DA13 - BRANCH CIRCUS

District Water Management Strategy

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1. INTRODUCTION

1.1 Background

The City of Cockburn proposes to rezone a 35.27ha parcel of land (the 'study area') from 'Urban Deferred' to 'Urban' under the Metropolitan Region Scheme (MRS). One of the requirements necessary in the process of rezoning of the land is a District Water Management Strategy (DWMS). The DA13 – Branch Circus DWMS aims to outline the water management strategies most appropriate for the environmental constraints and opportunities of the site. In addition, this document will provide further guidance to the data requirements and investigations that should be undertaken prior to development of the next level of planning in a Local Water Management Strategy (LWMS).

The study area is located 25km south-southwest of the Perth CBD, in the suburb of Success. The locality of the study area is shown in **Figure 1**. The study area is bounded by Hammond Road to the east, Branch Circus to the west, a Bush Forever site to the north and Bartram Road Buffer Lakes to the south. The study area includes Lots 3, 4, 5, 12, 13, 22 Hammond Road and Lots 2, 3, 4, 760, 761, 9000 Branch Circus (see **Figure 2**).

1.2 Key Principles and Objectives

The principles and objectives of best practice integrated urban water management (IUWM) and water sensitive urban design (WSUD) contained within this document have been predominately sourced from the following:

- *Stormwater Management Manual for Western Australia* (DoW 2007);
- *Liveable Neighbourhoods Edition 4* (WAPC 2007);
- *Better Urban Water Management* (WAPC 2008b); and

1.2.1 Stormwater Management Manual

The key principles and objectives outlined by the *Stormwater Management Manual for Western Australia* are:

- **Water quality** – to maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions;
- **Water quantity** – to maintain the total water cycle balance within development areas relative to the pre-development conditions;
- **Water conservation** – to maximise the reuse of stormwater;
- **Ecosystem health** – to retain natural drainage systems and protect ecosystem health;
- **Economic viability** – to implement stormwater management systems which are economically viable in the long-term;
- **Public health** – to minimise the public risk, including risk of injury or loss of life, to the community;
- **Protection of property** – to protect the built environment from flooding and waterlogging;

- **Social values** – to ensure that community social, aesthetic and cultural values are recognized and maintained when managing stormwater; and
- **Development** – to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

1.2.2 Liveable Neighbourhoods

The objectives outlined by the *Liveable Neighbourhoods Edition 4* are:

- **Objective 1** – To encourage best practice in the use and management of land and water resources, reduce reliance on potable water and improve 'at source' protection of water quality;
- **Objective 2** - To encourage water conservation and reduce consumption of potable (mains) water by maximising the retention, detention and reuse of stormwater, by maximising local recharge of groundwater, by wastewater reuse and water harvesting;
- **Objective 3** – to protect the built environment from flooding, inundation and stormwater damage;
- **Objective 4** – to provide an urban water management system to deliver appropriate water quality and quantity outcomes;
- **Objective 5** – to maintain and improve the surface and groundwater quality within the development, and ensure that stormwater runoff does not degrade the quality of surface and underground receiving waters;
- **Objective 6** – to prevent adverse impact to valued natural environments that are sensitive to changes in the natural water cycle;
- **Objective 7** – to ensure that the street system operates safely both during and after storm events;
- **Objective 8** – to ensure water management solutions are integrated with provision of an efficient urban structure and an appropriate range of parkland types;
- **Objective 9** – to enable minor adjustments to streams, gullies, wetlands and marginal flood plains to ensure that urban forms can be compact, walkable and efficient. The adjustments must have minimal environmental detriment and minimise disturbance caused by draining or filling natural streams and wetlands; and
- **Objective 10** – to provide an urban water management system that is sustainable, to ensure arrangements are in place for ongoing maintenance and management and ensure water management measures are appropriate to site-specific conditions and likely effectiveness.

1.2.3 Better Urban Water Management

The principles and objectives outlined by *Better Urban Water Management* are:

Water Conservation

- **Principle** – No potable water should be used outside of homes and buildings and achieve efficient use of scheme water;
- **Objective** – Consumption target of 100kL/person/yr.

Stormwater Quantity

- **Objective** – Post-development peak flows and event discharge volume be maintained relative to pre-development conditions, unless otherwise established through determination of Ecological Water Requirements for sensitive environments.

Ecological Protection

- **Objective** – For the critical 1 year average recurrence interval (ARI) event, the post-development discharge volume and peak flow rates shall be maintained relative to pre-development conditions in all parts of the catchment. Where there are identified impacts on significant ecosystems, maintain or restore desirable environmental flows and/or hydrological cycles as specified by the Department of Water (DoW).

Flood Management

- **Objective** – Manage the catchment runoff for up to the 1 in 100 year event within the development area to pre-development peak flows, unless otherwise indicated in an approved strategy or as negotiated with the relevant drainage service provider.

Water Quality

- **Principle** – Maintain surface and groundwater quality at pre-development levels (median winter concentrations) and, if possible, improve the quality of water leaving the development area to maintain and restore ecological systems in the sub-catchment in which the development is located.

2. PROPOSED DEVELOPMENT

One of the aims of a DWMS report is to determine appropriate land use within the study area e.g. areas for drainage, Public Open Space (POS) and development. A DWMS is typically produced prior to the development of a district or local structure plan, so that the structure plan can use the information gathered in the DWMS investigation to facilitate the development of a design that best suits the existing natural environment.

The initially proposed Branch Circus District Structure Plan (DSP) was developed with consideration of known constraints and opportunities for the study area. Following further detailed site investigations and a reclassification of geomorphic wetlands within the study area, the DSP was adjusted to accommodate the additional inputs. This revised DWMS is developed based on the revised DSP which is shown in **Appendix A**.

The key elements of the current DSP include:

- The provision of a variety of residential densities with higher density land being centred around the village centre and areas of POS;
- The special use swimming pool to assist in the creation of an activity node and village centre focus;
- A POS network that provides accessible POS and accounts for over 10% of subdivided area, which includes retaining a large portion of the existing remnant vegetation;
- Conservation zones, conservation category wetlands and surrounding buffer areas;
- Infiltration drainage areas within the POS; and
- Removal of a drainage sump for the existing development to the east of DA13 – Branch Circus. The drainage of this existing development will be incorporated into the proposed DA13 – Branch Circus drainage network.

The current DSP is shown in **Appendix A**. This is the proposed land use layout upon which this revised DWMS has been formulated.

3. PRE-DEVELOPMENT ENVIRONMENT - CONSTRAINTS AND OPPORTUNITIES

3.1 Sources of information

A number of broad level information sources have been used to determine the existing environmental constraints and opportunities of the study area. Through the analysis of this information, it was determined which areas required further and more detailed investigation.
The information sources included:

- Perth Groundwater Atlas, 2nd Edition (DOE 2004a);
- Acid Sulfate Soils Risk Mapping (WAPC 2007);
- Perth 1:50,000 Geology Map Sheet (Department of Industry and Resources 1970);
- Wetlands of the Swan Coastal Plain (Hill et al 1996);
- Data supplied by the Department of Water, the City of Cockburn and the Water Corporation; and
- Australian Government Bureau of Meteorology (BOM 2008).

In addition to the above broad level information, site-specific investigations into various aspects of the study area and surrounds have been utilised in characterising the existing environment. These additional site-specific investigations include:

- South Jandakot Drainage Scheme: Scheme Monitoring Report for 2000 to 2001. (Acacia Springs Environmental 2002);
- Branch Circus Local Structure Plan, Success. Figures 1-10. (City of Cockburn 2008a);
- Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 45 of the Environmental Protection Act (Froend et al 2004);
- Jandakot Groundwater Mound (WRC 2004); and
- Environmental Assessment Report – Branch Circus and Hammond Road, Success (RPS 2008).

3.2 Location and Climate

The study area is nested between the existing Success residential area in the east and Thomsons Lake to the west. The region experiences a Mediterranean climate with cool wet winters and warm dry summers. Only 15% of the total average 842mm of rainfall occurs during the six month period from November to April (BOM 2008).

3.3 Geotechnical Conditions

3.3.1 Topography

Accurate LiDAR topography data of the study area was source from the DoW. The topography of the study area general slopes in a westerly direction. The highest elevation of 33mAHD is near the eastern boundary and 18mAHD along the western boundary of the study area, giving a maximum slope of 5.5%.

There are two depressions in the study area that will collect stormwater runoff. These low points form natural wetlands and are located in the north-west and south-west portions of the study area. Topographic contours of the study area are shown in **Figure 3**.

3.3.2 Regional Geology and Site Soil Conditions

The Swan Coastal Plain consists of the Pinjarra Plain and three dune systems (Quindalup, Spearwood, Bassendean) of differing ages of deposition, whose soils are at different stages of leaching and formation. The study area is located on the Bassendean Dune system, which is described as the "most leached, infertile and acidic" of the three dune systems (DoA 2006).

Regional 1:50,000 Geological Mapping, with GIS data from the Department of Industry and Resources, identifies that the majority of the site consists of the soil type 'S8', which is described as "fine to medium grained, sub-rounded quartz duplex soils that is moderately well sorted" and has a high permeability. The north-west and south-west portions of the study area (wetland areas) consist of the soil type 'Ms5', which is described as "dark brownish grey, with fine-grained quartz sand and firm, variable clay content" and is generally prone to flooding. The extent of soil variation across the site is shown in **Figure 4**.

3.3.3 Acid Sulphate Soils

Acid Sulfate Soils (ASS) are naturally occurring soils and sediments containing sulphide minerals, predominantly pyrite (an iron sulphide). In an undisturbed state below the watertable, these soils are generally benign and not acidic. ASS in Western Australia commonly occurs in low lying wetlands, back-swamps, estuaries, salt marshes and tidal flats. These soils commonly have a pH of between 4.0 and 6.0

Disturbance of these soils can expose them to air, thereby causing oxidation and potentially leading to the production of sulphuric acid, iron particulates and elevated concentrations of dissolved heavy metals. Flushing of this acidic leachate to ground water and surface waters can cause obvious off-site impacts. The early identification of ASS is essential to ensure adoption of effective measures to reduce the generation of acidic soils and water.

The WAPC *Planning Bulletin Number 64* indicates that the majority of soils underlying the site are generally of "moderate to low risk of ASS occurring within 3m of natural soil surface" (WAPC 2007). However, areas with the Ms5 soil unit in the north-west and south-west portion of the study area have a "high to moderate risk of ASS occurring within 3m of natural soil surface" (WAPC 2008a). These areas will not be developed as they are proposed in the DSP to be POS areas. However, a small portion of the lots proposed in Lot 22 are within the high risk mapped area. ASS risk mapping underlying the site is shown in **Figure 5**.

3.4 Environmental Assets

3.4.1 Wetlands

The first version of the DWMS identified a number of wetlands within and surrounding the study area. A review of the classification of the wetlands and corresponding wetland boundaries was undertaken by the Department of Environment and Conservation (DEC). The majority of the resource enhancement wetland (REW) (UFI 6535) in the northern portion of the study area was reclassified as a conservation category wetland (CCW) with a portion classified as a multiple use wetland (MUW).

A section of the CCW located in the southern portion of the study area (UFI 13957) was modified to MUW classification. The remainder of UFI 13957 was considered an accurate representation of the wetland present. The DSP developable area was updated to reflect the changes in the required buffers for the reclassified wetlands. The southern CCW also includes the Bartram Road Buffer Lakes, located immediately south of the study area. The constructed Bartram Road Buffer Lakes are utilised by the Water Corporation for improving the water quality of surface water runoff from the road network to the east of the study area. This lake system is classified as an Environmental Protection Policy (EPP) wetland.

Other wetlands in the vicinity of the site include areas surrounding Thomsons Lake to the west, classed as a CCW, and the Kogolup Lakes to the north west. Thomsons Lake is described as a "seasonal/intermittent freshwater lake" and on a national level is included in the directory of Ramsar wetlands (Ramsar Wetland Type P) (Department of the Environment, Water, Heritage and the Arts 2008). The modified wetland mapping is shown in **Figure 6**.

3.4.2 Bush Forever

There are no Bush Forever sites within the study area. However, the Bush Forever Site 391 is located immediately west of the study area (see **Figure 6**).

3.4.3 Flora and Vegetation

According to 1:50,000 vegetation mapping, the study area is located within the Bassendean Complex. The Bassendean Complex – Central and South is described as "woodland of jarrah-sheoak-banksia on the sand dunes, to a low woodland of *Melaleauca spp*., and sedgelands on the low-lying depressions and swamps" (DEC 1980).

The vegetation survey conducted by RPS (March, 2008) found that "the site is mostly cleared with scattered pockets of remnant mature trees in certain areas across the site. There is virtually no understorey across the entire site, except in a couple of distinct locations at the rear of Lots 4 and 5 Hammond Road, part of Lot 3 Branch Circus and Lot 761 Gadd Street".

A search of the DEC Rare Flora Databases returned four Declared Rare Flora (DRF)(all ephemeral orchid species) and 15 Priority Flora species could potentially occur within the site

(RPS 2008). RPS is currently completing a Level 2 flora and vegetation survey of the study area. The results from this study will determine the presence or otherwise of rare flora and vegetation with the study area and this information should be included in future LWMS documents.

3.4.4 Environmental Sensitive Areas

Environmentally Sensitive Areas (ESAs) are areas prescribed under the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*. ESAs are only applicable when a clearing permit is required under these regulations. Where a clearing permit is required for an area that is situated within an ESA, then none of the exemptions pursuant to the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004* apply. These areas have been identified in order to protect the native vegetation values of areas surrounding significant, threatened or scheduled ecosystems or communities.

A search of the Department of Environment and Conservation's (DEC) Native Vegetation Mapping database revealed that there is an extensive ESA (ESA 3585) to the west of the study area that is associated with Thomsons Lake. The boundary of the ESA crosses into the study area and forms an approximate 50m buffer around the CCW. The DSP proposes to develop some of the land within the ESA. The boundary of this ESA is shown in **Figure 6**.

3.4.5 Fauna

Thomsons Lake is a "major migration stop-over and drought refuge area for water birds [and is] one of the few remaining refuges for Australasian Bitten (*Botaurus poiciloptius*)", a threatened species (Department of the Environment, Water, Heritage and the Arts 2008). Approximately 18 species located at Thomsons Lake are listed under treaties including: four cormorants, 11 herons, 11 ducks, eight rails and 20 shorebirds. The lake is one of the few Perth metropolitan wetlands at which the Marsh Harrier (*Circus aeruginosus*) still breeds and is one of the few known breeding localities for Baillon's Crake (*Porzana pusilla*) in WA. Eight species of migrant shorebirds frequent the lake annually. Aside from waterbirds, six wetland frogs and the Oblong Tortoise (*Chelodina oblonga*) have been recorded, but no threatened species occur (Department of the Environment, Water, Heritage and the Arts 2008).

In light of the close proximity and status of the fauna described above, the site has the potential to be a habitat for rare fauna. According to the Department of Environment, Water, Heritage and the Arts' *Environmental Protection & Biodiversity Conservation Act 1999* Matters of National Environmental Significance database, there could potentially be five threatened species within the study area (RPS 2008).

3.5 Historical Land Use

The majority of land parcels within the development area have been utilised for rural land purposes including horse agistment, and a number of the lots are vacant (CoC, 2008a). Detailed investigations have not been undertaken to determine all historical land uses; however, from the initial investigations there is potential for localised areas of contamination due to the rural land use. Localised contamination sources on rural properties typically consist of herbicides and pesticides; nutrients; salinity, metals and scrap metals, oils and general waste (DEP 2001).

3.6 Ethnographic Considerations

There is one site of Aboriginal Heritage significance recorded within the study area, as reported in the Aboriginal Heritage Dataset (DIA December 2008). This Aboriginal Heritage Site (Identifier 18938) covers an area of approximately 300ha and includes all of Thomsons Lake. A small portion (0.2ha) of this broad boundary crosses into the study area (see **Figure 6**). The Aboriginal Heritage Site boundary has been generically mapped (not following a specific physical boundary) and although a small portion crosses into the study area, it is unlikely to effect the development DA13 – Branch Circus.

3.7 Hydrology

A DWMS requires a good understanding of the quantity and quality of the surface water across and the groundwater beneath the proposed development area. A sound understanding of these constraints and opportunities enables appropriate management strategies to be determined.

The groundwater levels across the site are required to determine the most appropriate post-development land use e.g. areas of shallow water table are more suitable for POS than for dwellings or infiltration basins.

The quality of the groundwater leaving the site will affect the environmental health of the surface water body it drains into, as does the quality of the surface runoff. Understanding the quality of this water is the first step to managing it to acceptable water quality standards.

The quantity of the surface runoff is the most visually obvious constraint to management, yet it should be considered equally as important as the groundwater quantity and quality, and surface water quality. The management of surface runoff rates and volumes are important to protect areas from flooding and from potential erosion.

3.7.1 Groundwater Levels

A search of the DoW groundwater bores surrounding the study area revealed that there are five bores with long term data suitable for calculating regional Annual Average Maximum Groundwater Levels (AAMGL). **Table 3.7.1** shows the calculated AAMGL for the five bores.

Table 3.7.1 Calculated AAMGL Values for DoW Monitoring Bores

Bore Name	AAMGL (m AHD)
JE17C	18.08
JE7C	20.55
JM24	20.74
TM6C	18.52
TM16C	18.60

The data in the above table was used to create contours of the AAMGL. The AAMGL and the historic maximum groundwater levels (DoW 2004) are both shown in **Figure 7**. From this figure, it is seen that the groundwater can intersect with the surface in the vicinity of the CCWs.

The maximum groundwater levels are on the eastern side of the study area and the lowest levels on the western side of the study area. This indicates that the direction of groundwater flow is in a westerly direction.

Further groundwater level monitoring is required to inform the future stages of water management planning, Local Water Management Strategy and Urban Water Management Plan. This information will be used to determine appropriate fill and/or sub-soil drainage requirements. The monitoring should be conducted for a period of at least 18 months and include two winter peaks.

3.7.2 Groundwater Quality

Water from rainfall events can infiltrate through the soil and reach the underlying aquifer. During this process, the water can carry nutrients and other contaminants from the surface to the groundwater. If the aquifer intersects and discharges into a surface water body, it could alter the quality of the surface water body. In **Section 3.7.1** it was determined that both the existing CCWs may intersect the underlying aquifer for some periods of the year. Thus, these wetlands could currently receive nutrients from groundwater. The quality of the study area groundwater should be monitored to determine the risk of eutrophication of the wetlands due to the existing groundwater quality.

Groundwater quality data from the five bores used in the regional groundwater level investigation is shown in **Table 3.7.2**.

Table 3.7.2 Groundwater Quality for DoW Monitoring Bores

Parameter		Trigger[1] Value	Bore Name				
			JM24	JE7C	TM16C	TM6C	JE17C
pH in *situ*	Max	8	4.8	6.3	6	-	5.3
	Min	6.5	4.8	5	5	-	5.3
	Avg	-	4.8	5.6	5.3	-	5.3
Temperature (ºC)	Max	25	21	25.8	22.3	19.5	23
	Min	-	20.2	13.1	14.8	19.5	23
	Avg	-	20.7	20.6	19.6	19.5	23
Turbidity (NTU)	Max	20	70	0.8	67.2	5.6	1
	Min	10	1.3	0.5	4.9	5.6	1
	Avg	-	22.1	0.65	36.1	5.6	1
TP (µg/L)	Max	65	42.7	21.7	1367	20	15
	Min	-	42.7	2	51	20	15
	Avg	-	42.7	13.3	802	20	15
TN (µg/L)	Max	1200	889	5255	5465	2200	978
	Min	-	889	480	777	2200	978
	Avg	-	889	2358	3052	2200	978
NO_X (µg/L)	Max	150	5110	4260	441	1200	40.4
	Min	-	13.2	118	2	1200	40.4
	Avg	-	2562	1645	59	1200	40.4
TKN (µg/L)	Max	1000	886	5255	5323	-	938
	Min	-	886	480	693	-	936
	Avg	-	886	2276	3089	-	936
Total Chloride (mg/L)	Max	-	73.6	36.9	267	59	84.8
	Min	-	18.6	36.9	267	59	84.8
	Avg	-	40.8	36.9	267	59	84.8
Total Sulphate (mg/L)	Max	-	49	20.2	82	28	-
	Min	-	17	20.2	82	28	-
	Avg	-	33	20.2	82	28	-

[1] Trigger values are for slightly disturbed ecosystems – wetlands (ANZECC 2000). These surface water trigger values can be used to give an indication of the quality of the groundwater.

The groundwater flows in a westerly direction, thus bores TM6C and TM16C will intersect the groundwater that flows directly through the study area (**Figure 7**). These two bores are of particular interest for analysis of the quality of the groundwater within the study area; the remaining bores indicate the quality of the groundwater surrounding the study area.

The data in **Table 3.7.2** indicates that the groundwater within and outside of the study area has high nitrogen concentrations. All bores exceed the default trigger values for TN, TKN and NO_x

(ANZECC 2000). If the groundwater discharges into the wetlands within the study area, there is the potential for this groundwater to affect the quality of the surface water.

The groundwater quality data indicates that the Total Phosphorus (TP) concentrations in all bores except TM16C are lower than the default trigger values. The average TP concentration recorded for TM16C is 10 times the default trigger value. This concentration is very high and may be the result of being located downstream of the Bartram Road Buffer Lakes, as the upstream bore JE7C has an average TP concentration which is less than the trigger value.

Further groundwater quality monitoring is required to determine local groundwater quality, providing baseline data to inform the management of POS areas in the post-development environment. The monitoring should be conducted on a quarterly basis for a period of at least 18 months.

3.7.3 Surface Water Quantity

An understanding of the existing surface runoff throughout a proposed development site is required, so that an effective post-development stormwater management strategy can be designed. The surface runoff is estimated using accurate data on topography, infiltration rates, vegetation and existing drains. This information is used in a hydraulic and hydrologic model to calculate peak discharges and volumes of runoff.

3.7.3.1 Existing Drainage Network

Lot 3 Hammond Road contains a drainage sump that collects road runoff from a portion of the development immediately east of the study area (**Figure 8**). The DSP proposes that this sump will be removed and the drainage from this development will be incorporated into the DA13 – Branch Circus drainage network.

The surface water runoff from the existing study area is not currently managed by any drainage infrastructure. Surface runoff sheet flows following the natural topography to the CCWs. Surface water runoff would enter the northern CCW and for minor rainfall events it would infiltrate and/or evapotranspirate. For large rainfall events, surface water runoff will overtop the wetland and discharge north into the larger northern section of the CCW. This larger northern section of the CCW drains via a City of Cockburn open channel towards Lake Kogolup. See **Figure 8** for location of the City of Cockburn open channel.

The wetland in the south-western portion of the study area will also retain surface water runoff and infiltrate and/or evapotranspirate for minor rainfall events. Historically, there was a 300mm pipe culvert connecting the CCW and the buffer lakes. This culvert was intentionally blocked off to stop the buffer lakes discharging into the CCW and causing flooding of the area. An open channel was constructed so that during large events, the CCW could discharge to a storage area (immediately west of the buffer lakes, see **Figure 3**) and ultimately south to a tributary of Thomsons Lake. When the Water Corporation's 1400S-11 was installed under the unpaved road separating the buffer lakes and the CCW, the open channel was blocked off and a new culvert connecting the buffer lakes and the CCW was installed. The Water Corporation did not intend for this culvert to be reinstated and would like this culvert blocked again (Ted Evans, Water Corporation *pers comm*). Although there is currently a direct hydraulic link between the CCW and buffer lakes, this hydraulic link will be removed and thus the pre-development modelling has assumed that there is no hydraulic link via this culvert. The Water Corporation have advised they will block this culvert but have not provided a timeframe for completion.

The Bartram Road Buffer Lakes receive surface water runoff from road drainage networks to the east of the study area. Inflow is controlled so that it only receives the 'first flush' or less than the 1 yr ARI event (Ted Evans, Water Corporation *pers comm*). The lakes drain via the Jandakot Branch Drain (1500RC 3 RR). This piped drain partially discharges to the south-west of the study area, into a tributary of Thomsons Lake. The Jandakot Branch Drain also continues north following the western boundary of the study area and drains into Yangebup Lake (Frank Kroll, Water Corporation *pers comm*). There is an overflow connection from the Jandakot Branch Drain that discharges to a City of Cockburn open channel, which ultimately discharges to Lake Kogolup. See **Figure 9** for the location of the Water Corporation Drainage infrastructure.

The pre-development sub-catchments and the natural flow paths are shown in **Figure 10**.

3.7.3.2 Pre-development Surface Runoff Modelling

Modelling of the existing pre-development environment was conducted using XPSWMM. The methodology and assumptions made are presented in **Appendix B**. The results of the modelling are provided within the following **Section 3.7.3.3**.

3.7.3.3 Modelling Results

The modelling was performed for storms with an Average Recurrence Interval (ARI) of 1, 5, 10 and 100 years. The ARI rainfall events modelled were sourced from Australian Rainfall & Runoff (ARR) charts. A multi-storm analysis was performed to determine the critical duration event that produces the largest peak discharge from the study area. The modelling showed that the storm duration that produces the largest peak discharge for the 5, 10 and 100 year events is the 6 hour duration. The peak discharges from the study area's catchments, for the 6 hour duration event, are listed in **Table 3.7.3.3a**.

Table 3.7.3.3a Pre-development Runoff Results

Discharge Location	5 Year – 6 hour ARI		10 Year – 6 hour ARI		100 Year – 6 hour ARI	
	Discharge (m^3/s)	Volume (m^3)	Discharge (m^3/s)	Volume (m^3)	Discharge (m^3/s)	Volume (m^3)
Into Northern CCW	0.228	4,275	0.318	5,695	0.704	11,900
Into Southern CCW	0.210	3,050	0.312	4,065	0.655	8,545
Discharge from Northern CCW	0.042	975	0.061	1,325	0.133	2,880

From Catchment East	0.097	510	0.120	615	0.180	1,145

The modelling indicated that the surface runoff for the 1 year ARI event was negligible due to the anticipated high infiltration soils. The results for this event have therefore been omitted from the above table.

It is important to determine the maximum amount of water that will accumulate in each wetland as this flooding extent could impact on the proposed development area. With the use of the accurate high resolution LIDAR data, the XPSWMM model was used to calculate the maximum volume of water that would accumulate in the southern and northern CCWs. The storage capacity of the south-western wetland at differing height intervals are as listed below:

- 19.25mAHD there is no storage (bottom of the wetland);
- 20mAHD there is 7,910m^3 of storage;
- 20.5mAHD there is 40,175m^3 of storage.

Table 3.7.3.3b shows the depth of water, flooded surface areas and storage volumes within the wetlands for the 100 year – 72 hour ARI event (the maximum modelled flood event).

Table 3.7.3.3b Pre-Development Wetland Storage Dimensions

Wetland	Depth of Flooding (m)	Flood height (mAHD)	Flooded Surface Area (m^2)	Flooded Volume (m^3)
Northern CCW	1.02	18.77	28,635	16,685
Southern CCW	0.83	20.08	24,465	12,520

The flood height is based on the assumption that the wetlands are empty at the time of the 100 year ARI rainfall event. However, it is possible that the wetlands may contain water from previous rainfall events and/or from high groundwater levels; thus, the actual resulting flood heights may be higher than those shown in **Table 3.7.3.3b**.

The elevation of the invert of the culvert connecting the CCW to the Bartram Road Buffer Lakes is approximately 20.5m AHD and the road elevation is 20.75mAHD. Due to the significant storage potential in the wetland compared to the total runoff volume during the 100 year ARI rainfall event, it is not anticipated that the wetland will discharge to the buffer lakes via the culvert or by overtopping the road. However, the culvert should still be blocked as is required by the Water Corporation (Ted Evans, Water Corporation *pers comm*).

3.7.3.4 Flood Mapping

Proposed development sites that are near major rivers or are in a valley at the bottom of a catchment have the potential to be at risk from flooding from upstream catchments. Regional floodplain modelling can indicate the magnitude of this flooding.

The study area is effectively at the top of a catchment, due to the topography and the surrounding man-made structures (roads). It is not likely to be flooded from rainfall events originating outside the study area. The only area at risk of flooding are the CCWs due to runoff from within the study area, as described in **Section 3.7.3.3**; however, this area will not be developed.

3.7.4 Surface Water Quality

For water bodies in close proximity to residential developments, the most common form of contamination is from nutrients. Surface runoff from rainfall events will collect nutrients (fertilizers, organic matter, etc) as it washes through a development. These nutrients will accumulate in downstream receiving water bodies where excessive nutrient concentrations can cause eutrophication and damage the ecosystem.

There are no known water quality records for the CCWs. These two water bodies receive nutrients through surface runoff from the catchment and through groundwater interaction, thus the quality of the water in the wetlands will not directly indicate the quality of the surface water runoff. The optimal method of determining the quality of the runoff from a catchment is through direct measurements of the runoff in defined channels. The study area only has sheet flow (no defined channel) and therefore it would be difficult to accurately measure the quality of the runoff. See **Section 6.6** for water quality management strategy and water quality trigger values.

3.8 Summary of Existing Environment

In summary, the environmental investigations conducted to date indicate that:

- The study area is undulating, sloping gently from 30m AHD near the east to 20m AHD in the west. There are two low points within the north-east and south-east portions of the study area, which correspond to identified wetlands;
- The site is located on the Bassendean Dune system, which is described as "leached, infertile and acidic";
- The majority of the site consists of sandy (S8) soils. The wetland areas are described as the silty sand (Ms5) soil unit;
- The ASS risk maps indicate that the wetland areas have a "high risk of ASS being found within three metres of the surface". The structure plan proposes to develop areas of Lot 22 which are within the high ASS risk area;
- Two CCWs are present within the development after the DEC reviewed and reclassified the wetland classifications within the development;
- There are no Bush Forever sites with in the study area; however, there is a large Bush Forever site to the north and west of the study area;
- The study area has sparse understorey vegetation and few areas with remnant mature trees. RPS is currently conducting a flora investigation to determine the presence or otherwise of rare flora;

- Due to the proximity of Thomsons Lake and the large Bush Forever Site 391, the study area may contain rare fauna, particularly bird species;
- The historical land use of the study area has included rural purposes, with some lots currently vacant and unused;
- There is one Aboriginal Heritage Site located to the west of the study area and is associated with Thomsons Lake. A small portion of this site's boundary falls within the study area;
- There are two distinct surface water catchments within the study area. The northern catchment discharges to the northern CCW and the southern catchment discharges to the southern CCW.
- The peak discharge from the northern CCW in the 100 year – 6 hour duration rainfall event is $0.114m^3/s$;
- The historic hydraulic link between the CCW and the Thomsons Lake has been blocked due to the paved road separating the Bartram Road Buffer Lakes and the CCW, and the location of the 1400S-11;
- Lot 3 Hammond Road contains a sump that receives runoff from a portion of the development immediately east of the study area. The peak discharge from this development for the 100 year – 6 hour duration rainfall event is $0.18m^3/s$;
- The *Perth Groundwater Atlas* mapping indicates that maximum recorded groundwater levels across the southern portion of the study area are between 20 and 21mAHD. The minimum ground surface level in this wetland area is 19mAHD. Therefore, there is the potential for interaction between the groundwater and the natural surface;
- Groundwater flows in a westerly direction; and
- The DoW groundwater bores on the western (downstream) side of the study area indicate that the groundwater underlying the study area has nutrient concentrations.

3.9 Areas Requiring Further Investigation

Through the development of this DWMS, areas have been identified which require further investigation prior to beginning the next stage of development during a LWMS. These areas requiring further investigation are:

Groundwater

Groundwater monitoring bores should be installed across the study area as soon as possible to further refine the groundwater levels and quality data. A groundwater level and quality sampling regime should be implemented to capture monthly groundwater levels and quarterly groundwater quality data for a period of at least 18 months. This information will be used to determine the AAMGL and the groundwater interaction with the CCWs. Groundwater samples should be analysed for contaminants including nutrients, pesticides, metals and hydrocarbons. This information will provide baseline data and guide future management plans.

Geotechnical and Soil Types

A geotechnical investigation is required to determine the soil characteristics and how this could impact on the proposed development. The investigation should include infiltration tests, appropriate locations for onsite disposal of stormwater (infiltration basins), soil types, suitability of soils for development and if treatment is required, settlement tests, bearing ratios etc.

Acid Sulfate Soils

The study area is mapped as having areas of moderate risk and high risk of acid sulphate soils being found within three metres of the natural surface. An investigation is required to determine the actual presence or otherwise of the acid sulfate soils and the extent throughout the study area. If ASS are found within the areas that are proposed to be developed or disturbed, then appropriate management plans must be determined.

Fauna

Onsite fauna surveys should be conducted to determine the presence or otherwise of declared rare fauna and/or priority fauna within the site. Appropriate management may be required and this should be presented in a Fauna Management Plan.

Flora

The results of the Flora investigation by RPS should be presented in the LWMS. If rare flora is found, appropriate management measures should be presented in a Flora Management Plan.

Ethnographic

A small portion of the Aboriginal Heritage Site 18938 crosses into the study area. A Section 18 application must be submitted to ensure development of this portion of the study area.

Contamination

A site and desktop investigation is required to determine all previous land uses, possible contamination resulting from the land use and current presence of the suspected contamination.

Surface Water

The two wetlands within the study area require water quality monitoring. This information, in conjunction with the groundwater quality monitoring, will provide baseline data. The baseline data can be compared to the post-development monitoring and allow for a determination of the success of the implemented water quality management strategies. Wetland water quality data will also enable an assessment of the quality of the wetland and its classification.

The peak water levels within the wetlands should be monitored to determine the flood extent, this will aid in determining the sand fill requirements to achieve adequate lot freeboard.

4. STAKEHOLDER CONSULTATION

4.1 Water Corporation

Consultation has been conducted with the Water Corporation to seek feedback on existing infrastructure surrounding the study area and the likely interaction between this infrastructure and the proposed development. The conclusions from the feedback were:

- The Bartram Road Buffer Lakes were not designed to treat stormwater for developments west of Hammond Road. Thus the lakes cannot be used by the proposed development for treatment of stormwater runoff.
- Historically there was a culvert connecting the buffer lakes and the CCW. This hydraulic link was removed by the Water Corporation. During construction of the 1400S-11, a new 300mm pipe culvert was installed. However, this culvert should not have been installed and the Water Corporation will re-block this hydraulic link.
- Historically there was an open channel connecting the CCW to the low-lying area immediately west of the buffer lakes. These low-lying areas could discharge to a tributary of Thomsons Lake. This open channel was removed during construction of the 1400S-11. This link could be re-instated with co-operation with the Water Corporation.
- There is an existing 600mm water main alongside Hammond Road. This has capacity to supply water to the proposed development (see **Figure 9** for location of Water Corporation Infrastructure).
- There is an existing 1050mm sewer main located on the western side of the study area and a future 600mm sewer main is proposed to run alongside Darlot Avenue. These two sewers will have capacity for the proposed development.
- The developer is to fund all reticulation size works. Headworks size mains may need to be prefunded.

4.2 Department of Water

The Department of Water (DOW) was contacted in regard to groundwater extraction licences. The development is within the Jandakot Groundwater Area and Success Subarea. As of the 4 October 2010, the total allocated, committed and requested groundwater licences were equal to 3.74GL of the total 4.3GL allocation limit. The groundwater subarea is therefore 87% allocated. An application should be submitted as soon as possible to determine current extraction availability and to secure the resource. Currently within the study area there is a licence with a extraction limit of 4,885kL/year. This licence could be transferred to the developer of the land parcel.

4.3 City of Cockburn

The stormwater and groundwater design criteria presented in this DWMS document have been determined through consultation and report revisions with the CoC.

5. ANALYSIS OF DEVELOPMENT IMPACTS AND OPTIONS

Urban developments change the existing environment. This change may impact on the flora, fauna, biodiversity, hydrologic regime, traffic, employment, public transport, electricity demand and many other aspects of the site and the surrounding area. The degree of this impact can be reduced or prevented by appropriate planning and design. This section of the DWMS highlights some of the development's possible impacts on the study area, an assessment of the effectiveness of the proposed management strategies (to be discussed in **Section 6**) and the appropriateness of the land use scenario.

5.1 Assessment of Proposed Land Use Scenario

The Perth metropolitan population is increasing and there is the growing need for more land to be developed, particularly the vacant land within the city extents to reduce urban sprawl. The strip of land west of Hammond Road and immediately east of the Thomsons Lake is currently being developed and the study area is the last remaining parcel of land available to be developed. The study area has sandy soils and the majority of the site has adequate clearance to groundwater. The native vegetation of the study area is degraded, as is the CCW. The land has ideal location and characteristics for development and there is the potential to improve the quality of the CCW through community involvement.

5.2 Impact Assessment and Management Options

An impact assessment of the development (focusing on water and environmental impacts only) on the existing environment of the study area was conducted and the findings are shown in **Table 5.2**.

Table 5.2 Potential Impact Assessment and Management Options

Action	Potential Impact	Management Strategy	Resulting Impact
Clearance of the existing vegetation	- Loss of flora - Loss of fauna	- Relocate rare flora and fauna to the adjacent Bush Forever Site - Retain remnant trees where possible. - Retain and revegetate the existing CCWs	- Biodiversity is not regionally significantly effected
Development in close proximity to the CCWs	- Weed invasion - Damage to fauna habitat and consequential loss of fauna - Degradation of water quality	- Implementing revegetated native vegetation buffers around wetlands - Community involvement in revegetating and maintaining wetlands - Implementing WSUD drainage techniques - Retain appropriate portions of Wetlands	- Flora and fauna habitat protected or enhanced - Water management strategies will maintain or improve water quality of wetlands
Increased imperviousness of the study area	- Increase volume and runoff rates - Hydrologic regime altered - Decreased underlying aquifer recharge	- The use of Retention/detention infiltration basins to mitigate volumes and peak discharges - Infiltration encouraged through soakwells, bottomless junction chambers and infiltration basins.	- Hydrologic regime and aquifer recharge rates maintained
Disturbance of ASS	- Acidification of soil and groundwater - Acidification of downstream surface water bodies	- Site investigation to determine extent of ASS - Soil removed/treated - Construction locations altered	- ASS will not damage infrastructure or cause acidification of soils or groundwater

6. WATER MANAGEMENT STRATEGY

Water is a valuable resource that must be managed sustainably. Conservation of water through fit-for-purpose use and best management practices is encouraged so that water is not wasted. The total water cycle must be analysed for a new development so that all water in the developed is managed; this includes management of:

- Surface water quantity and quality;
- Groundwater quantity and quality;
- Water supply; and
- Waste water.

The following sections describe the water uses in the proposed development and how they should be best managed.

6.1 Total Water Cycle Management

The water cycle is complex, involving rainfall, evapotranspiration, overland flow and groundwater flow. WSUD grew out of recognition of the linkages in the water cycle between urban development, stormwater systems and the quality of downstream ecosystems, and is based on a holistic approach to water cycle management and regional natural resource management.

The application of WSUD principles involves incorporating water resource issues early in the landuse planning process. It addresses water resource management at the catchment, suburb, precinct, cluster and allotment scale. WSUD makes the entire stormwater treatment network part of the urban fabric via Multiple Use Corridors (MUCs) and Best Management Practice (BMP) treatment trains (DEH 2002).

Total water cycle management recognises the finite limit to a region's water resources, and the inter-relationships between the uses of water and its role in the natural environment.

Key principles of total water cycle management include:

- Considering all water sources, including wastewater, stormwater and groundwater;
- Using all water sources sustainably;
- Allocating and using water equitably; and
- Integrating water use with natural water processes, including maintaining environmental flows and water quality.

The *State Water Strategy* (Government of WA 2003) endorses the promotion of total water cycle management and application of WSUD principles to provide improvements in the management of stormwater, and to increase the efficient use of other existing water supplies.

Total water cycle management therefore addresses not only physical and environmental aspects of water resource use and planning, but also integrates other social and economic concerns. Stormwater management design objectives should therefore seek to deliver better outcomes in terms of:

- Potable water consumption;
- Stormwater quality and quantity management;
- Flood mitigation; and
- Shallow groundwater management.

A fundamental first step in applying total water cycle management in urban catchments is to establish agreed environmental values for receiving waters and their ecosystems. Guidance regarding environmental values and criteria is provided by a number of National and State policies and guidelines.

The overall objective for preparing total water cycle management plans for proposed residential developments is to minimise pollution and maintain an appropriate water balance. This objective is central to the DA13 – Branch Circus DWMS, and will be achieved by ensuring that hydrological regimes are changed minimally with respect to pre-development conditions.

6.2 Fit for Purpose

The term fit-for-purpose describes the use of water that is of a quality suitable for the required use of the water. For example the quality of the water used in a toilet does not require the same quality as the water required for a kitchen tap, as the kitchen tap water may be consumed. The water quality standards for potable drinking water are stricter than that for non-potable water. The conservation of the potable scheme water provided by the Water Corporation can be achieved by using lower quality water such as groundwater, recycled water or grey water for uses that do not require high quality water e.g. irrigation, toilets, washing machines etc.

The State Water Plan has set a target for domestic scheme water use of 100kL/year per person (Water Corporation 2006) with no more than 40 to 60kL/person/year from scheme water. The average household consumption of scheme water since 2001 (since the implementation of two sprinkler days per week) has been 110kL/year per person (Water Corporation 2005). **Section 6.4** describes a number of methods that the DA13 – Branch Circus development could implement to achieve the State Water Plan target.

6.3 Water Source Allocation and Infrastructure

A residential development will use water in the house, around the house (gardens), POS area and possibly on the road verge. The Water Corporation spreadsheet *AltWaterSupply_Water_Use_Model.xls* was used to estimate the total water requirements for the DA13 – Branch Circus development. The following assumptions were used in the calculation:

- 3.88ha of R25 lots (110 lots);
- 1.82ha of R30 lots (60 lots);
- 2.65ha of R40 lots (120 lots);
- 1.36ha of turfed POS;

- 6.86ha of road verge; and
- 0.40ha of land for a swimming pool.

For these parameters, the spreadsheet calculates that the total annual water consumption of the development would be 122,130kL. The Water Corporation has confirmed that the existing infrastructure surrounding the development is sufficient to supply this fresh water and remove the resulting waste water.

The Water Corporation spreadsheet calculates that the water consumption of the development per person is 80kL/year, which is less than the maximum consumption target of 100kL/year per person by 2012 set by the State Water Plan. **Section 6.4** details strategies to further reduce the development's potable scheme water requirements.

6.4 Water Conservation

6.4.1 Lot Potable Water Conservation

Significant reductions in water usage can be achieved through implementation of measures at a lot scale. These measures include In-house and Ex-house water saving devices and practices. Such measures could be promoted or mandated by the developers of the DA13 – Branch Circus development as a part of the state Waterwise program (DoW 2007b); however, the ultimate responsibility for their implementation/uptake usually rests with individual lot owners. Devices or practices where efficiencies can be made are:

- Shower heads;
- Toilets;
- Washing machines;
- Taps;
- Gardening practices;
- Rainwater tanks;
- Non-potable groundwater; and
- Recycled Greywater.

The use of groundwater is not recommended for the lots within the DA13 – Branch Circus development due to private bores being difficult for local councils to manage (water consumption) and the risk this may cause to the wetlands in the study area.

Recycled greywater can be used for non-potable water requirements such as for watering the garden. Greywater contain some concentration of nutrients, particularly phosphorus in detergents. These nutrients could be transported via groundwater and into downstream water bodies. Due to the close proximity of the development to the protected REW and CCW, recycled grey water is not recommend as there is the risk of increased nutrient conveyance to the wetlands.

6.4.1.1 In-House Water Consumption

A water balance analysis was conducted to determine the water uses within the house and the amount of water saved through common water saving devices. The guiding document *Domestic Water Use Study* (Water Corporation 2003) was used for device consumption rates and the analysis was for a four person family home. The results of the analysis are presented in **Table 6.4.1.1**.

Table 6.4.1.1 In-house water Consumption

Method	Assumption	Water Consumption (kL/year	Water Saving (kL/year)
Standard shower head	One 8 minute shower per person per day.	175	-
AAA rated shower head		93	82
Standard single flush toilet	Three flushes per person per day.	53	-
Dual flush toilet		20	33
Standard top loader washing machine	One load per household per day.	55	-
AAAA rated front loader washing machine		15	40
Standard taps	16% of all water used in the home is used via taps.	54	-
Water saving taps		27	27
Total – standard devices		337	-
Total – water saving devices		155	182

The above table indicates that through the use of water saving devices, the in-house water requirements can be approximately halved. The required water can be further reduced by altering water use practices such as: reduced shower durations, not leaving the tap running while brushing teeth or shaving, only use washing machines for full loads etc. These efficient water use practises can be encouraged through educational programs.

For the four person house using the water saving devices, the house hold uses 155kL a year or approximately 39kL/year/person within the house. Of this 155kL a year, 35kL/year could potentially be used for non-potable requirements (Toilet and Washing Machine). This 35kL/year could be sourced from rainwater. A 3kL rainwater tank on a 300m^2 roof could supply all of the non-potable water for the entire year; further reducing the total In-house scheme water requirement to 120kL a year.

The above calculations indicate the potential water savings possible through a range of measures. The use or otherwise should be further investigated and negotiated with the CoC and the developer to be presented in future LWMS documents.

6.4.1.2 Ex-House Water Consumption

The average Perth home uses 707L/day or 260kL/year on the garden, equating to 56% of all the water consumed by the lot (Water Corporation 2003). Therefore, out-door water saving techniques can produce dramatic reductions in the overall water use of the lot. The Water Corporation's Waterwise Display Village program recommends the following garden water saving techniques (Water Corporation 2006):

- Where required, soil shall be improved with soil conditioner certified to Australian Standard AS4454 to a minimum depth of 150mm where turf is to be planted and a minimum depth of 300mm for garden beds (for entry statement only);
- The irrigation system shall be designed and installed according to best water efficient practices. The controller must be able to irrigate different zones with different irrigation rates. Emitters must disperse coarse droplets or be subterranean;
- Entry statements should include a 1:1 mix of hardstand areas to turfed areas and garden beds;
- The adoption of Xeriscaped POS gardens, where garden beds within POS and community areas are landscaped using 'waterwise plants', which are local native species from regions with similar climates that require less water inputs than exotic species;
- The turf species used should be a genotype endorsed by the UWA Turf Industries Research Steering Committee (e.g. Couch grass – Cynodon dactylon); and
- Garden beds to be mulched to 75mm with a product certified to Australian Standard AS4454.

Using ex-house water saving techniques such as those listed above can reduce the ex-house water use by 50% (Melbourne Water 2008). On this basis, the average ex-house water use could potentially be reduced from 260kL/year to 130kL/year.

It is likely that 707L/day water used on the garden for 3.35 person household in the 2003 Water Corporation study, was for tradition styled small house on a large gardened lot. This type of house would require more water for the garden than a contemporary large house on a smaller garden block, as would be found in the Branch Circus District Structure Plan development. Therefore there is the potential that the total ex-house water (for this water balance analysis) use could be reduced lower than 130kL/year. Further evidence of this possible reduction is given by the average water use of a typical household in Melbourne, using water saving techniques (such as those described above), which uses only 34kL/year (Melbourne Water 2008).

Although there is potential for the lots to consume less than 130kL/year on the garden, this conservative value has been adopted in the water balance analysis.

The above ex-house water saving techniques and others should be further investigated and negotiated with the CoC and presented in future LWMS documents.

6.4.1.3 Total Lot Water Consumption

Through the above water balance analysis, it is calculated that a typical four person family house, not using water saving techniques will consume 595kL/year (335kL in-house and 260kL ex-house). This equates to approximately 150kL/year per person, which is greater than the State water consumption targets.

The water balances analysis showed that for a four person family home that does use all of the described water saving techniques, the total water consumption is 225kL/year (120kL in-house and 115kL ex-house). This equates to approximately 62kL/year per person. To achieve this will require educational programs and involvement of the lot owner, developer and the City of Cockburn.

6.4.2 Development Potable Water Conservation

It is widely thought that the local climate is undergoing a drying trend, and that as the City's population grows and demands for potable water sources increase, significant attention should be focused on the manner in which the resources currently available are utilised. This consideration is acknowledged, and therefore use of water within the subdivision should be minimised wherever possible. This should be achieved by application of the following approaches:

- Minimise water requirements for establishment of POS;
- Minimise water requirements for POS maintenance; and
- Minimise net use of water by maximising surface aquifer recharge.

The above criteria can be achieved through the various strategies; presented below are techniques that should be further investigated so that the developments potable water conservation strategy to be implemented can be presented in future LWMS documents.

Vegetation

Prior to clearing the development site, wherever possible, remnant native trees should be retained. As well as environmental benefits, the native vegetation will provide shade and reduce water requirements during POS establishment.

Native low-water requiring plants should be used in conjunction with soil conditioning and mulching to reduce water requirements and loss rates. Turfed areas require large quantities of water and thus these areas should be minimised.

Groundwater

The POS turfed areas of the development will require irrigation. It is recommended that where possible groundwater should be used as an alternative to scheme water. Typically, turfed POS areas require approximately 7,500kL/year/ha to irrigate. For the proposed development, the total POS area of approximately 1.36ha (excluding verge areas) would require 10,200kL of water a year. The DoW advices that combined extraction licences for up to 4,885kL/year exist across the study area. This could potentially be transferred to the DA13 – Branch Circus developers and subsequently to the CoC. The remainder of the irrigation requirements could be supplied from the superficial aquifer which has 560ML unallocated.

Infiltration

Recharging of the underlying superficial aquifer through infiltration of stormwater, allows for more groundwater to be drawn during dry periods. Strategies to aid in increasing infiltration are: infiltration basins, aquifer recharge by injecting stormwater into the aquifer (not recommended for the study area), reducing paved areas, using porous pavement and soakwells.

Education

The managing authorities of the POS and basin areas should be educated on best management practices to ensure conservation of water; particular attention should be made to irrigation design and management to ensure POS areas are not over watered.

6.5 Surface Water Quantity Management Strategy

Developments typically have a high proportion of impervious surface area (roads/paths and roofs) when compared to the pre-development environment. The increased imperviousness results in:

- Increased total volume of runoff;
- Increased maximum runoff rate (peak discharge); and
- Decreased time for runoff to occur.

The basic principle of stormwater quantity management is to slow down the stormwater runoff and infiltrate as much as possible, mimicking the existing environment. This ensures lower peak discharges and lower volumes of runoff in main drainage corridors, which could lead to flooding.

Through consultation with the Water Corporation, the Department of Water and the City of Cockburn, reviewing guiding documents and the water quantity strategies explained in this document, the following water quantity discharge objectives were determined:

- Retain the 1 year - 1 hour duration ARI rainfall event on site, preferably as close to source as possible;
- Detain the 5 year ARI rainfall event through to the 100 year ARI rainfall events so that the post-development peak discharge is attenuated to the pre-development peak discharge;
- The southern CCW must retain the 100 year ARI rainfall event in the post-development, as there is no discharge from this wetland for the existing environment; and
- A freeboard of 500mm between the lots floor level and the 100 year ARI peak flood level.

The above design criteria can be achieved through the use of various Water Sensitive Urban Design (WSUD) strategies. At a minimum, infiltration detention/retention basins are required to achieve the discharge requirements. This DWMS has achieved the requirements through the use of infiltration basins and proved the results through XPSWMM modelling (**Section 6.5.3**).

Although the water quantity design criteria can be satisfied by the use of infiltration detention/retention basins, the size of these basins can be reduced and infiltration located closer to source by implemented various WSUD techniques. Examples of possible WSUD techniques are discussed below and these should be further investigated and negotiated with the CoC and DoW and presented in future LWMS documents.

Lot Soakwells and Rainwater Tanks

The large impermeable roof area of each lot produces considerable runoff. This surface water runoff can be reduced at source by infiltration using soakwells and captured using rainwater tanks.

Roadside Swales and Buffer Strips

Swales and buffer strips are vegetated conveyance corridors. They typically have slopes of between 1% and 4%. This gradual slope combined with the increased roughness provided by vegetation reduces the stormwater runoff rate. The swales also provide some storage and infiltration capacity, thus reducing the total volume of runoff.

Flush Kerbing

Contemporary street drainage uses hard kerbing and pits draining the stormwater runoff to a sub-surface pipe network. This pipe network quickly transports the runoff through the development causing increased peak discharges from the area when compared to the pre-development peak discharge. Flush and intermitted kerbing allows most off this runoff to be directed to roadside swales, where it is more slowly conveyed or infiltrated. The location of flush kerbing must be approved by the CoC Engineers and Parks staff.

Bio-retention Swales

Bio-retention Swales (or ‘rain gardens’) are a combination of vegetated swale and pipe network. Water infiltrates through a vegetated porous soil medium and into a pipe, which then conveys the stormwater to a basin. The stormwater in the swale takes time to infiltrate through the soil medium and into the pipe network, thus reducing the peak discharge from the development (Bio-retention Swales also provide water quality treatment, see **Section 6.6**).

Porous Pavement and Non-porous Area Reduction

The majority of rain that falls on non-porous pavement will form stormwater runoff. The use of porous pavement or reduced area of non-porous pavement area can have a significant reduction in the total volume and peak discharge of the runoff.

Junction Chamber Infiltration

Bottomless junction chambers can allow infiltration of water captured by the pipe network. This results in a reduction in the total stormwater runoff volume. Bottomless junction chambers are only suitable in locations with high infiltration rates and where the superficial aquifer is lower than the pipe junction inlet.

Infiltration Detention Basins

An infiltration detention basin is a storage area that is dry throughout the year and only used during large rainfall events. They are typically incorporated into POS areas and used for recreational purposes for the majority of the year. During large rainfall events, typically greater than 1 year – 1 hour duration ARI rainfall event, the detention basin temporarily stores the runoff until the basin reaches maximum capacity, whereby the excess runoff will be discharged. By "holding back" the runoff, the peak discharge leaving the development is reduced. The storage volume of the basin is inversely proportional to the peak discharge from the basin. If the basin is located in an area of high infiltration soils e.g. sand, some of the runoff can be infiltrated into the superficial aquifer; thus reducing the total volume of runoff from the development. Infiltration detention basins are used in many contemporary developments in the Perth metropolitan area.

Retention Basins

A retention basin stores water and only releases the water through infiltration or evapotranspiration. These basins are typically vegetated and used to store the runoff from the 1 year – 1 hour ARI rainfall event. Retention basins can be located within a detention basin, so that excess runoff can be detained within the infiltration detention basin.

6.5.1 Post-development Surface Water Runoff Modelling

The DA13 – Branch Circus development DWMS will utilise retention and detention basins to ensure post-development peak discharges are comparable to the pre-development peak discharges. The calculation of these discharges is best achieved via a computational model. The post-development modelling uses the same methodology as the pre-development modelling. A detailed description of the methodology and parameters are provided in **Appendix B**.

6.5.2 Post-development Catchments

The post-development sub-catchments were determined based on the structure plan and assumed that the drainage network (flow direction) would be similar to the existing topography. Sub-catchments 1, 2, 3, 6, 7 and 8 have retention basins that retain the 1 year – 1 hour ARI storm event at close to source as possible and integrated into the POS areas. All runoff from these sub-catchments in the pre-development environment flows into and is retained in the northern and southern CCWs. The post-development stormwater drainage design was developed to maintain the pre-development hydrology and therefore no detention basins were provided in these sub-catchments.

Sub-catchment 12 is directed to the wetland to the north-east of the development. Retention and detention basins were designed in order to retain the 1 year – 1 hour event and detain events greater than the 5 year ARI event respectively. See **Figure 11** for indicative location of basins and post-development sub-catchments.

6.5.3 Modelling Results

The water quality design objectives (**Section 6.5.1**) states that the 1 year – 1 hour duration ARI rainfall event must be retained onsite. This runoff will be treated in a vegetated area prior to infiltration into the groundwater. The dimensions of the retention basins are shown in **Table 6.5.3a**. It is recommended that the vegetated basin has a maximum depth of 0.5m. This will contain the runoff within the vegetated area and enable nutrient removal of the stormwater runoff.

Table 6.5.3a Post-development Basin Dimensions

Catchment	Depth (m)	Side Slope	Surface Area (m^2)	Volume (m^3)
Retention Basin				
1	0.5	1:6	275	94
2	0.5	1:6	525	200
3	0.5	1:6	190	59
6	0.5	1:6	225	74
7	0.5	1:6	115	32
8	0.5	1:6	475	178
12	0.5	1:6	135	39
Detention Basin				
12	1.0	1:6	235	100

To satisfy the stormwater quantity management objective of ensuring the post-development peak discharges are comparable to the pre-development peak discharges, an infiltration detention basin was modelled within the XPSWMM model for Sub-catchment 12. The size (volume) of the basin was iteratively adjusted until the desired peak discharges from the basins were achieved. The dimensions of the detention basin are shown in **Table 6.5.3a**. The locations of the retention and detention basins are shown in **Figure 12**. Note that the retention basins identified for Sub-catchments 1 and 2 are located outside of the CCW buffer areas in Sub-catchment 5; the retention basin for Sub-catchment 8 is located in the south-western POS area in Sub-catchment 12; and the retention basin for Sub-catchment 3 is located in the Regional Open Space in Sub-catchment 4. Permission will need to be sought from the Department of Environment and Conservation (DEC) for the positioning of the Sub-catchment 3 retention basin within the Regional Open Space.

The comparison of the modelling results for the pre-development and the post-development peak discharges that exit the development are shown in **Table 6.5.3b**. The pre-development results differ from those listed in **Section 3.7.3** as the values in **Table 6.5.3b** are equivalent flow rates based on the post-development catchment areas.

Table 6.5.3b Post-development Peak Discharge

Catchment	5 Year – 6 hour ARI Discharge (m^3/s)		10 Year – 6 hour ARI Discharge (m^3/s)		100 Year – 6 hour ARI Discharge (m^3/s)	
	Pre	Post	Pre	Post	Pre	Post
12	0.037	0.014	0.054	0.024	0.118	0.114

The above **Table 6.5.3b** indicates that the post-development peak discharge for the 100 year ARI rainfall event can be mitigated to pre-development peak discharges when the detention basin in Sub-catchment 12 is implemented.

Due to the anticipated high infiltrating soils, vegetation of the existing environment, and moderate slope of the site, the pre-development peak discharges are low; this is particularly evident for the 10 year ARI rainfall event peak discharge. Consequentially when the detention basins are sized to mitigate the post-development 100 year ARI rainfall event runoff, the majority of the runoff is retained and thus the post-development peak discharges for the 5 and 10 year ARI events are less than the pre-development peak discharge. It should also be noted that the runoff from the 5 and 10 year ARI rainfall events retained in the detention basin will infiltrate and flow via subsurface flows into the adjacent CCW; thus the water dependant ecosystem (CCW) will still receive the inflow it requires albeit by a different flow path. This issue of reduced post-development peak runoff for the 5 and 10 year ARI events can be resolved with the design of a basin that has a weir and a low flow culvert. This level of detailed design should be completed during the LWMS stage.

The lots have been modelled assuming soakwells will be implemented (see **Appendix B** for modelling assumptions). However, no at source storage/infiltration (e.g. bio-pockets, porous pavement, bottomless junction chambers etc) has been modelled. This conservative approach provides the maximum discharge and basin requirements for the development. It is anticipated that at the LWMS stage, the WSUD at source storage strategy will be determined and the basin volumes can be reduced. The revised basin volumes and stormwater strategy should be presented within a LWMS document.

6.5.4 Flood Management

Both the northern and southern CCW do not discharge via surface runoff (only slow discharge through infiltration and evapotranspiration) and hence a large rainfall event could produce a significant area of flooding within the development. It is important to understand this flooding extent as it could affect the location and fill level of the proposed lots. The XPSWMM model was used to calculate the total volume of stormwater accumulating in the wetland for the pre-development and post-development environment. The results of the modelling are shown in **Table 6.5.4**. The post-development flooded areas are also shown on **Figures 12, 13** and **14**.

Table 6.5.4 Total Runoff Volume Accumulating in the CCW

Wetland	100 Year – 72 hour ARI					
	Pre-Development			Post-Development		
	Flood Level (mAHD)	Surface Area (m^2)	Volume (m^3)	Flood Level (mAHD)	Surface Area (m^2)	Volume (m^3)
Northern CCW	18.77	28,635	16,685	18.75	28,010	16,455
Southern CCW	20.08	24,465	12,520*	20.07	24,310	12,345

*This does not include runoff from Catchment East.

The detail modelling using the LidAR topography data shows that there is no significant difference in the flood level or flood volume for the 100 year ARI event, for the comparison for the pre-development and post-development environment. This is due to most of the wetlands catchment remaining undeveloped, the provision of at-source infiltration within soakwells and vegetated retention basins, and the proposed development area not encroaching into the inundation area.

As described in the pre-development modelling **Section 3.7.3.3**, it is not anticipated that there will be significant flooding within the southern wetland to overtop the unpaved road or flow through the existing culvert and into the Bartram Road Buffer Lakes, due to the significant storage potential of the wetland. However, the existing culvert must be blocked to satisfy the Water Corporation's requirements.

6.5.5 Inundated Area for POS Credit Calculations

The total inundated surface area of the retention and detention basins as well as the flooding occurring in the wetlands is shown in **Table 6.5.5**. These values can be used to determine the POS credit calculations within the development. **Figures 12**, **13** and **14** show the 1 year, 5 year and 100 year inundation areas respectively.

Table 6.5.5 Total Runoff Volume Accumulating in the CCW

ARI Storm Event	1 year – 1 hour (m^2)	5 year – 6 hour (m^2)	100 year – 6 hour (m^2)
Retention/Detention Basins	*1,940*	*2,110*	*2,175*
Northern CCW	0	15,640	28,010
Southern CCW	0	16,790	24,465
Total	*1,940*	*34,540*	*54,650*

The CoC POS credit calculations are shown in **Appendix C**.

6.6 Stormwater Quality Management Strategy

Better Urban Water Management (WAPC 2008b) advocates a water quality management approach that establishes pre-development water quality standards and then sets targets for post-development scenarios that reflect the pre-development water quality parameters. The stated principle is that existing surface and groundwater quality should be maintained as a minimum, and preferably improved prior to discharge from the development area.

Better Urban Water Management (WAPC 2008b) also indicates that if the pollutant outputs of the development could exceed catchment ambient conditions, and that if ambient conditions have not been determined, water quality targets should be derived from the water quality guidelines contained in the *National Water Quality Management Strategy* (ANZECC 2000).

The pollutant outputs of the pre-development environment runoff are difficult to accurately measure unless the runoff is directed into a surface water drain where the pollutants can be measured. For environments such as the study area where the runoff is 'sheet flow', there are no locations to measure all of the runoff from the area. Although the study area has two surface water bodies, measuring of pollutants in this water will not provide a direct link to the quality of the surface runoff and can not be used to determine runoff trigger values. Therefore, surface water quality targets have been derived from the *National Water Quality Management Strategy*.

The following water quality targets that should be met are percentage reductions that should be compared to a development that does not actively manage stormwater quality (WAPC 2008b):

- 80% reduction of Total Suspended Solids (TSS);
- 60% reduction of Total Phosphorous (TP);
- 45% reduction of Total Nitrogen (TN); and
- 70% reduction in gross pollutants.

The key design criteria that will be adopted to ensure that the above objectives are met will include:

- Retaining the 1 year – 1 hour duration ARI rainfall event on site; and
- Apply appropriate structural and non-structural measures to reduce applied nutrient loads.

Many of the surface water quantity WSUD techniques such as infiltration basin and swales also improve the quality of the surface water runoff. The following WSUD techniques should be investigated for their ability to improve the surface runoff water quality and presented in a future LWMS.

Infiltration Retention Basins

An infiltration retention basin treats stormwater runoff via nutrient uptake for events up to at least the 1 year – 1 hour ARI rainfall event. This guideline would capture most minor and first flush events and would result in treatment of over 98% of the average annual stormwater runoff volume in Perth (Wong *et al.* 1999). Therefore, the 1 year - 1 hour duration ARI rainfall event is a reasonable point to adopt a conservative design guideline.

Unlike a wetland, retention basins are not designed to be permanently wet. Instead, the stormwater will infiltrate into the soil (the rate of infiltration is dependant on the design criteria). A practical design is for the vegetated retention basin to be located within a larger detention basin or POS area, so that during large storm events the excess water can flood into the detention basin area. Careful consideration of the use of retention basins is needed when there is the requirement to maintain environmental flows for events less than the 1 year - 1 hour duration ARI rainfall event; however, this is typically only a concern for low infiltration (clay soil) sites and not applicable for the study area.

Bio-retention Swales

Bio-retention swales are used for achieving water quantity and quality management objectives. The filter medium and native vegetation in the swale removes nutrients. If designed well and maintained, bio-swales can be a very effective strategy for removing nutrients and conveying surface runoff (FAWB 2008). However, the technology is relatively new and as yet there are limited built working examples. Bio-retention systems are most suited to developments aiming to achieve a drainage network that very closely mimics nature.

Constructed Wetland

A constructed wetland removes nutrients and pollutants by biological nutrient uptake and settlement of sediment through extended detention of the stormwater. Wetlands generally consist of an inlet sedimentation zone, a macrophyte zone and a high flow bypass zone. The detention time for a constructed wetland is typically between 48 and 72 hours. A constructed wetland is not designed to dry out like an infiltration basin. Therefore, they can only be used in areas with suitably high groundwater and or low permeability soils (constructed wetlands should not be lined to artificially create the low permeability soils). The neighbouring Bartram Road Buffer Lakes are an example of a constructed wetland.

Sedimentation Basins

Stormwater runoff is temporarily stored in a sedimentation basin, to allow time for sediments to settle out of suspension. The time required for the sediment to settle is inversely proportional to the size of the sediment particle. Sedimentation basins are used where the surface runoff has a high concentration of sediment and there is a water quality requirement for the receiving (wetland) water body. For residential developments in sandy soil locations, a sedimentation basin would not normally be necessary but may be required in clay soil locations as these fine particles are easily transported by the stormwater runoff. During the construction stage there is typically a significant amount of sediment in the stormwater runoff and during this construction stage it may be necessary to use sedimentation basins.

Gross Pollutant Traps

Stormwater runoff can transport nutrients and gross pollutants (such as cans, bottles, packaging etc) to downstream water bodies. A Gross Pollutant Trap (GPT) can remove a proportion of these large pollutants and depending on the design can remove a proportion of the smaller particles such as sediments. The accumulated pollutants in the GPT must be removed to ensure the efficiency of the device. GPTs are best suited to developments with high gross pollutants loads such as commercial developments, retrofitting built environments where there is no available space for a natural pollutant remover such as a wetland, or for collecting gross pollutants during the construction period phase of the development. It is unlikely that a GPT will be necessary for the DA13 – Branch Circus development as the retention and detention basins will be used as a more natural alternative.

Educational Programs

The most optimal performance from the designed water quality treatment system can be achieved through educating the community on how the system works. If people understand how their actions could damage the water quality system (e.g. dumping chemical waste into the drains that end up draining to a wetland) they could be less likely to continue their actions. Education programs can target school children, home owners, developers and maintenance staff. A few examples of education topics are:

- Fertiliser application;
- Water use/saving techniques;
- Liquid chemical removal (oils, chemical, paints);
- Solid waste removal options (fridges, TVs, furniture);
- Littering;
- Weed identification and removal; and
- Recognising damage to the water quality treatment system.

6.7 Ground Water Level Management Strategy

Developments have the potential to alter the groundwater levels though a combination of reduced infiltration capacity (more impermeable areas such as roads and houses) and altered extraction rates (bores used for irrigation and reduced uptake due to tree clearance). It is important that the pre-development groundwater levels are maintained as any alteration could impact on the environment; particularly for surface water body recharge and water available for vegetation.

Groundwater can damage the foundations of buildings. It is therefore recommended that lot levels have sufficient clearance to groundwater to prevent such damage. Contemporary practice recommends that there is 1.2m clearance to the AAMGL (ERMC 2007).

The groundwater must be managed to prevent damage to the development and to the existing environment; that is, peak groundwater levels must be controlled or lots elevated sufficiently to prevent damage to the foundations and groundwater levels must also be maintained to provide water for Water Dependant Ecosystems (WDE). Therefore, the groundwater management criteria are

- Minimise changes to the underlying average groundwater level; and
- Ensure a separation distance of 1.2m between the lot level and the AAMGL.

The above objectives can be achieved through the following methods:

Sand Fill

For areas of land with a shallow depth to groundwater, a layer of sand can be placed on the natural ground surface to increase the depth from the surface to the groundwater. Sand fill is most appropriate for areas with high water tables but are well drained or where there is also the risk of high surface water level flooding as the fill can provide additional protection from the surface floodwater. The sand fill will not alter the natural groundwater level fluctuation; it will simply raise the lot level higher so that there is sufficient clearance to groundwater.

The majority of the study area has more than 1.2m of clearance to the AAMGL as shown in **Section 3.7.1**. The AAMGL intersects with both the southern and northern CCWs while the maximum clearance to the AAMGL is equal to 12.5m at the north eastern corner of the site at the intersection of Carmel Way and Hammond Road. The lots adjacent to the two wetlands are likely to require sand fill as these areas will also require fill to ensure adequate freeboard to the peak water levels in the wetlands. The AAMGL level must be confirmed (through onsite groundwater level monitoring) for the study area prior to determining the lot floor levels.

Sub-soil Drainage

The maximum groundwater level can be controlled by using sub-soil drains. Sub-soil drainage is a network of pipes installed under the ground surface. Any groundwater above the invert of the pipes will be drained. Typically, sub-soils drains are placed in areas with low infiltration capacity and have a shallow or perched groundwater. The existing ground surface is graded and the sub-soils placed on top, then a layer of high hydraulic conductivity (sand) soil is placed onto of the subsoils drains. This method reduces the total amount of sand fill that would have otherwise been required. The drained groundwater should be treated prior to discharge to a water body, as there is the potential for the groundwater to be contaminated with nutrients, heavy metals or draining through acid sulphate soils.

Sub-soil drains artificially alter the maximum groundwater level and thus could effect nearby WDEs by reducing the recharge of the surface water body with groundwater and providing less water for the vegetation. Due to the proximity of the DA13 – Branch Circus development to the two wetlands, it is unlikely that sub-soil drains would be suitable. If these are proposed for any areas within the development, these should be fully rationalised in future LWMS documents.

Encourage Infiltration

The increased imperviousness of the development will reduce infiltration and this has the potential of lowering the average groundwater level when compared to the pre-development environment. To satisfy the criteria of maintaining the average groundwater level to provide water for vegetation and the wetland, infiltration should be encouraged though techniques such as soakwells, bottomless junction chambers, porous pavement, swales and infiltration basins. These techniques should be further investigated and presented in the LWMS.

6.8 Ground Water Quality Management Strategy

This DWMS aims to encourage infiltration where ever practicably possible. This infiltrated stormwater will enter the groundwater and may ultimately enter downstream water bodies such as Thomsons Lake and two CCWs located within the development. Thus, the groundwater quality objective is to:

- Maintain or improve the existing groundwater quality.

The groundwater quality should only be improved by reducing existing nutrient loads and not by actively 'treating' the groundwater. In order to maintain the existing groundwater quality, first accurate baseline data is required and post-development monitoring is required to assess the success of the implemented groundwater quality management techniques.

The areas where management strategies can be implemented to achieve the water quality objectives are:

Basins

It is proposed in this DWMS that the surface water runoff from the development will be directed to retention and detention basins throughout the study area. The nutrient load from the development is concentrated at the basins and should therefore be intensively treated. As previously discussed, runoff from the 1 year – 1 hour ARI event will be retained in a vegetated retention basins. The selected vegetation species should be native, have a high nutrient requirement and can survive for a long period of time in dry conditions. The vegetation should be routinely trimmed/harvested to encourage further growth and nutrient uptake. The stormwater will be directed into the centre of the vegetated area by a Bubble-up pit chamber. Sediments will be contained within the Bubble-up pit chamber and should be routinely removed. These measures will ensure that the runoff that infiltrates via the core of the basin to the groundwater will be of acceptable quality.

POS

The success development is located near two CCWs. These wetlands require a buffer zone separating the development from the wetland (see **Section 3.4.1**). In this buffer zone, the use of natural vegetation is required. The use of turf in the POS, near the buffer zone, should be kept to a minimal. The natural vegetation will not require fertilisers however the turfed areas will require some input. Minimising the turfed area will reduce the nutrient load that could be transported to the wetlands via surface runoff and/or groundwater. The fertilizer requirements of the turfed area can be reduced by importing topsoil that has high phosphorus retention and using turf species that have low water and nutrient requirements such as:

- *Paspalum vaginatum;*
- *Stenotaphrum secundatum;* or,
- *Pennisetum clandestinum* (Water Corp, March 2008).

In addition to utilising low nutrient requiring turf species, other fertiliser management strategies included:

- Nutrient application rates should be matched to the seasonal requirements of the vegetation species;
- Soils tested to determine residual nutrient concentrations;
- Plant tissue testing;
- Utilising a fertiliser with the most optimal type and constituent for the specific vegetation species; and
- Utilising slow release fertilisers (DoW 2006).

Gardens

The lots in the DA13 – Branch Circus development range from R25 to R40. Due to the relatively dense zoning and anticipated large contemporary house design, there will only be a small proportion of the lots available for gardens. From a groundwater quality perspective, this reduces the proportion of the lots that could leach nutrients into the groundwater. Thus, the lots in the development would be expected to leach fewer nutrients into the groundwater than compared to developments that have a larger proportion of the lot as garden areas. Nutrient leaching from the garden areas can further be reduced by the use of native vegetation species and suitable nutrient retaining soils.

Soakwells

Runoff from roof areas can be stored and infiltrated into the groundwater via soakwells. The runoff from a clean roof (the roof gutters should be routinely cleaned to prevent build up of nutrients that could potentially enter the soakwell) can contain low nutrient concentration. Thus, this infiltrating water is of very high standard and will not increase the nutrient concentrations within the groundwater.

The lot connected soakwells only receive runoff from the roof area. This water is of high quality and could be alternatively stored in rainwater tanks and used within the house. Thus, the infiltrating water is of very high standard and will not increase the nutrient concentration in the groundwater. The roof gutters should be routinely cleaned to prevent build up of nutrients that could potentially enter the soakwell.

Bottomless Junction Chamber

On a development scale, bottomless junction chambers (bottomless manholes) are similar to soakwells as they allow infiltration of runoff from roads at drainage pipe junction chambers. This is an effective method of reducing the total volume of runoff from the impervious road network. However, this infiltrated water is untreated and has the potential to transport some contaminants into soil and groundwater (although the soil profile will treat some of the contaminants). Careful consideration must be given to balance the benefits to stormwater quantity against the disadvantages to groundwater quality.

Educational Programs

As previous discussed in **Section 6.6**, educational programs for the community can increase the success of water treatment strategies. The educational program should cover all aspects of water management including groundwater quality management.

6.9 Wastewater Management

The DA13 – Branch Circus development is located near a 1050mm sewer main. Therefore the development can use this sewer for disposal of waste water. It is estimated that approximately 65ML a year will be produced by the development.

An alternative method of disposal of some of the waste water is through greywater recycling to be used for irrigation. However, due to close proximity to wetlands, greywater reuse is not recommended as there is a high risk that nutrients will be transported to the wetlands.

7. NEXT STAGE - LOCAL WATER MANAGEMENT STRATEGY

The next stage of planning after a DWMS is a LWMS. The water management strategies for a development should be presented in the LWMS and the plan of how those strategies are to be implemented presented in the Urban Water Management Plan (UWMP). The specific areas of additional work required for input into the DA13 – Branch Circus LWMS include:

- Groundwater level monitoring;
- Determination of AAMGL and sand fill requirements;
- Groundwater quality monitoring;
- Determination of contamination or nutrient 'hotspots';
- Surface water quality monitoring;
- Determination of trigger values for post-development surface water and groundwater quality monitoring;
- Investigation of infiltration rates;
- Determination of suitable locations for infiltration techniques (soakwells, infiltration basins etc);
- Confirmation of stormwater management strategy consistent with the approach detailed in this DWMS;
- ASS investigation;
- Development of a management plan if ASS are found within the study area;
- Rare flora and fauna investigation; and
- Determine a management plan to protect rare flora or fauna found, whilst enabling the development to proceed.

8. IMPLEMENTATION FRAMEWORK

8.1 Monitoring

The groundwater quality and quantity (level) should be measured both prior to, during and after the completion of the development. The groundwater level data can be used to determine sand fill requirements and accurate baseline data is required for analysis of the performance of the implemented water management strategies. Where possible, the pre-development groundwater bores should be maintained for the post-development monitoring.

The existing environment of the study area has no defined channels and thus the quantity and quality of the surface runoff cannot be directly measured. However, the quantity and quality of the water in the wetlands and post-development basins can potentially be monitored.

Currently no site specific groundwater data has been collected. It is recommended that at least 18 months (two winters) of pre-development monitoring is completed to establish groundwater levels (WAPC 2008b). The duration of the post-development monitoring should be negotiated between the developer and the CoC, as ultimately the responsibility of the water management infrastructure will be transferred to CoC.

8.2 Technical Review

The stormwater management strategies presented in the Success DWMS have been recommended based on experience with similar developments and research into BMPs. The water management strategies presented in this DWMS, future LWMS and UWMP, will be reviewed by the DoW and CoC. This will ensure that the proposed strategies consistent with design guidelines approved by each authority.

8.3 Funding and Ongoing Maintenance Responsibilities

The development land owners will be responsible for all costs for the creation of the development including, monitoring, surveys, investigations and construction of the water management infrastructure. The maintenance of the infrastructure will initially be the responsibility of the developer, until which time the CoC is satisfied that the infrastructure is performing suitably and the responsibility will be transferred to CoC. The timing for the transfer must be negotiated between the CoC and the developer.

9. REFERENCES

Acacia Springs Environmental. 2002. *South Jandakot Drainage Scheme: Scheme Monitoring Report for 2000 to 2001*. Perth: Water Corporation.

Australian and New Zealand Environment and Conservation Council (ANZECC), 2000. *National Water Quality Management Strategy.* Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

Bureau of Meteorology (BOM). 2008. Climate Statistics for Australian Locations: Jandakot AREO. BOM Online. www.bom.gov.au (accessed 30 June 2008).

City of Cockburn. 2008a. *Existing Land Use: Branch Circus Local Structure Plan*, Success. Figure 8. Perth: City of Cockburn.

City of Cockburn. 2008b. *Opportunities and Constraints: Branch Circus Local Structure Plan, Success*. Figure 9. Perth: City of Cockburn.

Caroma Profile Toilet Suit. 2008. http://www.caroma.com.au/products/data/tsu/profile/main.html

Department of Agriculture and Food (DoA). 2006, *Soils of the Swan Coastal Plain – Bulletin 4359*. DoA online. www.agric.wa.gov.au (accessed 16th June 2008).

Department of Environment (DoE). 2007. *Stormwater Management Manual for Western Australia*. Perth: DoE.

Department of Environmental and Conservation (DEC). 1980. *Atlas of Natural Resources: Darling System, Western Australia*. Perth: DEC.

Department of Environment and Heritage (DEH), 2002. *Introduction to Urban Stormwater in Western Australia*. Canberra: Commonwealth of Australia.

Department of Environment and Protection (DEP). 2001. *Potentially Contamination Activities, Industries and Landuses*. Perth: DEP.

Department of Health (DoH). 2005. Code of Practice for the Reuse of Greywater in Western Australia.

Department of the Environment, Water, Heritage and the Arts. 2008. *Australian Wetlands Database*. Department of the Environment, Water, Heritage and the Arts online. www.environment.gov.au (accessed 16 June 2008).

Department of Water (DoW). 2006. *Water Quality Protection Note 33*.

Department of Water (DoW). 2007a. *Perth Groundwater Atlas*. DoW online. www.water.wa.gov.au (accessed 16th June 2008).

Department of Water (DoW). 2007b. *Waterwise Rebates*. DoW online. www.water.wa.gov.au (accessed 23rd June 2009).

Department of Water (DoW). August 2007. *Stormwater Management Manual*.

Department of Water (DoW). 2008. Water Information (WIN) database – discrete sample data. [5 February 2008]. Perth: Department of Water, Water Information Provisional section.

Department of Indigenous Affairs (DIA). 2008. www.dia.wa.gov.au (accessed 2nd October 2008)

Environmental Protection Agency (EPA). 1998. *Guidance for the Assessment of Environmental Factors No. 48 - Groundwater Environmental Management Areas*. Perth: EPA.

Environmental Protection Agency. 2008. *Environmental Guidance for Planning and Development*, Guidance Statement No. 33, May 2008, Perth. EPA.

Facility for Advancing Water Biofiltration (FAWB). June 2008. *Advancing the Design of Stormwater Biofiltration*.

Froend, R., Loomes, R., Horwitz, P., Bertuch, M., Storey, A. and Bamford, M. 2004. *Study of Ecological Water Requirements on the Gnangara and Jandakot Mounds under Section 45 of the Environmental Protection Act*. Joondalup: Edith Cowan University.

Government of Western Australia, 2003. *State Water Strategy.* Perth: Government of Western Australia.

Government of Western Australia, 1970. *Perth 1:50 000 Geology Map Sheet.*

Hill, A.L, Semeniuk, C.A, Semeniuk, V and Del Marco, A. (1996). *Wetlands of the Swan Coastal Plain Vol 12B: Wetland Atlas*. Perth: Department of Environmental Protection; Water and Rivers Commission.

Melbourne Water. 2008.
http://www.melbourne.vic.gov.au/rsrc/PDFs/Water/CalculatorWaterMark.pdf

RPS. 2008. *Environmental Assessment Report - Branch Circusand Hammond Road, Success*. Subiaco: RPS.

Water Corporation. 2008. *Water Corporation Infrastructure Data*. Perth: Water Corporation, Facilities Mapping Information.

Water and Rivers Commission. 2004. Jandakot Groundwater Mound. DEC Online. www.dec.wa.gov.au (accessed 30 June 2008).

Water Corporation. March 2003. *Domestic Water Use Study – In Perth, Western Australia 1998-2001*. Perth: Water Corporation.

Water Corporation. 2005. Integrated Water Supply Scheme Source Development Plan 2005.

Water Corporation. 2006. *Waterwise Display Village Criteria*. Water Corporation Online. www.watercorporation.com.au (accessed 30 June 2008).

Western Australian Planning Commission (WAPC). 2007. *Liveable Neighbourhoods Edition 4*. Perth: WAPC.

Western Australian Planning Commission (WAPC). 2006. *State Planning Policy 2.9 Water Resources*. Perth: WAPC.

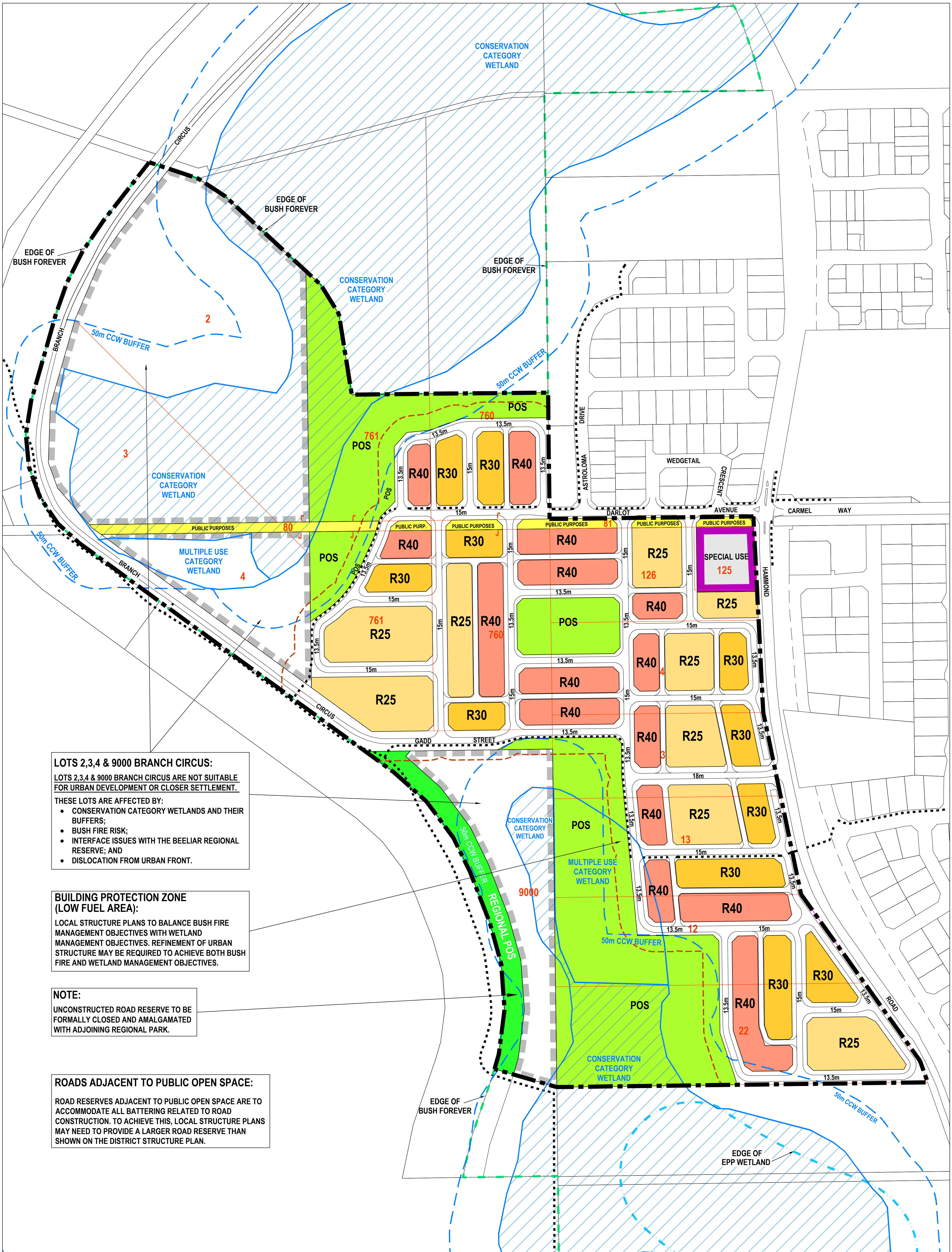
Western Australian Planning Commission (WAPC). 2008a. *Planning Bulletin 64: Acid Sulfate Soils*. WAPC online. www.wapc.wa.gov.au (accessed 18 June 2008).

Western Australian Planning Commission (WAPC). 2008b. *Better Urban Water Management*. Perth.

Wong, T.H.F., Wootton, R., Argue, J.R. & Pezzaniti, D. 1999. Bringing Order to the Pollution Control Industry: Issues in Assessing the Performance of Gross Pollutant Traps. International Congress on Local Government Engineering and Public Works.

APPENDIX A

District Structure Plan



LOTS 2,3,4 & 9000 BRANCH CIRCUS:

LOTS 2,3,4 & 9000 BRANCH CIRCUS ARE NOT SUITABLE FOR URBAN DEVELOPMENT OR CLOSER SETTLEMENT.

THESE LOTS ARE AFFECTED BY:

- CONSERVATION CATEGORY WETLANDS AND THEIR BUFFERS;
- BUSH FIRE RISK;
- INTERFACE ISSUES WITH THE BEELIAR REGIONAL RESERVE; AND
- DISLOCATION FROM URBAN FRONT.

BUILDING PROTECTION ZONE (LOW FUEL AREA):

LOCAL STRUCTURE PLANS TO BALANCE BUSH FIRE MANAGEMENT OBJECTIVES WITH WETLAND MANAGEMENT OBJECTIVES. REFINEMENT OF URBAN STRUCTURE MAY BE REQUIRED TO ACHIEVE BOTH BUSH FIRE AND WETLAND MANAGEMENT OBJECTIVES.

NOTE:

UNCONSTRUCTED ROAD RESERVE TO BE FORMALLY CLOSED AND AMALGAMATED WITH ADJOINING REGIONAL PARK.

ROADS ADJACENT TO PUBLIC OPEN SPACE:

ROAD RESERVES ADJACENT TO PUBLIC OPEN SPACE ARE TO ACCOMMODATE ALL BATTERING RELATED TO ROAD CONSTRUCTION. TO ACHIEVE THIS, LOCAL STRUCTURE PLANS MAY NEED TO PROVIDE A LARGER ROAD RESERVE THAN SHOWN ON THE DISTRICT STRUCTURE PLAN.

FIGURE 10

City of Cockburn — wetlands to waves

GNA 7/11

0 75m SCALE

- Structure Plan Boundary
- Residential R25
- Residential R30
- Residential R40
- Special Use
- Public Open Space
- Regional Open Space
- Public Purposes
- Not Suitable for Urban Development or Closer Settlement
- Conservation Category Wetland
- 50m CCW Buffer
- Mutiple Use Category Wetland
- Building Protection Zone (30m)
- Pedestrian/Cycle Links
- Bush Forever Boundary
- EPP Wetland Boundary

DRAFT DISTRICT STRUCTURE PLAN BRANCH CIRCUS

LOTS 3,4,12,13,22,81,125,126 & UCL, HAMMOND ROAD, LOTS 2,3,4,80,761,9000 BRANCH CIRCUS, & LOT 760 GADD STREET, SUCCESS

FIGURE 10

APPENDIX B

Modelling Methodology

1.0 Surface Runoff Modelling

Surface water runoff from rainfall events can be estimated using relationships between the surface slope, area, roughness, infiltration and rainfall. The interaction of runoff from areas with different characteristics and the routing of this runoff through a catchment can be very complex; it is for these reasons that computation models are used to ensure the accuracy and speed of the calculations.

For the calculation of the surface water runoff from the study area, the XPSWMM hydrologic and hydraulic modelling software was used. The hydrologic component of the software uses the Laurenson non-linear runoff-routing method to simulate runoff from design storm events. The Laurenson runoff-routing method assumes that runoff is proportional to slope, area, infiltration and percentage of imperviousness of a catchment. Sub-catchment areas and slopes are determined from topographical data. The infiltration rates and percentage imperviousness can be determined from field experiments or experience with model preparation with similar soil conditions. The runoff from each sub-catchment is routed though the catchment using the hydraulic component of XPSWMM.

1.1 Pre-development Catchments

Catchment boundaries are defined from topographical data; however, consideration must be made for man made structures such as roads and drains which may prevent or enable flow across natural catchment boundaries.

The physical boundaries of the study area are Hammond Road, Branch Circus, Darlot Avenue and the unpaved road separating the study area from the Bartram Road Buffer Lakes; these form the catchment boundaries. These physical barriers prevent surface water runoff from flowing into the study area. The exception is the runoff from a small portion of the development east of the study area that discharges to the sump located on Lot 3 Hammond Road (as described previously).

The study area is defined by four sub-catchments while three additional sub-catchments are located to the west of Branch Circus and discharges into the study area. Sub-catchments 1 and 5 discharge to the southern CCW, Sub-catchments 2, 6 and 7 discharge to the northern CCW and Sub-catchment 3 and 4 discharge to the CCW area to the north-east of the development.

The sub-catchment that drains the portion of the development to the east of the study area and into the sump on Lot 3 Hammond Road, is named 'Sub-catchment East'. The boundaries of all the sub-catchments are shown in **Figure 10**.

1.2 Pre-development Modelling Parameters

The total volume of runoff from an area is determined by the amount of rainfall less the losses (largely from infiltration). The rate of runoff is determined by the slope and roughness (Manning's n) of the surface.

An "initial loss – continuing loss" infiltration model was adopted for the sub-catchments, with loss values chosen based on Cardno's experience with similar vegetation and soil types to those found within the study area (**Section 3.3.2**). The Infiltration Land Types (ILT) used in the modelling are summarised in **Table B1.2a**.

Table B1.2a Initial and Continuing Loss Parameters for Hydrological Modelling

Infiltration Land Type	Manning's n	Initial Loss (mm)	Continuing Loss (mm/hr)
Sand Soil, Sparse Vegetation, High Infiltration (Pre-1)	0.15	17	3.00
Sand Soil, Medium Vegetation, High Infiltration (Pre-2)	0.20	21	3.00
Sand Soil, Dense Vegetation, High Infiltration (Pre-3)	0.25	25	3.00
Sand Soil, Sparse Vegetation, Medium Infiltration (Pre-4)	0.15	17	1.50
Sand Soil, Medium Vegetation, Medium Infiltration (Pre-5)	0.20	21	1.50
Sand Soil, Dense Vegetation, Medium Infiltration (Pre-6)	0.25	25	1.50
Sand Soil, Medium Vegetation, Low Infiltration (Pre-7)	0.20	21	0.75
Sand Soil, Dense Vegetation, Low Infiltration (Pre-8)	0.25	25	0.75
Road (Impervious) (Pre-9)	0.02	1	0.10
Verge (Pervious) (Pre-10)	0.07	9.5	2.00
Residential Sandy Soils (Pre-11)	0.06	15	3.00

The total area, slope and percentage impervious used for each sub-catchment is shown in **Table B1.2b**.

Table B1.2b Pre-Development Sub-Catchment Characteristics

Sub-Catchment	Slope	Parameter	Infiltration Land Type											
			Pre-1	Pre-2	Pre-3	Pre-4	Pre-5	Pre-6	Pre-7	Pre-8	Pre-9	Pre-10	Pre-11	Total
1	0.056	Area (ha)	1.914	6.012	1.446	-	2.522	0.776	0.775	-	-	-	-	13.445
		% Urbanisation	0	0	0	-	0	0	0	-	-	-	-	-
2	0.024	Area (ha)	3.054	7.988	-	0.694	2.265	-	-	1.352	-	-	-	15.354
		% Urbanisation	0	0	-	0	0	-	-	0	-	-	-	-
3	0.027	Area (ha)	2.007	0.388	0.856	-	-	-	-	-	-	-	-	3.25
		% Urbanisation	0	0	0	-	-	-	-	-	-	-	-	-
4	0.005	Area (ha)	-	2.798	0.455	-	-	-	-	-	-	-	-	3.252
		% Urbanisation	-	0	0	-	-	-	-	-	-	-	-	-
5	0.031	Area (ha)	3.727	1.318	-	-	-	-	-	-	-	-	-	5.046
		% Urbanisation	0	0	-	-	-	-	-	-	-	-	-	-
6	0.066	Area (ha)	2.775	1.590	-	-	-	-	-	-	-	-	-	4.365
		% Urbanisation	0	0	-	-	-	-	-	-	-	-	-	-
7	0.033	Area (ha)	2.096	3.987	-	-	-	-	-	-	-	-	-	6.083
		% Urbanisation	0	0	-	-	-	-	-	-	-	-	-	-
East	0.010	Area (ha)	-	-	-	-	-	-	-	-	0.263	0.263	1.606	2.132
		% Urbanisation	-	-	-	-	-	-	-	-	100	0	100	-

Refer to **Table B1.3b** for a description of the Infiltration Land Types.

The Laurenson runoff method uses a measure of urbanisation denoted as 'percentage urbanisation' to reflect the rate of response of runoff to the rainfall event i.e. a high percentage urbanisation results in a quick response to the rainfall event. However, the Laurenson urbanisation is not related to the infiltration capacity of the ground. The negligible infiltration capacity of impervious areas (roads) is accounted for in the loss rates and not in the percentage Urbanisation factor.

1.3 Post-development Modelling Parameters

The Infiltration Land Types (ILT) used for the post-development model were similar to the pre-development, with the addition of POS, Roads and Residential Lot infiltration areas. The parameters used in these ILT are shown below in **Table B1.3a**.

Table B1.3a Initial and Continuing Loss Parameters for Hydrological Modelling

Infiltration Land Type	Manning's n	Initial Loss (mm)	Continuing Loss (mm/hr)
Roads (Post-1)	0.02	1.0	0.1
Road Verge (Post-2)	0.07	9.5	2.0
Lot Impervious Areas (Post-3)	0.02	1.0	0.1
Garden (Post-4)	0.20	25.0	3.0
POS (Post-5)	0.10	17.0	2.5

The average infiltration rate for the whole of the lot areas (ILT 3) will have infiltration rates lower than the pre-development environment (ILT 2 and 3 within **Table B1.2a**). Lots typically have more impervious areas than the existing environment, thus higher runoff rates and lower loss rates are expected. However, it is anticipated that the BA13 – Branch Circus lots will compensate for some of this impervious area runoff by having soakwells, imported sand and mulch for garden areas, and that they will have pockets of storage. These factors have been included in determining the average infiltration rates for the lot. It is anticipated that these rates may be revised during the LWMS due to more available data and the proposed stormwater strategy.

The total proportion of each ILT, slope and Laurenson percentage impervious within each sub-catchment is shown in **Table B1.3b**.

Table B1.3b Post-development Sub-catchment Characteristics

Sub-Catchment	Parameter	Infiltration Land Description (Type)										
		Post-1	Post-2	Post-3	Post-4	Post-5	Pre-1	Pre-2	Pre-5	Pre-6	Pre-7	Total
1	Area (ha)	0.467	0.623	1.10	0.28	-	-	-	-	-	-	2.47
	% Urbanisation	100	0	100	0	-	-	-	-	-	-	-
	Slope	0.056	0.056	0.010	0.005	-	-	-	-	-	-	-
2	Area (ha)	0.662	0.882	1.64	0.40	-	-	-	-	-	-	3.584
	% Urbanisation	100	0	100	0	-	-	-	-	-	-	-
	Slope	0.056	0.056	0.010	0.005	-	-	-	-	-	-	-
3	Area (ha)	0.220	0.293	0.18	0.05	-	-	-	-	-	-	0.743
	% Urbanisation	100	0	100	0	-	-	-	-	-	-	-
	Slope	0.056	0.056	0.010	0.005	-	-	-	-	-	-	-
4	Area (ha)	-	-	-	-	-	3.491	1.318	-	-	-	4.809
	% Urbanisation	-	-	-	-	-	0	0	-	-	-	-
	Slope	-	-	-	-	-	0.031	0.031	-	-	-	-
5	Area (ha)	-	-	-	-	0.671	0.247	1.572	2.286	0.776	0.746	6.297
	% Urbanisation	-	-	-	-	0	0	0	0	0	0	-
	Slope	-	-	-	-	0.056	0.056	0.056	0.056	0.056	0.056	-
6	Area (ha)	0.333	0.444	0.73	0.19	0.22	-	-	-	-	-	1.917
	% Urbanisation	100	0	100	0	0	-	-	-	-	-	-
	Slope	0.024	0.024	0.010	0.005	0.024	-	-	-	-	-	-
7	Area (ha)	0.176	0.235	0.35	0.08	0.17	-	-	-	-	-	1.011
	% Urbanisation	100	0	100	0	0	-	-	-	-	-	-
	Slope	0.024	0.024	0.010	0.005	0.024	-	-	-	-	-	-

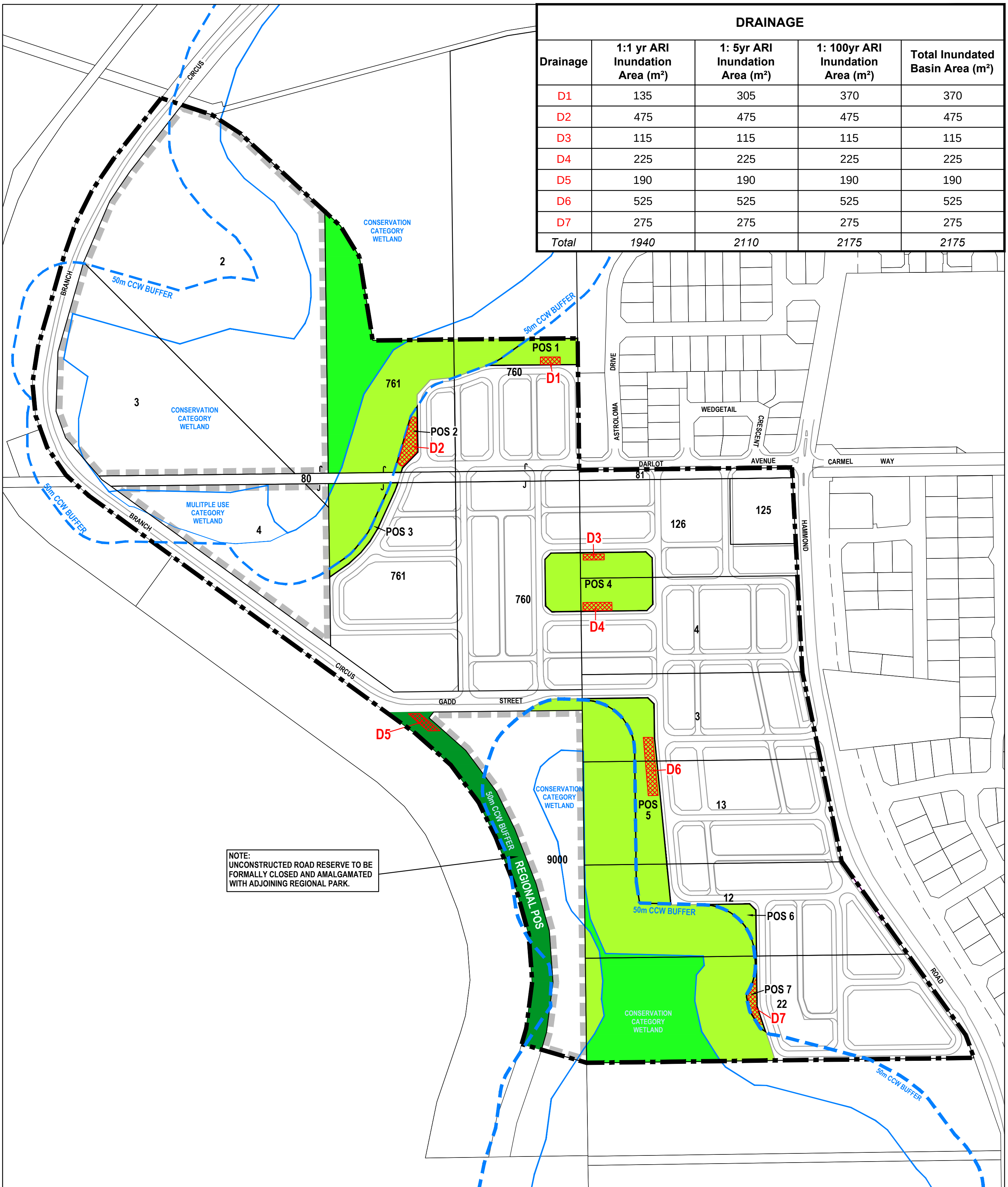
8	**Area (ha)**	0.873	1.164	2.70	0.64	0.29	5.667	-	-	-	-	1.011
	% Urbanisation	100	0	100	0	0	-	-	-	-	-	-
	Slope	0.066	0.066	0.010	0.005	0.066	-	-	-	-	-	-
12	**Area (ha)**	0.205	0.273	0.57	0.14	0.33	1.518	-	-	-	-	1.011
	% Urbanisation	100	0	100	0	0	-	-	-	-	-	-
	Slope	0.027	0.027	0.010	0.005	0.027	-	-	-	-	-	-

APPENDIX C

City of Cockburn POS Credit Calculations

Table 2 -Branch Circus DSP Public Open Space Schedule			
Site Area		37.501	ha
Less			
Land Not suitable for Urban Development or Closer Settlement (Lots 2, 3, 4 and 9000 Branch Circus)	11.401 ha		
Conservation Category Wetland	1.961 ha		
Existing Roads *	2.671 ha		
Restricted Open Space (above 20% threshold)	3.688 ha		
Total	19.721 ha		
Net site area		17.780	ha
Deductions			
Water Corporation Pipe Line (Public Purpose)	0.580 ha		
Special Use – Swimming Pool	0.396 ha		
Regional Open Space	0.075 ha		
Dedicated Drainage Reserve (1:1yr ARI)	0.175 ha		
Total	1.226 ha		
Gross Subdivisible Area		16.554	ha
Public Open Space @ 10 %		1.655	ha
Public Open Space Contribution			
May Comprise:			
minimum 80% Unrestricted Open Space	1.324 ha		
maximum 20% Restricted Open Space	0.331 ha		
Unrestricted Open Space			
POS 1	0.063 ha		
POS 2	0.124 ha		
POS 3	0.073 ha		
POS 4	0.557 ha		
POS 5	0.506 ha		
POS 6	0.062 ha		
POS 7	0.012 ha		
Total Unrestricted Public Open Space	1.396 ha		
Restricted Open Space			
Multiple Use Wetland	1.559 ha		
Conservation Category Wetland Buffer	2.443 ha		
Drainage (1:5yr ARI)	0.017 ha		
Total Restricted Use Public Open Space	4.019 ha		
Total Restricted Use Public Open Space contribution (ie 20% of 1.655 ha)	0.331 ha		
Public Open Space Provision		1.727	ha

DRAINAGE				
Drainage	1:1 yr ARI Inundation Area (m²)	1: 5yr ARI Inundation Area (m²)	1: 100yr ARI Inundation Area (m²)	Total Inundated Basin Area (m²)
D1	135	305	370	370
D2	475	475	475	475
D3	115	115	115	115
D4	225	225	225	225
D5	190	190	190	190
D6	525	525	525	525
D7	275	275	275	275
Total	*1940*	*2110*	*2175*	*2175*



Structure Plan Boundary

OPEN SPACE

- Local
- Regional
- Conservation Category Wetland
- Not Suitable for Urban Development or Closer Settlement
- Drainage
- 50m CCW Buffer

GNA 8/11

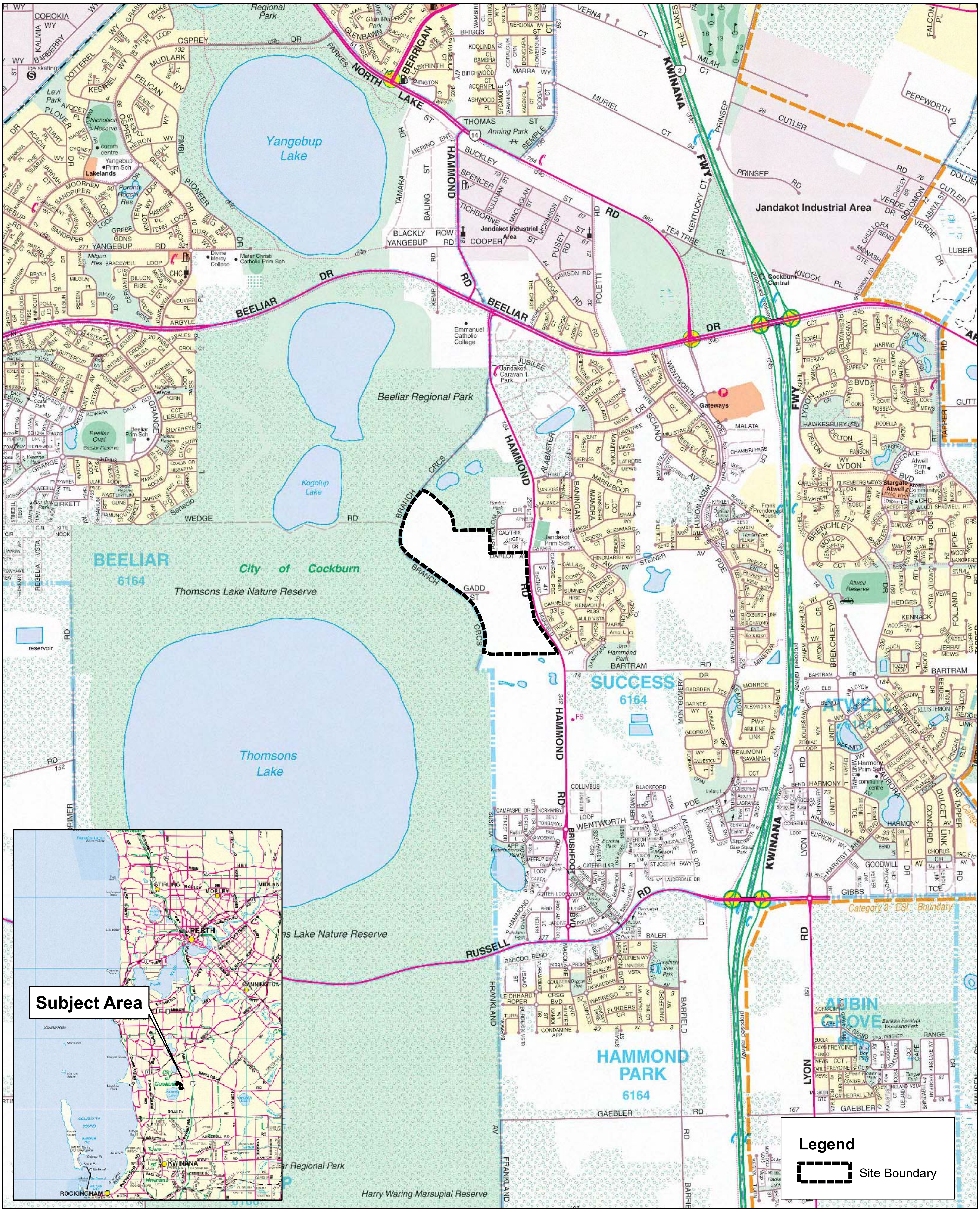
0 100m
SCALE 1:5,000

PUBLIC OPEN SPACE STRATEGY

BRANCH CIRCUS
DISTRICT STRUCTURE PLAN, SUCCESS

FIGURE 11

FIGURES



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Scale: 1:20,000 — 0 250 500 1,000 1,500 2,000 2,500 3,000 Metres

PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 1 : Locality Plan**

PRINCIPAL: **City of Cockburn**

Project Number V8034
Original A3
Drawing Number SK01
Revision 03
Designed DM
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Drawn MGW
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Local Authority City of Cockburn
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PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 2 : Study Area Boundary**

PRINCIPAL: **City of Cockburn**

Project Number **V8034** Original **A3**

Drawing Number **SK02** Revision **03**

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PROJECT **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE **FIGURE 3 : Topographic Contours**

PRINCIPAL **City of Cockburn**

Project Number **V8034**
Original **A3**
Drawing Number **SK04**
Revision **03**
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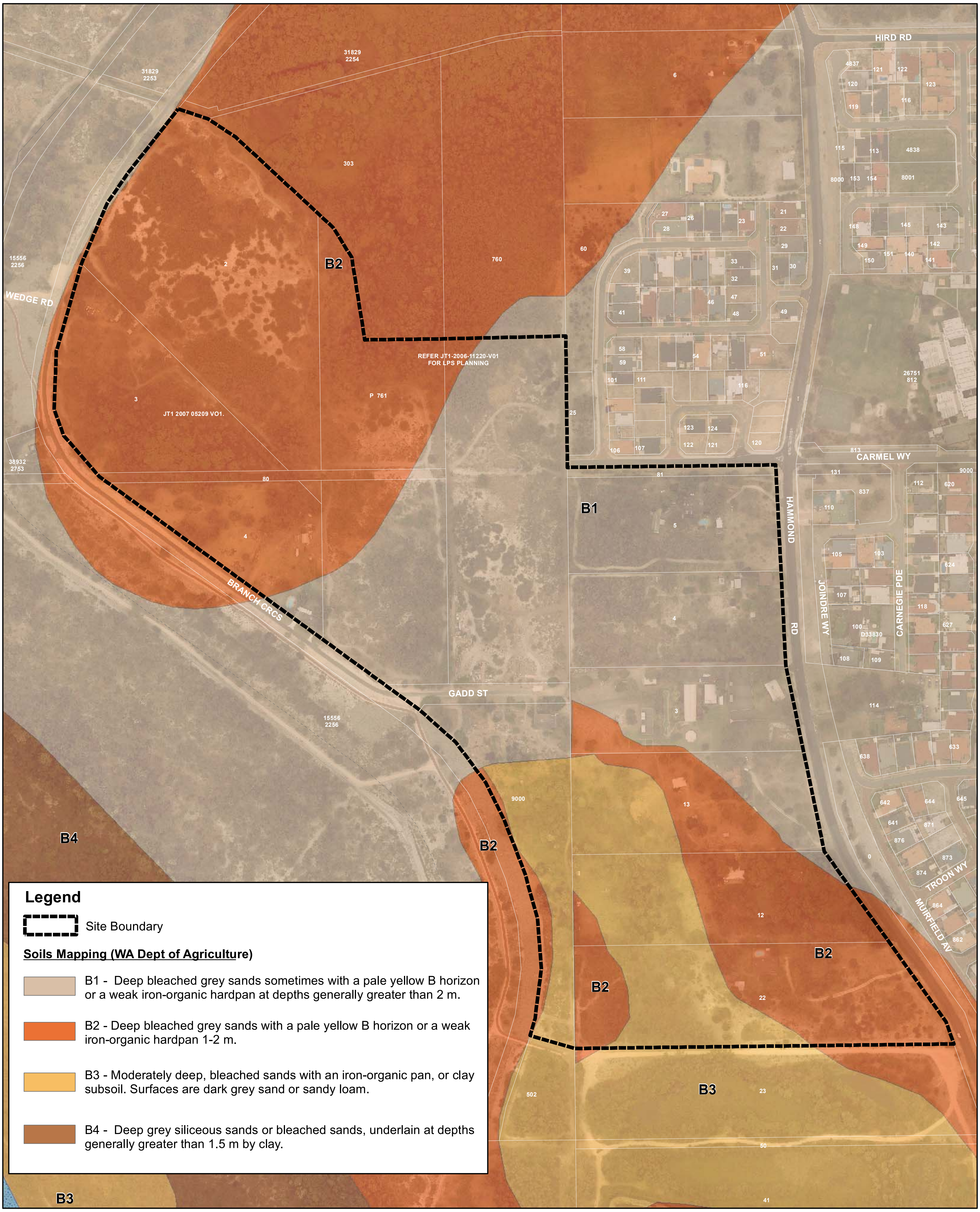
Document Set ID: 5546764
Version: 1, Version Date: 31/01/2017



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PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 4 : Soil Types**

PRINCIPAL: **City of Cockburn**

Project Number: V8034
Original: A3
Drawing Number: SK05
Revision: 03
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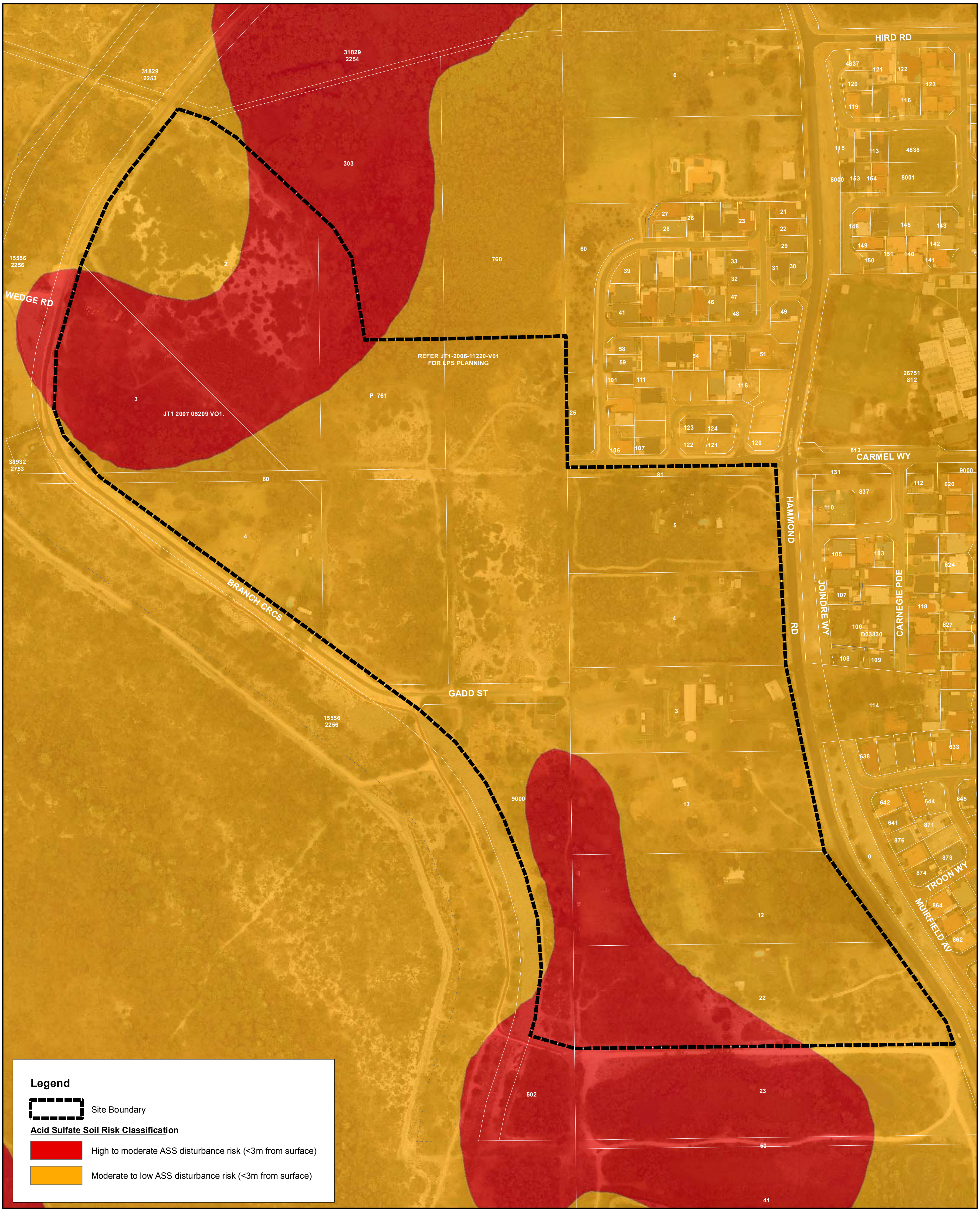

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PROJECT	DA13 - Branch Circus Success District Water Management Strategy
DRAWING TITLE	FIGURE 5 : Acid Sulfate Soil Risk Mapping
PRINCIPAL	City of Cockburn

Project Number V8034	Original A3
Drawing Number SK06	Revision 03
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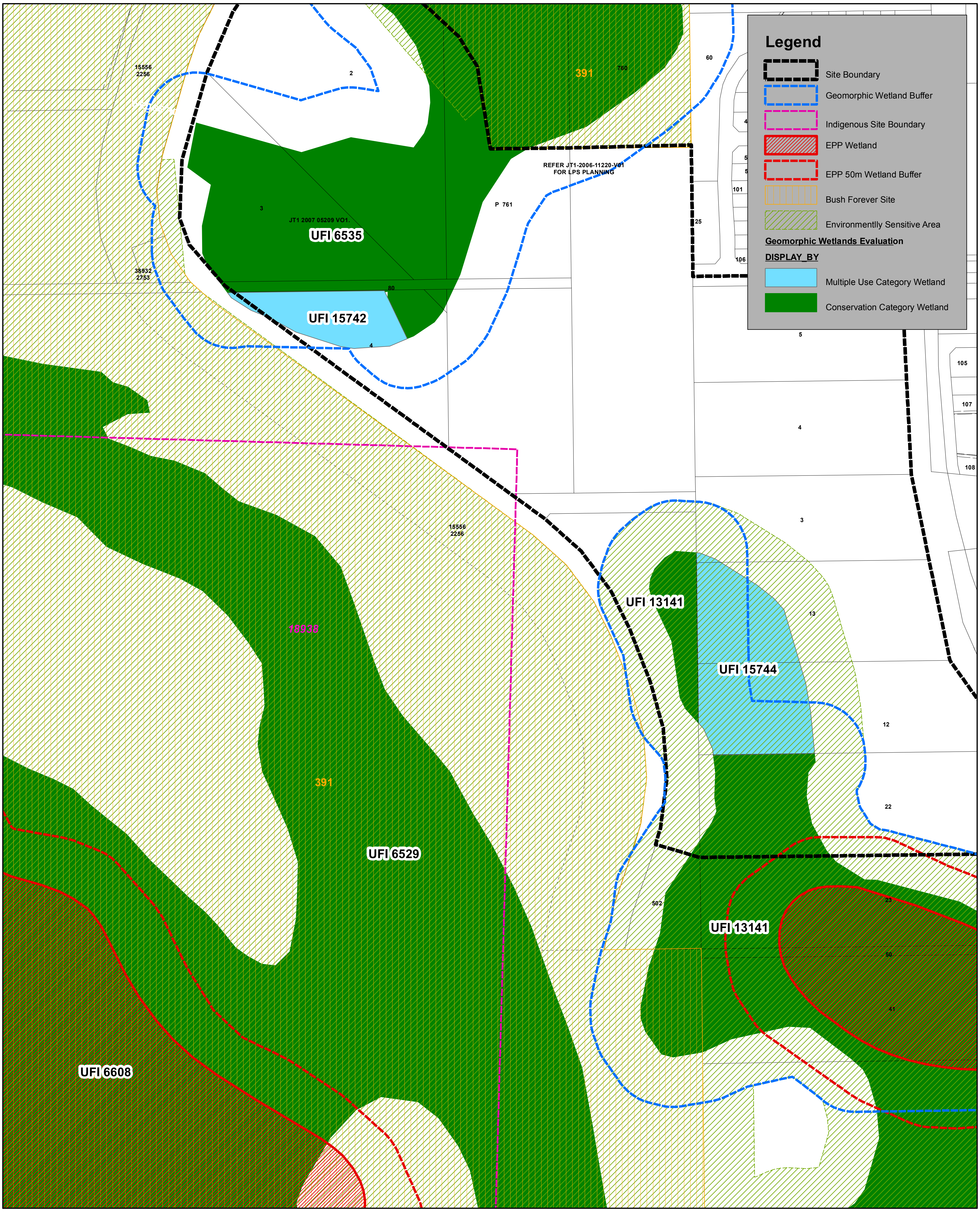

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PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 6 : Wetlands & Protected Areas**

PRINCIPAL: **City of Cockburn**

Project Number **V8034** | Original **A3**

Drawing Number **SK07** | Revision **03**

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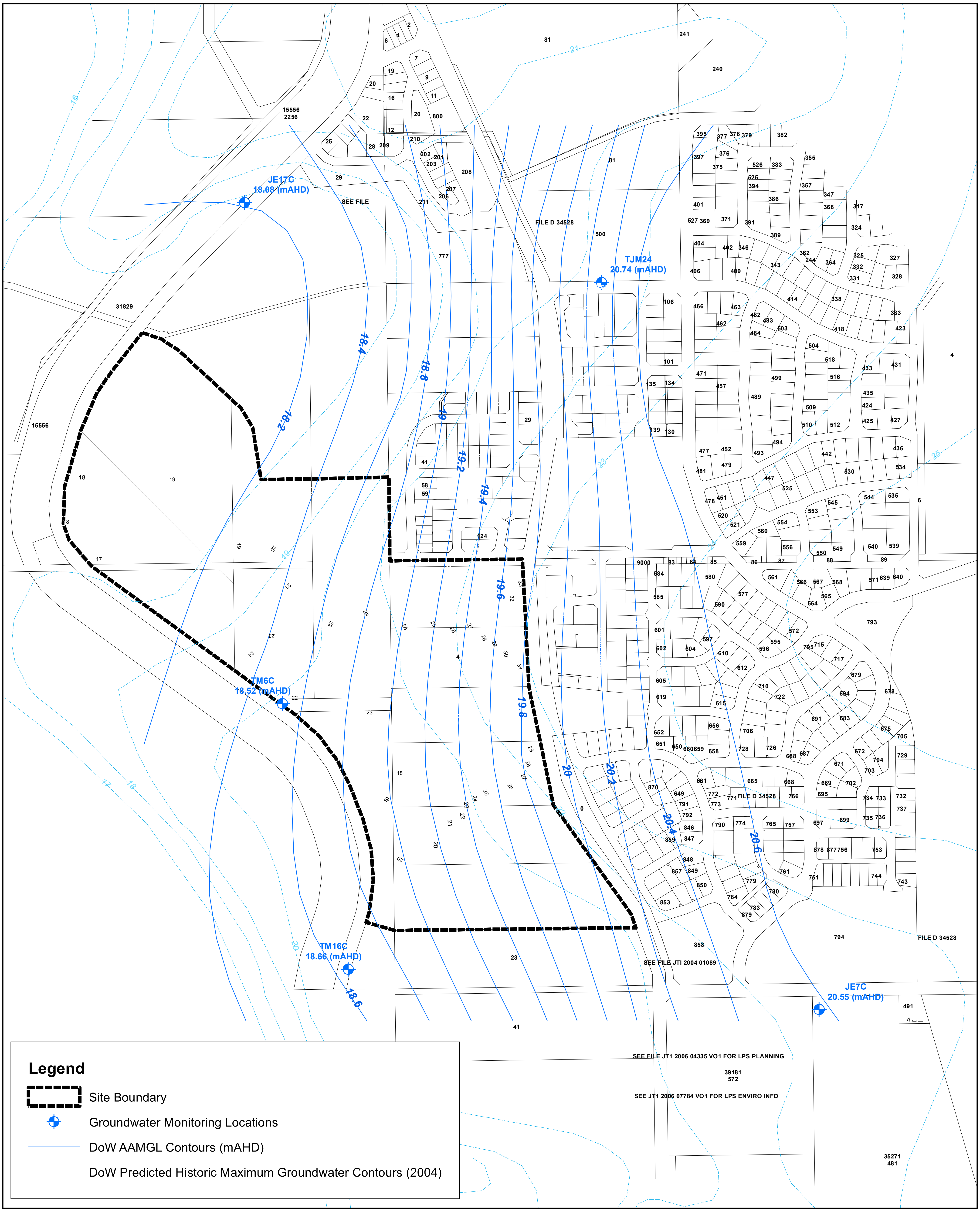

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PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 7 : Groundwater Monitoring Locations & Groundwater Contours**

PRINCIPAL: **City of Cockburn**

Project Number **V8034**
Original **A3**
Drawing Number **SK08**
Revision **03**
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PROJECT: DA13 - Branch Circus Success District Water Management Strategy

DRAWING TITLE: FIGURE 8 : Local Government Drainage Network

PRINCIPAL: City of Cockburn

Project Number V8034
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Drawing Number SK09
Revision 03
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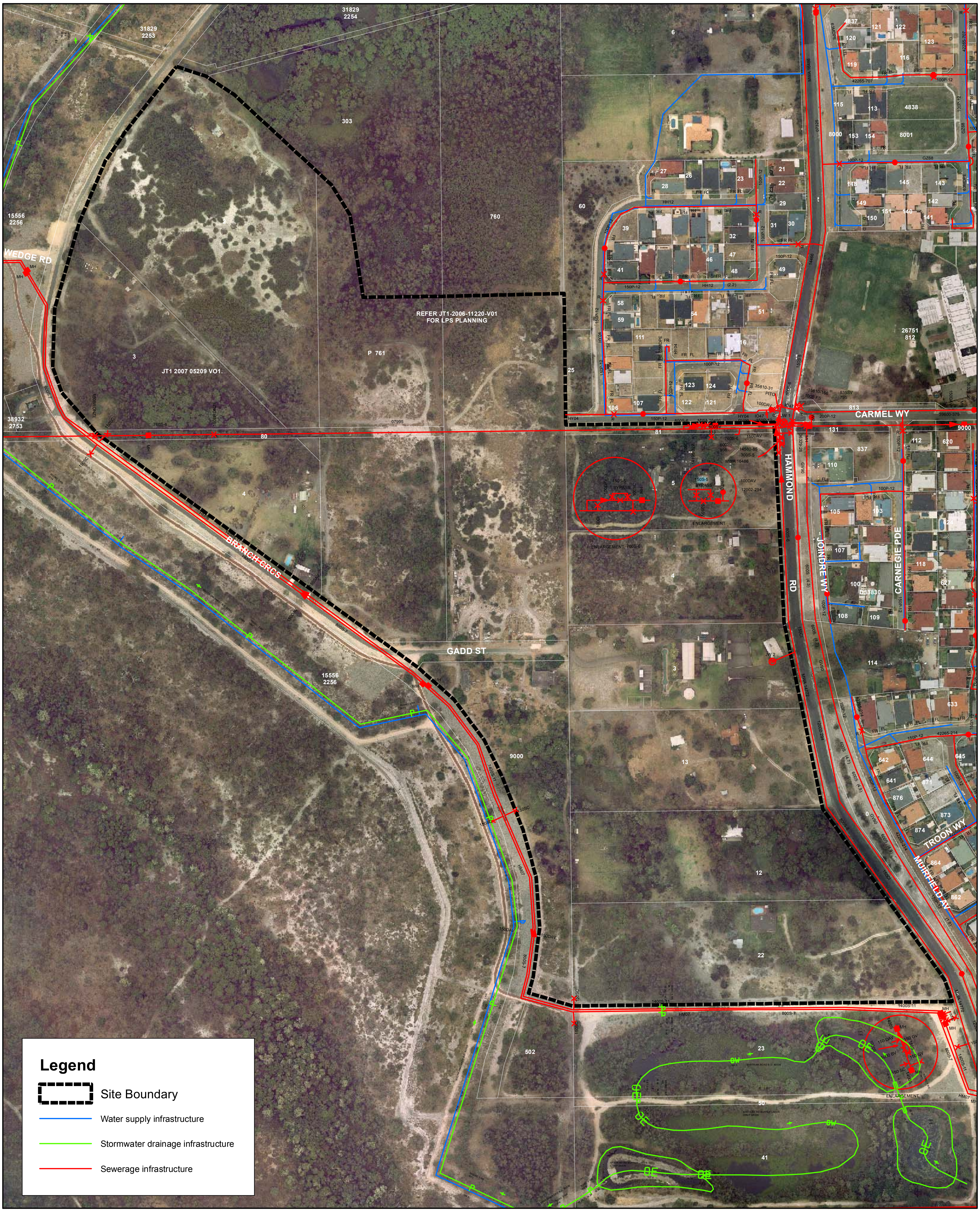

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PROJECT: **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE: **FIGURE 9 : Water Corporation Infrastructure**

PRINCIPAL: **City of Cockburn**

Project Number **V8034**
Original **A3**
Drawing Number **SK09**
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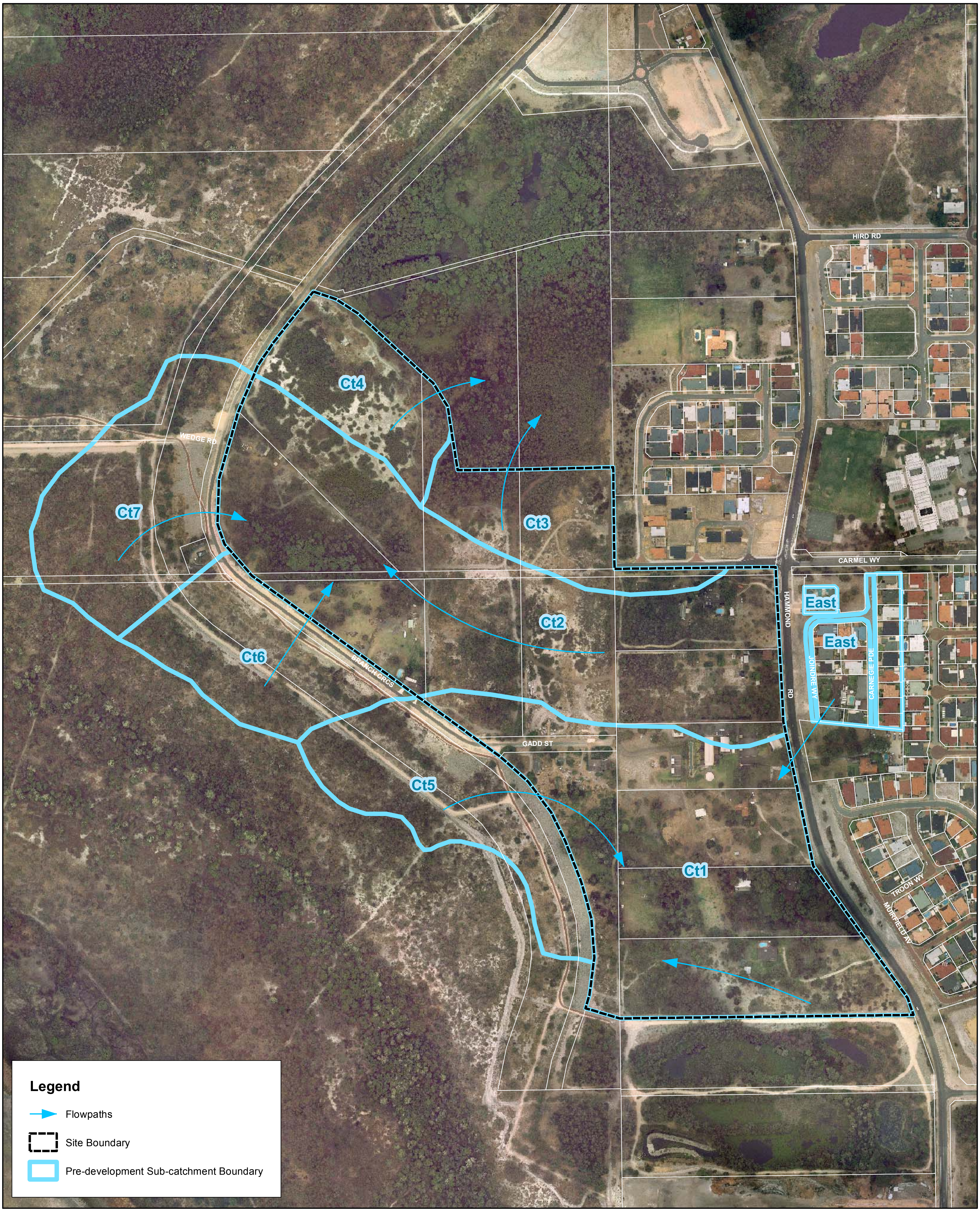

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PROJECT: DA13 - Branch Circus Success District Water Management Strategy

DRAWING TITLE: FIGURE 10 : Pre-development Sub-catchment Boundaries

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Project Number: V8034
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Drawing Number: SK11
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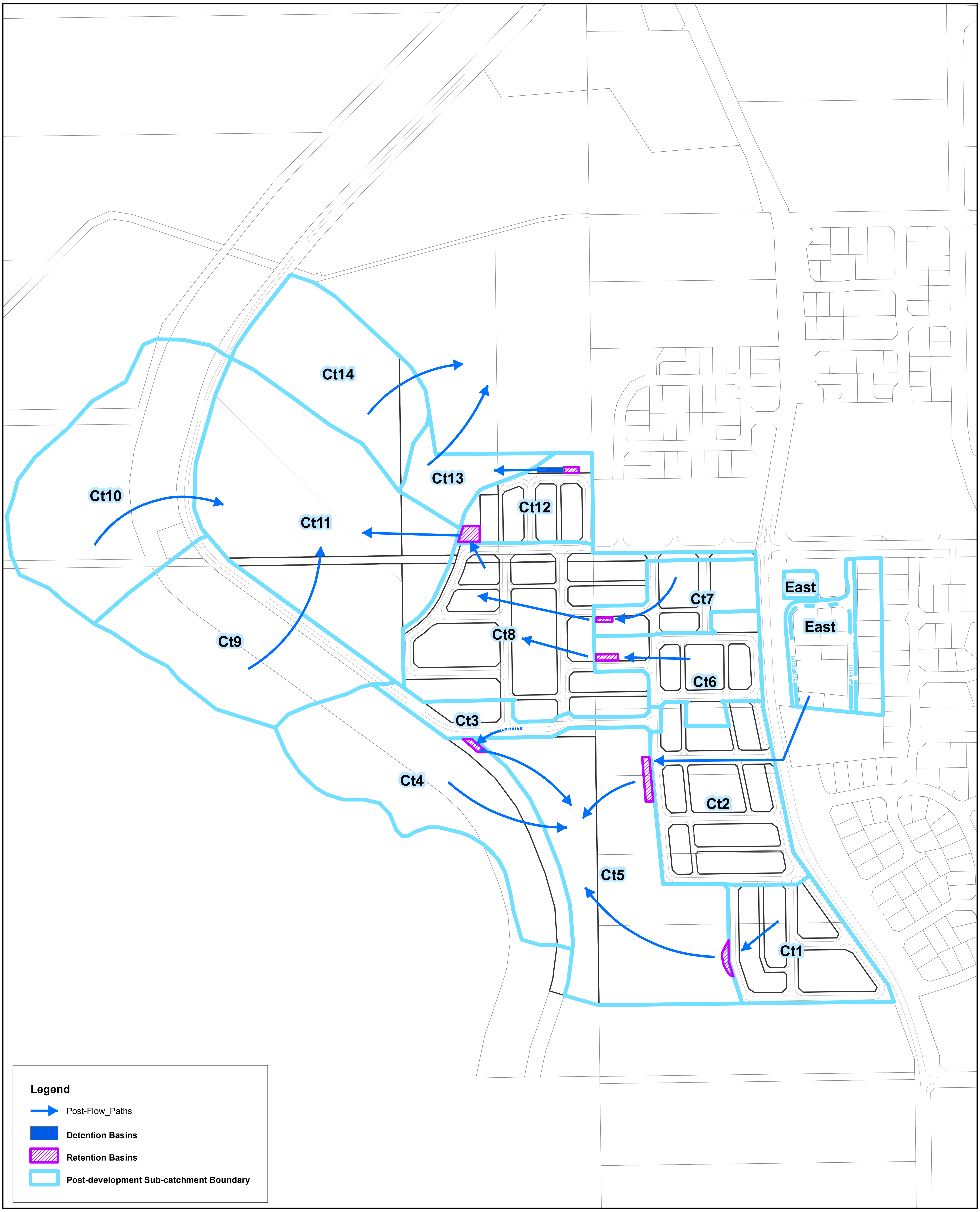

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0 50 100 200 300 400 500 Metres

PROJECT: DA13 - Branch Circus Success District Water Management Strategy

DRAWING TITLE: FIGURE 11 : Post-development Sub-catchment Boundaries

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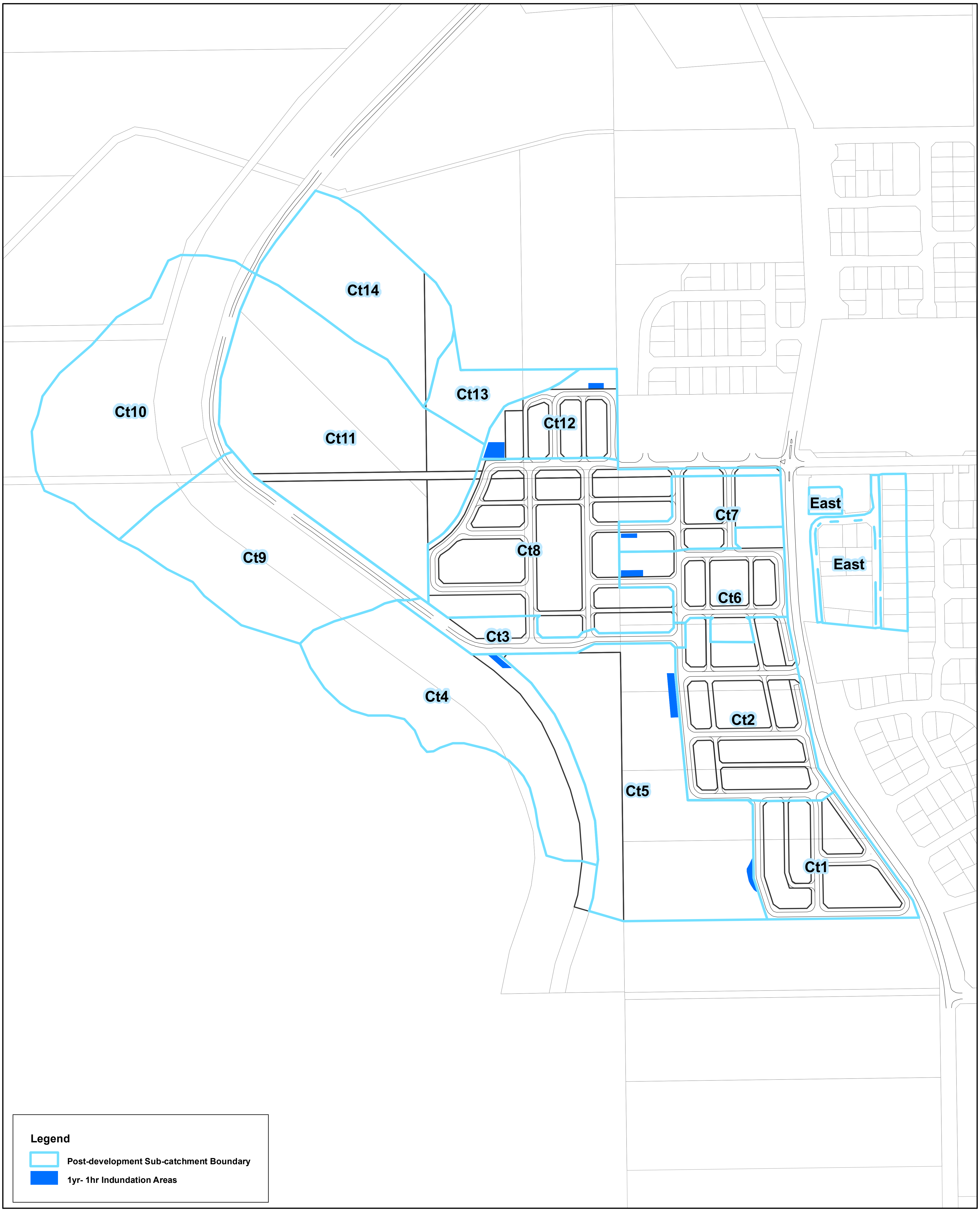

DATE	No.	ACTIVITY - REVISION DESCRIPTION	DES	DRN	CHK'D	APPD	DATE	No.	ACTIVITY - REVISION DESCRIPTION	DES	DRN	CHK'D	APPD

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Scale: 1:4,500

0 50 100 200 300 400 500 Metres

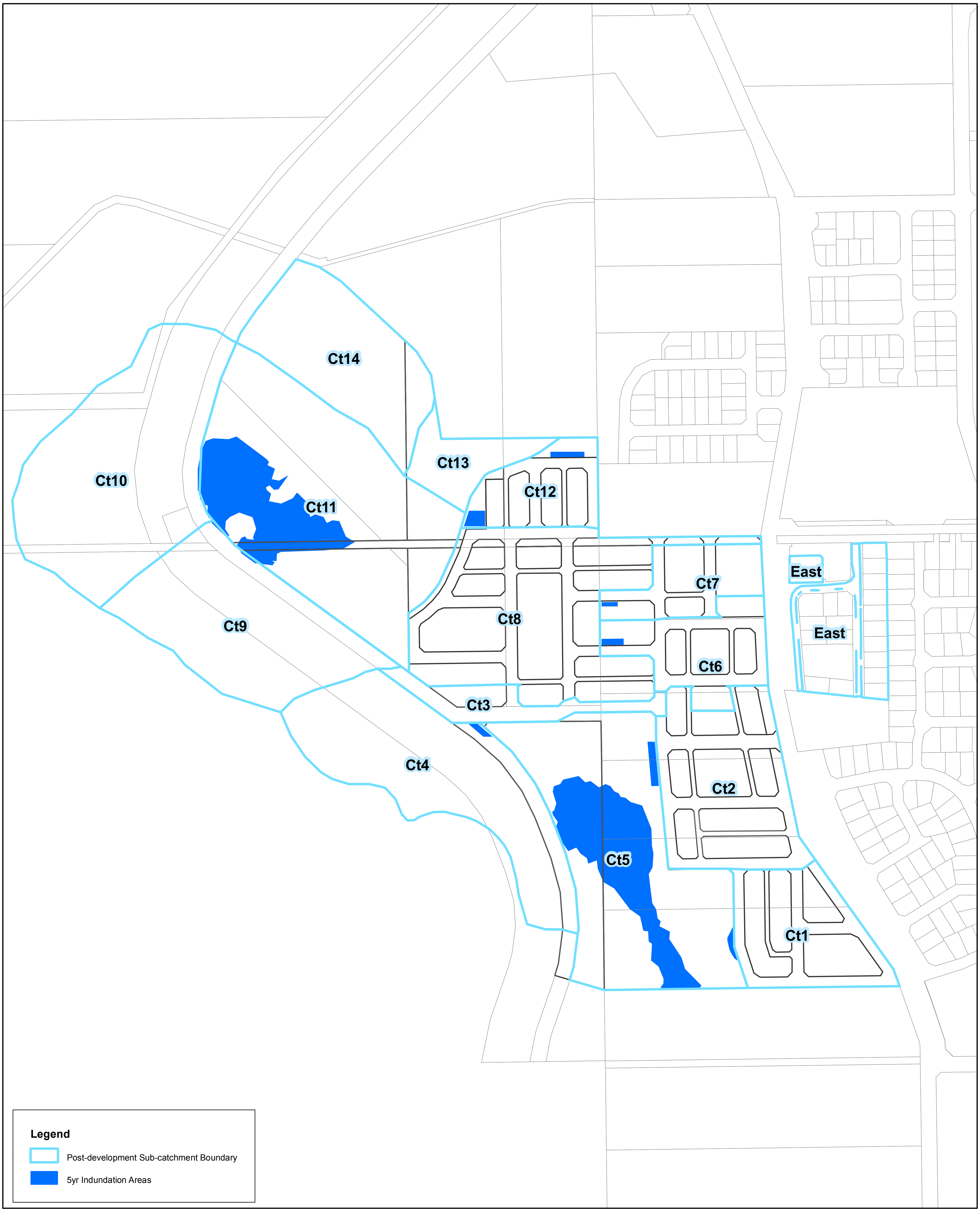
PROJECT **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE **FIGURE 12: 1yr - 1hr Indundation Areas**

PRINCIPAL **City of Cockburn**

N

Project Number **V8034**
Original **A3**
Drawing Number **SK13**
Revision **03**
Designed SLC
Checked
Drawn MGW
Approved
Local Authority City of Cockburn
Sheet 1 of 1
Date 2/02/11



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Scale: **1:4,500**

0 50 100 200 300 400 500 Metres

PROJECT **DA13 - Branch Circus Success District Water Management Strategy**

DRAWING TITLE **FIGURE 13 : 5yr Indundation Areas**

PRINCIPAL **City of Cockburn**

N

Project Number **V8034**
Original **A3**
Drawing Number **SK14**
Revision **03**
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PROJECT: DA13 - Branch Circus Success District Water Management Strategy

DRAWING TITLE: FIGURE 14 : 100yr Indundation Areas

PRINCIPAL: City of Cockburn

Project Number V8034 | Original A3

Drawing Number SK15 | Revision 00

Designed SLC | Checked

Drawn MGW | Approved

Local Authority City of Cockburn

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