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6th November 2015

Marcus Botte
City of Gosnells
PO Box 662
Gosnells 6990
Western Australia

Dear Marcus,

RE: VERSION 4: HOLMES STREET AND BALFOUR STREET LOCAL WATER MANAGEMENT STRATEGY

Enclosed is the revised Local Water Management Strategy (LWMS) to support the Outline Development Plan for Lots 1, 2, 23 and 24 Holmes Street and Lots 1600 and part Lot 1601 Balfour Street, Southern River. The strategy details the water sensitive urban design features for the proposed urban development of the site and incorporates the City's comments from Version 3.

As per the City's request I have included three copies.

Calibre Consulting, on behalf of Mammoth Nominees, is submitting the LWMS to the City of Gosnells for approval and comments. Calibre Consulting requests that the City reviews and endorse the LWMS.

A CD containing supporting documentation is also included. Calibre's response to the City's comments on Version 3 is included in this CD

If you have any queries, please contact Brendan Oversby on 9791 4411 or brendan@tme.net.au.

Yours sincerely
Calibre Consulting (Aust) Pty Ltd

Brendan Oversby
Principal Environmental Scientist

ATTACHMENTS

1. Holmes Balfour LWMS

LOTS 1, 2, 23, 24 HOLMES STREET, 1600 & Pt. 1601 BALFOUR STREET, SOUTHERN RIVER

LOCAL WATER MANAGEMENT STRATEGY

PREPARED FOR MAMMOTH NOMINEES

NOVEMBER 2015
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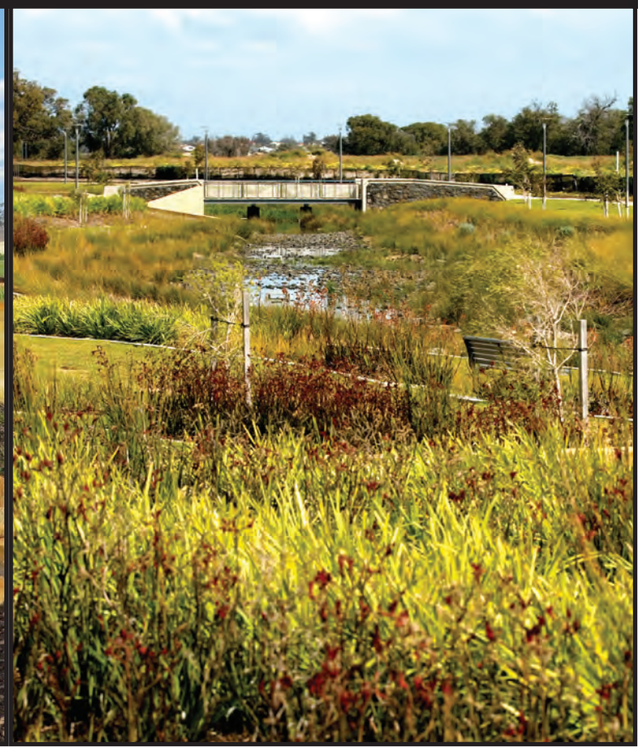

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DOCUMENT CONTROL
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EXECUTIVE SUMMARY

This Local Water Management Strategy (LWMS) articulates the range of management practices that are being considered for the proposed subdivision of Lots 1, 2, 23, 24, Holmes Street and Lots 1600 and Part of Lot 1601 Balfour Street, Southern River. The LWMS supports the Outline Development Plan being undertaken for the site. For ease and clarity, this area will subsequently be referred to as the subject area. The proposed layout of the site, including lots are shown in *Figure 3*.

The LWMS is specifically for the above lots however, due to the related nature of the surrounding land, it takes into account water management issues for the entire related catchment. The site's relationship to the greater Southern River area can be seen in *Figure 1*.

The objective of this LWMS is to detail a development that manages the total water cycle in a sustainable manner. This includes water conservation, stormwater management, groundwater management and management of associated water dependent ecosystems. It also follows the water management strategies outlined in the Southern River integrated land and water management plan. A full summary of the water management strategies can be found in the Key Elements (Section 1). In brief the site will manage stormwater as per the design parameters of both the Holmes and Balfour drainage systems. Larger events will be detained within the on site wetland. Stormwater is to be treated through bioretention gardens. All lots are to be fully serviced and POS area will be irrigated from groundwater. Suitable protection of the wetland is also provided and enhanced through revegetation and setbacks.

SUBJECT LAND DETAILS

The subject land is situated in the locality of Southern River, within the municipality of the City of Gosnells. The subject land is located approximately 20 kilometres south-east of Perth and approximately 5 kilometres from the Gosnells City Centre.

The subject land is bounded by Holmes Street and Balfour Street, Lots 1604 and the remainder of Lot 1601. The subject land has a total area of approximately 17.56 hectares.

The subject land is zoned 'Residential Development' under the City of Gosnells Town Planning Scheme No. 6 (TPS No. 6).

Part of the subject land, as well as the adjoining areas on Lot 1601 and Lot 1604 is within Bush Forever Site No. 125, which is zoned Parks and Recreation under the Metropolitan Region Scheme.

The proposed development is predominantly for residential development, with two large areas given over for Wetland Conservation and Bush Forever.

The residential lots will consist primarily of R25 with some R40 Lots. The POS and Reserve areas maximise protection and enhancement of the wetland system on the subject land and adjoining lots. These wetland areas also assist with flood storage and natural drainage of the sites stormwater.

The subject land has previously been partly cleared with agricultural activities taking place. There are some areas of bushland (including wetland vegetation) present across the site which is in a range of condition from Completely Degraded to Excellent. Parts of the site have recently been filled with clean sand.

The land is currently drained through a series of shallow spoon drains and surface sheet flow which discharge water into and through the onsite wetland and eventually into the Balfour Street Drain. This then drains to the Sutherland Drain and ultimately the Southern River.

The wetland system covers the middle sections of the subject land and interconnects with a broader wetland chain to the north and south. These wetlands have been classified as Multiple Use, Resource Enhancement and Conservation Category.

The key water management aspects relating to the subject land are detailed in the following Key Elements section. The Key Elements section summarises the design elements being adopted for the proposed development to comply and achieve the required design objectives for total water cycle management.

SUPPORTING DOCUMENTATION

The LWMS designs and models were compiled using information contained within the detailed assessments and reports undertaken for the subject land, they are listed below:

- Proposed Outline Development Plan Southern River Precinct 2 – Phase 3 Lots 1-4 , 1600 And Pt Lot 1601 Balfour And Holmes Street, Southern River. RPS
- Wetland Management Plan Lots 1-4 Holmes Street and Lot 1600 Balfour Street, Southern River. Endemic
- Lots 1-4 Holmes St and Lots 1600 and Pt Lot 1601 Balfour St, Southern River Flora and Vegetation Survey and Wetland Assessment. Cardno BSD
- Lots 1- 4 Holmes St and Lots 1600 &1601 Balfour Street, Southern River Review of Groundwater Levels
- Lots 1- 4 Holmes St and Lots 1600 &1601 Balfour Street, Southern River Conceptual Stormwater Modelling
- Lots 1,2,3,4 and 1600 Balfour Street Southern River Western Australia Geotechnical Investigation. Brown Geotechnical and Environmental
- Southern River integrated land and water management plan. Department of Water

Figure 1 - Location Plan

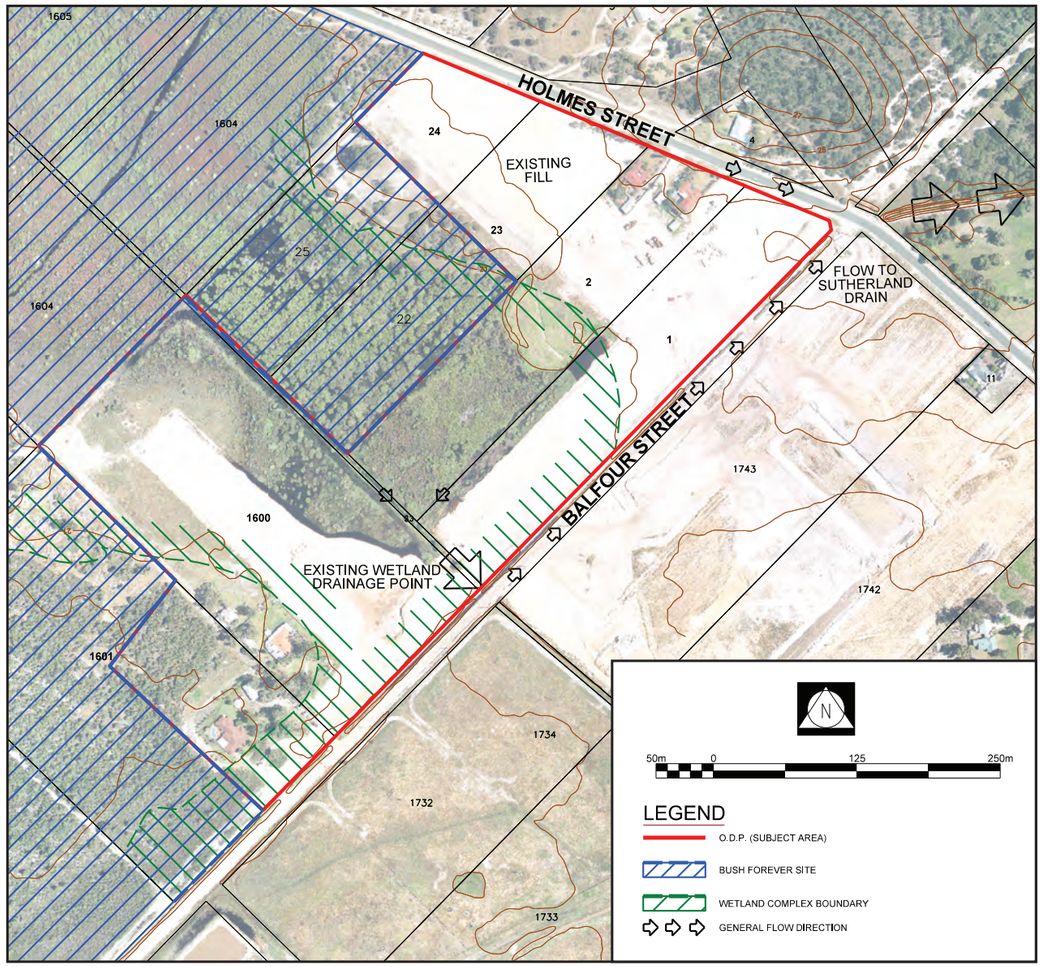


Figure 2 - Context Plan

1. KEY ELEMENTS

Water management for the proposed subdivision of the subject land is based on best practice water sensitive urban design. This is achieved through maximising the sustainable use of water through the encouragement of water conservation and efficiency measures, managing stormwater to irrigate bioretention gardens and recharge groundwater while controlling the flow of large storm events, managing the water quality reaching the area's significant ecosystems, as well as protecting and enhancing the sites wetlands.

A summary of the design elements and compliance with the best management practices objectives are outlined below with more detail provided in the sections that follow.

SUMMARY OF DESIGN ELEMENTS AND COMPLIANCE

WATER CONSERVATION

- The State Water Plan target of 100 KL per person per annum has been set for the subdivision.
- Encouragement of water efficient fixtures and fittings for all buildings constructed. Data suggests that a household on average per annum could save between 31 and 46 KL inside the house alone using adequate water efficient appliances and fixtures.
- Lot owners will be encouraged to install a minimum 3,000 litre rainwater tank that is plumbed into the toilet and laundry. The tank could reduce the quantity of mains potable water required for gardens and other outdoor purposes by 30KL per annum.
- Provision of awareness raising material on water saving measures and benefits for new residents, including Waterwise information booklets.
- Public open spaces and street landscaping will have a strong focus on using suitable local native Waterwise species and the retention of existing remnant native vegetation which require minimal irrigation.

FLOOD PROTECTION

- Finished floor levels are to be a minimum of 300mm above the kerb level and 500mm above the 1:100 ARI flood level of the adjoining wetland.
- The drainage network (designed for 1:5 ARI) will flow at capacity during the 1:100 ARI flood event and excess water will be directed down the road reserves to protect houses. Flows will be directed to the POS wetland area in the middle of the subdivision as well as onto Holmes and Balfour Street as currently happens in the pre development state. The POS area and associated wetland system, will store part of the 1:100 ARI flood event and help control the flow off the site onto Balfour Street and its drain.

STORMWATER MANAGEMENT

- Bioretention gardens and associated road batters are to be installed within the road reserves of the site. These will store and treat all flows up to the 1 year 1 hour 1:1ARI storm event.
- Soak wells, will be utilised for excess roof runoff for lots above 350m^2. A shared lot connection is to be supplied to all lots 350m^2 and less.
- Shallow swales/basins will hold and infiltrate flows up to and including the 1:5 ARI event around the central wetland. Perimeter catchments will discharge their flows above the 1:1 to the Holmes and Balfour Street drains at the rates set by previous modelling.
- All lots will manage the 1 in 20 year 5min ARI within the lot.
- The wetland system on site and on adjoining properties will assist with containing and releasing stormwater from events above the 1:5 ARI.
- Sediment and erosion management plans are to be produced and implemented in relation to construction works.

WATER QUALITY

- Water sensitive urban designs are to be installed including bioretention gardens and swales. These will remove sediments, large debris and nutrients from all stormwater generated within the road reserve.
- The public open space landscaping will focus on utilising native species with low nutrient requirements to reduce nutrient leaching.
- Households will be informed regarding nutrient wise garden practices, and be given packages to educate themselves about minimising lawn area and construction of Waterwise and nutrient wise gardens.

GROUNDWATER MANAGEMENT

- Groundwater levels will be maintained to the pre-development state through the use of subsoil piping set at the AAMGL.
- The function performed by the outlet drain from the central wetland to Balfour Street in controlling peak groundwater (and wetland) levels will be maintained by a piped outlet set at the same invert level. This will allow for groundwater levels to be maintained at their current AAMGL.
- Fill is to be used to maintain appropriate separation from the groundwater level to necessary infrastructure, with a minimum of 500mm clearance provided after mounding during 1:5 ARI events.
- Subsoils are to incorporate a filter media to treat inflowing groundwater for pollutants, including nutrients hydrocarbons and excessive metals.

ECOSYSTEM MANAGEMENT

- The site's wetland systems will be protected and enhanced through an appropriate buffer system including revegetation with appropriate native species.
- Stormwater will be treated and infiltrated on site to allow for maintenance of the groundwater level and quality that currently feed the wetland.

Figure 3 - Key Elements Plan

2. ENVIRONMENTAL

A Flora and Vegetation Survey and Wetland Assessment: Lots 1-4 Holmes St and Lot 1600 and Pt Lot 1601 Balfour St, Southern River was undertaken by Cardno BSD in 2007. This included both autumn and spring surveys. It is recognised that some of the condition assessments in this report are not fully supported by the City.

Further management strategies for the site were then outlined in the Wetland Management Plan Lots 1-4 Holmes St and Lot 1600 Balfour St, Southern River, which was written by Endemic in 2008 and updated in 2010. This report has been used to determine appropriate management of the wetland area ratherthen relying solely on the Cardno report. The following is a summary of this information as well as a site visit undertaken by Calibre Consulting.

Large portions of the site have historically been cleared or partly cleared then grazed by stock, which has resulted in degradation of the vegetation. The condition of the vegetation prior to filling can be seen in *Figure 5*. The subsequent fill areas have had all vegetation removed. The better quality vegetation tends to be in Lot 1601 (including areas outside of the original vegetation surveys) and the wetland system through the middle of the site.

WETLANDS

A wetland system occurs on the site that is composed of a number of different wetlands as defined by DPaW. These are outlined in *Figure 4* and *Table 1*.

This wetland system continues to the north west of the site on adjoining lots. This area is also part of Bush Forever Number 125.

WATERWAYS

There are no natural waterways on site.

Surface water discharges from the site via a shallow open drain network to the Sutherland Park Branch Drain System that then flows to Southern River and eventually the Swan Canning system. The Southern river is an seasonal flowing system that is known to experience poor water quality, mainly from high nutrient loads, from time to time.

FLORA

91 taxa were identified during the three site surveys, of which 50 were native species.

No Declared Rare Flora were located. The only Priority Flora noted was *Jacksonia sericea* which was located in Lot 1601 and out of the wetland habitats.

4 main plant communities occur on the site, two mainly composed of native species and two that have been cleared and developed for rural pursuits.

The following two communities are associated with the wetland habitats. These are:

S1 Community - Thicket to Shrubland of *Melaleuca rhaphiophylla* over *M. incana subsp incana* and *M. teretifolia* over *Lepidosperma longitudinale* and *Juncus pallidus*.

R2 Community - Composed of pasture grasses with isolated *Melaleucas*. This area has historically been heavily grazed.

These areas can be seen in *Figure 6*, shows the site conditions prior to fill being applied.

FAUNA

There are no dedicated fauna studies for the site however the wetland assessment has covered element of likely fauna present.

Species likely to be associated with the wetland habitats on site include :

Amphibians - *Crinia Georgiana* (Quacking Frog), *C glauert* (Glauert's froglet), and *C. insignifera* (Sign bearing frog)

Reptiles - *Cryptoblepharus plagiocephalus* (Skink), *Lerista elegans* (Four toed leristas), *Menetia greyii* (Skink), *Tiliqua rugosa* (Shingleback), *Lialis burtonis* (Burton's legless lizard), *Morethia obscura* (Skink) and *Acritoscincus trilineatum* (Skink).

Mammals – *Isoodon obesulus fusciventer* (Quenda), (Western Brush Wallaby), (Water Rat) and to a lesser extent the (Western Grey Kangaroo), *Chalinolobus gouldii* (Gould's Wattled Bat) and *Nyctophilus geoffroyi* (Lesser Long-eared Bat)

Birds – Australasian Grebe, Pelican, Eurasian Coot, Purple Swamp Hen, Little Black Comorant, Little Pied Cormorant, White Necked Heron, White Faced Heron, Nankeen Night Heron, Straw Necked Ibis and Australia White Ibis. Some other more terrestrial species may also use the wetland habitats during dry periods.

Bush Forever Site 125, which extends into the subject site, has been identified as an important breeding site for waterbirds including the Freckled Duck.

Wetland Number	Classification	Vegetation Condition/ Community
14280	CCW	Degraded (Lots 3 & 4), Excellent and Good (Lot 2). S1 Community
13985	REW	Degraded. S1 Community
13986	REW	Good. S1 Community
13987	REW	Completely Degraded. R2 Community

Table 1 - On-site Wetlands

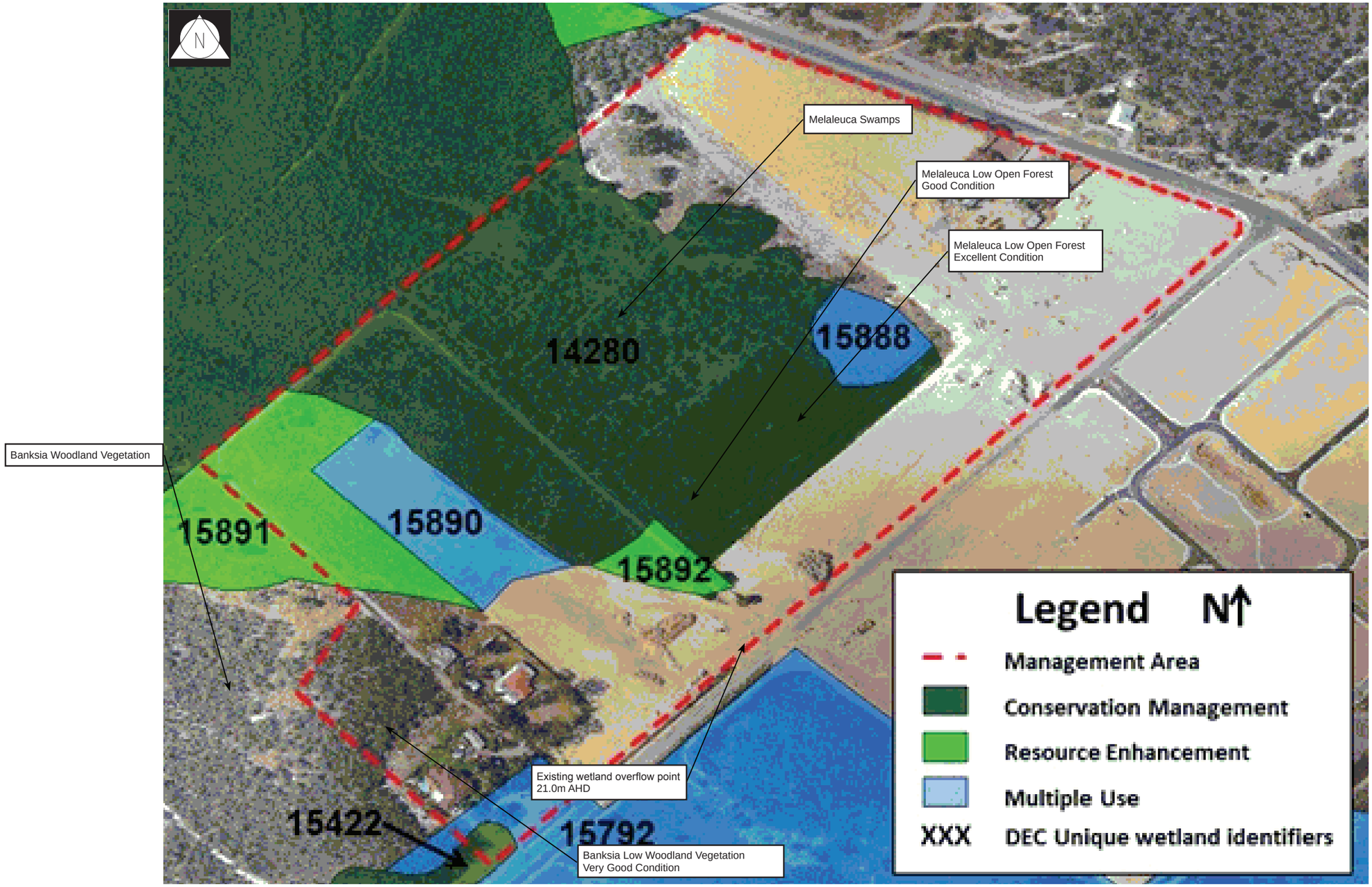
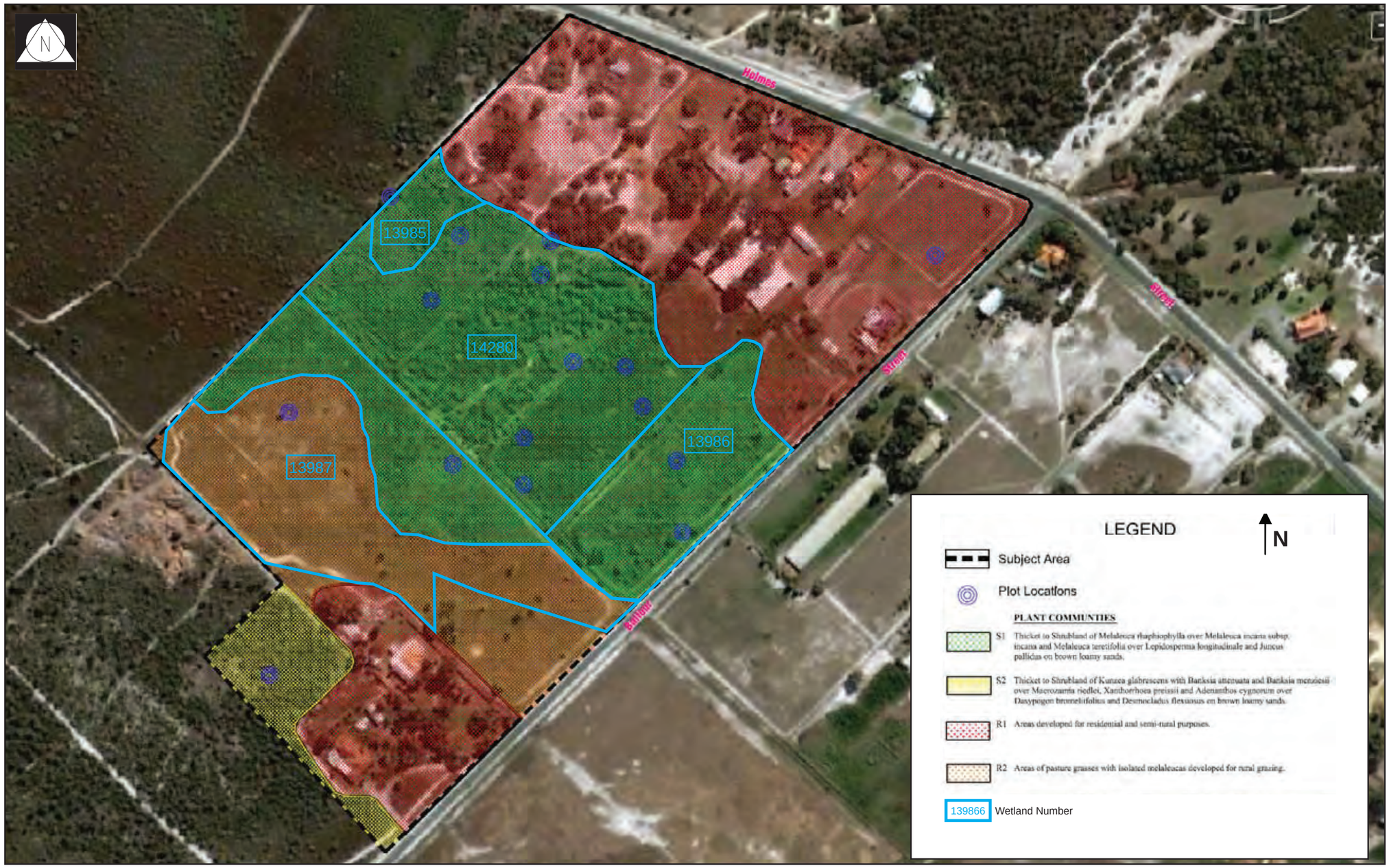


Figure 4 - Environmental characteristics

(Original Information, Cardno 2007)(Re Referenced from Wetland Management Plan, Lot 1-4 Holmes St & Lot 1600 Balfour St, Southern River, 2015)

Figure 5 - Vegetation Condition prior to recent filling



(Original Information, Cardno 2007)(Re Referenced from Wetland Management Plan, Lot 1-4 Holmes St & Lot 1600 Balfour St, Southern River, 2015)

Figure 6 - Vegetation Type prior to recent filling

3. GEOTECHNICAL INFORMATION

Geotechnical investigations were undertaken by Brown Geotechnical and Environmental Pty Ltd. The results were outlined in the report Lots 1,2,3,4 & 1600 Balfour Street Southern River Geotechnical Investigation. Field tests were undertaken on the 22nd and 23rd January 2008. 35 test pits were excavated using a 5 tonne excavator to a maximum depth of 2.9m. The investigations were undertaken prior to the majority of the fill being laid.

A second investigation was undertaken to determine permeability of the fill sand on the 23 July 2010 by TME.

LOCAL AND REGIONAL GEOLOGY

The environmental Geology sheets for the area indicate Bassendean Sands as well as deposits of peaty sands.

SOIL TYPES

The field studies showed the site to be generally underlain by a thin layer of topsoil, which is predominately grey sand with some roots. Under this there is a medium dense to dense grey sand of medium grain to approximately 1m depth. Below 1m there are areas where thin horizons of silty sand and gravel occur.

In the south west corner of the site and adjacent to the Bush Forever area there are soils composed of sand with gravel and/or silt over sandy clay/clayey sand below 1.5m.

There were isolated patched of coffee rock encountered across the site at depths from 1m to 2.4m.

ACID SULPHATE SOILS

No acid sulphate soil testing has been undertaken

Department of Environment and Conservation ASS mapping of the site indicates a low to moderate risk for the top 3m of the soil profile for the northern and southern parts of the site where the sand rises are located. A moderate to high risk is indicated for the middle of the site, which corresponds to the wetland area.

Further investigation may be needed in areas where excavation will take place below the groundwater, or dewatering is to be undertaken.

SITE CLASSIFICATION

The sandy nature of the site gives the majority of the site a classification of Class A. A small area of Class S has been identified in the southern corner. This can be bought up to Class A using appropriate fill and laying methods.

PHOSPHORUS RETENTION INDEX:

The Phosphorus Retention Index for the sites soils was not tested. It is likely to be low based on the soil type of Bassendean sands.

INFILTRATION/PERMEABILITY

The sand fill on site has a permeability of between 5.09x10^{-5}m/s and 8.88x 10^{-5}m/s (4.39 to 7.66 m/d). This is adequate for seepage from soakwells. The location of the permeability test pits can be seen in *Figure 9*. (Page 3 of permeability report with the result of each underneath)

FILL CHARACTERISTICS

Since the completion of the first Geotechnical Investigation, fill has been laid over parts of the subject land. This fill is composed of clean sand and is on average 1.2m deep.

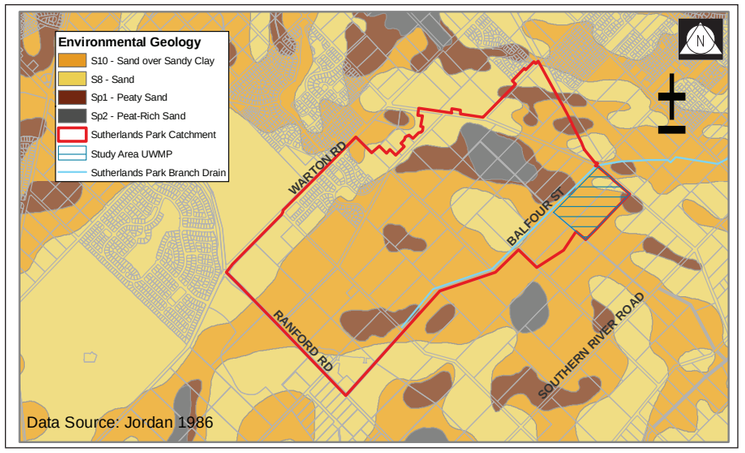


Figure 7 - Environmental geology

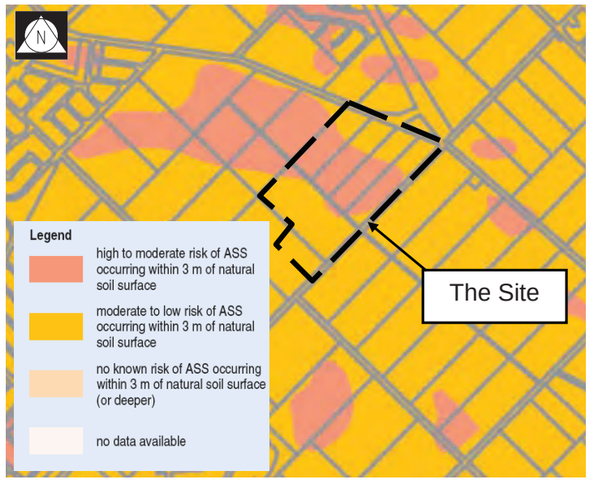


Figure 8 - Acid Sulphate Soil Risk

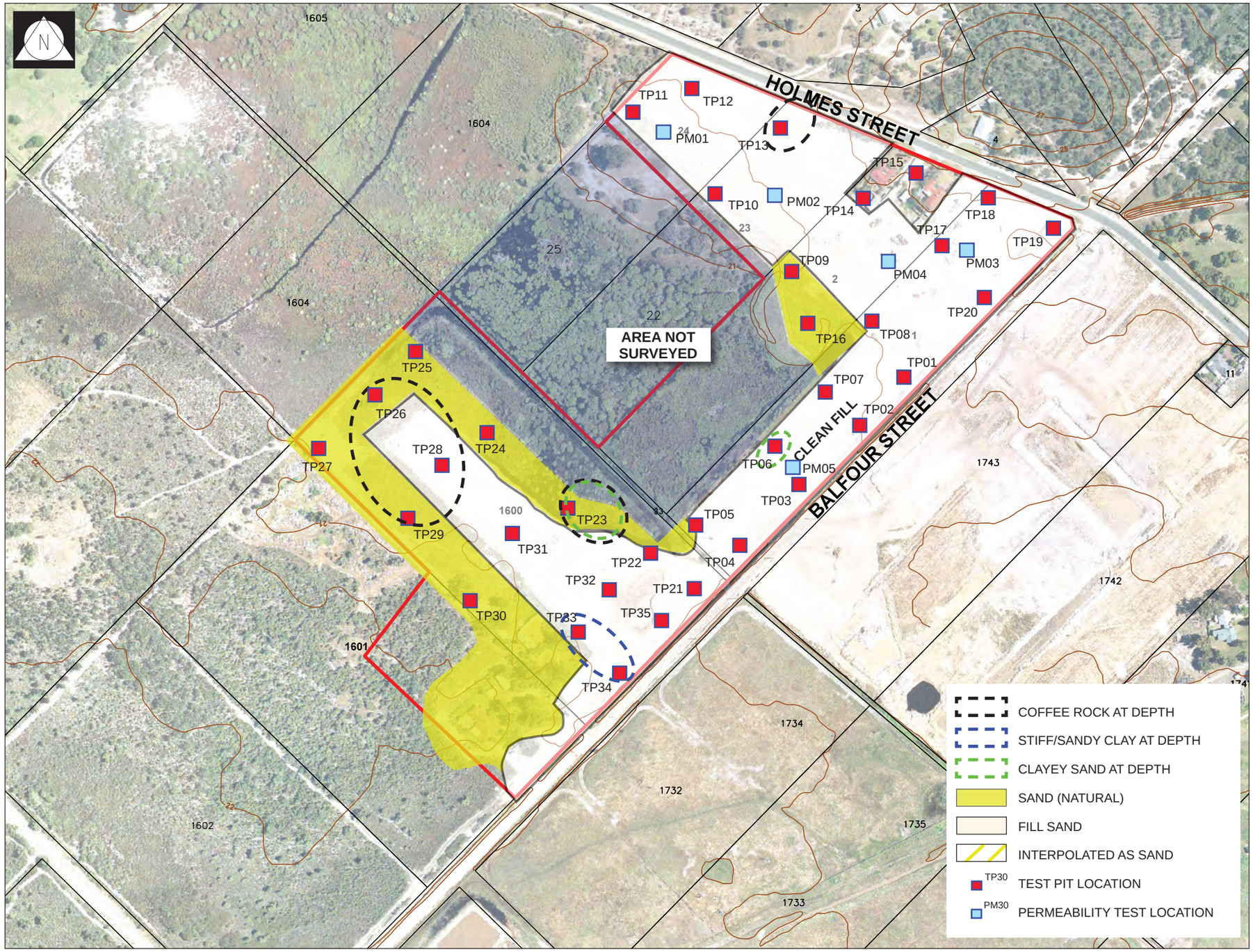


Figure 9 - Geotechnical Information

4. LANDFORM

The subject area is composed of two main landforms, seasonal wetlands and sand rises.

A natural sand rise occurs along the north – north east section of the site. Prior to fill this was approximately 23mAHD in height. The majority of this sand rise is now covered with sand fill with an average height of 23 -23.5m AHD,

Another small sand rise is located within Lot 1600 and 1601 with a maximum height of approximately 22mAHD. A thin portion of Lot 1601 now contain sand fill, with the fill height being 23.5m AHD.

The central portion of the site is a seasonally inundated wetland. This wetland is relatively flat in nature with an average height of 20.5m AHD. The lowest point is around 19.8m AHD. The wetland continues to the north west at a similar height.

The slopes between the wetland edges and the top of the sand rises are mainly between 1 and 5%.

The location of the sites landforms can be seen in *Figure 11*.

The sand rises will tend to have low runoff rates due to the soil type and flat nature. The run off rates for the wetland will be low until the groundwater has risen to the surface, due to the very flat nature and sandy soils of this landform. Once the wetlands are inundated, the flow rate will increase, however it is controlled by the exit drain on site. The majority of rainfall that falls on the inundated wetland will flow from the wetland to the drain during these periods of inundation.

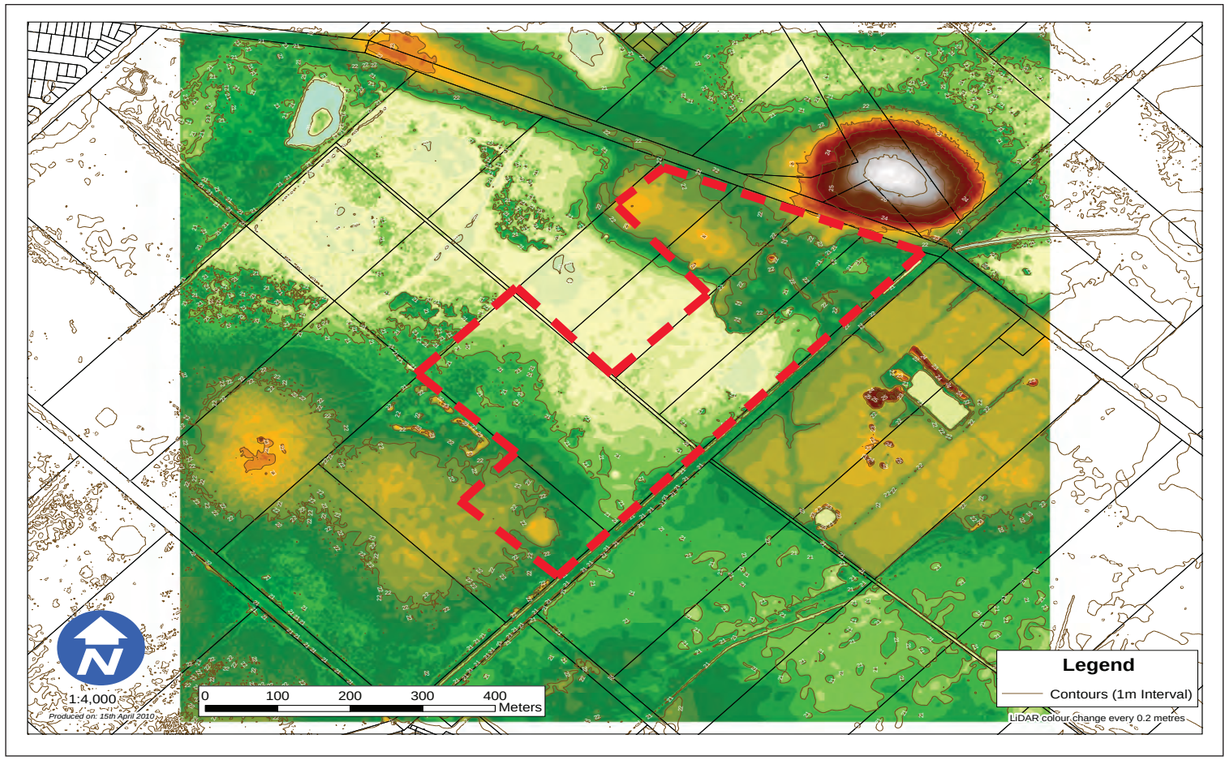


Figure 10 - LIDAR Mapping prior to filling

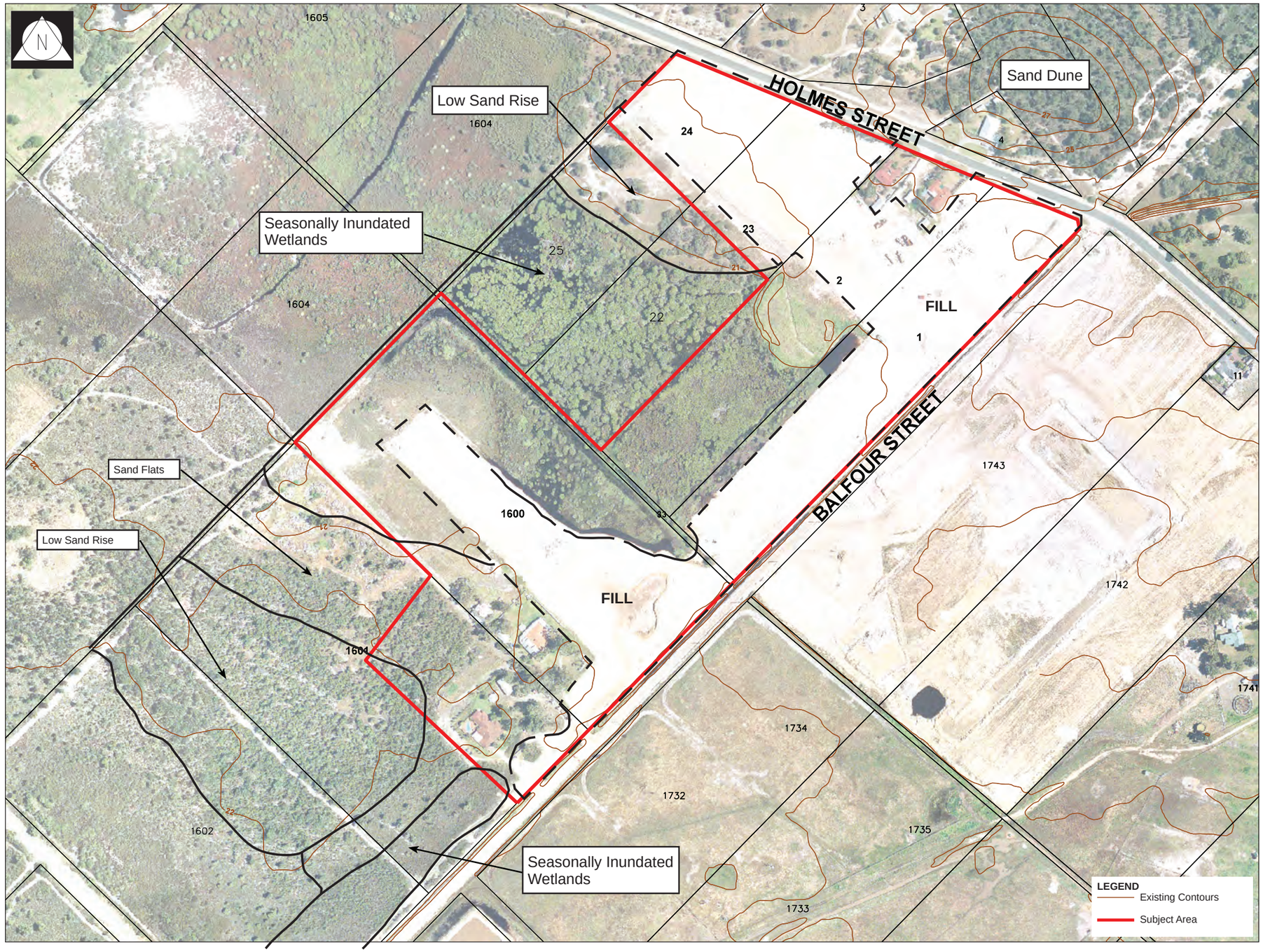


Figure 11 - Existing Landforms

5. SURFACE WATER (PREDEVELOPMENT)

Drainage analysis was undertaken by JDA as part of assessment of the capacity of the Balfour St and Sutherland Park Drains. This work was further refined for the structure plan area and summarised in the Lot 1-4 Holmes St and Lots 1600 and 1601 Balfour St, Southern River Conceptual Stormwater Modelling (attached). The report investigated pre development runoff and the current capacity of Balfour Street Drain. The modelling included both INFIL and XP-STORM.

The following is a summary of this information and on site assessments in relation to the pre development scenario for the subject land.

Much of the rainfall that currently falls on the site percolates through to the groundwater. This means that there is initially little surface runoff from the site. Once this groundwater rises to the surface in the middle of the site, in the form of a wetland, it can potentially exits via a control pipe to Balfour Street. There is also some minor runoff onto the swale drain along Holmes Street and directly to Balfour Street.

The Balfour Street Drain enters the Sutherland Park Drain before eventually connecting to the Southern River. This can be seen in *Figure 12*.

There are 3 main sub-catchments within the subject land area.

Sub-catchment 1 flows to Holmes Street directly.

Sub-catchment 2 flows to Balfour Street directly

Sub-catchment 3 flows into the wetland complex.

Indicative catchment boundaries can be seen in *Figure 13*.

SUB-CATCHMENT 1

This sub-catchment flows off the sand rise created by the on site fill and natural features to Holmes street directly. This is a thin catchment that stretches almost parallel to Holmes Street. Water that enters the swale along Holmes Street either infiltrates or flows south eastward and into the Balfour Street drain.

SUB-CATCHMENT 2

This sub-catchment has also been created by the introduction of fill, which loosely follows the original contours of the site. Flows from this area discharge to the Balfour Street reserve, before entering the recently installed drainage pits of the Balfour Street Drain.

SUB-CATCHMENT 3

This is the largest catchment on the site. The majority of the site flows directly into the central wetland complex. There is some overland flow after extreme events from the south western side of the fill and subject area that heads north into the wetland complex in Lot 1604. This is the same wetland complex as located on the subject land. Once the water in the wetland reaches 21mAHD, it discharges to the Balfour drain via a 225mm drainage pipe.

A number of shallow spoon drains cross this wetland complex, which assist with moving water across the wetland to the drain outlet.

SURFACE WATER FEATURES

The main surface water feature on site are the wetlands including two Conservation Category Wetlands, three Resource Enhancement Wetlands and two Multiple Use Wetlands. These wetlands in effect act as one wetland complex. The wetland boundaries can be seen in *Figure 4*. The total wetland boundary can be seen in *Figure 2*. These are all seasonal wetlands.

There are also a number of small constructed drains, which traverse the wetland area before discharging to the Balfour Street Drain. Their location can be seen in *Figure 13*.

SURFACE WATER QUALITY

No quality data has been collected from the site. The lack of waterways means that the only surface water, except for during storm events, is the wetland. This is connected directly to the regional groundwater and is therefore likely to have a similar quality to that shown in *Table 3*. Pre development information needs to be collected prior to the production of the UWMP.

Drain from wetland to Balfour Street

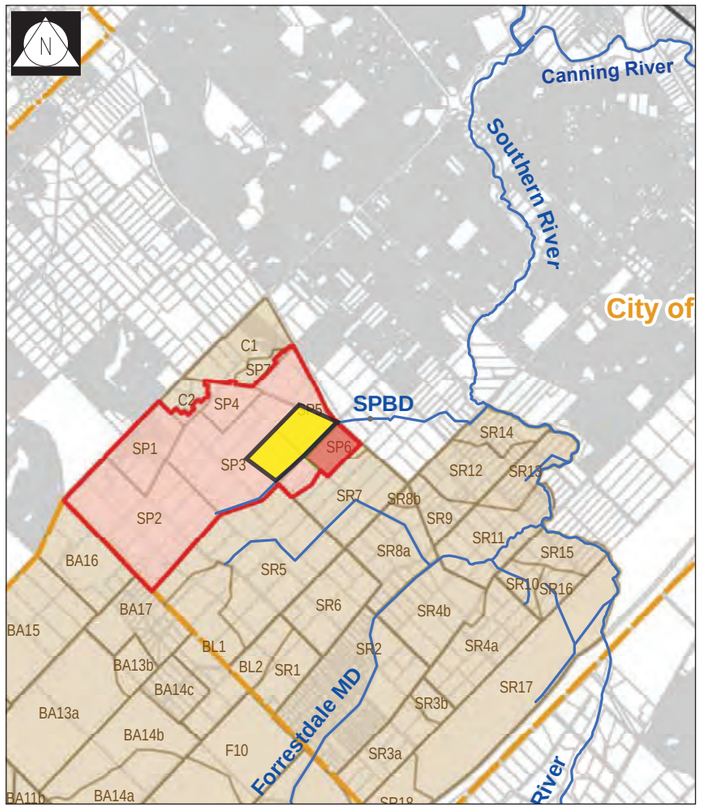


Figure 12 -Regional Drainage

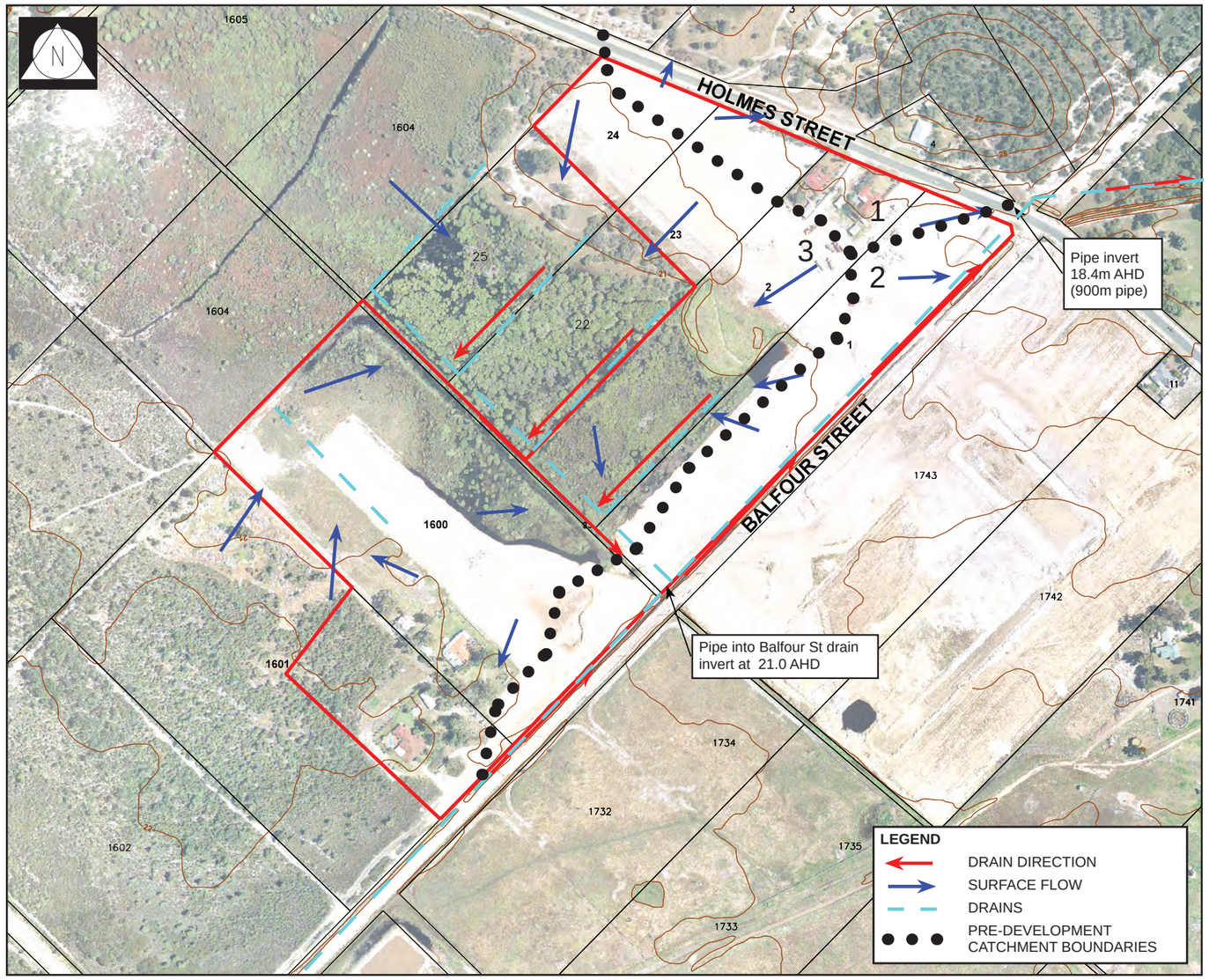


Figure 13 -Surface Water

6. GROUNDWATER PRE-DEVELOPMENT

SHALLOW SUPERFICIAL AQUIFER

Groundwater Monitoring of the superficial aquifer has been undertaken for the subject land area and the adjoining Lots1742 and 1743 to the south east. This monitoring and analysis of the AAMGL was undertaken by JDA.

7 bores were installed in September 2008 on the subject land to a depth of around 5m and have been monitored over two years. The bore field can be seen in *Figure 14*.

LEVELS AND AAMGL

Monitoring data collected over two years was analysed in reference to longterm Department of Water Bores. The effect of the site's landforms and drains was also considered.

Analysis of the longterm data suggested that the 2 years of monitoring were slightly drier than average which may of suggested that the groundwater levels may be higher in an average year. However the groundwater is more likely controlled by the on-site drain which allows for water in the wetland to exit to the Balfour Street drain (invert at 21m AHD). Given that in both years the groundwater for the site caused inundation of the wetland and flowed out through this drain, it is likely that the results recorded in both years are close to the maximum level for the site. Groundwater is unlikely to rise higher as it would generally run offsite through the open drainage system.

Table 2 shows a summary of the AAMGL levels for each bore on the site and its relationship to the surface of the site. The depth varies from 2.22m below the surface to ponding above the ground in the wetland areas.

The AAMGL falls from just over 21m AHD through the wetland and to the west and south of the site to just below 20m AHD in the north east corner close to the Balfour Street Drain. For most of the site the contours are very flat. This is due to the wetland feature over the majority of the portion of the site and the influence of the small surface drain which controls the wetlands level. There is however a localised decline in the contours in areas near the Balfour Street drain as can be seen in *Figure 14.*

Groundwater levels were also recorded as part of the Geotechnical studies for the site. The results from the geotechnical study support the information found in the long term groundwater monitoring program.

Minimum groundwater levels were also recorded and are outlined in *Table* 3.

QUALITY

As part of the groundwater monitoring, a range of quality parameters were recorded. The following is a summary of the results from the subject land. Full details can be found in the CD of attachments. Further monitoring that identifies the predevelopment organic nutrient status is to be undertaken prior to the UWMP being produced.

PH

The pH tends to fluctuate between acidic (4.6) to almost neutral (6.85). This may indicate Acid Sulphate soils (ASS). It is recommended that further investigation be undertaken into ASS as part of future planning for the site. There was no general trend in pH levels between bores or throughout the season except for a general rise in pH between May 2008 and September 2008, with another rise between March 2009 and May 2009.

ELECTRICAL CONDUCTIVITY

Electrical Conductivity was used as a reference for salinity. The conductivity for all bores other that H3 was fairly consistent throughout the monitoring period. For these bore the values fluctuated between 0.21mS/cm and 2.04mS/cm. Bores H4 and H7 tended to have the lowest readings through the sampling period. These conductivities are in the fresh to brackish category.

Bore H3 had significantly higher readings at every sampling period, with its conductivity ranging from 2.86 through to 20.08mS/cm which makes it brackish to saline.

NUTRIENTS

The nitrogen levels were generally above the recommended levels of 1.0mg/L for Total Nitrogen with only 6 readings below or at 1mg/L (all in different bores). Nitrogen levels peaked at 11mg/L in bore H6 with most levels aroun2-3mg/L. There was no clear trend in levels throughout the year or between bores.

Phosphorus levels were also generally above the recommended level of 0.1mg/L for Total Phosphorus, which has been set out in the Swan Canning WQIP. Bores H1, H5 and H7 tended to have levels around 0.1 to 2mg/L, while Bores H4 and H6 generally recorded higher levels between 2.4 and 6.9mg/L. Bore H2 was generally less that 1.1mg/L but did have a spike of 7mg/L once. The only bore that was consistently below the 0.1mg/L was H3 which fluctuated between <0.01 and 0.07mg/L. These values may suggest that the site's groundwater is being affected by past and current agricultural activities on the cleared farm land, both from the subject land and surrounding areas. The nutrients are most likely moving within the groundwater and through the wetland system.

SUPERFICIAL AQUIFER ALLOCATION

The superficial aquifer in this region has some allocation available. As at July 2010 the allocation available was approximately 200,000 Kl. As can be seen from the above data, the water quality may not be suitable for domestic use without further treatment.

DEEPER CONFINED AQUIFERS

The Department of Water provided the following information on the deeper aquifers located under the subject land.

Leederville aquifer: The Leederville is represented by the Perth South Confined Sub-area at this site. It tends to be around 700m in thickness and is located below the superficial aquifer which generally extends to around 29m deep. The aquifer is currently over allocated.

Yarragadee Aquifer: The subject land is located in the Perth South Confined North Yarragadee sub area. The aquifer is approximately 3000m thick and is located below the Leederville. This aquifer is also over allocated.

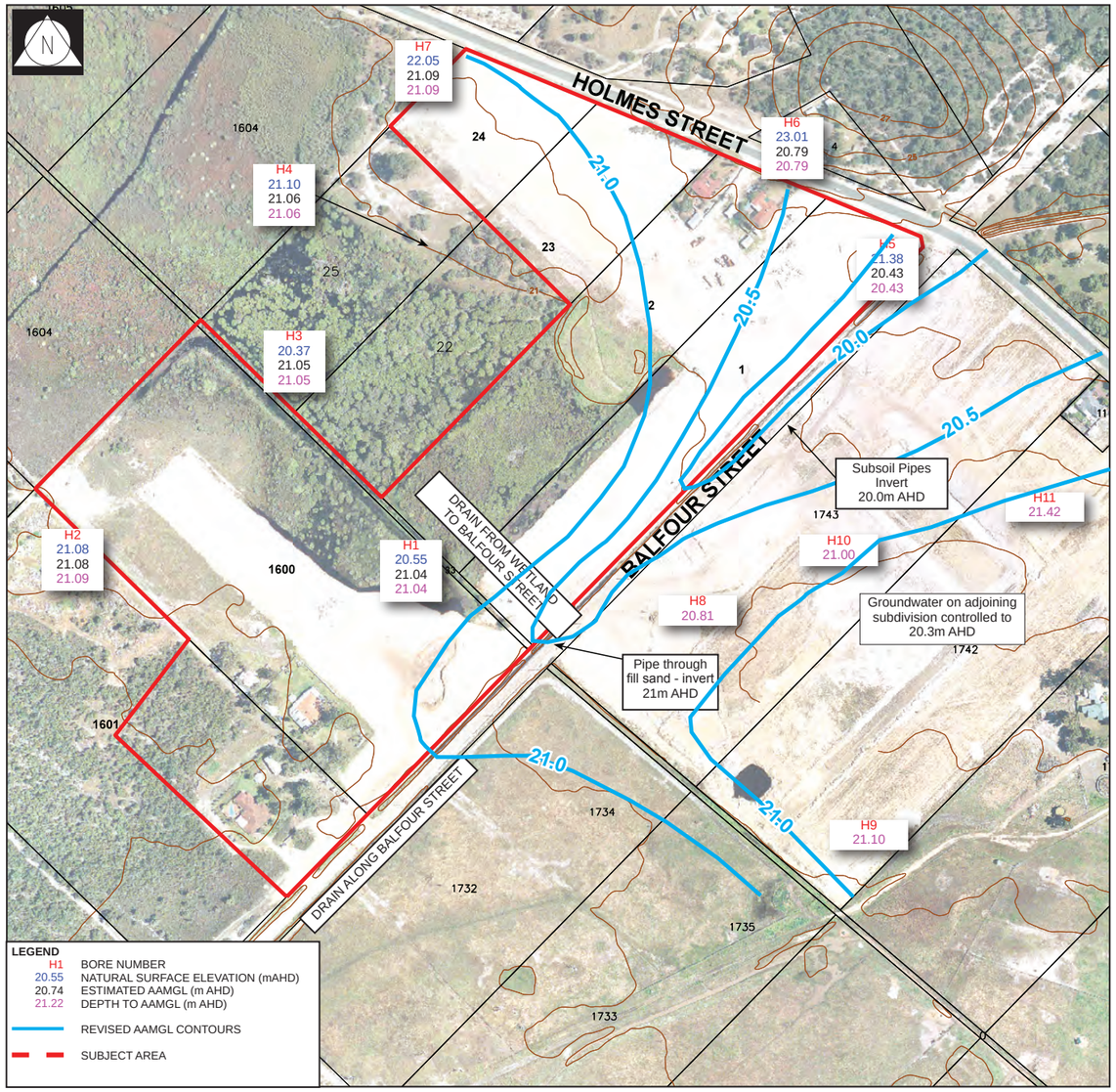


Figure 14 - Ground Water

Bore	Natural Surface level (mAHD)	Estimated AAMGL (mAHD)	Depth to AAMGL(m)	Depth to deepest recorded water level (m)
H1	20.55	21.04	Ponding above surface	1.80
H2	21.08	21.08	At natural surface	2.43
H3	20.27	21.05	Ponding above surface	2.54
H4	21.1	21.06	.04	2.48
H5	21.35	20.43	.95	2.9
H6	23.01	20.79	2.22	4.57
H7	22.05	21.09	.96	3.65

Table 2 - Groundwater Water Levels

Bore	Electrical conductivity (mS/cm)		pH		Total N (mg/L)		Total P (mg/L)		Total Suspended Solids (mg/L)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
H1	0.41	1	5.4	6.85	0.07	9.4	0.16	0.47	150	230
H2	0.28	2.04	4.65	6.45	1.5	9.1	0.58	7	9	960
H3	2.86	20.08	4.97	6.29	0.47	4.1	0.01	0.07	160	900
H4	0.16	0.27	5.1	5.86	0.6	3.3	3.7	6.9	110	120
H5	0.19	1.16	4.6	5.56	0.83	9.1	0.09	2	16	210
H6	0.31	1.14	5.59	6.24	0.86	11	3.1	6.3	20	530
H7	0.21	0.32	5.06	5.8	1	2	0.38	1.4	21	78

Table 3 - Groundwater Quality

7. DRAINAGE MANAGEMENT PLANS

The objectives of the drainage management of surface flows for the subject area is to mimic as close as possible the pre-development flows leaving the subject land and the wetland system while treating the necessary volumes prior to discharge. Stormwater discharged into the groundwater will similarly incorporate designs to mimic as close as possible the pre-development infiltration volumes and reduce nutrient and sediment loads entering the groundwater resource. Modelling has been undertaken by JDA as to the capacity of the existing stormwater drainage adjoining the site and predicted pre-development flows of the subject land. A summary of this modelling is attached (Lots 1-4 Holmes St and Lots 1600 & 1601 Balfour St, Southern River Conceptual Stormwater Modelling). Further modelling, by Calibre Consulting, for the internal catchments has also been undertaken. This was used to determine that the development can meet the latest City of Gosnells' discharge requirement of 132 l/s which is based on JDA modelling and presented in table 4A. This is significantly less than the original JDA drainage discharge rate, which looked at the actual pipe capacity.

The primary objective of the 1:1 annual recurrence interval (ARI) event drainage designs are to treat the stormwater to reduce nutrients and sediments prior to any discharge to the natural system. The priority for storm events above the 1:1 are to control the flow of drainage water throughout the subdivision and release the water from the subdivision in a controlled manner, whilst not creating any impacts to surrounding infrastructure or environments. These are represented by the 1:5 ARI and 1:100 ARI storm event scenarios.

The following three sections discuss and provide greater details of how water is proposed to be treated and conveyed in three different ARI scenarios. Also catchment boundaries, discharge points and volumes of flow are described within the respective sections.

- Section 7A – Up to and including the 1:1 event
- Section 7B – The 1:5 storm event
- Section 7C – The 1:100 flood event

The site has been divided into 13 post development catchments. The catchment boundaries can be seen in *Figure 19 and 21*.

- Catchments B1 and B3 drain to Balfour Street
- Catchments H1-H3 drain to Holmes Street
- Catchments B2, W1-W4 and E1-E3 drain to the central wetland.

These catchments have been further consolidated for modelling purposes for the 1:5 and 1:100 ARI events. More information on this can be found in the respective sections.

Catchment details including total sizes and flows can be seen in *Table 5A*.

Non-structural controls discussed in the Stormwater Management Manual of WA will be further investigated at subdivisional stages to determine appropriate and effective controls that can be implemented as part of the best management practice designs at the different stages of the development. Possible non-structural controls that may be implemented in the future have been outlined in the implementation section of the LWMS.

Name	Catchment Area (ha.)	Road Reseve Area (ha.)	Equivalent Imp. Area (80% of Road Reserve) (m^2)	Minimum Biogarden Area Required (3.5%) of Equiv. Imp. Area (m^2)	Remarks
B1	1.1377	0.345	2760	97	
W1	1.4199	0.5201	4161	146	Provide as West Swale 1 and 2
W2	1.563	0.7803	6242	218	
W3	1.1489	0.4811	3849	135	
W4	1.1463	0.4784	3827	134	
B2	0.1633	0.1632	1306	46	
B3	0.6785	0.1303	1042	36	
E1	1.6023	0.6413	5130	180	
E2	1.3365	0.4653	3722	130	
E3	1.4841	0.8302	6642	232	
H1	0.714	0.3369	2695	94	
H2	0.2577	0.0729	583	20	
H3	0.1499	0.037	296	10	

Table 4 - 1 Year 1 Hour Storage Areas

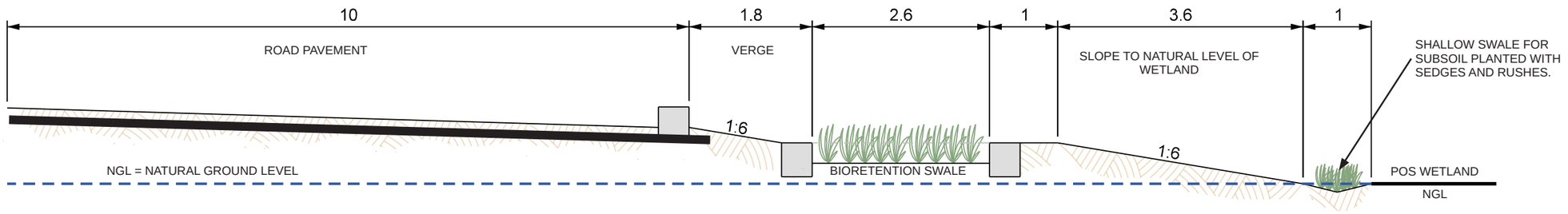


Figure 15 - Water Treatment Cross Section for area near Wetland
e.g. Catchment WS - Entire area including batters within Road Reserve

As per JDA extended area model — Allowable flow to the Balfour Street drain

Catchments	Area (ha.)	10 Year Flow (m^3/s)	100 Year Flow (m3/s)	Flow per ha. (10 Year ARI)	Flow per ha. (100 Year ARI)
SP3	86	0.197	0.456	0.00229	0.00530
SP5	37.5	0.088	0.257	0.00235	0.00685

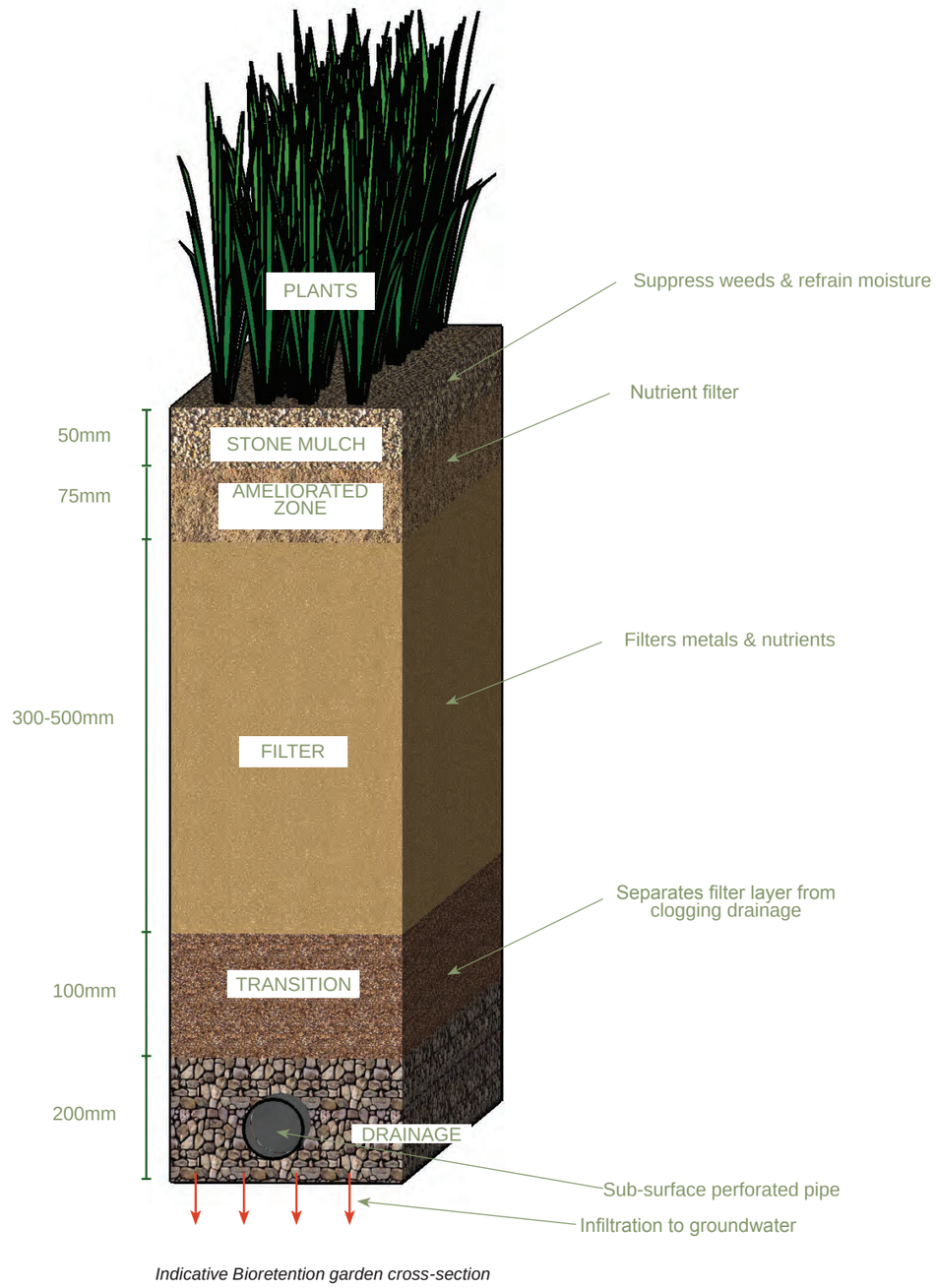
Allowable flow from the Subject Land

Catchments	Subject Land Area (ha.)	Flow per ha. (10 Year ARI)	Flow per ha. (100 Year ARI)	Allowable Flow (10 Year ARI, m^3/s)	Allowable Flow (100 Year ARI, m^3/s)
SP3 (SP3-2)	7.87	0.00229	0.00530	0.01803	0.04173
SP5 (SP5-1)	13.32	0.00235	0.00685	0.03126	0.09129
Total	21.19			0.04929	0.13302

Summary

Allowable Flow to Balfour Street Drain from the Subject Land (10 Year ARI) =	0.04929 m3/s	(49 l/s)
Allowable Flow to Balfour Street Drain from the Subject Land (100 Year ARI) =	0.13302 m3/s	(133 l/s)

Table 4a - Allowable Flow



Indicative Bioretention garden cross-section

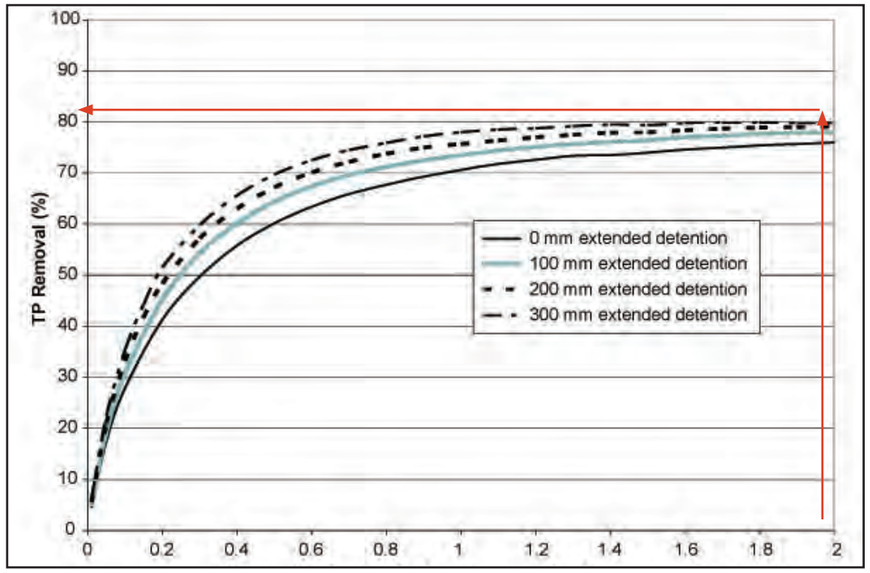
Figure 16 - Bio Garden Cross Section

Runoff Coefficients assumed for calculations

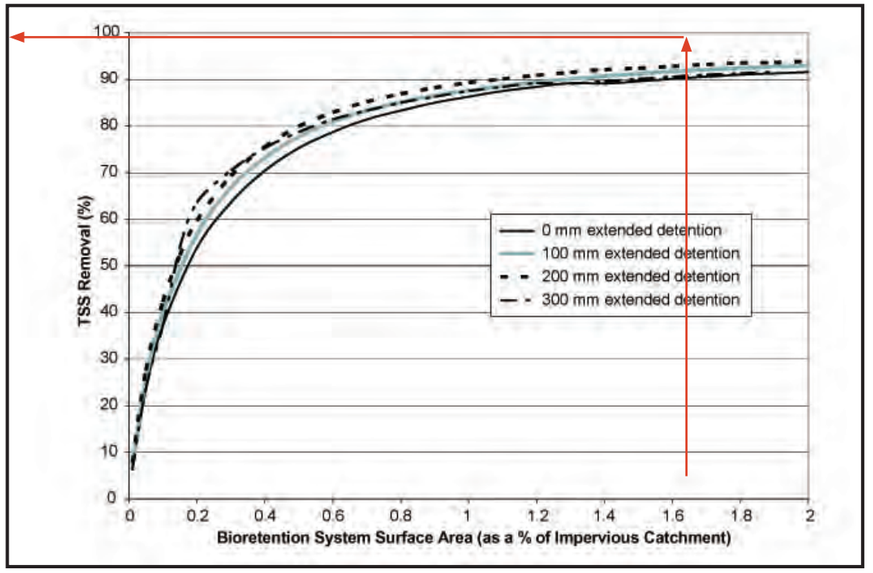
ARI	Runoff Coefficients		
	Lot (R25)	Lot (R40)	Road Reserve
1	0.56	0.64	0.64
5	0.665	0.76	0.76
100	0.84	0.96	0.96

*Note Runoff coefficients are based on 0.7 for lots and 0.8 for road reserves and lots (R40) for 10 year ARI.

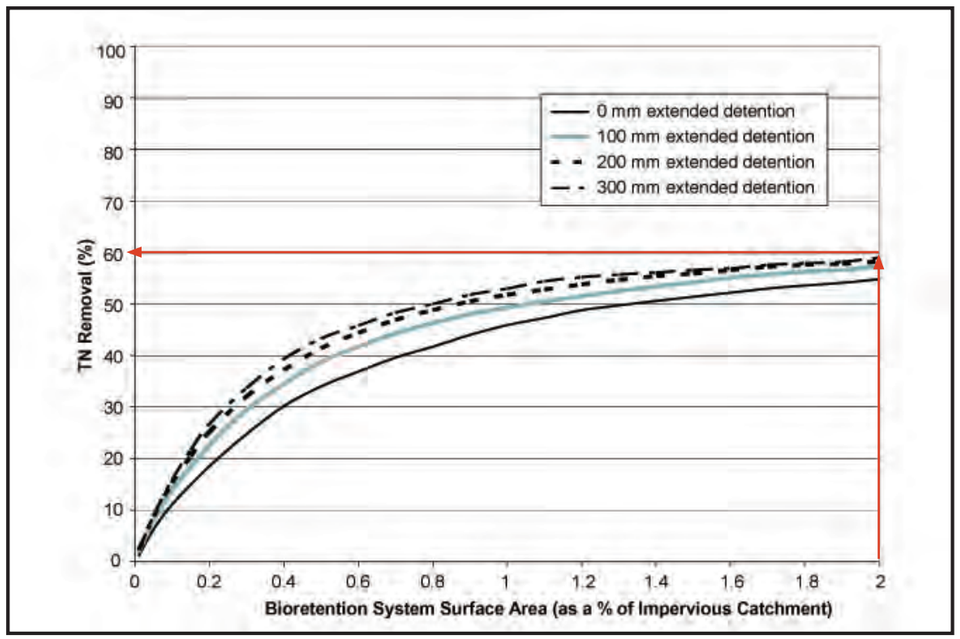
Table 5 - Run off Coefficients used



Bioretention System total phosphorus removal performance



Bioretention System total suspended solids removal performance



Bioretention System total nitrogen removal performance

Figure 17 - Typical Bio Garden Performance Graphs

7A. DRAINAGE MANAGEMENT PLAN - 1 IN 1 FLOOD

The drainage management system for the subject area has been designed to capture and provide treatment up to the 1 hour, 1 in 1 year average recurrence interval (ARI) event.

The drainage catchment and drainage points and flow direction for a 1 hour 1 in 1 ARI event are shown in *Figure 18*. The volume capacities of the bioretention gardens and swale have be designed to store and infiltrate stormwater for the 60 minute interval during the 1 in 1 ARI event. The storage of the 1yr 1 hour event provides a bioretention treatment area equivalent to 3.5%, well above the 2% area required. Indicative bioretention treatment sites are shown, subject to detail design at subdivision stage. All large swales/basins will also incorporate bioretention media and plants to achieve treatment of the 1 yr 1 hour event. All basin and soakwell infiltration has assumed a permeability of 4.8m/day to be conservative.

All lots are to manage on site the 5 minute 1:20 ARI event. This volume has been factored into the overall storage requirements for the site.

There are two main directions that drainage water will take in the proposed area; infiltration to the groundwater and surface run off. To deal with these different flow paths, two separate treatment trains have been designed.

INFILTRATION TO GROUNDWATER

The majority of the water that falls on pervious surfaces in the development area in events up to the 1:1ARI will infiltrate through to the shallow groundwater because of the high hydraulic conductivity of the proposed and existing imported clean, free draining, cohesionless sand fill over the entire site. The fines content of any additional fill should be restricted to less than 5% to promote drainage across the site.

Approximately 1.2 to 1.5 metres of fill will be required across the development to ensure that adequate separation is achieved over the static groundwater level to allow for the site's infrastructure and soak wells to be the required distances above the groundwater. All fill will be contained within the road reserves where they abut the bushland/ wetlands areas. This will be by way of retaining walls or ensuring that the toe of any batter is within the road reserve.

Subsoil pipes will be designed to control the groundwater levels and ensure soakage at the source and the conveyance of treated flows to the pipe and swale network. These are to be set at or above the AAMGL.

Rainwater tanks for each household that are sized at 2 to 3KL as a minimum will be encouraged for the development. Overflow from these or direct runoff from the rooves of houses will be directed to infiltration systems. The permeability of the fill is appropriate for shallow soak wells (actual size to be determined in UWMP based on final controlled groundwater level) on the subject land. The base of the soak wells will be installed 300mm above the Controlled Groundwater Level. Soakwells are likely to therefore be around 1m in depth. Water that enters the soak wells will infiltrate into the soil profile and ultimately the groundwater.

For modelling purpose, 300m^2 of average impervious area has been assumed per lot and 4.5m^3 of on lot storage has been provided which could be by means of rainwater tank or soak wells etc. For road reserve, a typical model for 100m^2 equivalent impervious area with 35 m^2 bio-garden of 0.3m deep has been modelled which was able to accommodate 1 year 1 hour rainfall. Hence, result shows that bio-garden with 3.5% of impervious area with 0.3m deep is capable of storing and treating 1 year 1 hour rainfall. Therefore 3.5% of equivalent impervious area (for road reserve 80% assumed) has been provided as bio-gardens. For sub-catchments draining to west swale 1 and 2, no extra bio-gardens have been proposed as west swale 1 and west swale 2 will be constructed as bio-gardens with depth 0.4m.

All stormwater modelling has assumed that there will be no on lot storage, and that the roadside system would need to cater for this water. This is a conservative approach. At the UWMP stage, when final lot sizes are known, this modelling can be refined. To assist with the movement of water off lots to the road network, all lots will be graded at 0.5 - 1% towards the road. Full earthworks models will be undertaken as part of detailed engineering design.

SURFACE FLOW

For the majority of the site, water flowing off impervious surfaces, including roads, pathways and driveways, and excess runoff from pervious areas will be directed to the edge of the roads. Here it will flow into bioretention gardens. The sizing of the bioretention gardens for each catchment can be seen in *Table 4*. These areas are based on capturing all flows generated in the 1 hour 1:1 ARI Storm event for the road reserves. To store the 1:1 1 hour event requires a storage area of 3.5% as mentioned above in infiltration and groundwater section. The total detention garden area is therefore more than 3.5% with a minimum of 2% bioretention treatment area. This storage includes a portion of the swales and basin system. The bioretention gardens will either be located part way along the edge of a road or at the end of a street or sub catchment. The indicative location for the bioretention gardens are shown in *Figure 18* with the majority located on the long side boundary of lots.

The bioretention gardens will be designed according to the FAWB Adoption Guidelines for Filter Media in Biofiltration Systems and the Stormwater Management Manual of WA guidelines and will be capable of treating all flows up to the 1hour duration 1:1ARI flood event. The typical design will be as per *Figure 16* and contain a 300mm detention depth, planted with suitable native species including sedge and rush species. Water will then infiltrate through a mulch layer and into a filter media designed to remove pollutants. Subsoil pipes will be located directly underneath or at the base of the bioretention garden. These are to be set at or above the AAMGL. Full Details of the bioretention systems will be provided in the UWMP.

The media is designed to remove nutrients, metals, suspended solids and other pollutants. This water then continues to infiltrate to the groundwater or flows into the perforated subsoil pipe below the bioretention garden. The water that enters the subsoil is then directed to the minor spoon swales adjacent to the wetland or directly into the Holmes and Balfour Street drains.

Predicted typical treatment results for the bioretention gardens can be seen in *Figure 17*.

Catchments	Total Area (ha.)	Flows (m^3/s) before Attenuation	
		5 Year ARI	100 Year ARI
Catchments Contributing to West Basin			
Cat-B1	1.1373	0.098	0.251
Catchments (Runoff retained in biogarden)			
Cat-B2	0.1633	0.022	0.065
Cat-H1	0.714	0.076	0.215
Cat-H2	0.2577	0.03	0.079
Cat-H3	0.1499	0.018	0.047
Catchments Contributing to Balfour St drain			
Cat-B3	0.6781	0.051	0.128
Catchments Contributing to East Basin			
Cat-E1	1.6023	0.153	0.393
Cat-E2	1.3365	0.123	0.307
Cat-E3	1.4868	0.118	0.299
Catchments Contributing to West Swale -2			
Cat-W1N	0.6095	0.063	0.173
Cat-W2	1.563	0.167	0.471
Cat-W3	1.1489	0.109	0.281
Cat-W4	1.1463	0.108	0.281
Catchments Contributing to West Swale -1			
Cat-W1S	0.5167	0.058	0.167

Table 5A - Flows

Figure 18 - 1 in 1 Year ARI Water Treatment Plan

7B. DRAINAGE MANAGEMENT PLAN - 1 IN 5 FLOOD

The drainage management system for the subject area has been designed to manage the 1:5 ARI event utilising a pipe/pit system and swales, with some extra storage in street side soak wells for catchments feeding Holmes Street and Balfour Street. The main functions during events up to and including the 1:5 events are to convey the excess water into the drainage network and away from the roads and house lots. The drainage system is designed to slow the water flow, allow for partial infiltration of water, and discharge water out of the site's residential areas in a controlled manner.

For the 1:5 event, all 13 post development catchments were analysed for their rate of runoff. This was compared to the pre-development runoff scenario and capacity of the existing drainage infrastructure. The catchments and generalised flow directions are illustrated in *Figure 19*. The volumes generated, as well as the required storage are seen on *Figure 19*.

During rainfall events between the 1:1 and 1:5ARI event, flood waters will flow along the roads, flood out the bioretention gardens, where they have been incorporated within the road reserves, then flow into the pit and pipe network. This water will then flow along the pipe system to one of three systems; depending on the catchments. These catchments relate to the outlet point and are:

- West Swale 1 and 2 (W1 – W4)
- West Basin (B1)
- East Basin (E1 - E3)
- Runoff will be retained within properly sized bio gardens for catchment H1, H2 and H3

The following is a summary of these drainage paths.

DISCHARGE TO SWALE AROUND WETLAND

The storage devices around the wetland include the following catchments

Catchments W1-W4 (drain to the west swale)

Catchment B2 (drains to west Basin

Catchments E1-E3 (drain to the east basin).

The swale system is located around part of the wetland, along the edge of the road reserve. The West Swale1 and West Swale 2 are located directly to the west of the Conservation Category (CC) Wetland. The east basin is located to the east of the CC Wetland in the POS area. The west basin is on the edge of the POS area in the road reserve. The location of these systems can be seen in *Figure 19* and *Table 5B*.

Stormwater runoff above the 1:1 flows to these bio-retention swales. These swales will have a flat base, 1 in 6 side slopes. The West swale1 is 600m long with a base width of 2.6m, West Swale 2 is 100m long with a base width of 2.6m and the East Swale has a base area of 307m².

The swales are designed to hold the entire 1:5 ARI flow and infiltrate it. There will be no overtopping of the swale in all events up to the 1:5 ARI event.

This will mimic what currently happens in the pre development state, where much of the water is trapped on site in the short term, with infiltration to the groundwater.

An Infiltration rate of 8.6m/d has been adopted for the structures as recommended in geo tech report. Stormwater runoff for events >5yr ARI critical storm overflows the bio-retention swale directly into the wetland.

Flows from the wetland outlet has been modelled as a 225mm diameter low flow pipe with invert at the estimated winter groundwater level of 21.0m AHD. Utilising this system will protect the wetland from direct stormwater runoff, while still providing the necessary injection of water to feed the groundwater upon which the wetland relies.

DISCHARGE TO EXTERNAL PIPE SYSTEM

The External Pipe system includes:

Catchments B3 drain to Balfour St

Catchments H1-H3 drain to Holmes St.

As street side bioretention has been sufficiently sized for catchment H1-H3 there will be no runoff discharging to Balfour St drain system. However, there will be limited overflow in 100 year event ultimately maintaining allowable flow at Balfour St drainage system.

The storage is provided in a combination of the streetside bioretention gardens and soakwells.

All stormwater above that contained in the bioretention gardens and soakwells flows into the Holmes and Balfour St drainage system.

Based on the pre-development discharge rate set by the City of Gosnells, storage is provided for each external draining catchment to reduce flows down to this amount (refer to *Table 4A* for allowable rates). The peak 5 year event includes all of these external draining catchments plus the controlled flow from the wetland. This gives a modelled flow of 0.011m³/s for the entire site.

It is not an objective of managing 1:5 storm events to treat for quality, however the soak wells, bioretention gardens and swales will allow for some trapping and settling of suspended sediments, especially after the flood peak has passed. This is due to the slowing of water and eventual filtering processes in the soakwells, swales and bioretention gardens. This means that the water that enters the wetland later through groundwater flow will have received some treatment.

RUN OFF COEFFICIENTS

Run off coefficients for all events and land uses are shown in *Table 5B*.

Catchments	Storage Provided (m^3)				Storage Required (m3)		Remarks
	Storage Basins	Bio-gardens	Lot Retention	Total Storage Provided	5 Year ARI	100 Year ARI	
Catchments Contributing to West Basin							
Cat-B1	161	58.5	90	309.5	199.5	220.5	100 Year overflows to Wetland
Catchments (Runoff retained in biogarden)							
Cat-B2		20		20	18	21	100 Year overflows to Wetland
Cat-H1		284	45	365	106	292	
Cat-H2			22.5				
Cat-H3			13.5				
Catchments Contributing to Balfour St drain							
Cat-B3		24	76.5	100.5	100.5	100.5	100 Year ovelflows to Balfour St drainage system limiting flow to allowable limit
Catchments Contributing to East Basin							
Cat-E1	233		121.5	539	431	556	100 Year overflows to Wetland
Cat-E2			103.5				
Cat-E3			81				
Catchments Contributing to West Swale -2							
Cat-W1N	624		58.5	898.5	816.5	932.5	100 Year overflows to Wetland
Cat-W2			90				
Cat-W3			63				
Cat-W4			63				
Catchments Contributing to West Swale -1							
Cat-W1S	104		31.5	135.5	112.5	142.5	100 Year overflows to West Swale 2
Total	**1122**	**386.5**	**859.5**	**2368**	**1784**	**2265**	

Table 5B - Storage Requirements

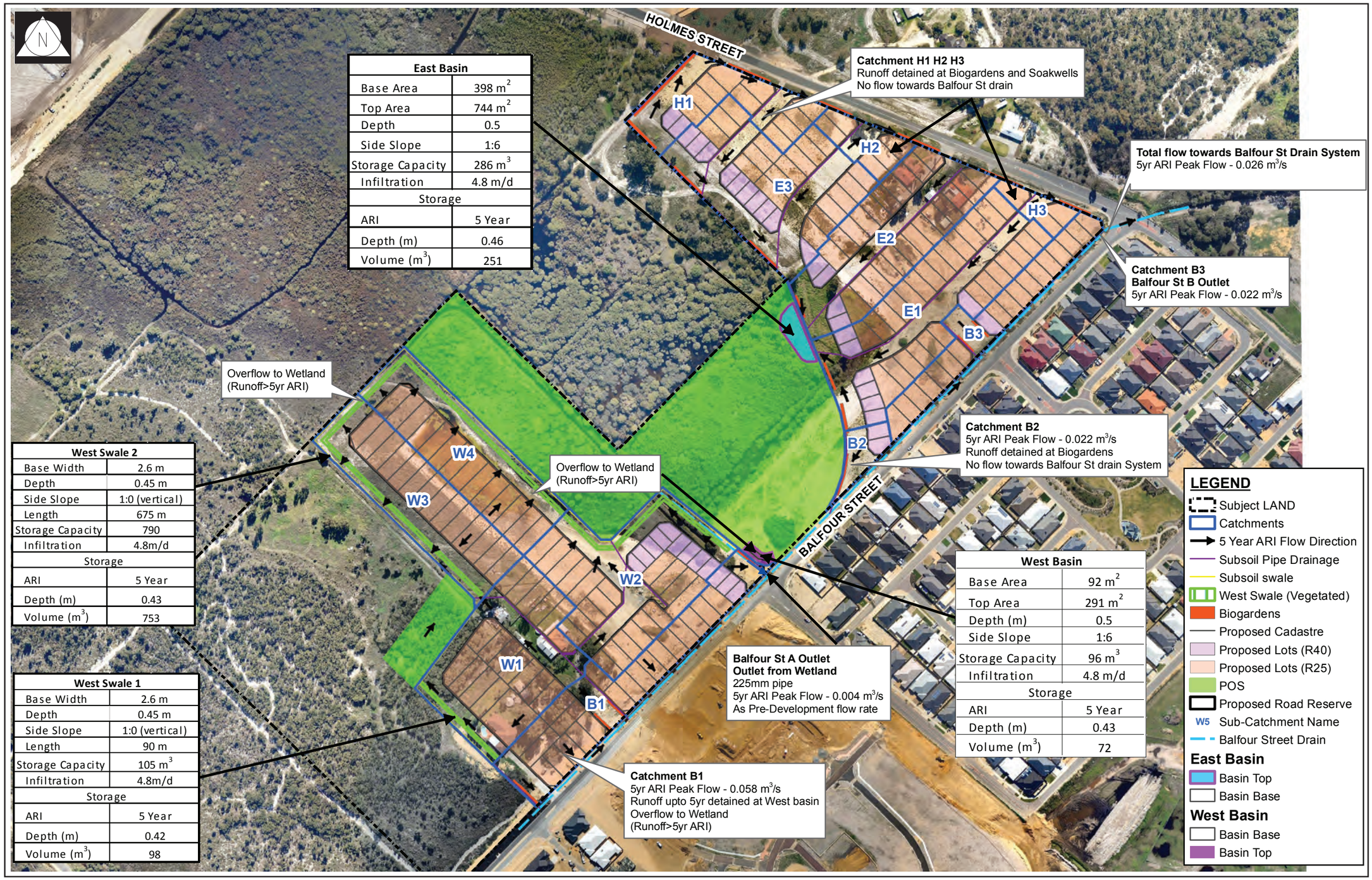


Figure 19 - 1 in 5 Year Drainage Management Plan

7C DRAINAGE MANAGEMENT PLAN - 1 IN 100 FLOOD

Modelling has been undertaken by JDA to determine the flood extent of the 1:100 ARI storm event for the subject land. This has focused on protection of the proposed infrastructure, the capacity of the wetland complex to store flood waters and the capacity of the existing drainage system on Balfour Street to take the 1:100 ARI discharge from the site. Further modelling has been undertaken by Calibre Consulting to check the flood level generated on site, including the wetland system. This modelling takes into account the modelled out flow rate for the site set by JDA. More critically however, is the modelling takes into account the rate of discharge determined by the City for the site of 0.132m^3/s. The actual post development peak flow rate for the 1:100ARI has been determined as 0.130m^3/s.

The proposed design of the subject land based on this information will allow for the safe conveyance the 1:100 ARI flood event so that impacts on infrastructure, the environment and people's safety are minimised.

Flood waters are to be transported through the subject land via the pit and pipe network (designed for 1:5 ARI) as well as overland flow down roads. The road system is to be designed to work in conjunction with the pipe network to allow a safe flood route for 1:100 ARI flows. Flow paths down roads have been marked and can be seen in *21.* All lots will have a finished floor level 500mm above any potential flooding from the 1:100 ARI event.

Flood waters will be discharged from the subject land through the same points of discharge as the 1:5 ARI event. Catchments feeding the wetland will flood out the bioretention gardens and 1:5 system before topping over into the wetland area. This wetland area has the capacity to store over 100,000m^3 of water from the subject area and surrounds. This water will be able to continuously discharge via the 225mm culvert at the end of the wetland into Balfour Street Drain. This is due to the culvert having an invert of 21m AHD and the hydraulic head of the Balfour Street Drain being only 20.72mAHD as seen in *Figure 20.* Due to large amount of retention and travel time involve, the peak 1:100 ARI event for the wetland catchments is the 72 hour event. This is after the critical 1:100 ARI event for the Pipe which is the 48 hour event. The effect of the residential development on the 1:100 ARI level of the wetland is to raise the wetland level by 10mm. This is in keeping with the Wetland Management Plan.

Catchments feeding Holmes and Balfour directly are able to discharge their waters directly into the Balfour Street drain system. The current design in the Balfour Street Drain has capacity to take these flood waters directly. This can be seen in *Figure 20.* More details can be found in the attached Conceptual Stormwater Modelling.

Due to the site discharging water from the site both prior to and after the critical event for the Balfour Street Pipe, the pipe will have a lower critical event flow post development.

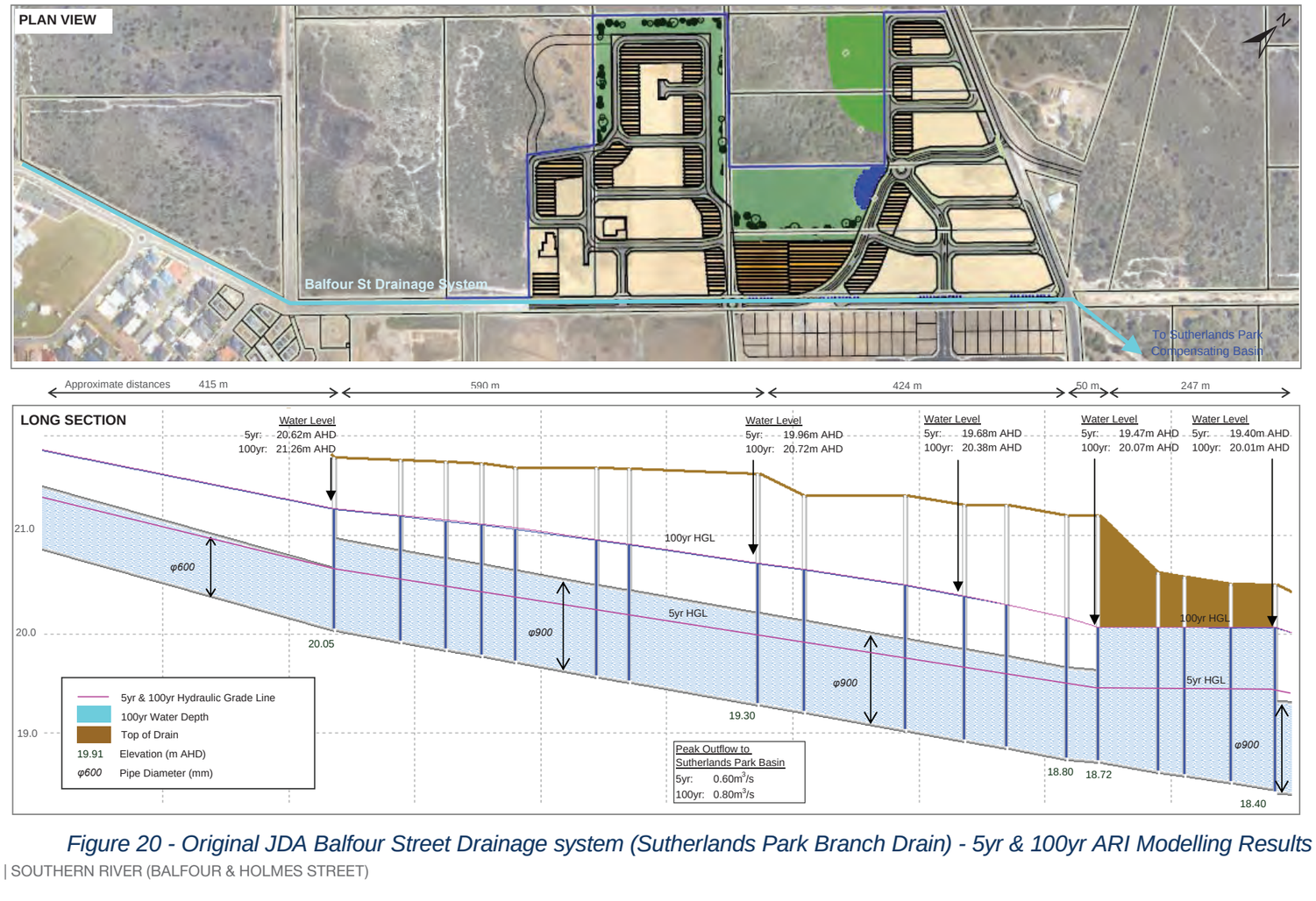


Figure 20 - Original JDA Balfour Street Drainage system (Sutherlands Park Branch Drain) - 5yr & 100yr ARI Modelling Results

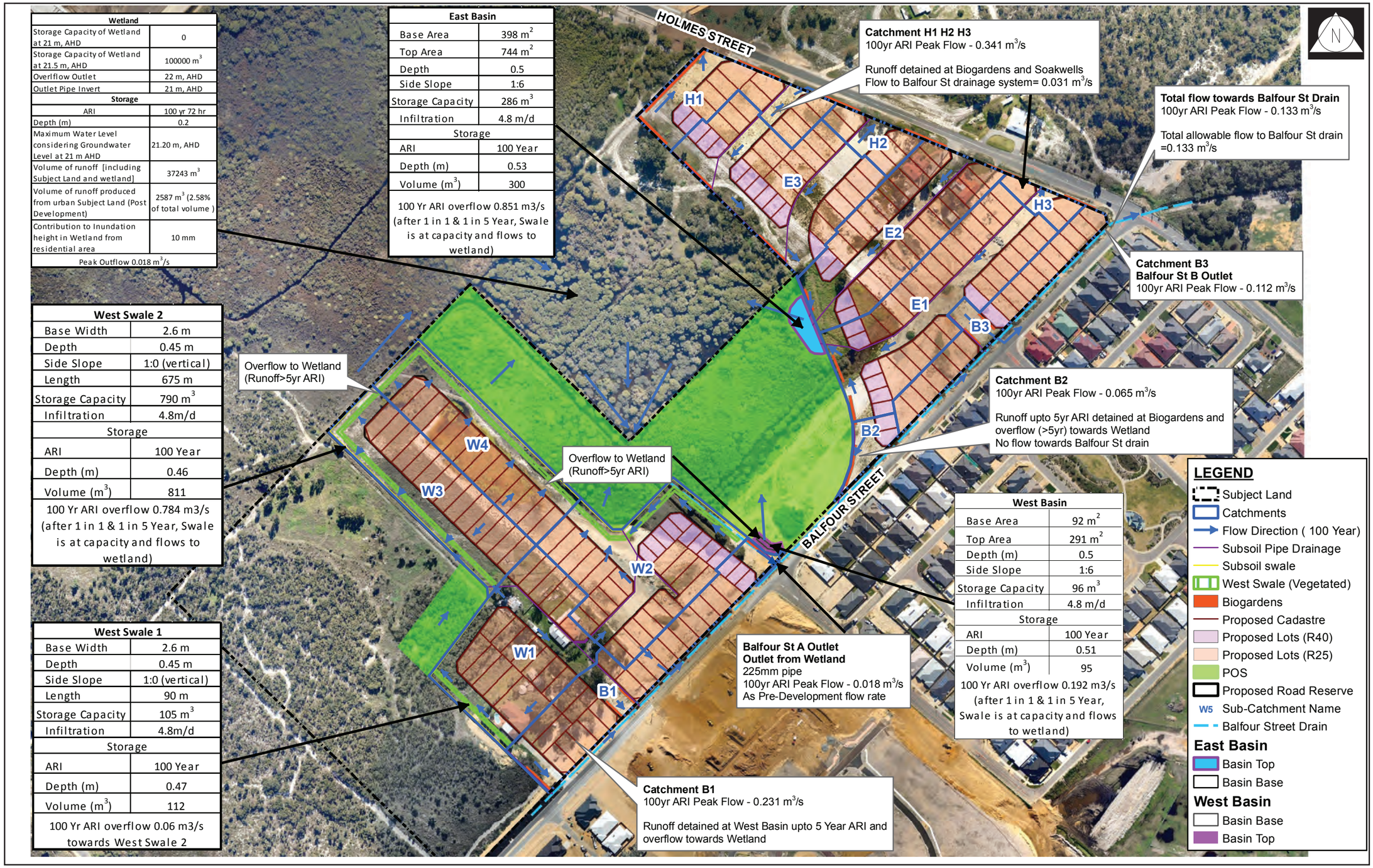


Figure 21 - 1 in 100 Year Flood Event Plan

8. GROUNDWATER MANAGEMENT STRATEGY

The focus of groundwater management for the development site is to maintain groundwater at existing levels within the wetland system, while maintaining appropriate separation from built infrastructure. In this instance, existing levels refer to the control level of pipe discharging to Balfour Street drain, which is set at the base of the historical open drain constructed in the wetland. Furthermore groundwater will be managed to achieve no reduction in water quality entering the wetlands. *Figure 22A* illustrates a cross section of how groundwater will be managed in relation to the residential and natural areas on site.

GROUNDWATER LEVEL MANAGEMENT

The subsoil will be set predominately at the AAMGL, especially in close proximity to the wetland. Subsoil pipes will then grade at 1:300 back under the residential fill areas. The subsoils will be located in the road reserves.

Mounding will occur between the subsoil pipes, with groundwater mounding to a maximum of 500mm below houses after a 1:5 ARI event in the wettest month of the year. This mounding will rapidly drain to the subsoil system to bring the water level under the lots back close to the pre development AAMGL. The post development CGL can be seen in *Figure 22A*. With the CGL set at 21m AHD around the wetland, there will be no change to wetland groundwater levels.

The use of free draining fill and distance between the subsoil pipes throughout the development will assist with holding the mounding to this height. The permeability of the sand used in the fill is between $5.09x10^{-5}$ and $5.88x10^{-5}$m/s. For all drainage calculations the permeability has been set at 4.8m / day.

Modelling of the fill permeability and subsoil drainage spacing for the site shows there is a need for an average of 1.2m of fill above the subsoil invert at the kerb, with approximately 1.5m under the lot. This will achieve the required 0.5m separation at the mid point between subsoil pipes.

To reflect this separation distance to groundwater, soakwells and other infiltrating systems will be at the front of lots and shallow in nature e.g. 1m.

The subsoils will free drain to a number of points. These include, the subsoil swale parallel to the west swale (as per Figure 15) and the pipe network of Holmes and Balfour Street and east basin. The general flow direction for the subsoil system will be the same as the surface drainage catchments.

The subsoils that drain to the wetland will bubble up in a small spoon swale along the edge of the wetland (this is a separate swale to the one which will hold the 1:5 ARI stormwater). The water from the subsoil drain can then enter the wetland system by soaking into the soil profile within and around the spoon drain.

The catchments where the subsoil system drains to Holmes and Balfour Street will enter the stormwater drainage pipes, for discharge to the street side drainage.

Figure 22A shows the indicative subsoil layout and inverts including indicative road levels.

The wetland water level will also be maintained by retaining the controlled surface water outlet pipe for the wetland into the Balfour Street drain. This in effect will continue to hold groundwater levels at an AAMGL of 21m AHD within and around the wetland. This is the wetland level set by the historical drain that took water from the wetland to the open Balfour Street drain. When Lot 1 was filled, the open drain was replaced with a pipe set at 21m AHD (old drain invert). By maintaining the groundwater at a level similar to the current level next to and within the wetland system, this development will have minimal impact on the groundwater dependent ecosystems that rely on water from the site.

Where ever possible water will be infiltrated on site to maintain similar overall infiltration volumes to the pre development scenario. This is to be achieved through the use of pervious surfaces, bioretention gardens, swales and soakwells, which are designed to infiltrate water.

No domestic bores are to be used in the development, due to the potential to impact on the adjoining wetland systems. This is to be achieved through restrictive covenants on lots.

GROUNDWATER QUALITY MANAGEMENT

All stormwater up to the 1 year 1 hour storm event will be treated in bioretention gardens. This means that the stormwater entering the subsoil system from the filtered stormwater should be treated to Department of Water guidelines. The bioretention gardens and swales will 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. The graphs provided in *Figure 16* demonstrate the potential capabilities of bioretention gardens in the removal of total phosphorus, total nitrogen and total suspended sediments, and provide the reasoning for adopting bioretention gardens to assist in the protect of groundwater quality. More information on the bioretention garden design can be found in Section 7A.

Roof runoff directed to soakwells, is another major source of groundwater. This water is relatively clean, which will assist with keeping groundwater pollutant concentrations within acceptable limits.

Suitable soil amelioration products will be laid within gardens and POS areas, to assist with binding nutrients in the soil profile. This will reduce potential movement of nutrients to the groundwater.

Furthermore an amended filter media will be used in conjunction with the subsoil pipes to treat in flowing groundwater. The Filter media will remove nutrients prior to the groundwater entering the subsoil pipe. The exact details will be provided in the UWMP, however based on recent research by the Department of Water, It is likely to be a 10% Iron man Gypsum / 90% Coarse Sand mix. This has shown significant reduction in nutrients and other pollutants entering the subsoil.

MONITORING

Sufficient pre development groundwater information has been collected to allow for design and construction of the development. The Department of Water has advised that post development monitoring of groundwater levels will be required. Full details of the monitoring will be outlined in the UWMP. Monitoring will be for both levels and quality for at least two years after the last lot is constructed. More information can also be found in Section 11 Monitoring and Implementation. The monitoring undertaken needs to follow the Australian Standard AS/NZ 5667 series of Water Quality Sampling Guidance Notes and a National Association of Testing Authorities accredited laboratory undertakes the water quality sample tests.

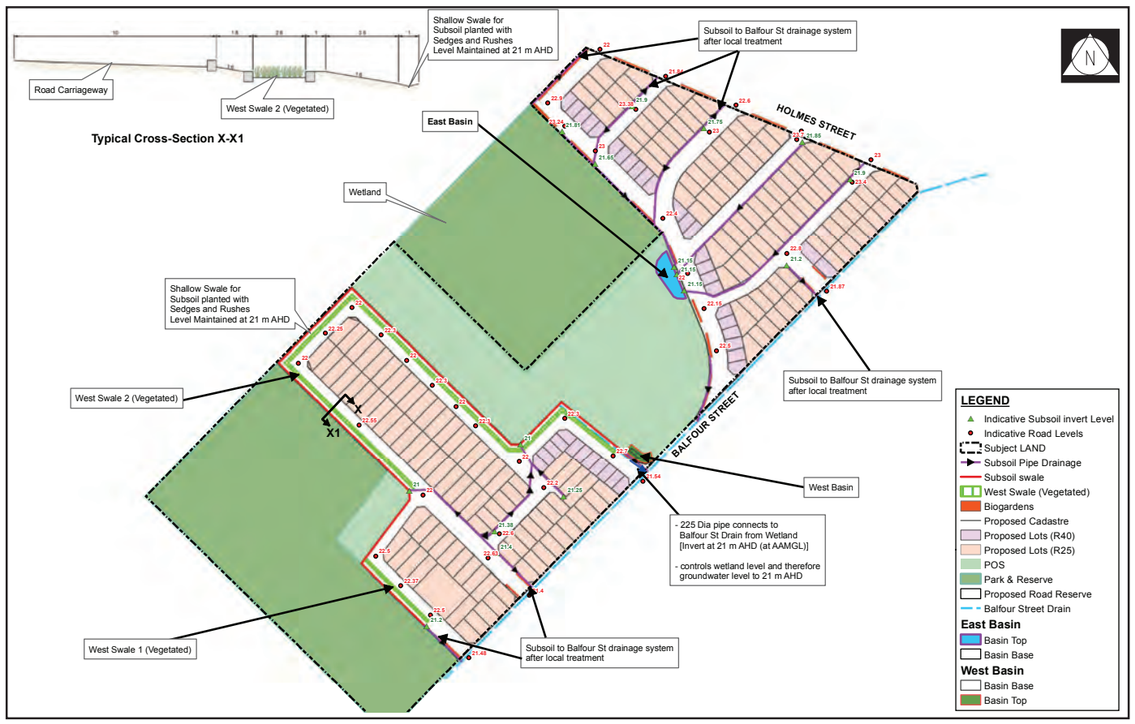


Figure 22A - Indicative subsoil and Road Inverts -

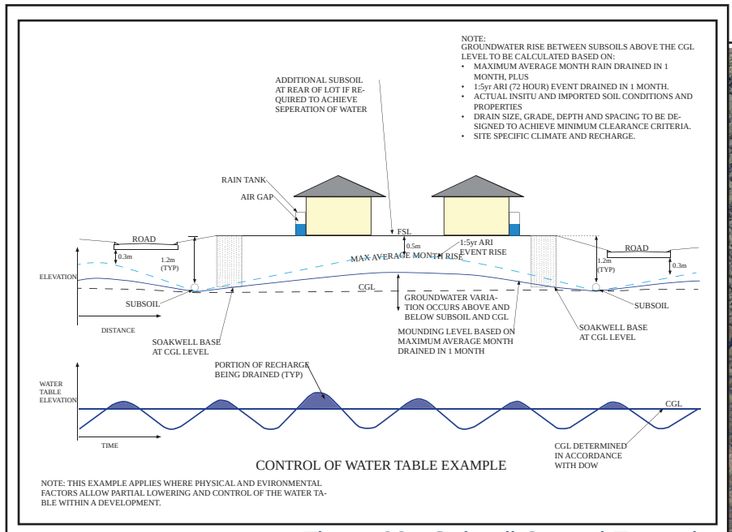


Figure 23 - Subsoil Control Example

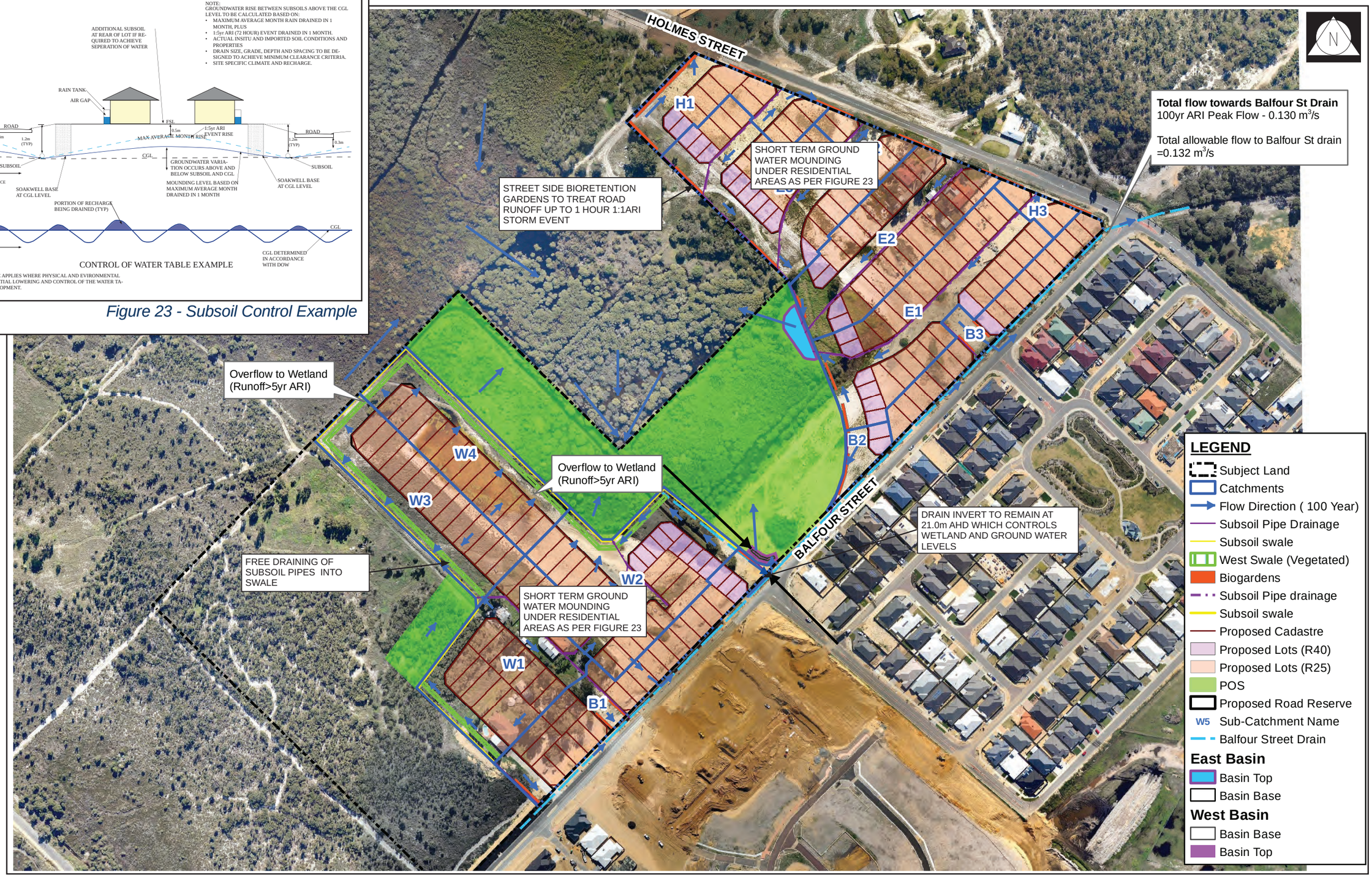


Figure 22 - Post Development Ground Water Management Plan

9. WATER DEPENDENT ECO-SYSTEM MANAGEMENT

Management of water is to be undertaken so that the significant wetlands within and near the subject land are protected and enhanced. The methods on how this is to be achieved are outlined below. Further details on wetland management for the site are contained in the Wetland Management Plan (WMP) Lots 1, 2 , 23, 24 Holmes St and Lot 1600 Balfour St, Southern River. The most relevant information can be found in Section 8 of the WMP. This plan provides sufficient information to outline the required protection and enhancement processes for the current structure planning phase.

Buffers are to be incorporated around the Conservation Category Wetland. The buffers reflect adequate separation distances between the future residential landuses and the wetlands, as well as incorporation of on site vegetation that is already present. The buffer distance has been set in negotiation between the developer, Department of Pakrs and Wildlife and Council. Some wider areas will also be included to reflect the sites existing vegetation. These buffers will allow for protection of the ecological functioning of the site by controlling public and providing areas that can be planted with suitable endemic native species. The buffers also assist with filtering any stormwater runoff from residential areas. Final and full Wetland Management Details will be reflected in the UWMP. This will take direction from the Wetland Rehabilitation Plan which is to be done as part of the subdivision process.

In general the planting of suitable native species along the edge of the wetland systems will assist with linking up areas of vegetation on the site and surrounding land. This will also improve the ecological functioning of the wetland including assisting with fauna habitat creation. Drainage infrastructure such as bioretention gardens constructed near these buffers are to be planted with appropriate native species including sedges and rushes to assist with the movement of fauna. Weeds will also be controlled. Disturbed areas within the wetland, such as the historical spoon drains will also be revegetated.

The water that flows into the onsite wetlands is to be managed so that the post development rate matches the pre development situation. This is to be achieved through detention and infiltration of all flows up to and including the 1:5 ARI Storm event that feed the wetland catchment. The details of how this water is to be managed is contained in Section 7B: Drainage Management. This management of flows will assist with maintaining the hydro regimes to which the ecosystems have evolved. It will also minimise the chance for erosion of sediment and leaching of nutrients and other contaminants into the system.

Water quality is also to be managed so that the surface water entering these ecosystems is treated to sufficient standards. This is to be achieved through the use of bioretention gardens, swales, and soakwells. These will assist with removing sediment, gross pollutants, nutrients and other contaminants. More details on these options can be found in Section 7A.

The wetland system is also highly dependent on groundwater. Groundwater on the site is to be managed to achieve the required water quality and levels to maintain and improve the wetlands health. This is to be achieved through the use of amended soils, encouragement of small and native private gardens, well managed POS areas including effective nutrient budgeting and extensive use of native species. Furthermore , the subsoil system is to incorporate an amended soil filter to bind nutrients and other pollutants. This will reduce organic and other nutrients being discharged from the development as well as potential legacy nutrients. Water quality management for road reserve stormwater will ensure all infiltrating stormwater is treated prior to entering the groundwater. These strategies will assist in managing the water entering the groundwater and moving through to the significant ecosystems to the required quality.

The post development groundwater level regime will also match the pre development scenario. The high infiltration rate on the subject land means that presently most of the water on site enters the groundwater and does not flow off site via the surface until there is significant surface water in the wetland. This high infiltration volume is to be maintained by detaining and infiltrating surface runoff wherever possible through bioretention gardens and soakwells. The permeable fill soils on site will continue to infiltrate at similar rates to the pre development rate. The level will also be controlled through the use of subsoil drainage set at the AAMGL around the wetland. The subsoil will drain to both the onsite wetlands and the existing Holmes Balfour St drains as deemed appropriate. Furthermore there will be careful management of any potential groundwater extraction from the superficial aquifer to minimise any localised drawdown. More details on these strategies can be found in Section 8 Groundwater Management.

It is acknowledged that the area is located in close proximity to wetlands which have the ability to support mosquito and midge breeding. Mosquito and midge management is to be an important objective in the planning, design, operation and maintenance of any proposed drainage systems. The developer is committed to implementing a mosquito and midge plan during the pre-development stage and for 2 years following practical completion of the subdivision. The design of the water management infrastructure will be done in a manner that ensures that the opportunities for nuisance insect breeding and movement are minimised, including:

- Bioretention gardens which reduce nutrient inputs to the wetland and have no standing water.
- Landscaping to reduce movement of nuisance insects to residential area.
- Rehabilitation of the wetland buffer so that the system is not degrade, which will therefore support predatory species and minimise nutrient rich stormwater.

The City of Gosnells will respond to any reports of mosquito or midge issues with appropriate monitoring and response. A detailed mosquito and midge plan is to accompany and inform the UWMP.

The POS areas have been designed so that they will generally retain native vegetation. Bordering these areas, a zone of locally native plants will be used, that are subject to minimal irrigation. Between these landscaped native plant areas and lawn, a concrete path will be used. This system will provide good protection to the ecologically significant wetland systems. A POS Nutrient Management Plan is to be developed as part of detailed design.

The wide road reserve in the southern portion of the site that incorporated a bioretention swale and subsoil discharge swale will also assist with providing a buffer to the wetland. An indicative design for this area is show in *Figure 15,* however this will be modified as is practical to accommodate existing significant vegetation in this area. This is to be incorporated into the UWMP.

All of these management strategies will ultimately improve the water quality that enters the downstream environments outside of the subject land including the Southern River, and Swan Canning system. These management options will assist with the site meting the water quality recommendation of 1.0mg/l for total nitrogen and 0.1mg/L for Total Phosphorus as recommended for the Swan Canning system.

DEWATERING

For any required dewatering, an assessment is to be undertaken to review volumes, quality and potential impacts on surface water level, especially in relation to nearby significant wetlands.

Local recharge, outside of the wetland area is the preferred method of disposal. This is to be reviewed in more detail as part of the UWMP and detailed engineering design.

Figure 24 - Water Dependant Eco-system Plan

10. SUSTAINABLE WATER USE & SERVICING

The sustainable usage and management of water within the subject land area requires consideration of the provision of services and the conservation of water. The following is a description of the aspects to enhance the sustainable management of water within the development and general servicing.

WATER SUPPLY

Mains potable water will be provided by the Water Corporation from existing infrastructure on Balfour Road. The entire site is within the Water Corporation licence area. Discussions with the Water Corporation are being undertaken and further details regarding provision of mains potable services will be investigated at relevant planning stages of the development.

The majority of water used both within and outside the individual houses will be from the mains potable source. Using the State Water Plan annual target of 100kl/annum per person and an average household size of 2.3 people, a total of 230KL/annum of mains potable water has been estimated per household. Of this, 150KL will be used inside with a further 80KL being allocated for gardens and other outside uses.

SEWERAGE MANAGEMENT

Sewerage will be maintained by the Water Corporation via their existing gravity system located within Balfour Street. All wastewater will be transported to the existing Water Corporation's treatment plant. Discussions with the Water Corporation are being undertaken and further details regarding provision of reticulated sewerage disposal services will be investigated at relevant planning stages of the development.

There are no plans at this point to bring the treated wastewater back into the structure plan area. On average 150KL per annum will be sent to the sewer from each household.

WATER USAGE

For the State Water Plan of 2007 water use target of 100 kilolitres per person a year to be met, conservation methods will need to be employed throughout the subject area.

The Water Corporation's Options for Our Water Future provides comparative data to the average Perth household water use of 246KL per annum since 2002, the average household usage peaked in 2000/01 to approximately 290KL per annum.

To achieve the necessary reduction, a number of water conservation strategies will be incorporated. These measures will both reduce overall water usage as well as specifically reduce potable mains water.

The table illustrates water savings that can be made in comparison to 'normal' and average water using devices, based on data collected between 1998 and 2001 from Perth households. Builders and house owners will be encouraged to install water efficient devices and participate in the water conservation methods outlined in *Figure 25* to achieve the potential savings. Information will also be provided to lot purchasers informing them about Waterwise devices and practices.

RAINWATER TANKS

Houses will be encouraged to install rainwater tanks to reduce the consumption of water from the Water Corporation mains supply. Encouragement will be via provision of written material on the benefits of rainwater tank. More details on this will be provided in the UWMP. The encouragement of their use will be for internal toilets and laundry as well as garden and outdoor purposes. Outdoor water usage in Perth households is typically slightly below 50% of total water usage.

For modelling rainwater runoff and capture, the following data sources were used and assumptions were made:

- Average tank size of 3000L
- Rainfall figures between 2000 and 2009 derived from the Bureau of Meteorology weather station.
- Average roof catchment percentage value of 50% (125m^2).
- Efficiency of collection value of 0.85 (85% efficiency).
- Loss associated with absorption and wetting of surface value of 24mm per year.
- First flush value of 0.2L per m^2.

Encouraging the installation of an average tank could potentially capture a maximum collection volume of approximately 80KL per annum for each household with a 3kl tank and inside usage. Much of this potential capture will however be unused if supply is solely for outside usage. With outside usage, total actual usable collection is likely to be around 30KL/year. With internal usage, this could increase to approximately 60KL per annum.

As the installation of rainwater tanks has not been mandated for the subdivision the volumes have been shown as alternative factors in the modelled water balance volumes (*Figure 25*). More details as to the use of rainwater tanks is to be provided in the UWMP.

ONSITE INFILTRATION AND STORMWATER DISCHARGE

Excess roof runoff of around 162KL per annum will be directed to a property connection soak well for lots over 350m^2 and to the stormwater system for lots under 350m2. This would be reduced with the installation of a rainwater tank by approximately 10,000-80,000L, depending on the size and usage, with 30,000L as an average. The soils at the site will predominantly infiltrate all of the runoff water into the soil profile and groundwater below. Runoff from the gardens and hard surfaces around the house will be directed predominately to the road drainage network discussed in the drainage management sections. The remainder will infiltrate into the soil and groundwater within the lot. This will assist with conserving water on site and maintaining the current groundwater regime.

WATERWISE GARDEN AND OTHER OUTSIDE USAGE

The water savings from planning and implementing Waterwise gardens and practicing other outdoor Waterwise techniques can vary from approximately 50 to 200KL per household per annum.

Natural rainfall alone should be sufficient to maintain Waterwise gardens. However, additional water for gardens, in particular lawns, and other outdoor use has been factored into the subject area's water balance model. To achieve the necessary target of 230KL per household per annum, an achievable target of 80KL per annum has been allocated to garden and other outside usage. The installation of a rainwater tank could be used to supplement or possibly even substitute for the use of mains potable water for usage on garden and other outdoor requirements.

Lot owners will be provided with information outlining the benefits of minimising lawn and incorporating Waterwise gardens. Educational material raising awareness of Waterwise gardens will be offered to new residents, including the Water Corporation's Garden Tips for the South West brochure. This will be further explored in details as part of the UWMP.

GREYWATER USE

Greywater use is a possibility for the subject area. However, as it will not be mandated, it has not been shown in the water balance model. Greywater, if well managed, could provide for most if not all of the Waterwise gardens water needs. This would reduce the amount going to the effluent disposal system by 45 - 120KL per annum, as well as saving up to 80KL per annum of mains potable water.

GROUNDWATER AND BORES

Bore water use has not been shown in the model as there will be restrictive covenants placed on the lots that bores are to be precluded.

POS WATERING

The reticulated POS area will be kept to a minimum through the choice of landscaping and plant selection. If an irrigation allocation from the confined aquifers is needed, this will be sought through water trading. More detail is to be supplied on POS irrigation as part of the UWMP. *Table 6* provides an indication of the likely POS irrigation requirements. The overall lawn and other irrigation areas are low compared to the total POS area, which includes the restricted area to native vegetation. Lawn areas will also be separated from existing native vegetation areas via a concrete path and locally native landscaping.

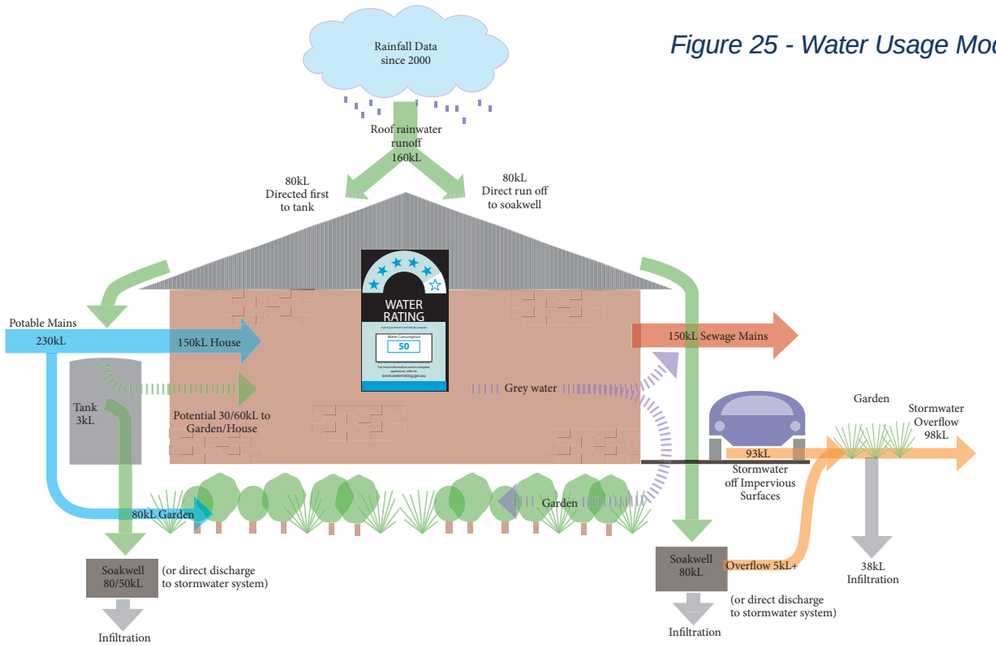


Figure 25 - Water Usage Model

TYPE OF POS	AREA (ha)	IRRIGATION RATE (Kl/ha/ Annum)	TOTAL IRRIGATION PER ANNUM (Kl)
Lawn Area	0.5	7 000	3 500
Native Gardens Areas	0.1	4 000	400
TOTAL			3 900

Table 6 - POS Irrigation Requirements

DEVICE/MEASURE	AVERAGE AMOUNT SAVED IN KL/HOUSEHOLD/ANNUM. (SAVING ARE BASED ON AVERAGE PERTH WATER USAGE FOR 1998-2001)
WASHING MACHINES (AUTOMATIC FRONT LOADER)	10-13
SHOWER HEAD	6-12
TAP AERATORS	15-22
TOILETS (DUAL FLUSH)	7-11
WATER WISE GARDENING (INCLUDES DRIP IRRIGATION AND LOW WATER USE PLANTS)	50 -200
TOTAL AMOUNT SAVED:	**88 - 258**

Data based on average Perth household Usage between 1998 and 2001 from Loh & Coghlan's Domestic Water Use Study, Water Corporation 2003

Table 7 - Water Efficient Devices / Conservation measures

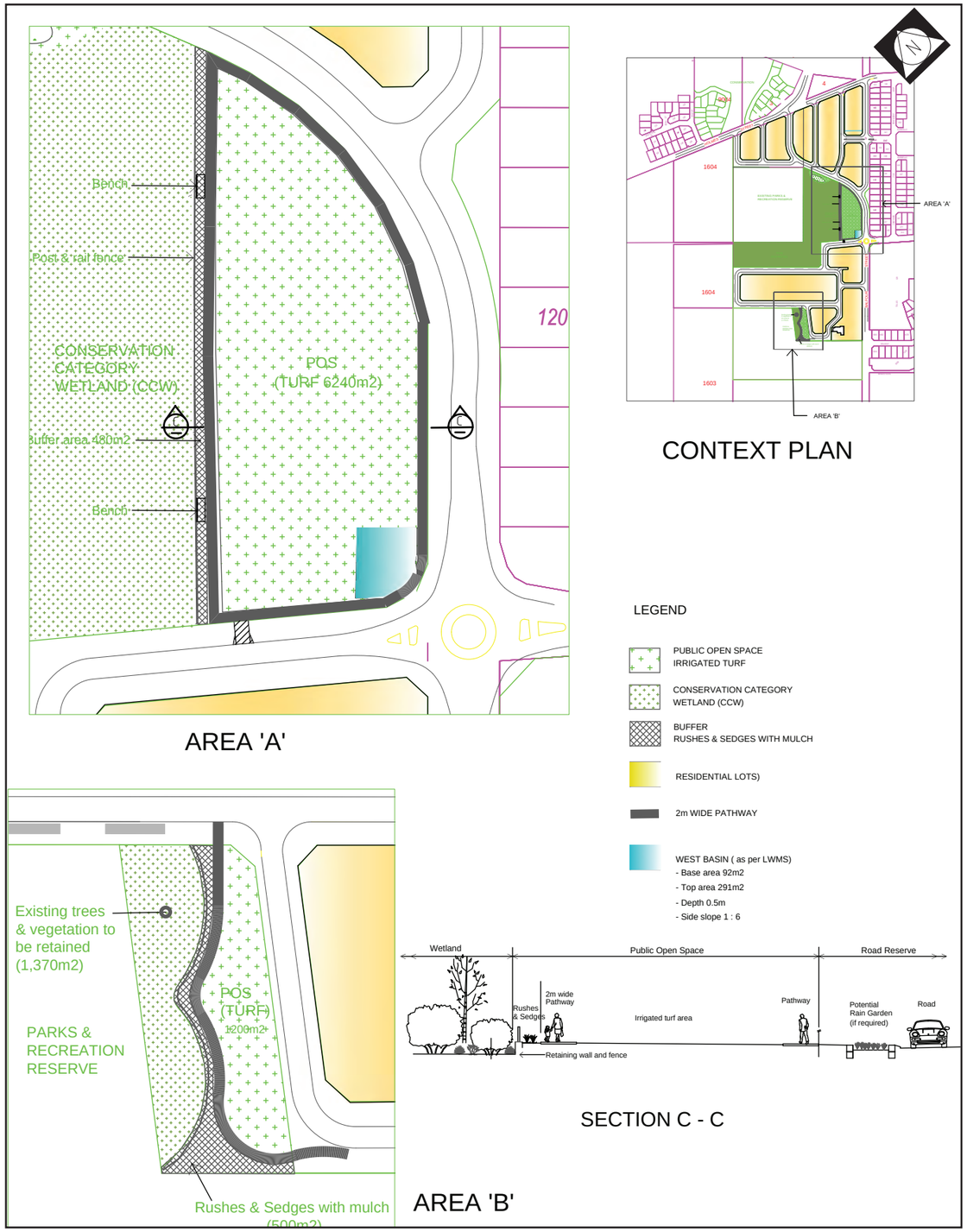


Figure 26 - Landscaping Plan

11. MONITORING, MAINTENANCE & IMPLEMENTATION

MONITORING PROGRAM

Monitoring within the subject land and the contingency actions to address any related problems are shown in *Table 8*. The following is a summary of the monitoring that has been and will be undertaken in relation to water management.

GROUNDWATER

Pre-development monitoring of groundwater levels and quality has been undertaken since May 2008. The full details can be seen in the previous groundwater sections.

The parameters tested include depth, pH, electrical conductivity, total suspended solids, as well as a range of nitrogen and phosphorus based chemicals. These parameters and the number of samples taken meet Department of Water guidelines for pre development monitoring.

Further monitoring is to be undertaken post development for a further 2 years after completion of subdivisional works. Monitoring is to be monthly for levels and quarterly for quality.

Trigger values set at 10% above the pre-development rates will be set in place. Should these trigger values be reached, contingency actions will be undertaken to rectify the issue.

WSUD AND OTHER INFRASTRUCTURE

Monitoring of the actual stormwater system will also be undertaken when the opportunity arises after significant rainfall. This sampling and analysis will provide a snapshot of the pollutant load and treatment effectiveness. A major monitoring point will be the exit point to the Balfour street drain.

The monitoring of surface water in the stormwater system and wetlands will continue for 2 years after the completion of subdivisional works.

The condition and operation of the WSUD measures should be inspected and monitored for an agreed upon time between developers and the Council (a minimum of 12 months after the completion of works). The tasks that should be undertaken quarterly after completion of the works should include:

- Visual assessment of vegetation growth and health;
- Assessment of sediment build-up at entry points to the systems;
- In-situ permeability testing of bioretention media;
- Monitoring of protection measures during construction phases of housing and implementation of sediment and erosion control by builders; and
- When possible observation of bioretention systems operating during rainfall events.

The post-development monitoring data may be used to quantify the impact, if any, on surface water quality, surface water flows and ground water quality and water level fluctuations. Pre-development base-line monitoring data will be used for post-development comparisons to target design objectives and criteria, including re-assessment of the validity of the monitoring program, setting triggers for contingency action and quantifying the performance of the WSUD system. The pre-development monitoring is to happen prior to the UWMP being approved and will follow the schedule outlined in *Table 6.*This would require comparative parameters to be collected pre and post development.

Monitoring of sediment control across the site is also to be undertaken during subdivisional works.

WATER DEPENDENT ECOSYSTEMS

Basic pre-development monitoring of the wetlands health has been undertaken as part of the assessment work for the subject land. Level monitoring has also happen by default through the groundwater monitoring of the site.

The Wetland Management Plan Lots 1-4 Holmes St, Lot 1600 and Pt Lot 1601 Balfour St Southern River outlines the post development monitoring regime for surface water within the wetland system. This is the major surface water feature on site with only sporadic occurrence of surface water after rainfall for the rest of the site. The monitoring parameters locations and regime can be seen in *Figure 27* and *Table 8* of this LWMS.

The monitoring will include;

- water level monitoring, using a sensor installed in the Conservation Category wetland
- opportunistic sampling for chemical parameters with a focus on organic nutrients, sediments and metals

Any monitoring undertaken needs to follow the Australian Standard AS/NZ 5667 series of water quality sampling guidance notes and a National Association of Testing Authorities accredited laboratory undertake the water quality tests.

More detailed monitoring information related to the site's wetland can be found in the Wetland Management Plan

The monitoring of the health of the water dependent ecosystems on the subject land is also to be undertaken for up to two years after practical completion of subdivisional works. This monitoring will be to allow for the analysis of the ecosystem's overall health compared to its current condition as detailed for previous vegetation and wetland assessments. A summary of the monitoring includes;

- Assessment of revegetation survival
- Assessment of weed encroachment
- Assessment of wetland vegetation health

Further details can be found in *Figure 26* and the report Wetland Management Plan Lots 1-4 Holmes St and Lot 1600 Balfour Street, Southern River.

Post Development monitoring of Water Quality and Wetland health will be provided to the City of Gosnells for review on an annual basis. Should there be issues identified, the Developer will also notify the Department of Environment and Conservation within 72 hours.

IMPLEMENTATION PLAN

The following information details the implementation schedule for the subject land and the organisation responsible. Further detail can be seen in *Table 8*.

Implementation of the strategies outline in this report will be undertaken prior to developmental works, as part of subdivisional works and into the post development phase. To assist with this implementation, an Urban Water Management Plan (UWMP) will be completed as part of subdivisional works. The UWMP will provide more detailed information on the relevant implementation of the water management aspects. The following is a summary of activities and responsibilities that are to be detailed in the UWMP.

THE DEVELOPER WILL BE RESPONSIBLE FOR:

- Construction of the bioretention gardens and swales.
- Construction of overall drainage system.
- The maintenance of bioretention gardens and swales including weed control, litters and sediment removal, plant replacement and any localise scouring until handover to the Council.
- Appropriate fill used across the site.
- Wetland management including revegetation and weed control within and around the onsite wetland system as necessary.
- Provide lot owners with information regarding Waterwise practices inside and outside the house.
- Provide lot owners with information regarding nutrient wise practices and designs for gardens.
- Undertake any further relevant geotechnical investigation, including acid sulphate soils tests, over the areas of the subject land.
- Undertake more detailed drainage analysis of the site as a part of subdivisional work.
- The preparation of Urban Water Management Plans as part of subdivision conditions.
- Monitoring of the sites water and associated ecosystems as outlined in the monitoring regime.
- Sediment control during construction
- Street sweeping for 2 years following practical completion to manage sediment arising from housing construction activities.

The City of Gosnells will have the following responsibilities:

- Maintenance of entire drainage network system after handover.
- Street sweeping after developers two year maintenance period.
- Enforcement of construction standards for WSUD infrastructure.
- Assessment of the UWMP in line with the Better Urban Water Management Framework.

The Water Corporation will need to provide the necessary potable water supply and sewage system.

The Department of Water will be required to assess the UWMP in conjunction with the City of Gosnells.

The lot owners will need to construct their dwellings and landscaping in keeping with the guidelines set out in the UWMP.

Function	Item to Monitor	Purpose of Monitoring	Trigger for Immediate Action	Maintenance Action Required	Monitoring Frequency	Responsibility
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 Council
	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 Council
	Sediment Build Up	A) Inspection for sediment accumulation within pits, on the surface of bioretention systems and within soakwells. B) Inspection of sediment build up on roadways.	A) Accumulation of large volumes of sediments in pits or on the surface or greater than 50% of the basins depth. B) Accumulation of sediment on roadway	A) Investigate, identify and stabilise cause of sediment source. Remove accumulated sediments and replace filter media or plants removed. B) Street sweeping to remove sediment	Every 3 months	A) Developer until handover to Council
	Compaction	Inspection of filter media for compaction, could include being driven on.	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 Council
	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.	Monthly	Developer until handover to Council
	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.	Monthly	Developer until handover to Council
	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.	Monthly	Developer until handover to Council
	Permeability	Inspection to determine that infiltration rate is maintained between 150mm and 400mm/hour	Infiltration rate is outside of these values.	If within the first 2 years, wait for settling and establishment of plant roots. After this period, enhance plant growth or remove media as necessary	Every 6 months for first 2 years then annually	Developer until handover to Council
	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.	Monthly	Developer until handover to Council
Groundwater	Pre development levels(Pre development)	To acquire baseline for wetland protection and to allow for effective post development management strategies. Eg fill levels	NA	NA as pre development base line.	Monitoring has been completed to DoW requirements already.	Developer (has already undertaken monitoring)).
	Pre Development Quality	To acquire baseline for wetland protection and to allow for effective post development management strategies. Eg subsoil flow treatment.	NA as pre development base line.	NA as pre development base line.	Organic nutrients 3 times during period of groundwater present eg Autumn to Spring)	Developer (has already undertaken monitoring of most aspects. Organic nutrients to be sampled still).
	Post development quality	To determine that pH, EC, TN, TP and Organic Nutrients are maintained at predevelopment levels or improved.	Results above agreed upon standards and or 10% variation from pre development monitoring results..	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Quarterly for two year after final stage of construction.	Developer
	Post development levels	To determine that levels are maintained at pre development levels	Results above agreed upon standards and or 10% variation from pre development monitoring results..	Investigate and identify source of change. Undertake appropriate responses to rectify the level change if not due to extreme weather conditions.	Quarterly for two year after final stage of construction. Annually there after if necessary	Developer until handover to the Council
Surface Water/Wetlands	Surface Water Quality (Pre-development)	Sampling of water quality (pH, TDS, N & P and Organic nutrients) at subject land drain outlet point and within wetland.	Results above agreed upon standards.	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination as part of development process.	Every 3 months (1 year duration)	Developer
	Surface Water Quality (Post development)	Sampling of water quality (pH, TDS, N & P) at subject land, bubble ups, drain outlet point and within wetland.	Results above agreed upon standards and or 10% variation from pre development monitoring results..	Investigate and identify source of contaminant. Undertake appropriate responses to rectify the contamination.	Every 3 months (for 2 years after practical completion)	Developer until handover to the Shire
	Wetland rehabilitation work	Determine if rehabilitation work has been successful as detailed in Wetland Management Plan	A) Death of plants above 20%. B) Weed invasion at a level where it hinders native regeneration, species composition maintained.	A) Replanting of native vegetation, irrigation if necessary. B) Removal of weeds,	Every 3 months (for 2 years after practical completion)	Developer until handover to Council
	Overall health	Allows for assessment of the existing wetland and its associated vegetation community	Deteriation in condition of existing vegetation or fauna plus other aspect as outlined in the Wetland Management Plan.	Rectifying of causes of degradation	Every 3 months (3 years)	Developer until handover to Council
	Levels pre development	Provides baseline for wetland and drain water levels	Extreme levels of flooding	Investigate and identify source of flooding. Undertake appropriate responses to rectify the flooding if not due to extreme rainfall.	Monthly for at least 1 year	Developer
	Levels post development	Allows for assessment of wetland and drain levels in comparison to predevelopment state	Results above agreed upon standards and or 10% variation from pre development monitoring results..	Investigate and identify source of change. Undertake appropriate responses to rectify the level change if not due to extreme weather conditions.	Quarterly for two year after final stage of construction.	Developer until handover to the Shire

Table 8 - Detailed Monitoring & Maintenance Schedule

Figure 27 - Monitoring Plan

REFERENCE

C. Arono BSD (2007) *Flora and Vegetation Survey & Wetland Assessment: Lots 1 - 4 Holmes St & Lot 1600 and Pt Lot 1601 Balfour St, Southern River*