Town Planning Management Engineering

CITY OF GOSNELLS

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Maddington Kenwick Strategic Employment Area Precincts 2 and 3

DISTRICT WATER MANAGEMENT STRATEGY

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EXECUTIVE SUMMARY

This District Water Management Strategy (DWMS) has been prepared to support the Maddington Kenwick Strategic Employment Area (MKSEA) Precincts 2 and 3 rezoning of the land to 'Industrial'. The subject land is bound by Roe Highway to the west; Tonkin Highway and Victoria Road to the east; Welshpool Road to the north; and Bickley Road to the south. The subject land's area is approximately 450 hectares and it is located within the City of Gosnells (see *Figure 1*). A section in the north-east is within the Shire of Kalamunda and has only been included in the DWMS for preliminary investigations and to assist with strategic planning

The Department of Parks and Wildlife (DPaW) Geomorphic Wetlands Swan Coastal Plan (GWSCP) dataset classifies approximately 82% of the subject land as wetlands across the three categories: Conservation (19%); Resource Enhancement (31%); and Multiple Use (32%). The wetland systems include the Greater Brixton Street Wetlands (GBSW) that are conservation wetlands and Bush Forever Sites, which provides State legislative protection. The GBSW is located between Precincts 2 and 3and the clay pan wetlands are listed on the Register of the National Estate, which provides Federal legislative protection of the system. Some of these wetland category classifications are under review and detailed investigations and reports of wetlands at the Local Structure Plan stages will be the responsibility of the developers to review any of the GWSCP evaluations.

A recent flora and wetland study (Tauss and Weston, 2010) was undertaken by the City of Gosnells and identified additional areas within both Precincts that meet the classification criteria for Conservation wetlands. The study also identified a number of Threatened Ecological Communities and Declared Rare and Priority Flora protected by State and/or Federal legislation. The City of Gosnells' Constraints Summary Mapping, endorsed by DPaW for the purpose of strategic land use planning and this DWMS, has been used as the base mapping of environmental constraints for this project.

The majority of the land is currently used for rural residential, agricultural production or vegetation conservation purposes. Yule Brook is major drainage system running from the north east to the north west through the subject land. The subject land is drained via a network of open drains.

The DWMS has been prepared to satisfy the *Better Urban Water Management guidelines* that require a DWMS to support the rezoning of the subject land to 'Industrial' under the Metropolitan Region Scheme. Given the local, state and national importance of the wetland ecosystems this DWMS focuses on the maintenance of the hydrological regimes across the subject land.

The objective of this DWMS is to demonstrate how utilising best management practices on the subject land, will achieve the principles, objectives and requirements of total water cycle management. The constraints of the site, proposed land use and surrounding environment have all been investigated to determine potential issues and outline potential strategies to manage, protect and conserve the total water cycle of the local environment and the greater catchment. The strategies include:

- Achieving acceptable water quality targets entering wetlands, waterways and the groundwater resource;
- Managing stormwater and flooding within the development and the hydrological regimes of relevant waterways;
- Managing the groundwater resource with close to source treatment trains and to minimise the required fill;
- Investigating opportunities for stormwater, superficial groundwater and grey water harvesting and reuse;
- Investigating innovative schemes for Industrial wastewater management;
- Protecting associated ecosystems dependent on water resources from the development (specifically the Conservation and Resource Enhancement wetlands); and
- Investigating practical methods to reduce potable water demand.

The effectiveness, efficiency and benefits provided by the best management practices will require a collaborative effort between local governments, developers and relevant regulatory authorities. All parties will need to be involved in the implementation of the strategies as the site progresses through the planning and development processes.

Typical shallow drain on subject land

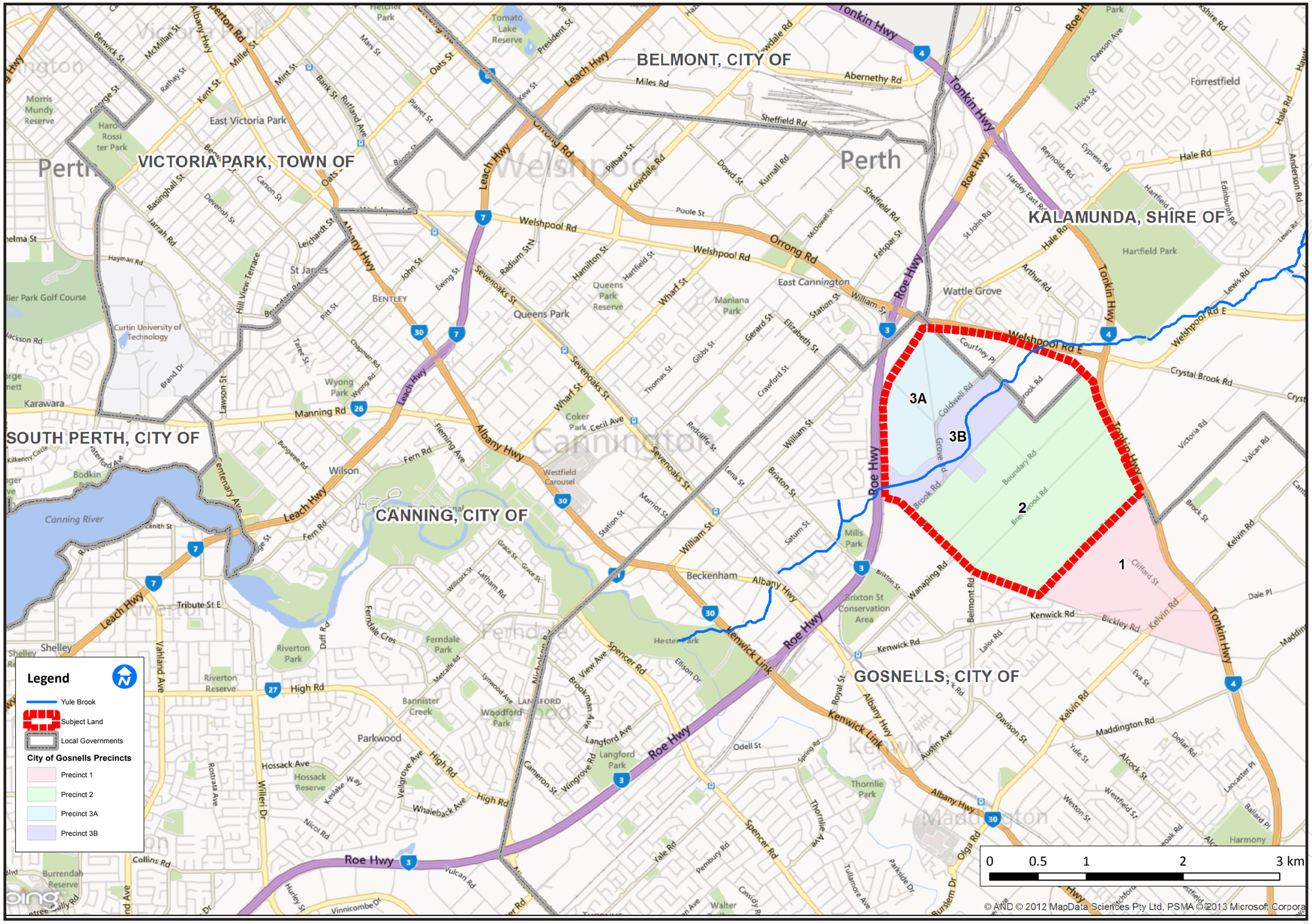


Figure 1 - Location Map

1. PLANNING SUMMARY

The District Water Management Strategy is to support the rezoning of land zoned 'General Rural' in Precincts 2 and 3 of the Maddington-Kenwick Strategic Employment Area (MKSEA), and the adjoining land in the Shire of Kalamunda, to 'Industrial' under the Metropolitan Region Scheme (MRS).

Figure 2 shows the current zoning of the land under the MRS. An amendment of the MRS is a prerequisite to the type and form of development indicatively shown in *Figure 3.*

Key planning phases of an MRS amendment need to address water management issues at the appropriate planning stages, these include:

- Amending the City of Gosnells Town Planning Scheme (TPS);
- Preparing Outline Development Plans (ODP);
- Reaching arrangements for the shared provision of required development infrastructure; and
- Subdivision and development proposals.

It is anticipated that the subject land, upon the completion of these planning phases, will be developed to cater for various general industrial activities, including manufacturing, transport and logistics, service commercial, trade display, warehousing/storage and light industry uses.

SUPPORTING DOCUMENTATION

The DWMS designs and models were compiled using information contained within the detailed assessments and reports undertaken for the subject land. These reports listed below have been included on the enclosed CD of attachments at the back of the DWMS. For detailed information relating to the water management on the subject land please refer to these supporting documents:

- Engineering Review for the Maddington Kenwick Strategic Employment Area
- MKSEA Surface Water & Groundwater Monitoring & Investigation ,Endemic 2012
- MKSEA Surface Water & Groundwater Monitoring & Investigation, Addendum, Endemic 2012
- EBS198AC Black Cockatoo Survey - the Maddington Kenwick Strategic Employment Area
- The flora, vegetation and wetlands of the Maddington Kenwick Strategic Employment Area by C. Tauss and A.S. Weston, 2010 (A confidential report)
- Environmental Review for the Maddington Kenwick Strategic Employment Area by Cardno BSD PTY LTD, July 2005
- District Water Management Strategy for Maddington Kenwick Strategic Employment Area, Precinct 1
- Preliminary MSKEA Precincts 2 & 3 Draft Subdivision Concept,2013
- Environmental Scoping Document, City of Gosnells, November 2012
- Framework for the Preparation of a District Water Management Strategy, December 2012
- Yule Brook Main Drain Scheme Review, Water Corporation, May 2008
- Yule Brook Modelling, Water Corporation, 2013

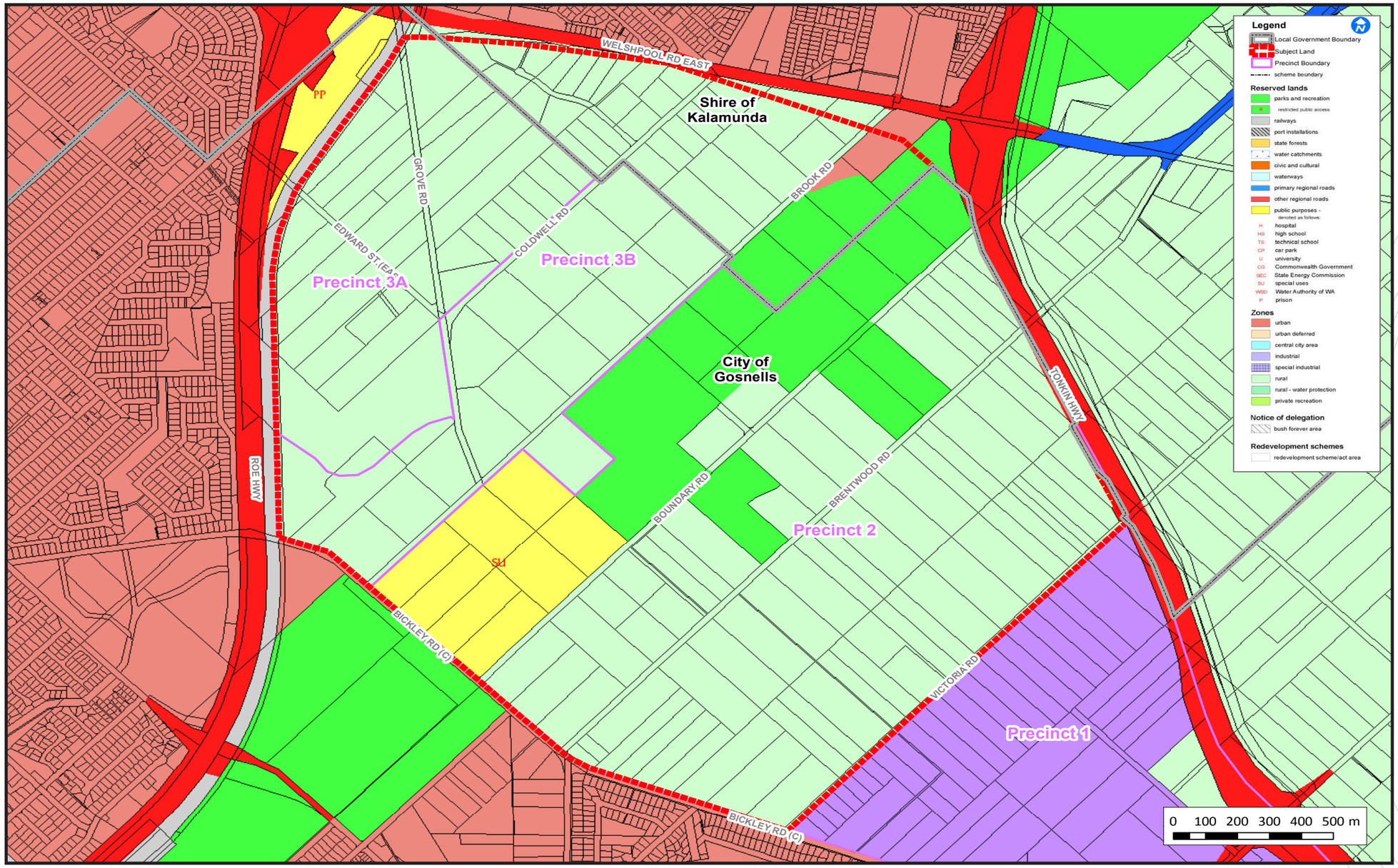


Figure 2 - Current Metropolitan Region Scheme (MRS) Map

2. KEY ELEMENTS

Water management strategies for the subject land are based on best practice water sensitive urban designs (WSUD) matched to the sites constraints. They also recognise the importance of water as a resource across the entire development and surrounding environment. Specific constraints and threats identified for the subject land are discussed in *Section 9*, and listed below:

CONSTRAINTS & THREATS

- Wetlands (and associated buffers);
- Waterways (and associated foreshore reserves);
- Threatened Ecological Communities (TECs);
- Declared Rare and Priority Flora (DRPF);
- Maintain environmental water requirements for surface and ground water dependent ecosystems;
- Further investigation of remnant vegetation 'Area of Interest' as mapped by Tauss and Weston (2010) at the Outline Development Plan (ODP) stage;
- Flooding;
- Aboriginal heritage sites;
- High groundwater quality and levels (including high seasonal peaks and dependent ecosystems);
- Acid sulfate soil (ASS) risks;
- Stormwater runoff flow rates, nutrients, contaminants and pollutants;
- Potable water supply costs; and
- Wastewater servicing costs

The City of Gosnells' assessment of environmental constraints in the MKSEA (Tauss & Weston, 2010) provided mapping and recommendations that differed from the Department of Parks and Wildlife's GWSCP dataset and its dataset of known Threatened Flora and Ecological Communities. The City prepared Constraints Summary Mapping (see *Figures 15*) whose polygons were derived from an overlay of the Department's mapping and that of Tauss & Weston. The polygons in the City's Constraints Summary Mapping represent the larger of the polygons resulting from this overlay. The Department subsequently endorsed the City's use of the Constraints Summary Mapping for the purposes of strategic land use planning, specifically as a base map for the preparation of this DWMS.

OPPORTUNITIES AND MANAGEMENT OPTIONS

The recommended strategies provide an integrated approach through the synthesis of industrial planning and designs to manage protect and conserve the total water cycle. The plans and designs for the development are appropriate for the subject land's development constraints, surrounding environment and providing a sustainable industrial estate.

A summary of the recommended key best water management practice elements for implementation within the development are outlined below, and visually represented in *Figure 4*:

WATER QUALITY AND ENVIRONMENTAL PROTECTION

- Determination, at the LWMS stage, of an appropriate foreshore buffer to Yule Brook based on a biophysical assessment, prepared in accordance with the Department of Water's (DoW) *Operational Policy 4.3: 'Identifying and establishing waterways foreshore areas'*, and its guidance;
- Provision of new wetland and waterway habitats within Multiple Use Corridors, storage/ attenuation basins and buffer areas;
- Establishment of appropriate management practices for waterway reserves along Yule Brook and wetland systems including buffers and specific management plans for significant ecosystems;
- Utilisation of water sensitive urban designs (WSUD), including bioretention gardens, basins, swales, and flow spreader devices to capture, detain, treat and convey all development runoff;
- Investigation of building design guidelines that encourage structural separation of potentially polluted runoff in work areas from the stormwater runoff pathways;
- Provision of lot owners with information relating the establishment and maintenance of Waterwise and nutrient wise gardens in their required landscape areas on each development; and
- Monitoring of storm water outflow rates and quality post-development.

Yule Brook

FLOOD PROTECTION

- No development to be within the 100 year flood ways;
- All habitable floor levels on lots to be designed to maintain a minimum separation clearance of 500mm to the 1:100 year flood levels of Yule Brook;
- All habitable floor levels on lots to be designed to maintain a minimum separation clearance of 300mm to the internal 1:100 year average recurrence interval (ARI) flood levels;
- Protection of buildings and infrastructure with conveyance and storage of flood waters via the open and piped drainage network and road reserves;
- Discharge of 1:10 year flow rates to Yule Brook River not to exceed pre development flow rates;
- Discharge of controlled 1:100 year flood flow rates to the Yule Brook River that will not cause adverse impacts ; and
- Designated safe 1:100 year flow paths within the development protect infrastructure from flood risks.

STORMWATER MANAGEMENT

- Utilisation of WSUD to treat, store, convey, control and discharge stormwater runoff in a managed practice;
- Ensure pre-development flows continue to maintain water dependent ecosystems, or other agreed flow regimes deemed necessary to support key ecological functions;
- Investigation of building design guidelines that encourage structural separation of potentially polluted runoff in work areas from the stormwater runoff pathways;
- Encourage non-structural best management practices to reduce flow rates and potential contamination;
- Utilise drainage pipes and swales to convey flows through the development;
- Lot storage and treatment of all runoff from the 1 year 1 hour event on the lot;
- Storage and treatment of the 1 year 1 hour event in road reserves; and
- Monitoring of water quality during construction and post-development.

GROUNDWATER MANAGEMENT

- Ensure development has no negative impact on the groundwater resource, or ecosystems dependent on the resource;
- A controlled groundwater level (CGL) is to be set at the average annual maximum groundwater level (MGL) across the site, unless further studies demonstrate that an alternative level satisfies infrastructure and environmental considerations. The CGL and MGL may be refined as part of the LWMS process;
- Filling building and infrastructure sites where necessary so that a minimum 1.2m clearance to the building pad and effluent disposal areas are maintained from the CGL;
- The City of Gosnells' requires a minimum 0.5m separation from the CGL (or critical groundwater level) to physical infrastructure, residential footings and to the invert level of the storm water management measures;
- Installation of a sub-soil drainage pipe network and swale systems at the proposed CGL to control groundwater from rising above the level set;
- Treatment of controlled groundwater and the stormwater runoff infiltration via bioretention and potentially wetland systems;
- Monitoring of the groundwater quality and levels across the subject land post development to identify any future detrimental impacts on the groundwater resource; and
- Managed use of groundwater resources within acceptable allocation limits.

WATER CONSERVATION AND SERVICING

- Development to be connected to a potable reticulated water supply;
- Encouragement of water efficient fixtures and fittings for all buildings constructed;
- Encouragement of lot owners to install a suitable rainwater tank. The tank size will be dependent on the roof area and water usage patterns of the business;
- Sewerage wastewater collection and treatment for all of the subject land with a provision for potential grey/waste water reuse after appropriate treatment; and
- Public areas, bioretention units and street landscaping will have a strong focus on using locally suitable native Waterwise species and use of soil amendments to reduce irrigation requirements.

HERITAGE

- Investigations and liaison with the Department of Aboriginal Affairs (DAA) prior to any construction.

Typical rural landuse on low sand rise

Typical road side drain in subject land

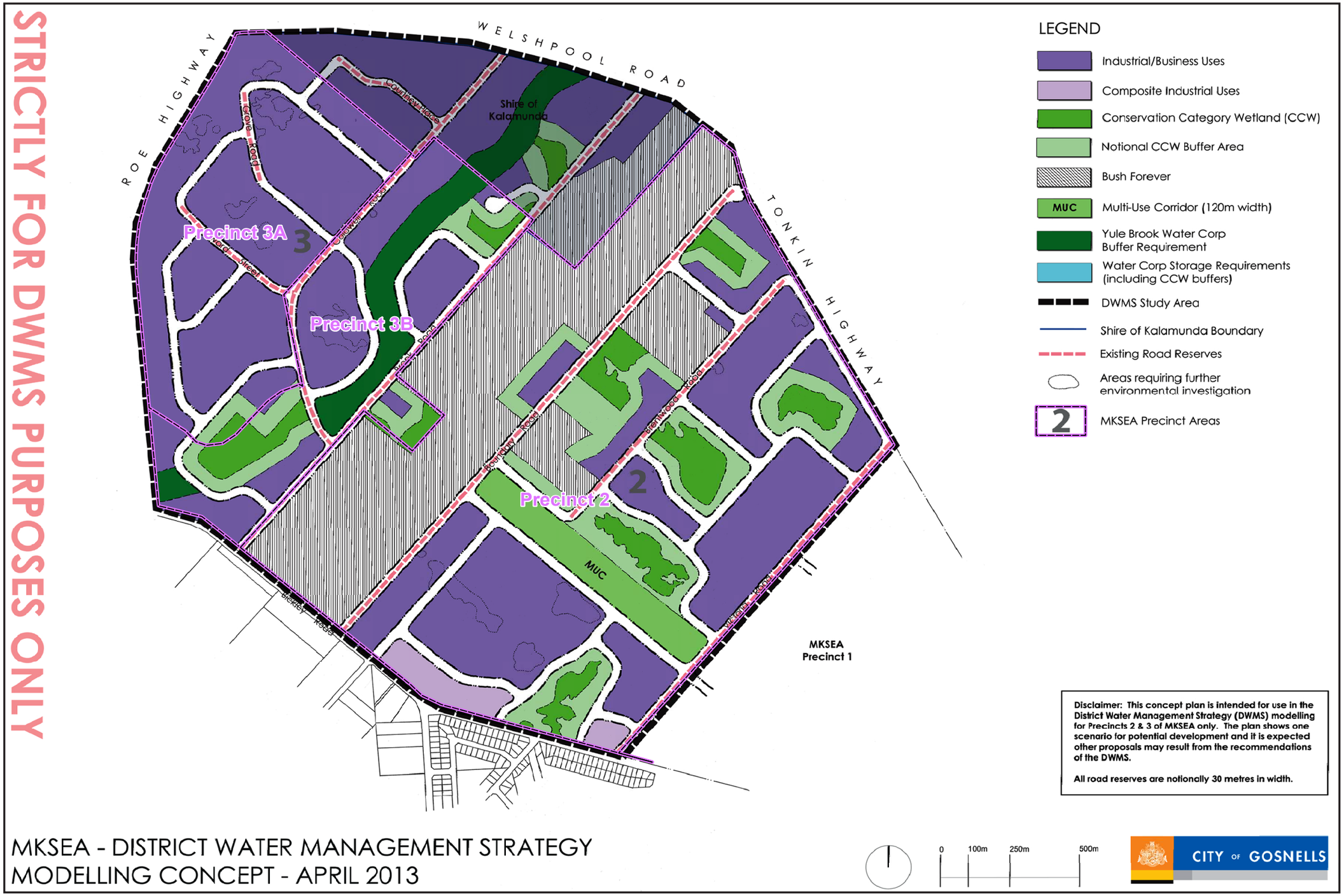


Figure 3 - City of Gosnells Indicative Development Concept Plan

(Based on City of Gosnells Constraints Summary Mapping, See Figure 15)

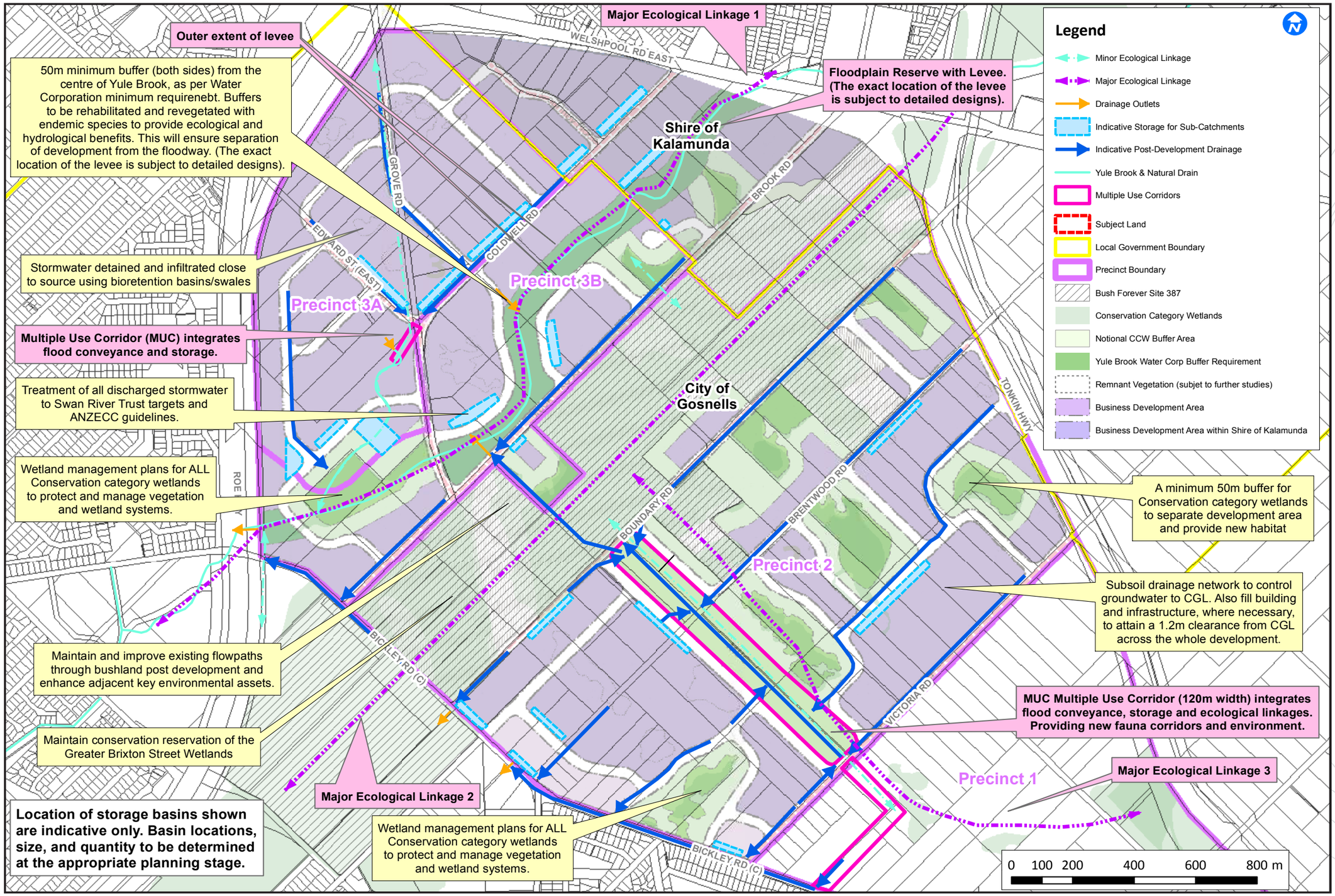


Figure 4 - Key Element Plan

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

3. SITE CHARACTERISTICS

LANDFORM & GEOLOGY

The subject land is located on the eastern Swan Coastal Plain approximately 3 to 4km west of the Darling Scarp. The regional scale landforms of the Swan Coastal Plain represented in the MKSEA comprise of: the Ridge Hill Shelf (Foothills); the Pinjarra Plain; and, the Bassendean Dunes (C. Tauss and A.S. Weston, 2010). The broad slope categories across the subject land are shown in *Figure 5*, with detailed analysis required at later stages of development. The landforms are typical of this region, and comprise four main local landform areas as shown in *Figure 6* and described below. The associated geological sub-system units to the landforms are on *Figure 7*.

SAND RISES

The subject land consists of vegetated sand ridges in the western section of the subject land, between Brook Rd and Boundary Rd. The dominant landscape subsystem (Bassendean S8) describes the land with deep Bassendean sands, average slopes of 7% and elevation ranging from 9 to 13m AHD. Most of the other areas within these two roads are of Bassendean S10 sub-system, which have deep Bassendean sands over sandy clay, and with low sand rises. In the south-west and southeast corners there are low sand rise areas within the Pinjarra Gf7 sub-system. A central area of land extending from Yule Brook to the northern boundary has low sand rises and elevation ranges from 11 to 12m AHD. The low slopes and predominately sandy surfaces of this landform produce a low runoff rate and waterlogging.

POORLY DRAINED FLATS

The extensive Palusplain extending below about 11m AHD to the south-west of Edward St, Grove Rd and Brook Rd in Precinct 3A consist predominantly of broad poorly drained flats (Pinjarra Gf3 sub-system). The area extending from the northeast boundary towards Grove Rd is also classified as poorly drained flats with low sand rises between these landforms. These areas have a higher runoff rate than the sand areas and surface inundation will substantially increase the rate after extended rainfall periods common during winter.

ALLUVIAL FANS

The area extending south of Yule Brook from the eastern boundary consists predominantly of alluvial fans (Pinjarra Gf4 sub-system) that are generally flats (less than 1% slope), elevation ranging from 13 to 20m, and poorly drained. The soils include sands, sandy loams, clays, grit and weathered granitic detritus.

FLOODPLAIN AREA

The Water Corporation has indicatively mapped the floodplain area associated with Yule Brook, which is not well defined, but is a significant feature of the subject land. The elevation ranges from 7 to 15m AHD, with a general slope of 0.4% except within the channel. The natural course of Yule Brook is mapped as sandy silt (Ms4).

Though the floodplain area is not defined, it is a significant feature of the site. It consists of a strip of area along both sides of the Yule Brook. Its elevation ranges from 15mAHD to 7mAHD, with general slope of 0.4% except within the channel. The natural course of Yule Brook is mapped as sandy silt (Ms4).

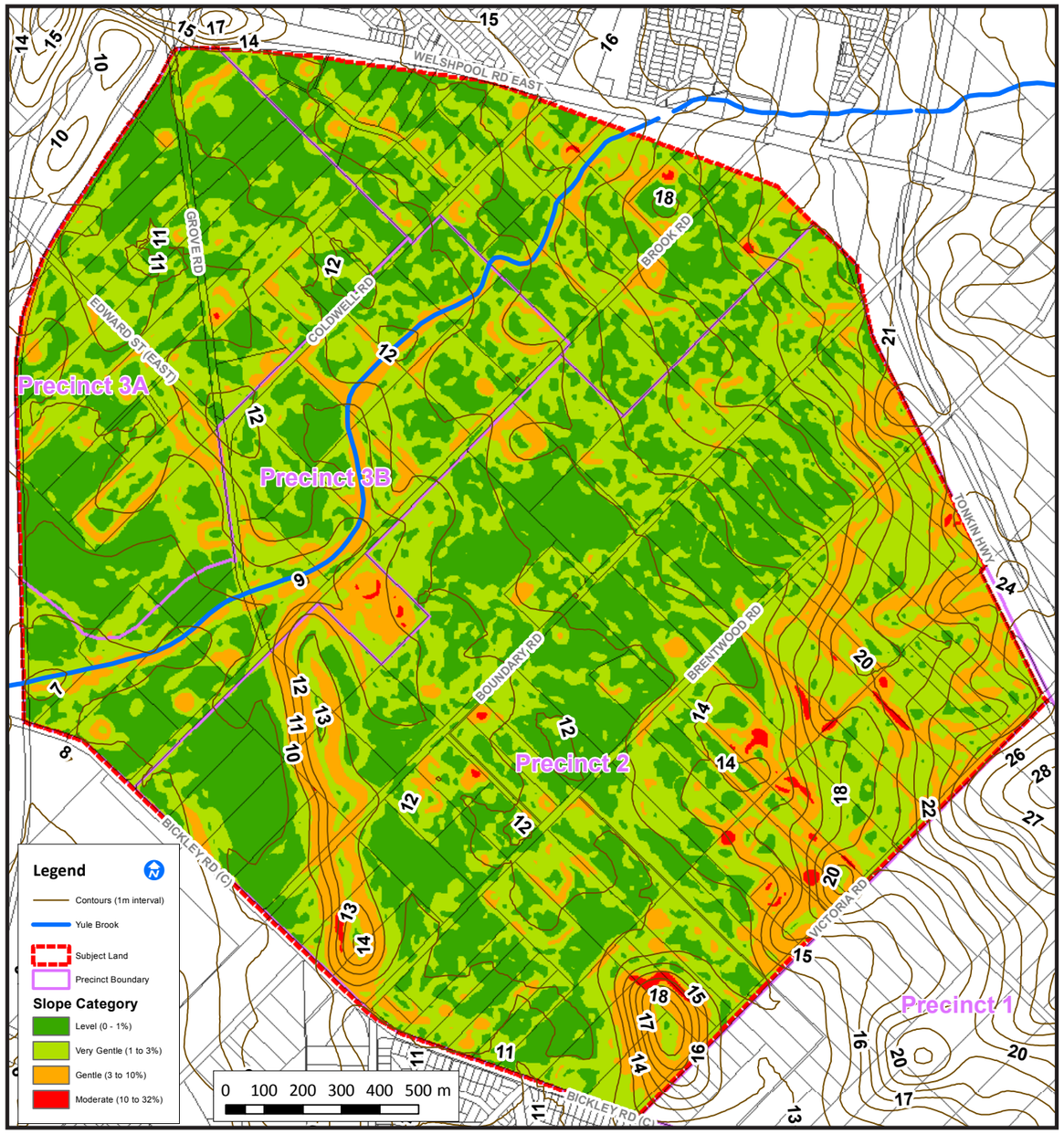


Figure 5 - Slope Category Map

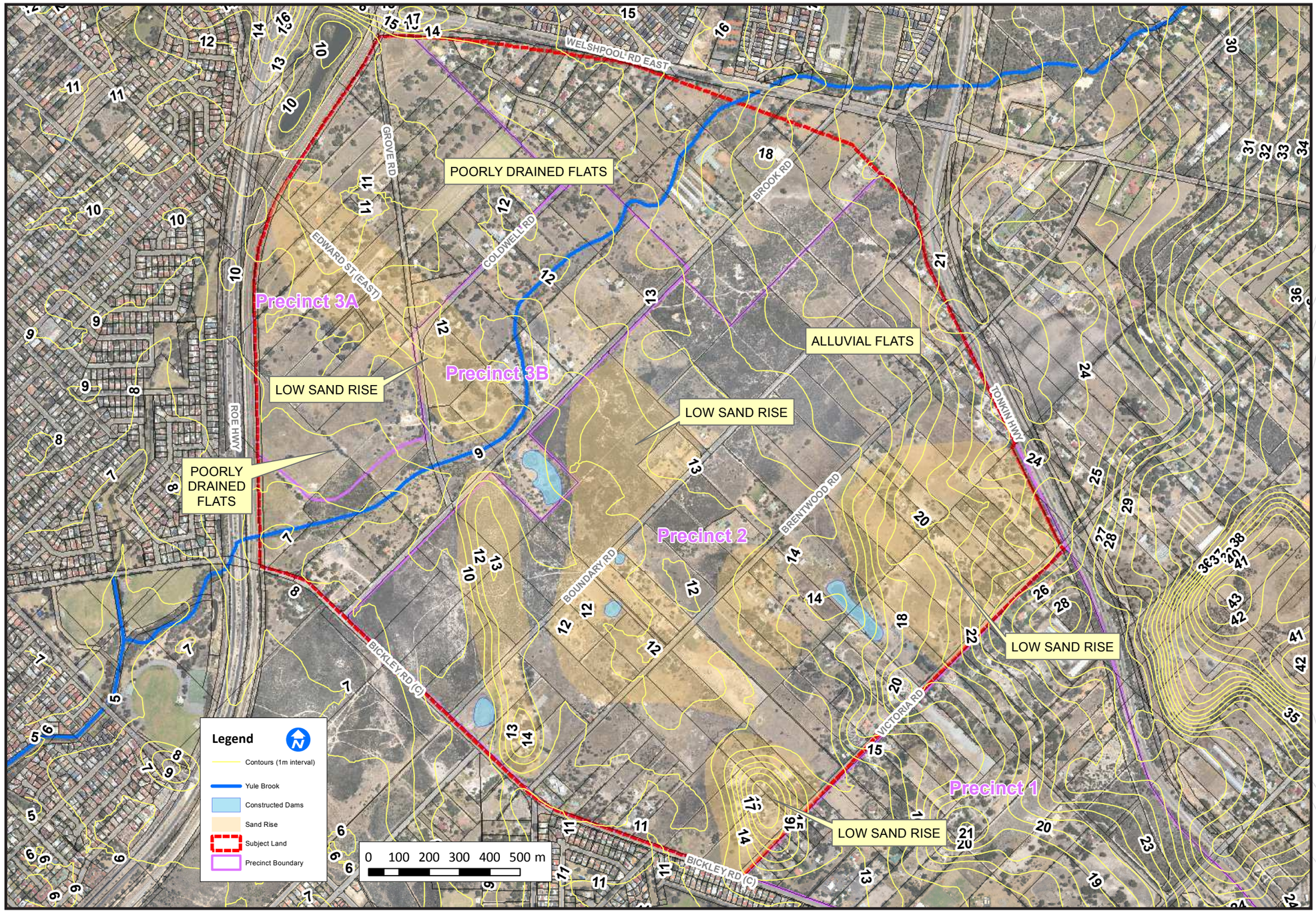


Figure 6 - Topographic Map

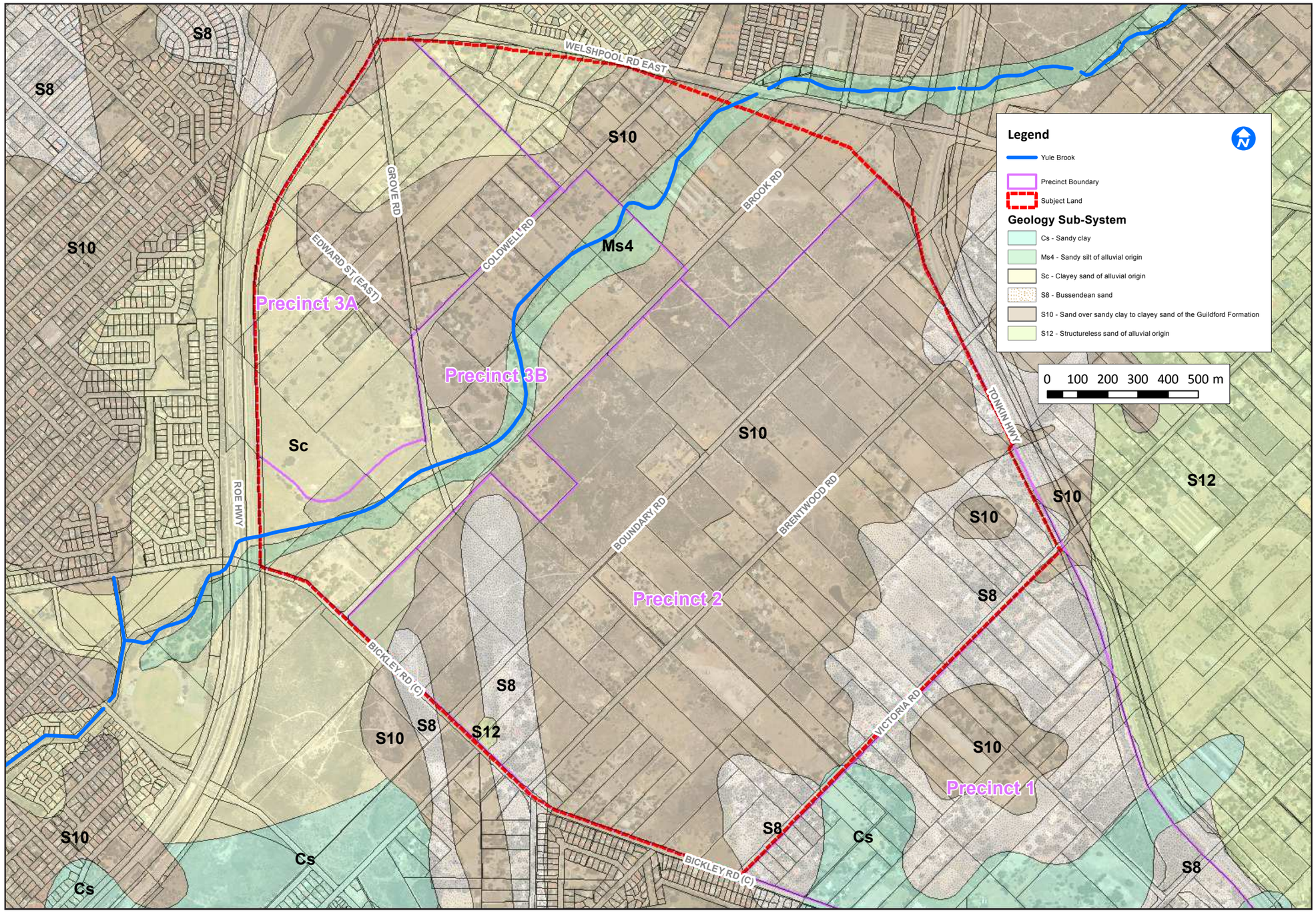


Figure 7 - Geological Subsystem Map

SOIL RISKS

ACID SULFATE SOILS (ASS)

The Department of Environment Regulation (DER) ASS risk mapping dataset for the Swan Coastal Plan has 'high to moderate' and 'moderate to loss' disturbance risks within 3m of the surface across the subject land. The geology associated with the Yule Brook floodplain and a small Resource Enhancement wetland (UFI 15418 confined to the geological unit S12, see *Figure 7*) have been classified as a 'high to moderate' risk (see *Figure 8*).

A preliminary ASS investigation by Endemic in 2012 identified five lithologies with varying degrees of acid generating potential, however there was no mapping produced to identify these areas:

1. Bassendean Sand;
2. White Sandy Clay;
3. White Clay;
4. Orange/White Clay; and
5. Blue/Grey Clay.

The Bassendean Sand, White Sandy Clay, White Clay and Orange/White Clay lithology samples were not acid generating, with zero samples exhibiting a net acidity greater than the assessment criteria of 0.03% elemental sulphur (S). The Blue/Grey Clay lithology generally had moderate acid generation, with both of the two samples exhibiting a net acidity greater than the assessment criteria of 0.03% S. The Blue/Grey Clay soil unit was rated a high risk of acid generation due to its low to moderate total sulphur concentration and presence at or below the water table.

The preliminary investigation recommended that "based upon the limited sampling undertaken, a moderate actual risk of ASS is generally associated with the Blue/Green Clay soil type; however, this is likely to be a localised impact" (p. 16). The investigation concluded that "the ASS onsite does not provide a significant impediment to development and appropriate management strategies for handling these moderate risk soils could be defined in accordance with the" Department of Environment Regulation (DER) guidance for ASS in WA (DEC, 2011 and DEC, 2013).

To protect on-site and downstream water resources, ASS investigations should be undertaken across the subject land at more detailed stages of planning to determine the potential and actual ASS risks for areas where there is likely to be a 'high to moderate' risk of actual or potential ASS.

Detailed ASS investigations and management plans (where appropriate) will also be required on land modelled as 'moderate to low' in accordance with DEC's 2013 Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes guidelines if any of the following works are proposed:

- Soil or sediment disturbance of equal to or greater than 100m^3 with excavation from below the natural water table.
- Lowering of the water table, whether temporary or permanent (e.g. for groundwater abstraction, dewatering, installation of new drainage, modification to existing drainage).
- Excavating to or greater than 3m below the natural ground surface level.
- Construction of flood mitigation works, including levees.

PHOSPHORUS RETENTION INDEX

The Pinjarra soils are likely to have a high Phosphorus Retention Index (PRI) while the Bassendean sands are likely to have a low PRI. There is a need for geotechnical investigations of the development sites at later stages of planning to determine site specific PRI values.

CONTAMINATED SITES

The Department of Environment Regulation's Contaminated Sites database was accessed on 23rd October 2013, and no known sites were found on the subject land. There are three contaminated site to the north of the subject land, including part of Welshpool Road, and two lots north of the road (see *Figure 8*). All three sites are classified as 'contaminated – remediation required'. There are no risks to the subject land associated with these sites.

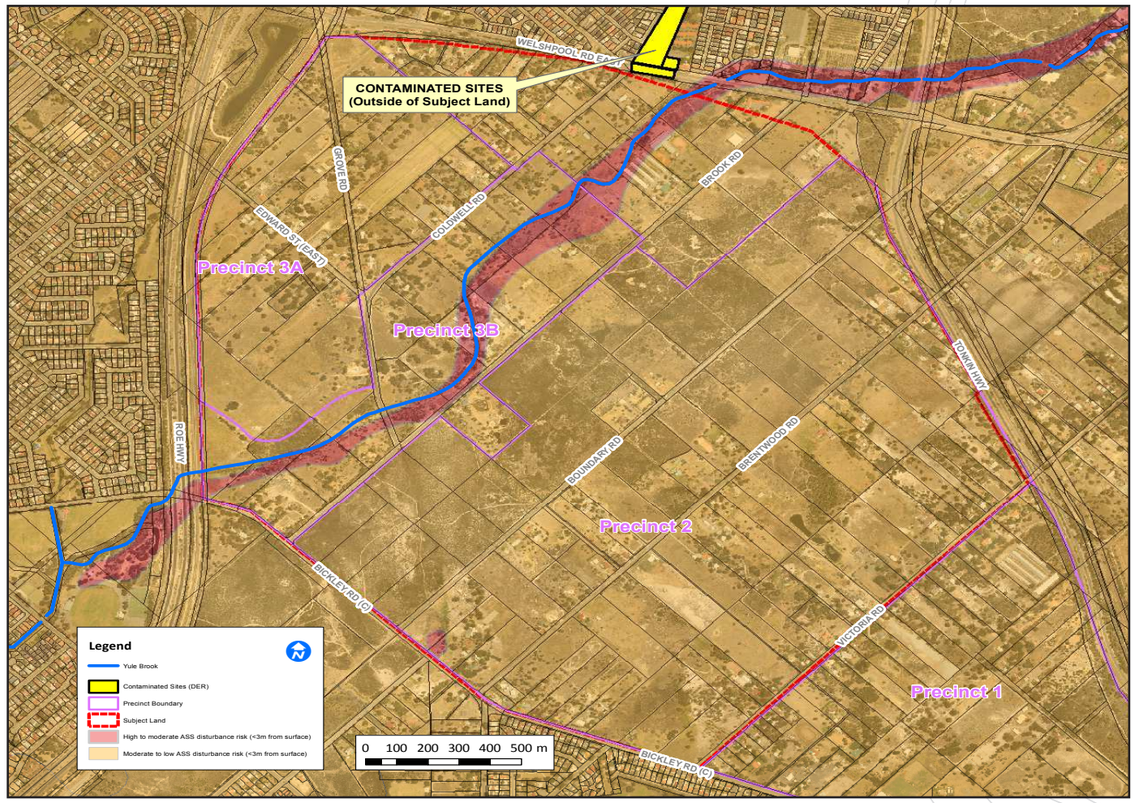


Figure 8 - Soil Risk Map

4. GROUNDWATER PRE-DEVELOPMENT

The presence of important wetlands and groundwater dependent ecosystems that are reliant on the site's groundwater regime is a critical issue for the sustainable development of the subject land. Preliminary studies (Endemic 2012) have been undertaken to form an understanding of this relationship between the site's ecosystems and groundwater regime. The information below provides a summary of this information, and the full reports are included on the enclosed CD of attachments.

The aquifers of the MKSEA include the superficial Perth Swan unconfined aquifer, which is a shallow aquifer formed from surficial sediments. The geological age of the site is Quaternary over a confined aquifer associated with the Perth Leederville Formation (Endemic, 2012).

The Perth Groundwater Atlas (accessed online form Department of Water 23rd October 2013) provides indicative groundwater elevations for the subject land. However the groundwater contours are based on levels measured in May 2003, and therefore it is unlikely that they capture the maximum peak for the water table. The contours are shown in *Figure 9*, with levels ranging from approximately 5m AHD in the south-west to 13m in the east. The Perth Groundwater Atlas also contains historical maximum groundwater contours, however the dataset only covers the western section (Precincts 3A and 3B)of the subject land (see *Figure 9*). Comparatively the intersection of Bickley Road and the Roe Highway has a historical maximum of 7m and a groundwater contour of 5m, and at the intersection of Grove Road and Edward Street the historical maximum is 3m higher than the groundwater contour.

Both contours for the groundwater show that the groundwater flow in a westerly to south-south westerly direction towards the Canning River. Comparison of topography to the groundwater contours contours suggests that groundwater is very close to the surface in the area west of Brook Road. This is consistent with the presence of the Greater Brixton Street Wetlands and the classification of the area as Palusplain. It is likely that at some times of the year Yule Brook is a surface expression of the surrounding groundwater table. Groundwater over the eastern half of the study area is not as close to the surface, with the gap to the surface generally increasing away from Yule Brook to a depth of over 2m by the eastern boundary (GHD, 2005).

GROUNDWATER LEVELS

GROUNDWATER & SURFACE WATER MONITORING PROGRAM (ENDEMIC, 2012)

Endemic Pty Ltd commenced 18 months of surface water and groundwater monitoring from June 2009. The objective of the monitoring program was to understand the level and quality of groundwater and nature of subsurface water movement, together with the spatial and temporal variation in those parameters. Eleven groundwater monitoring bores were installed to a maximum depth of 6m below the natural surface level in June 2009 for levels and quality sampling. Due to geology, potentially underlying calcrete, and encountering the water table depths of bores varied with the shallowest between 1 and 2.5m (bores GW12, GW2, GW4 and GW5 within the Greater Brixton Street Wetlands, see *Figure 10)*. A groundwater contour map based on the maximum recorded levels was determined in the report (Endemic, 2012) and has been reproduced in *Figure 10*. The depth from the natural surface level to the maximum recorded levels was modelled by comparing recorded groundwater contours to a digital elevation model (see *Figure 11*).

The Department of Water long-term water monitoring (WIN) sites that were within 5km of the subject land were acquired and investigated. There is a general lowering of the water table observed in all bores since the 1970's, from approximately 1 to 2m, in superficial aquifers, to over 20m ,in the artesian aquifer, between the maximum levels recorded. The majority of the bores showed that levels in 2009 and 2011 were representative of the last decade, and that 2010 was generally deeper than the average for the same period. The nearby DoW WIN Site hydrographs have been included on the enclosed CD of Attachments.

GREATER BRIXTON STREET WETLANDS (SEMENIUK RESEARCH, 2000)

The V & C Semeniuk Research Group undertook a study of the Greater Brixton Street Wetlands (GBSW) during 1999-2000 that covered wetlands inside and outside of the proposed MKSEA. The objective was to "investigate the hydrological mechanisms of recharge, flow, and discharge, within these remnant The Department of Water long-term water monitoring (WIN) sites that were within 5km of the subject land were acquired and investigated. There is a general lowering of the water table observed in all bores since the 1970's, from approximately 1 to 2m, in superficial aquifers, to over 20m ,in the artesian aquifer, between the maximum levels recorded. The majority of the bores showed that levels in 2009 and 2011 were representative of the last decade, and that 2010 was generally deeper than the average for the same period. The nearby DoW WIN Site hydrographs have been included on the enclosed CD of Attachments. wetlands areas, and to identify inter-related water/sediment/plant responses, where possible". The study involved: drilling six holes to a depth of between 6 and 17m; placing 34 piezometers along eight transects; and vegetation surveys. The wetlands were found to be maintained by "surface and near surface perching of direct precipitation, and by infiltration, most commonly via root cavities", with minimal interaction from the regional aquifer. For most of the area the groundwater was found to be semi-confined.

Furthermore the study found that the major effect of the drains adjacent to the GBSWs were upon the surface water in the wetlands, and that the draining of the wetlands has the effect of reducing the hydrological period of inundation and waterlogging in the surface sediments, and of reducing the potential for infiltration. It was found that alteration to water levels, through drainage, has had a serious impact on some of the vegetation.

GROUNDWATER QUALITY

The Endemic Pty Ltd 2009 and 2010 investigation of the eleven installed groundwater bores (as previously mentioned) involved six samples at each bore on a quarterly basis. After analysis the report concluded the following in regards to groundwater quality:

- **pH levels** across the land were neutral to slightly acidic with pH ranging from 4.15 to 8.18, with an average of 7.11. A pH ranging from 6 to 8.5 is considered typical for the area. The low pH of 4.15 in one bore is likely due to natural ASS oxidation associated with falling groundwater table.

- **Electrical Conductivity (EC)** ranged from 0.148 to 40.6 µS/cm (Microsiemens per centimetre) with an average of 6.504 µS /cm, which is typical of freshwater with lower values corresponding to months with rainfall and the influence of fresh rainfall driven discharge on the site.

- **Total Phosphorous (TP) and Total Nitrogen (TN)** are consistently above the S*wan-Canning Water Quality Improvement Plan* (SCWQIP) long term targets for Yule Brook (median concentration 0.075 mg/L and 0.75 mg/L respectively). The highest concentration of TN (19.0 mg/L) in one bore in September 2010 coinciding with elevated levels of Total Kjeldahl Nitrogen (TKN), Total Suspended Solids (TSS), Nitrate, TP and Chemical Oxygen Demand (COD) suggests that it is organic in origin or possibly a leachate from a nearby domestic septic tank.

- The average **Filter Reactive Phosphorus (FRP) to TP** groundwater concentration percentage was 23.2% over the monitoring period. This is indicative of clay terrains and hence a relatively high concentration of suspended particulate matter, which readily absorbs reactive phosphorus.

- **Pesticide and Hydrocarbon,** including Polycyclic Aromatic Hydrocarbons (PAH), the BTEX suite and most Total Petroleum Hydrocarbon (TPH), concentrations at the MKSEA were all found to be below the laboratory limit of reporting.

- **Metal concentrations** remain typical of broad scale grazing and rural land use activities undertaken in the broader region on the Bassendean sand and Guilford loams. Groundwater commonly exceeds the long-term irrigation trigger values (for Aluminium, Chromium, Copper, Iron, Manganese and Nickel) and the domestic non-potable trigger values (for Aluminium, Chromium, Iron, Nickel and Lead).

HYDROGEOLOGICAL RELATIONSHIPS

Groundwater levels and stream flows in the GBSWs area are highly responsive to rainfall (Endemic,2012). This is largely because of the presence of:

- well-formed calcrete at a shallow depth (<1m) underlying much of the GBSW complex;
- soils with a high clay content at a shallow depth (<1m), which inherently exhibit a high runoff coefficient; and
- deep drains along the roads bordering the wetland systems.

The calcrete, where encountered, is shallow, well formed (rock-like) and largely impervious. This feature influences the responsiveness of groundwater to rainfall infiltration and for the surficial (perched) groundwater that sustains the hydrology of the GBSW complex.

The perched groundwater underlying the GBSW complex commonly reaches and/or approaches the natural surface during the winter months, which creates extensive areas of wetland habitat. By the middle to late summer, the perched groundwater has receded to such an extent that there is no surficial groundwater evident within the GBSW complex.

The peak superficial groundwater on the land adjoining the wetlands is unlikely to flow directly into the wetlands because of roadside drains that intercept the high groundwater levels. The calcrete and high clay soils within the soil profile are also likely to limit lower levels of the superficial moving into the GBSWs. Therefore the main influences on high wetland groundwater levels are direct rainfall on the wetlands and the existing road side drains.

DEEPER AQUIFERS

The Department of Water was contacted on 7th November 2012 regarding groundwater availability for the subject land. The subject land is within Perth Groundwater Area and the four sub-areas: City of Gosnells, Shire of Kalamunda, City of Canning and Perth South Confined

The Department of Water's water register (accessed 23rd October 2013) maps four registered bores on the subject land with a total allocation of 240,650KL from the Perth-Superficial Swan aquifer. However 68% of that entitlement is held by the Department of Education for a use outside of the subject land.

The water register states no water is available in the Perth-Leederville and Perth-Yarragadee North aquifers. As of 7th November 2012 there was 1,069,328KL, 2,228,145KL and 423,178KL available from the Perth-Superficial aquifer in the City of Canning, City of Gosnells and the Shire of Kalamunda sub areas, respectively. Furthermore 100,000KL is available in the Shire of Kalamunda sub area's Combined-Fractured Rock West-Fractured Rock aquifer. Providing opportunity for use of the groundwater resources within the development, although the aquifer is generally thin and may contain clay and colluvium sediments and hydraulic conductivity may affect daily yields.

The developers have no entitlement to any groundwater, unless they presently own an entitlement. For any entitlements all applications need to be made to the Department of Water, at a later date.

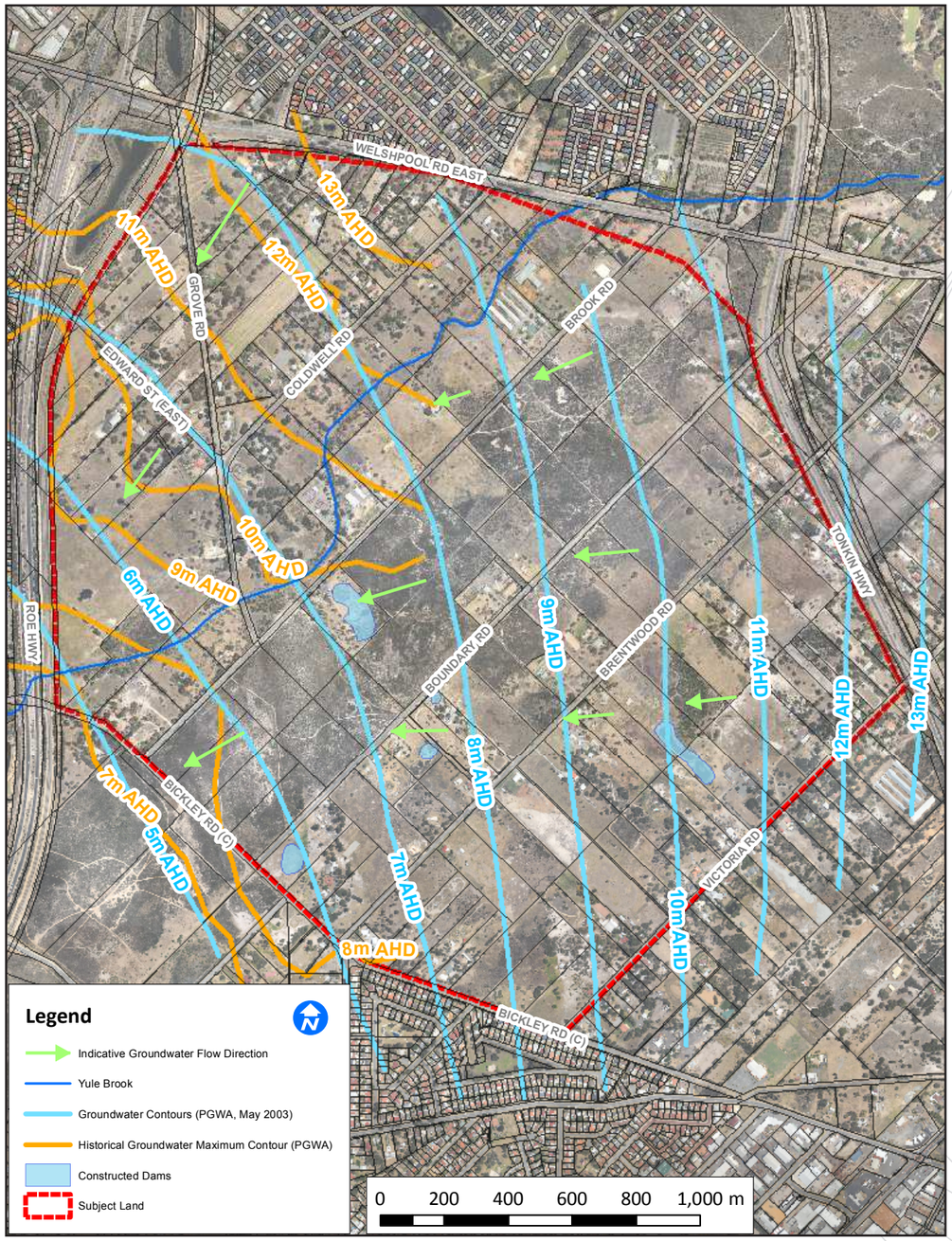


Figure 9 - Perth Groundwater Atlas (PGWA) Map

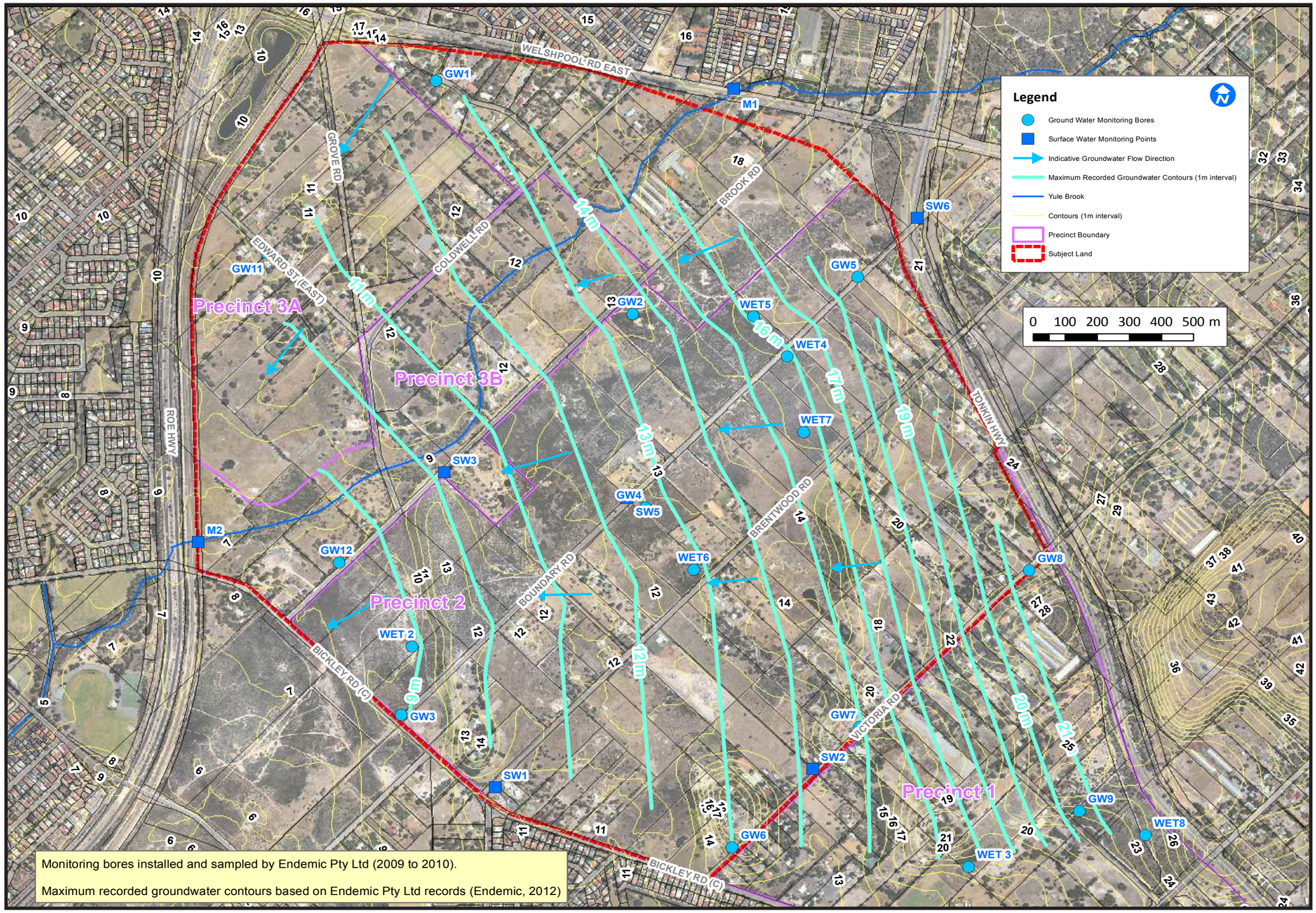


Figure 10 - Maximum Recorded Groundwater Contour Map
(Source: Endemic, 2012)

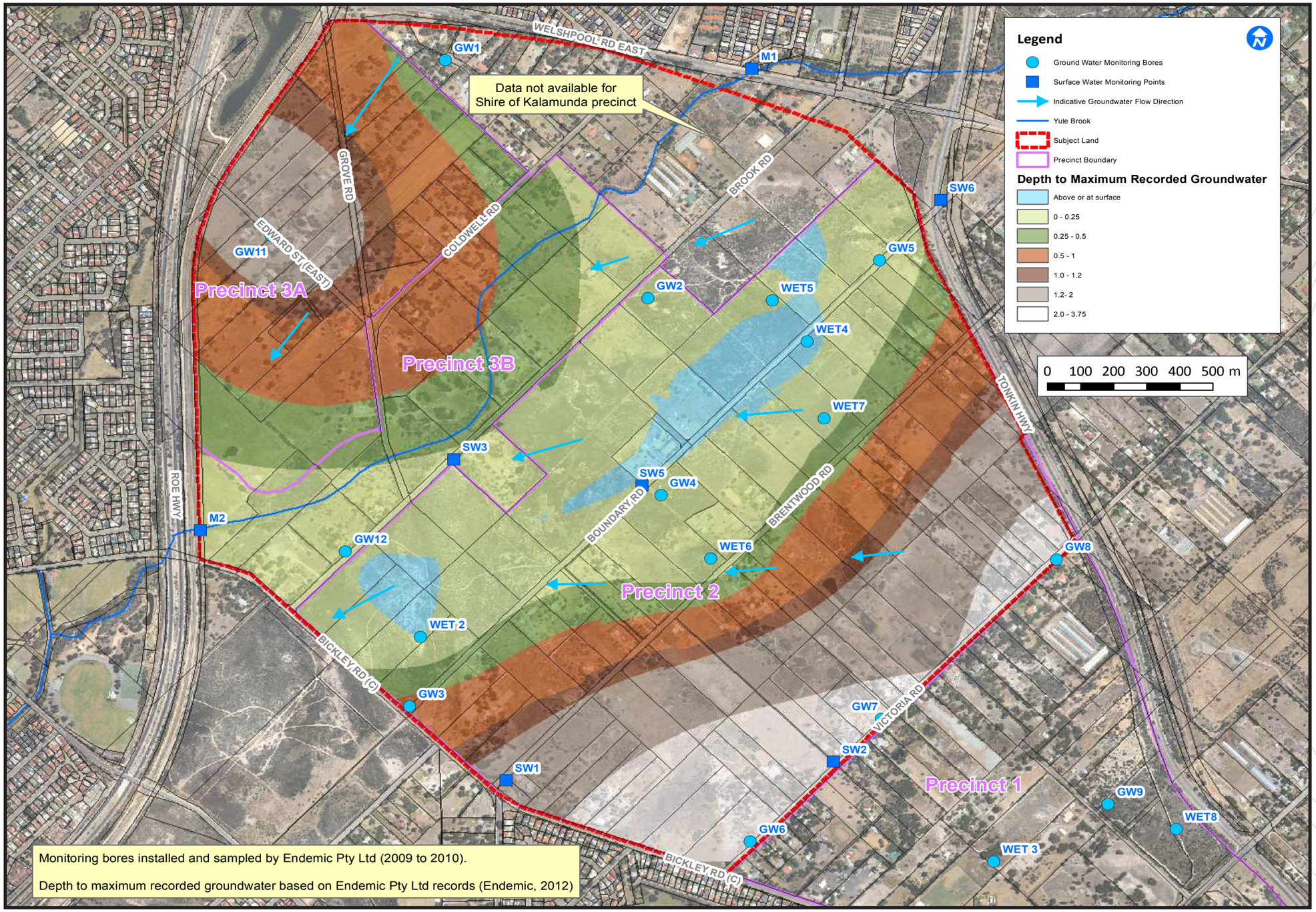


Figure 11- Depth to Maximum Recorded Groundwater Map
(Source: Endemic, 2012)

5. ENVIRONMENT

WETLANDS

CLASSIFICATION

The Department of Parks and Wildlife's (DPaW) Geomorphic Wetlands Swan Coastal Plain (GWSCP) dataset has evaluated approximately 82% of the subject land as wetlands (refer to *Figure 12*).

There are 14 Conservation wetlands evaluated on the subject land comprising approximately 19% of the subject land, with UFI (unique feature identification) wetland 14962 the largest at approximately 54ha (12% of the subject land).

The Greater Brixton Street Wetlands (GBSW) are evaluated as Conservation wetlands and are included within the dataset. The GBSW also include the Bush Forever Site 387 that encompasses majority of the land between Brook Road and Boundary Road on the subject land. The Bush Forever Site extends south and loosely links with remnant habitats along the Canning River. There is also some linkage with the degraded and rehabilitated habitats along Roe Highway. The GBSW are a listed natural feature on the Register of the National Estate, and according to the Australian Heritage Database (2004);

> *"Brixton Street and associated wetlands are an outstanding place of high botanical and educational significance and are listed in the Australian Register of Significant Wetlands. The place contains the last substantial wetland plant community found on the claypans of the Swan Coastal Plain."*

A further 31% of the subject land has been evaluated as 12 Resource Enhancement Palusplain wetlands (REW). The largest Resource Enhancement wetland is UFI 15420 that consists approximately 26% of the subject land. A significant area adjacent to Boundary Road and Yule Brook is evaluated as REW.

A total of 17 Multiple Use Palusplain wetlands (MUW) occur on approximately 32% of the subject land, with the largest (UFI 15254) covering approximately 26% of the subject land. Most of the area north of Brook Road is categorised as MUWs and are devoid of native vegetation. The field study done by Cardno BSD in 2005 identified the vegetation in most of the land categorised MUW and REWs as either 'degraded' or 'completely degraded'. These areas have limited ecological functioning and therefore provide few habitats for fauna.

The Cardno BSD report (2005) proposed revisions for some of the wetland DPaW classifications. Proposed revisions included parts of Lot 68 Brook Rd and Lot 279 Bickley Rd from Conservation to Resource Enhancement wetlands, and Lot 222 Brentwood Rd wetland increased to a Conservation wetland.

Tauss, C. and Weston, A.S. (2010) also recommended revisions to the DPaW management category of wetlands:

- Resource Enhancement to Conservation wetlands: Lot 4/264 Bickley Rd; Part of Lot 8, No. 41 Grove Rd (UFI 7635), Part of Lots 13, 14 and 73 Victoria Rd (UFI 8050), Part of Lot 137 Brentwood Rd (UFI 14122), Part of Lot 138 Brentwood Rd (UFI 14122), Part of Lot 225 Brentwood Rd (UFI 14122), Part of Lot 226 Brentwood Rd (UFI 14122), and Part of Lot 233 Bickley Rd (UFI 14122).

- Multiple Use to Conservation wetlands: Part of Lot 233 Bickley Rd (UFI 7800), Part of Lot 278, and No. 60 Victoria Rd (UFI 8046).

- Unclassified upland to Conservation wetlands: Part of Lot 101 Victoria Rd (No UFI)

- Multiple Use to Resource Enhancement wetlands: Part of Lot 279 Bickley Rd (corner Bickley Rd & Boundary Rd) (UFI 7645), Lot 25 Boundary Rd(UFI 7783), Part of Lot 278, No. 60 Victoria Rd (UFI 8047), Parts of Lots 6, 7 & 8 Brook Rd(UFI 13362), Lot 2008, No. 31 [west of] Grove Rd (UFI 13362), Yule Brook: Parts of Lots 66, 70, 73, 74, 76 Brook Rd and parts of Lots 67, 68, 71, 72 Coldwell Rd (UFI 13362), Part of Lot 5 Edward St (UFI 13362), Part of Lot 2 Edward St (UFI 13362), and Part of Lots 12, 14, 40 Edward St (UFI 13362).

The recommended changes to wetland classifications and boundaries proposed by Tauss and Weston (2010) should be regarded as indicative only and have the potential to change once proposed modifications to the GWSCP dataset, based on more detailed environmental assessment at the Outline Development Plan stage of planning, have been finalised.

The figures within the DWMS show that development is not constrained in areas demarcated as REW in both the GWSCP dataset and the Tauss and Weston (2010) review. The Environmental Protection Authority's (EPA) Guidance Statement 33 indicates that the management objective for these wetlands is to "manage, restore and protect towards improving their conservation value" (*p. 15, Chapter B4*). The development of REWs is not consistent with current government policy. Although the overwhelming majority of the REWs in the MKSEA are almost totally cleared of native vegetation and have been used for pasture purposes, more detailed assessment at the Outline Development Plan level of planning will examine the management classification and boundaries of REWs, with any modifications to the GWSCP dataset proposed and finalised prior to completion of the Outline Development Plan. All REWs confirmed as such will be required to be protected in accordance with the EPA's Guidance Statement 33.

To illustrate these recommendations *Figure 13* shows the recommended wetlands suggested by Tauss, C. and Weston, A.S. (2010) and *Figure 14* provides a comparison of the current DPaW dataset with the recommendations.

The City of Gosnells Constraint Mapping Summary (see *Figure 15*) were produced from the recommended wetland classifications, and the Threatened Ecological Community (TEC) and Declared Rare and Priority Flora (DRPF) mapping undertaken by Tauss and Weston (2010). The mapping summary was endorsed, in principle, by the Department of Environment and Conservation (now DPaW) for the purpose of strategic land use planning (as used in *Figures 3 and 4*).

The City of Gosnells' Environmental Scoping Document for the MKSEA MRS Amendment provides that, with regard to wetlands and waterways, Outline Development Planning (ODP) will establish a more refined development framework under the direction of the Local Structure Plan (LSP). The ODP will evaluate environmental aspects of the Proposal Area at an appropriate scale and establish more clearly areas to be set aside for conservation purposes, appropriate buffers between conservation assets and adjoining land uses, appropriate uses and management of buffers, and specific land uses themselves. Based on these investigations, requests to modify the GWSCP dataset will be proposed by the developer.

With regard to wetland buffers, a minimum 50m buffer should be considered the default for both Conservation and REWs. More detailed assessment at the ODP level of planning, including site-specific buffer studies, will assist in the absolute determination of these buffers.

HYDROGEOLOGY RELATIONSHIP

Water levels within the wetland systems are highly responsive to rainfall due to the shallow aquitard that sub-crops in much of the area within and adjacent to the GBSWs. Surface expression of groundwater was present at areas within the GBSW for approximately 4 weeks. For areas without expression at the surface the 2009 maximum recorded levels varied from 0.03 to 3.54m below the natural surface level, and 0.09 to 4.2m in 2010. The 2009 minimum recorded levels ranged from 0.85 to 3.9m, and 0.98 to 5.06m in 2010. The lower levels recorded in 2010 compared to 2009 was because of the lower rainfall and indicative of the high responsiveness of groundwater in the MKSEA to rainfall. *See Section 4 – Groundwater Pre-Development for more information.*

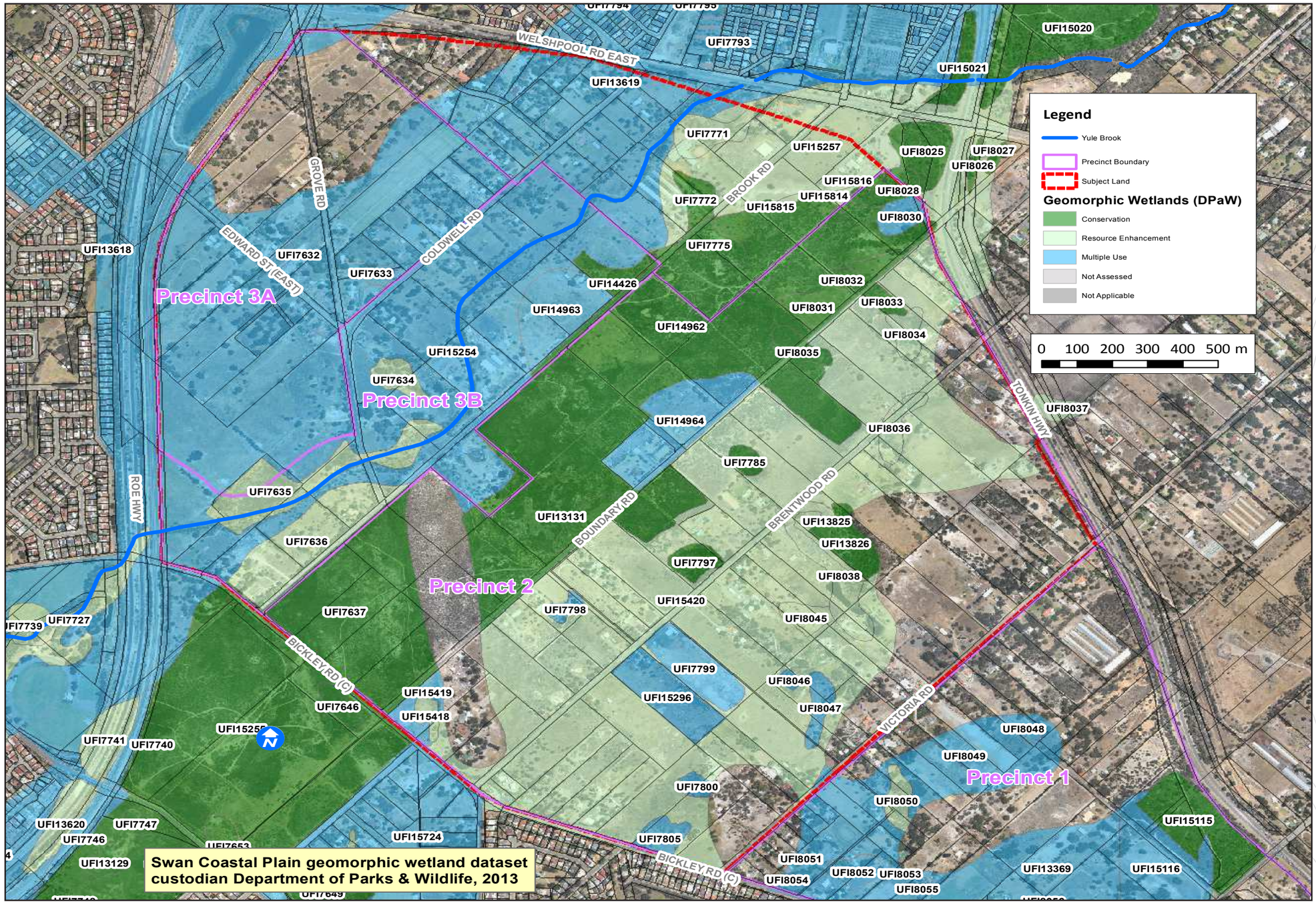


Figure 12 - DPaW Plain Swan Coastal Geomorphic Wetland Map

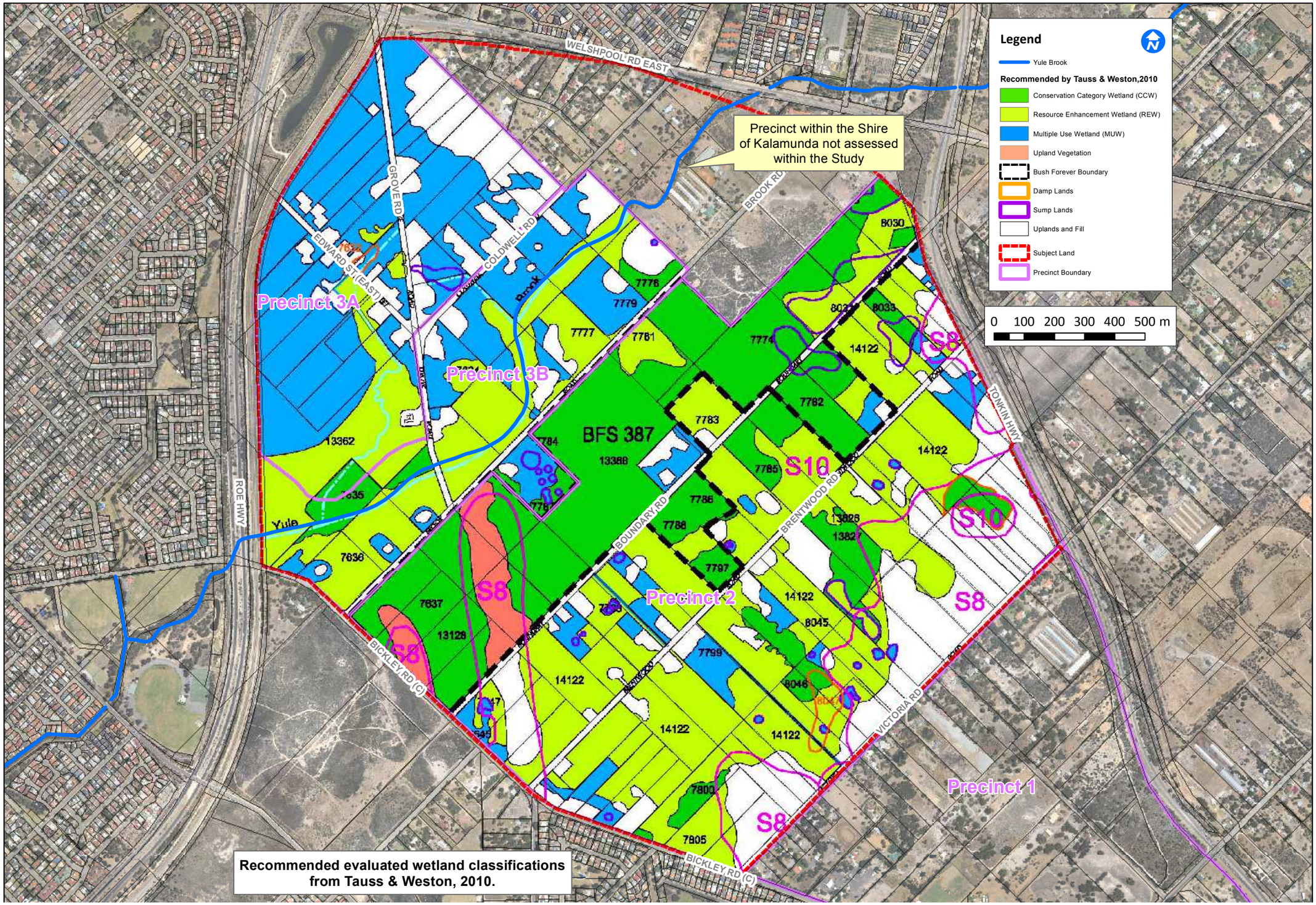


Figure 13 - Recommended Wetland Classifications & Boundaries Map

(Tauss & Weston 2010)

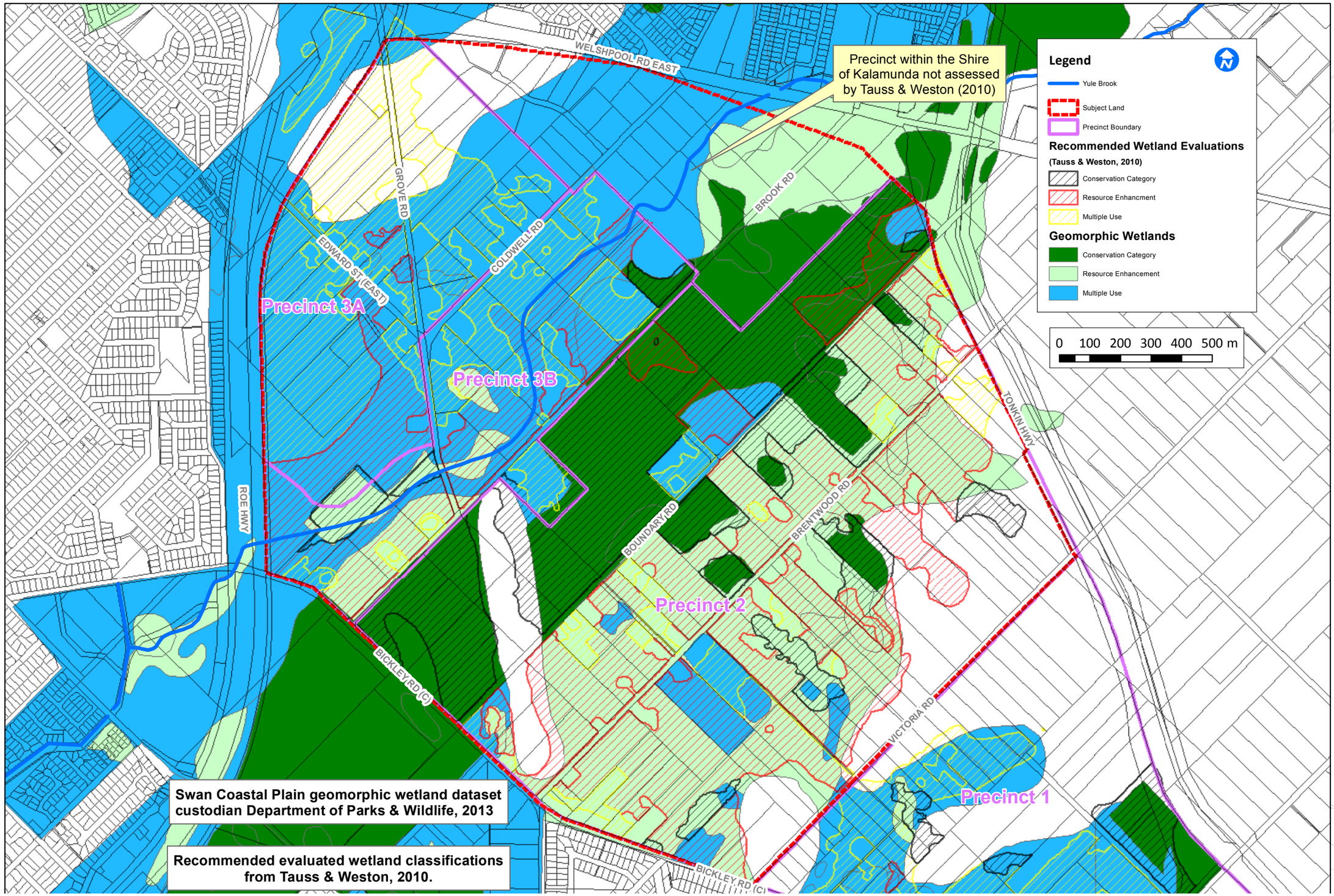


Figure 14- Overlay of Geomorphic Wetland Dataset with Recommended Classifications & Boundaries

(Tauss & Weston 2010)

WATERWAYS

Yule Brook flows through Precinct 3B from the north to the south-west. The brook is a tributary for the Canning River, however south of the Roe Highway (outside of the subject land) the brook is maintained as a Water Corporation main drain.

The brook originates from the Lesmurdie Falls National Park that is north-east of the subject land and there is the provision for limited ecological linkages along Yule Brook. Currently the vegetation along the brook is 'degraded' with a sparse native over-storey and a predominately weedy understorey. There is evidence of erosion and channeliastion (human intervention to channel the brook) along the waterway, a biophysical assessment of the brook will be required at the LWMS stage.

The other waterways and drains tend to be 'degraded' in nature with erosion present and limited ecological functioning, although there is still likely to be a limited range of fauna that use these waterways. The main flora along these systems is introduced grasses and pasture weeds.

FLORA

Tauss, C. and Weston, A.S. (2010) carried out flora, vegetation and wetlands field surveys from September 2007 to July 2009. The native flora of the remnant vegetation of the MKSEA was found to be very species-rich with 435 taxa (330 taxa of native vascular flora and 105 taxa of naturalised alien flora) recorded.

Three flora taxa of national conservation significance (listed under the EPBC Act) were found, and another taxon that is eligible for listing at national conservation significance but currently listed as Declared Rare Flora in Western Australia, was found. These species are: *Calytrix breviseta subspecies breviseta* (Myrtaceae)*; Conospermum undulatum* (Proteaceae)*; and Lepidosperma rostratum* (Cyperaceae).

Other flora species of interest surveyed were: *Eremophila glabra subspecies chlorella* (Myoporaceae); *Schoenus pennisetis* (Cyperaceae); *Lepyrodia curvescens* (Restionaceae); *Trichocline sp.* (Asteraceae); *Baeckea sp.* (Myrtaceae); *Cyathochaeta teretifolia* (Cyperaceae); *Calothamnus rupestris* (Myrtaceae); *Grevillea thelemanniana* (Proteaceae); and *Verticordia lindleyi subsp. lindleyi* (Myrtaceae).

Apart from above flora species, 97 flora taxa were considered as regionally significant. The regionally significant taxa that are in the MKSEA but not in Bush Forever Site (BFS) 387 or BFS 53 are: *Dielsia stenostachya; Eucalyptus decipiens* subsp. *decipiens*; *Eucalyptus gomphocephala; Gastrolobium ebracteolatum; Lepidosperma sp.; Leucopogon strictus; Schoenus subflavus subsp. subflavus; Schoenus unispiculatus; Tricoryne aff. elatior*; and *Trymalium odoratissimum subsp. odoratissimum.*

For further details the report *"The flora, vegetation and Wetlands of the Maddington- Kenwick Strategic Employment Area"* by Tauss, C.and Weston, A.S.(2010) has been included on the enclosed CD of Attachments.

VEGETATION UNITS

Twenty-eight vegetation units were described during the flora and vegetation survey and grouped in five major vegetation structure classification outline in *Table 1*. The majority of these are associated with wetland and waterway type habitats with the exception on the higher sand rises. Taus, C. and Weston, A.S. (2010) mapped the Threatened Ecological Communities (TECs) and high conservation value vegetation types which were provided in a confidential and not not for public reporting.

FAUNA

Cardno BSD in 2005 carried out an environmental review (Flora, Vegetation, Fauna and Wetlands) of the subject land. Findings of the study regarding fauna has been summarised below, and for details please refer to the report "Environmental Review-Flora, Vegetation, Fauna and Wetlands, MKSEA" (see enclosed CD of Attachments).

Only one fish species, the introduced Mosquito Fish, was recorded and nine frog species recorded or expected to occur, with the Granite Frog classified as "of regional or local significance". Thirty six reptile species may occur across the land with six of those classified as "of regional or local significance".

There are 120 bird species that may occur on the subject land, with 56 species recorded. 47 of the 120 species are waterbirds and would rely on the few permanent water bodies and seasonal inundated wetlands for habitat. The Australasian Bittern, Short-billed (Carnaby's) Black-Cockatoo, Long-billed (Baudin's) Black-Cockatoo, Peregrine Falcon, Great Egret, Rainbow Bee-eater, Sandpipers, Fork-tailed Swift are "protected under legislation" and the Little Bitten is "listed by state or federal government as of interest'". Numerous other bird species identified have been in decline on the Swan Coastal Plain and are grouped as "of regional or local significance.

The investigation for the presences of mammals yielded a 'poor' habitat and concluded that the majority of species were previously present are not anymore.

The native bees *Leioproctus douglasiellus* and *Neopasiphae simplicior* are listed under Schedule 1 of the *WA Wildlife Conservation Act* (1950) and another native bee *L. contrarius* is listed as Priority 3 by DPaW, and has been recorded at Forrestdale and Murdoch.

In 2012 a study of Black Cockatoo habitat in the MKSEA by 360 Environmental identified habitat areas that are subject to more detailed evaluation in future planning stages, and may be required to be set aside for conservation purposes. The further investigations are to occur at the ODP stage of planning. In many instances the remnant native vegetation identified by Tauss and Weston (2010), and reproduced in the City's Summary Constraints Mapping as "Area of Interest", coincides with the Black Cockatoo habitat identified by 360 Environmental (2012).

Weedy vegetation along Yule Brook

Brixton Street wetland vegetation

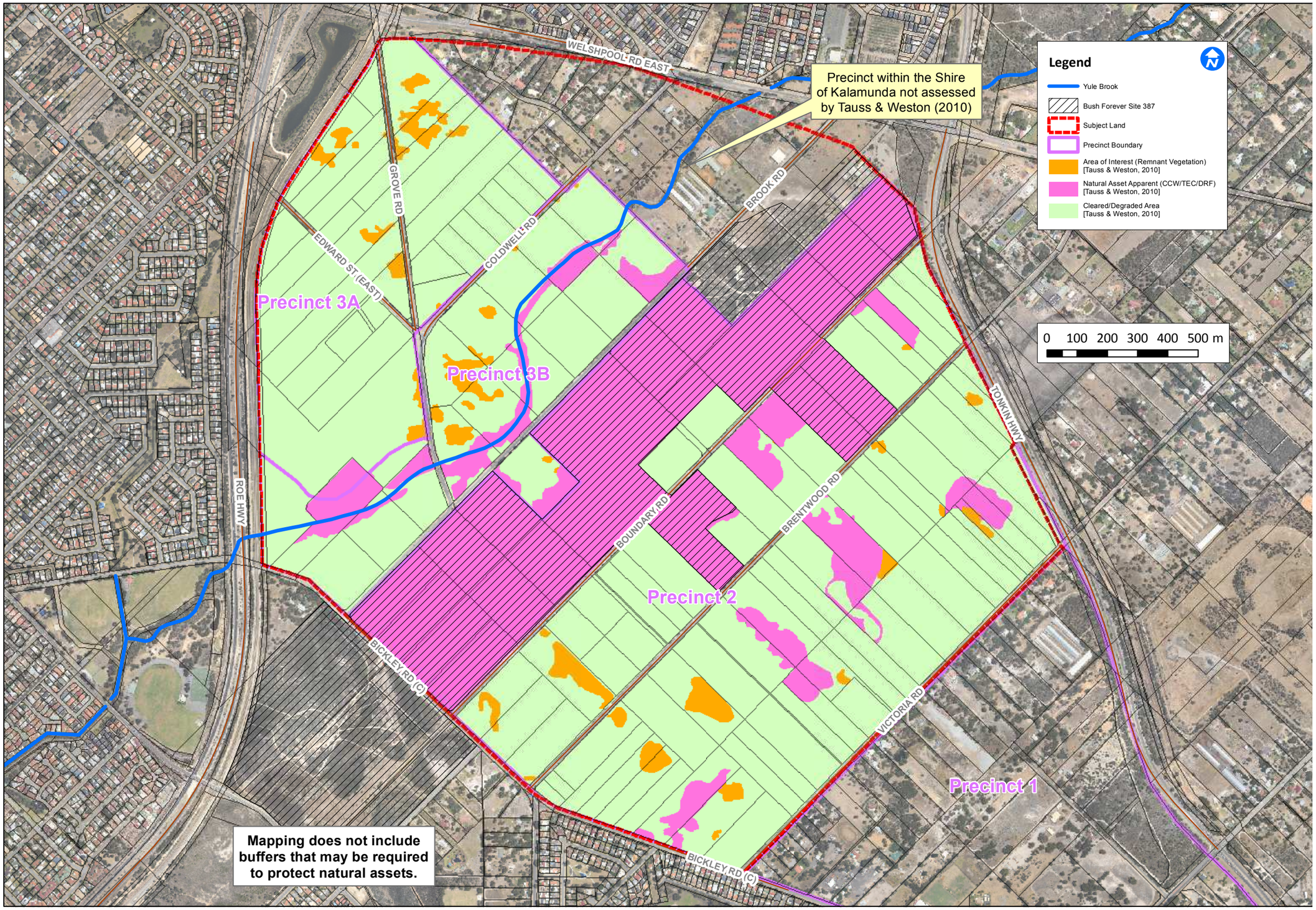


Figure 15 - City of Gosnells Constraints Summary Mapping

(Based on recommended wetland classifications and boundaries and Threatended Ecological Communities (Taus and Weston, 2010))

6. HERITAGE & CULTURAL SITES

There are eight Aboriginal sites mapped by the Department of Aboriginal Affairs (DAA) heritage register. The sites are shown in *Figure 16*.

1. Yule Brook Farm ('Stored Data' Site 122)
2. Yule Brook Farm 2 ('Lodged' Site 24785)
3. Boundary Road, Wattle Grove ('Registered' Site 3024)
4. Wattle Grove, Perth ('Insufficient Information' Site 3312)
5. Edward/Grove Street ('Insufficient Information' Site 4340)
6. Brentwood Road NW ('Insufficient Information' Site 4341)
7. Brentwood Road Quarry ('Registered' Site 4342)

ACHM in May, 2009 carried out an preliminary investigation for heritage sites within the MKSEA and reported that the most common Aboriginal site type are artefact scatters. These artefact scatters consist mainly of quartz artefacts, other materials such as chert, fossiliferous chert, dolerite and glass are not common.

The results of a previous ethnographic survey over a portion of Yule Brook have been extrapolated out to include Yule Brook on the subject land. The previous survey identified potential for the length of Yule Brook, as a tributary of the Canning and Swan Rivers, to be identified as an Aboriginal ethnographic site.

Investigations, at later stages of planning, will be required to be undertaken at future planning stages in accordance with DAA and Heritage Council to gain their approval for any for proposed designs and practices.

All contractors working on any future development of the site will be made aware of their responsibilities under the Aboriginal Heritage Act 1972 with regard to finding potential archaeological sites. In the event that a potential site is discovered, all work in the area will cease and DAA will be contacted.

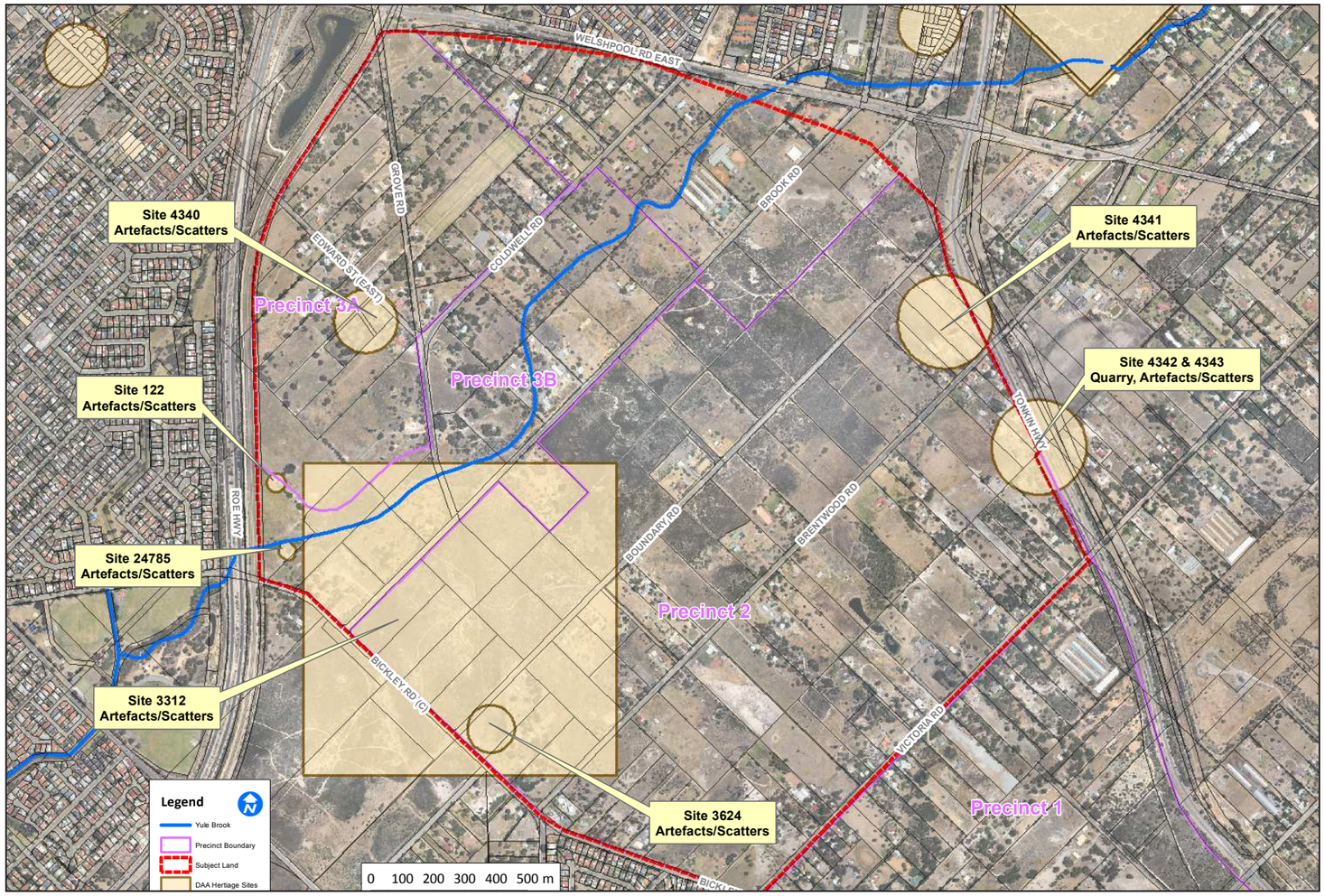


Figure 16 - Aboriginal Heritage Map

Source: DAA register

7. SURFACE WATER & DRAINAGE PRE-DEVELOPMENT

The main drainage system of the subject land is Yule Brook, which is a natural waterway that begins The main drainage system on the subject land is Yule Brook, which is a natural waterway that originates on the Darling Scarp. The brook enters the land in the north and flows in a south-westerly direction across the land. The brook is a direct tributary for the Canning River. There are also a number of other smaller drainage lines on the site. The drainage lines present on the subject land are shown in *Figure 17*.

In 2005 GHD undertook an assessment of the existing drainage on the subject land and commented the following:

- Surface runoff from the area west of Coldwell Road drains through an unlined open roadside drain that joins Yule Brook. There is also a natural drainage line for a short length in the west of Edward Street, this drainage channel is mainly formed by natural drainage line.
- Surface runoff from east of Yule Brook to Victoria Road predominantly drains via a network of unlined open drains that discharge into the Greater Brixton Street Wetlands, which direct water to Yule Brook.
- Discharges on the land north of Bickley Road, between Boundary Road and Victoria Road, currently are along an existing drain on Wanaping Road that eventually discharges to Binley Brook.

The District Water Management Strategy for Precinct 1 identified surface water linkage of Precinct 1 and Precinct 2 and noted that flow from a catchment area of 45ha flows towards Precinct 2 via a 375mm diameter culvert under Victoria Street. It also identified pre-development flows from Precinct 1 contributing to Precinct 2 are 0.91 m^3/s and 1.78 m^3/s for 1 in 10 year and 1 in 100 year rainfall events, respectively.

SURFACE RUN OFF ASSESSMENT

An indicative assessment of predevelopment flows and potential post development flows was modelled for the purpose of the District Water Management Strategy for Precinct 2 and 3. A detailed assessment with refined model assumptions and inputs will be required at the LWMS and UWMP stages.

PRE DEVELOPMENT RUNOFF RATES

Indicative pre-development design flows for the 1:10 year and1: 100 year ARI events for the Precinct 2 and 3 catchments were calculated for each sub-catchment using the Rational Method. LiDAR and site information was used to determine 14 sub catchments for the subject land, including 3 external catchments within the Shire of Kalamunda Precinct (see *Figure 17*). *Table 2* summarises the design flows from each sub-catchment, and *Figure 17* displays the drainage across the subject land. Assumptions in the pre-development scenario included:

- 0% imperviousness so that the allowable flow from sub catchments could be determined; and
- a roughness coefficient of 0.4 for pervious areas, based on land cover and high responsiveness of groundwater to rainfall.

YULE BROOK

TME undertook flood map modelling of Yule brook using the HEC-GEORAS and HECRAS steady state models (see *Figure 19*). The assumed flows were in line with the Engineering Review for MKSEA (GHD, 2005), at 16m^3/s for the 1:10 year ARI and 22m^3/s for the 1:100 year ARI events. LiDAR cross sections and Manning's roughness of 0.038 were assumed for models and will need to refine with site specific detailed studies for future planning stages. Further detailed investigations at the DWMS were considered unnecessary as the modelling provides sufficient confidence for broad scale planning, and that land use plans are only indicative currently. Therefore, detailed modelling at the DWMS stage would need refinement with any future planning alterations.

The Water Corporation had undertaken a review for the upgrade of the Yule Brook Main Drain Scheme in May 2008. Two options for the upgrade were proposed to the City of Gosnells, who endorsed the option to remove the existing Brookland Street culvert; construct an additional DN 1500mm pipe under the Perth-Armadale railway; raise the road level at the intersection of Sydenham Street and Railway Parade; and detain the existing flood plain between Roe Highway and Welshpool Road East. The review further advised for the retention of a 50m floodplain near Welshpool Road East, a 250m floodplain near Grove Road, and a 100m floodplain near Roe Highway. A recommendation for providing an extra s 100,000m^3 of storage for Precinct 2 and 20,000m^3 for Precinct 3.

The Water Corporation has also undertaken revised flood modelling of Yule Brook and provided 1 in 100 year flood levels based on a 50m and 100m floodplain, with a levee on both sides (shown in *Figure 19*). A 50m floodplain with a levee option, as suggested by the Water Corporation, is preferred because there is no significant flood level difference the 50 and 100m events, and less land requirements. To enhance the vegetated ('green') corridor and ecological linkage value along Yule Brook a minimum of 100m floodplain was recommended (see *Figure 18* for a concept cross section). This will create a minimum 50m foreshore reserve system on either side of the brook's floodway and buffer the floodway from any development. The models discount the recommendations, in their May 2008, regarding the requirements for a 50 to 250m floodplain and 120,000m^3 of storage.

As part of the LWMS, long sections of Yule Brook are to be developed. These will assist with the more detailed flood modelling.

Catchments	Area (ha.)	Pre Development	
		10 Years (cu.m/s)	100 Years (cu.m/s)
C01	59.36	0.68	1.43
C02	49.93	0.62	1.33
C03	45.3	0.53	1.13
C04	26.39	0.45	1.01
C05	26.33	0.43	0.82
C06	80.45	0.94	2.0
C07	15.43	0.25	0.84
C08	63.04	0.90	2.14
C09	16.96	0.53	1.07
C10	66.25	1.40	2.81
C11 (external)	21.22	0.48	1.06
C12 (external)	25.94	0.59	1.01
C13 (external)	19.83	0.31	0.7
C14 (external)	3.72	0.13	0.29

Table 1 - Pre-Development Runoff Rates

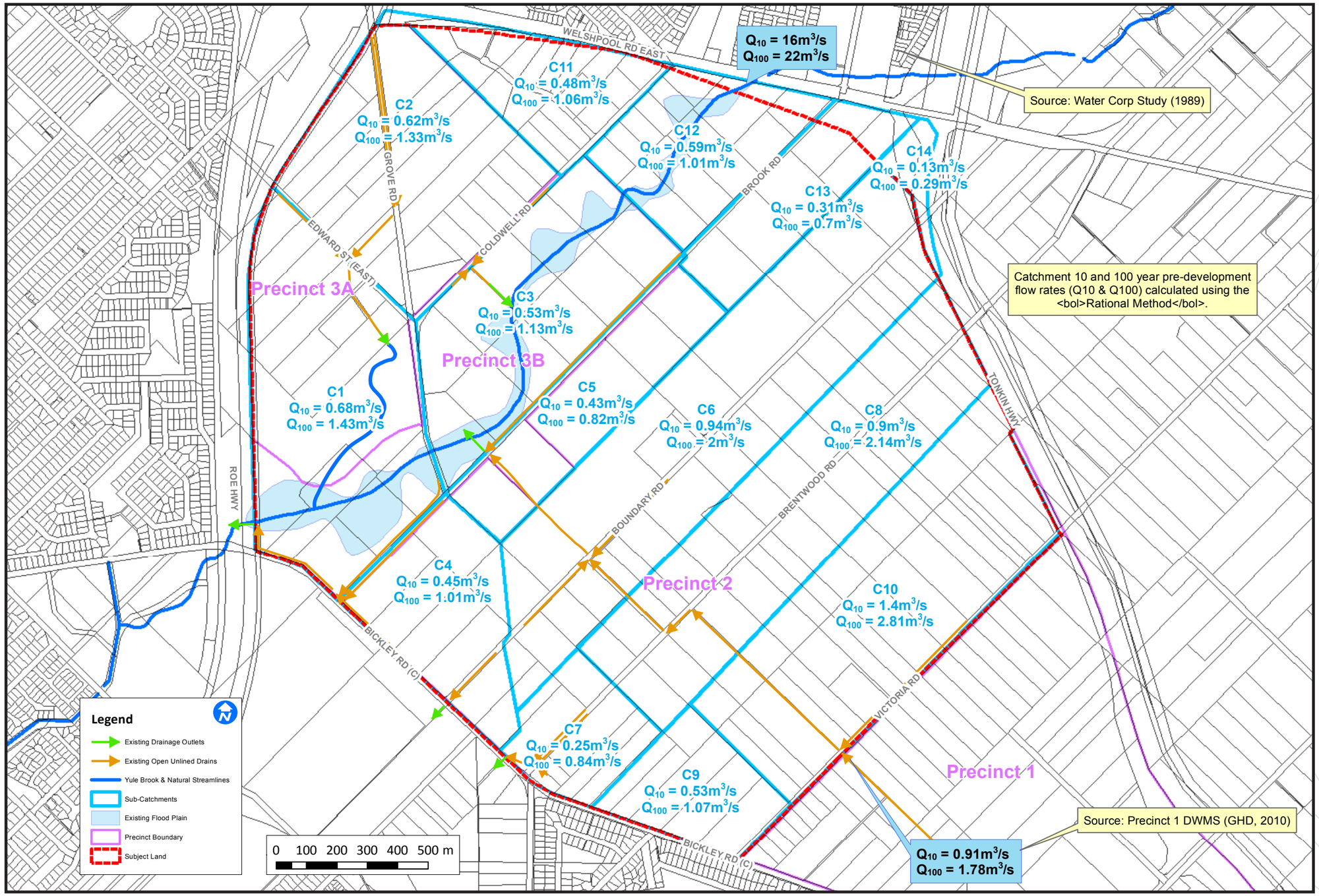
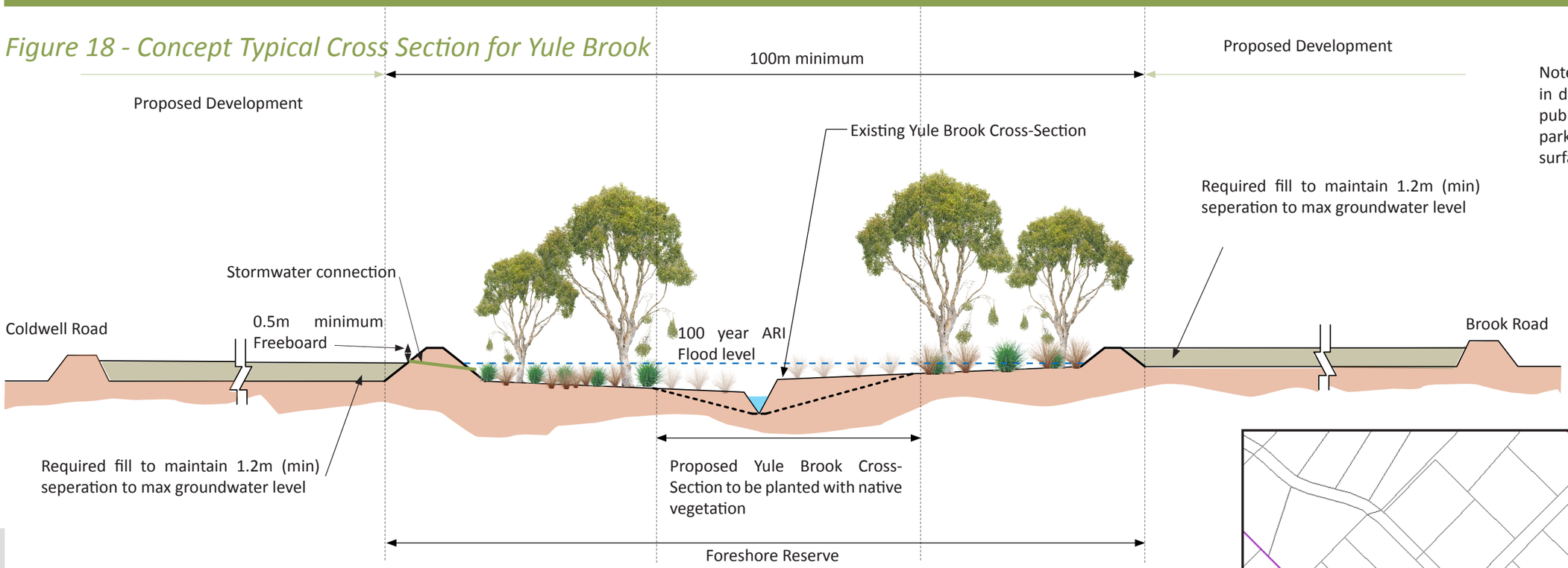
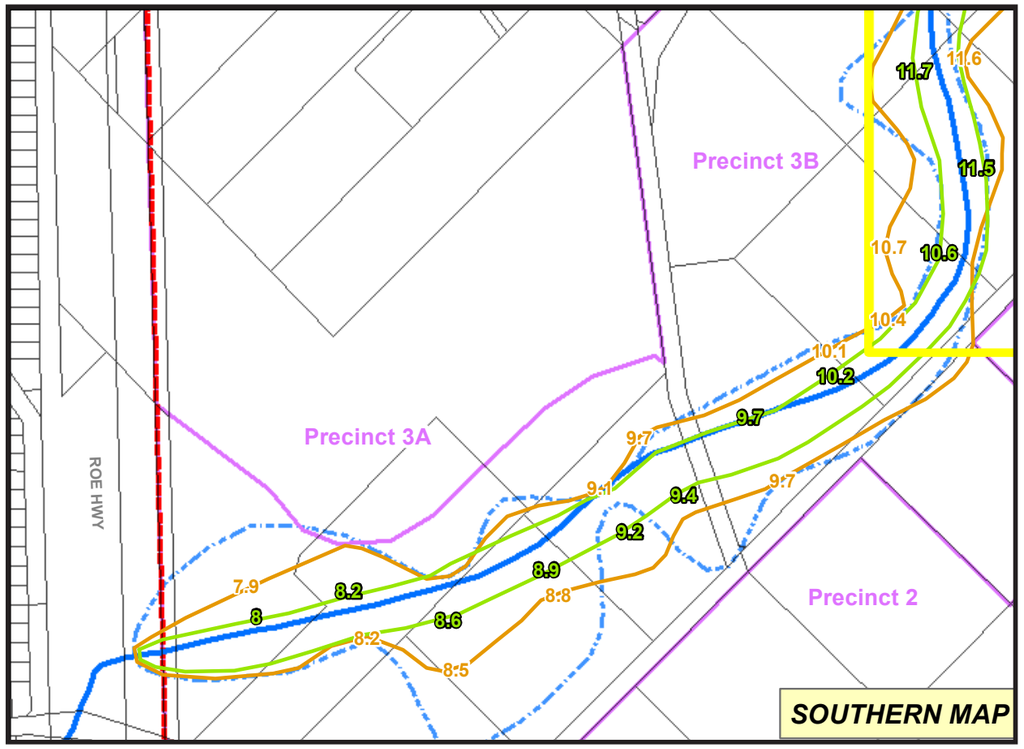


Figure 17 - Surface Water Pre-Development Surface Water Map

Figure 18 - Concept Typical Cross Section for Yule Brook



Note: Detail Design of Levee required in detail design phase incorporating public safety and utility of future parkland and necessary changes in surface levels of existing roads.



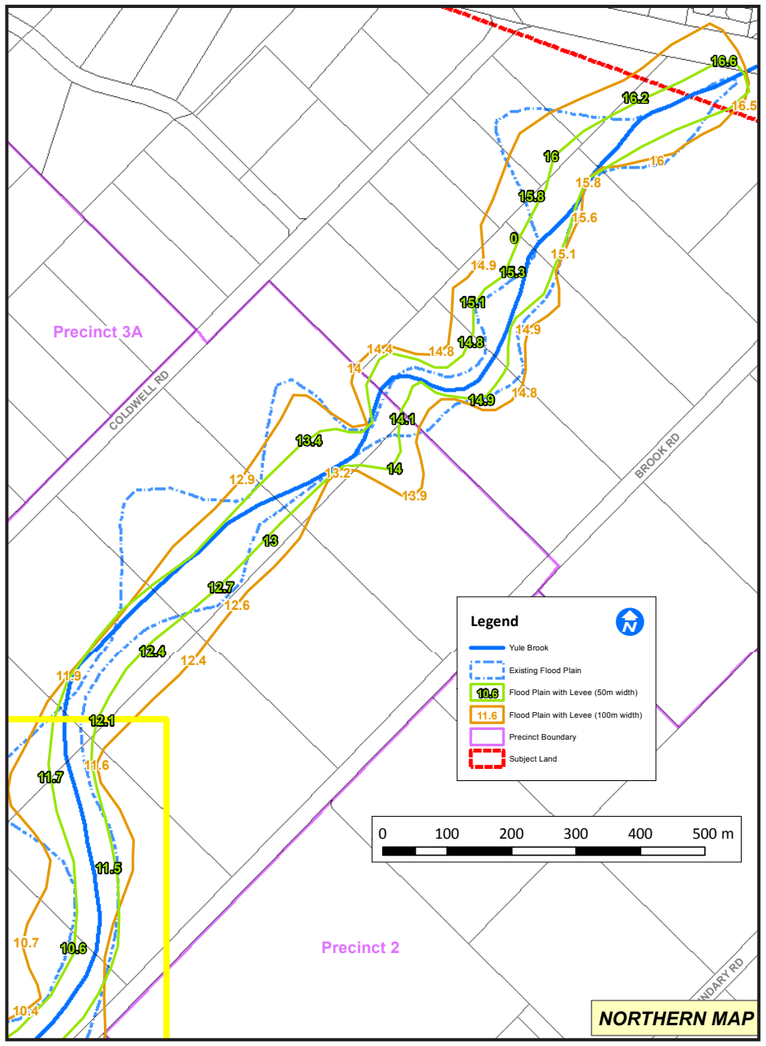


Figure 19- Yule Brook Floodplain Width Map

SURFACE WATER QUALITY

In 2012 Endemic Pty Ltd conducted a surface water monitoring program (sites shown in *Figure 20*) and reached the conclusion that elevated concentrations of Copper, Iron, Zinc and, on occasions, hydrocarbons were recorded in surface water flows, however the levels are considered typical for rural and road runoff. No adverse impacts associated with these elevated concentrations were observable with sensitive receptors located in the study area.

Importantly, the ANZECC water quality trigger values, for aquatic ecosystems, should not be applied to stormwater and urban drains, but instead the discharge levels into receiving water bodies, i.e. the Swan River Estuary.

The median Total Phosphorous (TP) and Total Nitrogen (TN) concentrations, 0.075mg/l and 0.75mg/l respectively, in the surface water samples were consistently above the *Swan-Canning* Water Quality Improvement Plan (SCWQIP) long-term targets for Yule Brook (DoW, 2009 and SRT, 2009). The average surface water TP concentrations increased from 0.046 to 0.203mg/l and the average Filterable Reactive Phosphorus (FRP) from 0.005 to 0.085mg/l between sites SW5 and SW3 (see *Figure 20* for location of sites). The FRP to TP ratio also increased from 1.4% to 36.5% between these sites, indicating that phosphorus, probably of anthropogenic origin, is entering the drainage network between these two sites. The existing aquaculture operation on 70 Brook Road, Kenwick may be one potential source of the observed elevated FRP concentrations.

The Swan River Trust/Department of Water's long-term monitoring stations on Yule Brook, to the south-west of the subject land (see *Figure 20* – no data for these sites though), consistently met the short term and regularly the long term SCWQIP targets between 1994 and 2006.

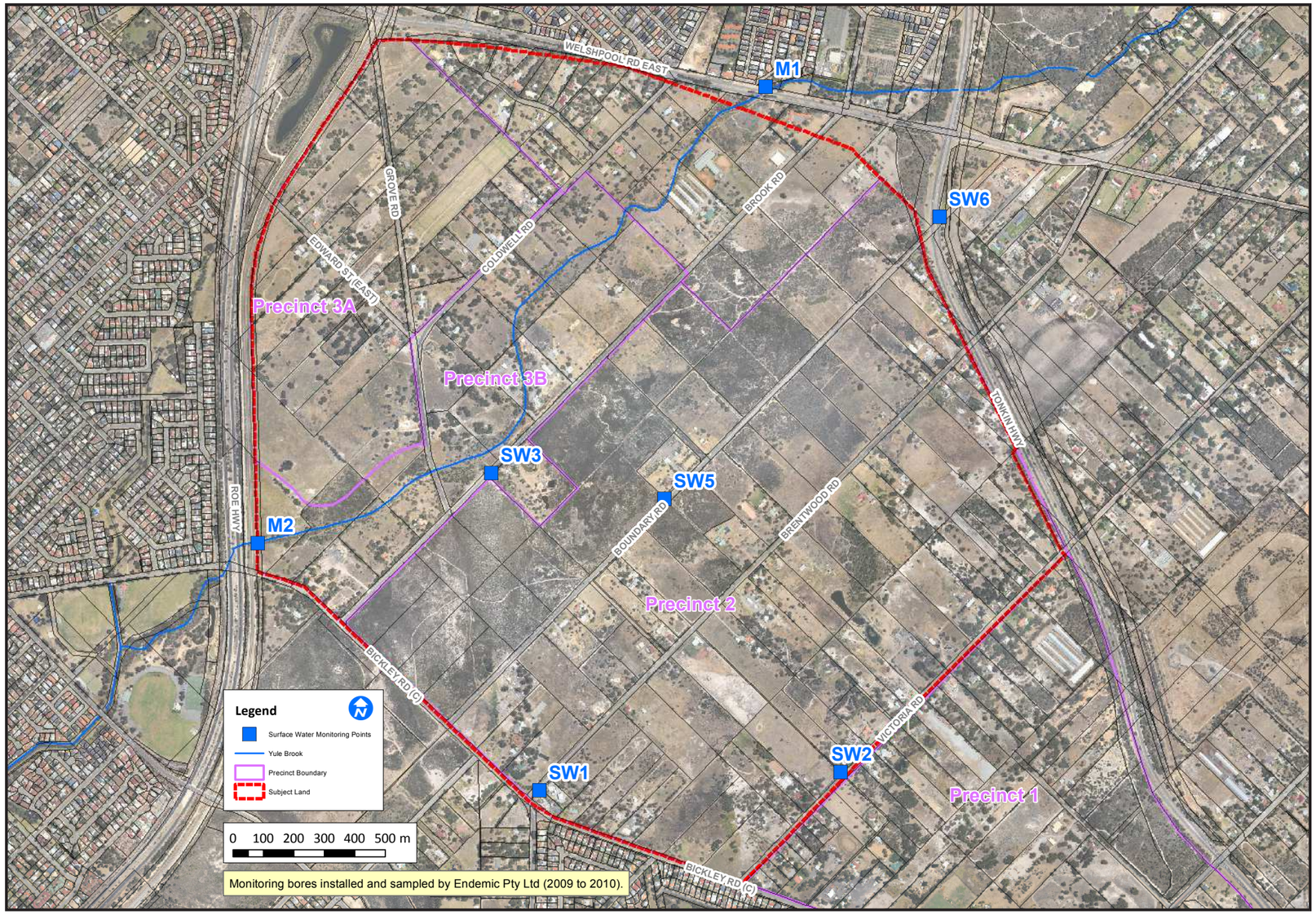


Figure 20 - Post development indicative water monitoring site plan

8. CONSTRAINTS, OPPORTUNITIES & SOULTIONS

The subject land and surrounds present a range of constraints, threats, opportunities and solutions to the proposed development in relation to water management. The two parts to *Table 3* provide a summary and how these can be managed to achieve best practice total water cycle principles and objectives.

Figure 21 identifies the water management related constraints and opportunities that require specific strategies and detailed consideration in future studies and water management strategies. *Figure 22* provides potential strategies to resolve the constraints, but they will require further investigations at detailed planning and water management stages. These figures reflect previous studies and investigations of the subject land, including City of Gosnells' flora, vegetation and wetland assessment of MKSEA by Tauss and Weston (2010).At this point in time, it is intended to maintain existing drainage situation along current alignments and inverts, as far as possible, so that there is minimal impact on the sensitive environmental attributes found within the subject land, as well as downstream.

It is the intention, at this broad level of planning, to maintain the existing drainage along their current alignments and inverts, as far as possible, so that there is minimal impact on the sensitive environmental attributes found within the subject land and downstream.

The following sections provide additional details and specific water management strategies for the subject land to guide future planning and water management.

Constraints/Threats	Opportunities and Management Options	
Aboriginal Heritage Site	A	Investigate sites with the Department of Indigenous Affairs to ensure development works satisfies Aboriginal Heritage Act 1972.
Wetlands (and associated buffers)	A	Creation of buffers around applicable wetlands.
	B	Preparation and implementation of a wetland management plan for appropriate wetlands, including advice on protection and rehabilitation management strategies.
	C	Enhancement of wetlands and their functional areas.
	D	Provide refuge for fauna between the large areas of native vegetation reserved on-site and to natural wildlife corridors by including in ecological linkages.
	E	Encourage planting of locally appropriate native plants in public and private areas to provide linkages between wetlands, reserved native vegetation and wildlife corridors.
	F	Use of Water Sensitive Urban Design (WSUD) techniques to treat and improve water quality that enters wetlands.
	G	Maintenance of existing flow rates via appropriately designed stormwater and groundwater management designs.
	H	No treatment within the wetland area with some flood storage within buffer area basins designed to mimic seasonal wetlands.
Waterways (and associated foreshore reserves)	A	Creation of foreshore reserves (buffers) around applicable waterways which are included within ecological linkages.
	B	Preparation and implementation of a ecological linkages management plan including advice on protection and maintenance management strategies.
	C	Enhancement of drainage lines so that they both transport the required volumes and flow rates while providing habitat for fauna through appropriate design.
	D	Encourage planting of locally appropriate native plants in public and private areas to provide linkages between swales and waterways.
	E	Use of WSUD to treat and improve water quality that enters waterways.
	F	Maintenance of existing water flow rates via appropriately designed stormwater and groundwater management designs.
	G	Potential construction of footpath (or interpretative trail) along and throughecological linkagesto improve recreational facilities and provide an educational resource for the greater community.
Flooding	A	No development allowed within the 1:100 floodway of the drainage system.
	B	Use of fill where necessary to achieve the required separation from appropriate flood levels.
	C	Utilise stormwater infrastructure to store and convey runoff during a flood event that protects both infrastructure and receiving water bodies. Post development release flow rates from the subject land will be designed to match pre-development flow rates and includes the existing pre development flood storage volumes.
Stormwater Flow Rate Runoff	A	Post development outflow rates to match pre-development rate.
	B	Use of Water Sensitive Urban Design (WSUD) to temporarily store and control the flow rates of stormwater runoff and discharges from the development both on private and public land.
	C	Drainage lines to be maintained as close as possible to existing inverts and locations, unless environmental investigations show changing them will be benifical.

Table 2 - Opportunities and Constraints Table (Part A)

Constraints/Threats		Opportunities and Management Options
Stormwater Nutrients, Contaminants and Pollutants	A	Use of water sensitive urban designs (e.g. bioretention units) to reduce total nutrient loads entering groundwater and leaving the subject land.
	B	Structural separation practices applied at a lot level to minimise pollution from industrial activities.
	C	Introduction of non-structural best management practice. Including provision of educational material to lot owners regarding responsible disposal and use of water from their business.
	D	Landscaping to utilise strategies that will not produce excessive fertiliser requirements and potential leaching of nutrients.
	E	Removal of potentially high nutrient loading agricultural practice currently on the land.
	F	Monitoring of water quality post development to improve treatment strategies, if required.
Groundwater Levels (including high peaks and dependent ecosystems)	A	Ensure development has no negative impact on groundwater resource, significant wetlands and waterways influenced by site.
	B	Use of suitable fill where necessary. Suitable fill should be stipulated in future geotechnical investigations, and should include appropriate permeability requirements and a provision for soil amendments to improve nutrient retention while having a permability which minimises mounding.
	C	Use of suitable fill, roadside swales and sub-soil drainage pipes where necessary to obtain adequate separation between controlled groundwater levels and infrastructure.
	D	Infiltration of stormwater wherever possible on both private and public lands.
	E	Monitoring of groundwater levels pre development to increase the accuracy of the site's AAMGL.
	F	Monitoring of groundwater levels post development to improve management strategies, if required.
Groundwater Quality	A	Use of WSUD (e.g. bioretention units) to reduce total nutrient loads entering groundwater.
	B	Treatment of sub-soil pipes that intercept groundwater with WSUD initiatives, including bioretention gardens, wetlands and other nutrient attenuation mechanisms to be discussed in more detail in the LWMS. Potentially this could improve the groundwater resource and dependent ecosystems (e.g. wetlands on-site) from their pre-development conditions.
	C	Landscaping to utilise strategies that will not produce excessive fertiliser requirements and potential leaching of nutrients.
	D	Removal of potentially high nutrient loading agricultural practice currently on the land.
	E	Monitoring of groundwater quality post development to improve treatment strategies, if required.
Acid Sulphate Soils (ASS) Risk	A	Undertake a preliminary ASS risk investigation of the site.
	B	Depending on preliminary ASS investigations a detailed ASS investigation and management plan may be required prior to any development (or ground breaking activities).
	C	Use of fill, WSUD and on-site effluent disposal should all minimise the disturbance to the existing soils and therefore minimise the risk of disturbing ASS.
Potentially Low Phosphorous Retention of Soils	A	Undertake a geotechnical investigation to determine PRI of soils across the site.
	B	Use of appropriate amended soils (and/or fill) to improve the phosphorous retention capabilities of the soils.
Wastewater Management	A	Development to be connected to an existing offsite wastewater collection system.
	B	Encourage greywater reuse schemes for businesses, where adequate treatment can be demonstrated. Designs to be undertaken in detail at a lot level to ensure system is appropriate for lot conditions, industry use and to be approved by the local government authority. Investigation into wastewater treatment and reuse schemes.
Potable Water Supply	A	Development to be connected to reticulated water supply.
	B	Encourage on-site capture of rainwater for supplement usage.
	C	Encourage of greywater reuse schemes for businesses.
Non Potable Water Supply	A	Investigation into wastewater treatment and reuse schemes.
	B	Investigations into superficial aquifer groundwater usage, which will also assist with controlling groundwater levels.
	C	Investigation into large scale groundater usage schemes from Leederville and other deeper aquifers.
	D	Investigation into roof runoff harvesting and reuse schemes at the lot scale.
	E	Develop recommendations for water use efficiency practices and targets for both businesses and irrigation of public areas.

Table 2 - Opportunities and Constraints Table (Part B)

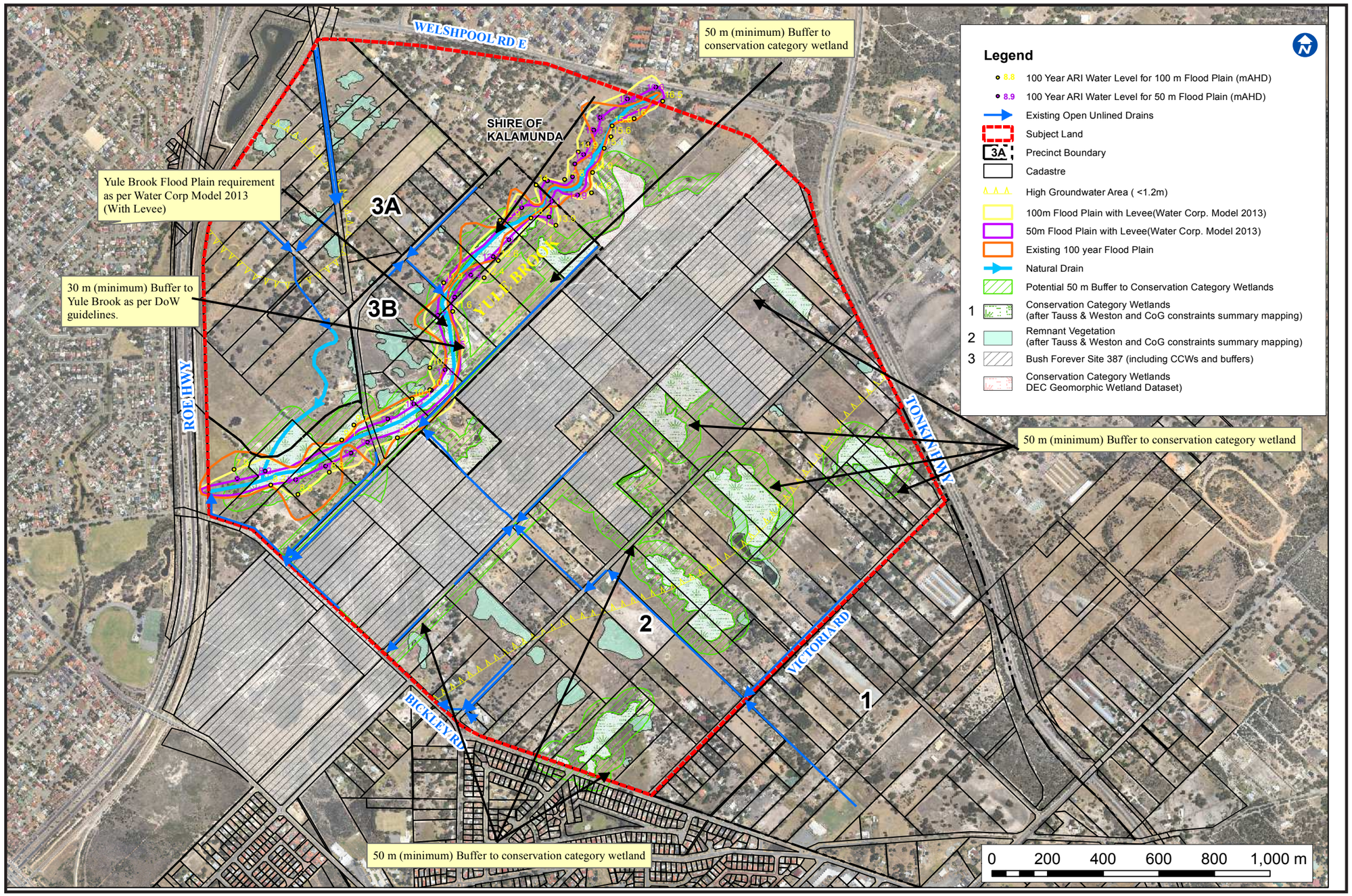


Figure 21 - Water Management Constraints Map

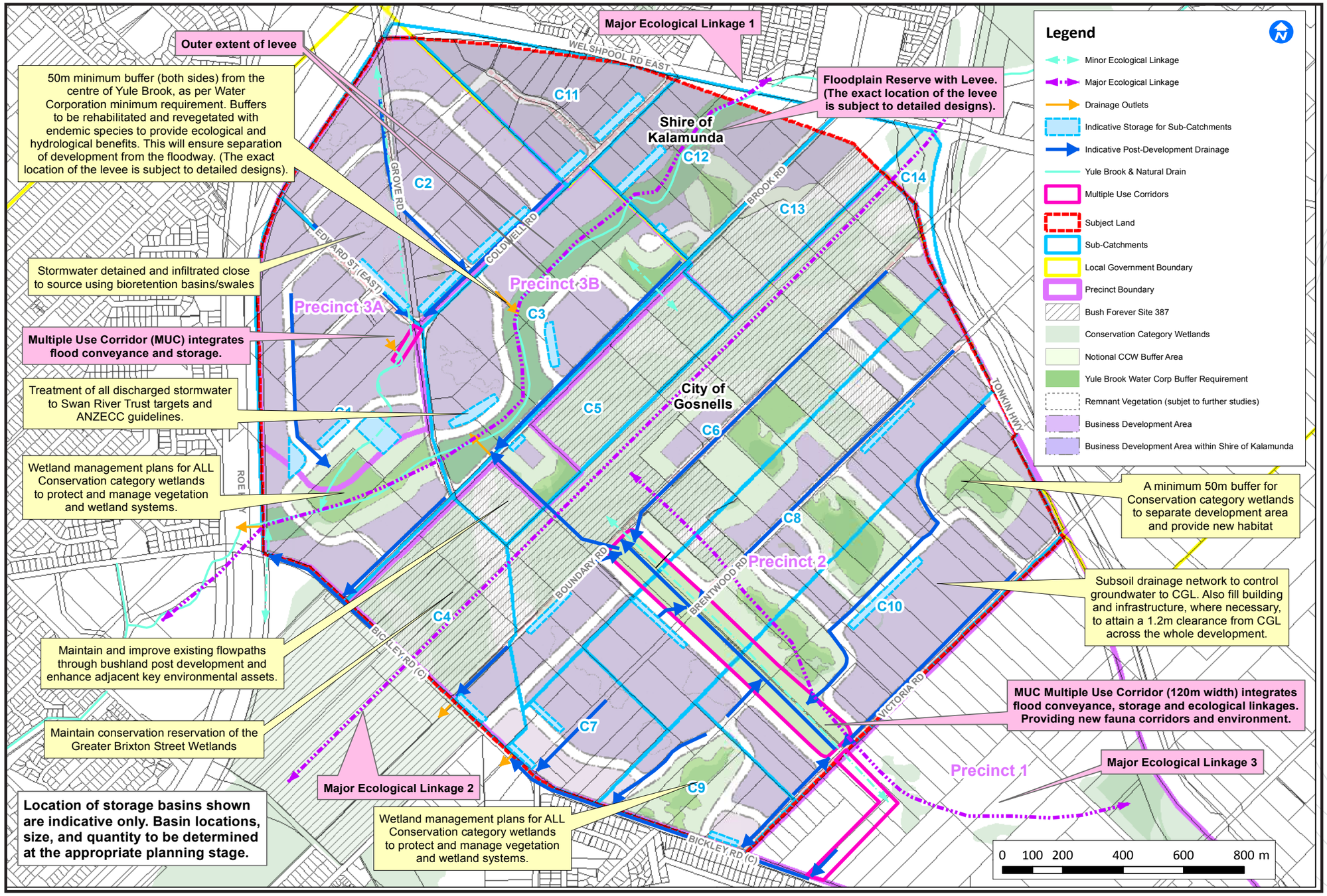


Figure 22 - Water Management Solutions and Opportunities Plan

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

9. DRAINAGE MANAGEMENT STRATEGY

The objectives of the stormwater drainage management for the development area are to mimic as close as possible the pre-development flows leaving the subject land and treating the necessary volumes before discharging the water to receiving water bodies. Stormwater discharged into the groundwater will similarly incorporate designs to mimic as close as possible the pre-development regimes and reduce nutrient and sediment loads entering the groundwater resource.

The primary objectives of the 1:1 year average recurrence interval (ARI) event drainage designs are to treat the stormwater and to protect the ecological functions of receiving natural environments. The priorities for storm events above the 1:1 year event are to control the flow of drainage water throughout the subdivision and release the water from the subdivision at pre-development rates, whilst not creating any negative impacts to surrounding or downstream infrastructure. To achieve this primarily temporary storage of runoff and controlled outlets will be utilised.

A preliminary engineering feasibility report (GHD, 2005) proposed that each property provide an onsite retention (OSR) system with a capacity to retain (for infiltration or reuse) runoff up to the 1:2 year ARI event. A estimated proportional volume of 340m^3 per hectare is required to achieve this retention. However, for efficiency and effectiveness it is proposed to treat the 1:1 year 1 hour flood event using on-lot bioretention swales and roadside bioretention swales. Furthermore, lots are to retain 1m^3 per 100m^2 of impervious area extra using rainwater tanks with air gaps, soak wells and/or other attenuation devices. The conveyance and storage of the 1:10 year ARI events will be via an integration of swales, pipes and storage units throughout the development, with allowable discharge rates set to the pre-development rates.

This initial report (GHD, 2005) utilised Rational Method calculations to estimate flow rates and required post development storages. This report is available on the enclosed CD of Attachments. The current DRAINS modelling undertaken for the DWMS on the subject land, is more detailed and accurate. The DWMS modelling predominantly calculated greater storage requirements.

Flooding up to and including the 1 in 100 year ARI events will utilise the 1:10 year's infrastructure, with excess runoff to be conveyed by swales and overland flow within road reserves and drainage easements. The protection of private property from inundation and detaining outflow rates into receiving water bodies are the primary objectives of these flood events. The ultimate discharge to Yule Brook will be maintained at the 1:100 year's pre development flow. Extra storage areas and basins at the sub-catchment level will achieve these targets. Multiple Use Corridors (MUCs) will also facilitate maintaining and conveying controlled discharges to Yule Brook.

Indicative locations of additional storage areas/basins are illustrated in *Figure 27*. Their ultimate location will be determined by a number of factors, key amongst which will be the requirement to comply with the decision process for stormwater management in WA (DoW, 2009) that provides all new constructed drainage infrastructure to be located outside of Conservation and Resource Enhancement wetlands and their associated buffers (minimum 50 metres). Where an existing road is proposed to provide a 'hard edge' in lieu of a buffer and new drainage infrastructure is proposed within 50 metres of a CCW or REW (i.e. on the opposite side of the road) and cannot be relocated, the developer will be required to undertake a site specific study to demonstrate that the drainage infrastructure will not negatively impact the wetland.

Conceptual modelling with DRAINS has been undertaken as part of the DWMS to estimate required sub-catchment volumes (listed in Table 4). The volumes for bioretention basins to retain the 1:1 year 1hour stormwater event with no outlet are also included in the table. Additional on-lot retention volume was estimated at 1m3 per 100m2 of impervious area. Extra sub catchment storage requirements to maintain outflows from each in the 1:10 year and 1:100 year to pre development rates were also calculated. To maintain 1:100 year pre development flows, storage requirement with this criteria were adopted. The storage volume requirements will need refinement at the detailed design stage after actual impervious areas are also defined.

It is anticipated that Yule Brook will be jointly managed by the Water Corporation and the City of Gosnells, as is the case with existing watercourses that serve drainage functions. The drainage functions will be the responsibility of the Water Corporation, whereas the management of environmental aspects of the waterway and its buffer will most likely be managed by the City of Gosnells.

The Water Corporation provided comment that the surface runoff into the Yule Brook main drain needs to be limited to pre-development flows for all average recurrence intervals. At the LWMS and UWMP stages plans are required that demonstrate the post development catchment boundaries, runoff coefficients, the location and depth-area relationship of compensating basins. These plans are to be provided to the Corporation so that a post development InfoWorks model can be designed to verify the flows and water levels in the Yule Brook main drain will not be increased by the development.

The Water Corporation requires the preparation of an acceptable drainage submission for any proposed modifications to the cross section of Yule Brook in accordance with their Design Standard No. 66 Urban Drainage Standard (see enclosed CD of Attachments), these submissions should be made at the Outline Development Plan/LWMS stage. The Water Corporation has also provided comment that pre-development and post development groundwater flows and levels need to modelled to demonstrate effects on the Yule Brook main drain. The modeller will need to meet with Water Corporation to discuss in detail the proposed model methodology and gain their acceptance prior to commencement of work.

The following three sections discuss and provide further details on how water is to be treated, conveyed, stored and discharged in three different ARI scenarios. Also catchment boundaries, discharge points and volumes of flow rates are depicted within the respective sections plans.

A – 1 in 1 year 1 hour event

B – 1 in 10 year flood event

C – 1 in 100 year flood event

Detailed drainage designs, models and drawings will be required at the structure plan and subdivisional stages, to accompany the Local Water Management Strategy (LWMS) and Urban Water Management Plan (UWMP) respectively. It is expected that this more detailed drainage planning will be informed by parallel detailed environmental assessments of wetland management classifications and boundaries, and the finalisation of these aspects through the conclusion of a wetland reclassification request to DPaW.

Name	Area (ha)			Pre-Development Flow (m^3/s)		Post Development Flow (m^3/s)		Storage Requirements (m^3) (See notes 1 -3)			Total Storage requirement (m^3) (See note 4)	Extra on lot retention by rainwater tanks, parking areas etc.	Total on lot retention including bioretention basin	Extra storage at sub catchment level
	Total	Pervious	Impervious	1:10 yr	1:100 yr	1:10 yr	1:100 yr	1 :1 Yr 1 Hr	1:10 Yr	1:100 Yr	1:100 Yr	$1m^3$ per $100m^2$ impervious area	m^3	m^3
C01	59.36	10.79	48.56	0.68	1.43	4.50	10.21	5282	17296	27336	32618	4856	10138	22480
C02	49.93	0.00	49.93	0.62	1.33	5.50	12.84	5560	16198	25977	31537	4993	10553	20984
C03	45.30	15.49	29.81	0.53	1.13	2.82	6.49	3319	9655	16871	20190	2981	6300	13890
C04	26.39	20.28	6.11	0.45	1.01	1.80	4.04	681	2309	4182	4863	611	1292	3571
C05	26.33	23.62	2.71	0.43	0.82	0.58	1.31	302	1035	2954	3256	271	572	2683
C06	80.45	59.15	21.30	0.94	2.00	1.38	2.99	2371	6576	15149	17520	2130	4501	13019
C07	15.43	0.00	15.43	0.25	0.84	1.81	4.08	1718	4279	5084	6802	1543	3261	3541
C08	63.04	24.37	38.67	0.90	2.14	3.89	8.58	4306	13925	21678	25984	3867	8172	17811
C09	16.96	6.69	10.27	0.53	1.07	1.40	3.14	1144	1583	3833	4977	1027	2171	2806
C10	66.25	21.64	44.61	1.40	2.81	4.89	10.88	4967	13895	19101	24068	4461	9428	14640
C11*	21.22	2.4	18.82	0.48	1.06	2.16	5.18	2100	5276	7319	9419	1882	3982	5437
C12*	25.94	11.93	14.01	0.59	1.01	2.55	5.96	1560	4336	7826	9386	1401	2961	6425
C13*	19.83	15.91	3.92	0.31	0.70	0.71	1.58	450	589	1275	1725	392	842	883
C14*	3.72	3.72	0.00	0.13	0.29	0.13	0.29	No Storage Requirements						
Total	520.15	215.98	304.16	8.23	17.63	34.11	77.58	33758	96952	158585	192343	30416	64174	128169

Notes:

1. *1:1 yr 1 hr storage requirement is based on the development area only with no outlets.*
2. *1:10 yr storage requirements based on the total sub catchment area with pre-development allowable out flows.*
3. *1:100 yr storage requirement is estimated based on total sub catchment area with 1 in 100 years pre-development allowable flows.*
4. *Total storage requirements for the 1:100 year is intended to discharge at 1 in 100 year predevelopment flows from the developed subcatchments.*

* *It is assumed that only pre-development flows discharge to the subject land from sub-catchments 11, 12, 13 & 14 and precinct 1, and the rest is retained within the sub-catchments.*

Table 3- Storage area requirements

9A. DRAINAGE MANAGEMENT STRATEGY – 1 YEAR 1 HOUR EVENT

The drainage management system for the development will be designed to capture and provide treatment for the 1 year 1 hour event, which effectively captures approximately 95% of all stormwater flow. The designs will also provide protection of the ecological functions for all receiving natural environments post development. It is proposed to treat 1 in 1 years 1 hour storm water within bioretention basins to improve storm water quality. Storage requirements for the 1 in 1 year 1 hour are presented in *Table 4*, which will need to be refined for future planning stages.

Surface water on the land will take two main directions; infiltration to the groundwater and surface run off. Two separate treatment trains have been designed and specified to treat and manage the two different flow paths.

INFILTRATION TO GROUNDWATER

The majority of the water that falls on pervious surfaces in the development area will infiltrate through to the shallow groundwater because of the high hydraulic conductivity of the imported fill's free draining nature that will be laid across the majority of the developable area. This will include any overflow from installed rainwater tanks, on-site bioretention systems, swale bases and property soak wells. Any fill used will need to ensure that the fines content of the fill is restricted to less than 5% to promote drainage across the site. Appropriate soil amelioration products should be investigated in the future where any water infiltrates through gardens and in public spaces where fertilisers would be applied.

Piped subsoil drains will intercept and convey ground water flows to the drainage system and ensure levels across the site do not rise above the designated controlled groundwater level (CGL) for the site. The CGL will be set at the average annual maximum groundwater level (AAMGL), unless further studies demonstrate alternative level satisfies infrastructure and environmental considerations. This includes the City of Gosnells' requirement for a minimum separation of 0.5m from the CGL to physical infrastructure, residential footings and to the invert level of the stormwater management measures. This means that if soak wells are installed to a depth of 1.2m there is a requirement for finished levels to achieve a separation of 1.7m from the CGL, or other approved critical groundwater level. The subsoil pipes also ensure the required vertical clearances to the lots are maintained.

Rainwater tanks, with air gaps, will also be encouraged for each lot and business throughout the development. The tanks would assist in reducing the peak runoff flows from the lots, providing some of their on-site storage requirements especially during summer storm events. Overflow from these is to be directed to infiltration areas and soak wells. The base of any soak wells and infiltration areas needs to maintain a 500mm clearance from the CGL in accordance with City of Gosnells' requirements. Water that enters the soak wells infiltrates into the soil profile and ultimately the groundwater. There is to be no direct link between roof runoff and the street drainage network.

SURFACE FLOW

Runoff within the development will occur within the lots and within the road reserves. Each lot will be responsible for capturing, detaining and treating all lot runoff for the 1 year 1 hour event on-site through bioretention basins. Furthermore, 1m3 storage per 100m2 impervious area will be provided as on lot retention. The runoff could be detained by a variety of methods and combinations, including shallow landscaped bioretention basins, rainwater tanks, carpark storage and soak wells.

The road reserve runoff in the 1 year 1 hour event will also be captured, detained and treated in roadside bioretention gardens and swales. The bioretention gardens and swales should be protected from traffic, where appropriate. They should also be located so not to obstruct lot access (see *Figure 23* for a typical arrangement). The water entering the bioretention systems will pass through an amended soil layer to reduce the quantity of sediments and nutrients entering the groundwater. The gardens should be constructed according to the latest FAWB Adoption Guidelines for Filter Media in Biofiltration Systems and the *Stormwater Management Manual for WA design guidelines* (an indicative cross section is shown in . These guidelines assist the units with remaining functional and assisting with the removal of nutrients, sediments and other potential contaminants from an industrial subdivisions runoff The three graphs in *Figure 25* are sourced from the *Stormwater Management Manual for WA* (DoW, 2008) and demonstrate the effectiveness of bioretention systems in removing nutrients from stormwater when built to the aforementioned guidelines. Indicative bioretention basin volume requirements, provided in *Table 4*, were derived from conceptual modelling using the DRAINS software package.

Bioretention gardens may require irrigation during the initial 2 to 3 years to assist with the establishment of plants. Irrigation and fertiliser applications should be met by storm water runoff after this period, although subsequent watering may still be required in drier years.

Overflow from the bioretention gardens should flow into roadside swales then onto sub-catchment level storage, which direct excess flows to the Multiple Use Corridors (MUCs). Flow channels within the MUCs are to be planted and will act as 'Living Streams' that provide further treatment of the surface water.

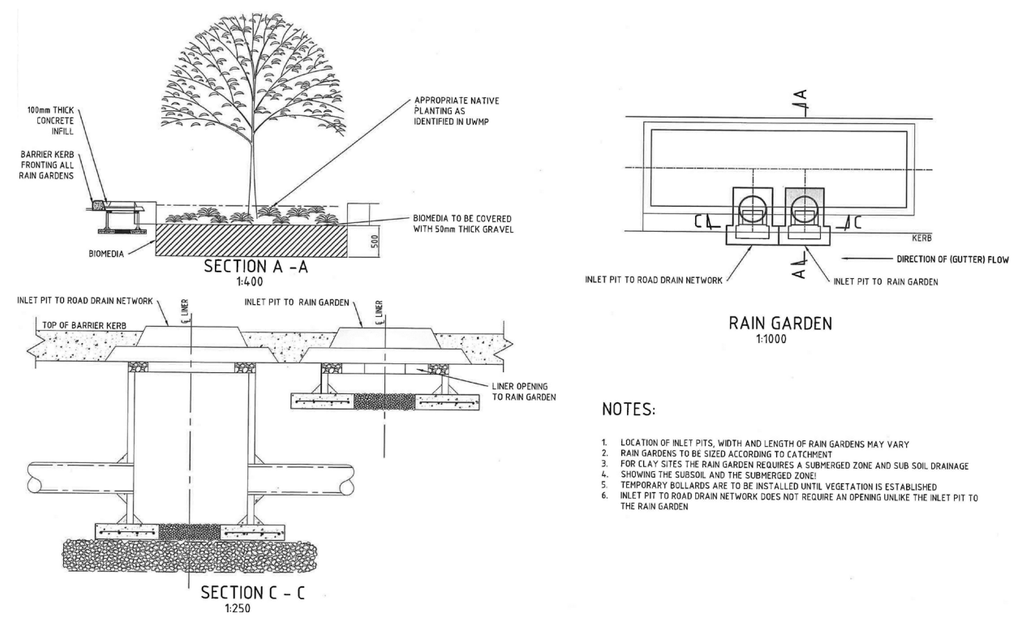


Figure 23 -Typical Bioretention (Rain Garden) Arrangements

Source: City of Gosnells (standard drawings)

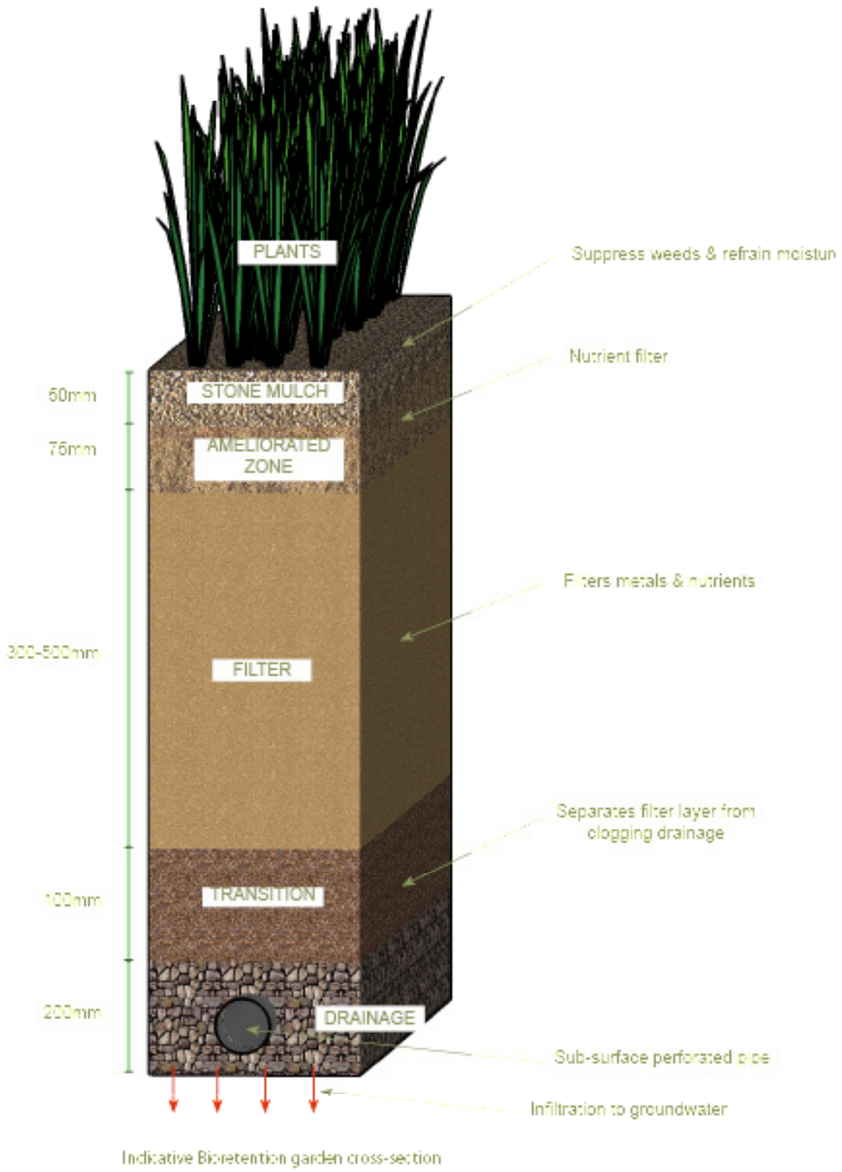
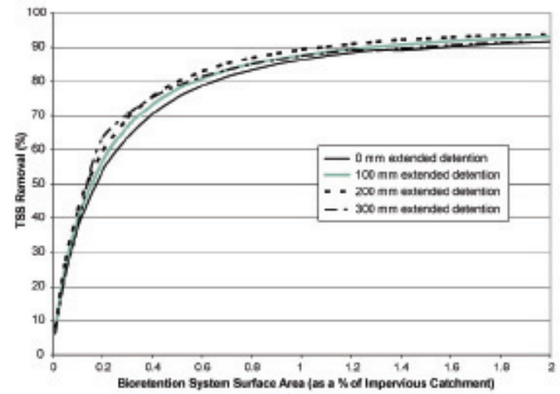
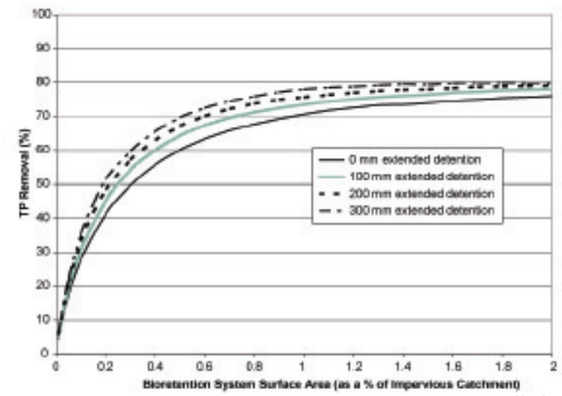


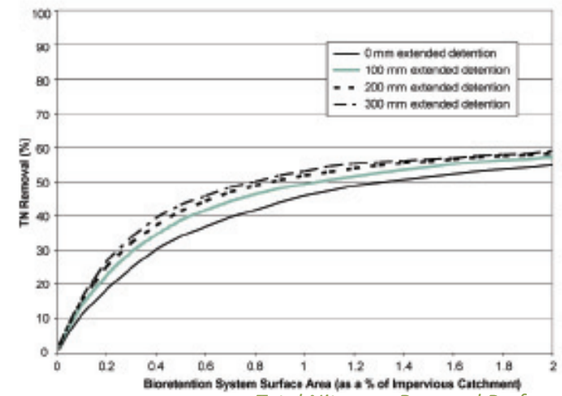
Figure 24 - Indicative Biorentention Garden Cross-Section



Total Suspended Solids Removal Perfomance



Total Phosphorous Removal Perfomance



Total Nitrogen Removal Perfomance

Figure 25 - Bio garden Performance Graphs

Source: Stormwater Management Manual, DoW 2007

9B DRAINAGE MANAGEMENT STRATEGY – 1:10 FLOOD EVENT

The drainage management system for the subject land for greater than 1:1 years events is to be designed to manage the 1:10 year ARI events utilising pipe, swale and detention basin systems, with controlled outlets. The objective of the drainage systems in 1:10 year events is to convey excess water off the roads and lots, and transport the excess water to drainage infrastructure designed to either convey and/or infiltrate the runoff. The drainage system should be designed to slow the rate of water flow, allow for partial infiltration of water on-site, and control discharged water out of the development at pre-development rates to Yule Brook or, where relevant, significant wetlands.

For management of the minor drainage system two concepts are to be considered:

1. Roadside vegetated/bioretention swales that require an approximate road reserve width of 30m (concept shown in *Figure 26*), with many existing roads too narrow, and therefore require a costly widening program. Any road reserve expansions should be evaluated and designed to minimise impacts on wetland conservation values. There are some locations where existing roads bisect Conservation and Resource Enhancement wetlands, and expansion in either direction will have potentially negative impacts; or

2. Piped drainage systems for up to and including the 1:10 year ARI events along the main roads and proposed roads within the development (indicative layout shown in Figure 27). The indicative layout maintains existing drainage alignments, where possible, to minimise impacts on wetlands and to assist with non-sequential development stages.

GHD, 2005 has recommended three multiple use corridors (MUCs) within the subject land to facilitate: drainage management; water quality; flood conveyance; wild life habitat and corridors; pedestrian and cycle paths; and, open spaces. A MUC 120m wide is proposed between Victoria Road and Boundary Road (see *Figure 27*), so that a continuous ephemeral living stream is created to facilitate drainage management in both quantity and quality. This will also enhance the aesthetics of the area and will be an important asset for the community. The location of MUCs 2 and 3 as proposed by GHD have been shifted north-east and are now adjacent to conservation areas, which enables optimal use and maintenance.

The piped and open road drainage system from each sub catchment will discharge into a length of open channel within a MUC, and will function as an ephemeral living stream. The ephemeral living streams are to be constructed above the groundwater table, and will provide water quality treatment of flows from the road drainage network. There will only be flows after significant rainfall events. The MUCs also provide additional storage and conveyance for flows greater than 1:10 year and up to the 1:100 year events.

Stormwater that infiltrates to the groundwater during a 1:10 year event will have minimal effect on the flood peak. However, later expressions through seepage into the perforated sub-soil pipe system may occur. If expressions do occur, they may extend the period of time that water will continue to move through the sub-soil pipe network, although at a much reduced rate.

It is not an objective of managing 1:10 year flood events to treat runoff for quality, but the bioretention units and conveyance would allow for trapping and settling of suspended sediments, especially after the flood peak has passed. This is due to the slowing of water near the surfaces of the swales from the in-stream and bank vegetation, and the residence time.

Additional storage required to maintain the 1:10 year pre-development flows has been calculated and documented in *Table 4*. This is additional storage after providing the 1 in 1 year 1 hour storage via bioretention basins and on-lot retention. The additional storage can be provided at the sub catchment level and on individual lots. Detailed site specific modelling at later planning stages is required to refine the sub-catchments, storage volumes and levels.

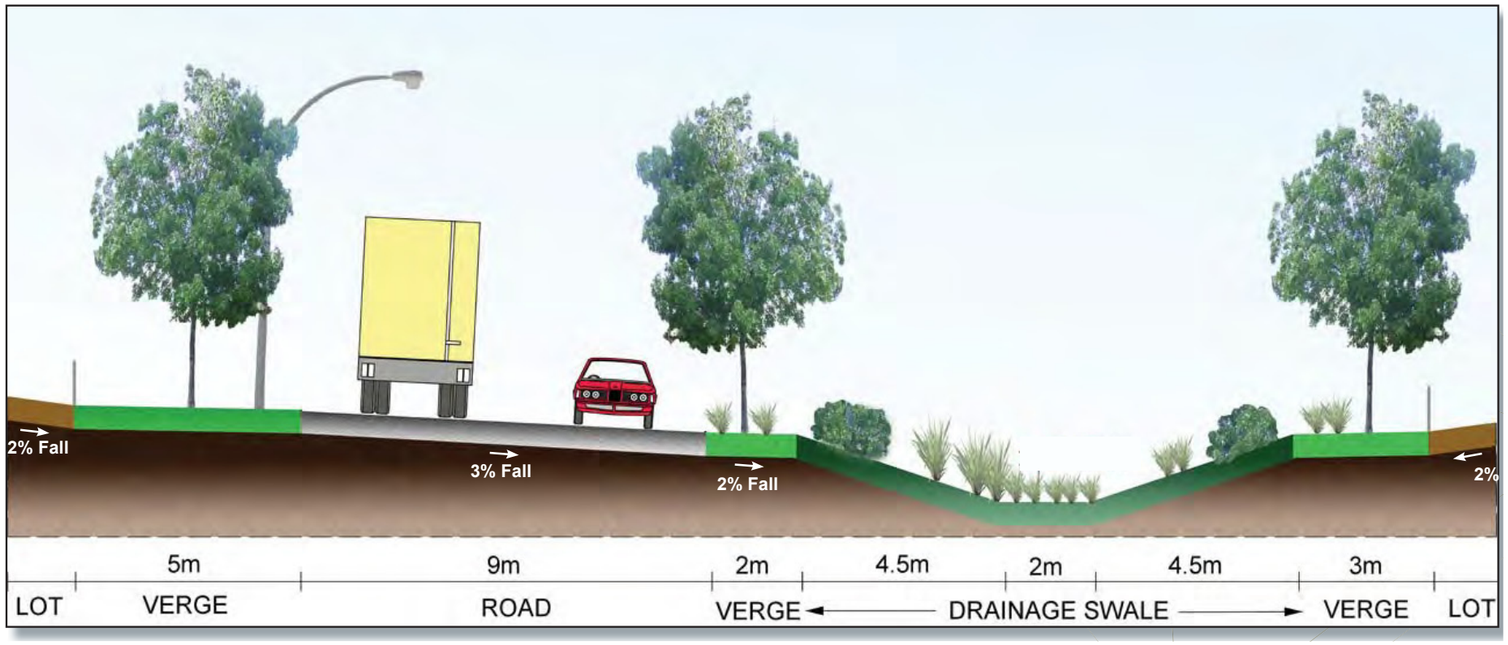


Figure 26 -Concept Cross-Section for a Road and Swale Arrangement on Major Drainage Lines

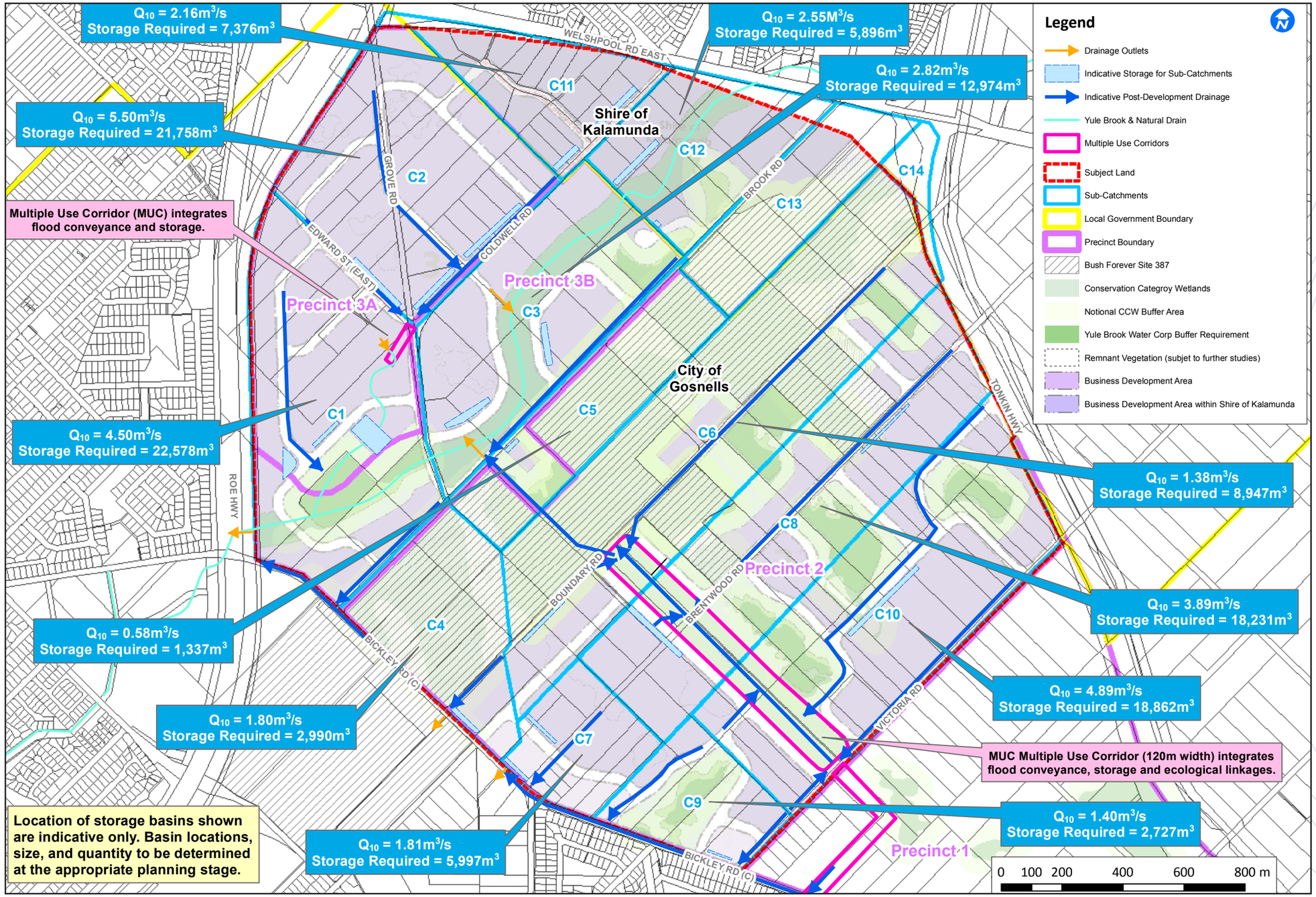


Figure 27 - Post Development Management Plan 1:10 year Drainage

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

9C DRAINAGE MANAGEMENT STRATEGY – 1:100 FLOOD EVENT

The development is designed to safely convey the 1:100 year ARI flood event to minimise impacts on infrastructure, the environment and people's safety. All future road and lots level designs need to maintain a minimum 300mm separation clearance between buildings and the internal 1:100 ARI flood levels.

The 1:100 year flood event's runoff would predominantly be conveyed via the road reserves and the drainage swale network. The drainage network within the development area would flow at capacity with excess water flooding the adjoining road reserves. Some roads would be expected to partially flood however they should remain serviceable for emergency vehicles.

During a 1:100 year flood event most of the road surfaces would need to convey flood waters, with excess water spilling over into the swale system as a sheet flow. The swales would flow at capacity with extra water flooding into the adjoining road reserves and public areas. The underground pipe system would be collecting water from the road and conveying it at capacity to the swale systems. The swales would transport water to dispersing basins. Within the basins the water would fill to capacity and then sheet flow towards Yule Brook.

Three multiple use corridors (MUCs) proposed in major sub catchments will also accommodate and convey 1:100 year flow events. It is proposed that the MUCs are designed to accommodate the 1:10 year ARI flood below the spillway and the extra 1:100 year ARI flood waters above the spillway, with the reserve areas either side of the main channel acting similar to the floodplain of a river. With these principles the sub-catchment storage basins and MUCs will achieve in controlling outflows from the development to pre-development flow rates (see *Figure 28).*

The Water Corporation has undertaken flood modelling of Yule Brook that included the provision of 1: 100 year flood levels with a 50m and 100m flood plain levee (see *Figure 19* for detailed maps). The modelling concluded that there is no significant difference in flood levels between the 50m and 100m floodplain levees. A 100m flood plain including a levee is proposed for the development, to maintain the foreshore's ecological corridor. A minimum 500mm separation clearance will be required between building levels and the Yule Brook 1:100 year flood levels.

As part of the LWMS, long sections of Yule Brook are to be developed. These will assist with the more detailed flood modelling. This detailled modelling will set levee sizes and flood levels adjacent to Yule Brook.

Bio swale example - Perth Airport

Bio swale example - Perth Airport

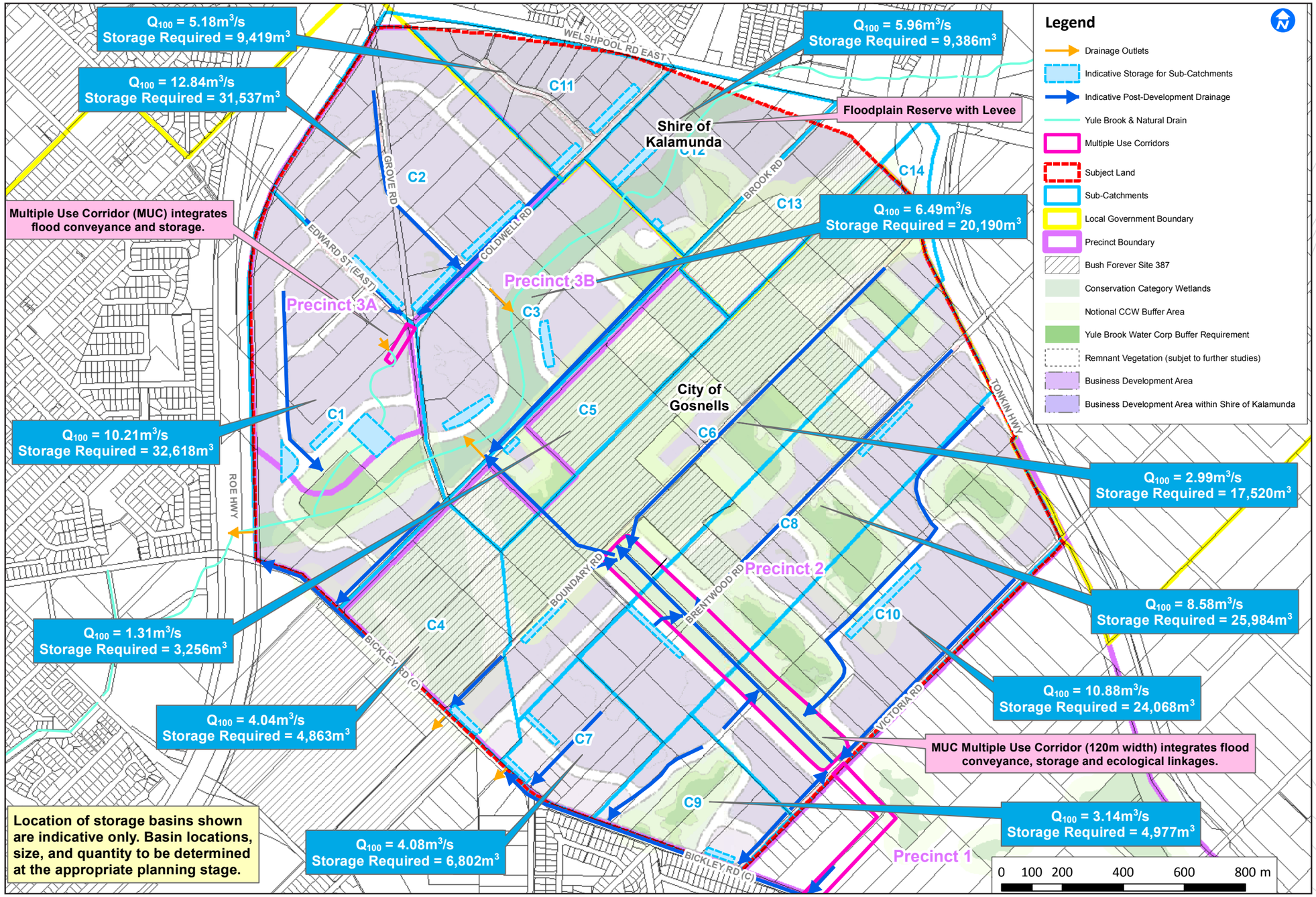


Figure 28- Post Development Management Plan 1:100 year Drainage

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

10. WATER QUALITY MANAGEMENT

The development will utilise a range of best management practices to manage water quality across the site. The major practice will be the implementation of water sensitive urban designs (WSUD) to manage stormwater up to 1:10 year flood events. Most of the other management practices will involve minimising the quantity of nutrients added to the surface and groundwater within the development. The development designs should concentrate on managing practices on lots for effluent disposal and stormwater runoff.

CONSTRUCTION CONTROLS

A key aspect of managing water quality for the development will be involved in the construction of the subdivision. At the subdivision stage of development there will be a requirement to prepare and implement erosion and sediment control plans. Management options should also focus on minimising potential pollutants during the construction phase. The management options may include:

- assessment of erosion risks;
- stabilisation of stock piles;
- minimise the exposure times for disturbed areas;
- sediment curtains, fences, and filters at inlets and other control points;
- cut off drains;
- temporary sediment basins;
- stone mattresses; and
- hydro-mulching and interim plantings.

ON-SITE LOT TREATMENT

It is proposed that individual lot owners will provide attenuation and treatment options for the 1 year 1 hour event lot runoff via on-site bioretention basins. Additional, $1m^3$ of storage per $100m^2$ of impervious area will be required to be provided as on-lot retention. The on-site flows could be detained with a variety of methods, including shallow landscaped bioretention basins, rainwater tanks, car parking areas and on-site soak wells.

The most effective method in implementing WSUD in industrial precincts is to ensure that pollution sourced from work areas does not discharge into the stormwater infrastructure. Practices that land managers and owners can undertake involve: roofing work areas; directing wash-down water to storage; and controlling activities undertaken in areas that link with the stormwater infrastructure. The guiding principles and practices in the construction and management of industrial lots should be an intention to separate areas subject to pollutants and contaminants from paths that would transport water to the stormwater infrastructure. The developers will encourage structural separation, and the local government agencies will be encouraged to ensure elements are included for building application approvals. Furthermore, facilities to separate contaminated wastewater (e.g. effluent disposal) from uncontaminated water sources (e.g. clean stormwater runoff).

EDUCATION

Education of employees is very important to ensure that they are knowledgeable about the different systems and potential impacts on the environment that their workplace could have. It is essential for the management of water quality within the subject land that employees are educated on the following:

- The difference between the stormwater and on-site effluent systems, and the WSUD infrastructure established within the subdivision;
- Do not sweep or dispose of litter or waste into gutters or drains, and keep the footpath, gutter and outside areas near their business free of litter. This includes providing adequate refuse storage for litter and cigarette butts;
- Where possible, all waste skips and bins should be stored in a designated area with a roof and surrounded by toe walls to prevent any leakage entering the stormwater system;
- Lids on bins and skips should be kept closed to stop loose litter being blown away. This also stops rain getting in which can wash oils, solvents and chemicals out of rags and into the stormwater;
- Spills from loading and unloading operations are a common source of stormwater pollution. Where possible conduct all activities with the potential to pollute water (e.g. loading and unloading, transfer of materials) within roofed and bounded areas or indoors;
- Storage of potential pollutants, including precautions in case of leakages, should be in secured areas. The storage may require roofing, a physical barrier for leaks to leave the storage (e.g. a lip at openings) and possibly a bund if appropriate.
- When moving, pumping, loading or unloading liquids make sure that a spill kit is available for use in case of a spill. Depending on the type of liquid, spill kits can be as simple as a drum full of sand or sawdust and a shovel; and
- How to handle materials to reduce waste and prevent spills.

CONTAMINANT RISK MANAGEMENT

There should be minimal nutrients added within the proposed development from gardens. However, the greatest risk to contamination of the natural environment from the subdivision will be industrial waste that can include petroleum hydrocarbons, heavy metals, surfactants, toxins and/or salts (DoW, 2009b). Details in regards to wastewater management, including contamination risks have been documented in the Water Supply & Wastewater Management (Section 14 of the DWMS).

As previously mentioned structural separation and education will be paramount to minimising the risks of contamination from any of the lots within the subdivision. The Western Australian Business and Environment Manual developed by the WA Chamber of Commerce and Industry and the Centre of Excellence in Cleaner Production provides an online resource. The manual is designed to assist WA businesses to successfully manage their environmental issues together with their business operations. Importantly it provides information relating to environmental legislative requirements and obligations at local, State and Commonwealth level for a range of industry practices.

Statutory requirements, approvals and managing agencies are outlined in environmental guidelines, codes of practice and Water Quality Protection Notes for a range of businesses and activities in Western Australia. Generally the Department of Environment Regulation, Department of Water and Department of Health are the three major State government agencies involved in waste management and contaminated sites. The DoW's WQPN 10: Contaminant Spills – Emergency Response is a useful reference that will be provided to all lot owners. The lot purchasers will be provided with a document regarding best management practices, such as structural separation, and lists appropriate references for further reading, including contact information for agencies and local governments.

There is potential for accidental spillage of hazardous materials either from vehicle movements or accidents within business premises. Without satisfactory means of containment, the spillage of contaminants could pass into the drainage system and impact downstream ecosystems. The risk of potential spills is to be reduced by the inclusion of spill containment structures in the road drainage design as well as on lot containment structures. Policies for the clean up procedures and remediation works should be developed and implemented by the appropriate local authorities. Furthermore, maps of likely routes for contamination and points to block spills are to be developed to assist in minimising the opportunities for contaminants mixing with stormwater and entering significant ecosystems.

BIORETENTION GARDENS

At the time of development bioretention gardens and swales should be constructed within the road reserves of the development and be sized to 2% of each equivalent impervious catchment. The bioretention gardens should be designed and constructed according to the latest *FAWB Adoption Guidelines for Filter Media in Biofiltration Systems* and the *Stormwater Management Manual for WA design guidelines*, and in consultation with the Shire engineers.

A standard bioretention garden will be planted with appropriate native species, which should only require irrigation during the initial 2 to 3 years of establishment, depending on the seasons. They should require no fertiliser application and irrigation demands should be met by stormwater alone, after this initial establishment period, with possible subsequent watering only in drier years. The gardens will be designed to assist in the removal of nutrients and sediments from stormwater before the water reaches the groundwater. The indicative design for the gardens composes a filter media of amended soils to 500mm below the surface, with an average particle size of 0.5mm. A plastic root barrier will also be incorporated to provide a vertical separation layer from surrounding soils to assist in maintaining adequate moisture levels for species planted in the gardens and assist with nutrient reduction. The plants will also assist with nutrient absorption because of the surface area provided by their roots for the formation of bio-films and nutrient uptake. Where practical, saturated zones should also be incorporated into the base of the bioretention gardens.

Bioretention gardens have been demonstrated to achieve a 50% decrease in nitrogen, 80% decrease in phosphorus and a 90% decrease in total suspended soils (Department of Water's Stormwater Management Manual). The graphs shown on *Figure 25* within Section 9A illustrate the potential removal performance of total solid solids, total nitrogen and total phosphorus by a bioretention garden under FAWB design guideline conditions. To standardise designs, maintenance and performance of bioretention gardens in the MKSEA a pre-fabricated modular system could be utilised, where conditions are appropriate.

MONITORING

The focus of groundwater management is to maintain existing hydrological regimes after development and to control groundwater at agreed upon levels. The controlled groundwater levels are to be determined at the Outline Development Plan stage as part of the LWMS. The CGL needs to consider impacts on surrounding ecosystems, and investigations should include assessment of the impact of localised draw down or rise from subsoil systems, swales and fill post development. Refined water monitoring programs should be undertaken at the ODP stage to determine site-specific groundwater levels and quality, and determine practical quantifiable objectives for the groundwater post development.

The Department of Water has commented that post development monitoring of the groundwater's quality at the sub-soil discharge points will be suffice. In general the monitoring should show a decrease in pollutant concentrations within the post development groundwater when compared to pre-development concentrations.

More information on groundwater monitoring is documented in Section 15 of this DWMS.

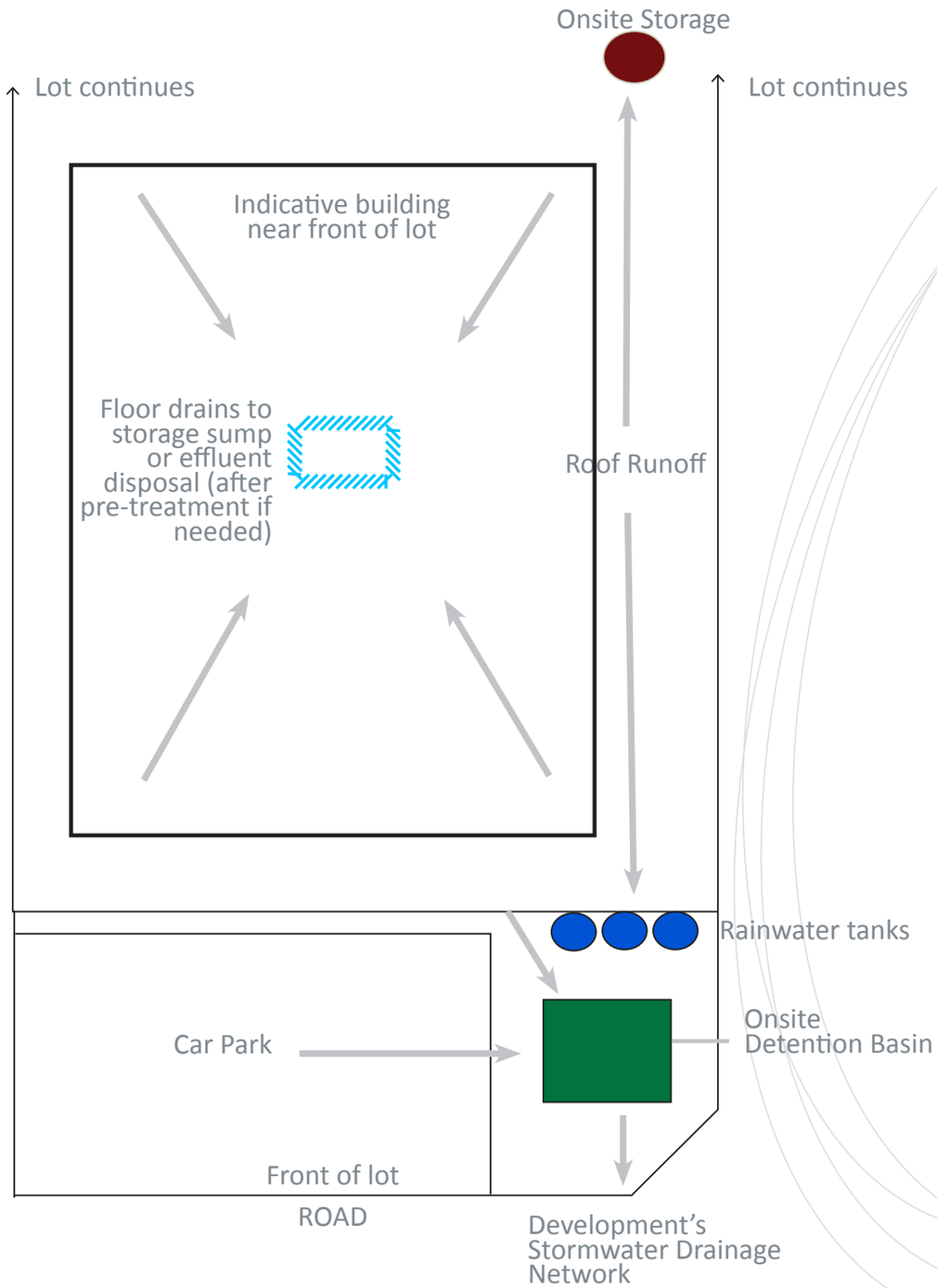


Figure 29- Structural Separation Concept

11 - GROUNDWATER MANAGEMENT

The protection of the groundwater dependent ecosystems the focus of groundwater management is to maintain existing hydrological regimes after development and to control groundwater at agreed upon levels. The controlled groundwater levels are to be determined at the Outline Development Plan stage as part of the LWMS. The CGL needs to consider impacts on surrounding ecosystems, and investigations should include assessment of the impact of localised draw down or rise from subsoil systems, swales and fill post development. The CGL is set at the MGL for the development, unless it can be demonstrated that the alternative level does not adversely impact on the environmental considerations mentioned in the previous sentence, and satisfies the infrastructure requirements. Refined water monitoring programs should be undertaken at the ODP stage to determine site-specific groundwater levels and quality, and determine practical quantifiable objectives for the groundwater post development.

INFRASTRUCTURE SEPARATION

An indicative vertical separation of 1.2m separation between lot levels and the CGL should be used as a standard benchmark where lots under 2,000m^2 are planned. For larger lots, that are not covered predominately with buildings, there is the opportunity to reduce the separation to groundwater. The minimum requirement of the City of Gosnells is 0.5m to footings, physical infrastructure and the invert level of stormwater infrastructure from the post development critical groundwater level across the development. This will require detailed analysis of groundwater mounding in relation to subsoil spacing, hydraulic conductivity of the soil/fill, and the sensitivity of the above and in ground infrastructure. The design parameters will also need to consider any potential impacts on water quality as well as the potential to change levels in nearby sensitive environments.

To achieve the vertical separation there are three proposed methods: use of porous clean fill where necessary; open swales and sub-soil pipes.

1. **Porous clean fill** will be used where necessary to achieve the required separation. Any fill of imported sands will require compaction to relevant standards. The sand fill will be required to have a high permeability to allow water to easily infiltrate down to the original soil layer. The depth of the imported fill must not detrimental effect reserved wetlands. Some of this water will then penetrate further into the natural soils below, while the excess will move laterally and horizontally via the sub-soil perforated pipe drainage system. The approximate fill needed has been calculated for the proposed developable land, under the assumption that 1.2m of clearance from the groundwater was required as a minimum. The approximate fill required will be in the range of 30 to 35 million cubic metres. The actual fill requirements may be reduced by only building envelopes needing to achieve 1.2m separation and with any refinements of the plans.

2. The **sub-soil perforated pipe system** will control groundwater rise to the existing soil surface or CGL, with minor mounding in between, as it will direct excess water into the swales or road reserve network. The distance between sub-soil pipes will be determined by the permeability of the soil within that section of the development.

3. The **swales** will be located in landscaped buffers and internal road reserves. The swales will generally be set at the CGL and will assist in groundwater control. Subsoil drains would also discharge at the just above the base of the swales to ensure the subsoils remain free draining between storm events. Maintaining the groundwater at the CGL will reduce the impacts on the groundwater dependent ecosystems. Groundwater should be fed into the wetland systems and the receiving rivers in the manner that it is currently doing.

A concept of the infrastructure separation and the influence of the proposed design initiatives on the site are illustrated in *Figure 30.*

Modelling of mounding and draw down effects created from the above management options is to be undertaken at the LWMS / UWMP. This modelling is to show there will be no adverse effects on infrastructure or surrounding significant ecosystems.

QUALITY MANAGEMENT

Groundwater quality is to be improved through the use of soil amendment products incorporated into the development's bioretention systems and swales. This will provide treatment of surface water runoff collected within the drainage network prior to infiltration into the groundwater. These products bind nutrients and other contaminants that are mobile within water infiltrating from the surface. The fill should similarly assist with binding potential pollutants.

Further treatment may be required at the discharge points of the subsoil. This treatment may be via bioretention systems, constructed 'wetlands' (surface or sub-surface), or another appropriate method. The method of treatment is to be determined in the LWMS.

ASS MANAGEMENT

Subject to further investigations, the impacts of any actual ASS or potential ASS should be integrated into site works through a detailed ASS Management and Dewatering Plan. Considering that shallow swales and sewers are planned it is not expected that any major ASS issues will occur on-site that conventional methods cannot adequately manage. This will need to be further investigated as part of more detailed design in the LWMS and UWMP.

MONITORING

The focus of groundwater management is to maintain existing hydrological regimes after development and to control groundwater at agreed upon levels. The controlled groundwater levels are to be determined at the Outline Development Plan stage as part of the LWMS. The CGL needs to consider impacts on surrounding ecosystems, and investigations should include assessment of the impact of localised draw down or rise from subsoil systems, swales and fill post development. Refined water monitoring programs should be undertaken at the ODP stage to determine site-specific groundwater levels and quality, and determine practical quantifiable objectives for the groundwater post development.

More information on groundwater monitoring is documented in Section 15 of this DWMS.

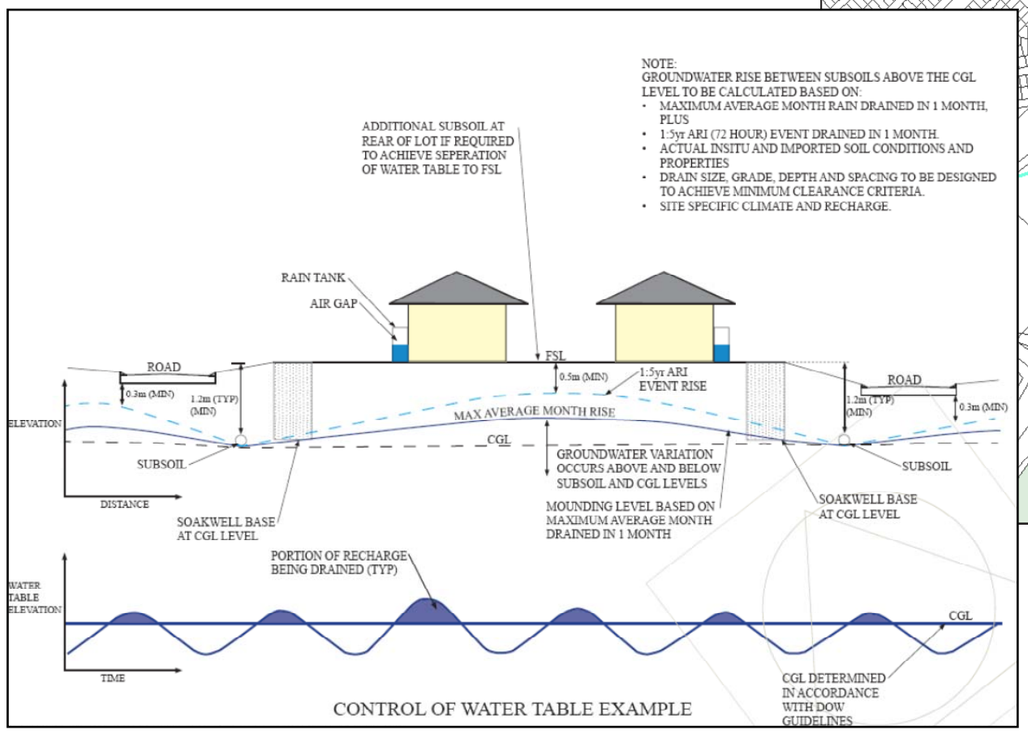


Figure 30 - Groundwater Control Concept

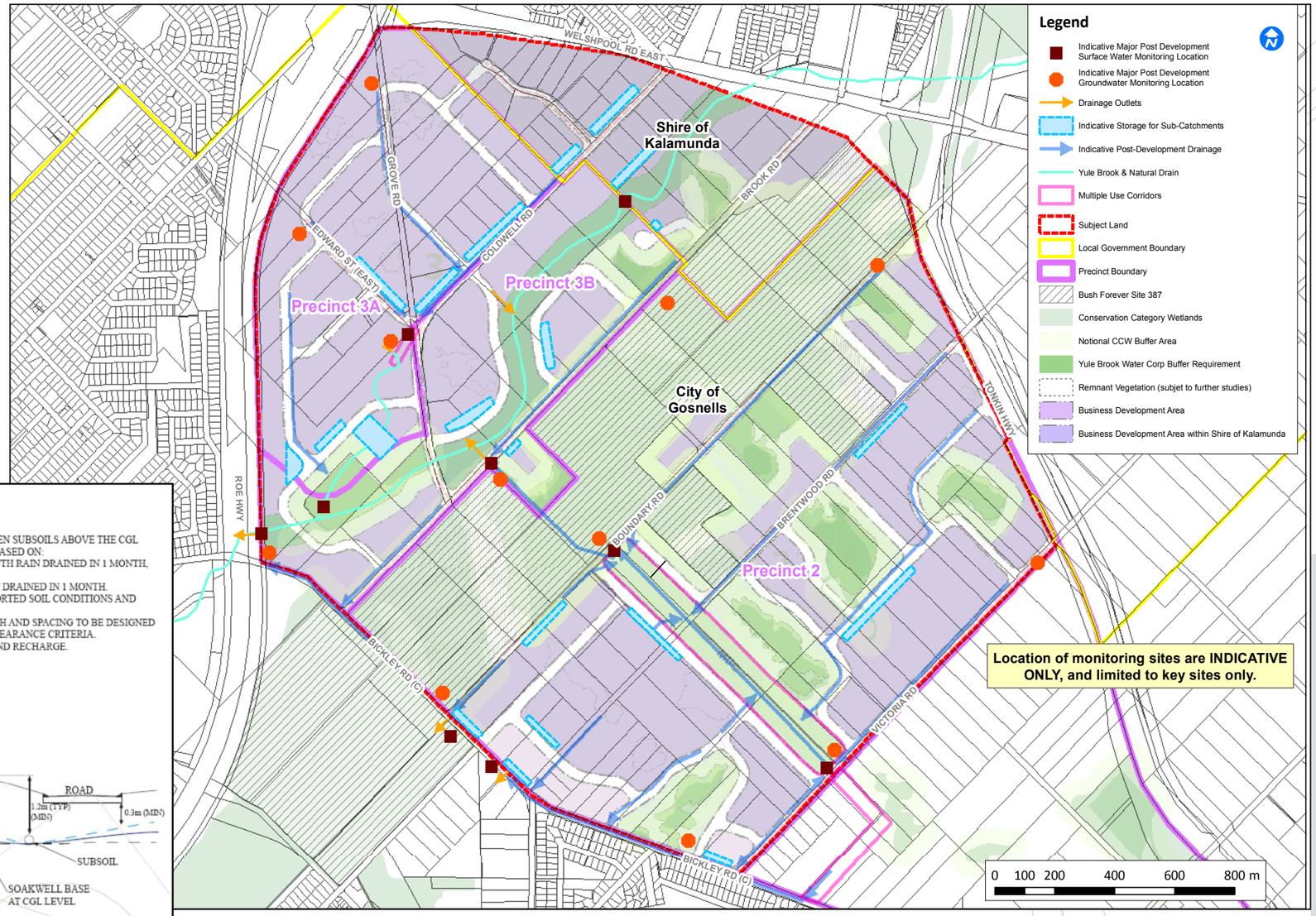


Figure 31 - Post-Development Indicative Water Monitoring Site Plans

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

12 - WETLAND AND WATERWAY MANAGEMENT

The main water dependent ecosystems (WDE) influenced directly by the development of the subject land are the Conservation Category wetlands (CCWs), Bush Forever Site 387 and Yule Brook. There are also a number of downstream and nearby significant wetLAnds and the Swan-Canning estuary that have the potential to be influenced by water management on the subject land. Stormwater and groundwater is to be managed so that the significant WDE areas retain hydrologic regimes comparable to pre-development. The water quality of the flows into these ecosystems will be managed through the treatment of surface and groundwater (detailed in *Section 10*) and the protection of the ecological functions of the receiving natural environments from the development, detailed below and in *Figure 32*.

The development of the subject land will need to be carefully managed so that the surface water flow regimes, groundwater levels and water quality entering these systems is appropriate. This is especially true for the Brixton Street Wetland System, which is recognised for its unique and diverse nature, and Yule Brook.

To understand changes in WDEs and ensure their protection there is a need to integrate surface water and ground water level and quality monitoring with ecological vegetation condition assessments. The annual monitoring enables assessment of short-term changes in the water dependent vegetation while long-term data allows tracking of changes in vegetation communities. There is a significant relationship between vegetation condition, groundwater level trends and ecological water requirements.

As part of understanding Yule Brook a biophysical assessment is to be undertaken at the LWMS stage. This assessment should be as per the Department of Water's Operational *Policy 4.3: Identifying and Establishing Waterway Foreshore Areas.*

GROUNDWATER LEVEL AND QUALITY MONITORING

Adequate groundwater level measurements are required to observe trends in the groundwater regime and ensure ecological water requirements. Regular water quality measurement is required to be conducted at representative and appropriate WDE sites pre and post development. This will form part of the overall water monitoring program for the development. Modelling of the effects of Groundwater control systems such as Subsoil and Swale systems on potential draw down and mounding in nearby sensitive environments is to be undertaken prior to installation. The model will need to prove no adverse effetcs.

SURFACE FLOW AND QUALITY MONITORING

Adequate surface water flow measurements, which account for in and out flows, need to be undertaken at representative and appropriate WDE sites. Regular water quality measurement should be undertaken at the sites and will form part of the overall water monitoring program for the development.

A system of sub-soil pipes and open swales will assist in controlling groundwater levels. The controlled groundwater level (CGL) is to be set at the AAMGL across the site, unless further studies demonstrate the alternative level satisfies infrastructure and environmental requirements. The AAMGL and CGL will be determined at future planning stages for the LWMS, and determined from historical monitoring and site specific monitoring results. The swales will be located in landscaped buffers and internal road reserves. The swales will generally be set at the agreed upon CGL except where existing drains have created a new hydrogeological regime by intercepting or influencing the surrounding groundwater. In these cases, any significant ecological systems nearby will be assessed in relation to the drain invert, with a detailed study into the most appropriate new invert. This will allow ecosystems that have evolved to the new hydrogeological regimes to continue functioning without significant changes. It also means that new hydrological regimes can be developed for those sites that are being flooded or drained to a detrimental effect to have their regimes modified accordingly.

Subsoil drains would also discharge just above the base of the swales to ensure the subsoils remain free draining between storm events. In general the subsoil system will sit close to the determined CGL, however modifications may be needed on a case by case basis.

By maintaining the groundwater at the agreed upon CGL the development will have minimal impact on the groundwater dependent ecosystems on the subject land and nearby. Groundwater will be fed into the wetland systems and the receiving rivers in the manner that it is currently doing.

ECOLOGICAL LINKAGES

There are two ecological linkage corridors ('greenways') proposed within MKSEA prior to the development proposal surveys (Government of Western Australia, 2000; and Del Marco et al., 2004) [ref: Tauss, C. and Weston, A.S. (2010)].

YULE BROOK & BUSH FOREVER 'GREENWAY'

Bush Forever Site (BFS) 387 is part of a natural ecological corridor between the Darling Range and the Canning River that was recognised by the Government of Western Australia (2000). The BFS incorporates CCWs and Resource Enhancement wetlands (REWs), and there are natural linkages with the proposed Yule Brook foreshore reserve.

A 100m wide flood plain, including levees, has been proposed along Yule Brook, as per Water Corporation recommendations. Currently, Yule brook has steep sides and an incised channel that does not support restoration of critical environmental values. To enhance the ecological linkage values there will be a requirement to modify the brook's channel morphology.. A biophysical assessment is to be undertaken at the LWMS stage for the book in accordance with the Department of Water's *Operational Policy 4.3: Identifying and Establishing Waterway Foreshore Areas.*

The Department of Water requires a minimum foreshores reserve buffer of 30m foreshore on either side of Yule Brook , which would be revegetated and rehabilitated, including the channel. This would provide a 70m wide vegetated corridor along the length of the brook. However, the Water Corporation recommended a minimum buffer of 50m from Yule Brook for flood and hydrologic reservation. It is recommended that a 50m buffer be employed, and this is shown in all maps within the DWMS. Detailed designs of the levee and main channel need to be done at a latter stage with detailed plans to ensure public safety, utility of the future park land and ecological functions.

BFS 387 & BFS 53 'GREENWAY'

The ecological linkage corridor proposed by Del Marco et al. (2004) should be supported in principle and adjusted to connect areas with high conservation values of Precincts 1 and 2 with BFS 387 and BFS 53. Of importance is providing a link in the Muchea Limestone, spring-fed, CCW wetlands along the interface of the Bassendean Sands and Pinjarra Plain in Precincts 1 and 2 and the Bush Forever sites.

CREATING NEW WDE

The creation of new WDE's are unlikely to provide the same level of value as the protection and enhancement of the existing high value ecosystems within the site, they can still provide benefits to the overall ecosystem functioning in the natural environment. The basin and swale systems, especially within the multiple use corridors (MUCs), will provide new areas of fauna habitat and importantly can act as a temporary refuge when moving through the subject land. To maximise the potential of the systems for habitat values and migration the landscaping should focus on locally native species, which should also be encouraged in lot gardens.

WETLANDS

GREATER BRIXTON STREEET WETLAND (GBSW)

The Greater Brixton Street Wetland is currently managed by WAPC and the University of WA and is likely to be managed by DPaW and UWA in the future. A separate management plan with overall strategy will be necessary for management and protection of GBSW, which should incorporate the impact of the proposed development surrounding the system.

Treated stormwater runoff is to be controlled into the wetland to retain the wetlands at pre-development hydrological regimes or otherwise, agreed upon rates that can be used to enhance critical ecological functions. The wetlands are affected by direct rainfall, rather than regional groundwater movement, and this may assist the management of the wetlands from the surrounding development. The existing deep roadside drains that surround the wetlands result in little lateral flow of water into them from surrounding areas, except in extreme events. The drains are effectively intercepting surface and groundwater flows from entering the wetlands and the system will be maintained post development.

CONSERVATION CATEGORY WETLANDS

The wetlands will be located within reserves and this zoning will assist in providing appropriate buffers for ecological sustainability. The CCWs will be protected through the a minimum 50m buffer (see *Figure 35*) and the implementation of future wetland management plans. The management plans are to detail strategies, practices and an implementation schedule that will provide protection and enhancement opportunities for the wetlands. The final buffer distance, and or separation strategy, is to be determined prior to completion of an Outline Development Plan (ODP) and any associated LWMS. The activities allowed within and/or adjacent to separation areas would also need to be documented. Wetland management plans will be required for any CCW or REW that influences or may be impacted by a development, including wetlands not within the planning area.

RESOURCE ENHANCEMENT WETLANDS

In many instances, remnant vegetation identified by Tauss and Weston (2010) and reproduced in the City's Summary Constraints Mapping as "Area of interest" coincides with Resource Enhancement Wetland classification and they are subject to more detailed evaluation in detailed evaluation in future planning stages. There may be requirement to set aside these area for conservation purposes and a 50m buffer as a minimum. Further investigation into these areas will occur at the ODP stage of planning. The findings of ODP study into these areas may result in the need for LWMS to address these areas in the context of environmental water requirements and other relevant aspects.

WETLAND BUFFERS

With regard to wetland buffers, a minimum 50m buffer should be considered the default for both CCW and REW. More detailed assessment at the ODP level of planning, including site-specific buffer studies, will assist in the absolute determination of these buffers.

Where an existing road is being used as a management boundary in lieu of a buffer, the local government may apply restrictions to the Business Development Area on the opposite side of the road to ensure that development does not impact the conservation values of the wetland. Site specific studies may be required of the proponent, depending on the potential impacts (e.g. taking into consideration direction of groundwater).

BIORETENTION AREAS

Bioretention gardens are to utilise species local to the Swan Coastal Plain to provide small ephemeral 'wetlands', which may provide small habitats and 'stepping stones' for fauna to move through the development. They provide linkages to other drainage treatments and landscaped areas to assist with creating potential ecological linkages.

DETENTION BASINS & LIVING STREAMS

Detention basins are, where appropriate, to be landscaped with species local to the Swan Coastal Plain and when combined with 'natural' basin shapes will provide functions similar to ephemeral wetlands. The large basins are likely to be incorporated into the multiple use corridors (MUCs) and will assist with the movement of fauna between areas of high habitat values.

The MUCs will provide 'living streams' and their extends will assist with the dispersion of species from Yule Brook and the GBSW across the landscape. Designing the 'living streams' to flow in the 1:2 year ARI events they will mimic natural waterways and the remainder of the channel can be used for events up to the 1:10 year ARI, with larger events spilling out across the MUC reserve similar to a floodplain. The use of native species within the channel and throughout the MUCs would assist with providing habitat and enhancing the ecological functions of these new waterways.

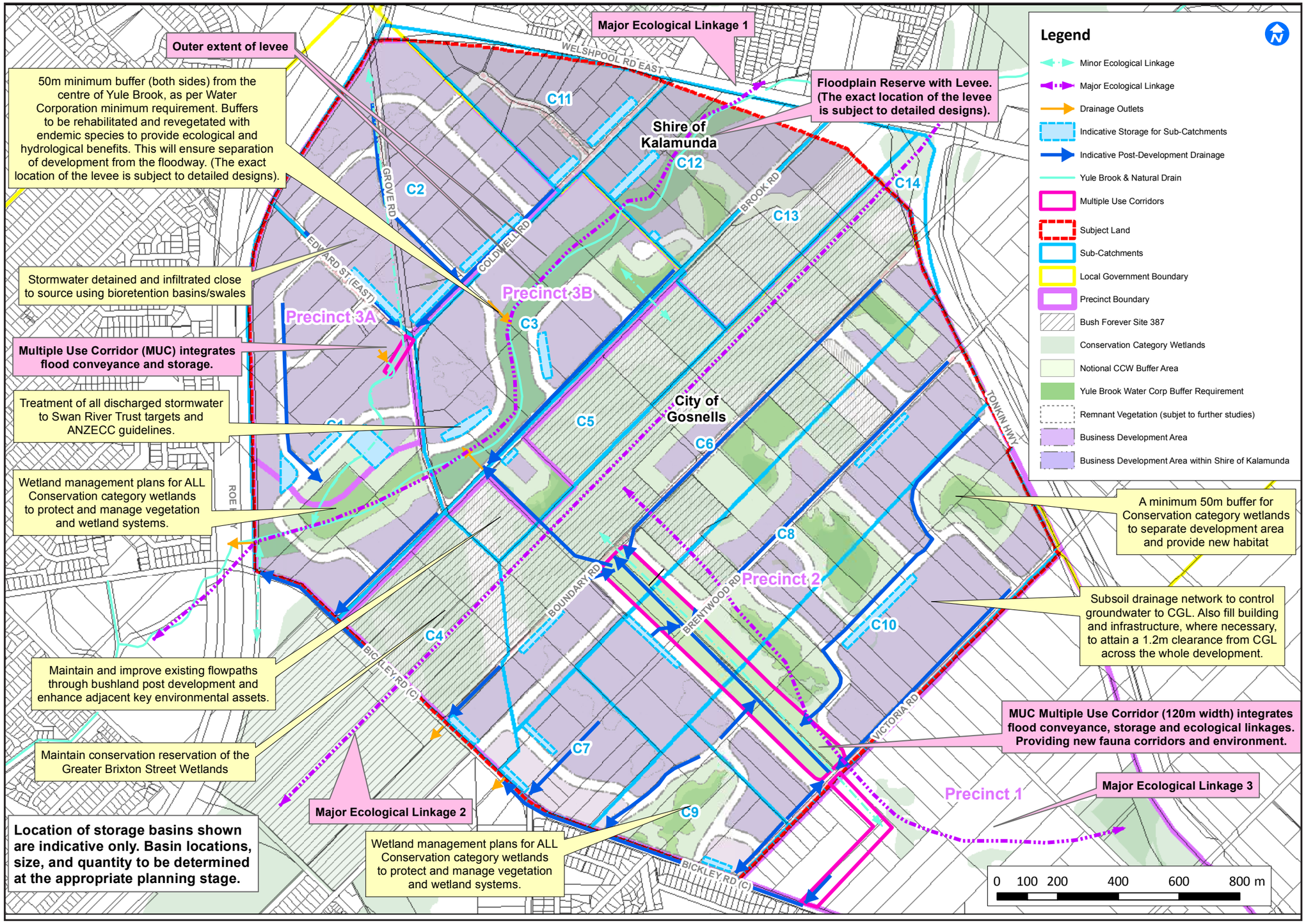


Figure 32- Water-Dependent Ecosystem Management

(Based on City of Gosnells Indicative Development Concept Plan, See Figure 3)

13. WATER CONSERVATION

According to the *State Water Plan of 2007* by the Western Australian Government, 16% of the state's total water consumption in 2005 was by the commercial and industry sector. The Plan did not set a goal for this sector, unlike the 100kL objective per person set for residential areas.

The state government of Western Australia does however require all businesses that use more than 20,000kL of scheme water per year to participate in the Water Corporation's Waterwise Business Program. This Program involves:

- Undertaking a water management assessment annually with the Water Corporation;
- Developing a 5 yearly Water Efficiency Management Plan (WEMP); and
- Annual review of WEMPs and reporting the progress against the water savings action plan.

These are requirements are under the *Water Agencies* (Water Restrictions) By-laws 1998 and are mandatory. The WEMP involves the preparation and implementation of water consumption targets over a 5 year period. The business has to monitor water usage throughout each year of the plan, and a report is to be submitted to the Water Corporation annually.

There is an opportunity as part of this process to develop ways to manage, recycle and conserve water within individual businesses and even sectors of the industrial park.

EDUCATION AND AWARENESS

Business owners are to be encouraged to promote water efficient behaviour amongst employees through awareness raising material and opportunities. Possible measures to encourage water efficient behaviour may be:

- Installing signs at all water using fixtures;
- Installing shower timers to encourage shorter showers where these facilities are provided;
- User education for dishwashers, washing machines and glass washers to ensure there is a full load, where these are provided;
- Include water conservation practices in staff or tenant inductions;
- Ensure water conservation or management is continually brought up at meetings;
- Promote their businesses water-saving initiatives or outcomes within the local community;
- Encourage employees to identify water-saving measures; and
- Offer an incentive scheme to encourage water-saving innovations and ideas.

Further details are to be developed in the relevant LWMS's and UWMP's

RAINWATER TANKS

Businesses are to be encouraged to install rainwater tanks, with a level controlled air gap, to reduce the quantity of water consumption from the water mains. The water may be used for a variety of fit for purpose uses, related to the industry and feasible treatment levels.

A suitable tank size should be determined according to the roof area of the buildings on a lot and the water usage practices and applications by the business.

There is also the possibility to utilise a larger scheme that takes excess roof runoff for storage within a suitable aquifer or water body. This scheme will require more detailed investigation prior to the LWMS being completed.

WATERWISE LANDSCAPING

Natural rainfall alone should be sufficient to maintain Waterwise landscaped areas once established. Front of lot landscaping and street reserve landscaping is to be composed of Waterwise plantings suited to the local environment. Details on appropriate species and areas of planting/landscaping are to be established as part of future planning for the site.

The source of water for any landscape irrigation will require further investigation. Details regarding water supply and irrigation of landscape areas are to be provided in the LWMS. The landscaped areas could potentially be watered from groundwater, treated wastewater, harvested stormwater or rainwater.

The use of swales and potentially bioretention gardens within landscaping areas, planted with native species are to be encouraged, as these structures receive much of their irrigation requirements from stormwater runoff.

14 – WATER SUPPLY & WASTEWATER MANAGEMENT

WATER SUPPLY

To determine the regional water balance (see Table 5) for the development, the Water Corporation's Design Standard DS 50: Design and Construction Requirements for Gravity Sewers (2012) wastewater design flow rates for industrial areas was used a guide (16,992L/¬net Ha/day). A conservative assumption was made that the wastewater outflow would be 95% of the water supply requirements. The net developable area of 200Ha was determined from the developable area of 290Ha with the assumed land reductions of 2% Public Open Space, 5% drainage, and 25% road reserves. The daily water usage for the net developable area would be approximately 5,200KL and approximately 1,900 mega litres per year. The actual types of industry and business will determine water requirements, and the volume of water that they source from resources other than the mains reticulated supply. Options for water supply sources are discussed below.

STANDARD POTABLE

GHD in 2005 undertook a preliminary assessment of servicing requirements and identified that on the southern boundary of the proposed industrial area, an existing 510 Cast Iron (CI) water main runs along Bickley Road from Roe Highway to Brentwood Road. This water main changes to a 460CI along Bickley Road from Brentwood Road to Kelvin Road. This main should be sufficient to service Precincts 1B, 2, 3A and 3B, with an extension to the main to service Precinct 1A (outside of this DWMS study area). The water services map is shown in *Figure 33*. Detailed alignments and drawings of the mains water connections and services need to be undertaken as part of the LWMS and/or UWMP.

ALTERNATIVE WATER SUPPLY

STORMWATER

Subject to further investigation there is the potential to harvest storm water for processing. This water could potentially be used for industrial uses throughout the year. Alternatively, it could be stored and utilised for the watering of public spaces as required. This will require extensive further investigations, including treatment and storage options. The stormwater will however assist with the watering of the general landscape in the development area through the direct discharge of stormwater to the bioretention gardens, swales and MUCs.

ROOF RAINWATER

There is likely to be significant areas of impervious roof catchment throughout the subject land. This represents an opportunity to harvest and reuse relatively clean water on a lot by lot basis or as an integrated scheme across the industrial precinct. On-lot rainwater harvesting could be for internal non-potable uses including toilets, wash-down sprays and general industrial processing. Further investigations into the potential resource should be undertaken in the LWMS and/or UWMP.

TREATED AND RECYCLED WASTEWATER

Presently it is highly unlikely that treated wastewater will be returned to the MKSEA for usage within public places or private lots as a Water Corporation service. Opportunities to secure an alternative supplier that could run the scheme should be investigated at future planning stages to determine if viable.

GROUNDWATER

There is the possibility to utilise groundwater resources from both shallow and deeper aquifers located under the subject land. These will be subject to licences granted through the Department of Water and relate to the entitlements available.

Within the superficial aquifer there is the potential to harvest groundwater from the increased volume that is often generated by developing from agricultural to industrial land. This is because the potential for increased infiltration and reduced evapotranspiration leads to a build up of water stored within the soil profile. This can further be enhanced with the use of fill, which increases the level of available storage height prior to running off the land. This extra groundwater could be harvested through pumping and/or subsoil drainage piping.

MANAGED AQUIFER RECHARGE SYSTEM

A managed aquifer recharge system is not economically viable presently, because of the cost of available technology. However options should be investigated at the LWMS and UWMP stages to determine the viability of such systems in the future. A detailed investigation would be required if considered viable and any studies should be guided by the *Operational Policy 1.01 - Managed Aquifer Recharge in WA* (DoW, 2011).

PUBLIC SPACE IRRIGATION

Irrigation requirements for public space areas within the MUCs will be minimal due to the use of mainly locally native species. Where irrigation is necessary there is sufficient entitlements available from the groundwater aquifers under the subject land. Any entitlements would require application to the Department of Water, and their approval for the construction of any extraction bores. A water supply for public spaces and entitlement requirements will need to be determined in the LWMS.

REGULATIONS

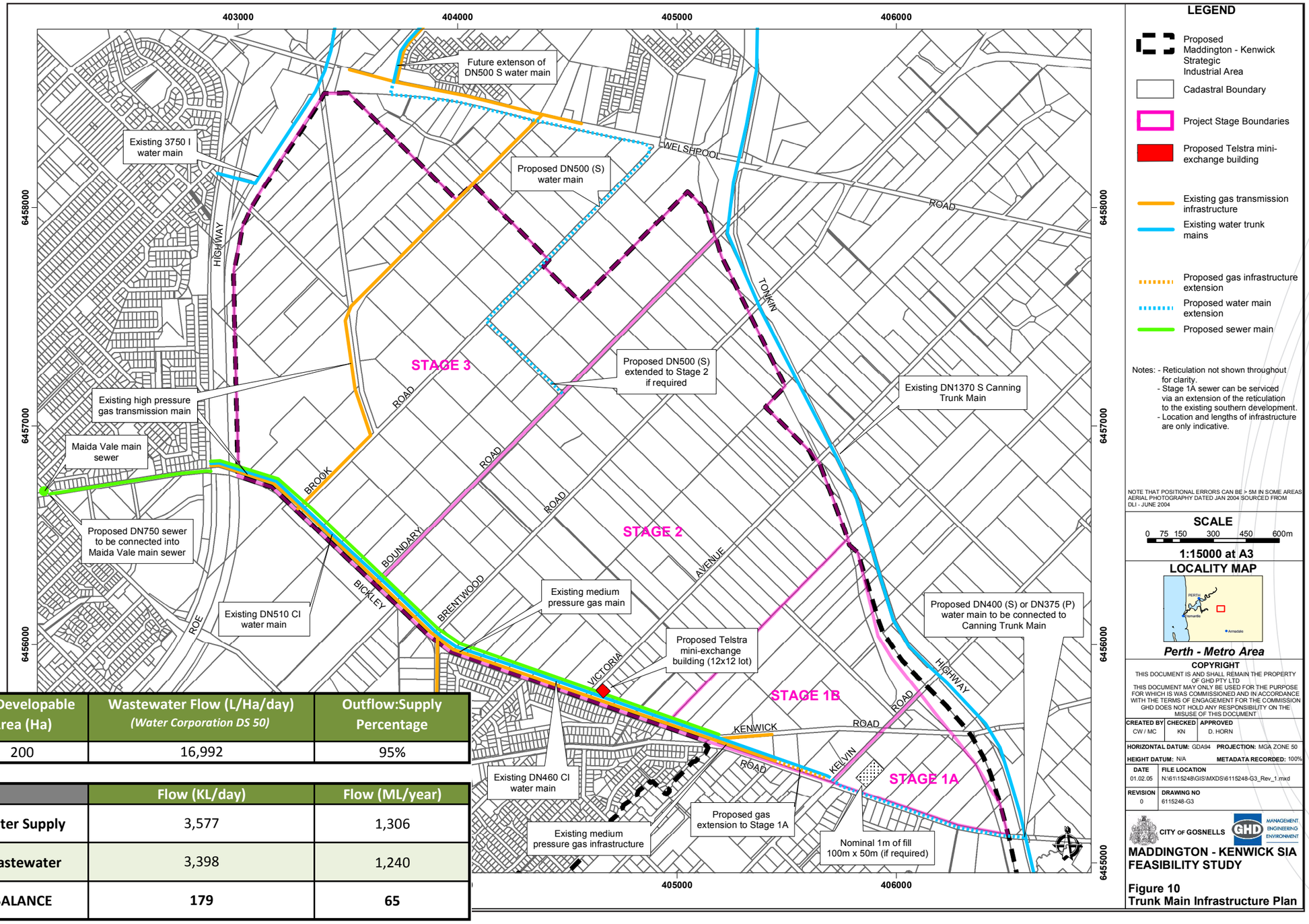
The schemes will need to comply with the *Australian Guidelines for Water Recycling* (EPHC et al, 2006) where relevant and where non-drinking water is used they will need to comply with the *Draft approval framework for the use of non-drinking water in Western Australia* (DoW, 2010).

Approval will need to be sort with relevant authorities that may include Department of Health, Department of Water, Department of Environment Regulation, Economic Regulation Authority and Local Government Authority.

WASTEWATER

It was determined that the water supply requirement for the development was approximately 1,900ML per year. The requirement was determine using the Water Corporation's Design Standard DS 50: Design and Construction Requirements for Gravity Sewers (2012) wastewater design flow rates for industrial areas (16,992L/Ha/day). The wastewater flow for the developable area based on this flow rate and a net area of approximately 290Ha was approximately 5,000KL per day and 1,800ML per year (see *Table 4* for the regional water balance comparison to water supply requirements).

The Maida Vale Main Sewer (*see Figure 33*), west of Roe Highway, will require a trunk main along Bickley Road, Precinct 3 and 3A will require a 600RC pipe and Precinct 2 will require a 450RC pipe. A 750 sewer will need to be tunnelled under Roe Highway to the boundary of Precinct 3A, and extended along the Maida Vale Main Sewer. Detailed alignments will need to be prepared for the Water Corporation's review at the LWMS and UWMP stages.



Net Developable Area (Ha)	Wastewater Flow (L/Ha/day) *(Water Corporation DS 50)*	Outflow:Supply Percentage
200	16,992	95%

	Flow (KL/day)	Flow (ML/year)
Water Supply	3,577	1,306
Wastewater	3,398	1,240
BALANCE	**179**	**65**

Table 4 - Regional Water Balance

Figure 33- Water Services Map

Source: Engineering feasibility study, GHD (2005)

15. MONITORING & IMPLEMENTATION FRAMEWORK

PRE-DEVELOPMENT

In 2012 Endemic Pty Ltd completed a groundwater and surface water monitoring program across the entire subject land.

GROUNDWATER

Eleven monitoring bores were installed between a depth of 1m to 6m, and a further seven monitoring bores were installed for wetlands. The focus for the monitoring was to determine maximum and minimum groundwater levels; and general quality. The quality parameters sampled were: electrical conductivity (EC), pH, salinity, temperature, alkalinity, nitrate (as NO3), ammonia (as N), total nitrogen (TN), total phosphorous (TP), filterable reactive phosphorous (FRP), and total metals (Al, As, Cd, Cr, Cu, Fe, Mn, Pb, Zn).

SURFACE WATER

Eight surface water monitoring sites along Yule Brook were sampled to detail flows and the spatial and temporal variation in quality. The monitoring was conducted for winters of 2009 and 2010. Parameters sampled were: EC, pH, dissolved oxygen (DO), salinity, temperature, oxygen replacement potential (ORP) turbidity, total suspended solids, alkalinity, nitrate (as NO3), ammonia (as N), TN, TP, FRP, and metals (Al, As, Cd, Cr, Cu, Fe, Mn, Pb, Zn).

WETLAND

An assessment of Conservation Category wetlands (CCW) was undertaken by Tauss and Weston (2010) and in 2005 Cardno conducted an environmental review of flora, fauna and wetlands within the MKSEA.

RECOMMENDED MONITORING

- Site Specific Water Monitoring Programs: There may be a requirement to undertake more detailed site specific ground and surface water monitoring at future planning stages, especially near the Greater Brixton Street Wetlands (GBSW), to determine appropriate management strategies for specific sites. The detailed monitoring may also be required to refine the average annual maximum groundwater level (AAMGL) and controlled groundwater levels (CGL) for sites. Detailed CGLs needs to determined at the LWMS stage.

- Wetland Evaluation: Further detailed assessments of the wetland systems, especially in relation to surface and subsurface water movement, will be required prior to the LWMS.

CONSTRUCTION PHASE

Installation of drainage control structures is to occur ahead of the construction phase of the development. This would include the use of water sensitive design techniques such as sediment curtains, hydro-mulching and temporary detention basins to maintain the quality of the water leaving the development area during construction. The collection pits should be monitored for any damage, including sediment build up and litter accumulation during, and at the completion of, construction to ensure the pit's effectiveness is not diminished post-development.

All contractors working on any future development of the site will be made aware of their responsibilities under the *Aboriginal Heritage Act 1972* with regard to finding potential archaeological sites. In the event that a potential site is discovered, all work in the area will cease and the DAA should be contacted.

POST-DEVELOPMENT

WSUD INFRASTRUCTURE

Routine monitoring within the development area that checks the status of key functional WSUD elements is to be undertaken to ensure they meet specified design requirements. This may include, but not limited to:

- ensuring the inlet and outlet structures are free of debris;
- vegetative cover of the systems is maintained;
- sediment build up is not impeding the functionality;
- erosion is not present;
- soils are not compacted;
- litter is removed; and
- hydrocarbons are not present in the system.

Monitoring of the established WSUD elements operations can provide important insights on the likely performance of them in pollution reduction and stormwater management functionality. Inspection of the WSUD elements should be undertaken by the developer until an agreed upon time between developers and the local government authorities. The indicative timeframe is for 2 years after the completion of works with inspections every three months. This is to be reviewed at the LWMS and UWMP stages. Table 4 summaries the particular items to monitor and the purpose of monitoring, the trigger signs that require immediate action and the maintenance action required.

Compared to traditional engineered structures for stormwater runoff management, the WSUD elements will only require minimal routine maintenance many of these related to a landscaping and ecological corridor maintenance nature. The most common maintenance is the removal of weeds, debris and siltation. The most time intensive period of maintenance for a vegetated WSUD system is during plant establishment (which typically includes two growing seasons), when supplementary watering, plant replacement and weeding may be required.

It is recommended that vegetated WSUD elements are monitored by personnel with floristic knowledge and/or qualifications, as they will be capable of identifying evasive species within the natively vegetated WSUD systems. Furthermore, personnel in charge of monitoring should have a good understanding of principles and the functional design of the WSUD elements and the treatment system. The maintenance activities prompted through monitoring activities will generally require coordination between landscape and civil services.

The WSUD elements will be constructed and utilised in different stages so that the functions of the WSUD elements are protected from elevated pollutant loads generated from a developing catchment.

Maintenance inspections should be scheduled to be conducted after a significant storm event. Inspections should focus on ponding time for the different systems, unequal surface flow distribution, sedimentation and scouring, as well as deposition of coarse litter.

Performance monitoring of WSUD elements via detailed water sampling and testing for contaminant concentrations has not been scheduled at this stage. The exact parameters and monitoring schedule is to be detailed in the LWMS and subsequent UWMP for the sites.

GROUNDWATER

Groundwater monitoring may be required post development to determine that the development is not impacting on nearby significant wetlands through changes in levels or poor water quality. The exact parameters and monitoring regime are to be determined by the final land uses. For this reason, further details on post development monitoring are to be developed as part of the LWMS and UWMP.

SURFACE WATER

Surface water monitoring will be required post development to determine that the development is not impacting detrimentally on the surface water quality leaving the site. Sampling points should be set up at the discharge points form the subject land or on site significant wetlands. These should be checked against pre-development concentrations, established guidelines and the quality of water entering the site from upstream. The exact parameters and monitoring regime will be determined by the final land uses. For this reason, further details on post development monitoring are to be developed as part of the LWMS and UWMP.

WETLAND

Major part of the conservation category wetland within the subject land is Greater Brixton Street Wetland(GBSW) which is currently managed by WAPC and UWA. It is likely to be managed by DEC and UWA in future. A separate management plan with overall strategy will be necessary for management and protection of GBSW, which should incorporate impact of proposed development in surroundings. It should include integrated ground water level and quality monitoring with surface flow and quality monitoring with ecological vegetation condition. This will assist with ensuring ecological water requirement and maintaining ecological health.

Wetland Management Plans will be required to encompass the CCW and Resource Enhancement wetlands on the land, including evaluation of management classifications, buffers, and boundaries. The plans should be undertaken at Outline Development Plan (ODP) stage. The development and implementation of Wetland Management Plans will be to the satisfaction of DPaW.

The monitoring program provided in the Wetland Management Plans will include the development of trigger levels and contingency measures, to the satisfaction of DPaW. Baseline monitoring should be conducted for a minimum of two years prior to development and monitoring should continue for a minimum of three years post-development. In the event that unusual seasonal conditions (significantly drier or wetter than average) confound interpretation of the data, monitoring should be continued until DPaW is satisfied that the pre-development hydrology of the wetland has been maintained.

The DWMS monitoring program (see *Table 5*) provides for the installation and monitoring of bores appropriately situated so as to provide quality data with regard to groundwater quality and levels in proximity to wetlands. The exact location of these bores will be further refined through the LWMS and UWMP processes. This information will ultimately inform UWMP reporting, and be integrated into the Wetland Management Plan monitoring and reporting.

The implementation of integrated wetland monitoring will be the responsibility of the developer. The LWMS will discuss and propose implementation arrangements, options for which will include developer funding and/or inclusion in the Developer Contribution Scheme.

Preliminary concepts for the Wetland Management Plans, including monitoring aspects, will be developed in the LWMS, with the preparation of Management Plans and their integration with UWMP monitoring being undertaken at the UWMP stage.

RESPONSIBILITY AND REPORTING

All lot purchasers are to be provided with appropriate guidelines regarding their on-site water management requirements. This will include the required on-site detention, structural separation practices, spill response and treatment procedures, and general industrial best water management practices initiatives.

The developer of the land will be responsible for the monitoring and reporting of all aspects listed above. Advice should be sort from the Department of Water, Department of Environment Regulation, Department of Parks and Wildlife, and Local Government Authorities on exact parameters and regimes for inclusion in the LWMS and UWMP.

Information collected from monitoring programs, where necessary should be recorded and provided in an agreed format to the Department of Water, Local Government and other relevant agencies in a structure and format to be agreed upon. Reports, including data tabulations and trend analysis, to be submitted for review by the Local Governments and DoW to compare monitoring results with target design and performance criteria to ascertain what, if any, further actions may be required, and will provide ongoing assessment of the suitability of monitoring and reporting strategies. If a trigger value for a contingency action is reached, a more detailed report on the occurrence, its impact and proposed action to prevent recurrence is to be compiled by the developer and submitted to the Local Government, DoW and DPaW, if appropriate.

Function	Item to Monitor	Purpose of Monitoring	Trigger for Immediate Action	Maintenance Action Required	Monitoring Frequency	Responsibility
PRE-DEVELOPMENT						
Groundwater	Quality	To determine pre-development quality to assist with setting base lines for the subject land.	NA	NA	Minimum of two samples a year for 2 years	Developer
	Levels	To determine pre-development levels to assist with setting AAMGL and MGL for the subject land.	NA	NA	Monthly sampling over 'winter' period, 3 monthly over summer. Minimum of 2 winters.	Developer
Surface Water	Quality	To determine pre-development quality to assist with setting base lines for the subject land.	NA	NA	Minimum of two samples a year for 2 years	Developer
	Flow	To determine pre-development flow rate to assist with setting base lines for the subject land.	NA	NA	Minimum of two samples a year for 2 years	Developer
CONSTRUCTION PHASE *(up to completion of development)*						
Groundwater	Quality	To monitor the quality during construction to assist with determining if the sites meet guidelines.	Sample results do significantly exceed pre-development values.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer
	Levels	To monitor post-development levels to assist with determining if site is meeting guidelines.	Levels significantly vary from pre-development values or from modelled drawn down / mounding due to subsoil network	Undertake appropriate responses to address the issue.	Monthly sampling over 'winter' period, 3 monthly over summer	Developer
Surface Water	Quality	To monitor the quality during construction to assist with determining if the sites meet guidelines.	Sample results do significantly exceed pre-development values.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer
	Flow	To monitor flows during the construction stage to assist with determining if site is meeting guidelines.	Flows significantly vary from pre-development values.	Undertake appropriate responses to address the issue.	Minimum of two samples a year	Developer
Wetlands	Surface and Groundwater Quality	To monitor surface and groundwater quality during the construction stage to determine any change from pre-development levels that might impact on wetland health	Triggers to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Contingencies to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Monitoring frequencies to be identified in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Developer
	Surface and Groundwater Levels	To monitor surface and groundwater levels during the construction stage to determine any change from pre-development levels that might impact on wetland health.	Triggers to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Contingencies to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Monitoring frequencies to be identified in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Developer

Table 5 - Ground Water and Surface Water Monitoring and Maintenance Table Part A

Drainage Management Systems	Structural Effectiveness (inlets, traps and outlets)	Inspection for debris, litter and sediments surrounding structural components.	Debris, litter or sediments causing blockages or impairing functions.	Remove any debris or blockages. Inspect system for any erosion related issues.	Every 3 months	Developer until handover to the City/Shire
	Erosion	Inspection for erosion.	Presence of severe erosion or erosion impairing functions.	Investigate, identify and rectify the cause of the erosion. Replace filter media as required.	Every 3 months	Developer until handover to the City/Shire
	Sediment and Silt Build Up	Inspection for sediment and silt accumulation within pits, on the surface of bioretention systems and within basins.	Accumulation of large volumes of sediments and/or silts in pits or on the surface (according to City standards).	Investigate, identify and stabilise cause of sediment source. Remove accumulated sediments and replace filter media or plants removed.	Every 3 months	Developer until handover to the City/Shire
	Compaction	Inspection of filter media for compaction.	Water remains ponding longer than designed in bioretention system after a storm event.	Investigate cause of compaction. If localised, remove top 500mm of filter media, break up the filter and then return to system without any compaction. If extensive seek expert advice.	Every 3 months	Developer until handover to the City/Shire
	Weeds	Inspection for the presence of weeds.	Weeds are noxious or highly invasive or if weeds cover more than 25% of area.	Manual removal or targeting herbicide application, with waterway approved products.	Every 3 months	Developer until handover to the City/Shire
	Plant Condition	Inspection of vegetation health and cover, and presence of dead plants.	Plants dying or a pattern of plant deaths.	Investigate cause of plant deaths and rectify. Infill plantings may be required.	Every 3 months	Developer until handover to the City/Shire
	Organic Litter	Inspection for the presence of organic litter (e.g. leaves) on surface.	Litter coverage is thick or extensive, or detracting from the visual appearance of the system.	Investigate source of litter and undertake appropriate response, e.g. alter landscaping maintenance practices, community education). Remove litter.	Every 3 months	Developer until handover to the City/Shire
	Rubbish/Litter	Inspection for the presence of litter.	Litter is blocking structures or detracting from the visual appearance of the system.	Identify source of litter and undertake appropriate responses. Remove litter.	Every 3 months	Developer until handover to the City/Shire
	Oil/Hydrocarbons	Inspection for the occurrence of oil on surface.	Oil coverage persists for more than 3 weeks, and is thick.	Notify the EPA of the spill and clean up requirements.	Every 3 months	Developer until handover to the City/Shire
POST-DEVELOPMENT ***(commencing at completion of development)***						
Water Conservation	Water Consumption	Review and report on WEMP to the Water Corporation.	Determined by WEMP and Water Corporation.	Determined by WEMP and Water Corporation.	Yearly	Business Owners
Groundwater	Quality	To determine post-development quality and testing to be done at sub-soil discharge points.	Sample results do significantly exceed pre-development values.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer (for a minimum of 2 years)
	Levels	Monitoring required to sub-soil drainage system is operating as designed and that modelled level from draw down match actual levels.	Levels exceeding controlled groundwater levels.	Undertake appropriate responses to address the issue.	Quarterly	Developer (for a minimum of 2 years)
Surface Water	Quality	To determine post-development quality to assist with determining if site is meeting guidelines.	Sample results do significantly exceed pre-development values.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer (for a minimum of 2 years)
	Flow	To determine post-development flow rate to assist with determining if site is meeting guidelines	Flows significantly vary from pre-development values.	Undertake appropriate responses to address the issue.	Minimum of two samples a year	Developer (for a minimum of 2 years)
Wetlands	Surface and Groundwater Quality	To monitor surface and groundwater quality post-development to determine any change from pre-development levels that might impact on wetland health.	Triggers to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Contingencies to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Monitoring frequencies to be identified in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Developer (for a minimum of 2 years)
	Surface and Groundwater Levels	To monitor surface and groundwater levels post-development to determine any change from pre-development levels that might impact on wetland health.	Triggers to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Contingencies to be defined in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Monitoring frequencies to be identified in Wetland and Conservation Area Management Plan (integrated with UWMP at subdivision stage).	Developer (for a minimum of 2 years)
Watercourses	Water Quality	To monitor surface water quality in watercourses post-development to determine any change from pre-development levels.	Sample results do significantly exceed pre-development values.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Minimum of two samples a year	Developer (for a minimum of 2 years)
	Flows	To monitor surface water flows in watercourses post-development to determine any change from pre-development levels.	Flows significantly vary from pre-development values.	Undertake appropriate responses to address the issue.	Minimum of two samples a year	Developer (for a minimum of 2 years)

Table 5 - Ground Water and Surface Water Monitoring and Maintenance Table Part B

16. RECOMMENDATIONS FOR FUTURE STUDIES

For future development of the land past the rezoning and DWMS stage, the following additional studies may be required to support the LWMS and/or the subsequent UWMPs:

- **Wetland Assessment and Management Plans**: to alter any DPaW evaluations and/or boundaries, detailed assessments are required to be submitted to DPaW for their approval. The wetland recommendations of Tauss and Weston (2010) will provide the basis for, and guide, further wetland studies. Predominantly the Resource Enhancement wetlands are shown as rezoned to 'Industrial' however detailed assessments are required to reclassify these otherwise they will require reservation and a minimum 50m buffer. Any subsequent wetland management plans should be undertaken to the satisfaction of DPaW, and document the management (including buffers) and rehabilitation works required.

- **Long Section of Yule Brook**: a long section feature survey of Yule Brook may be required at the LWMS stage. The Water Corporation may undertake this work as part of their InfoWorks model.

- **Preliminary ASS investigation**: to identify potential and actual ASS risks at specific sites, and to provide recommendations for management plans.

- **Detailed Drainage Strategies**: at the LWMS stage drainage studies for specific layouts will be require, including how the concepts will be incorporated into the layouts. The drainage modelling from the DWMS should be refined at the LWMS. The assumptions, runoff coefficients, catchment boundaries, flow rates, layout and actual strategies should be documented in further detail in the LWMS, which should also be refined from the calculations made in this DWMS. A complete set of detailed drawings for all engineering services will be required for the UWMP. Detailed modelling and further refinement of details and assumptions will be required as part of the UWMP.

- **Drainage Submissions for any Modifications to Yule Brook cross section**: any proposed modifications to the cross section of Yule Brook will be required to be submitted to the Water Corporation and in accordance with their Design Standard No. 66 Urban Main Drainage Standard prior to approval. The modifications should be submitted at the LWMS, if appropriate.

- **Drainage Strategy implications for Yule Brook Main Drain**: preparation of plans to the Water Corporation that show post development catchments, runoff coefficients, the location and depth-area relationship for all basins so the flows and levels can be included in a InfoWorks model for Yule Brook main drain. The post development surface runoff flows for all average recurrence intervals need to be limited to predevelopment flows into the Yule Brook main drain, and not increased as a result of the development.

- **Groundwater Flow and Level Model into Yule Brook**: preparation of a groundwater model methodology, in agreement with the Water Corporation, that models the pre-development and post development groundwater flows and levels into the Yule Brook main drain, and the effects.

- **Controlled Groundwater Level Model:** potentially further pre-development monitoring programs and modelling will be required to determine the CGL for ODPs at the LWMS stage. The CGL is to set at the MGL across the site, unless further studies demonstrate an alternative level satisfies the infrastructure and environmental requirements. Detailed modelling of the MGL and CGL will be required to be determined at the LWMS, and this level should be based on site specific groundwater monitoring, long-term nearby Department of Water sites and interactions with groundwater dependent ecosystems. The City of Gosnells have requirements for having a minimum of 0.5m separation from the critical ground water level (i.e. MGL or CGL depending on the site conditions) to physical infrastructure, residential footings and to the invert level of the storm water management measures. To determine the CGL there will be a need to consider drawdown implications and interaction with surface water to the nearby wetlands and Yule Brook.

- **Water Services Plans:** Confirmation of an agreed service provision strategy will be required, with detailed drawings required for the UWMP. The Water Corporation has commented that further examinations will be required are more detail of the proposal becomes available during structural planning.

- **Alternative Water Supply and Treatment Options:** preliminary investigations to determine the viability of options, including a range of sources. Production of a report to document any options that are considered viable.

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