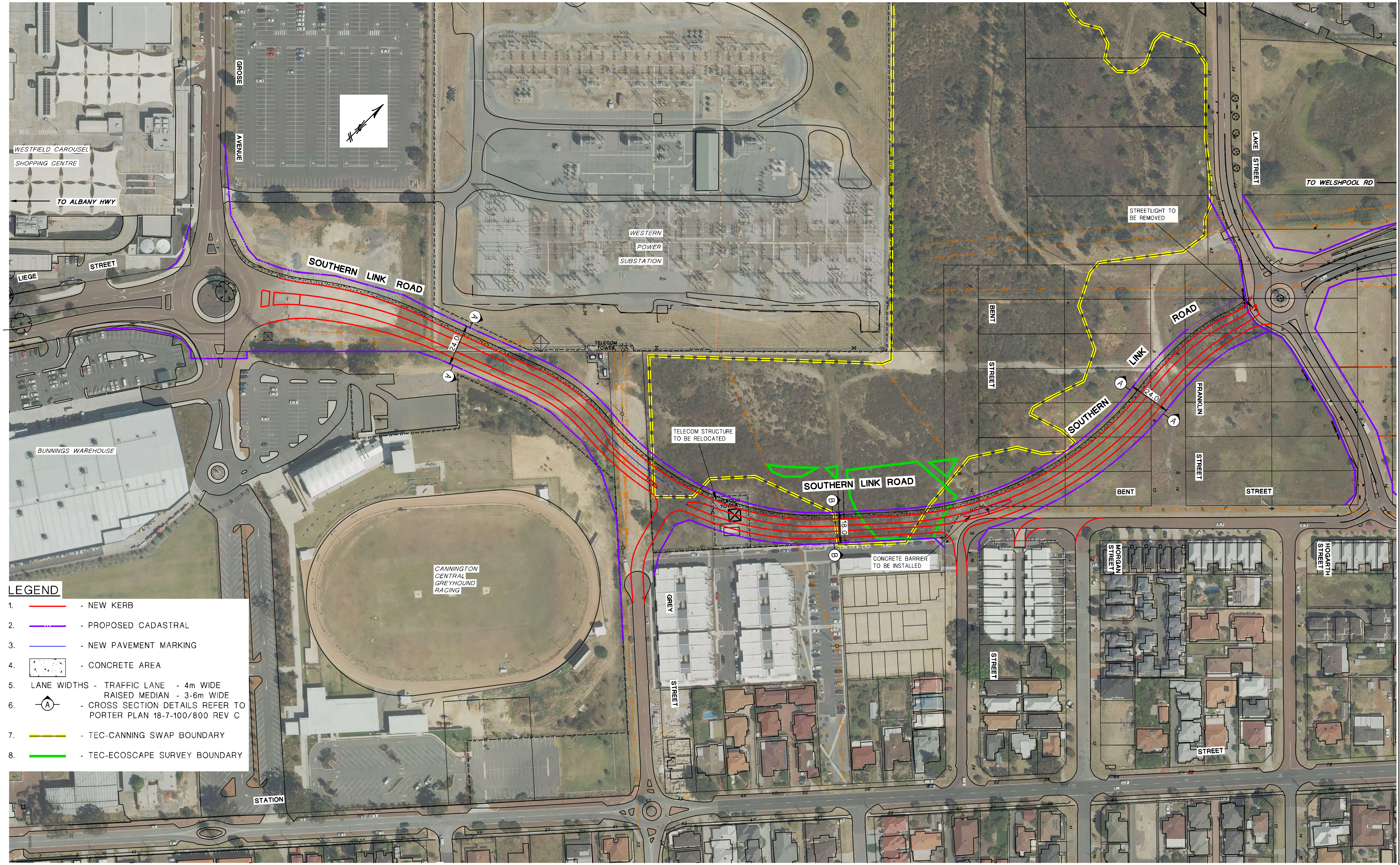
Annual Inflow	ML
Maximum	0.0
Minimum	0.0
Average	0.0



Annual fluxes | **Hydroperiod**

Year	**Recharge**	**Rainfall**	**Runoff**	**Evap**	**twl**	**Max vol**	**days**	**months**
2008	83516	14231	4994	13974	4.22	8263	262	8.6
2009	77259	8908	3118	9538	4.16	6586	171	5.6
2010	48313	3758	3281	5172	4.04	3130	186	6.1
2011	83483	13748	3653	13275	4.19	7476	212	7.0
2012	73666	2587	2038	3694	3.98	1730	146	4.8
2013	70529	11599	4606	12396	4.22	8439	226	7.4
2014	61520	13426	4308	13617	4.21	8012	224	7.4
2015	61665	5744	3466	6789	4.07	3861	204	6.7
2016	76705	9684	3110	9737	4.13	5583	204	6.7
2017	65217	9321	4581	10664	4.16	6603	195	6.4
Maximum	83516	14231	4994	13974	4.22	8439	262	8.6
Minimum	48313	2587	2038	3694	3.98	1730	146	4.8
Average	70188	9301	3716	9886	4.14	5968	203	6.7

APPENDIX D – ENGINEERING DRAWINGS OF THE PROPOSED WORK



LEGEND

1. - NEW KERB
2. - PROPOSED CADASTRAL
3. - NEW PAVEMENT MARKING
4. - CONCRETE AREA
5. LANE WIDTHS - TRAFFIC LANE - 4m WIDE
   RAISED MEDIAN - 3-6m WIDE
6. (A) - CROSS SECTION DETAILS REFER TO PORTER PLAN 18-7-100/800 REV C
7. - TEC-CANNING SWAP BOUNDARY
8. - TEC-ECOSCAPE SURVEY BOUNDARY

DIAL 1100 DIAL BEFORE YOU DIG

LEGEND			
EXISTING KERB		DRAINAGE	
EXISTING NO KERB		WATER	
DESIGN KERB		SEWER	
DESIGN DRAINAGE		GAS	
FENCE LINE		TELSTRA	
9.50 EXISTING LEVEL	55.68 DESIGN LEVEL	POWER	

REV.	AMENDMENTS	DRAWN	AUTH'D	DATE
A	ISSUED FOR DESIGN REVIEW	BW	GC	26.3.19

SHEET 01 OF 01

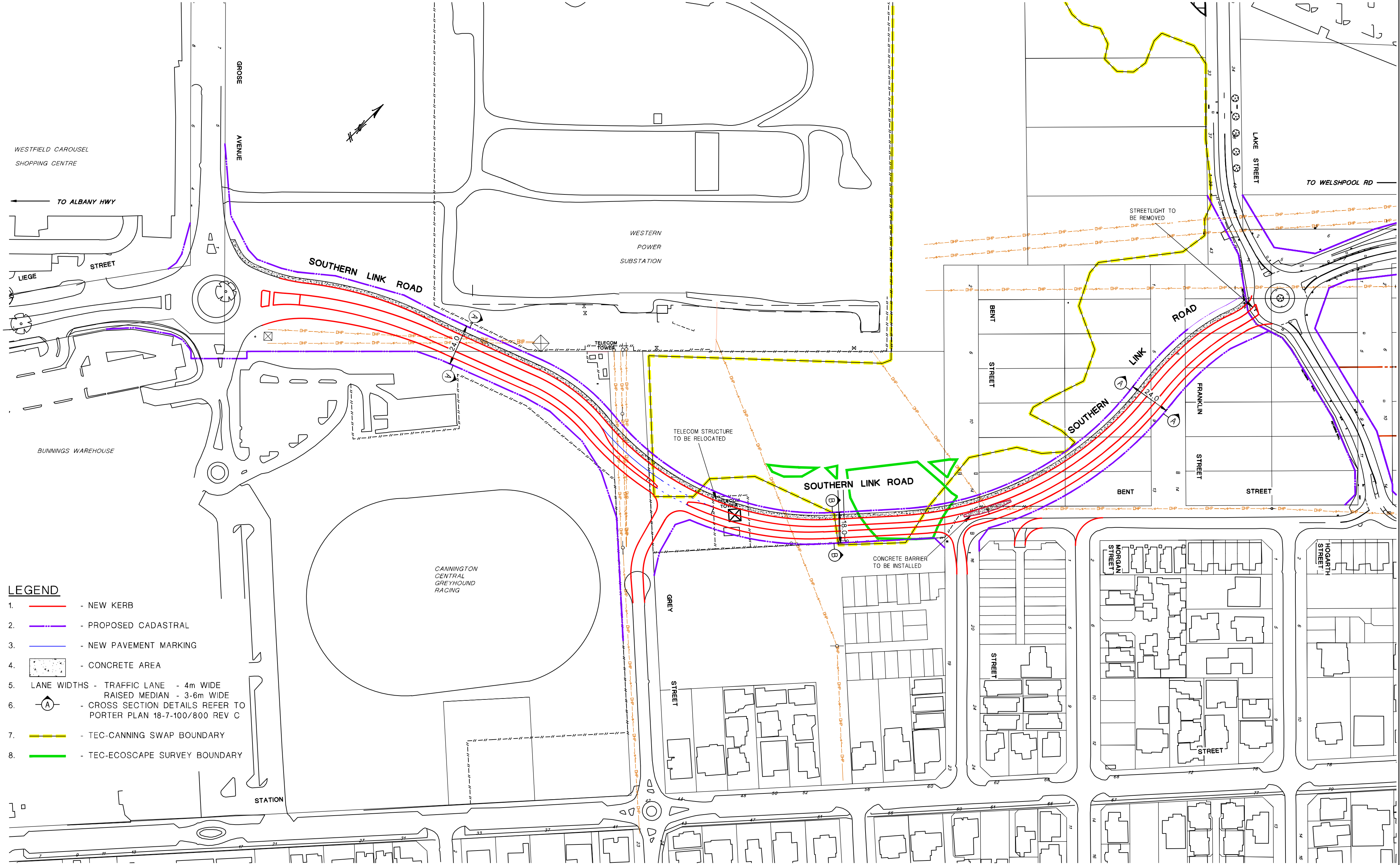
SCALE 1 : 1000

DESIGNED / DRAWN	B.WONG	OCT'12
CHECKED		
RECOMMENDED	MANAGER	
APPROVED	EXECUTIVE	

CITY OF CANNING

SOUTHERN LINK RD - OPTION I
GROSE AVENUE TO LAKE STREET

FILE No. CAD2420 | PLAN No. S429-I | REVISION A | ORIGINAL A1



LEGEND			
EXISTING KERB		DRAINAGE	
EXISTING NO KERB		WATER	
DESIGN KERB		SEWER	
DESIGN DRAINAGE		GAS	
FENCE LINE		TELSTRA	
9.50 EXISTING LEVEL	15.68 DESIGN LEVEL	POWER	

REV.	AMENDMENTS	DRAWN	AUTH'D	DATE
A	ISSUED FOR DESIGN REVIEW	BW	GC	26.3.19

SHEET 01 OF 01

SCALE 1 : 1000

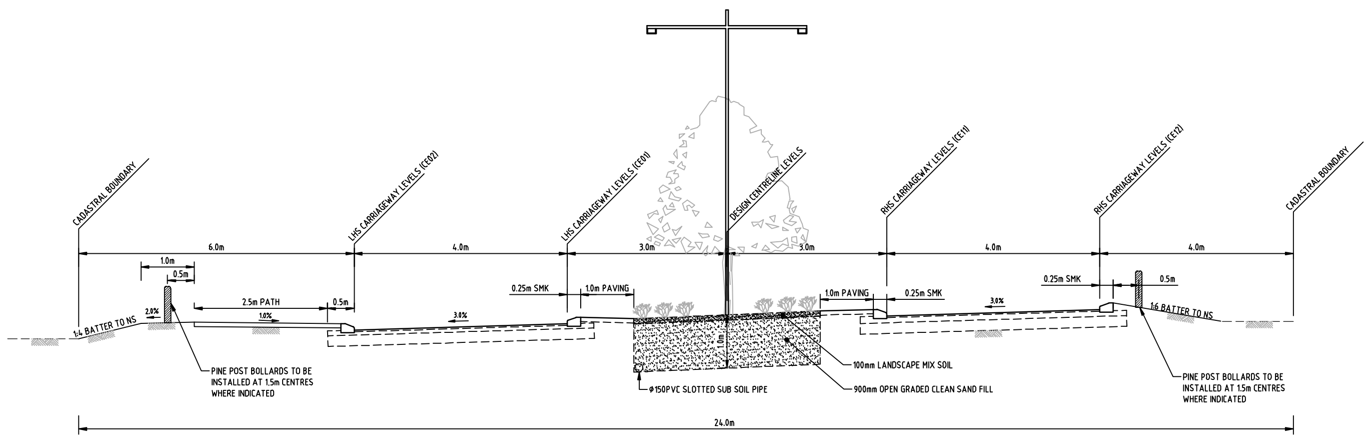
DESIGNED		
DRAWN	B.WONG	OCT'12
CHECKED		
RECOMMENDED	MANAGER	
APPROVED	EXECUTIVE	

CITY OF CANNING

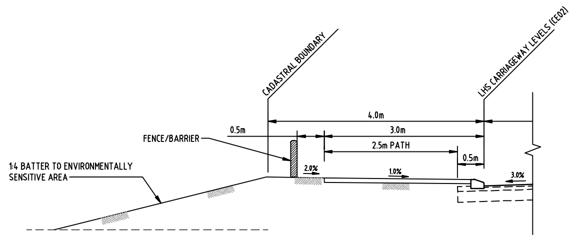
SOUTHERN LINK RD - OPTION I GROSE AVENUE TO LAKE STREET

FILE No.	PLAN No.	REVISION	ORIGINAL
CAD2420	S429-I	A	A1

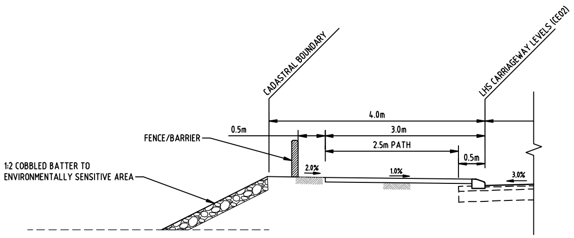
DIAL 1100 BEFORE YOU DIG — PERTH ONE CALL SYSTEM



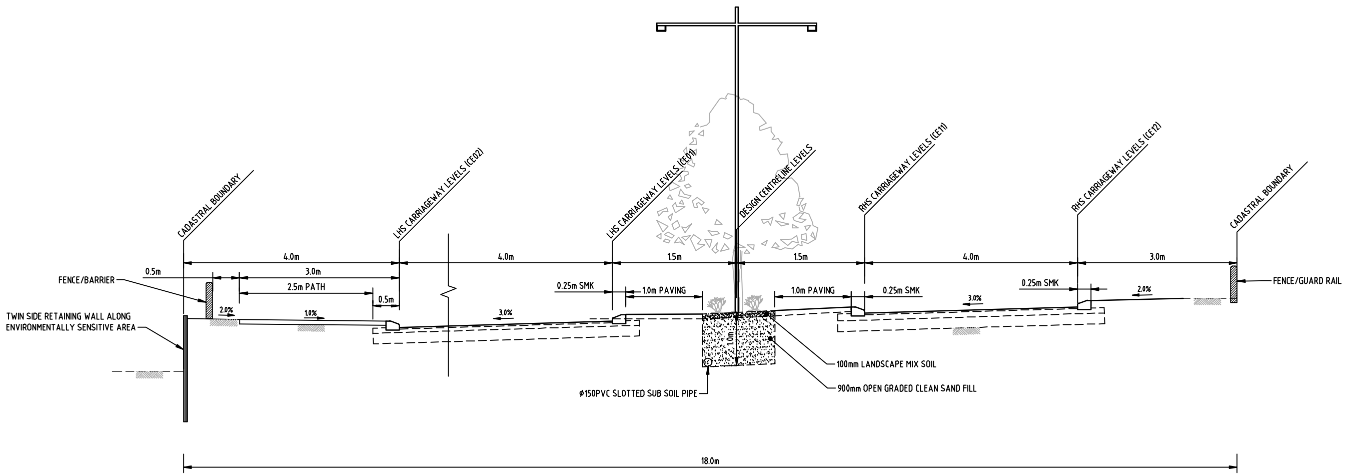
TYPICAL CROSS SECTION (A-A)
NTS



1:4 BATTER TO ENVIRONMENTALLY SENSITIVE AREA (OPTION 2)
NTS



1:2 COBBLED BATTER TO ENVIRONMENTALLY SENSITIVE AREA (OPTION 3)
NTS



TWIN SIDE RETAINING WALL (OPTION 1) TYPICAL SECTION ENVIRONMENTALLY SENSITIVE AREA (B-B)
NTS

PROJECT:

SOUTHERN LINK ROAD CANNINGTON

No.	DATE	REVISION	BY
D	15-4-2019	BLOCK RET WAQLL REMOVED. 3 OPTIONS ADDED, TWIN SIDE, 1:4, 1:2.	MJV
C	22-3-2019	UPDATED TO 24m ROAD RESERVE.	MJV
B	21-3-2019	25m AND 18m ROAD RESREVE ARAS NOTED.	MJV
A	14-2-2019	PRELIMINARY PLOT FOR DISCUSSION	MJV

Porter Consulting Engineers

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Mt Pleasant 6153 WA

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Email office@portereng.com.au
www.portereng.com.au

TUSNO Pty Ltd ACN 010 097 148 as trustee for the Consulting Engineering Unit Trust trading as Porter Consulting Engineers ABN 78 636 396 385

CLIENT:

CITY OF CANNING

DRAWING:

TYPICAL CROSS SECTIONS

STATUS: **FOR COMMENT**

SCALE	NTS
DATE	FEB 2019
DESIGN	ELW
DRAWN	MJV
CHECK	

DRAWING No.	REV No.	ORIGINAL DRAWING SIZE
18-7-100/800	D	A1

FILE NAME \\192.168.101.102\Data\ACTIVE PROJECTS\18-07-100\ACAD\187100-800

APP'D

APPENDIX E – WATER BALANCE MODEL RESULTS– POST DEVELOPMENT

WATER BALANCE CALCULATIONS
Lagoon Water Balance - Options Analysis

Calculation Sheet | 1

Scenario	Existing Condition
Inf Model	Aquifer connected
Rainfall Data	
Source	
Reference	9106

Climate Data

Month	Pan Evap mm/month	mm/day	Surr GWL m AHD
Jan	297	9.6	2.80
Feb	257	8.9	2.52
Mar	224	7.2	2.33
Apr	123	4.1	2.33
May	87	2.8	2.30
Jun	59	2.0	2.95
Jul	60	1.9	3.21
Aug	69	2.2	3.83
Sep	106	3.5	3.68
Oct	154	5.0	3.53
Nov	203	6.8	3.13
Dec	259	8.4	2.80
Jan	297	9.6	2.80125

Lake Surface Area Contours

Level	Area (m2)	Perimeter	Storage
3.5	0	0	0
3.75	16	15	2
4	6923.2	2458	869
4.25	35335.4	4476	6152
4.5	70385.9	4334	19367
4.75	105000	2988	41290

Model Results	Total (ML)
Change in Storage	0.0

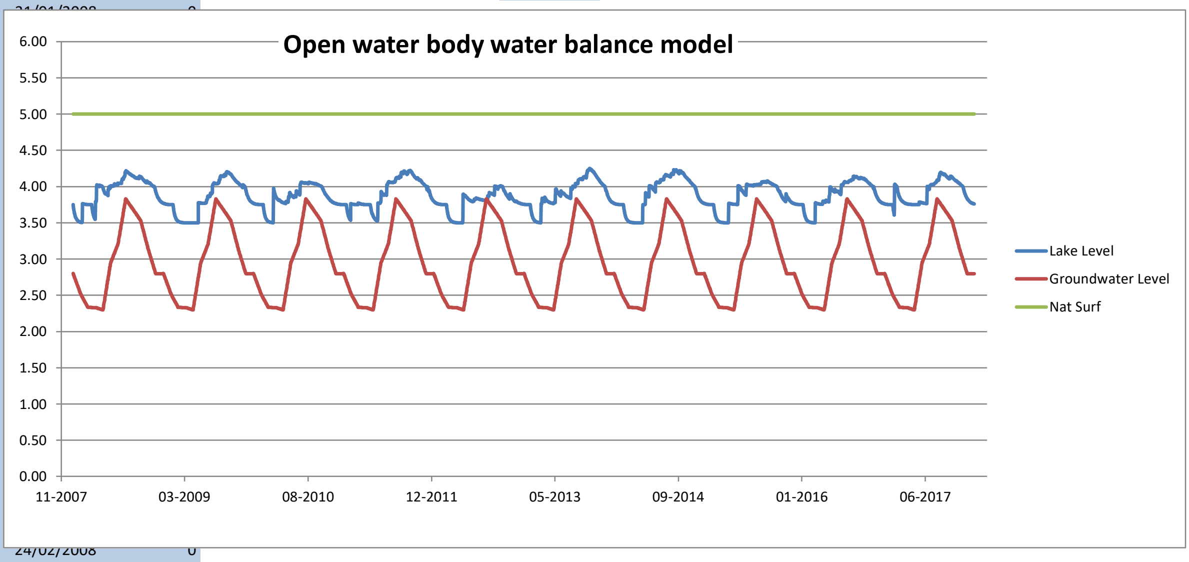
Model Inputs

initial water level	3.75	mAHD
pan evaporation factor	0.75	El/Ep
aquifer conductivity - 10^		m/s
aquifer conductivity	0.1	m/day
distance of influence	150	m
base of aquifer	-8	m
base of lake	3.75	mAHD
depression storage	15	mm
natural surface level	5	mAHD
site area draining to lake	10.5	ha
overflow level	4.75	mAHD
max volume	41290.125	m3
Runoff parameter	20.00%	
Low flow discharge rate		L/s
Drain invert		mAHD

INPUTS		Peak Annual
Direct Rainfall	70.0	10.9
Catchment Runoff	29.5	4.0
net inflow/outflow	0.0	0.0
	99.4	14.9
OUTPUTS		
Evaporation	70.7	10.1
Net seepage to GW	28.7	38.7
Overflow as Stormwater	0.0	0.0
Low flow discharge	0.0	0.0
	99.4	48.8

Annual Inflow	ML
Maximum	0.0
Minimum	0.0
Average	0.0

Date	Rainfall mm
1/01/2008	0
2/01/2008	0
3/01/2008	0
4/01/2008	0
5/01/2008	0
6/01/2008	0
7/01/2008	0
8/01/2008	0
9/01/2008	0
10/01/2008	0
11/01/2008	0
12/01/2008	0
13/01/2008	0
14/01/2008	0
15/01/2008	0
16/01/2008	0
17/01/2008	0
18/01/2008	0
19/01/2008	0
20/01/2008	0
21/01/2008	0
22/01/2008	0
23/01/2008	0
24/01/2008	0
25/01/2008	0
26/01/2008	0
27/01/2008	0
28/01/2008	0
29/01/2008	0
30/01/2008	0
25/02/2008	0
26/02/2008	0
27/02/2008	0
28/02/2008	0
29/02/2008	0
1/03/2008	0
2/03/2008	0
3/03/2008	0
4/03/2008	0
5/03/2008	0
6/03/2008	0
7/03/2008	0.8
8/03/2008	2
9/03/2008	0.1
10/03/2008	0
11/03/2008	0
12/03/2008	0



Annual fluxes / **Hydroperiod**

Year	Recharge	Rainfall	Runoff	Evap	twl	Max vol	days	months
2008	67638	9654	4006	9126	4.22	5544	259	8.5
2009	61090	7418	2450	7421	4.21	5214	178	5.9
2010	38658	2648	2602	3464	4.06	2190	204	6.7
2011	66439	10872	2882	10118	4.22	5601	213	7.0
2012	58619	1697	1618	2270	4.01	1113	201	6.6
2013	56265	8993	3656	9188	4.25	6242	245	8.1
2014	49270	10357	3415	9996	4.23	5821	225	7.4
2015	49518	3943	2750	4425	4.08	2561	210	6.9
2016	61401	7092	2475	6778	4.14	3903	214	7.0
2017	51997	7292	3617	7892	4.20	5038	202	6.6
Maximum	67638	10872	4006	10118	4.25	6242	259	8.5
Minimum	38658	1697	1618	2270	4.01	1113	178	5.9
Average	56089	6997	2947	7068	4.16	4323	215	7.1

Client: City of Canning

Report	Version	Prepared by	Reviewed by	Submitted to Client	
				Copies	Date
Preliminary draft	V1	AN	HB	Electronic	9/02/2018
Draft for consultation	V2	AN/HL	HB	Electronic	4/02/2019
Final draft	V3	AN/HL	HB	Electronic	06/03/2019
Revised draft	V4	AN/HL	HB	Electronic	19/08/2019
Final report	V5	AN/HL	HB	Electronic	10/12/2019

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