YARRABILBA PRECINCT 1 AND 2
STORMWATER MANAGEMENT PLAN

DesignFlow
Prepared for Lend Lease
February 2014

Document Control Sheet

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Disclaimer

Potential implications of climate change

Unless expressly stated otherwise, historical climate data has been used in, or underpins, the analyses that are presented in this report. The historical climate is not necessarily a valid indicator of future climate, which may contain prolonged periods that are wetter or drier than the historical record used for this analysis. There is significant uncertainly surrounding how climate, and in particular, rainfall, will be impacted by various levels of greenhouse gas accumulation in the atmosphere. Rainfall has a much greater spatial variability than temperature and some areas are likely to become wetter whilst other areas become drier. Further to this there may be changes in the seasonality and intensity of rainfall. Such changes in climate could affect the conclusions and recommendations of this report.

Inherent natural variability in soils and plants

Where particular types of soils are recommended, such recommendations are based on information provided by soils suppliers, laboratories and published industry guidelines. There can be inconsistencies in the behaviour of soils under field conditions compared to laboratory conditions, and, for both natural and blended soils, many soils are non-homogenous and properties and behaviour can be variable. Where particular plant species have been recommended, such recommendations are based on botanical knowledge and observations of similar species growing in similar, but not identical conditions. Plants can be sensitive to subtle changes in climate, hydrology, soil and surrounding ecological conditions. Further to this, plant health is often closely linked to the level of maintenance provided. No warranty or guarantee, whether explicit or implied is made with respect to the suitability or performance of soils or plant species recommended in this report

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1 INTRODUCTION

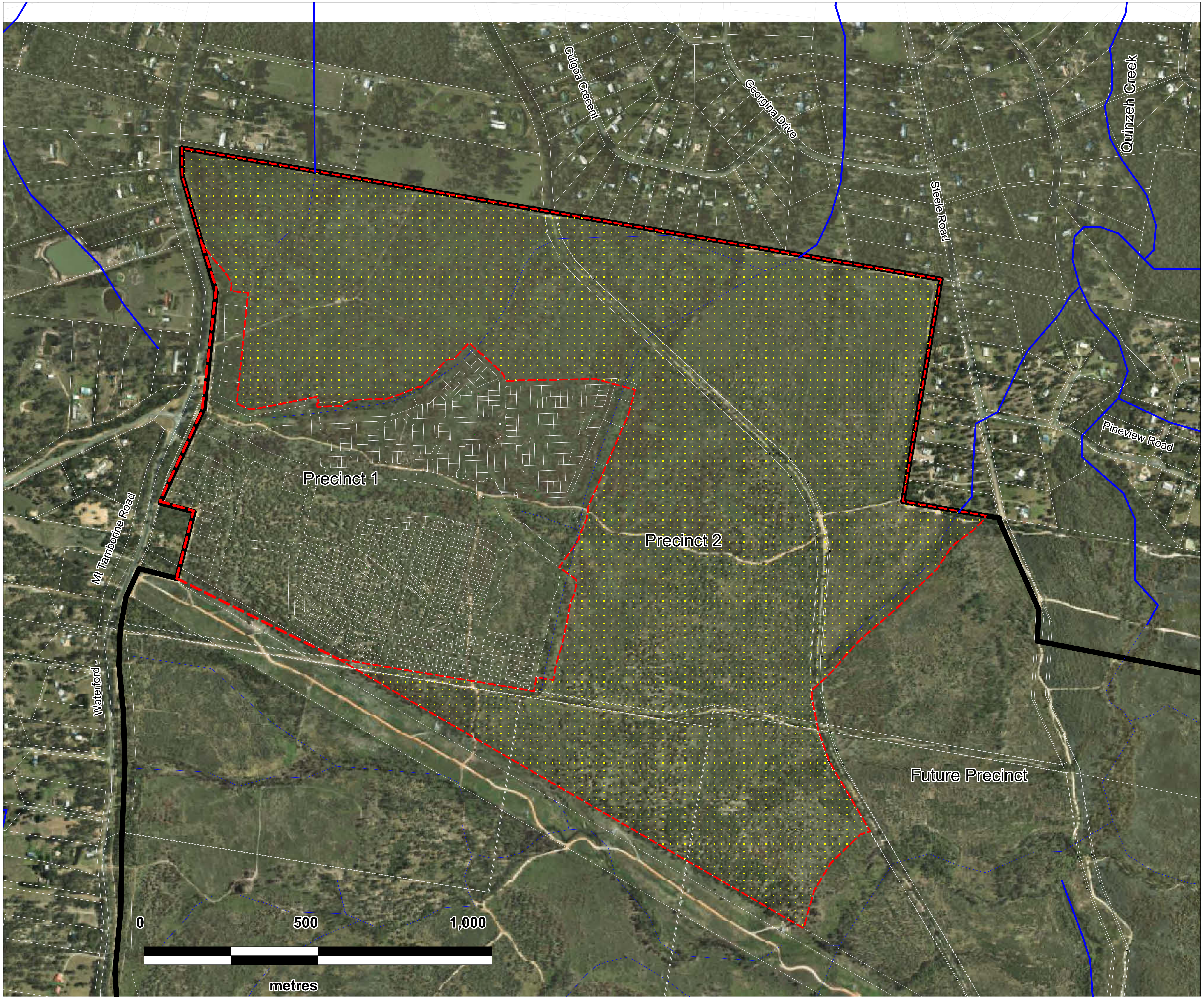
The Yarrabilba Priority Development (PDA) is located within the Logan City Council area and occupies a former pine plantation. The Yarrabilba PDA has been declared by regulation under Economic Development Act (2012). Yarrabilba is part of a regional growth area identified in the South East Queensland Regional Plan 2009-2031, which identifies a need for a further 70,000 dwellings in the Logan council area by 2031. The Yarrabilba development aims to provide 17,000 dwellings for a population of approximately 45,000.

The land, under management of Lend Lease, is located east of Waterford-Tamborine Road, south of Logan Village. The intention of the development is to create a community development complimentary to its natural environment that achieves a diverse and healthy community drawing upon innovative design initiatives. The development is being guided by principles of Water Sensitive Urban Design (WSUD). It is envisaged that WSUD will be used extensively to create a development zone that promotes sustainable and integrated management water of resources for environmental protection.

To meet these principles Lend Lease commissioned DesignFlow to develop a WSUD strategy with the objective of ensuring that all forms of development incorporate WSUD to minimise any impact on aquatic ecosystems and property, enhance the natural and created waterways and landscape. The principles, objectives and broad concepts associated with the WSUD strategy were established as part of *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and the *Yarrabilba Total Water Cycle Management Plan* (DesignFlow, 2012). These plans set consistent policy and design objectives to be applied across Yarrabilba for all future development applications.

This report presents the Stormwater Management Strategy for Precinct 1 and 2 of Yarrabilba (refer Figure 1). The report focuses in on the development layout proposed for these areas and identifies specific waterway, flood and stormwater management approaches, locations and sizes to support the development application for this area. The report is provided to support the Context Plan application and subsequent reconfiguring of lot applications for Precinct 2.

This report supersedes the previously approved *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011).



DesignFlow

LEGEND

Yarrabilba Site Boundary

Precinct Boundary

Waterway / drainage line

FIGURE 1
Yarrabilba Precinct 1 and 2 Locations and Extent

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

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1 November 2013

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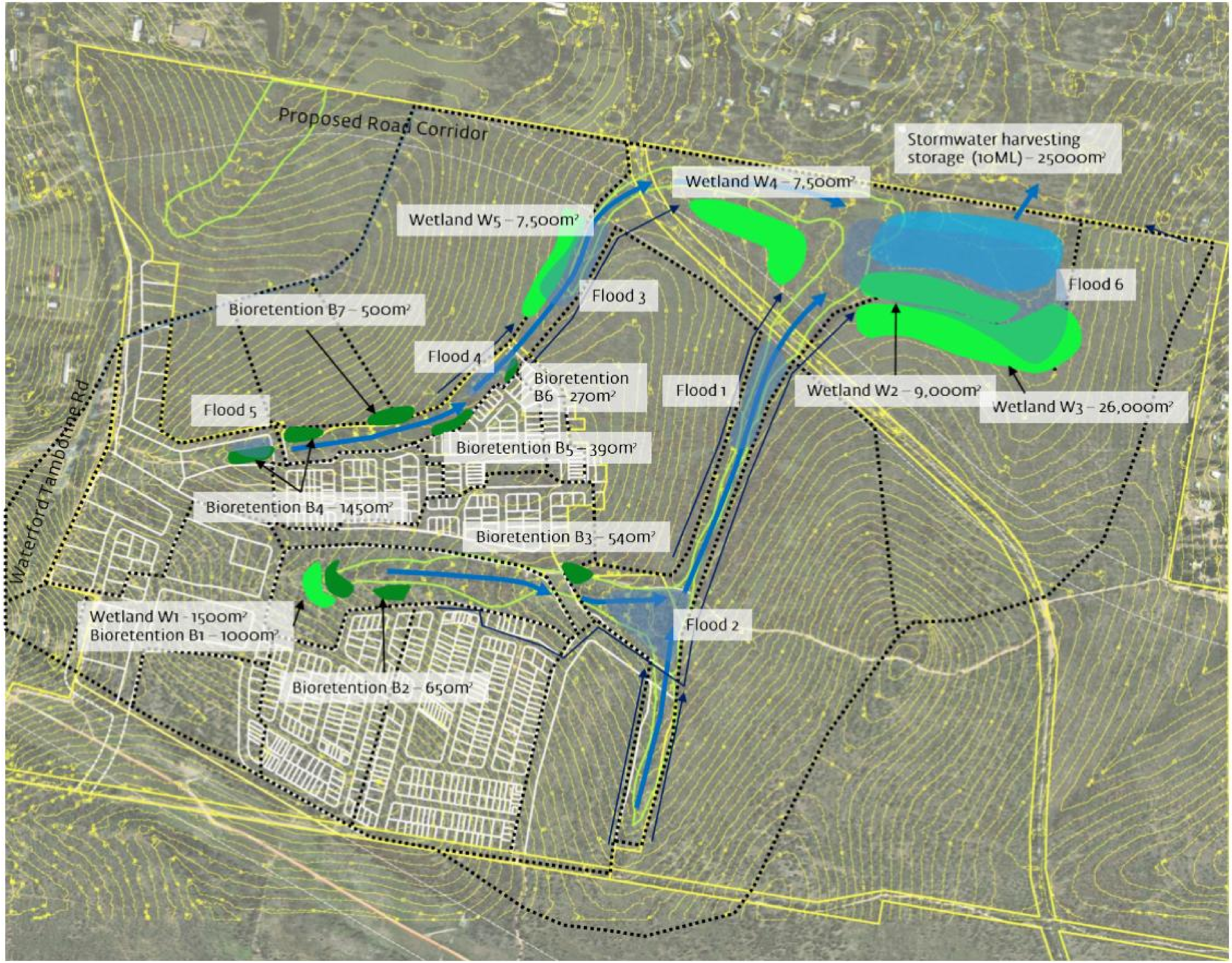
Lend Lease

1.1 PRECINCT 1 SMP

Development within Yarrabiliba to date has been occurring in accordance with the approved *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011). The plan presents a stormwater management strategy for Precinct 1 as well as a strategy for the whole northern catchment including Precinct 2. Figure 2 presents the strategy for Precinct 1 and highlights the systems which have been constructed.

This report (Y*arrabilba Precinct 1 and 2 Stormwater Management Plan*) documents an updated stormwater management strategy which includes the already constructed stormwater management systems in Precinct 1. Once approved, Y*arrabilba Precinct 1 and 2 Stormwater Management Plan* will supersede the *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011).



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Rehabilitate waterways involving revegetation, as a Melaleuca waterway and preservation of existing tree.

Bioretention systems located at the top end of the waterways to accept local stormwater flows and treat before discharge to waterways.

Constructed wetlands located at the downstream end of the waterways to accept and treatment local development catchments as well as diverted flows from further upstream.

Flood detention storages located within the waterways ponding over retained vegetation or revegetation zones. The smaller upstream storages will focus on managing the 1yr ARI flows with the large downstream storages focusing on the larger events up to 100yr ARI.

Stormwater harvesting storage to capture treated stormwater and reuse for parkland irrigation. The storage and reuse is sized to minimise the risk of nuisance flood downstream (minimise the change in surface flow frequency).

FIGURE 2
Precinct 1 Stormwater Management Strategy

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

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1.2 INFRASTRUCTURE MASTERPLANS

In 2012, the following infrastructure master plans were established for the whole Yarrabilba site:

- *Yarrabilba Total Water Cycle Management Plan* (DesignFlow, 2012)
- *Yarrabiliba Stormwater Infrastructure Master Plan* (DesignFlow, 2012)

The purpose of the *Yarrabiliba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) is to define specific principles and design objectives that will guide stormwater management across the whole site. These objectives include:

- Erosion and sediment control
- Waterway buffers
- Stormwater quality
- Frequent flows
- Flooding
- Waterway stability

These objectives have been established on the basis of an understanding of the condition of waterways and drainage lines across the site.

It is intended that this strategy will be implemented through the development of detailed management plans to be prepared as part of development applications (on a Context Plan or sub-catchment scale). The intent of these detailed pans is to illustrate how the objectives identified in the *Yarrabiliba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) are met at a development scale through appropriate urban design and provision of appropriate stormwater infrastructure.

This report (Y*arrabilba Precinct 1 and 2 Stormwater Management Plan*) documents the detailed stormwater management plan for Precinct 1 and 2 in accordance with the requirements of the *Yarrabiliba Stormwater Infrastructure Master Plan* (DesignFlow, 2012)

2 SITE OVERVIEW

2.1 TOPOGRAPHY, CATCHMENTS AND WATERWAYS

Precinct 1 and 2 covers an area of approximately 321 ha (including waterways) and is located in the northern part of the Yarrabilba PDA. The site is located across four broad catchments which drain to the northern boundary of the Yarrabilba site as illustrated in Figure 3. The site is defined by ridgelines on the east, south and western sides. These ridgelines effectively mean the Precincts 1 and 2 site is self-contained (i.e. there are no significant external catchment inflows). Internal ridge lines divide the area into the four catchments.

All the drainage from the Precinct 1 and 2 site is via broad ephemeral vegetated waterways. The condition of the waterways has been assessed as part of the infrastructure planning for the Yarrabilba site (*Yarrabilba - General Waterway Condition Assessment*, DesignFlow, 2012) and refined as part of Precinct 1 and 2 planning.

Table 1 summarises the details of each catchment presented in Figure 3 and the condition of the waterways. Figure 4 presents the waterway condition rating for Precinct 1 and 2.

Existing catchment conditions for flood modelling

An important part of the flood modelling for Yarrabilba is defining the pre-development conditions. It is clear from the air photos and vegetation mapping (Section 2.3) that the vast majority of the vegetation (80%+) on the site is grassland or open pine regrowth. The pre-development flood modelling assumptions and associated rational method checks need to accurately consider this existing vegetation.

Table 1: Precinct 1 and 2 Catchments and Waterway Condition

<table>
<tr><th>Catchment</th><th>Area (ha)</th><th>Slopes</th><th>Catchment Vegetation</th><th>Waterway Description and Condition</th></tr>
<tr><td>1</td><td>22.8</td><td>4-6%</td><td>70% grass and/or former pine plantation, 30% remnant vegetation</td><td>Ephemeral waterway with vegetation cover in downstream reach. Drains north into a large dam on private property and then subsequently via open drain to large stand of native vegetation. Waterway condition is Average with good riparian vegetation. The highest value portion of the waterway on the Yarrabilba site will be cleared as part of the State Governments Southern Infrastructure Corridor (SIC).</td></tr>
<tr><td>2</td><td>222.2</td><td>3-6%</td><td>90% grassed and/or former pine plantation, 10% remnant vegetation</td><td>Ephemeral waterway with two small ponded wetlands in the mid reaches. The majority of the waterway has been cleared of vegetation and is now either grass or pine regrowth. Therefore the waterway condition is mostly Poor or Average. A small section of the upper reach is high quality and rates Good and has been preserved in Precinct 1.</td></tr>
<tr><td>3</td><td>45.7</td><td>3.5-5% (waterway 1.2%)</td><td>100% grass and/or former pine plantation</td><td>Ephemeral grass drainage depression which drains to north into easement across private property containing dams and flat wide drainage channel.</td></tr>
<tr><td>4</td><td>54.3</td><td>4-5% (waterway <1% grades)</td><td>90% grass and/or former pine plantation, 10% sparse remnant vegetation</td><td>Forms part of the larger Quinzeh Creek Catchment. Does not drain directly to Quinzeh Creek but rather the floodplain. The floodplain condition is Poor (no native vegetation) but Quinzeh Creek at this location is in Good condition and contains groundwater dependent ecosystems.</td></tr>
<tr><td rowspan="3">Minor catchments</td><td>5.4</td><td colspan="3">Thin catchment in north east corner of site. Development earthworks will result in this catchment draining into Catchment 2.</td></tr>
<tr><td>3.7</td><td colspan="3">Small triangular catchment adjacent to Catchment 3. Development earthworks will result in this catchment draining into Catchment 3.</td></tr>
<tr><td>7.9</td><td colspan="3">Thin catchment along the southern boundary of the site which drains to the electrical easement. Development earthworks will reduce the size of this catchment</td></tr>
<tr><td>Quinzeh Creek</td><td></td><td colspan="3">Quinzeh Creek ultimately accepts all stormwater from Precincts 1 and 2 either directly or indirectly downstream of the site. Ecological assessment of the creek within the Yarrabilba site has been completed as part of broad infrastructure planning for the site and is presented in Yarrabilba - General Waterway Condition Assessment (DesignFlow, 2012). Given the private land ownership downstream of the site, assessment of the creek in this location was limited to road crossings.

The creek exhibits a range of conditions. Some of the riparian zones to the creek are in a healthy condition whereas others are affected by weed and vegetation clearing. There is some evidence of erosion within the waterway whereas there are other sections of the creek that are stable and healthy. The Yarrabilba - General Waterway Condition Assessment (DesignFlow, 2012) found that upper reach of the creek are in Average or Poor condition and the lower reach are in Good condition (refer Figure 4).</td></tr>
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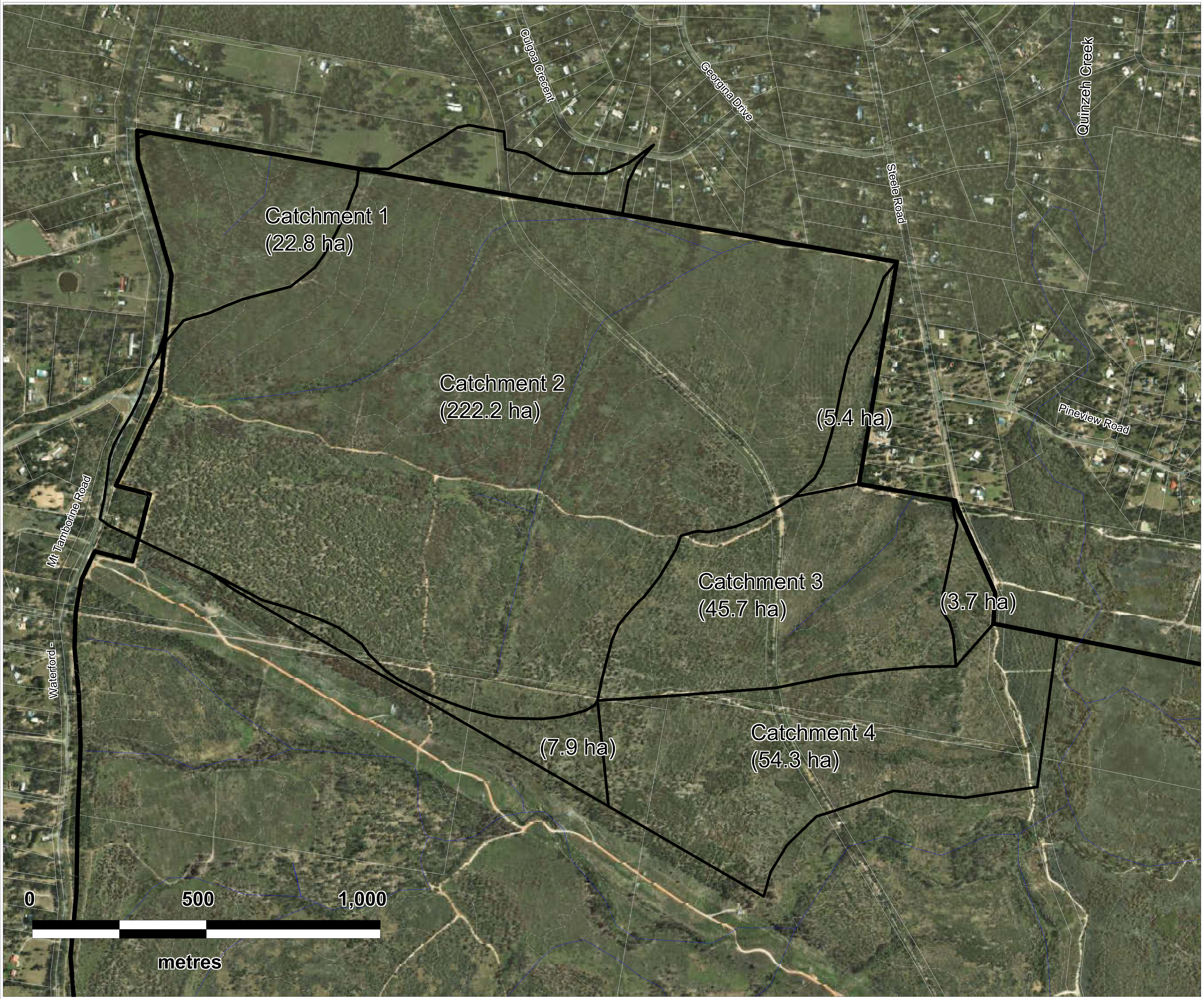

DesignFlow

LEGEND

- Yarrabilba site boundary
- Existing catchment boundary
- 5m contour
- Waterway / drainage line

FIGURE 3
Precinct 1 and 2 Catchments

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

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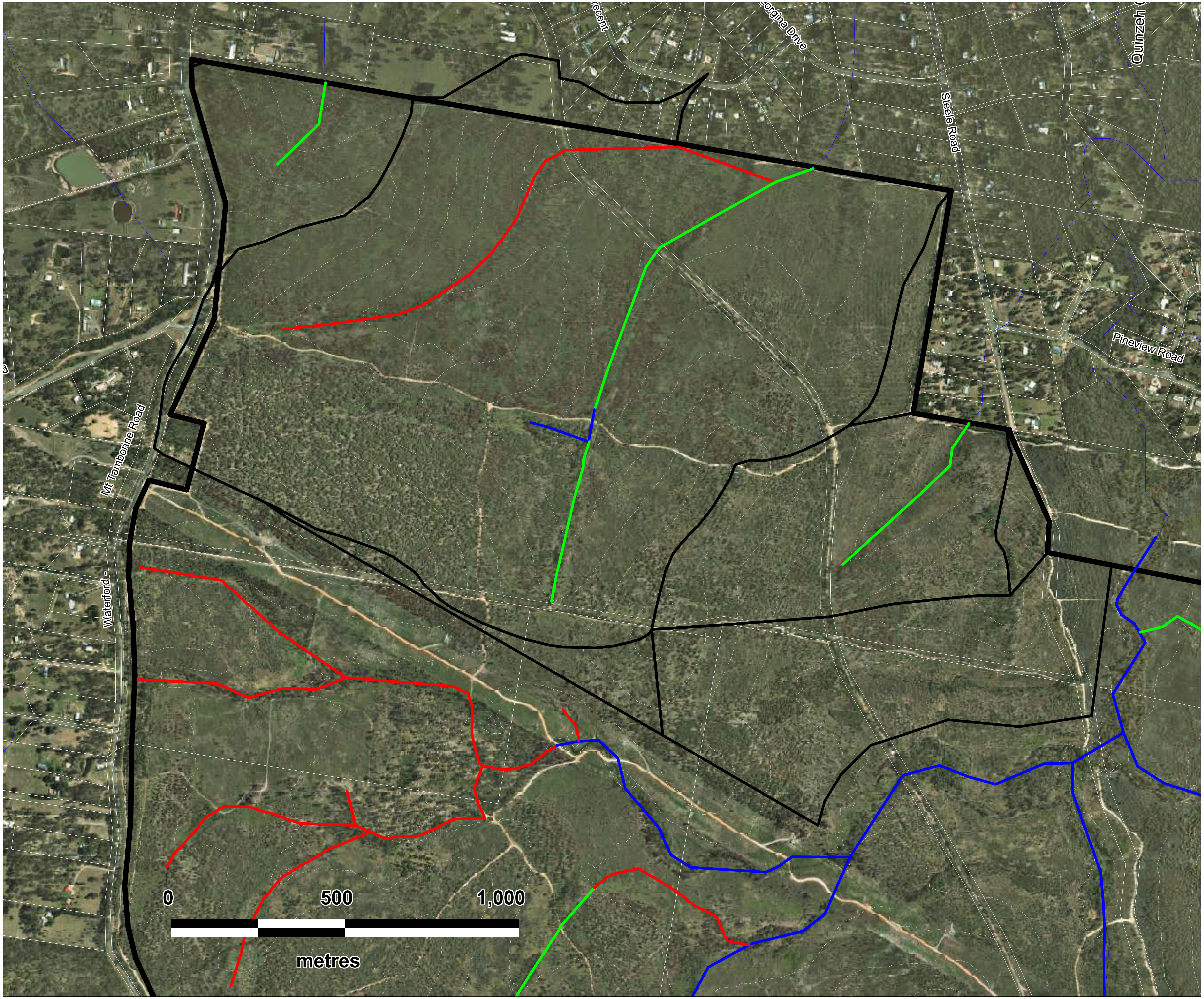

DesignFlow

LEGEND

Yarrabilba site boundary

Existing catchment boundary

5m contour

Waterway condition rating

Good Condition

Average Condition

Poor Condition

FIGURE 4
Precinct 1 and 2
Waterway Condition Rating

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

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2.2 DOWNSTREAM DRAINAGE

The following sections outline the drainage issues downstream of the four catchments in Precinct 1 and 2.

2.2.1 Catchment 1

Flows from Catchment 1 discharge to private property at the northern boundary of the Yarrabilba site (refer Figure 5). Immediately downstream of the site, a large farm dam accepts flows with overflows from the dam entering a short length of grass channel. Flows then enter a large parcel of land which is fully vegetated. No drainage easement is present through these properties.

As stormwater must travel through private property downstream of the of the Yarrabiliba site before discharging to Quinzeh Creek, the stormwater strategy must manage stormwater quality, maintain peak flood flows, minimise the impact of nuisance flood flows and preserve the method of flow entering the property immediately downstream.

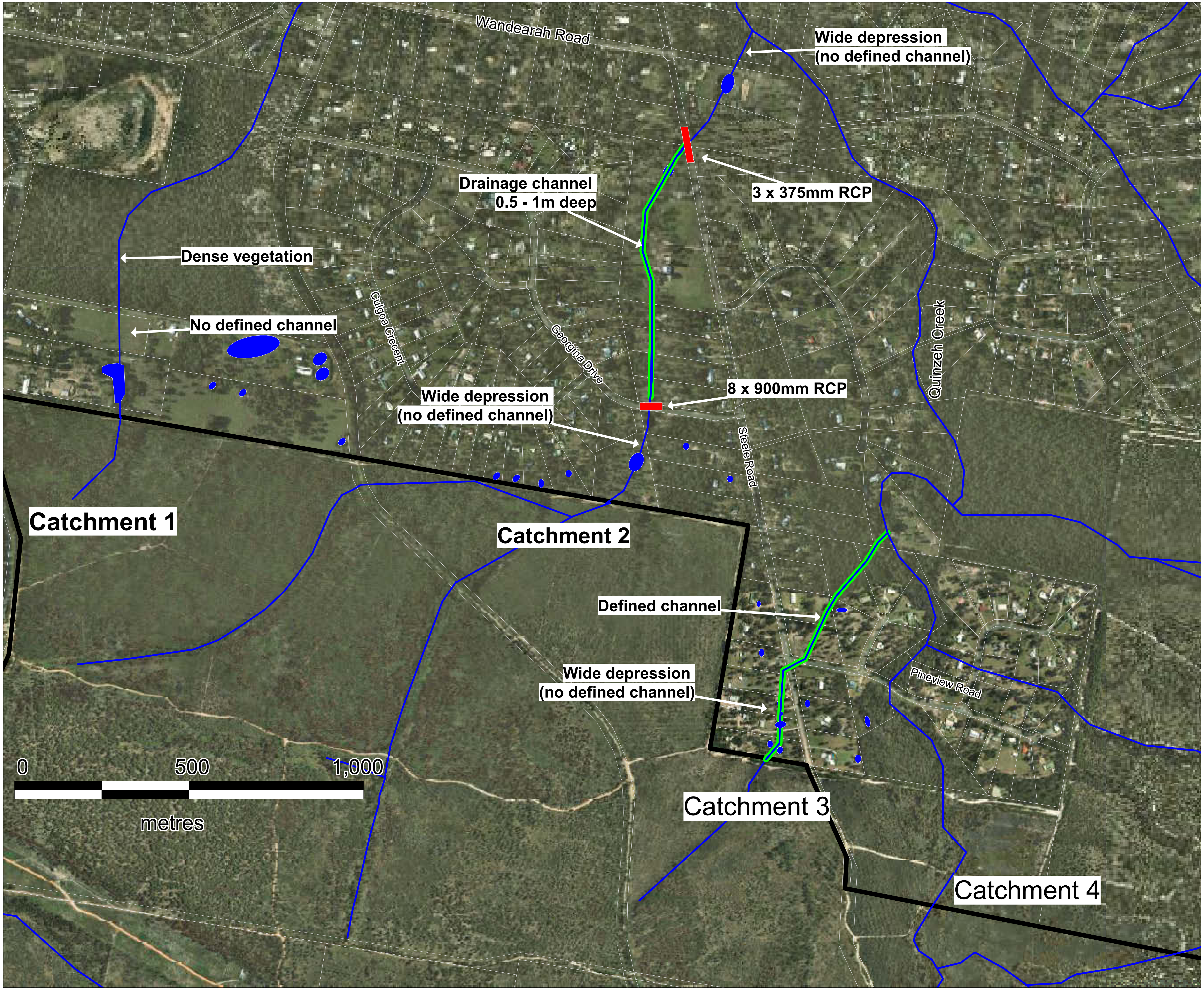
2.2.2 Catchment 2

Flows from Catchment 2 discharge to private property at the northern boundary of the Yarrabilba site (refer Figure 5). Flows travel approximately 1.5 km downstream from the Yarrabilba boundary through private property to Quinzeh Creek and then ultimately the Logan River.

Immediately downstream of the Yarrabilba boundary there is no defined waterway within the private property (refer Figure 5), just a flat wide ephemeral waterway. This waterway currently flows only during moderate rainfall events (>15mm) or during long wet periods.

Once the waterway reaches Georgina Drive, it passes under the road via a large set of culverts to enter a small constructed channel. The constructed channel is located within a drainage easement through private property. The channel has very flat longitudinal grade (<0.5%) and congested with vegetation. Although the capacity of the channel is limited (<0.5m^3/s), it conveys smaller flows all the way through a number of private properties to Quinzeh Creek.

As stormwater must travel through private property downstream of the Yarrabilba site before discharging to Quinzeh Creek, the stormwater strategy must manage stormwater quality, maintain peak flood flows, minimise the impact of nuisance flood flows and preserve the method of flow entering the property immediately downstream.



DesignFlow

LEGEND

- Yarrabilba site boundary
- Waterway drainage line
- Existing drainage easement
- Existing Culvert
- Existing Dam

FIGURE 5
Downstream drainage

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

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2.2.3 Catchment 3

Flows from Catchment 3 discharge to private property at the northern boundary of the site (refer Figure 5). Flows travel approximately 0.75 km downstream from the Yarrabilba boundary through private property to Quinzeh Creek. A 10m drainage easement exists through these properties which conveys low to moderate flows. Flood flows inundate areas beyond the easement.

The drain is a flat wide depression between Yarrabilba and Pineview Road with a number of farm dams and driveway crossings. At Pineview Road a 10m wide channel has been created ensuring low to moderate flows are contained within the easement. All the property downstream of Catchment 3 is subject to flooding and has been the focus on recent Council flood modelling. The confluence of the Catchment 3 tributary and Quinzeh Creek is a particular hot spot for flooding with a number of properties entirely inundated according to the Council flood modelling.

The stormwater strategy will need to ensure stormwater quality is managed, peak flood flows are preserved and that the immunity of the driveway crossings on the private properties is preserved. The details of the crossings have not been obtained as part of this assessment so refinement of the driveway immunity will need to occur as part of operational works applications.

2.2.4 Catchment 4

Catchment 4 drains into Quinzeh Creek within the Yarrabilba site before discharging downstream as illustrated in Figure 5.

Catchment 4 is only a very small portion of the Quinzeh Creek catchment within Yarrabilba which will be subject to a broader stormwater management strategy. Therefore, the focus of the stormwater strategy for this catchment is to treat stormwater and manage the peak flood flows from the local Catchment 4 until the broader strategy is resolved.

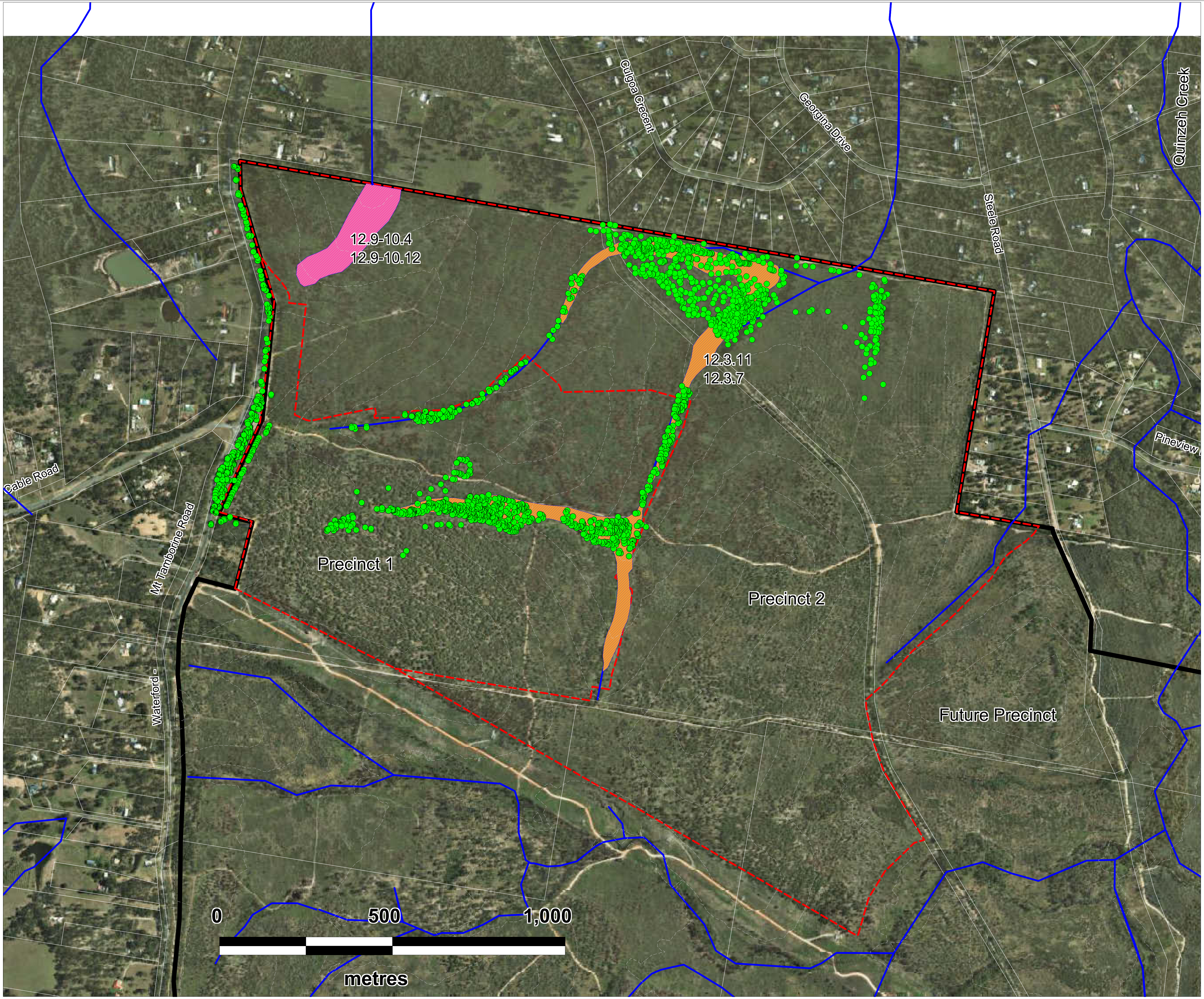
2.3 VEGETATION

The majority of the site was previously a pine plantation, with most of the vegetation in the proposed development area (outside of drainage lines) consisting of grassland or pine and eucalypt/acacia re-growth with little or no value. As illustrated in Figure 6 and Figure 7, the grassland and pine areas represent 80%+ of the existing landuse across the Yarrabilba site including Precinct 1 and 2. The air photos dating back to 2003 show the extent of the pine plantation and grassland.

Vegetation along sections of waterway within Precinct 1 and 2 has been mapped as 'Endangered' (RE 12.9-10.12) and 'Of Concern' (RE 12.11.12, and 12.3.11) Regional Ecosystems (RE) as illustrated in Figure 6. No other vegetation is mapped by the State Government in Precinct 1 and 2.

Lend Lease are committed to preserving significant vegetation and have completed a vegetation/tree survey to identify the accuracy of the RE mapping and completed an ecological assessment of vegetation to identify potential habitat. The mapping was completed to ensure the planning for Precinct 1 and 2 avoids the significant vegetation within the Vegetation Management Act mapping. The tree survey information is presented in Figure 6. As illustrated, the actual location of vegetation does not always align with the Vegetation Management Act mapping which is not surprising given the VMA mapping is desktop based.

The intention of the stormwater strategy will be to retain the good value and essential vegetation (trees, groundcover and aquatic) within the waterway corridors.



DesignFlow

LEGEND

- Yarrabilba site boundary
- Precinct boundary
- 5m contour
- Drainage line
- Tree
- Remnant vegetation containing endangered regional ecosystem
- Remnant vegetation containing of concern regional ecosystem

FIGURE 6
Precinct 1 and 2 Vegetation

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

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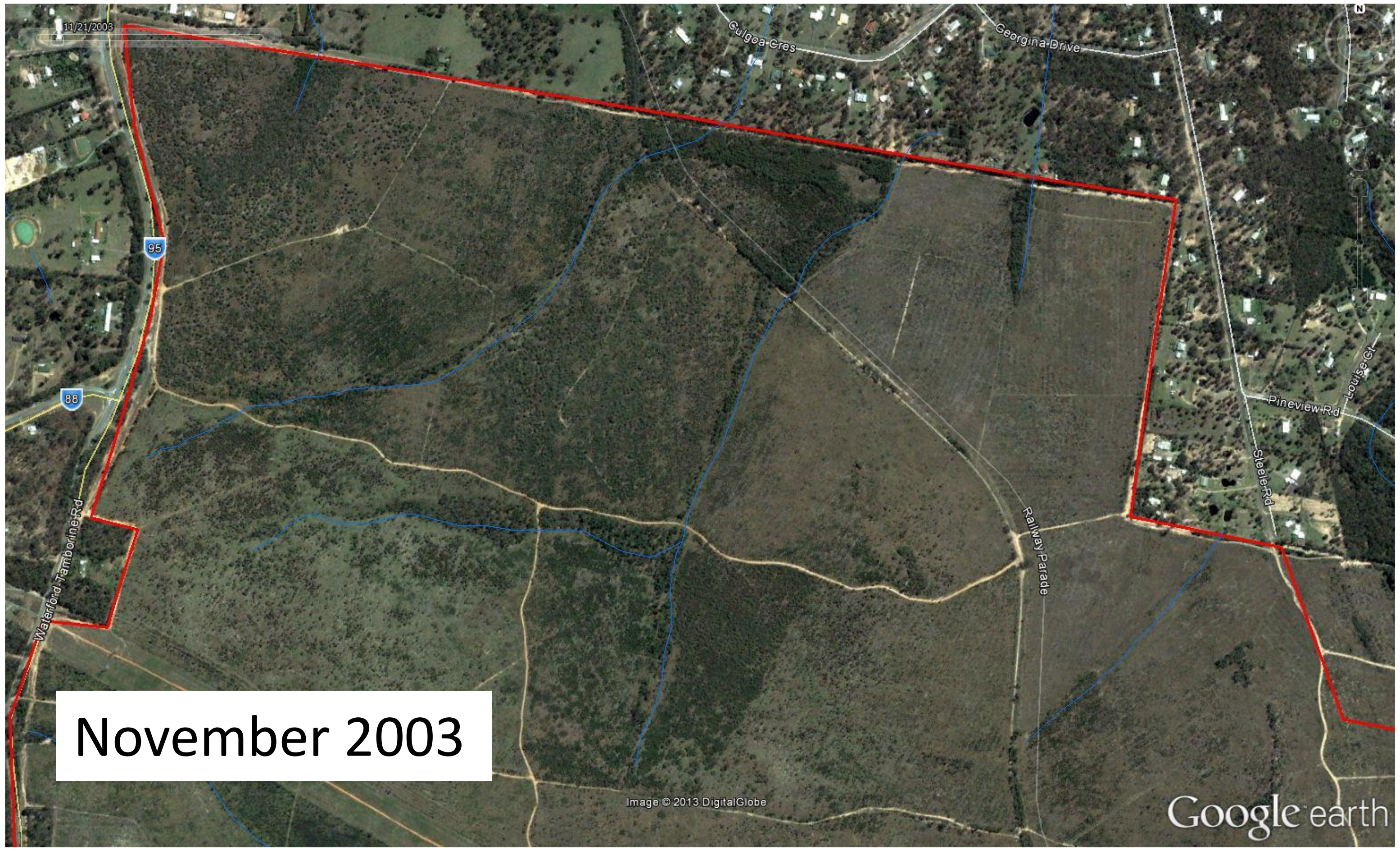

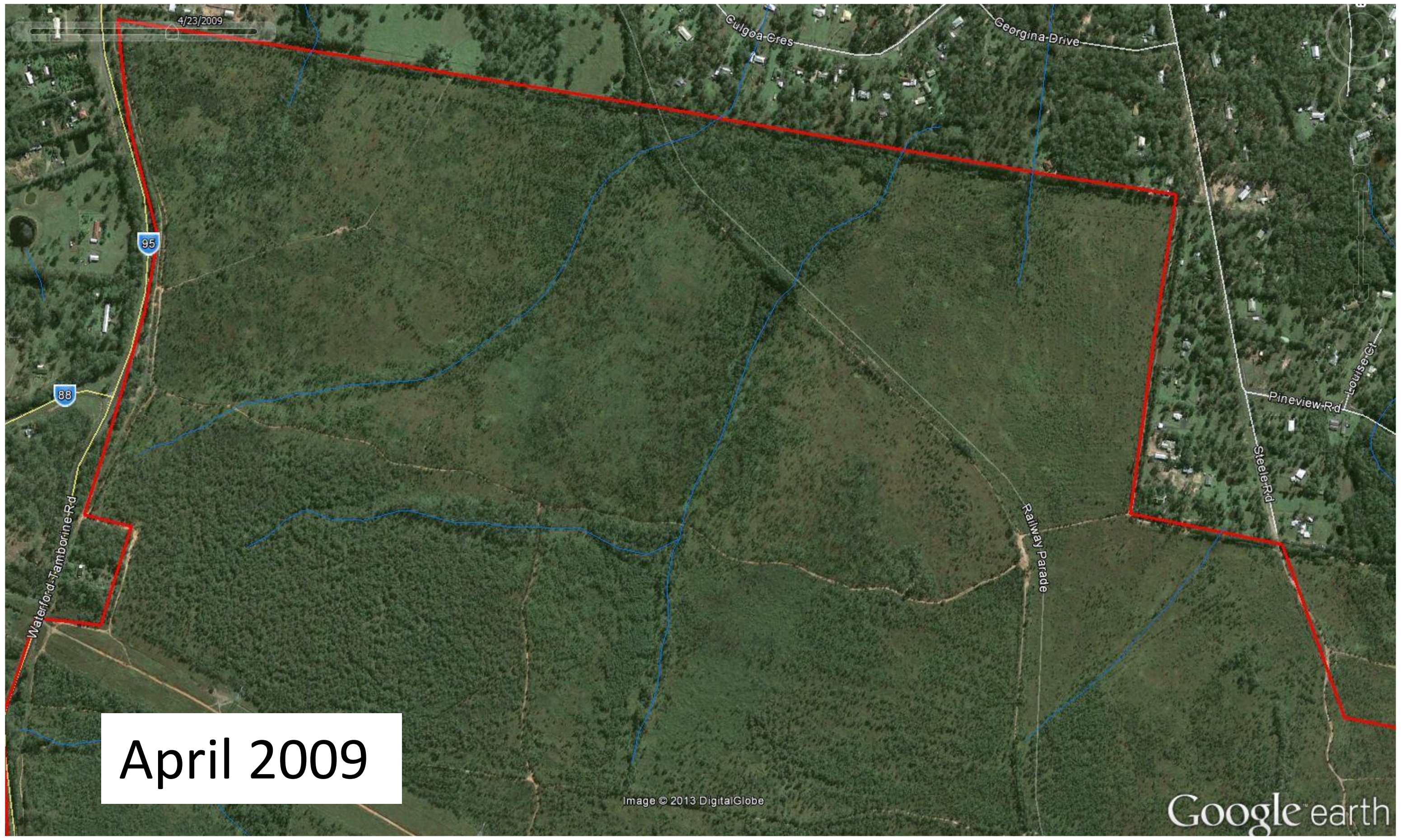

DesignFlow

LEGEND

Drainage line

Yarrabilba site boundary

FIGURE 7
Vegetation across recent air photos

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

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2.4 SOILS AND GROUNDWATER

The general geology of the site area is characterised by sandstone, siltstone, shale and conglomerate of the Woogaroo sub-group of the Bundamba group. These consist typically of weathered and cemented sequences of fine grained sedimentary rock. Surficial soils above these weathered sequences are typically silty sands.

Based on the findings of the Broadscale Geotechnical Investigation (Bowler, 2004) and the recent detailed investigations in Precinct 1 and 2, there were broadly similar soil conditions existing across the site, albeit with differing profile depths.

Generally, ridgelines exhibited thin silty sand topsoil (0.1m) overlying silty sand, sand and silty sandy gravel to varying depth (typically 0.1 to 0.4m). Some areas the silty sand topsoil overlays sandy silty clay and silty clay. In all cases, extremely weathered sandstone was encountered at between 0.4m and 2.7m below the surface. A shallow groundwater system exists above the impervious clays or weathered sandstone.

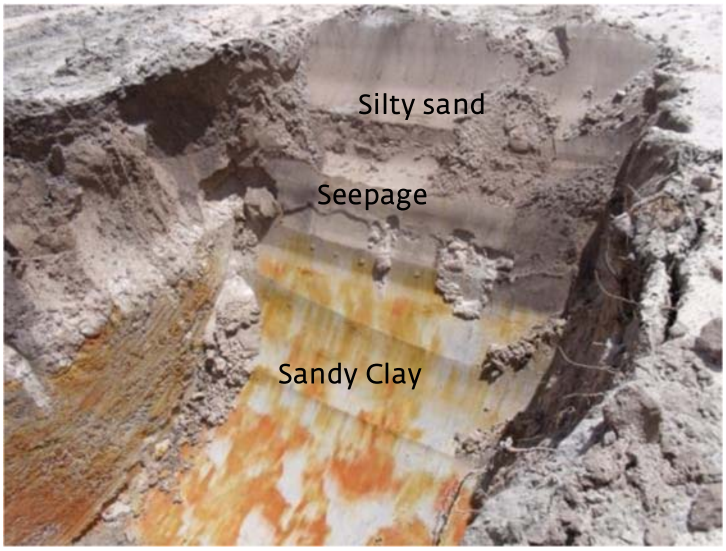
The lower lying gullies predominantly exhibit deeper surface profiles of dense sand, silty sand and clayey sand with some sandy silty clay overlying similar weathered sandstone and in some cases clayey sand and silty clay. Localised areas of deep silty sands were encountered in some boreholes and a number of rock outcrops have been found at various locations.

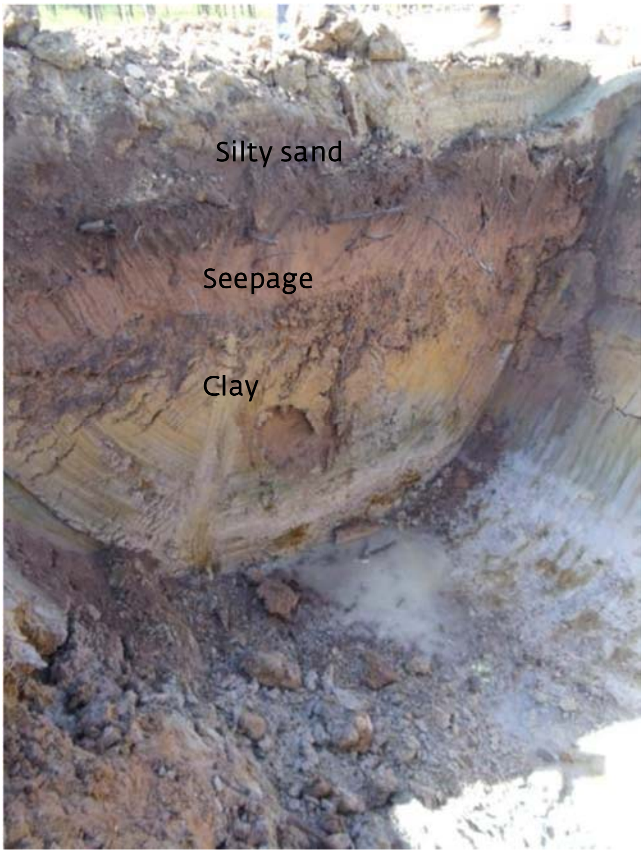
Figure 8 provides series of photos which illustrates the variable nature and depth of the surface sandy layer. Detailed investigations in Precinct 1 found that the permeability of the sand is typically 20mm/hr. Furthermore, the impermeable clay/weathered sand stone comes close to the surface creating a barrier to groundwater flow. At these locations groundwater is observed expressing at the surface created 'wet' or 'boggy' zones located throughout the Precinct 1 and 2 landscape .

Bowlers (2004) appraisal of the silty sands found in the surface layers indicated that these tend to be loose in-situ, can carry water after periods of wet weather and are slow to drain and dry out. This confirms the observations discussed above.

This is an important aspect of the hydrogeology and stormwater runoff on the site,. During wet conditions the ground becomes waterlogged and is slow to drain or dry out or water is re-expressed back to the surface. When larger rainfall events occur, typically as part of general wet conditions, the ground conditions are wet because there is no deep seepage beyond the impermeable layers.

Photo: Silty sand over weathered sandstone





Photos: Shallow silty sand over sandy clay and clay

Figure 8: Soil profiles encountered onsite

The silty sand topsoil is observed to be erosive when devoid of vegetation. A number erosion gullies were observed in the steeper parts of the Precinct 1 along the northern waterway where earthen tracks were present (no vegetation).

Soil testing completed by Environmental Soil Solutions Australia (2011) indicates the soils are acidic (naturally or through the Pine Plantation process) and as a result contain Aluminium. Given the sandy nature, the soils are erosive which confirms the onsite observations of erosion in areas of no vegetation. There is fine fraction within some of the soils which is dispersive.

Consideration to erosive velocities will be required and waterway stabilisation will be required in areas where erosion is already observed, or where potential erosive velocities may occur post development. During construction careful erosion and sediment control is required to manage sand as well as the finer dispersive fraction of the soil.

2.5 MONITORING WELL INSTALLATION

Four monitoring wells were recently installed to 5 m depth at the northern end of the site, in the location of the main holding storage, wetland and flood storage. Lithology during drilling indicated typically mixtures of silts, clays and sands in the upper 5 m.

These wells will be monitored over the coming 12 months to understand the seasonal groundwater variation and provide important information in understanding seasonal groundwater flows and interactions with adjacent waterways. Falling head tests are to be completed on these wells shortly, which will also inform potential for this area to provide management of frequent flows though the creation of "leaky" ephemeral wetlands.

2.6 DEVELOPMENT LAYOUT

Error! Reference source not found. the layout for Precinct 1 and the proposed layout for Precinct 2. Precinct 1 is under construction and comprises approximately 700 residential lots, retail area and school within a footprint of 83 hectares. Precinct 2 involves the creation of approximately 680 residential lots, two new schools and a small retail area.

The main and northern waterway corridors/buffers are to be preserved along with the significant existing vegetation within the waterways. The development will result in changes in catchment areas which in some location has been specifically designed to simplify the stormwater management strategy.

YARRABILBA

Yarrabilba
Precinct Two Concept Plan

NOTE: This plan is indicative only, and specific uses, road alignment, boundaries, setbacks, and building layout shown may vary due to detailed design consideration.

0 100 200 300 400 500m
Scale 1:10,000 at A3
North

Lend Lease

Figure 9: Precinct 1 and 2 Development Plan

2.7 SOUTHERN INFRASTRUCTURE CORRIDOR (SIC)

The Southern Infrastructure Corridor (SIC) is a 100m wide corridor that has been defined by Department of Transport and Main Roads for a new connecting highway. At the time of writing this report it was not clear when the SIC will be constructed but it is expected to be within 10-20 years from the date of this report.

The SIC is located along the northern boundary of the Yarrabilba site as illustrated in Figure 9. This presents significant challenges for stormwater management because the SIC is located at the downstream end of the site catchments. This means that in some locations stormwater runoff form the SIC will discharge northwards into the downstream waterways directly from the SIC land. It is not clear whether Department of Transport and Main Roads will apply the same stormwater management objectives, such as flood management, or even if achieving these objectives is feasible within the linear space allowed within the SIC. When establishing the stormwater management strategy for Precinct 1 and 2, the following SIC considerations were made:

- In Catchment 1 and 3, the SIC is located in the far downstream section of the waterway. This means stormwater runoff from the SIC will discharge downstream without entering the Yarrabilba site once the road is constructed. It is not clear whether stormwater management will be delivered in the SIC, what stormwater objectives will apply or practically how stormwater management will be delivered.

- In Catchment 3, the proposed level of the SIC corridor is below natural ground. This makes the creation of the flood bund on the Yarrabilba land to manage flood flows impossible without creating a flood bund within the Regional Ecosystem.

- In Catchment 2, there is ample room north of the SIC for stormwater management to occur. Therefore, in this location Lend Lease will manage stormwater from Yarrabilba as well as the SIC to ensure certainty for downstream residents.

- The location of any stormwater management systems needs to carefully consider the SIC. For example, permanent stormwater treatment systems cannot be placed in the SIC because they will ultimately be removed. Also the placement of the flood detention basins and outlet structures should align with the ultimate batter and pipe location of the SIC to ensure these systems continue to function after construction of the SIC (i.e. flood embankment and hydraulic controls should be located in the SIC such that will form part of the ultimate SIC and not be deconstructed).

- The SIC represents a significant barrier to the shallow groundwater. Construction of the road will involve massive cut and fill into the existing ground along with compaction to provide a stable embankment of the road. It is fair to say the SIC will stop local groundwater movement along the local waterways and force water to the surface to discharge through culverts. This has already occurred at the old railway crossing in Catchment 2 resulting in the creation of the ponded zone.

3 SUMMARY OF STORMWATER STRATEGY

Collaboration between Lend Lease, WSUD specialists (DesignFlow), civil engineers (KN Group), ecologists (Austecology) and urban designers/landscape architects (Lend Lease) has ensured that the development plan for Precinct 1 and 2 is suitably informed by WSUD. As a result, the stormwater management elements have been integrated into the conceptual design of the development layout, drainage infrastructure, earthworks, landscape and public open spaces to ensure that the stormwater management objectives required by the *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) are achieved.

The Precinct 1 and 2 stormwater management strategy is presented in Table 2 and Figure 10. The location and size of the stormwater management infrastructure is provided along with the systems already constructed as part of the approved *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011) shaded light blue. The strategy presented in this report supersedes the *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011). The following sections provide details of the erosion and sediment control plan, waterway buffers, stormwater quality management, frequent flow management, flood management and waterway stability management.

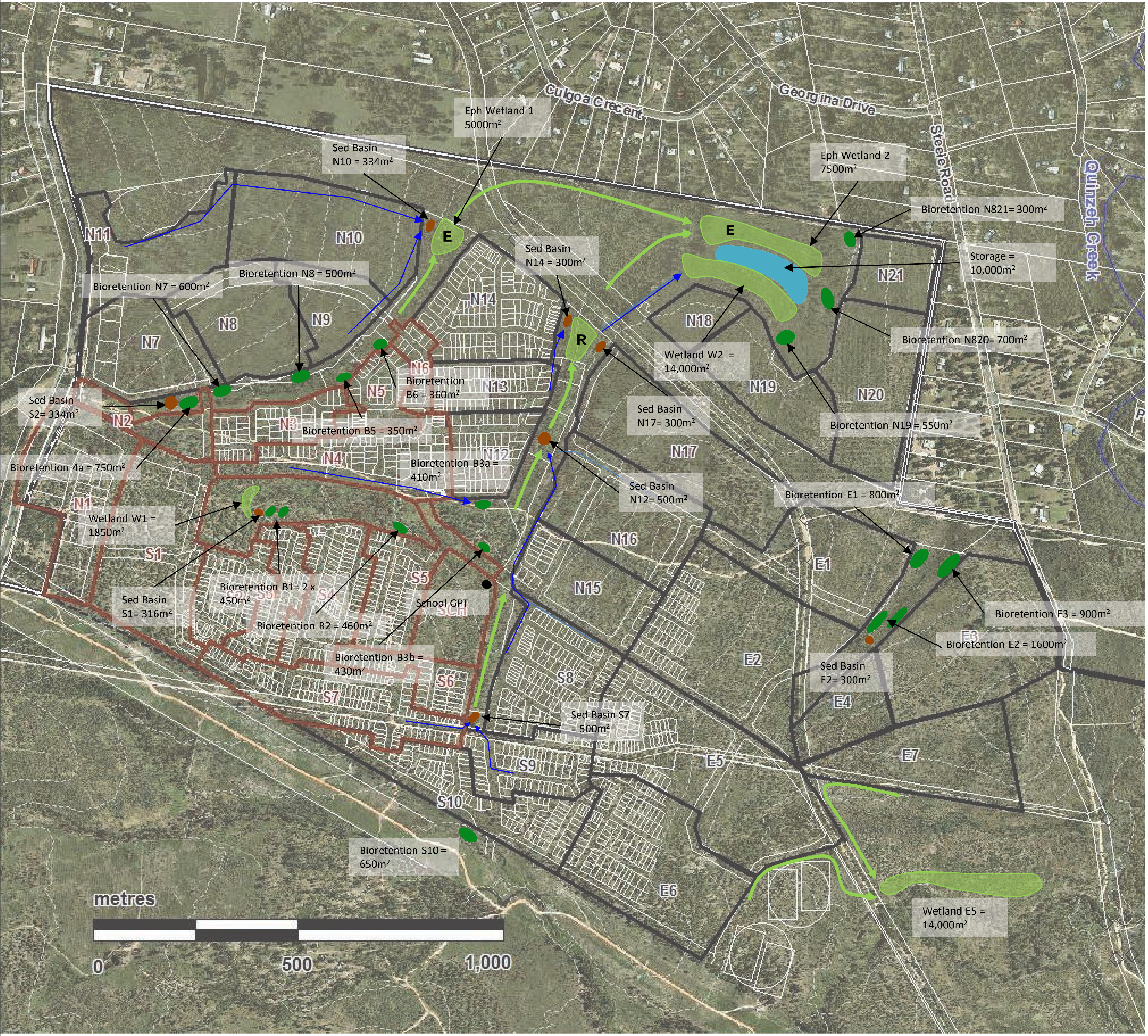
Table 2: Precinct 1 and 2 Stormwater Management Strategy

ID	Total Area* ha	Water savings	Stormwater quality Treatment type and ID	Area/Length	Flood detention basin (including waterway stability storage) Flood detention ID**	Volume**	Frequent Flow management
S1	12.01		Sediment basin S1 Wetland W1 Bioretention B1a	316m^2 1850m^2 450m^2	Flood 1 Flood 2 Flood 3 Flood 6 + wetland W2	37,023m^3 17,142m^3 14,453m^3 43,264m^3 + 3,6842m^3	Local waterway infiltration plus either of stormwater harvesting, ephemeral wetland infiltration or downstream drainage works
S2	3.88	Tanks (already installed)	Bioretention B1b	450m^2			
S3	3.25	Tanks (already installed)					
S4	4.99		Bioretention B2	460m^2			
S5	5.09		Bioretention B3b	430m^2			
S6	2.93		Swale S6 Wetland W2	125m 14,000m^2			
SCH	4.00		GPT (within School) Wetland W2	14,000m^2			
S7	7.48		Sediment basins S7	300m^2			
S9	4.61		Wetland W2	14,000m^2			
S8	7.53		Sediment basins N12 Wetland W3 Wetland W2	500m^2 5000m^2 14,000m^2			
S10	7.55		Bioretention S10	650m^2	Flood 11 (interim)	3,576	Infiltration from base of bioretention
N1	8.86		Sediment Basin N2	334m^2	Flood 3 Flood 4 Flood 5 Flood 6	14,453m^3 4,721m^3 4,385m^3 43,264m^3	Local waterway infiltration plus either of stormwater harvesting, ephemeral wetland infiltration or downstream drainage works
N2	2.97		Bioretention 4a	750m^2			
N3	3.90	Tanks (already installed)	Bioretention B5	350m^2			
N4	6.44	Tanks (already installed)	Bioretention B3a	410m^2	Flood 1 Flood 2 Flood 3	37,023m^3 17,142m^3 14,453m^3	
N5	2.65		Bioretention B6	360m^2	Flood 3 Flood 4 Flood 5 Flood 6	14,453m^3 4,721m^3 4,385m^3 43,264m^3	
N6	1.54						
N7	5.62		Bioretention N7	600m^2			
N8	6.93		Bioretention N8	500m^2			
N9	3.75		Sediment Basin N10	500m^2			
N10	9.77		Ephemeral Wetland 1	5000m^2			
N11	6.37		Swale N10	300m			
N12	3.84		Sediment Basin N12 Wetland W3 Wetland W2	Refer above (S8)	Flood 1 Flood 6 + wetland W2	37,023m^3 43,264m^3 + 3,6842m^3	
N13	3.69		Sediment Basin N14	300m^2			
N14	7.59		Wetland W3 Wetland W2	Refer above (S8) Refer above (S8)			
N15	6.16		Sediment Basin N12	Refer above (N12)			
N16	8.76		Wetland W3 Wetland W2				
N17	10.63		Sediment Basin N17 Wetland W3	300m^2 Refer above			

ID	Total Area* ha	Water savings	Stormwater quality		Flood detention basin (including waterway stability storage)		Frequent Flow management
			Treatment type and ID	Area/Length	Flood detention ID**	Volume**	
			Wetland W2	Refer above			
N18	2.24		Wetland W2	Refer above	Flood 6	43264m^3	
N19	3.03		Bioretention N19	500m^2			
N20	8.06		Bioretention N20	550m^2			
N21	3.16		Bioretention N21	700m^2			
E1	8.14		Bioretention E1		Flood 9	26,552m^3	Attenuation of low flows (<1yr ARI) and drainage upgrades downstream
E2	14.43		Sediment Basin E2	300m^2			
E4	3.60		Bioretention E2	1600m^2			
E3	12.45		Bioretention E3	900m^2			
E5	15.55		Swale E5	250m	Flood 10 (interim)	33,138m^3	Wetland storage and slow release at baseflow rates
E6	11.77		Wetland E5	10,000m^2			
E7	8.16		Bioretention E7	750m^2			
Total	253.4						

* Catchment areas of development footprints only (exclude waterways and retained vegetation). Flood catchments include the whole area so areas are different

** Flood detention storages accept flood flows from a number of catchments. In some cases the flood detention storage catchment is different from the stormwater quality catchments..



DesignFlow

LEGEND

- SW Diversions
- Remediated waterway
- Sediment Basin
- Bioretention
- Wetland
- Remediated Ponded Zone
- Ephemeral Water
- Stormwater harvesting storage
- Precinct 1 Catchment
- Precinct 2 Catchment

NOTE: Refer to Figure 22 for Flood Detention Locations

FIGURE 10
Precinct 1 and 2 Stormwater Management Strategy

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

N W E S	SCALE: ~1 : 1000	Date: 1 November 2013

Client:
Lend Lease

4 EROSION AND SEDIMENT CONTROL

4.1 DESIGN OBJECTIVE

The management of stormwater runoff during the construction phase is a critical part of protecting the Yarrabilba waterways and drainage lines. Construction phase design objectives for Precinct 1 and 2 are provided in Table 5 as defined by the *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and the *State Planning Policy for Healthy Waters*.

Table 3: Construction Phase Stormwater Quality

Pollutant/issue	Performance criteria [1]
Coarse sediment	Retain coarse sediment on site
Fine sediment (Total Suspended Solids - TSS)	Reasonable and practical measures should be taken to capture runoff from disturbed areas. Concentrations of TSS in water discharged (either by runoff or dewatering of siltation basins) should be less than 50mg/l.
Turbidity[2]	Turbidity in discharge waters should be <10% higher than receiving water turbidity (measured directly upstream of discharge point).
Nutrients (eg. N and P)	Construction phase nutrient management should occur via appropriate sediment management.
pH	Subject to the mobility of specific elements that may be present on site, pH of waters discharged from site must be between 6.5 and 8.5.
Dissolved oxygen	Dissolved oxygen concentration > 80% saturation.
Litter and gross pollutants	Prevent discharge of litter from site entering stormwater system/internal watercourses by ▪ Minimising litter production ▪ Containing litter on site by the provision and maintenance of rubbish bins with appropriate lids
Hydrocarbons and other contaminants[3]	Discharge of hydrocarbons and other contaminants should be prevented from site by: ▪ At-source control of contaminants. ▪ Preventing entry of contaminants into stormwater system or internal watercourses. ▪ Disposing of waste must be to authorised facilities. ▪ Storing hydrocarbons according to Australian Standard AS1940. ▪ Ensuring that discharged waters have no visible oil or grease sheen
Wash down areas	Prevent entry of wash down water into stormwater system or internal watercourses that discharge from site.
Cations and anions	As required under an approved Acid Sulfate Soil Management Plan, including aluminium, iron and sulphate.
Stormwater Quantity	Take all reasonable and practical measures to minimise changes to the hydrology of the receiving environment. Protection of in-stream habitat and flood characteristics by: ▪ managing peak flows for the 1-year and 100 year ARI event ▪ managing run-off volumes entering receiving waters ▪ preventing uncontrolled release of contaminated stormwater.

Notes:
1. Compliance release limits for rainfall events less than the design storm event – (based on the 80%ile 5 day rainfall depth).
2. Site-specific calibration of turbidity must be performed.
3. Refer to the contaminant list in the *Environmental Protection Regulation 1999*.

4.2 STRATEGY

4.2.1 Local erosion and sediment control

Erosion and sediment control will occur on a development stage by stage basis in accordance with *Best Practice Erosion and Sediment Control* (IECA, 2008) to achieve the objectives listed in Table 3. This will involve a combination of:

- Erosion control - Ensuring that all exposed surfaces are stabilised as soon as possible and that erosion of un-stabilised areas of works are minimised

- Drainage control - Ensuring that provision is made to control all on site runoff to designated treatment areas and to enable appropriate bypass of external flows which do not require treatment

- Sediment capture - Ensuring that mobilised sediment is captured through a combination of source controls such as silt fences and appropriately designed sediment basins. Where possible sediment basins for construction will be located within the voids required for the future stormwater quality treatment systems (sediment basins, bioretention basins etc.).

The details of the local erosion and sediment controls for each stage of development are not provided in this report given the high level nature of the document. However, prior to any works commencing on a particular development stage in Precinct 1 and 2, a site specific Erosion and Sediment Control Plan (E&SCP) will be documented for the development stage in question and submitted to EDQ prior to works starting. This will occur as part of the operational works application but can be adjusted by the contractor and site supervisor prior to commencement of construction provided the E&SCP complies with *Best Practice Erosion and Sediment Control* (IECA, 2008) and delivered the objectives listed in Table 3.

4.2.2 Regional sediment basins

Given the dispersive fraction present in the soils on Yarrabilba, large sediment basin are proposed at the downstream end of Catchments 2, 3 and 4. The basins will capture flows from the catchment to allow the management of any turbid water still present in stormwater prior to discharge downstream. The basin will be actively flocculated and dewatered in accordance with *Best Practice Erosion and Sediment Control* (IECA, 2008). The basins will also provide a source of construction and landscape establish water for Precinct 1 and 2. The basins will site within proposed wetlands or flood detention basins with the sizes listed below (based on area available and proposed treatment systems in these locations):

- Catchment 2 – 15,000m^2 (min)

- Catchment 3 – 4,000m^2

- Catchment 4 – 8,000m^2

4.2.3 Monitoring/auditing

As part of the current construction work within Precinct 1, independent auditing of the erosion and sediment control practices being delivered by the contractor is undertaken. This occurs on a 1-2 monthly basis and has identified a range of problems which have been resolved and is resulting in improved erosion and sediment control. This auditing will continue for the whole of Precinct 1 and 2 on a monthly basis.

Furthermore, water monitoring will be completed on the regional sediment basins in accordance with the *State Planning Policy (for Healthy Waters)* and *Best Practice Erosion and Sediment Control* (IECA, 2008). As part of the detailed design of the regional sediment basin an operation and monitoring specification and handbook will be developed to ensure easy implementation of monitoring by Lend Lease.

5 WATERWAY BUFFERS

5.1 DESIGN OBJECTIVE

Waterway buffers for Precinct 1 and 2 have been adopted in accordance with *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012). The requirements of the waterway buffers are listed in Table 4 with the relevant buffer of 15m for natural drainage path highlighted for Precinct 1 and 2.

Table 4: Waterway buffer objectives

Waterway Category	Definition	Desirable minimum buffer width from waterway centreline or defined bank / edge of wetland
Major creek	Creeks with permanent flow and defined bed and banks	30 metres
Minor creek	Creeks with defined bed and banks and either permanent or intermittent flows	15 metres
Natural drainage path	Intermittent overland flow paths with or without defined bed and banks	15 metres
Major wetland	Wetlands of regional significance*	100 metres
Minor wetland	Wetlands of local significance**	50 metres

* No regional significant wetlands at Yarrabilba

** Only 1-2 wetlands of local significance at Yarrabilba

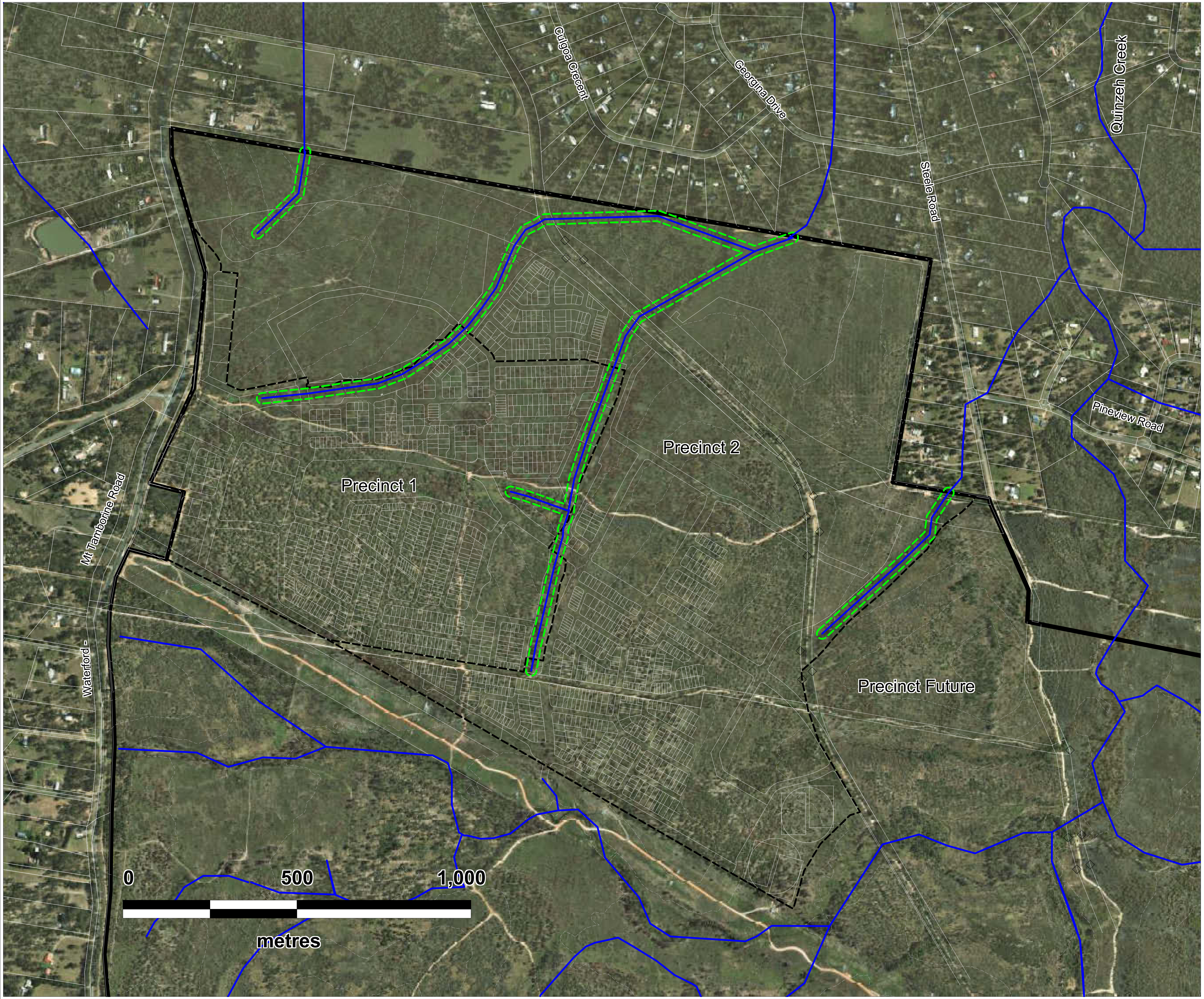
The buffer requirements listed in Table 4 are subject to ground truthing prior to adoption (or designation of alternative buffers) for the purpose of development approval and detailed design.

Where the waterway buffers are degraded and clear of vegetation, there is opportunity for co-location of treatment devices, remediation to allow some water quality treatment, recreational infrastructure and to restore the waterways. The specific requirements of this is provided in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012).

5.2 WATERWAY BUFFERS

The development plan for Precinct 1 and 2 retains all the key waterways and preserves the significant vegetation as illustrated in the Figure 11. All the waterways have been ground truthed with significant vegetation surveyed to refine the regional ecosystem mapping. As noted in Figure 11, the SIC will inevitably destroy existing vegetation which is mapped as Regional Ecosystem. In order to limit damage to this vegetation, it is proposed to co-locate flood detention bunds with the SIC corridor.

As outlined in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012), where the waterway buffers are degraded and clear of vegetation, there is opportunity for co-location of treatment devices and recreational infrastructure and to restore the waterways. It is proposed to include some stormwater management recreational elements and vegetated development edges within these degraded sections of the waterway buffer in accordance with the requirements listed in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012).



DesignFlow

LEGEND

- Yarrabilba site boundary
- Precinct boundary
- 5m contour
- Waterway / drainage line
- 15m buffer

FIGURE 11
Precinct 1 and 2
Waterway Buffers

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

SCALE:
1 : 1000

Date:
1 November 2013

Client:
Lend Lease

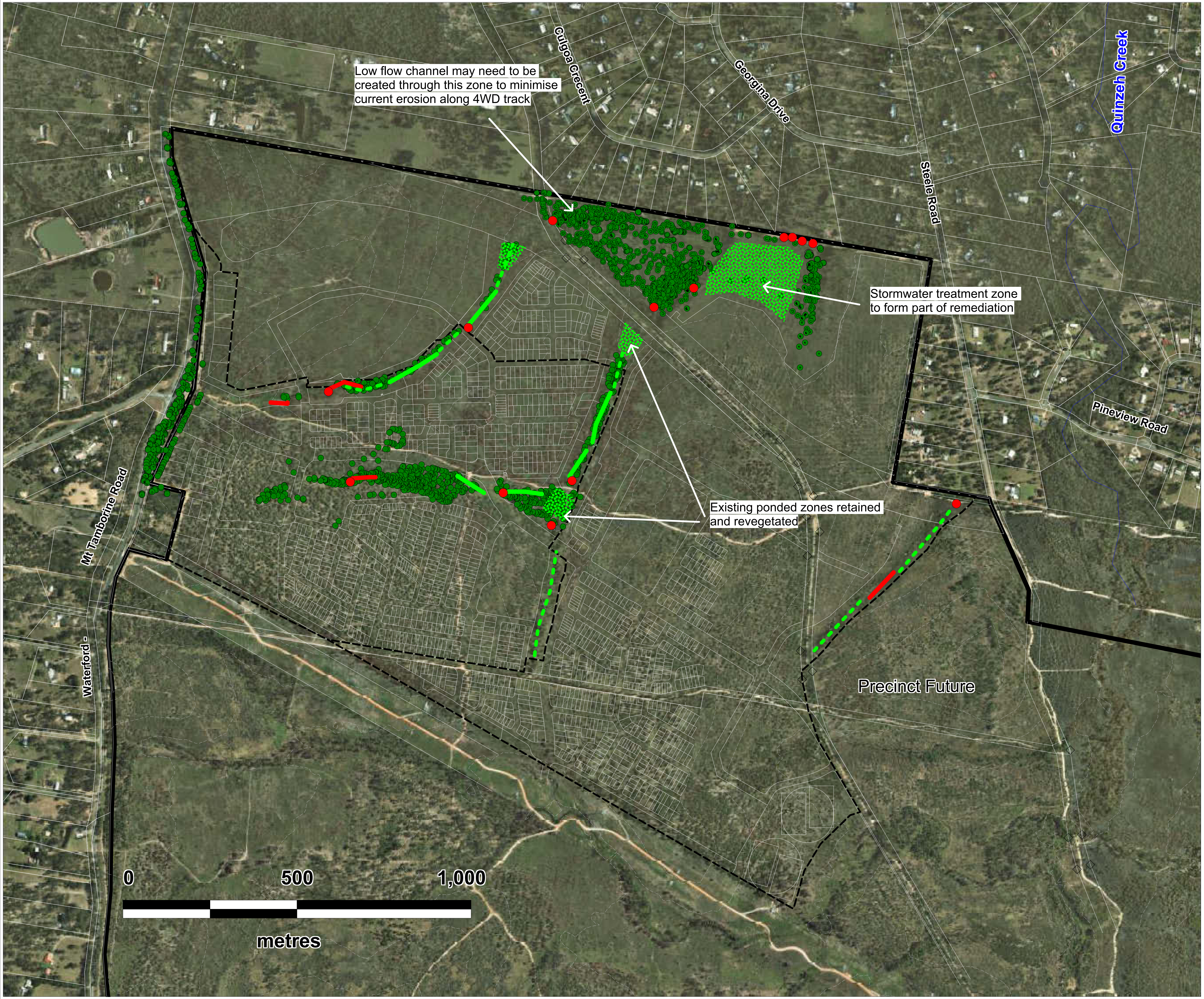
5.3 WATERWAY REMEDIATION

As illustrated in Figure 4, waterway condition assessment completed by DesignFlow found only a small portion of waterway in Good condition along with two small ponded zones. The development that has already occurred as part of Precinct 1 has preserved this Good condition waterways in Precinct 1 and 2 and one of the ponded zones. The second wetland to the north will be mostly destroyed as part of the future SIC.

The majority of the waterways are in Poor or Average condition due to lack of vegetation (i.e. grasses and regrowth pine plantation). It is proposed that these waterways will be remediated in accordance with the following:

- Significant vegetation within the waterways will be preserved.
- Waterway revegetation works will be completed on Average and Poor to remove pine/weeds and establish a densely vegetated ephemeral waterway.
- Any existing erosion will be stabilised using best practice methods and revegetated.
- Stormwater will be discharged to the waterways in a manner that minimises the risk of erosion and promotes infiltration into the silty sand topsoil to recharge the local shallow groundwater.
- Where flow velocities are altered within the waterways as a result of landuse change to the point where erosion may occur even following revegetation (i.e. velocities >1.5m/s), these waterway reaches will be stabilised using best practice methods and revegetated.

The waterway remediation concept for Precinct 1 and 2 is presented in Figure 12. A waterway revegetation strategy exists for part of Precinct 1 and is being delivered by Lend Lease. DesignFlow are working with Lend Lease to establish a waterway remediation and revegetation strategy for all the waterways Precincts 1 and 2. The intent is to create waterways that reflect the natural waterways of the region, contain a structure of groundcovers and trees, are low maintenance and provide a water quality treatment function. A typical section of a remediated waterway for Precinct 1 and 2 is presented in Figure 13.



DesignFlow

LEGEND

- Yarrabilba Site
- Precinct 1 and 2
- Outlet rock scour protection
- Waterway rock scour protection
- Revegetate and observe (for local scour)
- Revegetate waterway
- Revegetate ponded zone
- Existing Trees (to retained in waterway)

FIGURE 12
Precinct 1 and 2
Waterway Remediation Concept

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

SCALE:
1 : 1000

Date:
1 November 2013

Client:
Lend Lease

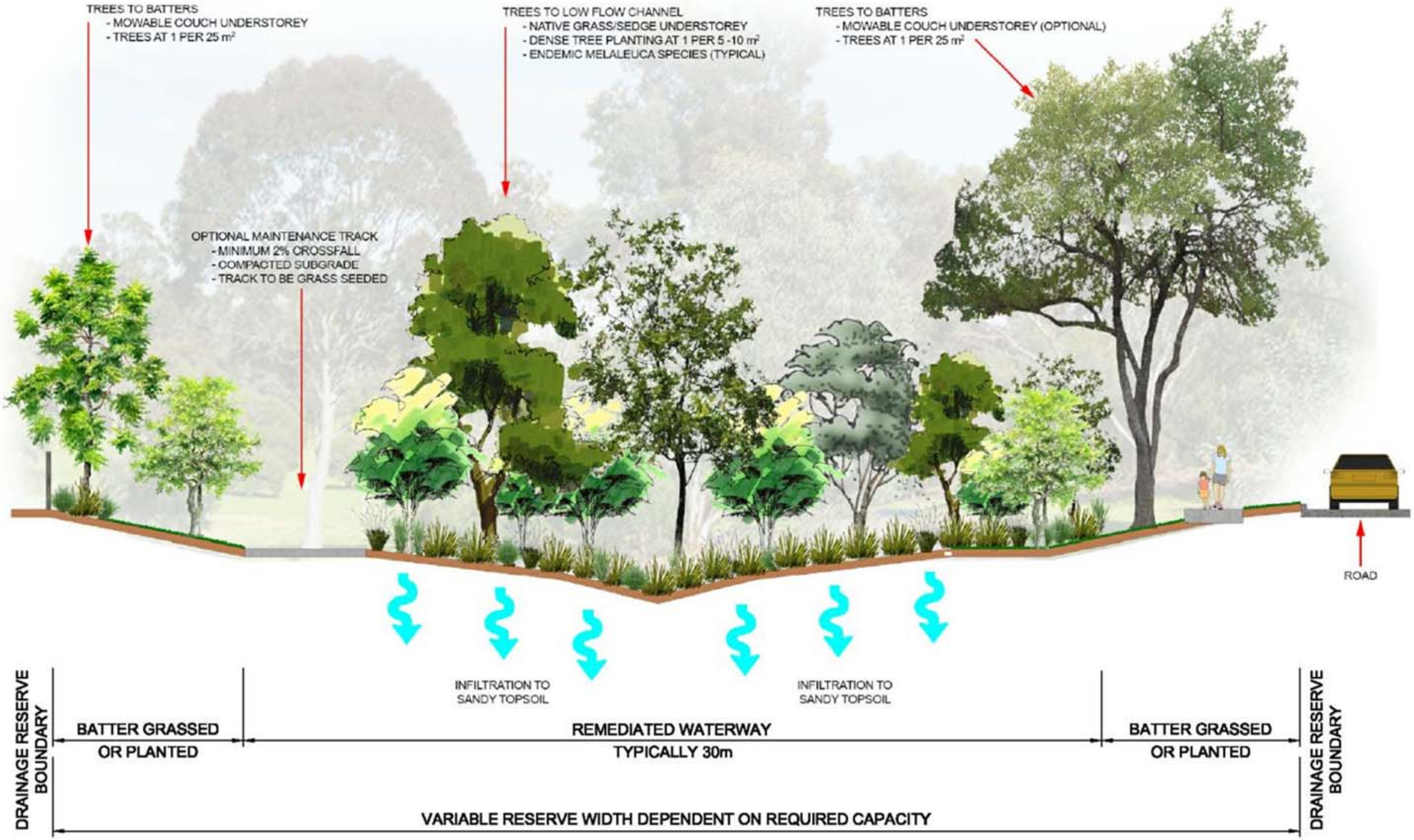


Figure 13: Remediated waterway typical section

6 STORMWATER QUALITY

6.1 DESIGN OBJECTIVE

The stormwater management strategy for the Precinct 1 and 2 will achieve the objectives listed in Table 5 as defined by the *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012). The objectives require the reduction of pollutant loads discharged from the developed site once all construction works is complete. These load reductions are aimed at protecting the environmental values of downstream receiving waterways from the impacts of urban stormwater runoff.

Table 5: Stormwater quality objectives

Pollutant	Discharge Criteria (% reduction in mean annual load)
Total suspended solids (TSS)	80%
Total phosphorus (TP)	60%
Total nitrogen (TN)	45%
Gross Pollutants (GP)	90%

Note: criteria based on State Planning Policy 4/10

6.2 STRATEGY

6.2.1 Overview

The stormwater quality management strategy has been refined since the approval of *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011) to consider the following:

- Preference to focus on waterway remediation initially and integrate the stormwater management with the waterways as much as possible. This approach is consistent with EDQ's preference and also Logan City Council's new approach to stormwater and waterway management.
- Allowing some stormwater management to occur within the remediated waterways as part of the integration of waterways and stormwater management. This has the benefit of reducing the overall footprint of the stormwater management systems.
- EDQ and Council's preference to minimise the number of stormwater management systems.
- Catchment diversions and new catchment areas derived as part of the planning for Precinct 2.

The updated stormwater quality strategy is presented in Table 2 and Figure 10. The following sections describe the individual elements of the strategy.

6.2.2 Remediated Waterways

As outlined in Section 5.3, the waterways in Average and Poor condition will be remediated. This will involve complete revegetation of the waterways to reflect the natural ephemeral waterways of the region. These remediated waterways will provide infiltration of low flows (when the local topsoils are not already waterlogged) and some removal of sediment and particulate nutrients (phosphorus) from stormwater runoff. Stormwater from the development will pass through either sediment basins or bioretention systems prior to entering the waterways. These will provide partial or full treatment of stormwater and create an easy point of maintenance for Council rather than having to get into the waterway to complete coarse sediment and litter management. The length of waterway being remediated and a typical section of a remediated waterway are presented in Section 5.3.

6.2.3 Sediment basins

Eight sediment basins are proposed in Precinct 1 and 2. The size and location of the sediment basins are presented in Table 2 and Figure 10.

All of the sediment basins are to accept stormwater from piped flows and provide scour protection, sediment and litter removal before stormwater enters either remediated waterways or bioretention basins. The sediment basins provide an easy point of access for maintenance of litter and sediment. All of the sediment basins are located offline (or at the far upstream end) of the waterway other than Sediment Basin N12. This particular system is located on-line in Catchment 3 to allow development catchments from both sides waterway to enter a single sediment basin. The location of this basin has been selected to minimise the impact of vegetation. Three trees will be removed for this sediment basin and these will be offset through replanting in the direct vicinity of the basin.

Sediment basins will be designed in accordance with the *WSUD Technical Design Guidelines* (Water by Design, 2006) and the design requirements outlined in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) when located within the waterway buffer. Particular attention will be given to the design of the outlets from the sediment basins into the remediated waterways to minimise the risk of scour.

6.2.4 Bioretention systems

Eight bioretention basins have already been constructed in Precinct 1 as part of the approved *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011). Ten additional bioretention basins are proposed for Precinct 2 as illustrated in Table 2 and Figure 10.

Photo: Bioretention B1a in Precinct 1 with protective turf in place

The bioretention basins are located along the waterway corridors, and protected from frequent waterway flows. The basins accept and treat piped stormwater from Precinct 1 and 2 sub-catchments before discharging to the waterways. Bioretention systems will be designed in accordance with the *WSUD Technical Design Guidelines – Bioretention Chapter* (Water by Design, 2012) and the design requirements outlined in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) when located within the waterway buffer.

Flows from the bioretention basins will be encouraged to enter into the low shallow groundwater either through the base of the bioretention basins, which is proving to be difficult based on construction experience in Precinct 1, or through constructed gravel trenches connect to the outlet of the bioretention basin.

6.2.5 Wetlands

Six wetlands are proposed for Precinct 1 and 2 with one of the wetlands (W1) in Precinct 1 under construction (1850m^2). The size and location of the wetlands are presented in Table 2 and Figure 10.

Two conventional stormwater wetlands are proposed for Precinct 2 are located at the downstream end of Catchment 2 and Catchment 4 where the site becomes wide and flat. At these locations they can be incorporated with flood detention storage and Wetland W2 (1.4ha) will be used in combination with stormwater storage to provide for stormwater harvesting.

The existing ponded zone at location Wetland W3 (0.5ha) will be rehabilitated to form a wetland. All flows entering this wetland will be pre-treated in sediment basins and swales. The wetland will provide minor treatment of nutrients but will not have a defined extended detention as flood storage needs to be maximised at this location.

We have also created two ephemeral wetlands. The first ephemeral wetland will be created within the remediated waterway behind the SIC at location Ephemeral Wet 1 (0.5ha). All flows entering this wetland will be pre-treated in sediment basins and swales. The wetland will be densely vegetation with melaleuca and provide minor treatment of nutrients but will not have a defined extended detention as flood storage needs to be maximised at this location.

The second ephemeral wetland (Eph Wetland 2 - 0.75ha) will be located at the downstream end of Catchment 3. The wetland will be a melaleuca based wetland and form part of the rehabilitation area and be placed between the stormwater storage and the flood bund to manage flows from the western tributary of Catchment 3.

The wetlands will be designed in accordance with the *WSUD Technical Design Guidelines – Bioretention Chapter* (Water by Design, 2012) and the design requirements outlined in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) when located within the waterway buffer.

6.2.6 Gross pollutant traps and other specific land use pollutants

Gross pollutants loads from the urban residential areas of the site are considered sufficiently low to be adequately managed through the pre-treatment areas of wetland and bioretention basins via the standard maintenance regime for these systems. However, for commercial and industrial sites where high gross pollutant or other non-typical pollutant loads are likely (e.g. higher than typical urban nutrient, sediment or hydrocarbon loads), individual lots must provide measures or devices to capture these pollutants onsite prior to discharge to local vegetated stormwater treatment measures. As the exact land use for the commercial and industrial portions of the catchment have not be defined at the high level master planning of the site, it is the responsibility of these landowners to provide these measures. Further, any stormwater management requirements for Environmentally Relevant Activities (ERA) scheduled in the Environmental Protection Regulation 2008 are to be done in addition to those specified in this Stormwater Management Plan.

6.3 CONCEPTUAL EARTHWORKS PLANS

The treatment sizes described in Table 2 and Figure 10 do not allow for batters, embankments, maintenance access and hydraulic structures. To properly assess the spatial requirements of the stormwater management systems within the development plan, total footprint need to be considered (not just the treatment area).

To confirm there is enough space within the within the development layout, conceptual earthworks designs have been generated for each of the sediment basins, bioretention basins and wetlands proposed in Catchment 2 and 3. The designs have been completed in accordance with *WSUD Technical Design Guidelines* (Water by Design, 2006). The conceptual earthworks design is provided in Appendix B. No conceptual designs were completed for Catchment 4 because there is ample space in development layout for the proposed treatment systems.

6.4 MODELLING

MUSIC modelling was conducted to quantitatively assess the stormwater treatment performance of the proposed stormwater strategy. MUSIC version 5.0 was used for the assessment and the parameters have been established in accordance with the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010).

Details of the modelling assumptions, parameters and results are presented in the following sections.

6.4.1 Model Structure

The modelling was undertaken using 10 years (1990-2000) of modified Shailer Park meteorological data. Six minute rainfall data and monthly average evapotranspiration data was used. The Shailer Park station was selected for adaption as it is the closest rainfall station to the site with 6 minute data. The rainfall data set was modified to generate a data set closer representing Logan Village rainfall. Mean annual rainfall for Shailer Park is 1179 mm (Station 040715), whereas Logan Village is 994 mm (Station 040766).

To test the appropriateness of using the Shailer Park rainfall, a double mass curve analysis between Shailer Park and Logan Village rainfall data sets was completed over common years of available rainfall data (1988-98) and demonstrated that rainfall distributions were similar. The Shailer Park 6 minute rainfall was reduced by 0.849 to produce a rainfall data set with the same annual total to Logan Village for the period considered.

The structure of the MUSIC model is shown in Figure 6 with the general data upon which the model is based provided in Table 6.

Table 6: MUSIC model general parameter summary

Input	Data used in modelling
Rainfall station	Modified Shailer Park Station 040715
Time step	6 minute
Modelling period	1990-2000
Mean annual rainfall	950 mm (factored)
Evapotranspiration	1,446 mm (1990-2000)
Rainfall runoff parameters	Urban Residential Commercial
Pollutant export parameters	Urban Residential Commercial

All information above has been sourced from Water by Design, 2009

6.4.2 Catchment data

The development has been split into sub-catchments. The model adopts the lumped catchments approach. Each of the sub-catchments has been assigned areas and imperviousness based on the development plan for the site. The catchments in Precinct 1 (S2, S3, N3 and N4) where rainwater tanks have been adopted use the split catchment approach (i.e. separated out the roof area draining to tanks)

Most of the site is urban residential with smaller area of commercial, schools, sports fields and parks. For the purposes of water quality assessments, only those areas proposed to be developed or under development were included. Waterways and stormwater treatment systems were excluded from the model as these areas are not being developed and are being rehabilitated. The SIC was also excluded from the catchments is not responsibility of Lend Lease. Note that the catchments for flood modelling and frequent flow model do include the waterways treatment systems and SIC (Catchment 2 only) to ensure accurate representation of total flows.

Summary catchment data is provided in Table 7. The MUSIC model layout and catchment delineation is shown in Figure 14. Note the different Catchment IDs have been used in the MUSIC modelling than the flood modelling. This is because the catchments for the MUSIC modelling excluded the waterways and retaining vegetation and therefore are different in area.

Table 7: MUSIC catchment data

ID	Total Area ha (% impervious)	Residential	Roof*	Parkland	Commercial	School
S1	12.01 (49%)	0.57 (60%)		5.56 (2%)	5.99 (90%)	
S2	3.88 (60%)	3.25 (60%)	0.63 (100%)			
S3	3.25 (60%)	2.71 (60%)	0.54 (100%)			
S4	4.99 (54%)	4.47 (60%)		0.52 (2%)		
S5	5.09 (60%)	5.09 (60%)				
S6	2.93 (60%)	2.93 (60%)				
SCH	4.00 (70%)					4.00 (70%)
S7	7.48 (60%)	7.48 (60%)				
S8	7.53 (60%)	7.53 (60%)				
S9	4.61 (60%)	4.61 (60%)				
S10	7.55 (60%)	7.55 (60%)				
N1	8.86 (90%)				8.86 (90%)	
N2	2.97 (90%)				2.97 (90%)	
N3	3.90 (60%)	3.28 (60%)	0.62 (100%)			
N4	6.44 (60%)	5.70 (60%)	0.74 (100%			
N5	2.65 (49%)	2.15 (60%)		0.50 (2%)		
N6	1.54 (60%)	14.54 (60%)				
N7	5.62 (69%)	4.00 (60%)			1.62 (90%)	
N8	6.93 (60%)	6.93 (60%)				
N9	3.75 (60%)	3.75 (60%)				
N10	9.77 (60%)	9.77 (60%)				
N11	6.37 (65%)	5.26 (60%)			1.11 (90%)	
N12	3.84 (60%)	3.84 (60%)				
N13	3.69 (60%)	3.69 (60%)				
N14	7.59 (60%)	7.59 (60%)				
N15	6.16 (65%)	3.12 (60%)				3.04 (70%)
N16	8.76 (64%)	5.17 (60%)				3.59 (70%)
N17	10.63 (60%)	10.63 (60%)				
N18	2.24 (60%)	2.24 (60%)				
N19	3.03 (60%)	3.03 (60%)				
N20	8.06 (60%)	8.06 (60%)				
N21	3.16 (60%)	3.16 (60%)				
E1	8.14 (60%)	8.14 (60%)				
E2	14.43 (62%)	13.35 (60%)			1.08 (90%)	
E3	12.45 (62%)	9.88 (60%)				2.57 (70%)
E4	3.60 (70%)					3.60 (70%)
E5	15.55 (60%)	9.55 (60%)				6.00 (70%)
E6	11.77 (60%)	11.77 (60%)				
E7	8.16 (67%)	2.33 (60%)				5.83 (70%)
Total	253.4	197.6		6.6	21.6	28.6

* Only split where rainwater tanks have been delivered with lot prior to Queensland Development Code change in January 2013.

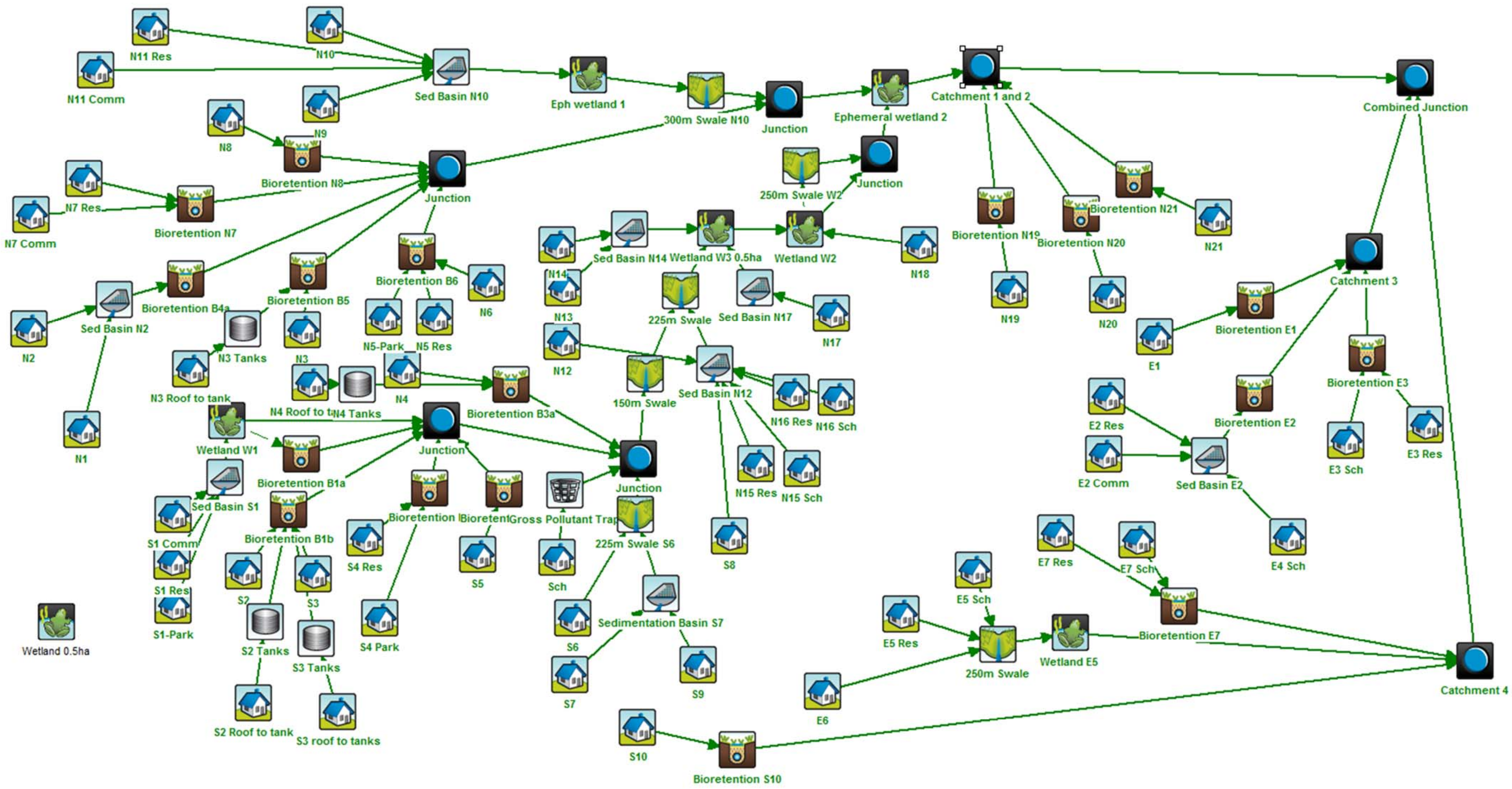


Figure 14: MUSIC catchment delineation and model layout

6.4.3 Sediment Basins

The sediment basins were modelled in accordance with the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010). The parameters that have been adopted for the Yarrabilba site are shown in Table 8

Table 8: Sediment Basin node reporting table

Catchment ID	S1	N2	S7	N10	N12	N13, N14	N17	E2
Surface area (m^2)	316	334	300	500	500	300	300	300
Has the surface area been appropriately? (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y
Extended detention depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Permanent pool volume (m^3)	316	334	300	500	500	300	300	300
Exfiltration rate (mm/hr)	0	0	0	0	0	0	0	0
Evaporative loss as % of PET	75	75	75	75	75	75	75	75
Equivalent pipe diameter (m)	300	300	300	300	300	300	300	300
Overflow weir width (m)	10	2	2	2	2	2	2	2
Notional detention time	0.3hr	0.24hr	0.22hr	0.36hr	0.36hr	0.22hr	0.22hr	0.22hr
Number of CSTR cells	1	1	1	1	1	1	1	1
Confirmation that K and C* remain default? (Y/N)	Y	Y	Y	Y	Y	Y	Y	Y

6.4.4 Bioretention Systems

The bioretention basins were modelled in accordance with the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010). The parameters that have been adopted for the Yarrabilba site are shown in Table 9.

Table 9: Bioretention Basin node reporting table

Parameter	Bioretention Basin																	
	B1a	B1b	B2	B3b	B3a	B4a	B5	B6	N7	N8	N19	N20	N21	E1	E2	E3	E7	S10
Surface Area (m^2)	465	450	460	460	410	750	350	360	600	500	550	700	300	800	1600	900	750	650
Has the surface area been calculated appropriately?	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method	Yes, equal surface area method
Extended detention depth (m)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Filter area (m^2)	450	450	460	460	410	750	350	360	600	500	550	700	300	800	1600	900	750	650
Hydraulic conductivity (mm/hr)	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Filter depth (m)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Filter median particle diameter (mm)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Overflow weir width (m)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Seepage loss (mm/hr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Confirmation that K and C* remain default?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

6.4.5 Remediated Waterways

The remediated waterways were modelled as swales in MUSIC. The purpose of the waterways is to manage fine sediment and particulate nutrients prior to flows enter the wetlands downstream. The swale treatment node provides this treatment function appropriately.

Catchment ID	S6	S6a	N12	W2	N10	E5
Low-flow bypass (m^3/s)	-	-	0.25	-	0.25	-
Length (m)	225	150	150	250	300	250
Bed slope (%) - maximum 4%	2.0	1.5	1.5	1.0	1.5	0.5
Base width (m)	5	5	5	5	5	5
Top width (m)	15	15	15	15	15	15
Depth (m)	0.6	0.6	0.6	0.6	0.6	0.6
Vegetation height (m)	0.5	0.5	0.5	0.5	0.5	0.5
Exfiltration rate (mm/hr)	0	0	0	0	0	0
Confirmation that K and C* remain default? (Y/N)	Y	Y	Y	Y	Y	Y

6.4.6 Constructed wetlands

Stormwater quality from four catchments at Yarrabilba will be managed using constructed wetlands. The wetlands were modelled in accordance with the *MUSIC Modelling Guidelines for South East Queensland* (Water by Design, 2010), with the parameters adopted for the Yarrabilba site shown in Table 9 below.

Table 10: Constructed wetland node reporting table

Parameter	Constructed Wetland					
	W1	W2	W3	Eph Wet 1	Eph Wet 2	E5
Inlet pond volume (m^3)	0 (separate sediment basin W1)	0 (swale pre-treatment)	0 (swale pre-treatment)	0 ((separate sediment basin N10)	0 ((separate sediment basin N10)	600
Macrophyte zone area (m^2)	1850	14,000	5,000	5,000	7,500	10,000
Has the surface area been calculated appropriately?	Yes, surface area = macrophyte zone at normal water level	Yes, surface area = macrophyte zone at normal water level	Yes, surface area = macrophyte zone at normal water level	Yes, surface area = macrophyte zone at normal water level	Yes, surface area = macrophyte zone at normal water level	Yes, surface area = macrophyte zone at normal water level
Extended detention depth (m)	0.5	0.5	0.5	0.5	0.5	0.5
Permanent pool volume (m^3)	555	4500	500	50	50	3000
Average depth (m)	0.3	0.35	0.1	0.01	0.01	0.3
Exfiltration rate (mm/hr)	0	0	0	0	0	0
Evaporative loss (% of PET)	125	125	125	125	125	125
Notional Detention Time (h)	48	48	3	1.5	22	48
Number of CSTR cells	4	4	4	4	4	4
Confirmation that K and C* remain default?	Y	Y	Y	Y	Y	Y

6.4.7 Results

The results of the MUSIC modelling for the proposed development are shown in Table 11. The results demonstrate that the proposed stormwater strategy meets the stormwater quality design objectives for Precinct 1 and 2.

Table 11: MUSIC model results – load removal

Catchment		Annual Pollutant Load removal (%)		
ID	Area (ha)	TSS	TP	TN
Catchment 1 and 2	171.7	89	73	43
Catchment 3	38.6	84	65	52
Catchment 4	43.0	88	73	47
Total	253.3	88	72	45
Objective		80	60	45

The model has not included the potential load removal associated with infiltration within the waterways or the stormwater harvesting system within Catchment 2. This additional treatment would ensure the stormwater quality objective are exceeded (not just achieved).

7 FREQUENT FLOWS

7.1 DESIGN OBJECTIVE

The frequent flow objectives defined for the Yarrabilba site in *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) are presented in Table 12.

Table 12: Interim frequent flow design objective adopted for Yarrabilba (from *Yarrabilba - Stormwater Infrastructure Master Plan*)

Objective	Design Criteria
Preserve groundwater fed baseflows within groundwater dependent aquatic ecosystems. (Mandatory)	No increase in the number of days with zero flow; OR ALTERNATIVELY Preserve volume of water infiltrated into the sandy surface soil profile
Reduce the frequency of disturbance to aquatic ecosystems from urban development by managing the frequency of surface runoff. (Secondary objective at this stage applied based on waterway ecosystem assessment)	Minimise the change in surface flow frequency post-development to 2-2.5 times the pre-development surface flow frequency (Surface flow = flow rate above baseflow)

To assign the frequent flow objectives to each of the catchments in Precinct 1 and 2, site inspections were completed by aquatic ecologist and stormwater engineer both of whom are qualified an experienced in assessing aquatic ecosystems and hydrology. The inspections were combined with the findings of *Yarrabilba - General Waterway Condition Assessment* (DesignFlow, 2012) and *Yarrabilba - Broad Scale Groundwater Management Strategy* (DesignFlow, 2012). A summary of the waterway condition is presented in Section 2.3 and downstream drainage conditions in Section 2.2.

The key outcomes of this work and associated frequent flow objective for each catchment is provided in Table 13.

Table 13 Frequent flow design objective adopted for Yarrabilba

Catchment	Inspection Findings	Design Objective
Catchment 1	Stormwater passes through private property downstream to enter significant stand of Regional Ecosystem. A Regional Ecosystem exists within the Yarrabilba site which more than likely accesses the shallow groundwater during dry conditions. Drying out of these may cause health issues. The SIC will have a massive impact on stormwater flows and groundwater downstream. The stormwater strategy must minimise the impact of nuisance flood flows and avoid drying out of the local RE.	No increase in the number of days with zero flow. Minimise the change in surface flow frequency post-development to 2-2.5 times the pre-development surface flow frequency
Catchment 2	Stormwater passes through private property downstream. The stormwater strategy must minimise the impact of nuisance flood flows.	Minimise the change in surface flow frequency post-development to 2-2.5 times the pre-development surface flow frequency.
Catchment 3	Stormwater passes through private property downstream and crosses under a number of driveways. Nuisance flows over the driveways need to be managed. Quinzeh Creek is located downstream but is 750m away and any local infiltration initiatives to preserve groundwater are unlikely to be expressed into Quinzeh Creek. Plus the SIC will have a massive impact on local stormwater flows and groundwater. Therefore, no groundwater and baseflow objectives are defined for these reasons.	Minimise the change in flow frequent over driveway accesses in within the private property to 2-2.5 times the pre-development flow frequency. Note: local infiltration will be promoted in the stormwater treatment systems and waterway of this catchment even though the SIC will ultimately change local groundwater conditions.
Catchment 4	This catchment drains directly to a Good reach of Quinzeh Creek which contains groundwater dependent ecosystems. Preserving groundwater fed base flows is important.	No increase in the number of days with zero flow; OR ALTERNATIVELY Preserve volume of water infiltrated into the sandy surface soil profile

7.2 STRATEGY

The frequent flow objectives are different for each of the catchments and as a result the management responses vary as well. Concept strategies are presented in Figure 15 with further details in the sub-sections below

The final configuration of the most appropriate frequent flow management strategy is still under review. A series of four monitoring wells to 5 m depth have recently been installed at the northern end of the site. These monitoring wells are programmed to be monitored over the next 12 months to understand the shallow groundwater regime at the bottom end of the development, as well as interactions with the ephemeral waterways. Based on drilling, there may be opportunities to use the downstream ephemeral wetland zones as sites to infiltrate low flows to the shallow groundwater system, where sandier materials have been noted. This may well form an important strategy for frequent flow management.

It is felt that basing a frequent flow management strategy on real measured information on the site is more appropriate than modelling results from MUSIC or other based on parameters that have not relationship to the site. The final frequent flow management strategy will be resolved over the next 6-12 months as monitoring data becomes available. The concept strategies presented are to demonstrate that various alternatives are being considered. The final strategy may include some or all of the options presented depending on further testing.

7.2.1 Catchment 1

Given the SIC corridor at this location will ultimately be cut down below existing ground level, the management of stormwater flows becomes difficult (any flood bunds would need to be placed upstream of SIC corridor within the RE). So stormwater from this catchment is to be diverted into Catchment 2. Conceptual earthworks and drainage layout have been developed for Catchment 1 in collaboration with the engineers (KN Group) to confirm the diversion can be achieved. This will ensure the "surface flow days" objective is achieved.

Allowance is to be made within the drainage system to take a portion of the diverted flow and discharge this to surface into the RE or infiltrate this adjacent to the RE. The hydraulic control will be via a valve to allow adaptive management of flows into the RE. This will ensure that groundwater conditions are preserved in the RE and the "no increase in the number of zero flow days" objective is achieved.

Given the simplicity of the strategy for Catchment 1 and there is no land take associated with the strategy, no modelling has been completed. Details will be resolved as part of operational works design.

7.2.2 Catchment 2

Three options are available for achieving the frequent flow objective for Catchment 2:

- Stormwater harvesting – Capturing treated stormwater from the wetland and remediated waterways at the downstream end of Catchment 2 and storing the water in an open waterbody. The water is filtered and disinfected for irrigating parklands areas in precinct 1 and 2 and surrounds. The stormwater harvesting system will reduce the volume and frequency of flow to downstream properties. Preliminary assessment of the stormwater harvesting system has found that a 10-15ML storage (1ha in area) is required to irrigate 20ha of parkland (80% reliability) and to meet the frequent flow objective for Catchment 2.

- Infiltration – Geotechnical assessment of the downstream areas in the vicinity of the proposed stormwater storage and Ephemeral Wetland 2 has found a number of areas where deep sands are present. This option involves the collection and infiltration of treated stormwater at this location. Assuming infiltration rates are 20mm/hr (based on infiltration testing elsewhere on the site), the area of infiltration is in the order of 0.5ha.

- Attenuation and drainage works downstream – Given the focus of the frequent flow objective in Catchment 2 is nuisance flooding, there is an option of attenuating low flows to the point where they can be contained within downstream drainage without causing nuisance flooding. Low flows could be attenuated significantly within the Ephemeral Wetland W2 to the point overland nuisance flows are minimised in accordance with the frequent flow objective. This would require excavation of a small drain from the Yarrabilba site to Georgina Drive with the agreement of the private property owner. Once flows reach Georgina Drive, there is an open drain from here through to Quinzeh Creek.

7.2.3 Catchment 3

The focus on frequent flow management in Catchment 3 is to preserve the immunity of driveway accesses on the private properties downstream. It is not practical to install a stormwater harvesting system at this location and the practicality of a large scale infiltration system upstream of the SIC is not clear. Therefore, the most practical solutions available for meeting the objective in this catchment involves:

- Attenuation of low flows – Attenuation of low flows (<1 yr ARI) to ensure regular flows are attenuated to pre-development flows.

- Driveway/drainage upgrades – Where the attenuation of low flows is unable to fully achieve the frequent flow objective, drainage works will be required within the downstream property to contain the increase in surface flow frequency. This could come in the form of an underground pipe or open channel within the existing drainage easement. The conveyance system would be designed contain the increase in surface flows particularly at the driveway crossings.

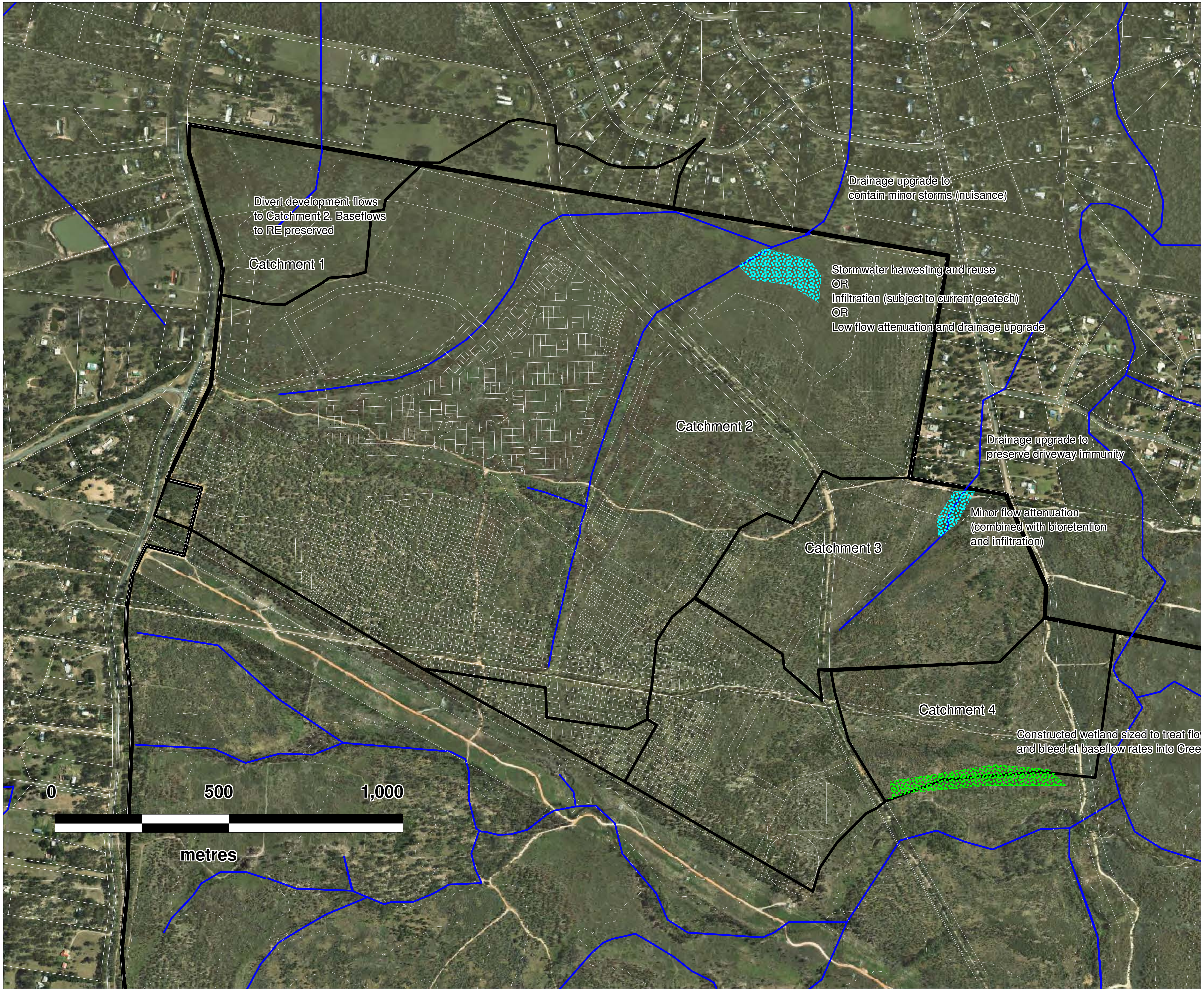
The other option is raising the level of driveways and increasing the culvert crossings to preserve immunity. Close collaboration with private property owners will be required to ensure a successful outcome.

7.2.4 Catchment 4

The focus of frequent flow management in Catchment 4 is ensuring baseflows to Quinzeh Creek are not reduced. This will be achieved by treatment and storage in the constructed wetland and the slow release of flows out of the wetland to the creek. This will act to capture 'peaky' urban stormwater runoff and convert this to steady low flows into the creek thus mimicking baseflows.

7.3 MODELLING

The conceptual modelling associated with frequent flow management for each catchment is presented in Appendix C. The modelling completed to date has been based on broad modelling assumptions for soil properties in the MUSIC model (which has flaws in hydrologic modelling unless careful calibrated). These results and resulting stormwater infrastructure can be sensitive to assumed parameter. The monitoring data that will be gathered over the coming 6-12 months will provide important information to update modelling and gain a better understanding of strategies that will be most effective in managing frequent flows.



DesignFlow

LEGEND

- Yarrabilba site boundary
- Developed sub-catchment
- 5m contour
- Waterway drainage line

FIGURE 15
Frequent Flow
Management Strategy

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

N W E S	SCALE: 1 : 1000	Date: 1 November 2013

Client:
Lend Lease

8 FLOODING

The conversion of the Yarrabilba site to urban development will increase stormwater runoff which, if left unmitigated, will result in greater flood flow entering downstream properties. Recent modelling completed by Council for the unmitigated case was released to the community in early 2013. This resulted in concerns being raised by community members regarding the flood information provided by Council and the impact of Yarrabilba.

Lend Lease is highly aware of the flood risk to property owners downstream of Yarrabilba and is committed to ensuring flood risk is managed by achieving the objectives listed in Section 8.1. This section presents the flood management strategy adopted for Precinct 1 and 2 along with the flood modelling completed.

8.1 DESIGN OBJECTIVES

The stormwater management strategy for the Precinct 1 and 2 will achieve the objectives listed in Table 14 as defined by the *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012). The objectives require the management of flood flows discharged from the Yarrabilba site. These objectives are aimed at protecting property both with and downstream of the site from the impacts of urban stormwater runoff.

Table 14: Flood management objectives

Objective	Design Criteria
Protect people, property and infrastructure from flooding within and external to site boundary	• Preserve peak site discharges and flood levels at the boundary of the site at or below pre-development conditions for all events from 2 to 100 year ARI • Maintain flood conveyance capacity through site • Provide for 100 year ARI flood immune development within the site

8.2 STRATEGY

As part of delivering Precinct 1 and 2, the following initiatives will be delivered to attenuate flood flows:

- **Catchment 1 diversion** – Flows up to the 10 year ARI will be diversion from Catchment 1 to Catchment 2. This will ensure all peak flows existing Catchment 1 will remain at and below pre- development.

- **Waterway remediation** - Remediation of the major waterways including revegetation. The increase in vegetation within the waterways will slow down and attenuate flows before flows enter the flood detention basins.

- **Flood detention basins** configured in the following manner:

  - Catchment 2 – Detention systems will be located throughout the waterways, typically behind roads, to manage the major flood events. The culverts have been sized to retain pre-developed flows, thus creating temporary ponding conditions behind the road. A large flood detention basin is required at the downstream end of Catchment 2 in addition to the storages behind the road. This storage is designed to manage the smaller events (1-20yr ARI) whereas most of the attenuation of the larger floods occurs upstream behind the road.

  - Catchment 3 – A flood detention basin will be created at the downstream end of the waterway at the proposed SIC location. The detention storage has been designed with a multiple stage outlet to provide attenuation of all flood flows.

  - Catchment 4 – This catchment drains into the Quinzeh Creek catchment on the Yarrabilba site. The regional flood management strategy for this larger catchment has not been resolved. Therefore, flood detention will be provided via an interim storage co-located with a stormwater wetland and flood over future playing fields. This detention storage will manage all flood flows via a multi-stage outlet.

Details of the flood basins and associated outlet structures are provided in Section 8.7. All of the systems have been designed using two flood modelling packages (XP-SWMM and TUFLOW) to ensure the proposed configurations will achieve the flood objectives.

Some of the flood management initiatives have already been constructed as part of Precinct 1 works. This includes remediation of some of the waterways and the construction of Flood Basins 2, 4 and 5.

8.3 MODELLING METHOD

8.3.1 Previous modelling

The following flood modelling has been completed for the Yarrabilba or the broader Quinzeh Creek. All of this modelling was considered when completing the modelling for Precinct 1 and 2:

- *Yarrabilba Northern Development Area Stormwater Quantity Management Plan* (Water Technology, February 2011) – Flood modelling completed for Precinct 1 and approved by EDQ

- *Yarrabilba - Development: Flood Risk Management Strategy* (WBM BMT, 2012) – High level flood modelling completed for the whole Yarrabilba site to inform the Infrastructure Master Plan.
- *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) – Summarises calculations and modelling to define RAFTS modelling parameters for Quinzeh Creek and presents design flows using the RAFTS model.

- *Revised Quinzeh Creek Flood Study Letter* (Engeny, 23 August 2013) – Presents the updated flood modelling completed for Quinzeh Creek using the updated RAFTS parameters derived by WRM (2013). Flood levels were defined using TUFLOW modelling. This work was completed following the release of the Logan flood maps for Quinzeh Creek which presented flood maps for the unmitigated scenario with Yarrabiliba undeveloped. Understandably the local community was concerned with these flood maps because of the increased extent of flooding (much more than existing case). This letter report presents the existing case flood modelling.

A meeting was held with Logan City Council on the 27th May 2013 to discuss the Quinzeh Creek flood modelling approach and resolve a way forward for Yarrabilba. Given the problems associated with the Council flood mapping (i.e. presenting the unmitigated case flood maps rather than existing case floodmaps), it was resolved that Council would establish hydrologic parameters and discuss these with Lend Lease. Then the Quinzeh Creek flood model (RAFTS and TUFLOW) would be updated to create an existing base case model. This would then be used by Lend Lease as the pre-development model and updated to define post development flood mitigation requirements. It was agreed this is a transparent process for assessing flood mitigation for Yarrabilba.

However, the Council modelling was not completed until September 2013 and Council were unable to release the model to Lend Lease. The updated flood models are being reviewed by EDQ at the time of writing this report. Therefore, a separate flood modelling process has been completed by DesignFlow for Precinct 1 and 2 using methods and parameters that are consistent with the Council modelling for Quinzeh Creek. It is hoped that future flood modelling will be able to utilise the Quinzeh Creek flood model.

Comment on Council flood modelling

Review of the flood modelling completed for Council indicates the consultants have assumed forested conditions across Yarrabilba for the pre-development or existing case flood modelling. This forested assumption is inaccurate and in DesignFlow's opinion results in an under-estimation of pre-development or existing base case flows from Yarrabilba.

The concerns with the modelling completed for Council have been communicated to Council and EDQ as part of completing this stormwater strategy.

8.3.2 Method for Precinct 1 and 2

The following tasks were undertaken as part of the flood modelling:

- Collation of existing information and gap analysis to determine additional information required.
- Review of various flood modelling completed by Council.
- Site inspections of Yarrabilba Precent 2 site, overland flow paths from the site boundary to Quinzeh Creek and Quinzeh Creek between Wandearah Road to Miller Road.
- Manual survey of culvert crossings between Yarrabilba Precinct 1-2 site boundary and Quinzeh Creek.
- Preparation of hydrological data, including sub-catchment delineation for existing predevelopment and post development conditions, rainfall intensity frequency duration (IFD) information, and a review of rainstorm losses.
- Construction of rainfall runoff hydrological model using the XP SWMM software, and determination of pre-development and post-development hydrographs.
- Construction of hydraulic flood model using the TUFLOW software, and incorporation of hydrological outputs.
- Assessment of pre-developed and post-developed flood conditions, and design of mitigation and detention options.

8.4 HYDROLOGIC MODELLING

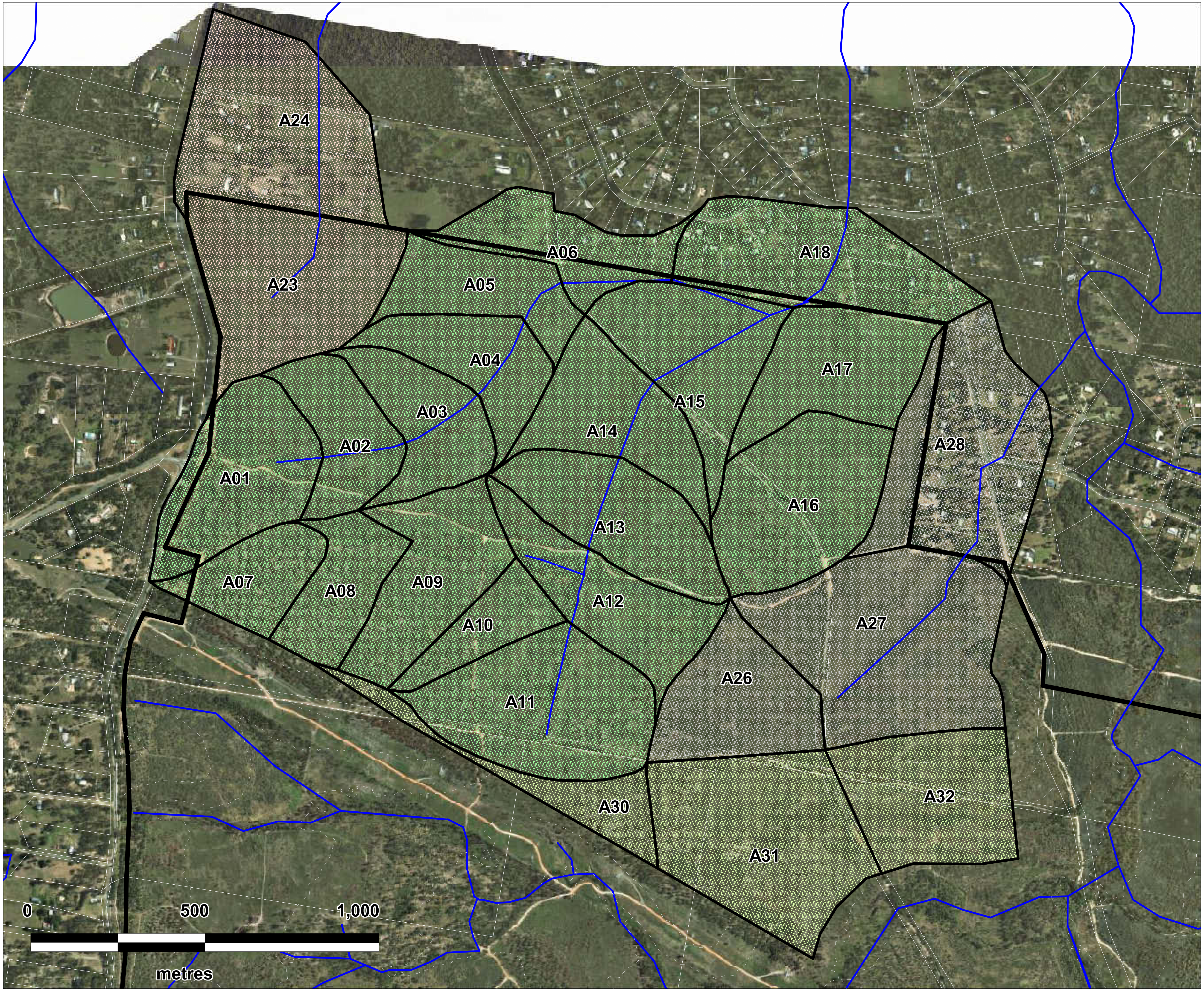
Flood flows from the existing and developed site were estimated using the XP-SWMM hydrologic model. The Laurenson runoff-routing method (as used in RAFTS) was adopted in this model to generate sub-catchment hydrographs based on slope, rainfall losses, catchment roughness and routing parameters. Storm durations between 30 minutes and 12 hours were considered for the 1, 2, 5, 10, 20, 50, and 100 year ARI events. These sub-catchments were then routed through 1D open channel links to the downstream site boundaries using the hydraulic component of XP-SWMM.

XP-SWMM peak discharge estimation was compared to the Rational Method (refer to Section 8.5) at key locations to provide a check of the parameters adopted in the Laurenson methodology.

8.4.1 Catchment parameters

Existing (pre-development) catchment delineation is based on the aerial laser survey (ALS) prior to the commencement of any development works. Post development catchments were delineated based on the earthworks design for the development. Where earthworks was not available an estimate of earthworks was generated based on the existing terrain and the land use plan for Precinct 2. Both existing and developed catchments were extended downstream of the site boundary to enable the hydraulic modelling to appropriately identify and consider tail water controlling boundary conditions (refer to Section 8.6.5).

Figure 16 illustrates the pre-development catchment boundaries while Figure 17 shows the modified catchments for the post development scenario. Pre-development catchment data is summarised in Table 15 with post development in Table 16.



DesignFlow

LEGEND

Yarrabilba site boundary

Existing case subcatchment

5m contour

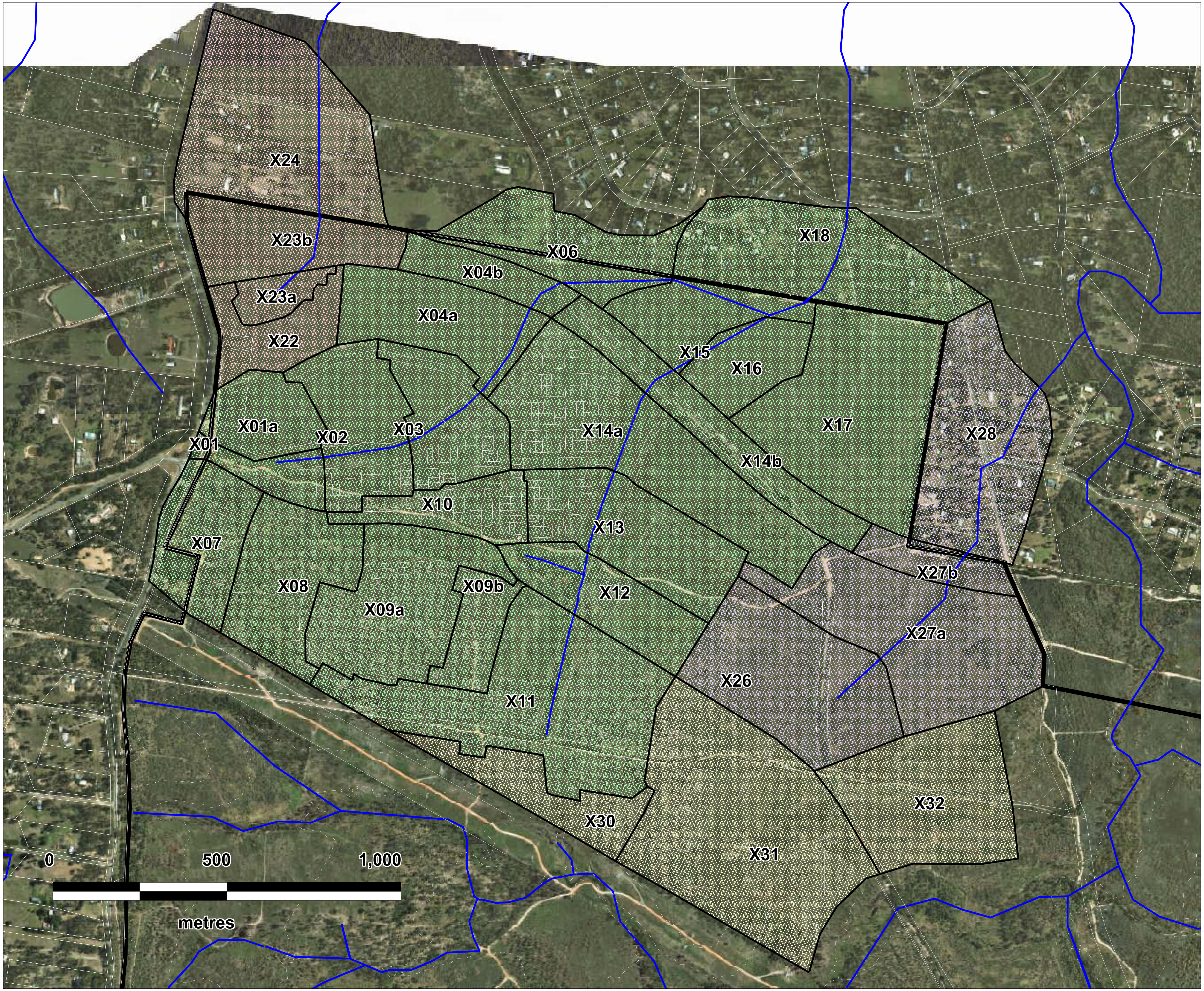
Waterway drainage line

FIGURE 16
Existing case subcatchments

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

N W E S	SCALE: 1 : 1000	Date: 1 November 2013

Client:
Lend Lease



DesignFlow

LEGEND

	Yarrabilba site boundary
	Developed sub-catchment
	5m contour
	Waterway drainage line

FIGURE 17
Post development sub-catchments

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

N W E S

SCALE:
1 : 1000

Date:
1 November 2013

Client:
Lend Lease

Table 15: Pre-development sub-catchment summary

Catchment	Area (ha)	Slope (%)	Impervious (%)*	Land Use **
A01	17.03	4.2%	5%	ex- pine plantation/road
A02	10.2	3.3%	0%	ex- pine plantation
A03	11.16	2.7%	0%	ex- pine plantation
A04	10.8	3.0%	0%	ex- pine plantation
A05	10.8	2.8%	0%	ex- pine plantation
A06	11.48	1.7%	5%	rural residential
A07	8.59	5.0%	0%	ex- pine plantation
A08	9.35	3.4%	0%	ex- pine plantation
A09	15.4	3.8%	0%	ex- pine plantation
A10	6.66	5.2%	0%	ex- pine plantation
A11	22.17	3.9%	0%	ex- pine plantation
A12	14.33	3.4%	0%	ex- pine plantation
A13	15.6	3.1%	0%	ex- pine plantation
A14	14.32	2.5%	0%	ex- pine plantation
A15	16.54	1.4%	0%	ex- pine plantation
A16	19.82	3.5%	0%	ex- pine plantation
A17	15.18	1.6%	0%	ex- pine plantation
A18	20.73	2.1%	5%	rural residential
A23	22.76	4.0%	0%	ex- pine plantation
A24	25.42	3.2%	5%	rural residential
A26	14.3	3.9%	0%	ex- pine plantation
A27	31.23	2.3%	0%	ex- pine plantation
A28	26.3	2.3%	10%	rural residential
A30	7.54	3.7%	0%	ex- pine plantation
A31	26.34	2.1%	0%	ex- pine plantation
A32	17.41	1.6%	0%	ex- pine plantation
TOTAL	*421.5*			

* Rural-residential % impervious was approximated from aerial photography

** Some localised areas of remnant vegetation exist within parts of sub-catchments – these are mainly focused within the retained drainage lined in the post development layout.

Table 16: Post development sub-catchment summary

Notations: For = Forest, **Rur-res** = Rural residential, **Res** = residential, **Com** = Commercial/ Retail/Industrial, **Sch** = School, **OS** = Open Space, SIC = Southern Infrastructure Corridor. Refer to **Table 17**.

Catchment	Area (ha)	Slope (%)	Total Impervious (%)	Predominant Land Use*
X01	3.9	2.0%	67%	Res/Com/OS
X01a	6.72	3.0%	60%	Res
X02	11.63	3.0%	50%	Res/OS
X03	10.03	3.0%	48%	Res/OS
X04a	12.19	3.0%	48%	Res/OS
X04b [1]	5.15	3.0%	90%	SIC [1]
X06	12.15	1.7%	7%	Rur-res/OS
X07	10.01	3.0%	81%	Res/Com
X08	12.75	3.0%	45%	Res/Com/OS
X09a	16.58	3.5%	44%	Res/OS
X09b	5.21	4.0%	60%	Res
X10	6.79	2.5%	57%	Res/OS
X11	28.05	3.0%	56%	Res/Sch/OS
X12	9.9	3.0%	46%	Res/Sch/OS
X13	14.87	3.0%	53%	Res/Sch/OS
X14a	24.72	3.0%	54%	Res/OS
X14b [1]	11.02	3.0%	90%	SIC [1]
X15	7.95	1.0%	2%	OS
X16	6.64	1.5%	67%	Res/OS
X17	24.7	1.5%	42%	Res/OS
X18	19.73	2.1%	10%	Rur-res
X22 [3]	6.64	2.0%	60%	Res [3]
X23a	2.84	2.0%	0%	For (existing)
X23b [2]	10.78	2.0%	0%	For (existing) [2]
X24	25.36	3.2%	10%	Rur-res
X26	19.81	3.5%	58%	Res/Com/Sch/OS
X27a	22.99	2.5%	55%	Res/Sch/OS
X27b [2]	4.45	2.5%	0%	For (existing) [2]
X28	20.26	2.3%	10%	Res
X30	7.71	1.5%	45%	Res/OS
X31	34.1	3.0%	48%	Res/Sch/OS
X32 [4]	18.02	1.6%	0%	For (existing) [4]
TOTAL	*433.7*			

Notes on Table 16:

1. Catchments X4b and X14b do not form part of Lend Leases developable land as they are within the future Southern Infrastructure Corridor. However, as these discharge directly into Lend Lease flood management infrastructure, they have been assigned their ultimate development imperviousness for roadway (90%) to ensure hydraulic structures can cope with future flows.

2. Catchments X23b and X27b also lie within the SIC (as for X4b and X14b above) but discharge directly downstream of the Yarrabilba site. Therefore, these catchments have been modelled as existing/undeveloped in both the pre-development and post development scenarios as they do not form part of Lend Leases flood management requirements.

3. Provision of flood detention upstream of the SIC in Catchment 1 to manage post development increases in flow was not practical as the SIC concept alignment/earthworks was locally in cut. Thus, catchment X22 flows are diverted to Flood 3 via the piped drainage network to reduce post development flows to reporting location LA_23.

4. Catchment X32 was included in the model (despite being external to Precinct 1 and 2) as this drains directly to Interim Flood Basin 10. The catchment is however modelled as existing/undeveloped which is how this catchment will remain in the interim.

Land use and fraction impervious

All catchments (both pre and post development) were modelled in XP-SWMM with the pervious and impervious fraction as separate sub-catchment areas with 0% and 100% imperviousness respectively. This split catchment approach reflects best practice modelling of urban drainage and enables the rainfall losses and catchment roughness to be appropriately assigned to these parts of the sub-catchment separately. Table 17 summarises the assumptions used for each landuse as defined by Table 2.3 in the *Design and Construction Manual* (Beaudesert Shire Council, 1999) which are generally consistent with QUDM.

The existing site comprises a fully undeveloped catchment (former pine plantation with mostly pasture vegetation and some regrowth pine and natural vegetation) and assigned 0% imperviousness. Where sub-catchments extended across the site boundary into existing rural residential or road areas, the portion of the sub-catchment that was developed was defined and imperviousness applied in accordance with Table 17 below.

Developed case land-use was derived from the Lend Lease Land Use Plan for Precinct 1 and 2 with the relevant landuse impervious fraction then applied as Table 17.

Table 17: Land use categories and impervious fraction

Land Use	Impervious Fraction
Forest (retained existing)	0
Rural Residential (existing)	0.05 - 0.1 *
Residential	0.6
Commercial/Retail/Industrial	0.9
School	0.7
Open Space**	0.02
SIC (Southern Infrastructure Corridor)	0/0.9***

* varies - actual areas were derived from aerial photography

** Open space comprises both active use space and retained drainage/vegetation corridors. Conservative allowance for embellishments generally across these areas.

*** Where the future SIC discharges internal to the site, ultimate imperviousness was allowed for. Where it discharges downstream of the site, undeveloped land use was assumed.

Slope

Existing sub-catchment slope was assigned based on the average equal area slope of a minimum of four slope paths overlaid on the Digital Elevation Model (DEM) for each sub-catchment. Developed case sub-catchment slopes were derived from the design DEM (where available) along the main road and/or overland flow paths. Where no design grading was available in future precincts, an assumed slope of 0.03 was assigned based on the post development slope being delivered in the already constructed areas of Precinct 1. Development earthworks will generally reduce slopes in the catchment.

Catchment roughness

Catchment roughness was assigned to sub-catchments based on values provided in Table 18. The pervious values are representative of the surface roughness change from the existing site (as a mix of grassland, ex-pine plantation and some bushland) to urbanised (landscaping and lawn) while the impervious roughness were kept constant (and generally applies to development only).

Table 18: Catchment roughness

Catchment condition	Catchment Manning's n	
	Pervious	Impervious
Existing/undeveloped	0.05	0.015
Developed	0.035	0.015

Bx parameter

The Bx parameter representing a multiplier of the parameter B in the Laurenson method, was used in XP-SWMM to adjust the available storage within sub-catchments during runoff-routing. This adjustment was done during the comparison against the Rational Method discussed in Section 8.5. A Bx value of 1.2 was adopted across the modelling which is consistent with best practice values for Bx and also that adopted for the Logan City Council modelling of Quinzeh Creek.

8.4.2 Rainfall patterns and losses

Intensity-Frequency-Duration (IFD) data was sourced from the Bureau of Meteorology website for hydrologic modelling in XP-SWMM and Rational Method Check. The IFD data summary and raw data details are provided in Table 19.

Table 19: IFD data summary

Intensity-Frequency-Duration Table

Location: 27.825S 153.125E NEAR.. Yarrabilba Issued: 21/10/2013

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	117	149	184	204	231	268	295
6Mins	110	139	172	191	217	251	277
10Mins	89.8	114	141	157	178	207	228
20Mins	66.0	84.0	104	116	132	153	169
30Mins	53.8	68.5	85.3	95.0	108	126	139
1Hr	36.2	46.2	57.8	64.5	73.7	85.7	95.0
2Hrs	23.0	29.5	37.0	41.3	47.3	55.1	61.2
3Hrs	17.4	22.3	28.0	31.3	35.8	41.8	46.4
6Hrs	10.7	13.7	17.3	19.3	22.2	25.9	28.7
12Hrs	6.73	8.63	10.9	12.3	14.1	16.5	18.4
24Hrs	4.37	5.63	7.22	8.18	9.45	11.1	12.5
48Hrs	2.84	3.69	4.83	5.53	6.44	7.68	8.65
72Hrs	2.12	2.77	3.65	4.21	4.93	5.91	6.67

(Raw data: 46.97, 8.63, 2.79, 84.88, 15.99, 5.78, skew=0.11, F2=4.4, F50=17.16)

Rainfall multipliers used in XP-SWMM to convert the above rainfall intensity data to rainfall depth for the respective storm duration are provided in Table 20.

Table 20: Rainfall multipliers

	Average Recurrence Interval (ARI)						
Duration	1	2	5	10	20	50	100
5 mins	9.8	12.4	15.3	17.0	19.3	22.3	24.6
6 mins	11.0	13.9	17.2	19.1	21.7	25.1	27.7
10 mins	15.0	19.0	23.6	26.1	29.8	34.5	38.0
20 mins	22.0	28.0	34.8	38.7	44.1	51.1	56.4
30 mins	26.9	34.3	42.7	47.5	54.2	62.9	69.6
1 hour	36.2	46.2	57.8	64.5	73.7	85.7	95.0
2 hours	46.1	58.9	74.0	82.7	94.6	110.2	122.4
3 hours	52.2	66.8	83.9	93.9	107.4	125.3	139.2
6 hours	64.3	82.3	103.6	116.1	132.9	155.1	172.5
12 hours	80.7	103.5	131.0	147.4	169.1	198.0	220.7
24 hours	104.8	135.1	173.3	196.4	226.7	267.1	299.4
48 hours	136.3	177.0	231.5	265.6	309.2	367.8	415.8
72 hours	152.6	198.7	262.2	303.5	354.8	423.9	481.6

Temporal Patterns

Rainfall temporal patterns for Zone 3 have been adopted for each design storm duration at Yarrabilba in accordance with Australian Rainfall and Runoff. A range of storm events between 30 minutes and 12 hours were assessed to ensure the critical storm duration for the respective parts of the site was identified.

Rainfall losses

Losses adopted for the various models are provided in Table 21. These have been selected following literature reviews, comparison of peak flows with the Rational Method and in consideration of the broader Quinzeh Creek Flood Assessment undertaken by Logan City Council.

Table 21: Hydrologic model losses

Surface type	Initial Loss (mm)	Continuing Loss (mm/hr)
Pre-development pervious	30*	2.5
Post development pervious 1 – 20 year ARI 50 – 100 year ARI	 10** 0	 2.5 1.0
Impervious	0	0

* The pre-development initial loss of 30mm is consistent with *Australian Rainfall Runoff* and *Modelling Losses in Flood Estimation* (Thesis M Ilahee, 2005) for the Logan catchment. *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) recommends an initial loss of 49mm based on Rational Method verification. DesignFlow has reviewed the assumptions and calculations which underpin this parameter and feel the forest assumption and C10 values used for Yarrabilba are not correct. If these are adjust to values recommended by QUDM for moderate density bushland the resulting flows related well to an initial loss of ~30mm.

** *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) recommends 19mm initial loss. It was decided to use 10mm for this post development parameter it is agrees with *Australian Rainfall Runoff*, generates close agreement with the Rational Method calculation and is more conservative (i.e. creates larger post development flows and therefore greater flood detention requirements).

8.4.3 Routing (1D Hydraulic Links)

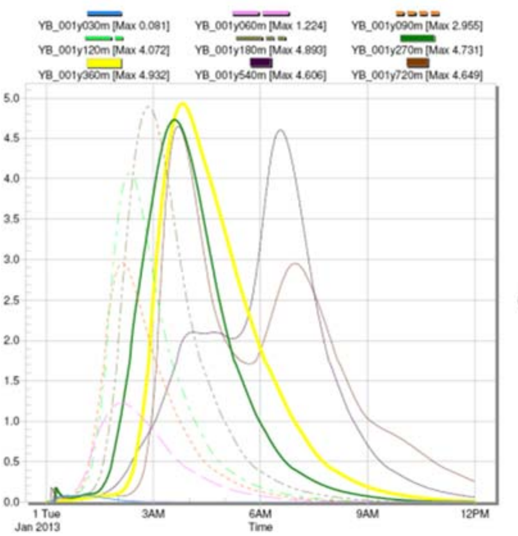
Design stormwater hydrographs were extracted from each sub-catchment and then applied to the TUFLOW modelling for final flood assessments.

To allow a check of the XP-SWMM model, the sub-catchment flows needed to be routed through the model to the outlet locations for the site. This was done using 1D hydraulic links in the software. The 1D hydraulic links in XP-SWMM were established using waterway cross sections extracted from the pre and post development DEMS and Manning's values outlined in Section 8.6.2 were applied.

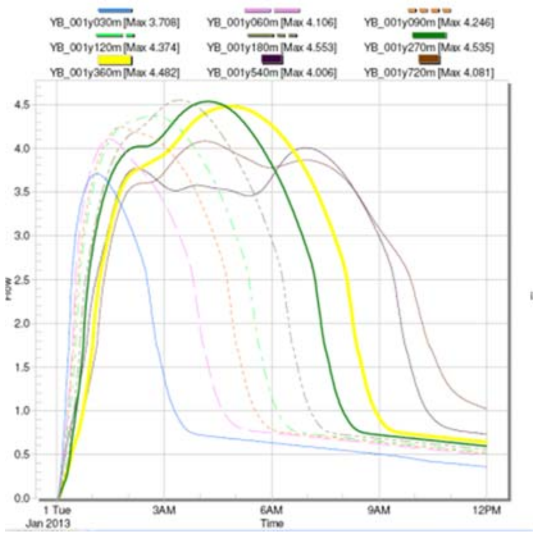
8.4.4 Critical Storm Duration

A range of storm durations were generated in XP-SWMM and routed through the hydraulic model (both in XP-SWMM and TUFLOW) in order to determine what storm durations were critical for the site. Based on experience of small catchment hydrology in South East Queensland, the critical duration for catchments similar to Yarrabilba in area are typically in the order of 60 minutes (for large events). For this analysis, the full range of durations were tested. The longer durations were tested in order to ensure the delayed catchment response time was capture with the introduction of detention basins.

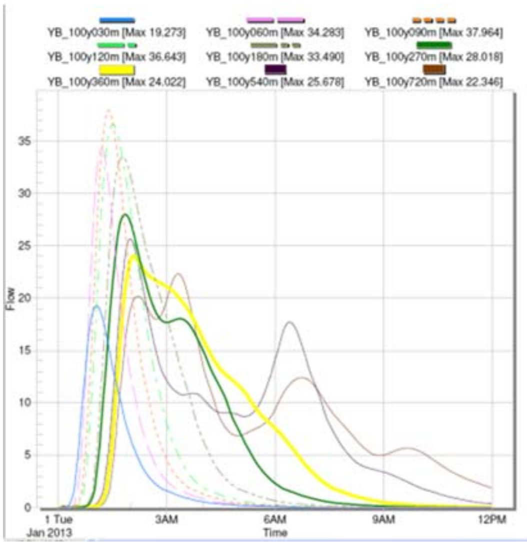
Both the pre-developed and post-developed mitigated cases were run for all scenarios. The resulting hydrographs are presented Appendix C for the 1 yr and 100 yr ARI events. **Figure 18** presents the hydrographs extracted from XP-SWMM for Catchment 3 (reporting location LA-17). For the 100 yr ARI event the critical storm is 90 minute pre-development and 120 minute post development. For the 1 yr ARI the critical storm is the 360min storm pre-development and the 270 min storm post development. This result of the 1 yr ARI is the pre-development is caused initial loss assumptions.



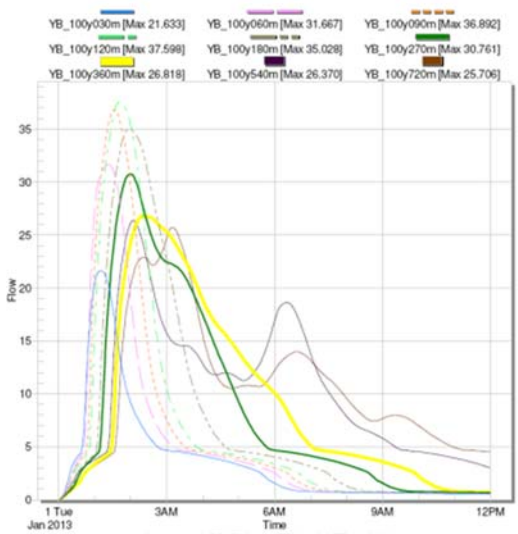
Pre-development 1 yr ARI



Post development mitigated 1 yr ARI



Pre-development 100yr ARI



Post development mitigated 100yr ARI

Figure 18: Catchment 3 pre-development critical storm durations

8.5 RATIONAL METHOD COMPARISON

The XPSWMM modelling for the site was compared against the peak flows estimated from the application of the Rational Method. This was undertaken for the existing site conditions (broadly 0% imperviousness) and for an unmitigated developed case (by simply assigning the overall average % impervious and related loss parameters to the existing case model).

Rational method is not a preferred method for verifying hydrologic models particularly at this catchment scale and larger. The method involves a number of assumptions and parameters which can be interpreted differently and have a dramatic influence on calculated flows. It is accepted that a hydrologic model with well accepted parameters is more accurate than Rational Method at this scale. The Rational Method presented in this section has been provided only because this method was used in *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) to define hydrologic modelling parameters for Quinzeh Creek. The Rational Method calculations completed for Precinct 1 and 2 are presented to assist with justifying the parameters used in XP-SWMM for Yarrabilba.

The Rational Method assessment was carried out on 5 main discharge locations at the subject development boundary (LA17, LA23, LA27, LA30 and LA32) plus an internal catchment location (LA12, approximately mid-way up Catchment 2. This represents a range of catchment sizes, slopes and main drainage path lengths. All ARIs from 1 to 100 were compared with the outcomes of the assessment. The results for the 100 year ARI only provided below. Full details for all ARIs are provided in Appendix B.

Table 22: XPSWMM and Rational Method peak discharge comparison for Q100

Location	Existing/Undeveloped			Developed (unmitigated)		
	XPWMM	Rational Method	% difference	XPSWMM	Rational Method	% difference
LA17	37.97	35.94	-5%	69.67	63.03	-10%
LA12	14.73	15.90	8%	29.50	27.67	-6%
LA23	4.10	4.73	15%	9.21	8.23	-11%
LA27	6.70	8.95	34%	13.23	16.47	24%
LA30	1.65	2.06	25%	3.98	3.89	-2%
LA32	4.95	5.94	20%	9.13	10.81	18%