YARRABILBA PRECINCT 1 AND 2
STORMWATER MANAGEMENT PLAN
Version 3

DesignFlow
Prepared for Lend Lease
August 2014

PLANS AND DOCUMENTS
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Table of Contents

1 INTRODUCTION 1
1.1 PREVIOUS STORMWATER MANAGEMENT PLANS 3
1.1.1 PRECINCT 1 3
1.1.2 PRECINCT 2 3
1.2 INFRASTRUCTURE MASTER PLANS 5
2 SITE OVERVIEW 6
2.1 TOPOGRAPHY, CATCHMENTS AND WATERWAYS 6
2.2 DOWNSTREAM DRAINAGE 10
2.2.1 CATCHMENT 1 10
2.2.2 CATCHMENT 2 10
2.2.3 CATCHMENT 3 12
2.2.4 CATCHMENT 4 12
2.3 VEGETATION 13
2.4 SOILS AND GROUNDWATER 16
2.5 MONITORING WELL INSTALLATION 18
2.6 DEVELOPMENT LAYOUT 18
2.7 SOUTHERN INFRASTRUCTURE CORRIDOR (SIC) 20
3 SUMMARY OF STORMWATER MANAGEMENT STRATEGY 21
4 EROSION AND SEDIMENT CONTROL 25
4.1 DESIGN OBJECTIVE 25
4.2 STRATEGY 26
4.2.1 LOCAL EROSION AND SEDIMENT CONTROL 26
4.2.2 REGIONAL SEDIMENT BASINS 26
4.2.3 MONITORING/AUDITING 27
5 WATERWAYS AND DRAINAGE LINES 28
5.1 DESIGN OBJECTIVE 28
5.2 WATERWAY BUFFERS 28
5.3 WATERWAY REMEDIATION 29
6 STORMWATER QUALITY 33
6.1 DESIGN OBJECTIVE 33
6.2 STRATEGY 33
6.2.1 OVERVIEW 33
6.2.2 REMEDIATED WATERWAYS 34
6.2.3 SEDIMENT BASINS 34
6.2.4 BIORETENTION SYSTEMS 35
6.2.5 WETLANDS 35
6.2.6 GROSS POLLUTANT TRAPS AND OTHER SPECIFIC LAND USE POLLUTANTS 36
6.3 CONCEPTUAL EARTHWORKS 36
6.4 MODELLING AND RESULTS 37
6.4.1 MODEL STRUCTURE 37
6.4.2 CATCHMENT DATA 38
6.4.3 SEDIMENT BASINS 41
6.4.4 BIORETENTION SYSTEMS 42

6.4.5 REMEDIATED WATERWAYS 43
6.4.6 CONSTRUCTED AND REMEDIATED WETLANDS 44
6.4.7 GROSS POLLUTANT TRAPS 45
6.4.8 RESULTS 45
7 FREQUENT FLOWS 46
7.1 DESIGN OBJECTIVE 46
7.2 STRATEGY 48
7.2.1 CATCHMENT 1 48
7.2.2 CATCHMENT 2 49
7.2.3 CATCHMENT 3 49
7.2.4 CATCHMENT 4 50
8 WATERWAY STABILITY 52
8.1 DESIGN OBJECTIVE 52
8.2 STRATEGY 53
8.3 MODELLING AND RESULTS 55
9 FLOODING 58
9.1 DESIGN OBJECTIVES 58
9.2 FLOOD MITIGATION STRATEGY SUMMARY 58
9.3 ASSESSMENT METHODOLOGY 61
9.3.1 PREVIOUS YARRABILBA SITE MODELLING 61
9.3.2 PREVIOUS QUINZEH CREEK CATCHMENT MODELLING 61
9.3.3 QUINZEH CREEK FLOOD MODEL EXPANSION 64
9.4 HYDROLOGY 68
9.4.1 CATCHMENTS 68
9.4.2 LAND USE AND FRACTION IMPERVIOUS 75
9.4.3 SLOPE 76
9.4.4 CATCHMENT ROUGHNESS 76
9.4.5 BX PARAMETER 76
9.4.6 RAINFALL DATA 77
9.4.7 RAINFALL LOSSES 78
9.4.8 CRITICAL STORM DURATION 78
9.4.9 RATIONAL METHOD COMPARISON 79
9.5 HYDRAULICS 83
9.5.1 MODEL TERRAIN AND EXTENT 83
9.5.2 ROUGHNESS 85
9.5.3 HYDRAULIC STRUCTURES 85
9.5.4 BOUNDARY CONDITIONS 87
9.5.5 MODEL VALIDATION 88
9.5.6 HYDROGRAPH TIMING IN UPPER QUINZEH CREEK 91
9.6 RESULTS 94
9.6.1 SUMMARY 94
9.6.2 FLOOD MITIGATION STRATEGY 96
9.6.3 DETENTION BASIN DETAILS 97
9.6.4 DETENTION BASIN DEPTH RISK 101
9.6.5 DETENTION BASIN CONSTRUCTION TIMING 103
9.6.6 OUTLET STABILISATION 103

9.6.7 FLOOD WARNING TIME 106
9.6.8 BLOCKAGE ANALYSIS 106
10 CONCLUSIONS AND RECOMMENDATIONS 109
11 REFERENCES 110

APPENDIX A: RATIONAL METHOD COMPARISON 112
APPENDIX B: TUFLOW RESULTS 120
APPENDIX C: FLOOD IMPACT MAPPING 123
APPENDIX D: FLOOD SAFETY MAPPING 125
APPENDIX E: REVIEW OF COUNCIL FLOOD MODEL AND DATA 127
APPENDIX F: JANUARY 2013 EVENT SENSITIVITY TEST (ENGENY) 129

List of Tables

Table 1: Precinct 1 and 2 Catchments and Waterway Condition 7
Table 2: Precinct 1 and 2 Stormwater Management Strategy 22
Table 3: Construction Phase Stormwater Quality 25
Table 4: Waterway buffer objectives 28
Table 5: Stormwater quality objectives 33
Table 6: MUSIC model parameter summary 37
Table 7: MUSIC catchment data 39
Table 8: Sediment Basin node reporting table 41
Table 9: Bioretention Basin node reporting table 42
Table 10: Constructed and Remediated wetland node reporting table 44
Table 11: MUSIC model results – load removal 45
Table 12: Interim frequent flow design objectives 46
Table 13 Frequent flow design objective adopted for Yarrabilba 47
Table 14: Derived waterway stability objectives 52
Table 15: Internal waterway stabilisation criteria 53
Table 16: 1 year ARI peak discharge from site 55
Table 17: Flood management objectives 58
Table 18: Logan City Council Models Provided 63
Table 19: Pre-development sub-catchment summary 72
Table 20: Post development sub-catchment summary 73
Table 21: Land use and impervious fraction 75
Table 22: Catchment roughness 76
Table 23: IFD Data Summary 77
Table 24: Hydrologic model losses 78
Table 25: Critical duration assessment 79
Table 26: Pre-development Rational Method comparison to XPRAFTS 81
Table 27: Post-development (unmitigated) Rational Method comparison to XPRAFTS 82
Table 28: Manning's roughness 85
Table 29: Existing cross road drainage downstream of site (1D structures) 86
Table 30: Existing cross road drainage downstream of site (2D structures) 86
Table 31: Surveyed vs modelled flood level for January 2103 event 88
Table 32: Peak flood level results at properties 90
Table 33: Peak discharge results 94
Table 34: Peak water Level results 96
Table 35: Peak velocity results 96
Table 36: Flood detention basin descriptions 99
Table 37: Precinct 1 and 2 hydraulic structures 100
Table 38: Detention basin peak water levels 101
Table 39: Detention basin depth 102
Table 40: Outlet velocity and scour protection 105
Table 41: Blockage factors for outlets and culverts 107
Table 42: Blockage analysis impact 108

List of Figures

Figure 1: Yarrabilba Precinct 1 and 2 Location and Extent 2
Figure 2: Precinct 1 Stormwater Management Strategy 4
Figure 3: Precinct 1 and 2 Catchments and Discharge Locations 8
Figure 4: Precinct 1 and 2 Waterway Condition Rating 9
Figure 5: Downstream drainage 11
Figure 6: Precinct 1 and 2 Vegetation 14
Figure 7: Vegetation clearing and regrowth - recent history 15
Figure 8: Soil profiles encountered onsite within Precinct 1 and 2 17
Figure 9: Precinct 2 Context Plan 19
Figure 10: Precinct 1 and 2 Stormwater Quality Management Strategy 24
Figure 11: Waterway Buffers 30
Figure 12: Precinct 1 and 2 Waterway Remediation Concept 31
Figure 13: Remediated waterway typical section 32
Figure 14: MUSIC model layout 40
Figure 15: Frequent flow management strategy 51
Figure 16: Waterway stabilisation concept 54
Figure 17: 2 year ARI flow velocities 56
Figure 18: 50 year ARI flow velocities 57
Figure 19: Broad catchment delineation and discharge locations 60
Figure 20: Flood model expansion/data zones 67
Figure 21: Quinzeh Creek sub-catchments 69
Figure 22: Precinct 1 and 2 Pre-development Catchment Plan 70
Figure 23: Precinct 1 and 2 Development Catchment Plan 71
Figure 24: Pre-development natural attenuation zones 80
Figure 25: TUFLOW model terrain and extent 84
Figure 26: TUFLOW model validation locations 89
Figure 27: Hydrograph timing assessment 93
Figure 28: Quinzeh Creek flow reporting locations 95
Figure 29: Flood mitigation strategy elements 98
Figure 30: 100 year ARI peak flow warning time 106

1 INTRODUCTION

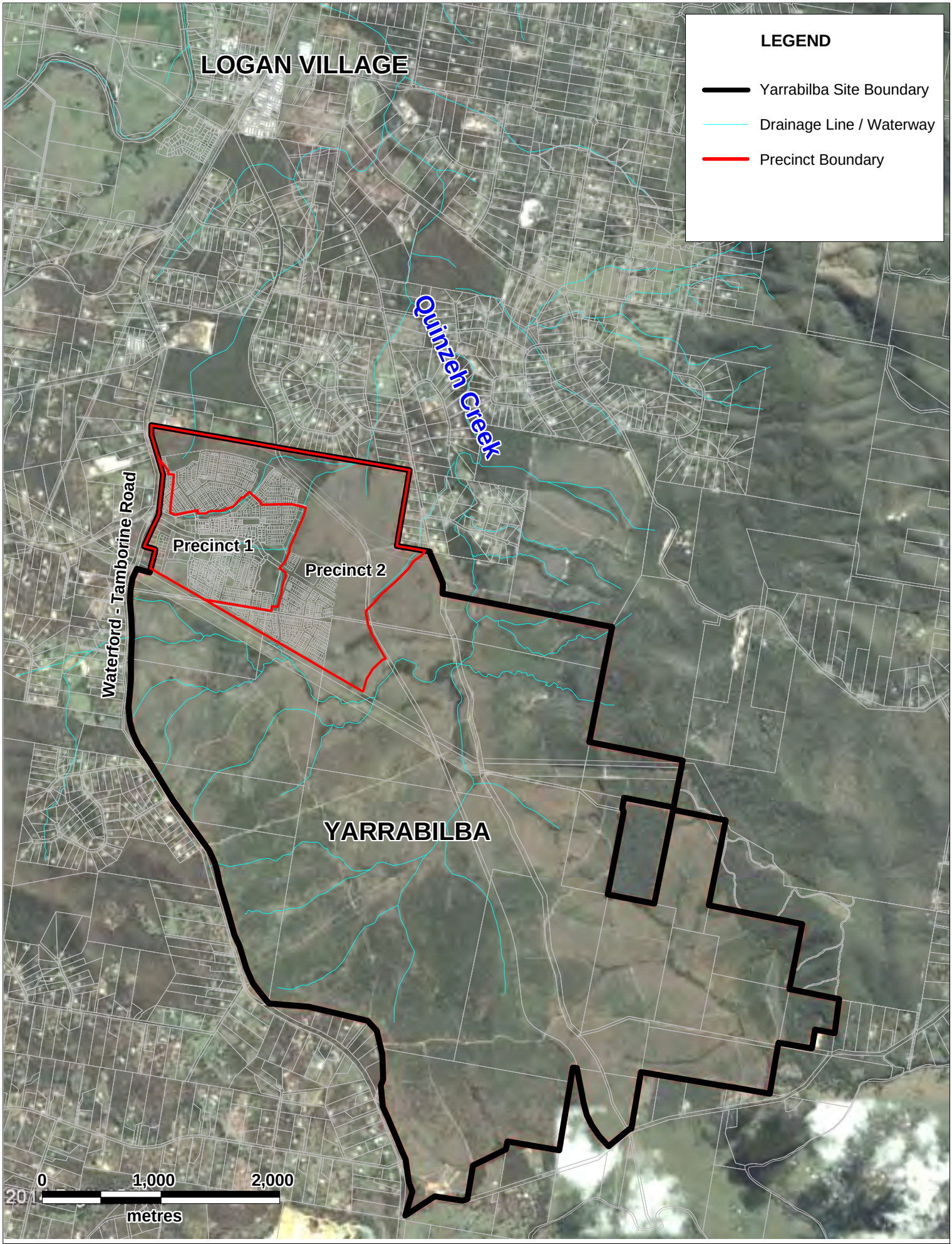
The Yarrabilba Priority Development (PDA) is located within the Logan City Council area and occupies a former pine plantation. The Yarrabilba PDA has been declared by regulation under the Economic Development Act (2012). Yarrabilba is part of a regional growth area identified in the South East Queensland 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 an urban area complimentary to its natural environment that draws upon innovative design initiatives to promote a diverse and healthy community. 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 of water resources for environmental protection.

Lend Lease commissioned DesignFlow to develop a WSUD strategy with the objective of ensuring that all forms of development incorporate WSUD to minimise impact on aquatic ecosystems and property, enhance the natural and rehabilitated waterways and integrate the urban and natural 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 updated 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 stormwater, waterway and flood 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 (ROL) applications for Precinct 2 and addresses conditions of approval from the original ROL application within Precinct 2.

This report supersedes the previously approved *Yarrabilba Precinct 1 Stormwater Management Plan* (DesignFlow, 2011) and represents an update to the previous *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, 2014).



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 40,000 (A4)	**FIGURE 1** **Precinct 1 and 2** **Location and Extent**
	Client: Lend Lease	Date: 21 July 2014	

1.1 PREVIOUS STORMWATER MANAGEMENT PLANS

1.1.1 Precinct 1

Development within Yarrabilba Precinct 1 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.

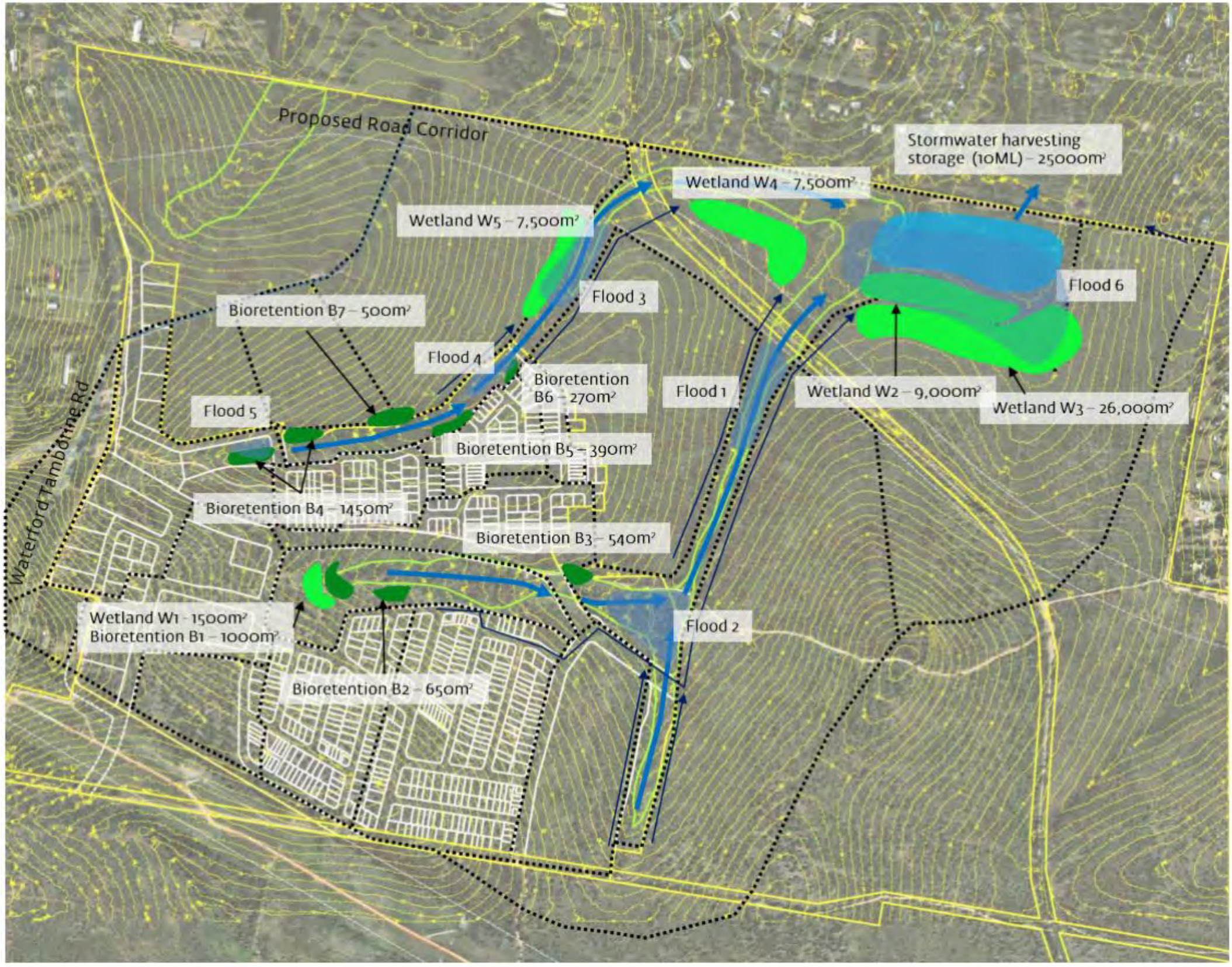
1.1.2 Precinct 2

The *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, 2014) was submitted as part of the initial ROL application in Precinct 2 approved by EDQ in 10 March, 2014 (Ref: DEV2013/523). This previous report provided a detailed strategy for the Precinct 1 and 2 development zone in terms of Stormwater quality and local flood management.

Condition 36 of the EDQ approval associated with this application requires an updated Stormwater management plan and flood study that integrates the local Yarrabilba flood model with the broader Quinzeh Creek flood model from Logan City Council (prior to any subsequent ROL approvals).

Therefore, this report (*Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 3*) documents an updated stormwater management and flood mitigation strategy which satisfies condition 36.

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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

SCALE: 1 : 1000

Date: 1 November 2013

Client: Lend Lease

1.2 INFRASTRUCTURE MASTER PLANS

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

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

The purpose of the *Yarrabilba 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 *Yarrabilba 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 – Version 3*) documents the detailed stormwater management plan for Precinct 1 and 2 in accordance with the requirements of the *Yarrabilba 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.

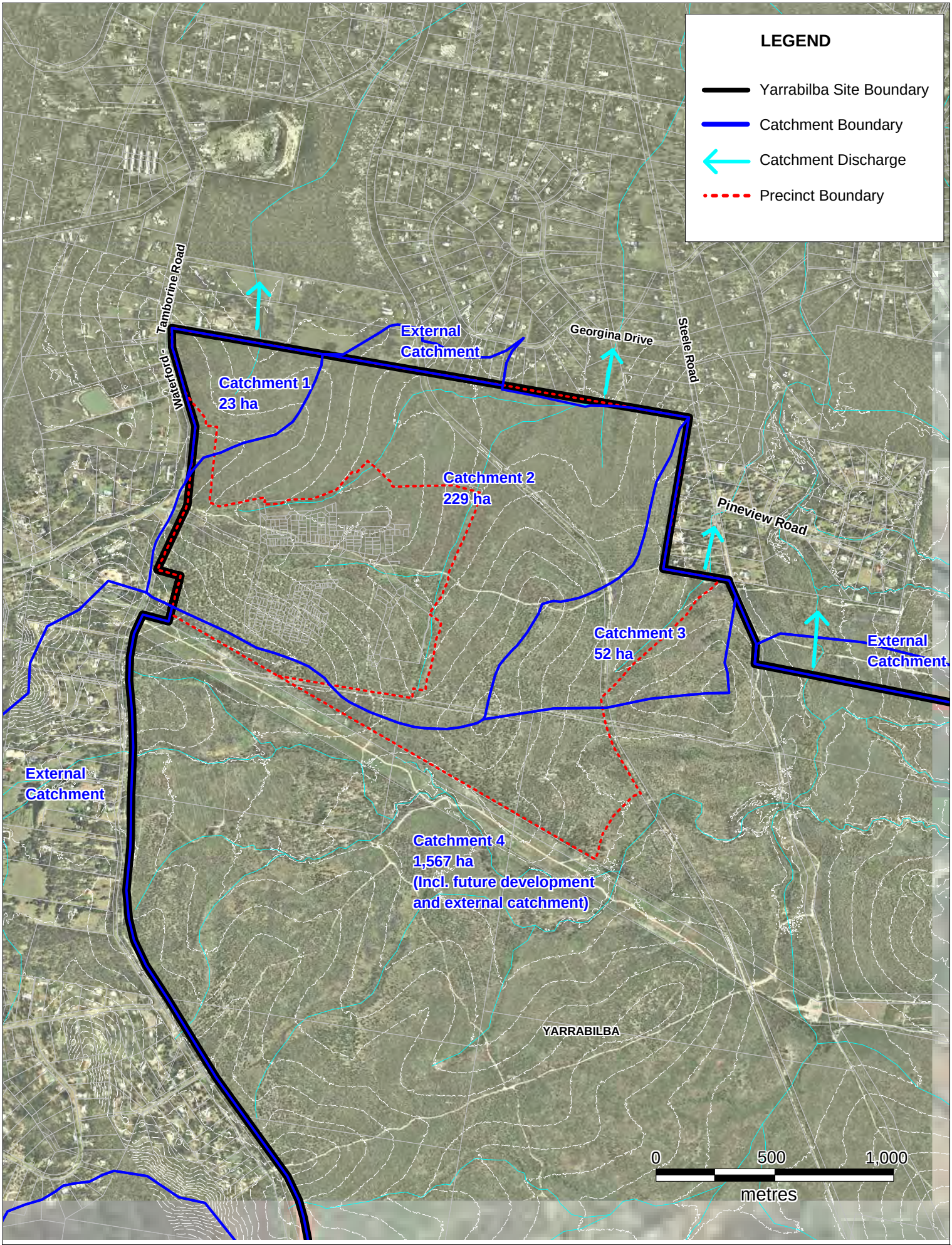
Table 1 summarises the details of each catchment presented in Figure 3 and the condition of the waterways. Figure 4 presents the waterway condition rating for Precinct 1 and 2.

Existing catchment conditions for flood modelling

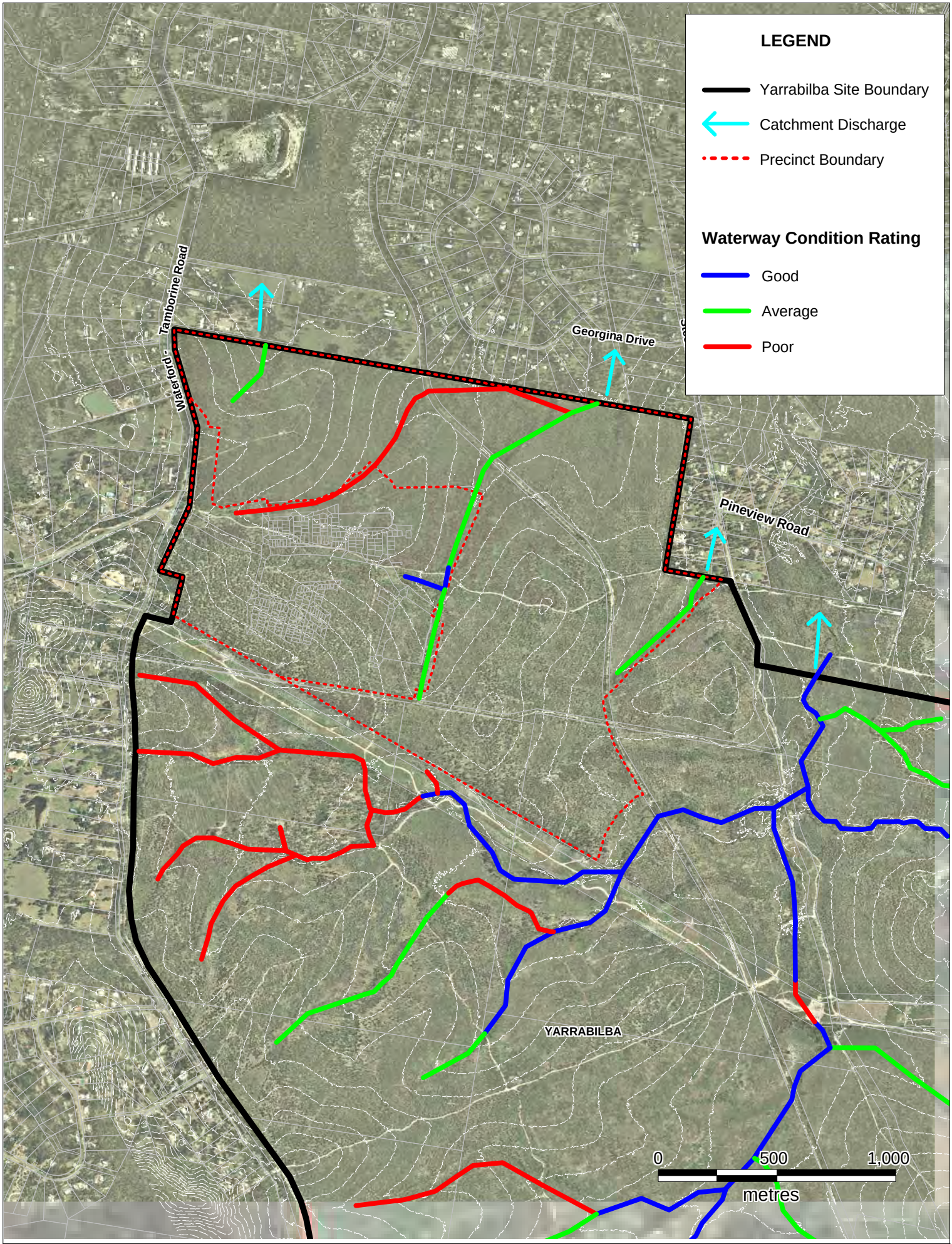
An important part of the flood modelling for Yarrabilba is defining the pre-development conditions. It is clear from the air photos and vegetation mapping (Section 2.3) that the vast majority of the vegetation (80%+) on the site is grassland or open pine regrowth. The pre-development flood modelling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

Table 1: Precinct 1 and 2 Catchments and Waterway Condition

Catchment	Area (ha)	Slope	Catchment Vegetation	Waterway Description and Condition
1	23	4-6%	70% grass and/or former pine plantation, 30% remnant vegetation	Ephemeral waterway with vegetation cover in downstream reach. Drains north into a large dam on private property and 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 ultimately cleared (State Government) as part of the Southern Infrastructure Corridor (SIC).
2	222 (+7 ha external)	3-6%	90% grassed and/or former pine plantation, 10% remnant vegetation	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.
3	52	3.5-5% (waterway 1.2%)	100% grass and/or former pine plantation	Ephemeral grass drainage depression which drains to north into easement across private property containing dams and flat wide drainage channel.
4	42 (within broader 1567 ha)	4-5% (waterway <1%)	90% grass and/or former pine plantation, 10% sparse remnant vegetation	Forms part of the larger Quinzeh Creek Catchment. Does not drain directly to Quinzeh Creek but rather the broad drainage confluence within the north eastern portion of Yarrabilba. This broad area (surrounding the waterway) is generally in **Poor** condition (virtually no native vegetation) but the main drainage line/waterway through this location is in **Good** condition and contains groundwater dependent ecosystems.
Minor catchment	5.4 3.7	Thin northern portion of catchment 3. Post-development earthworks will result in this catchment draining back into Catchment 2. Small triangular catchment at eastern edge of Catchment 3. Post-development earthworks will result in this catchment draining into Catchment 3.		
Quinzeh Creek		Quinzeh Creek ultimately accepts all stormwater from Precincts 1 and 2 downstream of the site. Ecological assessment of the drainage lines and waterway corridors upstream of Quinzeh 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). Assessment of Quinzeh Creek downstream of Yarrabilba was mainly limited to road crossing locations due to private land ownership over most of the creek length. The drainage lines and waterway corridors upstream of Quinzeh Creek (within Yarrabilba) exhibit a range of conditions. Some of the riparian zones to the waterway are in a healthy condition whereas others are affected by weeds and historical vegetation clearing. There is some evidence of erosion within the waterway whereas there are other sections of the waterways that are stable and healthy. The *Yarrabilba - General Waterway Condition Assessment* (DesignFlow, 2012) found that upper reach of the main waterway through Yarrabilba are in Average or Poor condition and the lower reaches in Good condition (refer Figure 4).		



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 20,000 (A4)	**FIGURE 3** **Precinct 1 and 2 Catchments and Discharge Locations**
	Client: Lend Lease	Date: 21 July 2014	



DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client: Lend Lease

N W E S

Scale: 1 : 20,000 (A4)

Date: 21 July 2014

FIGURE 4

Precinct 1 & 2
Waterway Condition Rating

2.2 DOWNSTREAM DRAINAGE

The following sections outline the drainage issues downstream of the four main 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 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.

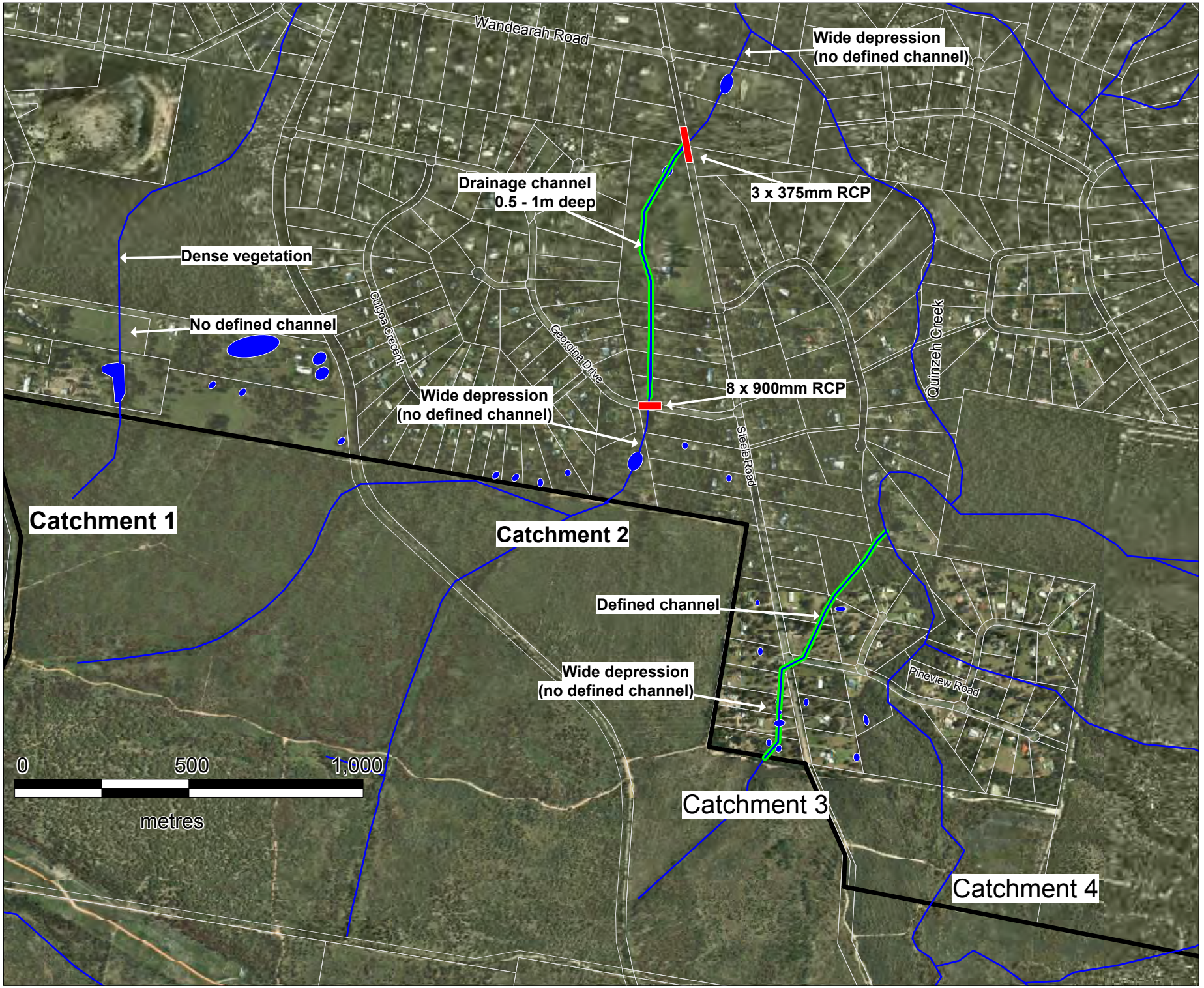
2.2.2 Catchment 2

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 overland flow path/ephemeral waterway. This waterway currently flows only during moderate rainfall events 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

SCALE:
1 : 1000

Date:
1 November 2013

Client:
Lend Lease

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 existing flooding and has been the focus on recent Council flood modelling. The confluence of the Catchment 3 tributary and Quinzeh Creek is a particular issue for flooding with a number of properties entirely inundated according to the Council flood modelling/mapping.

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 the upper reach of Quinzeh Creek via a broad ephemeral drainage line as illustrated in Figure 5.

The area of Precinct 1 and 2 land within 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.

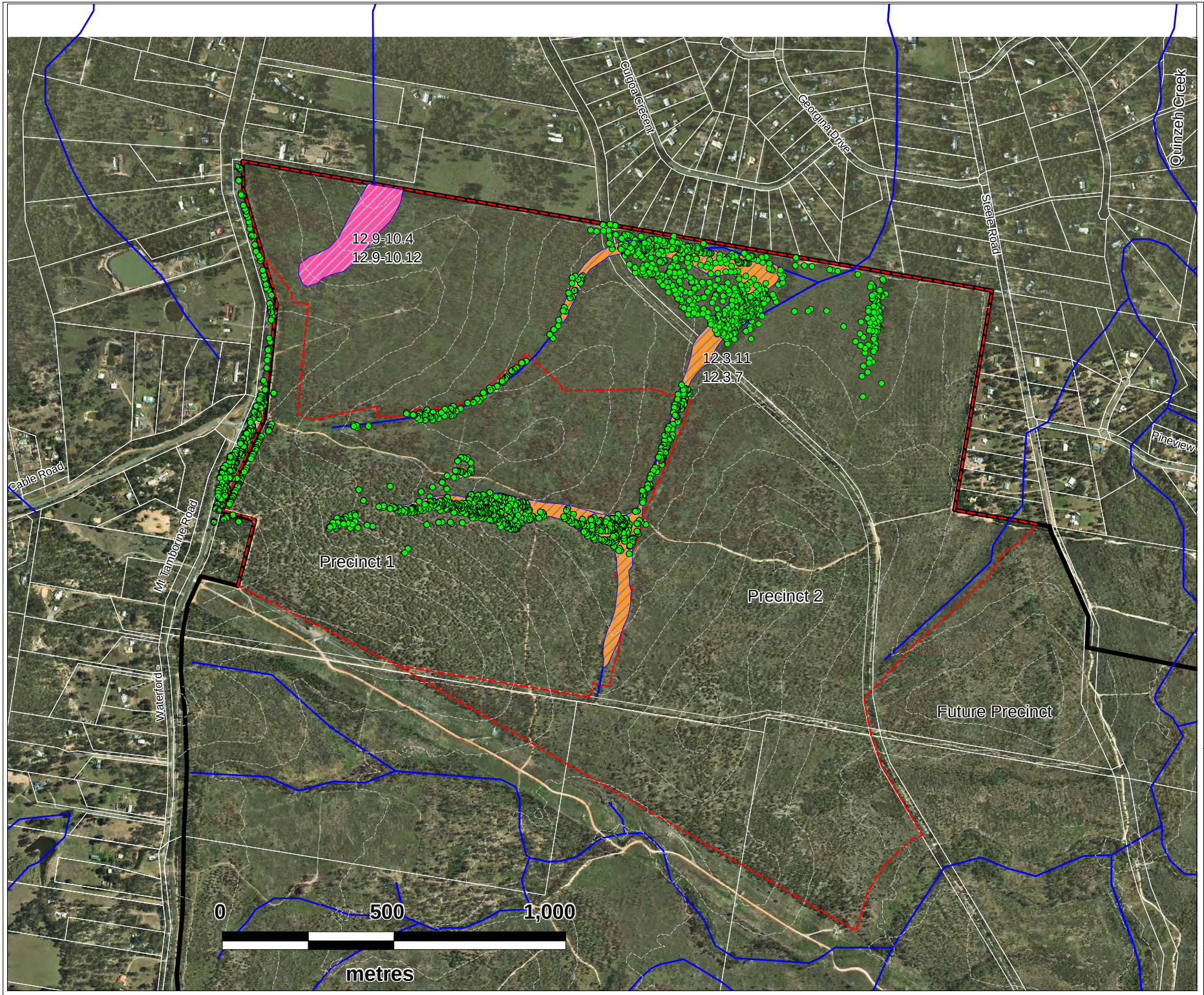
2.3 VEGETATION

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 limited ecological value. As illustrated in Figure 6 and Figure 7, the grassland and pine areas represent roughly 80% of the existing land use across the Yarrabilba site including Precinct 1 and 2. The 2003 image highlights the minimal vegetation cover onsite with dense vegetation occurring (generally) only within waterways and drainage lines. The subsequent images from 2009 and 2011 show the gradual regrowth of abandoned pine plantation areas as well as native regrowth of naturally propagated species across the formerly cleared/grassland areas.

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

SCALE:
1 : 1000

Date:
1 November 2013

Client:
Lend Lease

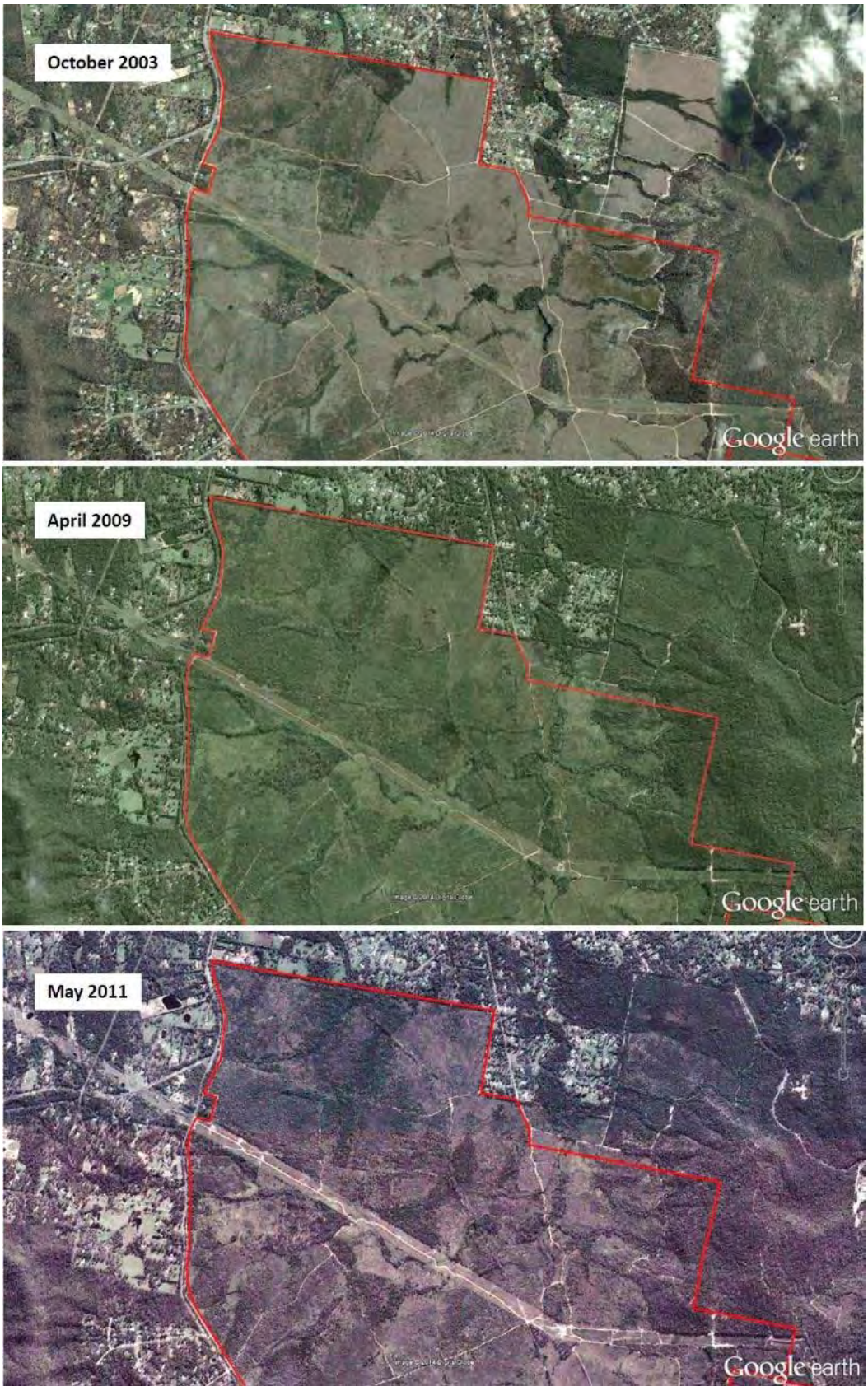


Figure 7: Vegetation clearing and regrowth - recent history

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



Photo: Shallow silty sand over sandy clay and clay



Photo: Shallow silty sand over sandy clay and clay

Figure 8: Soil profiles encountered onsite within Precinct 1 and 2

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 around 5.0 m depth at the northern end of the site, in the location of the main stormwater storage, wetland and flood basin 6. Lithology during drilling indicated typically mixtures of silts, clays and sands in the upper 5.0 m.

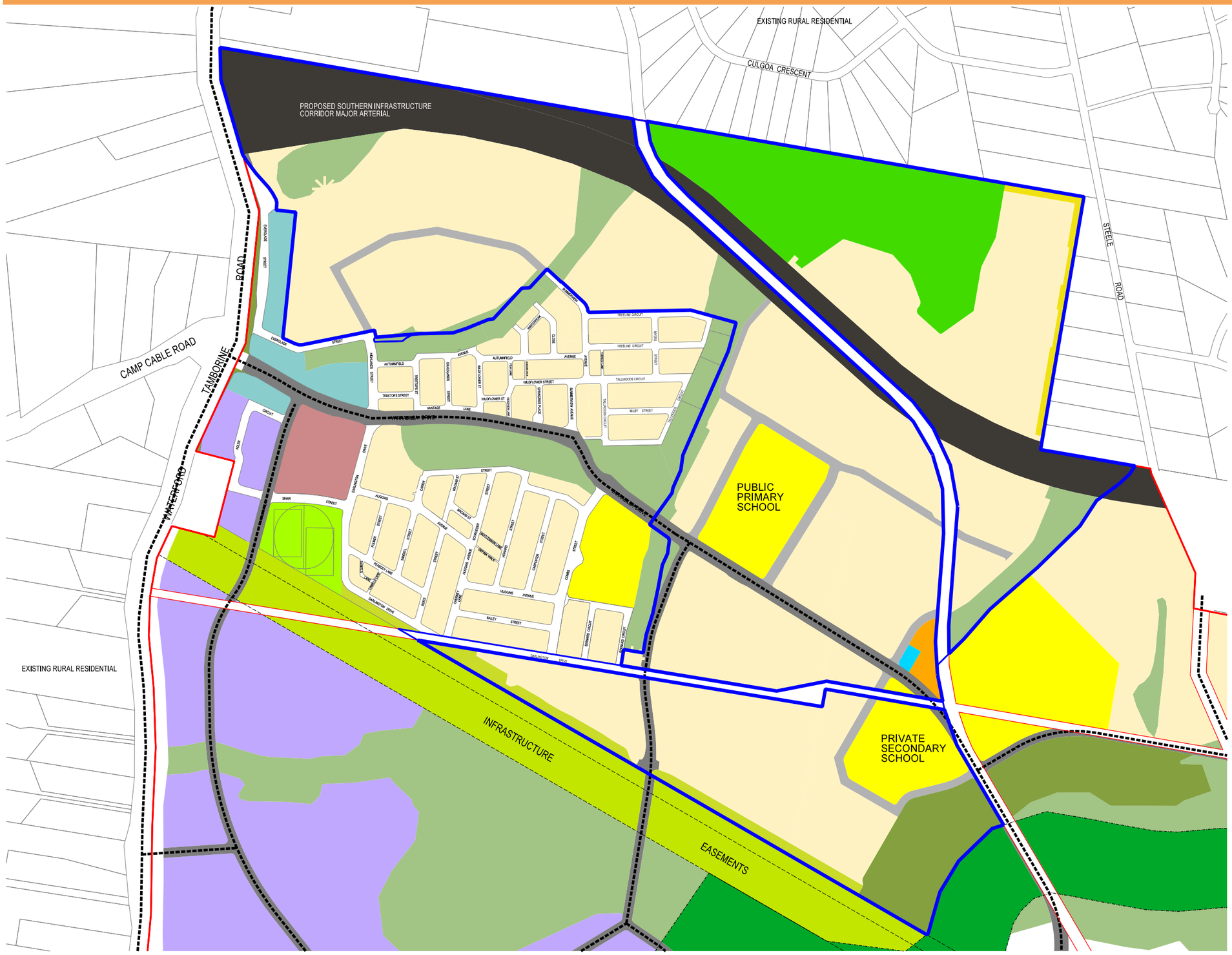
These wells are currently being monitored to gather data on the seasonal groundwater variation and provide important information in understanding seasonal groundwater flows and interactions with adjacent waterways. Falling head tests are to be completed on these wells shortly, which will also inform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

2.6 DEVELOPMENT LAYOUT

Figure 9 shows 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 2100 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



LEGEND

- YARRABILBA SITE BOUNDARY
- PRECINCT TWO BOUNDARY
- INFRASTRUCTURE EASEMENTS
- RESIDENTIAL
- BUSINESS AND INDUSTRY
- NEIGHBOURHOOD CENTRE
- RETAIL/COMMUNITY/COMMERCIAL MIXED USE
- MIXED USE DEVELOPMENT
- EDUCATIONAL ESTABLISHMENT
- DISTRICT COMMUNITY CENTRE
- NEIGHBOURHOOD PARK
- FAUNA CORRIDOR
- GREENSPACE CORRIDOR
- DISTRICT SPORTS PARK
- DISTRICT RECREATION PARK
- MAJOR SPORTS PARK
- NEIGHBOURHOOD RECREATION PARK
- LANDSCAPE BUFFER
- ELECTRICITY EASEMENT AND BUFFER
- SOUTHERN INFRASTRUCTURE CORRIDOR
- PRIMARY MOVEMENT NETWORK
- SECONDARY MOVEMENT NETWORK
- 400m FROM OPEN SPACE

TOTAL PRECINCT AREA	220 ha
GROSS RESIDENTIAL AREA	122ha
Approx 1700 lots at an average density of 15dw/ha	
NEIGHBOURHOOD CENTRE	0.2ha
DISTRICT COMMUNITY CENTRE	1.0ha
PUBLIC PRIMARY SCHOOL	7.0ha
PRIVATE SECONDARY SCHOOL	6.0ha

DISCLAIMER
The context plan is intended to guide development within the Yarrabilba Precinct Two area and show the preferred land use designations and structural elements. The context plan does not prescribe these designations and structural elements with complete accuracy and the final location will be determined through further detailed design and development applications.

NOTES
The contents of this plan are conceptual only. All areas are approximate only and subject to relevant studies, survey, engineering and relevant authority approvals.

YARRABILBA - PRECINCT TWO PROPOSED CONTEXT 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. ©2014 Lend Lease Communities (Australia). All rights reserved. Except as permitted by Lend Lease, no part of this publication may be reproduced or distributed in any form or by any means, or stored in a database or retrieval system, without the permission of Lend Lease.

0 100 200 300 400 500m

Scale 1:10,000 at A3

North

Lend Lease

File No. D05.03 Dgn No. YAR-P02-PCP140219 Date 19 FEB 2014

Figure 9: Precinct 2 Context Plan

2.7 SOUTHERN INFRASTRUCTURE CORRIDOR (SIC)

The Southern Infrastructure Corridor (SIC) is a 100m wide zone that has been defined by Department of Transport and Main Roads (DTMR) for a new connecting highway. At the time of writing this report it was not clear when the SIC will be constructed but advice from the DTMR indicates that it will be 20-30 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 as 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 the DTMR 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 by Main Roads.

- In Catchment 3, the proposed level of the SIC corridor is below natural ground. This makes the creation of a flood detention 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 as they will ultimately be removed as part of future roadworks. 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 such that will form part of the ultimate SIC and not be deconstructed).

- The SIC represents a potentially significant barrier to the shallow groundwater. Construction of the road is likely involve major cut and fill of the natural ground level along with compaction to provide a stable embankment of the road. It is therefore expected the SIC will inhibit 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 a ponded zone and establishment of wetland vegetation.

3 SUMMARY OF STORMWATER MANAGEMENT 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) and *Yarrabilba Precinct 1 and 2 Stormwater Management Plan – Version 2* (DesignFlow, February 2014). 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

Catchment		Water savings	Stormwater quality		Flood detention	Frequent Flow management
ID	Area (ha)		Treatment Type / ID	Area/ Length	ID**	
S1	12.01		Sediment basin S1 (c) Wetland W1 (c) Bioretention B1a (c)	316m² 1850m² 450m²	Flood 1 Flood 2 Flood 3 Flood 6 + wetland W2	Local waterway infiltration plus either of stormwater harvesting, ephemeral wetland infiltration or downstream drainage works
S2	3.88	Tanks (already installed)	Bioretention B1b (c)	450m²		
S3	3.25	Tanks (already installed)				
S4	4.99		Bioretention B2 (c)	460m²		
S5	5.09		Bioretention B3b (c)	430m²		
S6	2.93		Swale S6 Wetland W2	125m 14,000m²		
SCH	4.00		GPT (within School) Wetland W2	 14,000m²		
S7	7.48		Sediment basin S7 Wetland W2	300m² 14,000m²		
S9	4.61					
S8	7.53		Sediment basin N12 Remediated Wetland W3 Wetland W2	500m² 4,000m² 14,000m²		
S10	7.55		Bioretention S10	650m²		Infiltration from base of bioretention
N1	8.86		Sediment Basin N2 Bioretention 4a (c)	334m² 750m²	Flood 3 Flood 4 Flood 5 Flood 6	Local waterway infiltration plus either of stormwater harvesting, ephemeral wetland infiltration or downstream drainage works
N2	2.97					
N3	3.90	Tanks (already installed)	Bioretention B5 (c)	350m²		
N4	6.44	Tanks (already installed)	Bioretention B3a (c)	410m²	Flood 1 Flood 2 Flood 3	
N5	2.65		Bioretention B6 (c)	360m²	Flood 3 Flood 4 Flood 5 Flood 6	
N6	1.54					
N7	8.30		Bioretention N7	600m²		
N8	4.28		Bioretention N8	500m²		
N9	4.19		Sediment Basin N10 Ephemeral Wetland W4 Swale N10	500m² 8,000m² 300m		
N10	10.29					
N11	5.71					
N14a	1.35					
N12	3.84		Sediment Basin N12 Remediated Wetland W3 Wetland W2	500m² 4,000m² 14,000m²	Flood 1 Flood 6 + wetland W2	
N13	4.49		Sediment Basin N14 Remediated Wetland W3	300m² 4,000m²		
N14a	5.67					

Table 2 continued over page

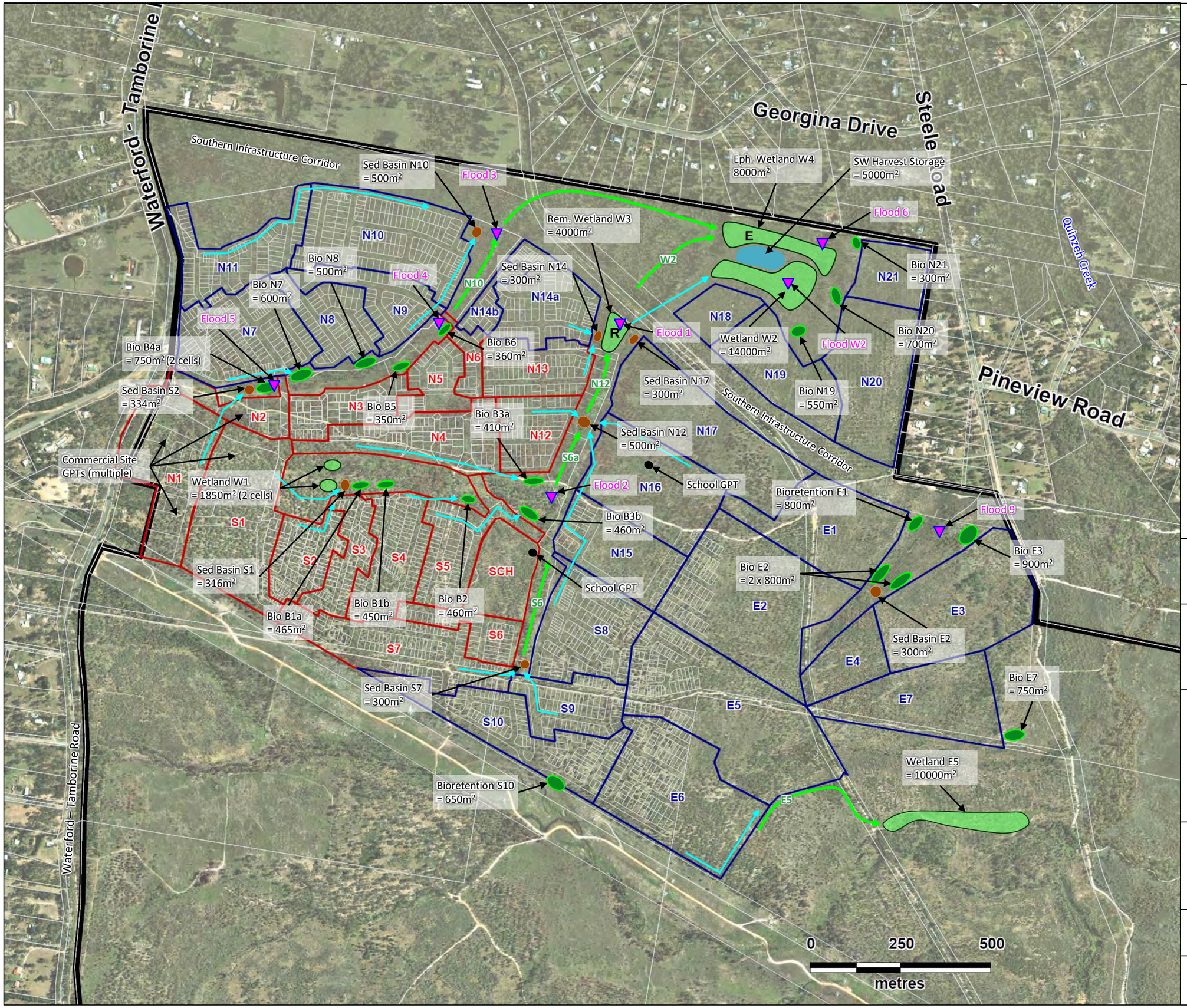
Table 2 (continued)

Catchment		Water savings	Stormwater quality		Flood detention	Frequent Flow management
ID	Area (ha)		Treatment Type / ID	Area/ Length	ID**	
N14b	1.35		Wetland W2	14,000m²	*Continued from column on previous page*	*Continued from column on previous page*
N15	6.16		Sediment Basin N12	500m²		
N16	8.76		Remediated Wetland W3 Wetland W2	4,000m² 14,000m²		
N17	10.63		Sediment Basin N17 Remediated Wetland W3 Wetland W2	300m² 4,000m² 14,000m²		
N18	2.24		Wetland W2	14,000m²	Flood 6	
N19	3.03		Bioretention N19	500m²		
N20	8.06		Bioretention N20	550m²		
N21	3.16		Bioretention N21	700m²		
E1	8.14		Bioretention E1	800 m²	Flood 9	Attenuation of low flows (<1yr ARI) and drainage upgrades downstream
E2	14.43		Sediment Basin E2	300m²		
E4	3.60		Bioretention E2	1600m²		
E3	12.45		Bioretention E3	900m²		
E5	15.55		Swale E5	250m	-	Wetland storage and slow release at baseflow rates
E6	11.77		Wetland E5	10,000m²		
E7	8.16		Bioretention E7	750m²		
Total	253.9					

* 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.

(c) Denotes treatment systems already constructed as part of Precinct 1



DesignFlow

LEGEND

- Site Boundary
- Stormwater Diversions
- S6 — Remediated Waterway / Swale
- Sediment Basin (Sed)
- Bioretention Basin (Bio)
- Constructed Wetland
- R — Remediated Wetland Zone (ephemeral)
- E — Ephemeral Wetland
- Stormwater Harvesting Storage
- Precinct 1 Treatment Catchments
- Precinct 2 Treatment Catchments
- Flood Detention Zone

N W E S

Scale:
Approx. 1 : 10,000 (A3)

FIGURE 10

Precinct 1 and 2
Stormwater Management Strategy

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Date:
28 July 2014

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 basins 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 basins 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 establishment water for Precinct 1 and 2. The basins will sit within proposed constructed wetlands or flood detention basins with the sizes listed below (based on area available and proposed treatment systems in these locations):

- Catchment 2 – 14,000m^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 currently occurring. This occurs on a 1-2 monthly basis and has identified a range of issues 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 an ongoing 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 WATERWAYS AND DRAINAGE LINES

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.

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).

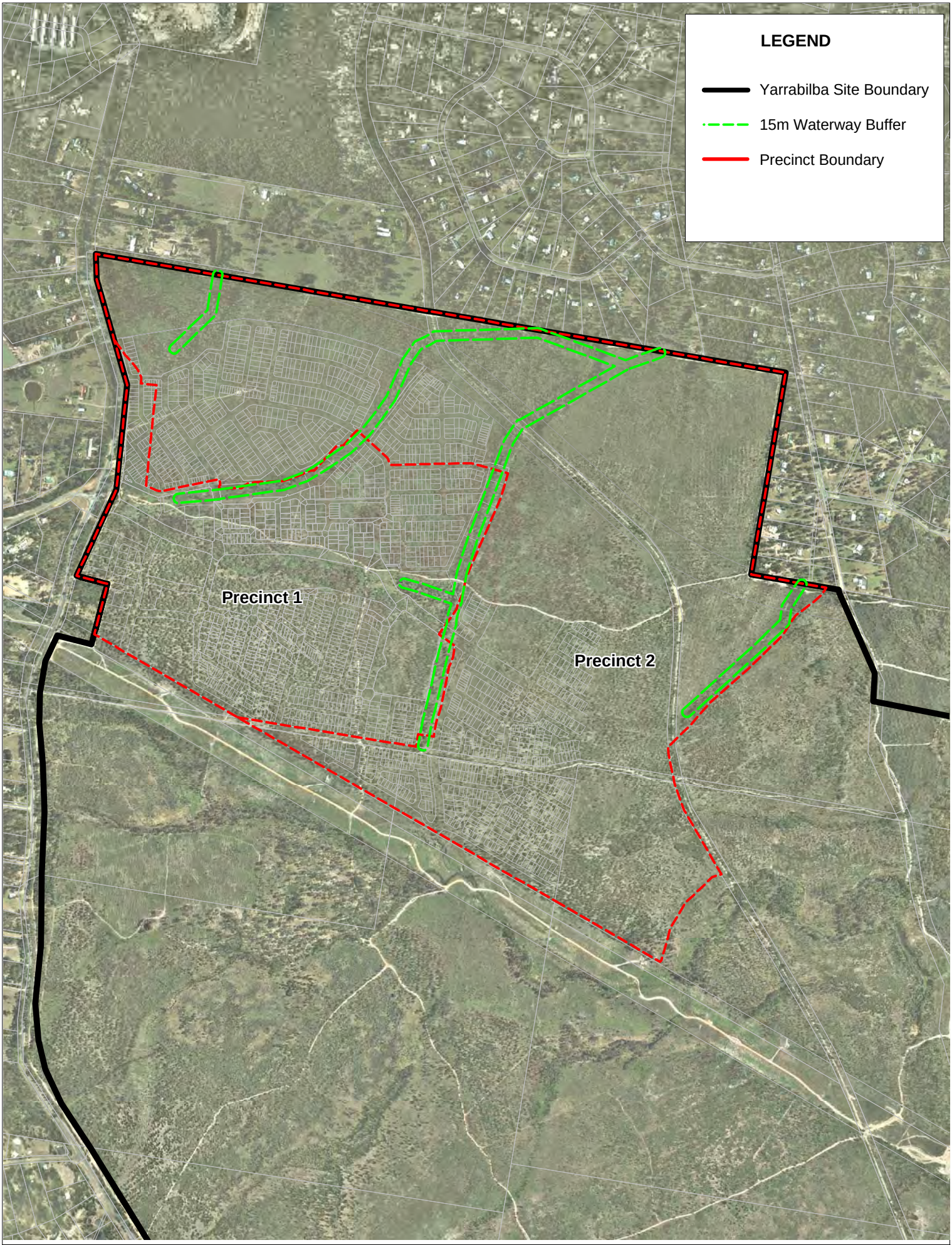
5.3 WATERWAY REMEDIATION

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.

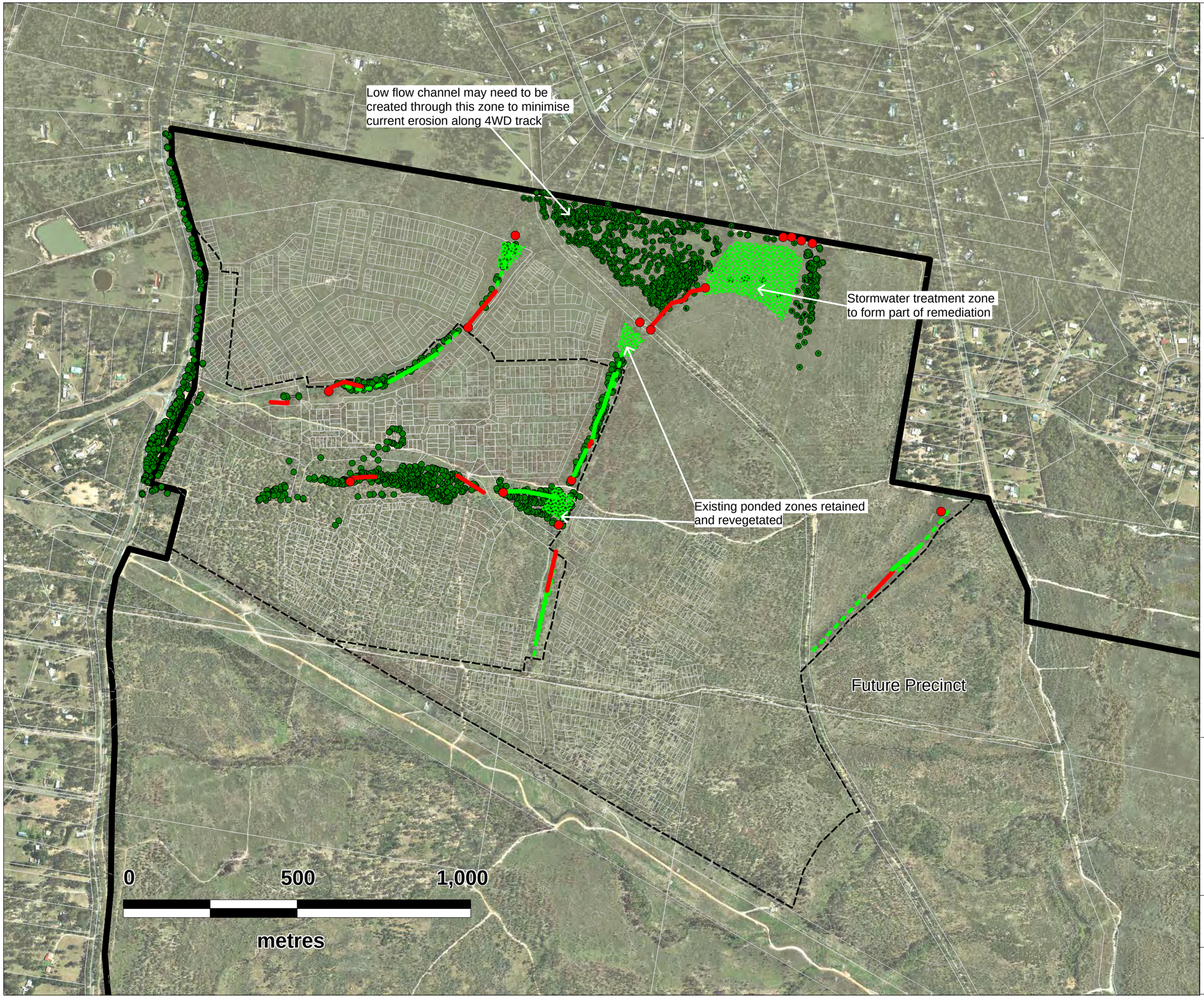
The majority of the waterways are in Poor or Average condition due to lack of vegetation (i.e. grasses and regrowth pine plantation). It is proposed that these waterways will be remediated in accordance with the following:

- 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	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 15,000 (A4)	**FIGURE 11** **Precinct 1 and 2** **Waterway/Drainage Line Buffers**
	Client: Lend Lease	Date: 21 July 2014	



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:
28 July 2014

Client:
Lend Lease

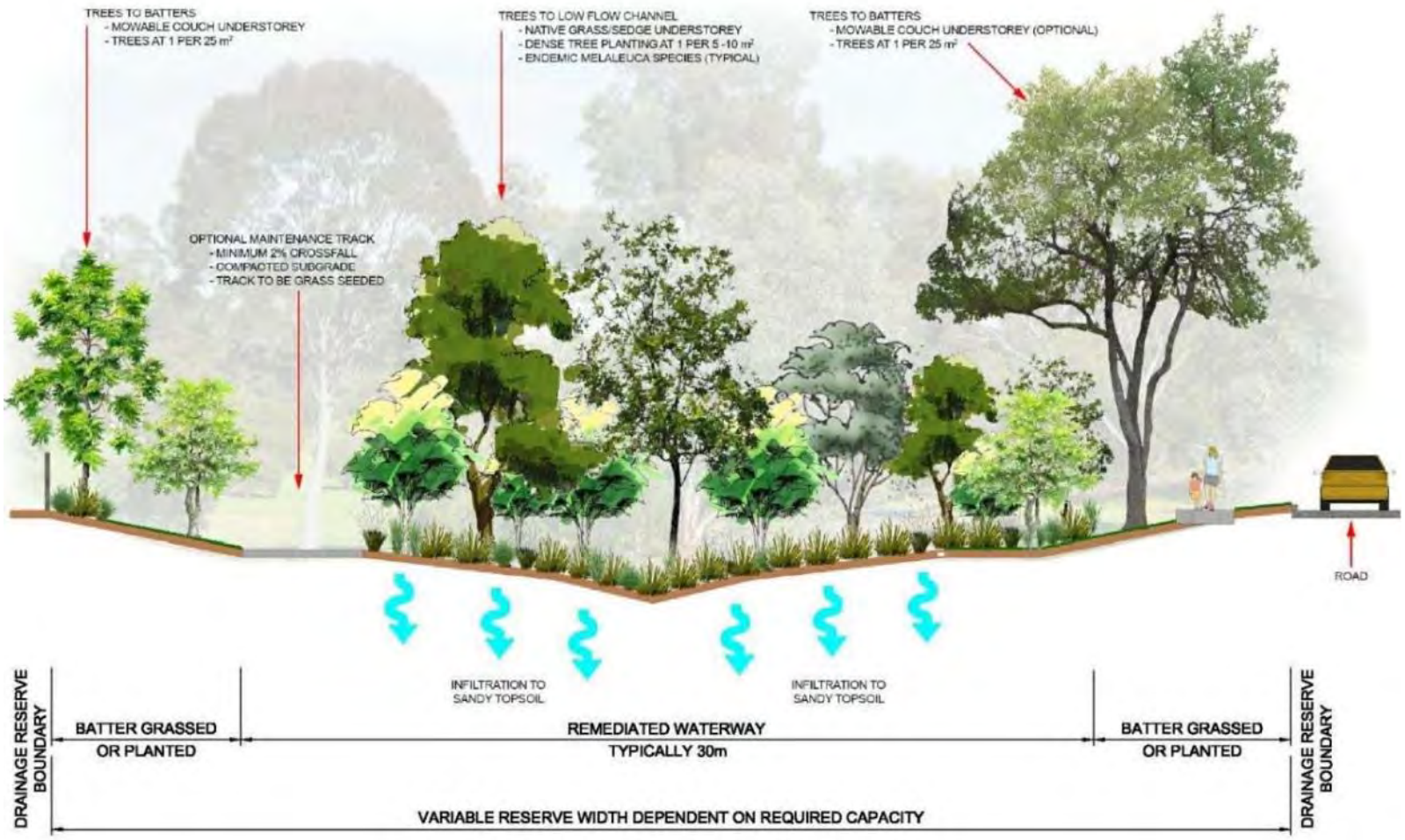


Figure 13: Remediated waterway typical section

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 the former State Planning Policy 4/10 but remain consistent with the current single State Planning Policy (2013).

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) and *Yarrabilba Precinct 1 and 2 Stormwater Management Plan* - Version 2 (DesignFlow, February 2014) 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 previously in Section 3 (Table 2 and Figure 10). The following sections describe the individual elements of the strategy.

6.2.2 Remediated Waterways

As outlined in Section 2.1, the waterways in Average and Poor condition will be remediated. This will involve 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. Two of these sediment basins (S1 and S2) have been constructed.

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 (Precinct 1) with protective turf during building phase

The bioretention basins are located along the waterway corridors but offline from the 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. The bioretention basins are saturated zone systems to ensure the plant health within the basins during extended dry periods.

6.2.5 Wetlands

Five wetlands are proposed for Precinct 1 and 2 with one of the wetlands (W1) in Precinct 1 already constructed and under vegetation establishment. 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 the Precinct 2 zone of 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 future (optional) 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/or 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.

An ephemeral wetland will also be created at the downstream end of Catchment 2. 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 2.

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

For the commercial/retail and school sites in Precinct 1 and 2, high gross pollutant and/or other non-typical pollutant loads are expected. Therefore, as a minimum, gross pollutant traps (GPTs) will be required on these lots to manage primarily litter prior to discharging to downstream vegetated stormwater treatment measures. Other commercial/light industrial land uses that trigger specific stormwater requirements (e.g. service stations) must provide the relevant treatment device and structural controls (such as oil/grit separators, covered/bunded areas) in addition to gross pollutant capture to avoid or manage stormwater pollutants. These sites may also be subject to trade waste requirements to avoid stormwater contamination from site activities and must comply with the relevant environmental guidelines for the specific land use.

Gross pollutant loads from the residential areas of the site are considered sufficiently low to be adequately managed through the pre-treatment areas of sediment basins, wetlands and bioretention basins via the standard maintenance regime for these systems. Therefore, gross pollutant traps are not proposed for the residential catchments.

6.3 CONCEPTUAL EARTHWORKS

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).

Preliminary earthworks models have been generated for each of the treatment measures where they impact the flood detention basins. Refinement of these concepts will occur as part of the civil and landscape design development within development stages to ensure all desired outcomes can be achieved.

6.4 MODELLING AND RESULTS

MUSIC modelling was conducted to quantitatively assess the stormwater treatment performance of the proposed stormwater strategy. MUSIC version 6 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 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 as this is not the 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	8.30 (60%)	8.30 (60%)				
N8	4.28 (60%)	4.28 (60%)				
N9	4.19 (60%)	4.19 (60%)				
N10	10.29 (60%)	10.29 (60%)				
N11	5.71 (60%)	5.71 (60%)				
N12	3.84 (60%)	3.84 (60%)				
N13	4.49 (60%)	4.49 (60%)				
N14	5.67 (60%)	5.67 (60%)				
N14a	1.35 (60%)	1.35 (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	**254**	**197.4**	**2.5**	**6.6**	**18.9**	**28.6**

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

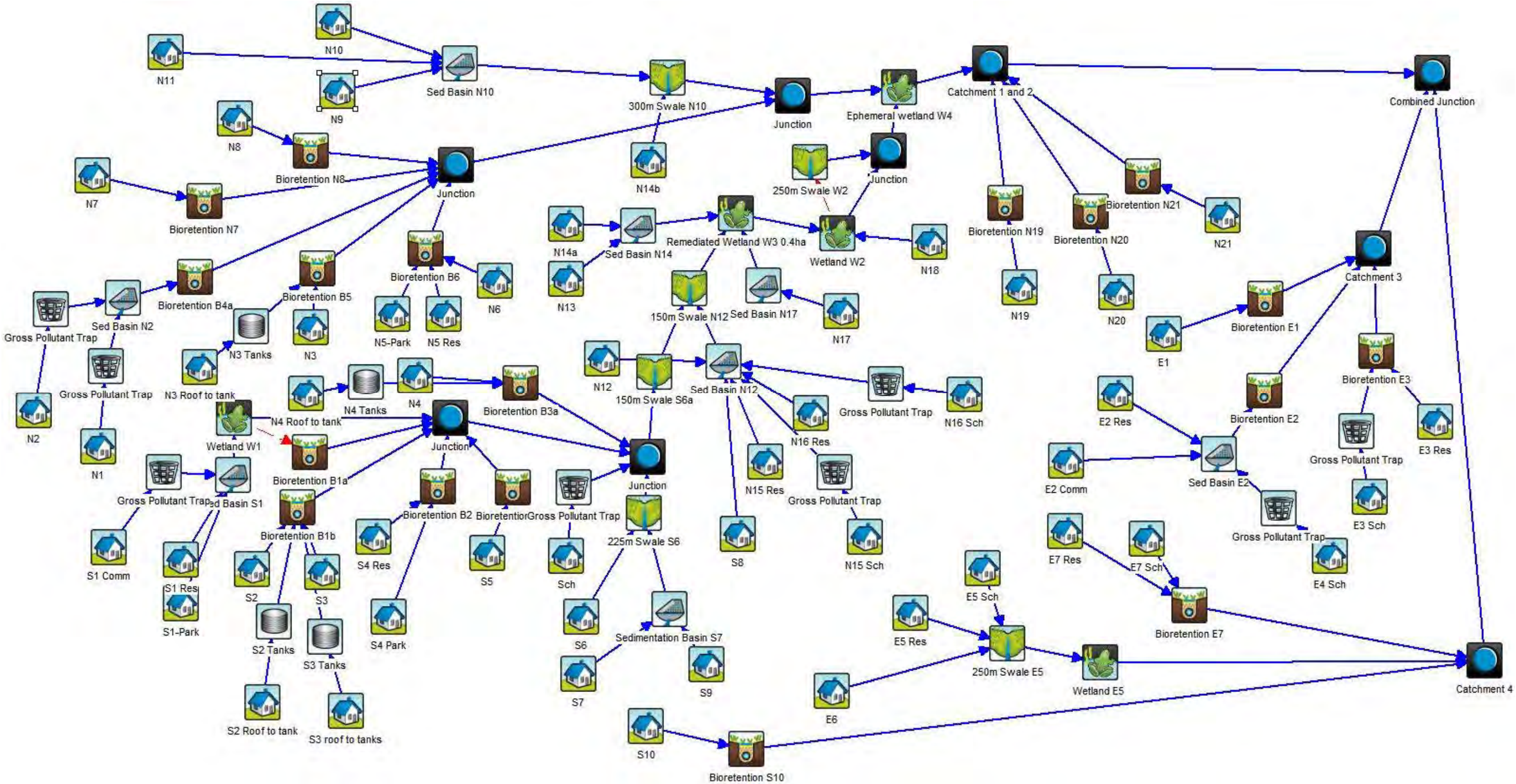


Figure 14: MUSIC model layout

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

Parameter	Sediment Basin ID							
	S1	N2	S7	N10	N12	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	200	300	200	200	300
Overflow weir width (m)	10	2	2	2	2	2	2	2
Notional detention time	0.23hr	0.24hr	0.22hr	0.8hr	0.36hr	0.49hr	0.49hr	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 ID																	
	B1a	B1b	B2	B3a	B3b	B4a	B5	B6	N7	N8	N19	N20	N21	E1	E2	E3	E7	S10
Surface Area (m²)	465	450	460	410	460	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 (m²)	450	450	460	410	460	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.

Parameter	Remediated Waterway 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	10	10	5
Top width (m)	15	15	15	20	20	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 and Remediated Wetlands

Stormwater quality from four catchments at Yarrabilba will be managed using constructed wetlands and remediation of degraded wetland zones. 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 and Remediated wetland node reporting table

Parameter	Wetland Zone ID				
	W1	W2	Rem. Wetland W3	Eph Wet W4	E5
Inlet pond volume (m^3)	0 (separate sediment basin S1)	0 (swale pre-treatment)	0 (swale pre-treatment)	0 ((separate sediment basin N10)	600
Macrophyte zone area (m^2)	1850	14,000	4,000	8,000	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
Extended detention depth (m)	0.5	0.5	0.5	0.3	0.5
Permanent pool volume (m^3)	555	4500	100	50	3000
Average depth (m)	0.3	0.35	0.25	0.01	0.3
Exfiltration rate (mm/hr)	0	0	0	0	0
Evaporative loss (% of PET)	125	125	125	125	125
Notional Detention Time (h)	48	48	0.5	3.5	48
Number of CSTR cells	4	4	4	4	4
Confirmation that K and C* remain default?	Y	Y	Y	Y	Y

6.4.7 Gross Pollutant Traps

Gross pollutant traps were installed in the model downstream of the school and commercial catchments. The focus on the traps is litter however, they do provide some level, albeit minor, treatment of sediments and nutrients. The following treatment removal was assumed for the GPT's based on a recent peer review completed for Gold Coast City Council:

- TSS = 25% removal
- TP = 10% removal
- TN = 10% removal

6.4.8 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	74	43
Catchment 3	38.6	85	66	54
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 remediated 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 objectives

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. Monitoring wells to 5 m depth have been installed at the northern end of the site but have been the subject of vandalism. These monitoring wells are being monitored 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 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. Based on the constraints in this location only 0.5ha of storage is available for stormwater harvesting meaning any stormwater harvesting needs to be combined with other frequent flow management.

- **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 flows, there is an option of attenuating low flows (within ephemeral wetland W4) to the point where they can be contained within downstream drainage without causing nuisance. The potential then exists to work with the downstream landholder to improve current drainage (through either open channel or pipes) to manage these low flows between Yarrabilba and Georgina Drive (the pre-development overland flow path appears to be regularly saturated, limiting the use of this part of the lot). Once flows reach Georgina Drive, there is an open drain easement 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

DesignFlow

Catchment 1

Divert development flows to Catchment 2. Baseflows to RE preserved

Drainage upgrade to contain minor (nuisance) storms through lot

Stormwater harvesting and reuse;
OR
Infiltration (subject to current geotech);
OR
Low flow attenuation and drainage upgrade

Catchment 2

Drainage upgrade to preserve driveway immunity

Catchment 3

Minor flow attenuation (combined with bioretention and infiltration)

Future Precinct

Constructed wetland sized to treat flows and bleed at baseflow rates into Creek

Catchment 4

0 500 1,000

metres

LEGEND

- Yarrabilba site boundary
- Precinct boundary
- Developed 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 WATERWAY STABILITY

8.1 DESIGN OBJECTIVE

The waterway stability objectives adopted for the site are based on protecting waterways and drainage lines from erosion as a result of increased flow from urban development. The waterway stability objective has been set as part of the *Yarrabilba - Stormwater Infrastructure Master Plan* (DesignFlow, 2012) for a range of situations as shown in Table 14.

Given the state of the waterways in Precinct 1 and 2 (mostly Average-Poor condition), the second and third objectives highlighted in blue have been adopted for Precinct 1 and 2. The first objective has been used as a stretch target for the internal waterways where possible.

Table 14: Derived waterway stability objectives

Waterway classification	Waterway Stability Objectives
Site waterway reach in good condition* (i.e. well vegetated and stable waterway)	Limit post development 1 year ARI flows in waterway to pre-development conditions** OR Ensure the stream erosion index remains below 1.5 when comparing pre and post development flows.
Site waterway reach in poor condition* (i.e. poorly vegetated or active erosion)	As per above OR Rehabilitate waterway to convey the post development 1 year ARI flows without the risk of erosion**
External waterways	Limit 1 year ARI flows at site boundary for critical duration event (60 minutes or longer) to pre-development conditions

* Refer Figure 4 for preliminary waterway condition

** Localised increases in 1 year ARI flows can be accepted provided the erosion criteria for sandy vegetated soils (50% cover for native grasses) is achieved in accordance with QUDM

*** The objective supports the rehabilitation of degraded waterways and allows local increases in 1 year ARI provided the rehabilitation design provides an appropriately stable waterway for the increased 1 year ARI flows.

8.2 STRATEGY

The waterway stability objectives for Precinct 1 and 2 will be achieved through the following initiatives as presented in Figure 16:

- **Flood detention** (flows exiting Yarrabilba) – The 1 year ARI flows at the boundary of the site will be attenuated within the flood detention storages to ensure the pre-development flows are maintained. The location and size of the storage is provided in Section 9.6. The outlet structures from all the detention systems are staged to ensure the 1 year ARI flow is attenuated as well as larger flows up to 100 year ARI.

- **Waterway remediation** (within Yarrabilba) – Although flow attenuation is provided along the length of the waterways, there are waterway reaches within Yarrabilba where flows will increase as a result of development. This is unavoidable and creates a risk of erosion. Furthermore, there are signs of existing erosion in some of the waterways as a result of previous land use practices.

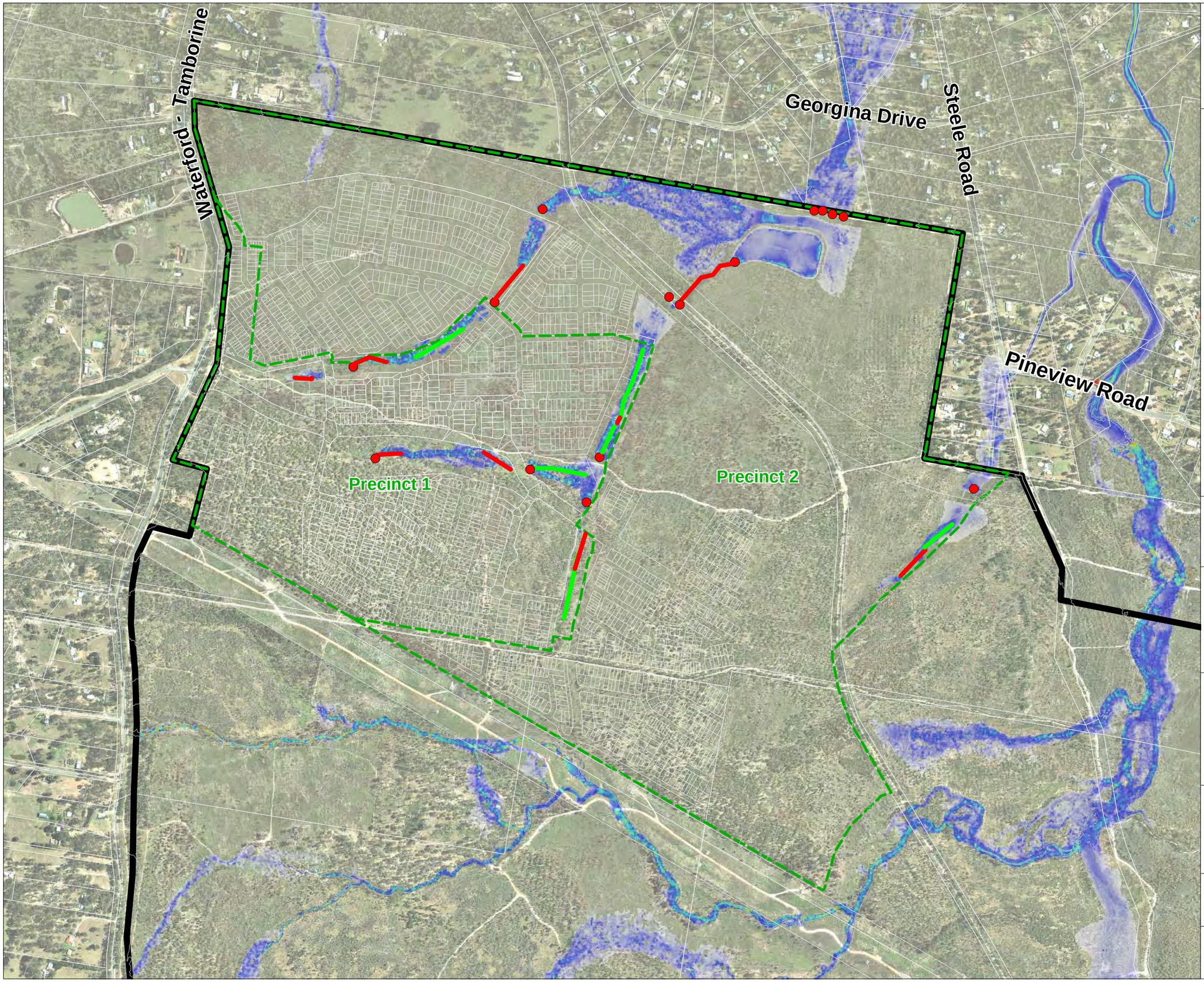
  Waterway remediation is proposed for essentially all the waterways within Precinct 1 and 2. The waterway remediation concept is described in Section 5.3 and involves mostly revegetation with additional stabilisation provided in the zones where criteria listed in Table 15 is not achieved. The areas of additional stabilisation have been identified through interpretation of the 2-dimensional flood modelling presented in Section 9.5.

DesignFlow are developing the concept presented in Figure 16 into a waterway remediation strategy with Lend Lease at the time of writing this document. This involves further interpretation of the waterway stabilisation criteria and flood modelling along with assessment of bed shear stress (over both design storms and continuous simulation) to inform planting and stabilisation. The scope of this work is too detailed to be presented in this report.

Table 15: Internal waterway stabilisation criteria

Parameter	Criteria* (above which additional stabilisation is required beyond revegetation, based on 50% vegetation coverage on erodible soils)
1 and 2 year ARI velocity (QUDM, 2013) (ACARP, 2002)	1.0m/s
50 year ARI (QUDM, 2013)	1.5m/s

* Criteria based on 50% vegetation coverage on erodible (i.e. sandy) soils



DesignFlow

LEGEND

- Outlet Rock Protection
- Waterway Rock Scour Protection
- Revegetate and observe (for local scour)
- Precinct Boundary
- Yarrabilba Site

N W E S

Scale:
1 : 15,000 (A3)

FIGURE 16

Precinct 1 and 2 Waterway Stabilisation Concept

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease

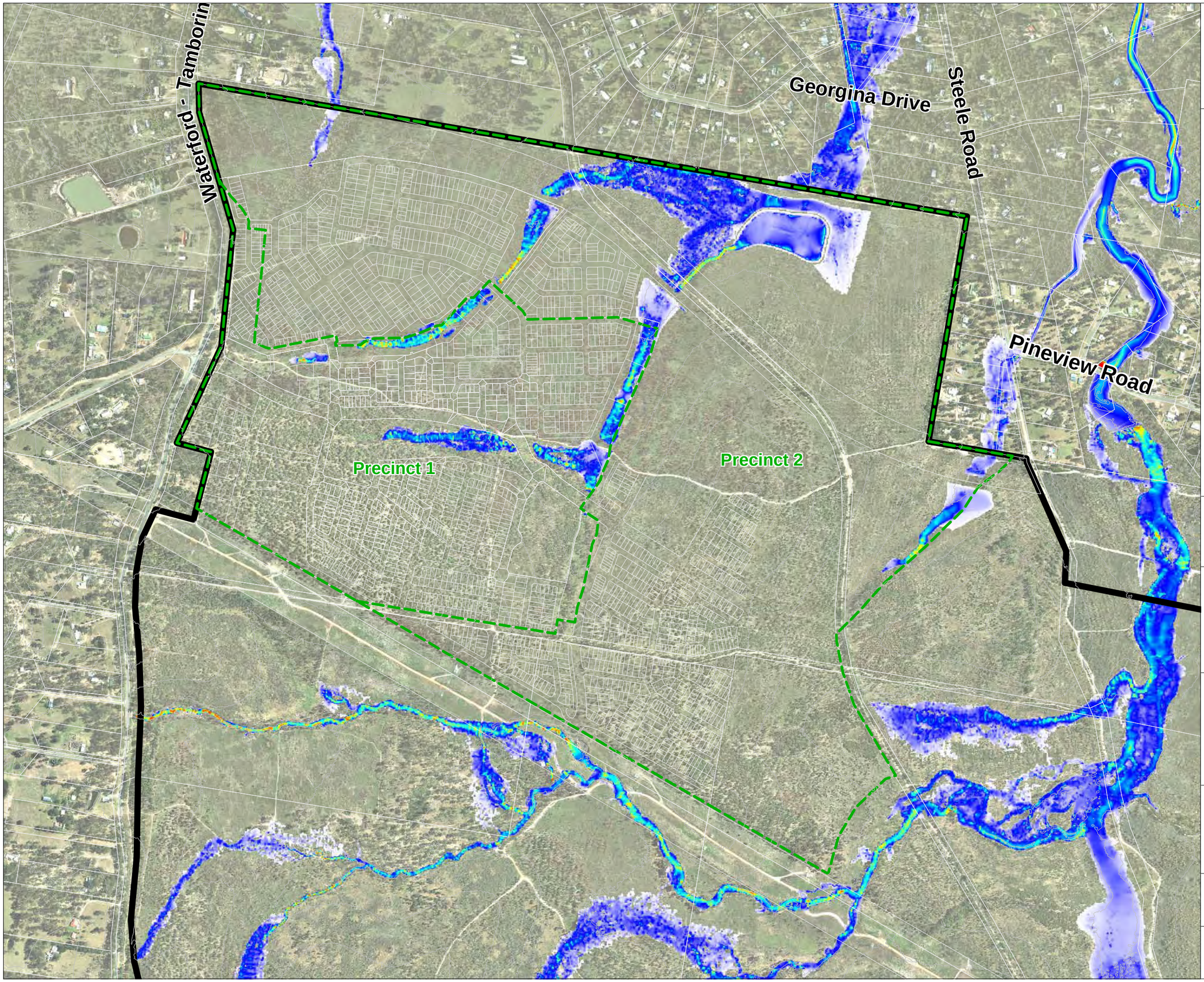
8.3 MODELLING AND RESULTS

All the modelling required for the waterway stability objectives was completed using the hydraulic modelling presented in Section 9.5. As presented in Table 16 the 1 year ARI flow at the boundary of Precinct 1 and 2 have been preserved at pre-development rates. This ensures the 'external waterways' component of the waterway stability objective is achieved.

Table 16: 1 year ARI peak discharge from site

Location	Discharge m^3/s		
	1 year ARI		
ID	PRE	DEV	Change
4	4.82	4.51	-0.32
9	0.95	0.96	0.02
A23	0.57	0.30	-0.27
8	22.19	21.64	-0.55

In terms of managing waterway stability within internal waterways, the peak velocities for the 2 year ARI and 50 year ARI have been extracted from the TUFLOW modelling and are presented in Figure 17 and Figure 18 respectively. The figures indicate that velocities are below the criteria listed in Table 15 for the majority of the internal waterways indicating that the waterways should remain stable provided they are revegetated. The locations where velocities are elevated above the criteria in Table 15 are highlighted previously in Figure 16 and will require additional stabilisation. The details of the stabilisation (i.e. rock protection, bed level control etc.) is being resolved as part of the waterway remediation strategy for Precinct 1 and 2.



DesignFlow

LEGEND

- Precinct Boundary
- Yarrabilba Site

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

N W E S

Scale:
1 : 10,000 (A3)

FIGURE 17

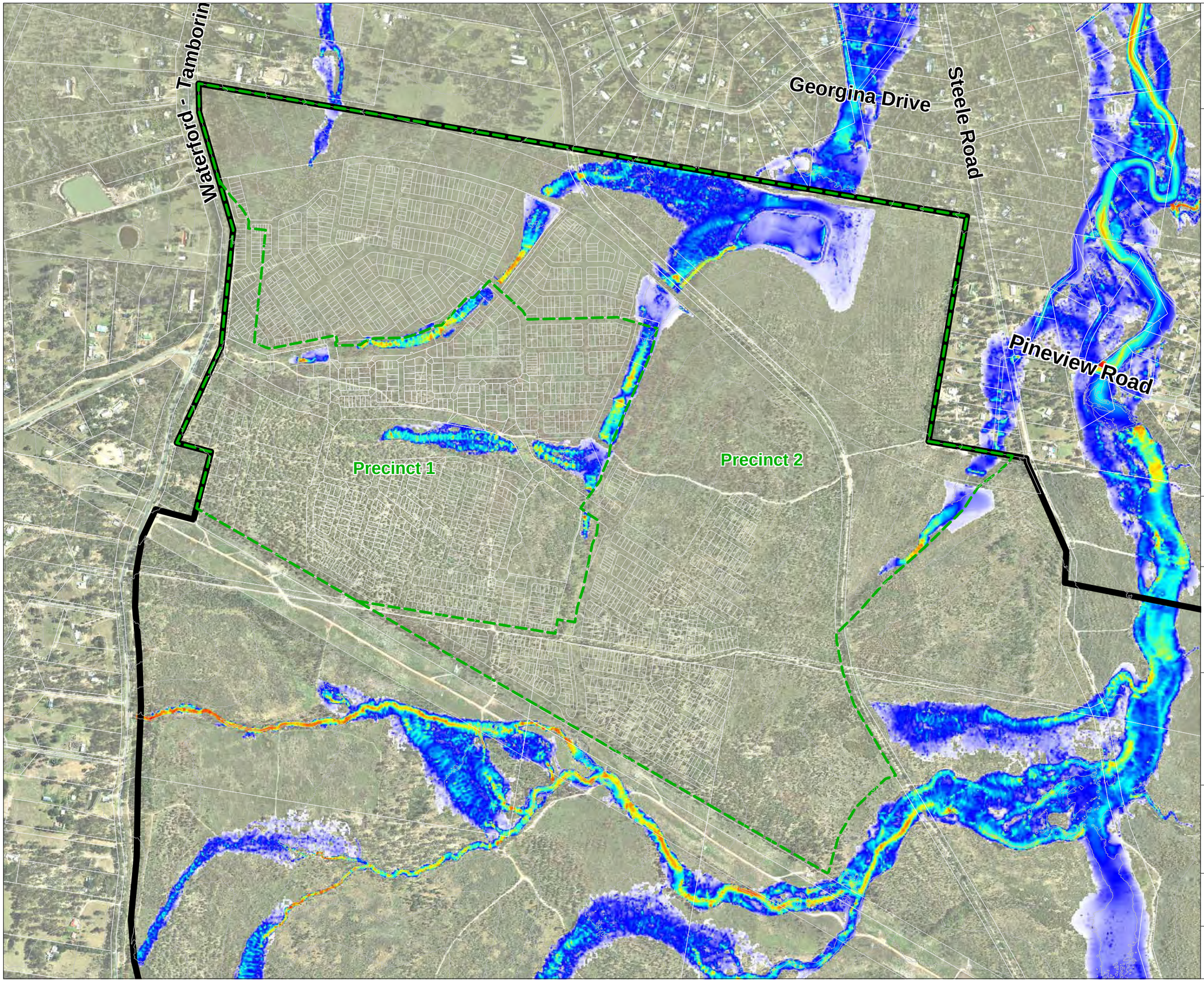
2 year ARI Velocity

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease



DesignFlow

LEGEND

- Precinct Boundary
- Yarrabilba Site

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

N W E S

Scale:
1 : 10,000 (A3)

FIGURE 18

50 year ARI Velocity

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease

9 FLOODING

The conversion of the Yarrabilba site to urban development will increase stormwater runoff which, if left unmitigated, will result in adverse flood impacts on downstream properties. In 2013 Council completed the Quinzeh Creek Flood Study which guided the flood inundation mapping 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. More recent revisions to this study have resulted in amendments to the flood mapping.

Lend Lease is acutely 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 9.1. This section presents the flood management strategy adopted for Precinct 1 and 2 along with the flood mapping completed.

9.1 DESIGN OBJECTIVES

The stormwater management strategy for the Precinct 1 and 2 will achieve the objectives listed in Table 17 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 within and downstream of the site from the impacts of urban stormwater runoff.

Table 17: 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 downstream 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

9.2 FLOOD MITIGATION STRATEGY SUMMARY

As part of delivering Precinct 1 and 2, the following initiatives will be delivered to achieve the objectives identified above and are based broadly on the key catchments identified in Figure 19:

- **Flood detention basins** configured in the following manner:
    - Catchment 2 – Detention systems will be located throughout Precinct 1 and 2 within the main drainage lines (typically upstream of road crossings or dedicated bunds) to manage flood events. The culverts/outlet structures have been designed to control discharge and create temporary ponding conditions upstream. A large flood detention basin is required at the

downstream end of Catchment 2 in addition to the storages behind the roads. This storage is designed to primarily manage the smaller events (1-20yr ARI) whereas most of the attenuation of the larger floods occurs upstream of road crossings.

- Catchment 3 – A flood detention basin will be created upstream of the Southern Infrastructure Corridor. The detention storage has been designed with a multiple stage outlet to provide attenuation of all flood flows.

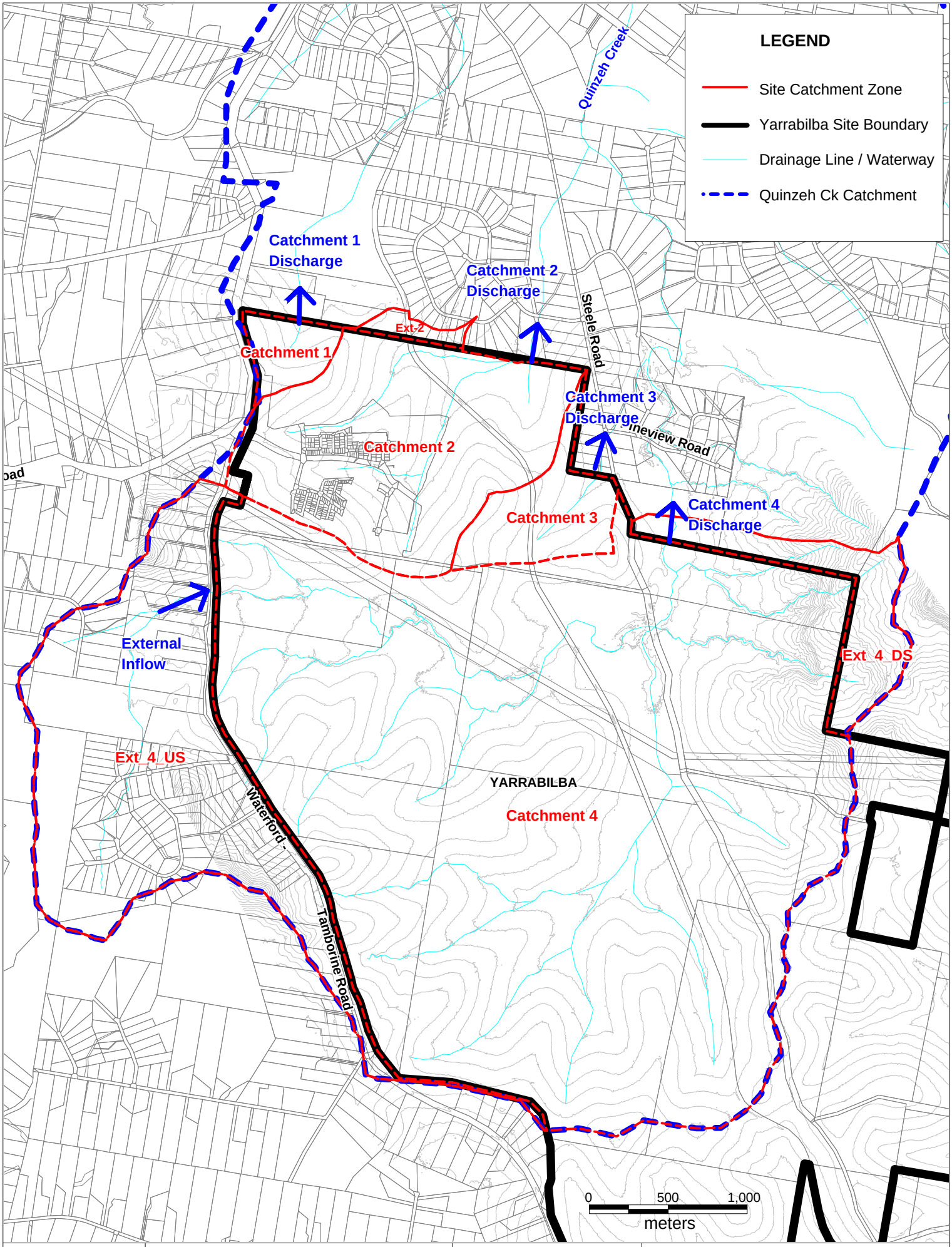
- Catchment 4 – (Future Development) A flood detention basin will be constructed within the southern catchment of the future Yarrabilba development area. This provides flow attenuation to avoid hydrograph coincidence further downstream in the catchment (refer to Section 9.6.3 for further discussion). Minor area of southern Precinct 2 within this catchment will not require detention.

- **Catchment diversion** – Flows up to the 2 year ARI pipe drainage and part of 100 year ARI overland flow will be diverted from Catchment 1 to Catchment 2. This will ensure all peak flows existing Catchment 1 will remain below pre-development. This is required due to the limited opportunity to provide flood detention at this location as a result of significant vegetation and the Southern Infrastructure Corridor.

- **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.

Details of the flood basins and associated outlet structures are provided in Section 9.6.3. All of the systems have been assessed using XPRAFTS and TUFLOW modelling software to ensure the proposed configurations will achieve the flood objectives. An existing XPSWMM model has also been used for rapid design appraisal of the Precinct 1 and 2 hydraulic structures and detention basins but does not currently form part of the broader Quinzeh Creek model at this stage.

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.



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A4)	**FIGURE 19** **Broad Catchment Delineation and Discharge Locations**
	Client: Lend Lease	Date: 21 July 2014	

9.3 ASSESSMENT METHODOLOGY

This flood assessment has been undertaken to expand the earlier modelling undertaken as part of the previous *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, February 2014) and draws on a number of existing studies that have occurred within Yarrabilba and the broader Quinzeh Creek Catchment.

9.3.1 Previous Yarrabilba Site Modelling

The following flood assessments have been completed previously for the Yarrabilba site as part of planning and preliminary design. 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) – Broad scale flood modelling completed for the whole Yarrabilba site to inform the Infrastructure Master Plan.

- *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, February 2014) – updated flood modelling undertaken for Precinct 1 and 2 only. Subsequent EDQ review and conditions have resulted in a total review and expansion of the Yarrabilba flood modelling based on the receipt of Council's modelling data (see below) and the need to extend the model over the full extent of Quinzeh Creek.

9.3.2 Previous Quinzeh Creek Catchment Modelling

Flood assessment projects undertaken by Logan City Council (and their commissioned consultants) for the broader Quinzeh Creek (including part of the Yarrabilba site) are:

- *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) – Summarises calculations and modelling to define XPRAFTS modelling parameters for Quinzeh Creek and presents design flows using the XPRAFTS model.

- *Revised Quinzeh Creek Flood Study* (Engeny, 23 August 2013) – Presents the updated flood modelling completed for Quinzeh Creek using the updated XPRAFTS parameters derived by WRM (2013). Flood levels and mapping were defined using TUFLOW modelling. This work was completed following the previous release of the Logan flood maps for Quinzeh Creek which presented the unmitigated scenario with Yarrabilba fully developed. Understandably the local community was concerned with these flood maps because of the increased extent of flooding (much more than existing case). This revised letter report presents the existing case flood modelling (prior to any development at Yarrabilba).

A meeting was held with Logan City Council (and their consultants), Lend Lease, DesignFlow and WBM on the 27th May 2013 to discuss the Quinzeh Creek flood modelling approach and resolve a way forward for Yarrabilba. Given the initial concerns associated with the Council flood mapping (i.e. presenting the unmitigated developed case flood maps rather than existing case flood maps), it was resolved that Council would establish hydrologic parameters and a Quinzeh Creek 2D hydraulic model (base case) and discuss these with Lend Lease. The Quinzeh Creek flood model (XPRAFTS and TUFLOW) would then be updated (by Council) to create an existing base case model for the entire catchment. This would then be made available to Lend Lease for use as the pre-development model and updated (by DesignFlow) to define and assess post development flood mitigation requirements. It was agreed between all parties that this was a transparent process for assessing flood mitigation for Yarrabilba.

The Council modelling was not completed until September 2013 and Council were unable to release the model to Lend Lease prior to the modelling and documentation required for the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, 2014). The updated flood models were peer reviewed by Cardno (commissioned by EDQ) with feedback provided. Therefore, for the purpose of *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, 2014), a separate flood modelling process was completed by DesignFlow for Precinct 1 and 2 using methods and parameters derived for the Yarrabilba site that were generally consistent with the Council modelling for Quinzeh Creek.

Comment on Council flood modelling

DesignFlow's initial review of the flood modelling completed for Council in 2013 indicated the consultants had assumed fully forested conditions across Yarrabilba for the pre-development (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 Quinzeh Creek modelling completed for Council were communicated to Council and EDQ as part of completing of the previous *Yarrabilba Precinct 1 and 2 Stormwater Management Strategy - Version 2* (DesignFlow, February, 2014).

In February 2014 Logan City Council supplied their hydrologic (XPRAFTS) and hydraulic (TUFLOW) flood modelling data to Lend Lease to enable Yarrabilba flood impact assessment across the total catchment to progress as was originally discussed in the original meeting with Council 27th May 2013. This modelling information comprised a number of components based on investigations to date by Council's commissioned consultants as summarised in Table 18. All reference to 'Engeny' or 'WRM' models or data collectively refers to the Logan City Council flood assessment work and are used where required to differentiate specific work undertaken by each consultant for Council.

Table 18: Logan City Council Models Provided

Model Name/ID	Developed by	History/Purpose
Quinzeh Creek XPRAFTS	WRM	Validation of catchment land use assumptions and parameters for runoff estimation based on the Rational Method
Quinzeh Creek XPRAFTS	Engeny	Based on WRM validation and used to provide hydrologic input to the Quinzeh Creek TUFLOW hydraulic model
Quinzeh Creek TUFLOW	Engeny	Hydraulic assessment and flood mapping within a small portion of Quinzeh Creek catchment using the derived hydrologic inputs from XPRAFTS

Council's TUFLOW model (Prepared by Engeny) was to form the base case for the Quinzeh Creek catchment prior to development of Yarrabilba from which the no worsening criteria for flooding are benchmarked. However, DesignFlow's detailed review of Council's model data provided from both the WRM and Engeny hydrological and hydraulic models identified a number of important concerns that impact the useability and reliability of the models. The key concerns are summarised below with a details provided in Appendix E:

- The Engeny TUFLOW model extent covers only a small portion of Quinzeh Creek (as shown in Figure 20)
- The Engeny XPRAFTS model does not cover the full Quinzeh Creek catchment (only used for inputs to TUFLOW)
- The XPRAFTS models produced by WRM and Engeny are not consistent with each other (routing method and initial loss assumptions in particular).

Furthermore, DesignFlow's review of the WRM and Engeny XPRAFTS modelling, specifically in the context of the Yarrabilba site, indicates a number of concerns including (but not limited to):

- The models do not reflect the pre-development land use in Yarrabilba which is predominantly cleared plantation and/or open woodland and regrowth (not fully forested as assumed).
- The initial loss parameters for the entire Quinzeh Creek catchment have been justified using the Rational Method at a single location approximately 9.5km downstream from the head of the catchment. The Rational Method approach appears to have a number of very broad assumptions (waterway slope and runoff coefficient) that greatly impact this validation approach.

- The XPRAFTS models do not account for areas of significant natural attenuation occurring within parts of the Yarrabilba site as discussed in Section 9.4.9 (which then translates to inaccurate validation of hydrological assumptions for input to the TUFLOW model).

- It is acknowledged by WRM that the XPRAFTS parameters derived using a Rational Method validation at a single location may/will not apply at a sub-catchment scale (i.e. Yarrabilba).

- The January 2013 flood event was used by Engeny to validate the XPRAFTS and TUFLOW model parameters. Sensitivity testing completed by Engeny at the request of Lend Lease indicates that the adopted initial/continuing loss model parameters have no influence on the validation of the January 2013 flood levels at Pineview Road (i.e. an initial loss of 5mm delivers the same peak flood levels as an initial loss of 39mm for this event), The results of this are provided in Appendix F.

In a meeting with Council, Engeny, WRM, Lend Lease, EDQ and DesignFlow on 21 January 2014, Council confirmed their Quinzeh Creek hydrological and hydraulic studies and validation approach was finalised and that these models represent current best information available for Quinzeh Creek.

It is acknowledged that the flow assessment and validation at a single point in a catchment (as done by WRM) can feasibly be undertaken with simplified data and catchment parameters to broadly define catchment behaviour. However, where detailed assessment is required on a number of sub-catchments/tributaries and at a range of scales for the purpose of impact assessment, it is not reasonable to extrapolate these broad catchment parameters for application to localised sub-catchment and achieve acceptable results as this poorly represents the hydrologic processes at a fine scale, which if coupled with 2D hydraulic modelling, can result in duplication of flow routing processes.

As the Quinzeh Creek TUFLOW model (and associated XPRAFTS models) provided by Council did not provide sufficient detail or extent to allow the detailed investigation of Yarrabilba site flood impacts down the extent of Quinzeh Creek, it was necessary to expand the model based on the approach outlined below.

9.3.3 Quinzeh Creek Flood Model Expansion

In order to undertake a full catchment assessment of the Yarrabilba site in the context of flood impacts downstream in Quinzeh Creek, it was necessary to expand (and merge) Council's current hydrologic and hydraulic model(s) with the Yarrabilba site and downstream areas. The method for this process is summarised below and has been divided into zones to delineate the relevant hydrologic and hydraulic model elements and responsibilities. These zones are illustrated in Figure 20.

This process acknowledges the work undertaken by Council in Quinzeh Creek downstream and therefore aims to retain as much of Councils data and modelling for

the catchment downstream of Yarrabilba while undertaking a higher level of detailed assessment within the Yarrabilba site.

Zone 1: Lower Catchment

Zone 1 hydrology is as per the WRM XPRAFTS model. All nodes and links (and associated data) were inserted directly into the merged catchment XPRAFTS model without modification.

Zone 1 hydraulic (TUFLOW) model is based on Council's DEM. Surface roughness (TUFLOW material file) is as per the Engeny data and mapping which formed part of the original Quinzeh Creek model (but extended downstream of their TUFLOW model). No modification of this roughness mapping in Zone 1 occurred as part of the merged model. The TUFLOW model focusses on the main creek channel with boundary condition inflow hydrographs applied for the main tributaries. All hydrological data is sourced from the WRM component of the merged XPRAFTS model described above and applied as local sub-catchment hydrographs or as boundary condition total hydrographs (for tributaries not under detailed assessment).

Zone 2: Mid Catchment

Zone 2 hydrology is as per the Engeny XPRAFTS model. All nodes and links (and associated data) were inserted directly into the merged catchment XPRAFTS model except where Zone 2 XPRAFTS catchments were overlapped by Yarrabilba (Zone 3, see below) sub-catchments. At these locations, the southern extent of Zone 2 was trimmed (i.e. Engeny XPRAFTS catchment areas reduced by the relevant area of Zone 3 overlap).

Zone 2 hydraulic model is retained as per the Engeny TUFLOW model provided by Council. This includes the coupled 1d/2d representation of the main Quinzeh Creek channel. Certain boundary condition inflows have been removed from this section of the hydraulic model as they are now replaced by full hydraulic modelling of upstream Yarrabilba catchments (i.e. Zones 3 and 4).

Zone 3: Yarrabilba Precinct 1 and 2

Zone 3 hydrology is based on the detailed catchment assessment undertaken by DesignFlow in the *Yarrabilba Precinct 1 and 2 Stormwater Management Plan Version 2* (DesignFlow, 2014) and refined as part of this current assessment. As mentioned previously, the Zone 3 sub- catchments were used to trim the extent of Zone 2 and 4 sub-catchments (i.e. reduced areas by overlap area) to ensure no duplication of catchment areas occurs.

The Zone 3 hydraulic model is derived from the DEM for the Yarrabilba site under pre- and post-development scenarios and uses the same 3m grid size adopted in Councils TUFLOW model. Catchment roughness has been based on Yarrabilba site specific assessment and site inspection of land use and drainage conditions.

Zone 4: Yarrabilba future development and external catchment

Zone 4 hydrology is based on two sources:

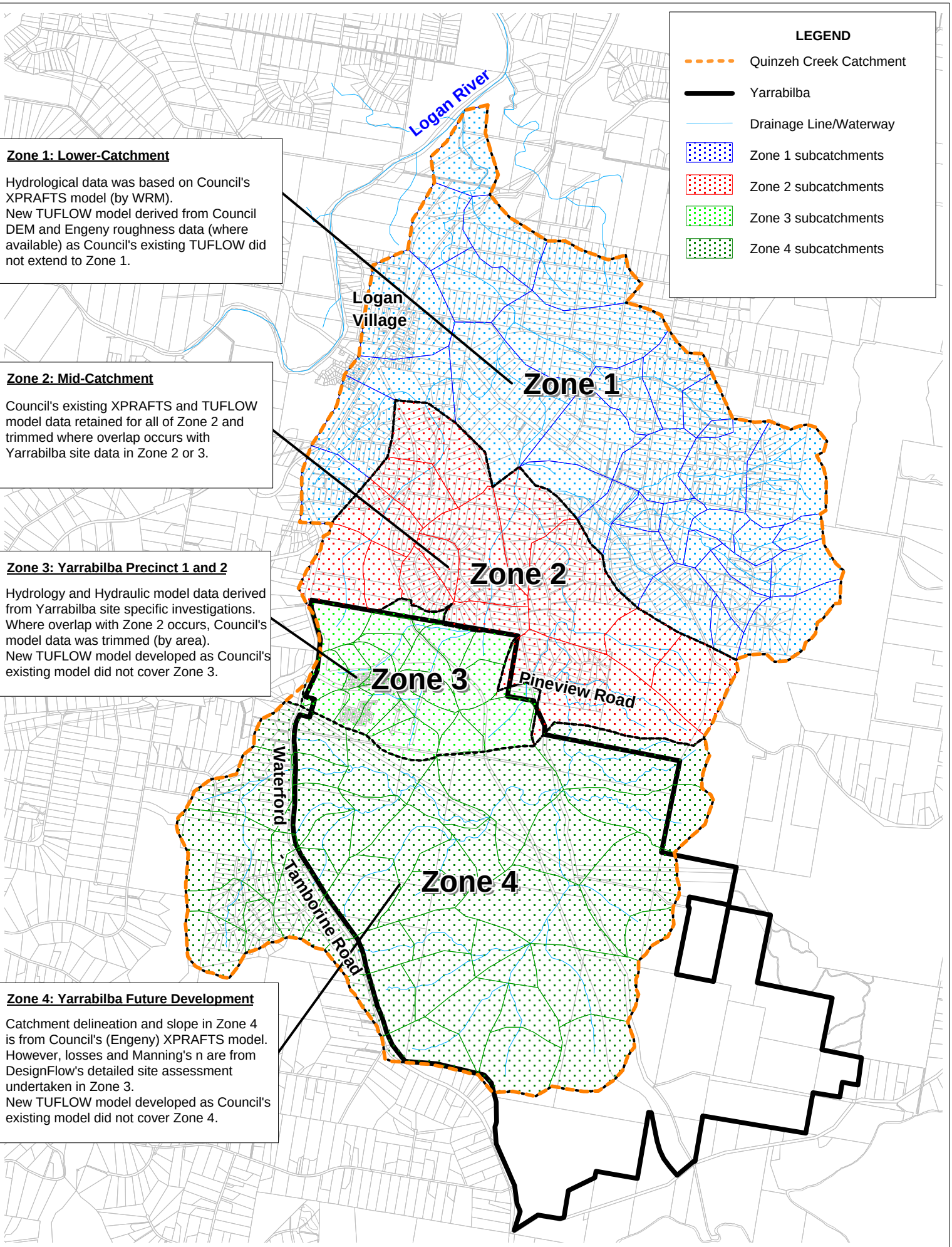
1. Catchment delineation and slope and channel link length, slope and cross section data was retained from the Engeny XPRAFTS model (with a prefix 'A_' added to all Engeny catchment names in Zone 4 for the merged model to identify those retained)

2. Initial/continuing losses and catchment/channel Manning's n were updated for all Zone 4 sub-catchments based on Yarrabilba site specific derived parameters (consistent with Zone 3)

Statement regarding the use of the merged Quinzeh Creek Model:

Based on the compilation of the hydrological and hydraulic data and assumptions described above for the 4 zones of Quinzeh Creek, DesignFlow can verify that the flood inundation mapping is only valid upstream of the northern boundaries of the site (within Yarrabilba).

All other flood inundation and flows downstream of this boundary rely on the data inputs of Council's hydrologic and hydraulic models which DesignFlow have not validated nor have control over. Therefore, flood model results external to Yarrabilba are valid only for assessment of relative impacts between pre- and post-development scenarios and not for absolute flood inundation mapping at locations downstream (i.e. cannot be used for Council Flood mapping of downstream properties in Quinzeh Creek). DesignFlow and Lend Lease are not responsible for the model and results downstream of Yarrabilba as the Council model and data has been adopted in this zone.



Zone 1: Lower-Catchment

Hydrological data was based on Council's XPRAFTS model (by WRM).
New TUFLOW model derived from Council DEM and Engeny roughness data (where available) as Council's existing TUFLOW did not extend to Zone 1.

Zone 2: Mid-Catchment

Council's existing XPRAFTS and TUFLOW model data retained for all of Zone 2 and trimmed where overlap occurs with Yarrabilba site data in Zone 2 or 3.

Zone 3: Yarrabilba Precinct 1 and 2

Hydrology and Hydraulic model data derived from Yarrabilba site specific investigations.
Where overlap with Zone 2 occurs, Council's model data was trimmed (by area).
New TUFLOW model developed as Council's existing model did not cover Zone 3.

Zone 4: Yarrabilba Future Development

Catchment delineation and slope in Zone 4 is from Council's (Engeny) XPRAFTS model. However, losses and Manning's n are from DesignFlow's detailed site assessment undertaken in Zone 3.
New TUFLOW model developed as Council's existing model did not cover Zone 4.

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client: Lend Lease

Scale: 1 : 50,000 (A4)

Date: 21 July 2014

FIGURE 20

Yarrabilba - Quinzeh Creek Flood Model Data Zones

9.4 HYDROLOGY

Runoff from the existing and developed catchment were estimated using the XPRAFTS (Version 2013 SP1a) hydrologic model. Storm durations between 30 minutes and 12 hours were reviewed for the 2 to 100 year ARI events to identify the critical durations for the required parts of the catchment (Table 25). Key hydrological parameters are presented and discussed in the following sections. This discussion focusses primarily on the Yarrabilba site hydrology (Zones 3 and 4 as identified in Section 9.3.3) as this is where the detailed analysis has been undertaken by DesignFlow. All other hydrological parameters for Quinzeh Creek (downstream of Yarrabilba) have been derived by Council (or their consultants) and reference to the relevant flood study reports should be made for these.

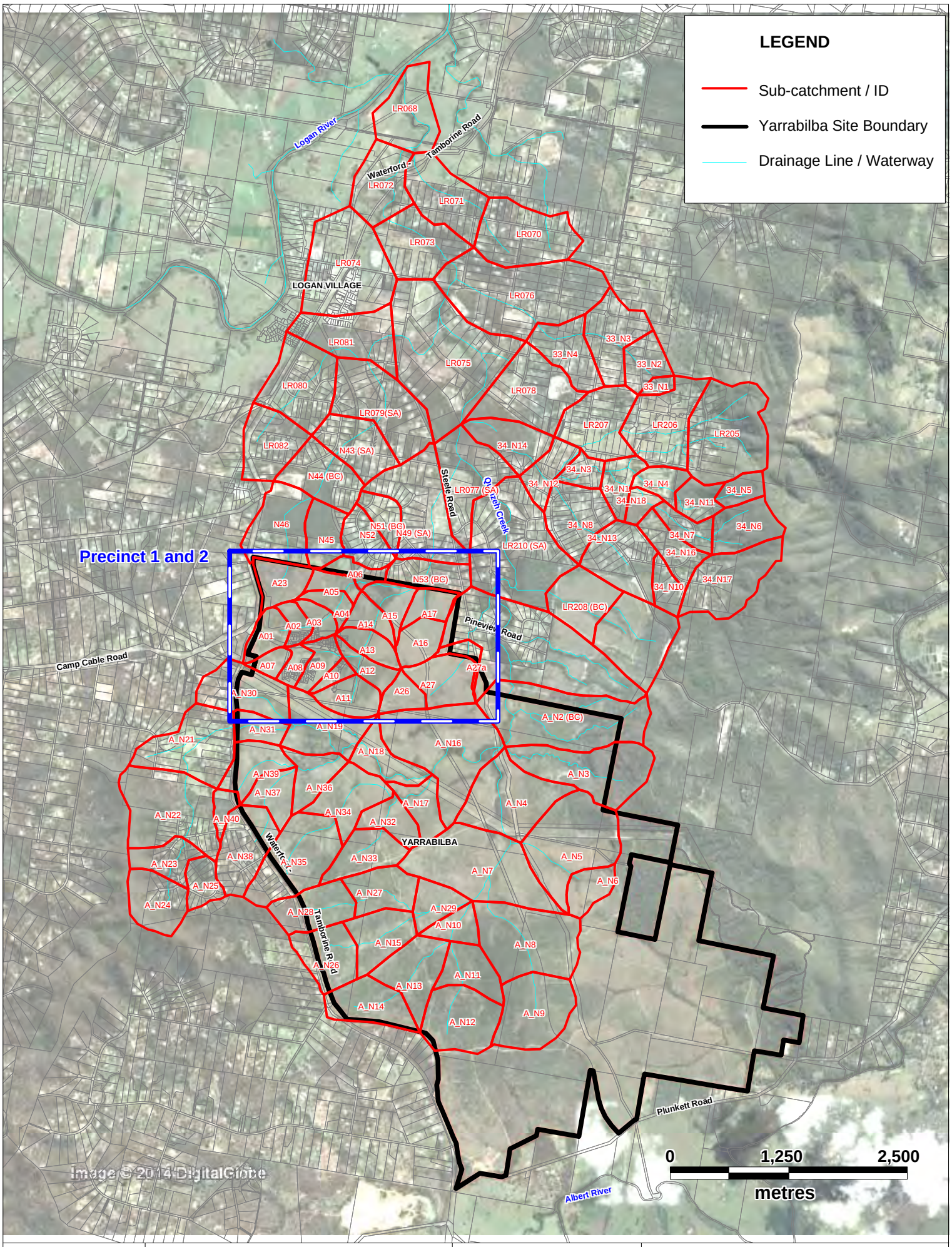
Note: The previous *Yarrabilba P1 and P2 Stormwater Management Plan – Version 2* (DesignFlow, February 2014) adopted hydrologic data generated from XPSWMM for input to the site specific TUFLOW model. This data has now been transferred and updated into the XPRAFTS software to be consistent with Council's modelling and allow merging of the various model zones as described in Section 9.3.3. However, XPSWMM and XPRAFTS adopt the same runoff-routing approach (Laurenson method) and are therefore equivalent.

All catchment parameters presented below apply to the Yarrabilba site based on site specific assessment. These are generally consistent with the Logan City Council model with the main exception being the initial/continuing loss model. However, due to the more detailed hydraulic modelling undertaken by DesignFlow within Yarrabilba, the overall flood results/extent (under existing base case conditions) are broadly consistent with the flooding outcomes of Council's Quinzeh Creek model (refer to validation in Section 9.5.5).

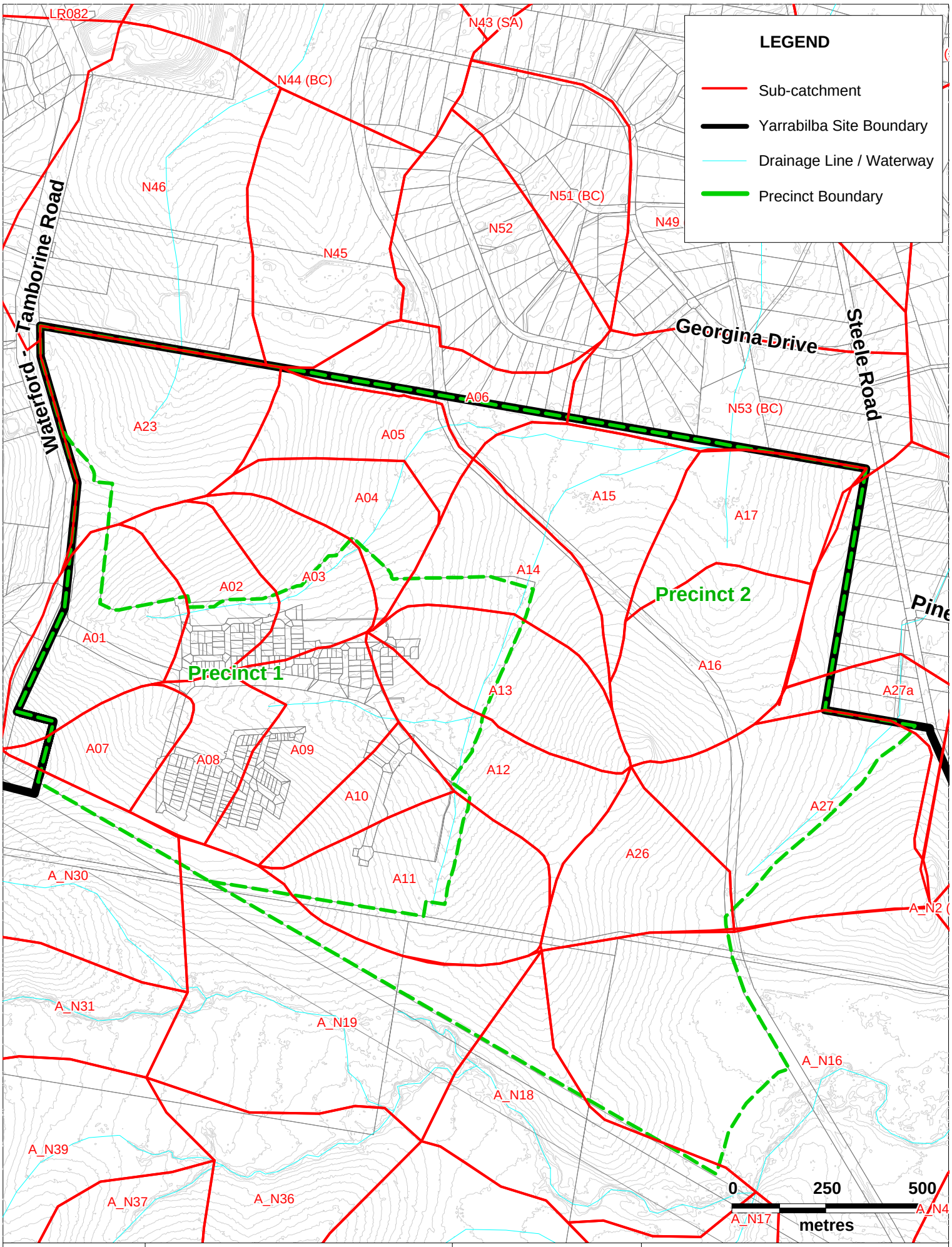
9.4.1 Catchments

Existing (pre-development) catchment delineation within Yarrabilba Precinct 1 and 2 area 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 and drainage design for the development. Where earthworks/drainage was not available at the time of modelling (i.e. for future development), an estimate of post development catchment was generated based on the existing terrain and the land use plan for Precinct 1 and 2.

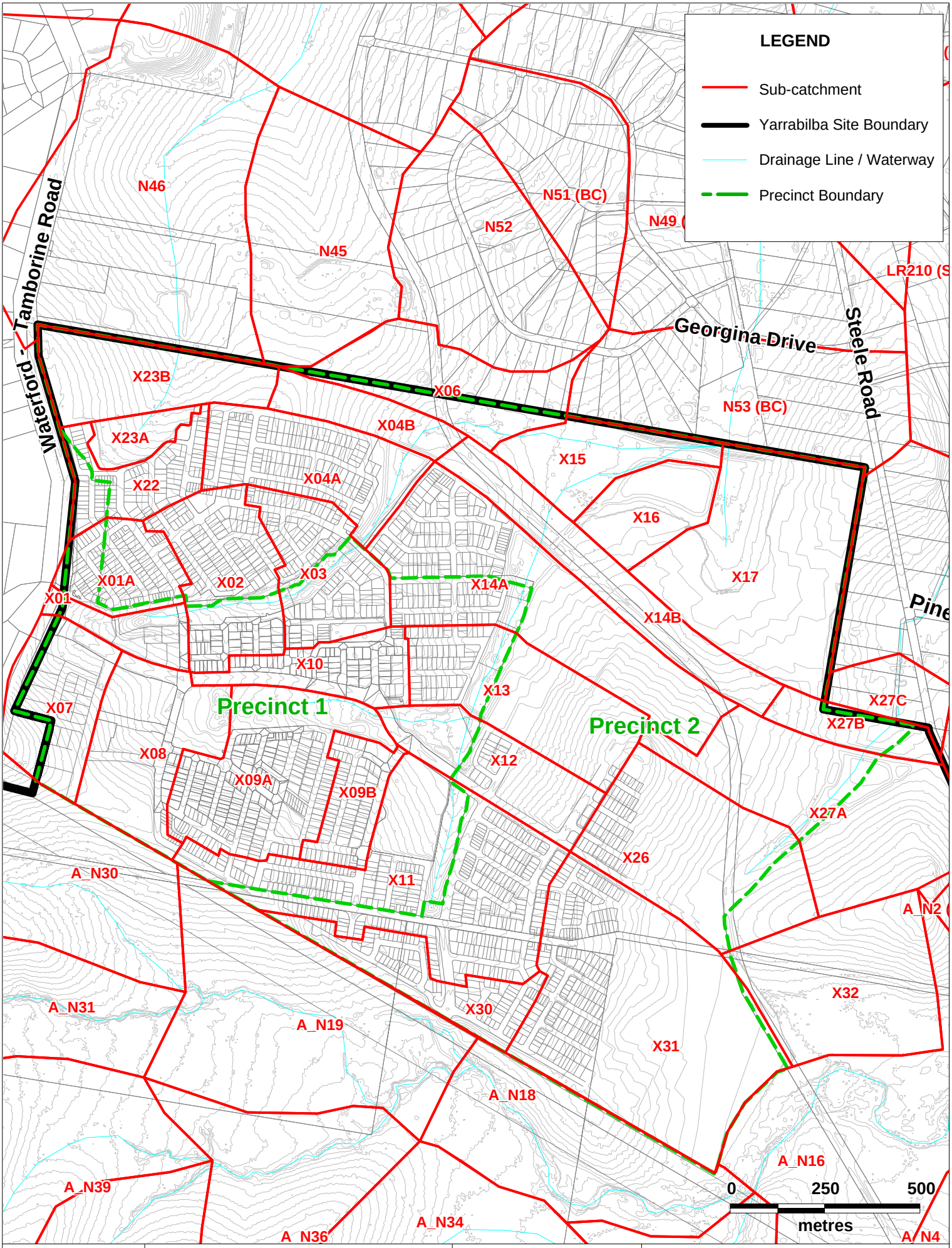
The broader Quinzeh Creek sub-catchment delineation (external to the Yarrabilba P1 and P2 sub-catchments but within Yarrabilba) is based on the WRM/Engeny (Council) hydrologic model as described previously in Section 9.3.3 but with the Yarrabilba catchment parameters applied as per the following sections. The total catchment layout used in XPRAFTS is shown in Figure 21. The updated pre and post development catchment delineation within Yarrabilba precinct 1 and 2 is shown in Figure 22 and Figure 23 respectively. Pre-development catchment data is summarised in Table 19 with post development in Table 20.



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	Scale: 1 : 50,000 (A4)	**FIGURE 21** **Quinzeh Creek Sub-catchments**
	Client: Lend Lease	Date: 21 July 2014	



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	Scale: 1 : 12,500 (A4)	**FIGURE 22** **Precinct 1 and 2** **Pre-development Catchment Plan**
	Client: Lend Lease	Date: 21 July 2014	



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	Scale: 1 : 12,500 (A4)	**FIGURE 23** **Precinct 1 and 2** **Development Catchment Plan**
	Client: Lend Lease	Date: 21 July 2014	

Table 19: Pre-development sub-catchment summary

Catchment	Area (ha)	Slope (%)	Impervious (%)*	Land Use **
A01	17.03	4.2%	0.5%	Ex-plantation/road
A02	10.2	3.3%	0%	Ex-plantation
A03	11.16	2.7%	0%	Ex-plantation
A04	10.8	3.0%	0%	Ex-plantation
A05	10.8	2.8%	0%	Ex-plantation
A06	11.48	1.7%	4%	Ex-plantation/rural res
A07	8.59	5.0%	0%	Ex-plantation
A08	9.35	3.4%	0%	Ex-plantation
A09	15.4	3.8%	0%	Ex-plantation
A10	6.66	5.2%	0%	Ex-plantation
A11	22.17	3.9%	0%	Ex-plantation
A12	14.33	3.4%	0%	Ex-plantation
A13	15.6	3.1%	0%	Ex-plantation
A14	14.32	2.5%	0%	Ex-plantation
A15	16.54	1.4%	0%	Ex-plantation
A16	19.82	3.5%	0%	Ex-plantation
A17	15.18	1.6%	0%	Ex-plantation
A23	22.76	4.0%	0%	Ex-plantation
A26	14.3	3.9%	0%	Ex-plantation
A27	31.23	2.3%	0%	Ex-plantation
A27A	7.219	2.3%	4%	Ex-plantation /rural res
TOTAL	*304.9*			

* 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 20: Post development sub-catchment summary

Notations: Ex = ex-plantation/regrowth, **Rur-res** = Rural residential, **Res** = residential, **Com** = Commercial/ Retail/Industrial, **Sch** = School, **OS** = Open Space, **SIC** = Southern Infrastructure Corridor. Refer to **Table 21**.

Catchment	Area (ha)	Slope (%)	Total Impervious (%)	Predominant Land Use
X01	3.90	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
X06	12.15	1.7%	7%	Rur-res/OS[1]
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	9.90	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]	11.04	3.0%	90%	SIC[1]
X15	7.95	1.0%	2%	OS
X16	6.64	1.5%	67%	Res/OS
X17	24.70	1.5%	42%	Res/OS
X22[3]	6.64	2.0%	60%	Res
X23A	2.84	2.0%	0%	Ex
X23B[2]	10.78	2.0%	0%	Ex
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%	Ex/rur res
X27C	4.60	3.0%	5%	Rur-res
X30	7.71	1.5%	45%	Res/OS
X31	34.10	3.0%	48%	Res/Sch/OS
X32	18.02	1.6%	0%	Ex
TOTAL	*372.9*			

Notes on Table 20:

1. Catchments X4B and X14B do not form part of Lend Leases developable land as they are within the future Southern Infrastructure Corridor (SIC). However, as these areas 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 A_23.

9.4.2 Land Use and Fraction Impervious

All catchments (both pre and post development) were modelled in XPRAFTS 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 in XPRAFTS and enables the rainfall losses and catchment roughness to be appropriately assigned to these parts of the sub-catchment separately. Table 21 summarises the assumptions used for each land use as defined by Table 2.3 in the *Design and Construction Manual* (Beaudesert Shire Council, 1999) which are generally consistent with QUDM (as required by the Draft Logan Planning Scheme).

The existing Yarrabilba site comprises a fully undeveloped catchment (former pine plantation with a mix of open grassland, pine regrowth and scattered native bush) 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 21 below.

Developed case land-use was derived from the Lend Lease Land Use Plan for Precinct 1 and 2 with the relevant land use impervious fraction then applied as Table 21.

Table 21: Land use and impervious fraction

Land Use	Impervious Fraction
Ex-plantation, grassland, bush or regrowth (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.

9.4.3 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 within Precinct 1 and 2. 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 to date (in Precinct 1) have generally reduced slopes in the catchment compared to the pre-development case.

All other sub-catchments within Yarrabilba (outside Precinct 1 and 2) have retained the slope data provided by Council.

9.4.4 Catchment roughness

Catchment roughness was assigned to sub-catchments within the Yarrabilba site based on values provided in Table 22. 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 22: Catchment roughness

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

9.4.5 Bx Parameter

The XPRAFTS Bx parameter is a storage coefficient multiplication factor used to uniformly modify all sub-catchment storage time delay coefficient values to achieve a lumped calibration of catchment outflow peak. In the absence of flow gauging data for this catchment, there is no justification for modifying this parameter and was therefore retained as 1.0 (default).

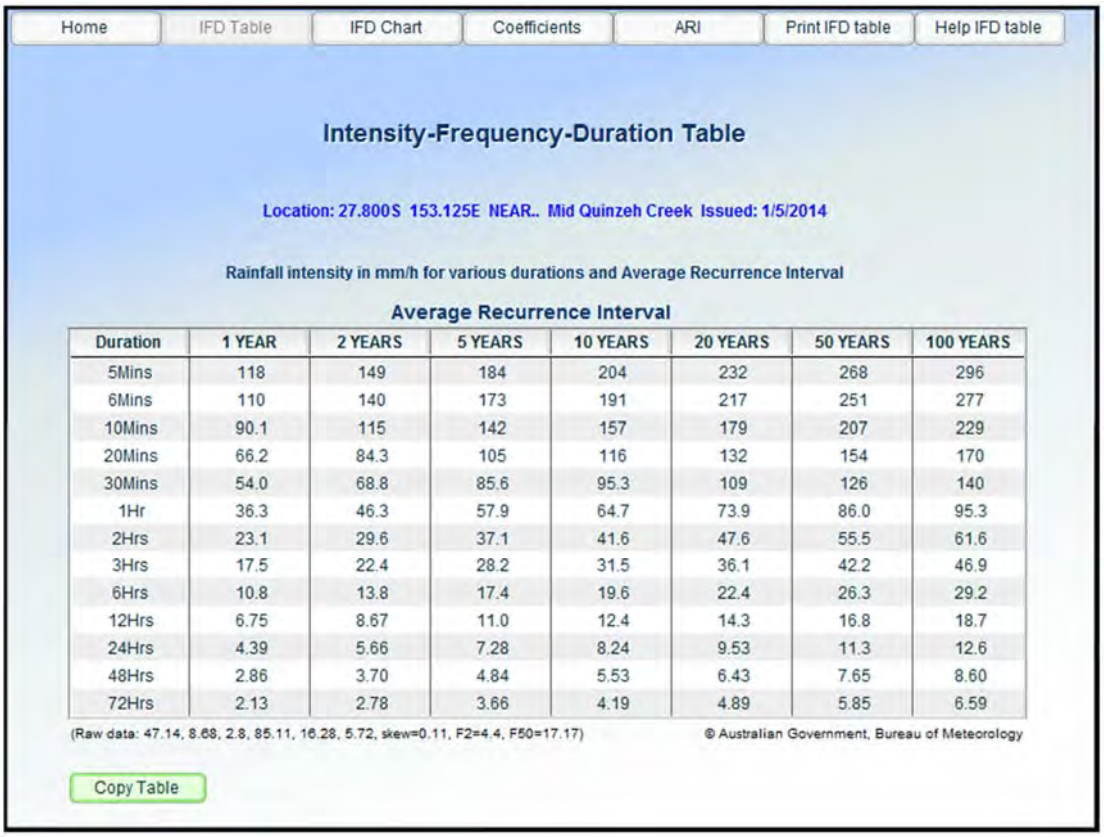
It is recognised that while Council's hydrological model utilised a Bx value of 1.2, this was derived from a verification involving the Rational Method at a single point downstream (refer Section 9.4.9) and not actual gauged flow data. This was therefore considered to insufficiently represent the in stream storage/attention, particularly within areas of the Yarrabilba site.

9.4.6 Rainfall Data

Intensity-Frequency-Duration (IFD) data was sourced from the Bureau of Meteorology website for hydrologic modelling in XPRAFTS and Rational Method check. The IFD data summary and raw data details are provided in Table 23.

The two XPRAFTS models provided by Council (WRM/Engeny) adopted slightly different IFD data between each model. In order to verify a suitable data set for the combined model, the IFD data was obtained from BOM for 3 locations within Quinzeh Creek representing the lower, mid and upper catchment. While rainfall intensities varied by less than 1mm/hr for the major event, this subtle difference can translate to peak flow variations when applied over thousands of hectares. The mid-catchment IFD data was adopted as the most appropriate for the catchment wide assessment.

Table 23: IFD Data Summary



Home | IFD Table | IFD Chart | Coefficients | ARI | Print IFD table | Help IFD table

Intensity-Frequency-Duration Table

Location: 27.800S 153.125E NEAR.. Mid Quinzeh Creek Issued: 1/5/2014

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	118	149	184	204	232	268	296
6Mins	110	140	173	191	217	251	277
10Mins	90.1	115	142	157	179	207	229
20Mins	66.2	84.3	105	116	132	154	170
30Mins	54.0	68.8	85.6	95.3	109	126	140
1Hr	36.3	46.3	57.9	64.7	73.9	86.0	95.3
2Hrs	23.1	29.6	37.1	41.6	47.6	55.5	61.6
3Hrs	17.5	22.4	28.2	31.5	36.1	42.2	46.9
6Hrs	10.8	13.8	17.4	19.6	22.4	26.3	29.2
12Hrs	6.75	8.67	11.0	12.4	14.3	16.8	18.7
24Hrs	4.39	5.66	7.28	8.24	9.53	11.3	12.6
48Hrs	2.86	3.70	4.84	5.53	6.43	7.65	8.60
72Hrs	2.13	2.78	3.66	4.19	4.89	5.85	6.59

(Raw data: 47.14, 8.68, 2.8, 85.11, 16.28, 5.72, skew=0.11, F2=4.4, F50=17.17)

© Australian Government, Bureau of Meteorology

Copy Table

(source: Bureau of Meteorology)

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.

9.4.7 Rainfall Losses

Losses adopted for the Yarrabilba site are provided in Table 24. These have been selected following literature reviews, comparison of peak flows with the Rational Method and in consideration/validation with of the broader Quinzeh Creek Flood Assessment undertaken by Logan City Council.

Table 24: 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	15**	2.5
50 – 100 year ARI	0	2.5
Impervious	1	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 approximately 30mm. Engeny adopted an area weighted average of loss of 38mm for the range of land uses derived by WRM. This loss was retained for areas outside Yarrabilba.

** *Quinzeh Creek Design Discharge Estimate* (WRM, 2013) recommends 19mm initial loss. Site specific review against the Rational Method and the final hydraulic model results concluded that 15mm was more appropriate for the Yarrabilba site. This is still generally consistent 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).

9.4.8 Critical Storm Duration

A range of storm durations were generated in XPRAFTS in order to determine which storm durations were critical for the site and downstream reporting locations (See Figure 28 in Section 9.6). For this analysis, a range of durations were tested from 30 minutes to 12 hours. The longer durations were tested in order to ensure the delayed catchment response time was capture with the introduction of detention basins. Table 25 provides the critical durations down the catchment at reporting locations for the minor (2 year ARI) and major (100 year ARI) event. The critical duration within the development site (post development) for the purpose of maximum flood detention depth was typically between 60 and 120 minutes.

Table 25: Critical duration assessment

Reporting Location		Location	Critical Duration (min)			
			PRE		DEV	
			2 year ARI**	100 year ARI	2 year ARI**	100 year ARI
Site Discharge	4	Upstream of Gerogina Dr	180	90	360	120
	9	Upstream of Steele Rd (at Pineview Rd)	120	90	120	90
	A23	Upstream of Lot 8 RP203663	120	90	120	90
	8	Upstream of Pineview Rd	360	120	360	180
Downstream	14	Quinzeh Ck (adjacent to Ellen Ct)	360	180	360	180
	16	Railway Pde (at Wandearah Rd)	360	90	360	120
	QC87	Quinzeh Ck (Upstream of Millers Rd)	360	180	360	180

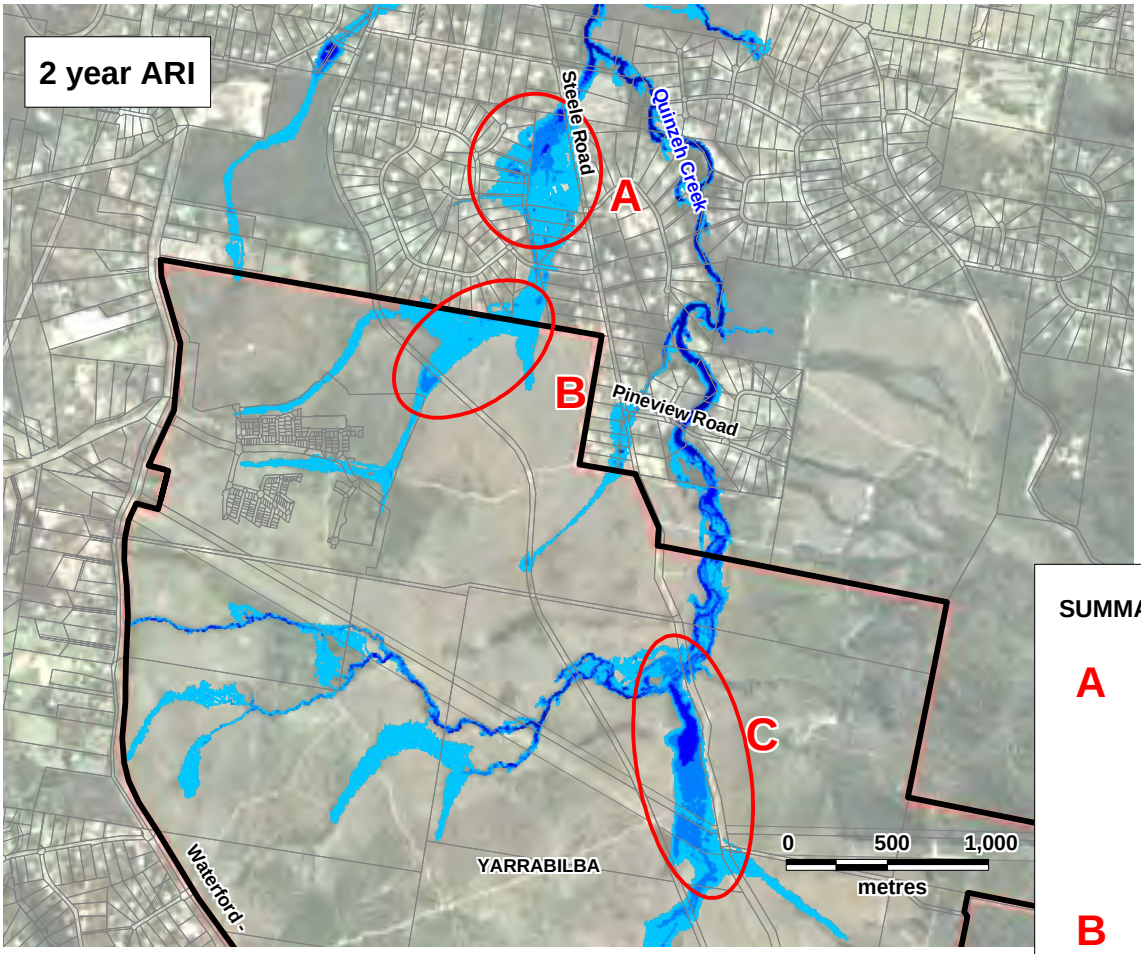
* post-development (DEV) critical duration occurs with flood detention basins in place and/or developed catchment diversion.

** critical duration for minor events is longer due to lower flow and comparatively longer flow time through catchment

9.4.9 Rational Method Comparison

The XPRAFTS modelling for the Yarrabilba site was compared against the peak flows estimated from the Rational Method. This was undertaken for selected catchments within Yarrabilba under the existing and developed (unmitigated) conditions. This enabled a reasonable comparison to the equivalent discharge locations in the XPRAFTS model to validate the catchment parameters selected. No comparison of catchment parameters outside the site was undertaken as these were adopted directly from the Council assessment.

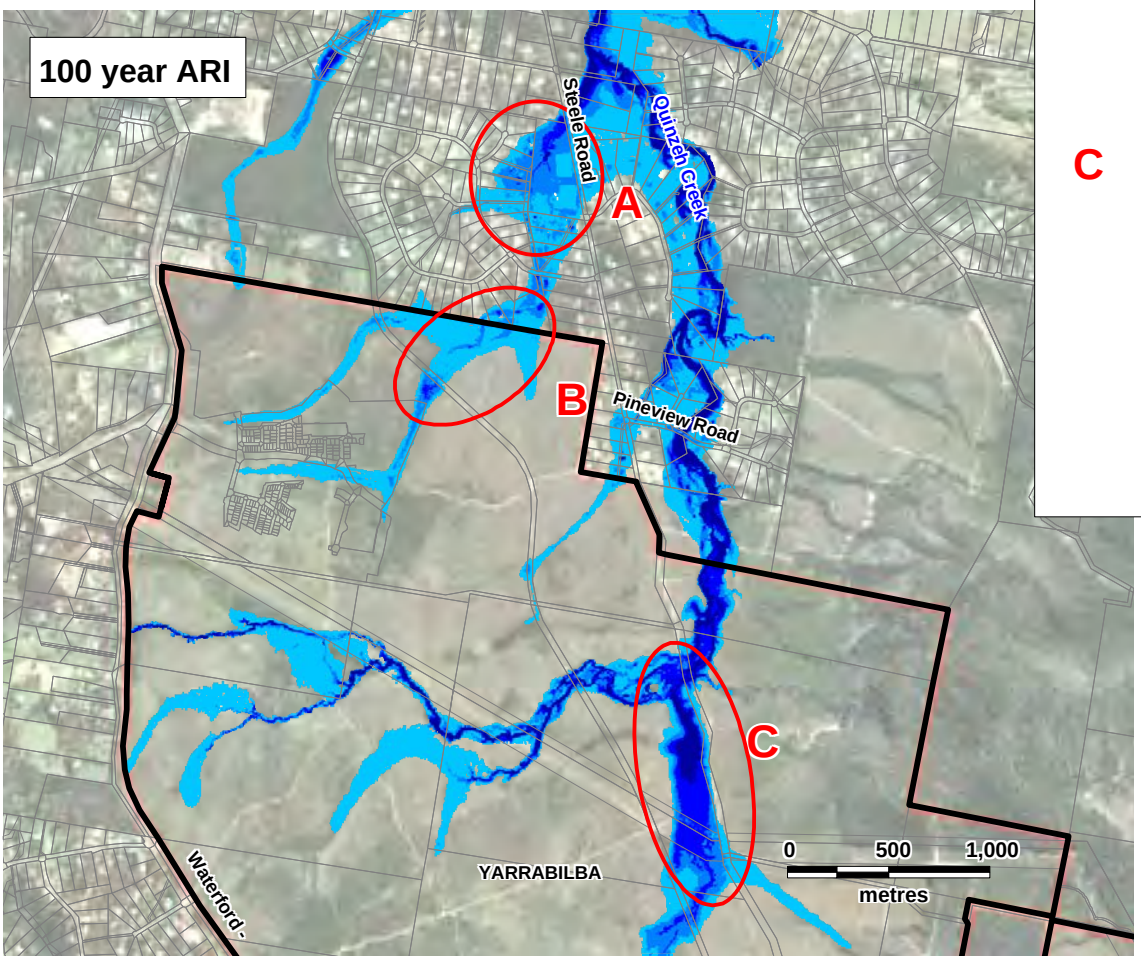
The Rational Method was not applied to the total Yarrabilba site discharge as detailed analysis had identified areas of significant natural attenuation (typically in wetland areas or upstream of existing topographic features such as the disused rail corridor) as shown in Figure 24.



LEGEND

Depth (m)

- < 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- Yarrabilba Site



SUMMARY:

A Attenuation upstream of Steele Road due to under-sized road culverts and broad flat land area. Depths up to 1.0m (2 year ARI) and 1.5m (100 year ARI)

B Ponding pstream of disused rail corridor embankment and in downstream flat zone. Depths up to 1.0m (2 year ARI) and 1.5m (100 year ARI).

C Significant natural attenuation within broad open channel and natural wetland zone in souther tributary. Depths up to 1.5m (2 year ARI) and 2.0m (100 year ARI)

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client: Lend Lease

Scale: 1 : 40,000 (A4) approx.

Date: 21 July 2014

FIGURE 24

Pre-Development Natural Attenuation Zones

The application of the simplistic Rational Method peak flow estimate is not suitable for catchments with areas of significant detention or significant variation in the degree of in-stream storage where accurate peak flow is required for validation against runoff-routing models. Doing so can lead to derivation of artificially high catchment parameters (e.g. initial/continuing loss, roughness, etc) to compensate for the inability of the Rational Method to account for natural detention/attenuation. When coupled with a detailed hydraulic model such as TUFLOW, poorly validated catchment hydrological parameters can be subsequently re-routed through the actual terrain, essentially causing double routing of flows (this is a significant concern with the Council approach to the Quinzeh Creek discharge estimation, and the use of these derived parameters for the detailed hydraulic model by Engeny at a more local sub-catchment scale).

While simple channel link routing was included in the XPRAFTS model (using channel cross section, length and slope) for comparison of local catchment peak flows (for single and multiple catchments), no reliance on this was made when looking at broader Yarrabilba site discharge (i.e. with the influence of natural detention areas). Instead, XPRAFTS individual catchment discharges were routed hydraulically through the TUFLOW model (2d domain) which is considered preferable when a higher degree of accuracy in flood flow behaviour is required.

The results for the 2 and 100 year ARI Rational Method comparison are summarised below. Details of the comparison locations and all events are provided in Appendix A.

Table 26: Pre-development Rational Method comparison to XPRAFTS

Comparison Location	Peak Flow (m^3/s)			
	2 year ARI		100 year ARI	
	Rational Method	XPRAFTS	Rational Method	XPRAFTS
A01	1.40	0.87	4.67	3.77
A05	3.52	2.85	12.50	12.28
A09	2.27	1.75	7.37	7.68
A14	5.74	5.10	20.99	22.00
A16	1.35	0.94	4.38	3.96
A_N32	3.09	2.10	10.47	8.88
A_N10	21.53	16.63	73.13	69.01
A_N5	4.76	3.78	16.28	15.90
A_N3	2.76	2.61	11.10	11.05

Generally, the Rational Method is over-estimating peak pre-development flows for the minor events and with relatively close agreement of the major events. While it appears that the XPRAFTS initial losses could be reduced further to obtain better agreement the

Rational Method estimates, no further reductions were undertaken in consideration of Councils high initial loss assumptions for the flood mapping in the downstream catchment. As the XPRAFTS model provides a more accurate rainfall-runoff estimation, no further modification to the minor event parameters was undertaken as the Rational Method peak flows were considered to provide satisfactory agreement for the purpose of this comparison.

Table 27: Post-development (unmitigated) Rational Method comparison to XPRAFTS

Comparison Location	Peak Flow (m^3/s)			
	2 year ARI		100 year ARI	
	Rational Method	XPRAFTS	Rational Method	XPRAFTS
X01	3.66	5.75	10.36	12.38
X04A	8.18	11.17	24.27	27.74
X12	10.04	15.02	29.78	35.69
X14A	12.88	17.30	39.82	45.16
X26	3.51	4.55	9.95	10.47
X30	1.37	1.40	3.87	3.29

Under the developed (unmitigated) scenario, the Rational Method is (in most catchments) slightly underestimating the minor and major peak discharge. The final values adopted (refer to Table 24 previously) were considered conservative limits for the site and as the post development hydrological parameters define flood detention requirements, further reduction in the XPRAFTS peak flows through parameter manipulation was not pursued.

It is noted that application of the XPRAFTS 'Bx' factor greater than 1.0 (as discussed in Section 9.4.1) may uniformly reduce the peak flow across all sub-catchments in XPRAFTS to achieve better overall agreement with the Rational Method estimates. However in absence of accurate flow gauging data, there is no justification for modifying this parameter and was therefore retained as 1.0 (default).

The XPRAFTS model can therefore be seen to show satisfactory agreement with the Rational Method and will generally result in a conservative approach to pre versus post development flood attenuation requirements.

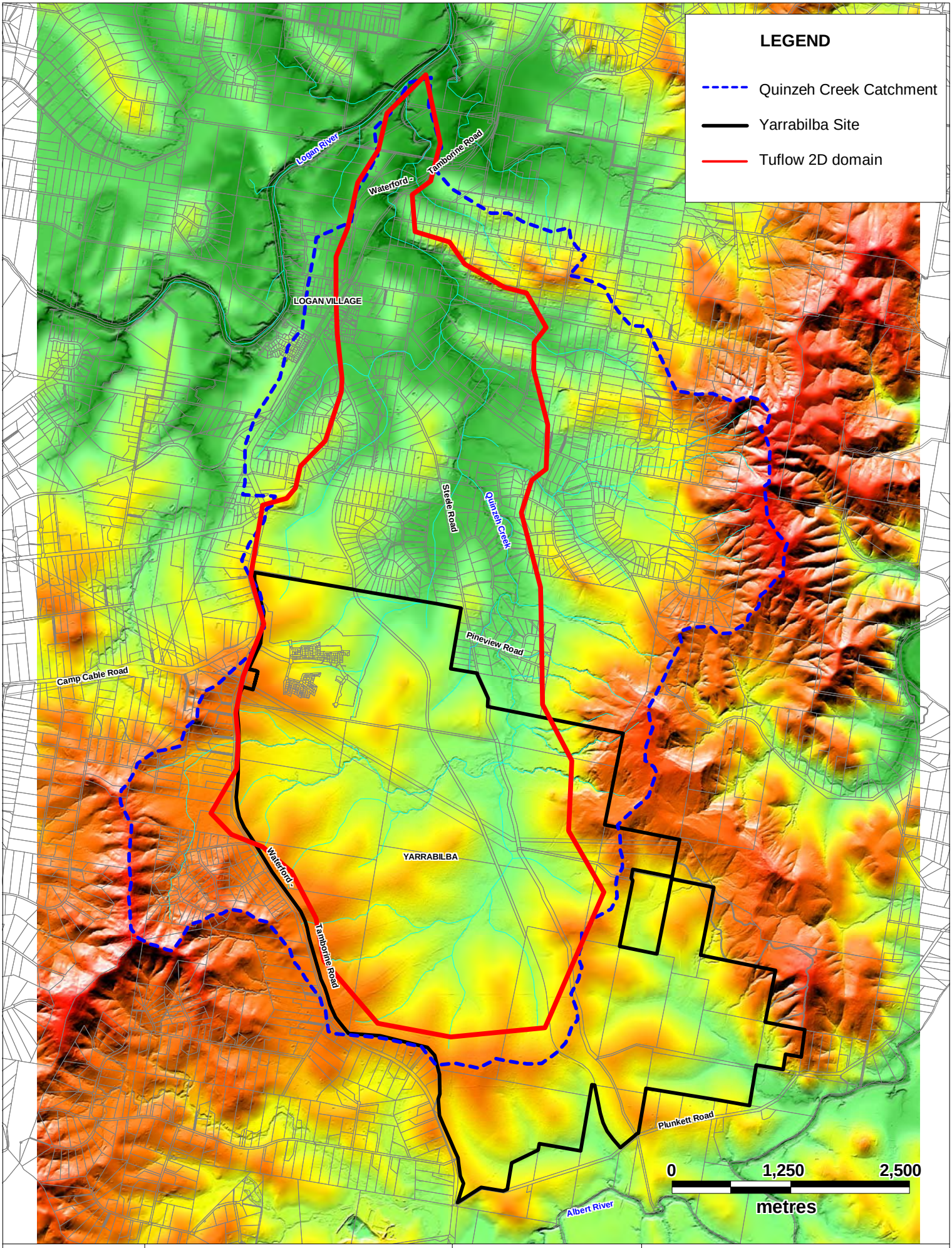
9.5 HYDRAULICS

Hydraulic assessment of the site and downstream Quinzeh Creek was undertaken using TUFLOW (1D/2D linked hydrodynamic model) to determine the flood inundation under existing and developed site conditions as discussed in Section 9.3. The current TUFLOW model represents an update since the previous *Precinct 1 and 2 Stormwater Management Plan – Version 2* (DesignFlow, 2014) to include the downstream Quinzeh Creek catchment and broader Yarrabilba site (in addition to the previous Precinct 1 and 2 extent). As noted previously, the hydraulic model downstream of the Yarrabilba site boundary has been merged and expanded from Council's hydrologic and hydraulic models provided (refer to Section 9.3.3). The discussion below therefore refers primarily to the development of the Yarrabilba component of the broader Quinzeh Creek hydraulic model. For details of the downstream model, refer to the *Revised Quinzeh Creek Flood Study* (Engeny, August 2013) and Quinzeh Creek Design Discharge Estimation (WRM, September 2013)

9.5.1 Model Terrain and Extent

The pre-development model is based on the Aerial Laser Survey data (supplied by RPS) merged with Councils' existing digital elevation model (DEM) for Quinzeh Creek. Overlapping areas of the two DEMs were compared for consistency, and it was found that the two DEMs aligned very well in the vertical plane, and there was no significant elevation offset between the datasets.

Development earthworks models (from KN Group) were superimposed over the natural terrain model to create the post-development DEM which includes batters and road crossings as they impact on the drainage lines through the site. Additional earthworks design DEMs were prepared by DesignFlow for the proposed stormwater treatment measures (predominantly bioretention basins, sediment ponds and wetlands) and overlaid on the developed case DEM to ensure accurate representation of the stage-storage relationship at propose detention basins. The hydraulic boundary and terrain model for the expanded TUFLOW model is shown in Figure 25.



DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client: Lend Lease

N W E S

Scale: 1 : 50,000 (A4)

Date: 21 July 2014

FIGURE 25

Tuflow Model Terrain and Extent

9.5.2 Roughness

An estimate of the roughness through the main overland and open channel flow paths in Yarrabilba was undertaken using the Modified Cowan method and compared with photographic examples in Appendix C of the *Natural Channel Design Guidelines* (BCC, 2003). Assignment of vegetation groups across the drainage lines was undertaken from review of aerial photography and on-ground visual inspection/verification of the various reaches. The Manning's n values in Table 28 have been derived for the range of open channel conditions observed onsite and applied to the TUFLOW model.

Table 28: Manning's roughness

Description	Manning's n
Roads and impervious surfaces	0.015
Maintained open space (pervious areas)	0.035
Cleared plantation/grassland with sparse regrowth, rural residential and unmaintained light vegetation/scattered trees	0.050
As above with higher density of saplings and light undergrowth with scattered mature trees	0.060
Native, healthy undergrowth, low to moderate density trees and some natural debris. Typically broad, shallow flow path profile	0.070
Moderately vegetated/wooded main waterway	0.080
Heavily vegetated/wooded main waterway	0.100

For the purpose of XPRAFTS comparison with the Rational Method (Section 9.4.9 previously), the natural channels were represented by 1D links with typical cross sections and slopes derived directly from the DEM. Roughness values were applied to each reach in accordance with the Manning's used on the TUFLOW model. Beyond the validation locations, the XPRAFTS routing was not relied on for peak flow assessment as full hydraulic routing was undertaken in TUFLOW.

9.5.3 Hydraulic Structures

Hydraulic structures are modelled in TUFLOW as 1D structures embedded within the 2D model domain. The existing structures identified in Table 29 downstream of Yarrabilba were provided directly from Logan City Council or were already included in the TUFLOW model received (by Engeny). These are assumed to have been surveyed or verified as part of Councils flood study so no further field assessment was undertaken.

Table 29: Existing cross road drainage downstream of site (1D structures)

ID	Location	Type and Size (mm dia or m)	Length (m)	US : DS Invert (m AHD)
16	Georgina Dr (west)	4 x 1.2 x 0.6 RCBC	18.1	17.08 : 16.99
20	Steele Rd (south of Wandearah Rd)	300 dia RCP	10.2	15.59 : 15.52
21	Georgina Dr (east)	7 x 900 dia RCP	20.6	16.60 : 16.45
Culvert1A Culvert1B	Pineview Road (east)	3 x 1.8 x 3.6 RCBC 1 x 3.7 x 2.04 RCBC	19.0	19.10 : 18.98
Culvert2	Steele Rd (south)	3 x 375 dia RCP	17.6	20.85 : 20.77
Culvert3	Pineview Rd (west)	5 x 1.2 x 0.6 RCBC	18.5	19.97 : 19.87
184	Quinzeh Creek Rd	4.25 x 1.2	4.25	unknown
185	Steele Rd (north)	1.65 x unknown	9.9	13.82 : 13.72
45	Waterford – Tamborine Rd	2 x 1.5 x unknown	18.5	5.96 : 5.86

Additional structures in the lower portions of Quinzeh Creek were provided by Council on 3 June 2014 and understood to form part of the broader Logan-Albert River flood model. These structures are bridge type waterway crossings and are represented as 2D structures in TUFLOW. Details of these are provided in Table 30.

Table 30: Existing cross road drainage downstream of site (2D structures)

Location	Obvert (mAHD)	Deck Height (m)	Rail Height (m)
Miller Rd	10.14	0.50	1.01
Railway Line -Quinzeh Creek	10.97	1.03	-
Railway Line – Waterford – Tamborine Rd	11.27	1.03	-
Waterford – Tamborine Rd	8.38	0.7	1.10

All proposed structures within Yarrabilba (as either cross road culverts and/or detention basin outlets) were derived from the discharge control requirements for flood detention basins and/or the conveyance of flows under roads. The hydraulic performance of these structures in TUFLOW has been verified against the XP-SWMM 1D hydraulic model used in Version 2 of the SMP to allow rapid testing of configurations

ultimately used in the TUFLOW model. The details of these structures are discussed further in Section 9.6.3.

9.5.4 Boundary Conditions

Boundary conditions have been applied to the TUFLOW models in a number of ways to account for both downstream discharge conditions as well and upstream inflows.

Tailwater

Quinzeh Creek discharges directly into the Logan River approximately 7 km downstream from the northern site boundary of Yarrabilba. Under regional Logan River flooding (100 year ARI), the backwater impact extends up Quinzeh Creek around 4.5km from the downstream confluence (to just north of Ellen Court). This indicates that peak flood levels in the lower half of Quinzeh Creek are dominated by the Logan River and not from the local Quinzeh Creek flooding. The regional flood is dominated by a significantly longer duration critical storm event (72 hours) compared to Quinzeh Creek (6 hours). It is therefore practical to expect that the Quinzeh Creek flood peak would occur well before the regional flood peak (assuming catchment wide rainfall).

For the purpose of this assessment, the comparative assessment of pre and post development peak flows and flood levels (for the full range of ARIs) has assumed no Logan River flooding and adopted a normal flow discharge slope at the downstream boundary of the model. This provides sufficient offset from any boundary conditions (particularly in minor flood events) that will impact the flood assessment focussed on the Yarrabilba site discharge tributaries and the confluence of these in the main channel of Quinzeh Creek.

Inflows

Inflows to the TUFLOW model were derived from XPRAFTS model described previously. Within the TUFLOW model boundary, inflow hydrographs are applied as source/area inputs to the low end of each sub-catchment to introduce local discharge into the 2D domain of the hydraulic model. For sub-catchments (and tributaries) outside the TUFLOW boundary (i.e. where detailed assessment is not required), XPRAFTS hydrographs are applied as a boundary inflow (across a line) to the edge of the 2D domain. Hydraulic routing and accumulation of sub-catchment inflow hydrographs thus occurred progressively down the catchment/channel.

9.5.5 Model Validation

The existing case model was run with the data from the January 2013 flood event (contained within Engeny's XPRAFTS model) in order to validate the merged catchment hydraulic model with Council's TUFLOW model. The rainfall and temporal pattern global database was extracted from the Engeny XPRAFTS model and imported into the merged Yarrabilba XPRAFTS model described in Section 9.3.3. The output from XPRAFTS was then run through the expanded TUFLOW model to undertake the flood level validation. A comparison of surveyed and modelled flood levels from the January 2013 event at key locations is provided in Table 31. Comparison to Councils current Quinzeh Creek Flood model for properties of interest for both the January 2013 event and the 100 year ARI design event are provided in Table 32. These locations are taken from the *Revised Quinzeh Creek Flood Study* (Engeny, 2013).

NOTE: The Engeny results are based on the assumption of the main Pineview Road culverts being 10% blocked during the calibration event. No specific justification was provided for this assumption (nor any additional allowance for potential partial of full blockage of the guard rail that exists on both road edges in this location), and no other culverts in the model have any blockage factor applied. This isolated blockage factor has therefore been excluded from the DesignFlow (2014) model and the results can therefore be expected to be marginally lower than the Engeny results.

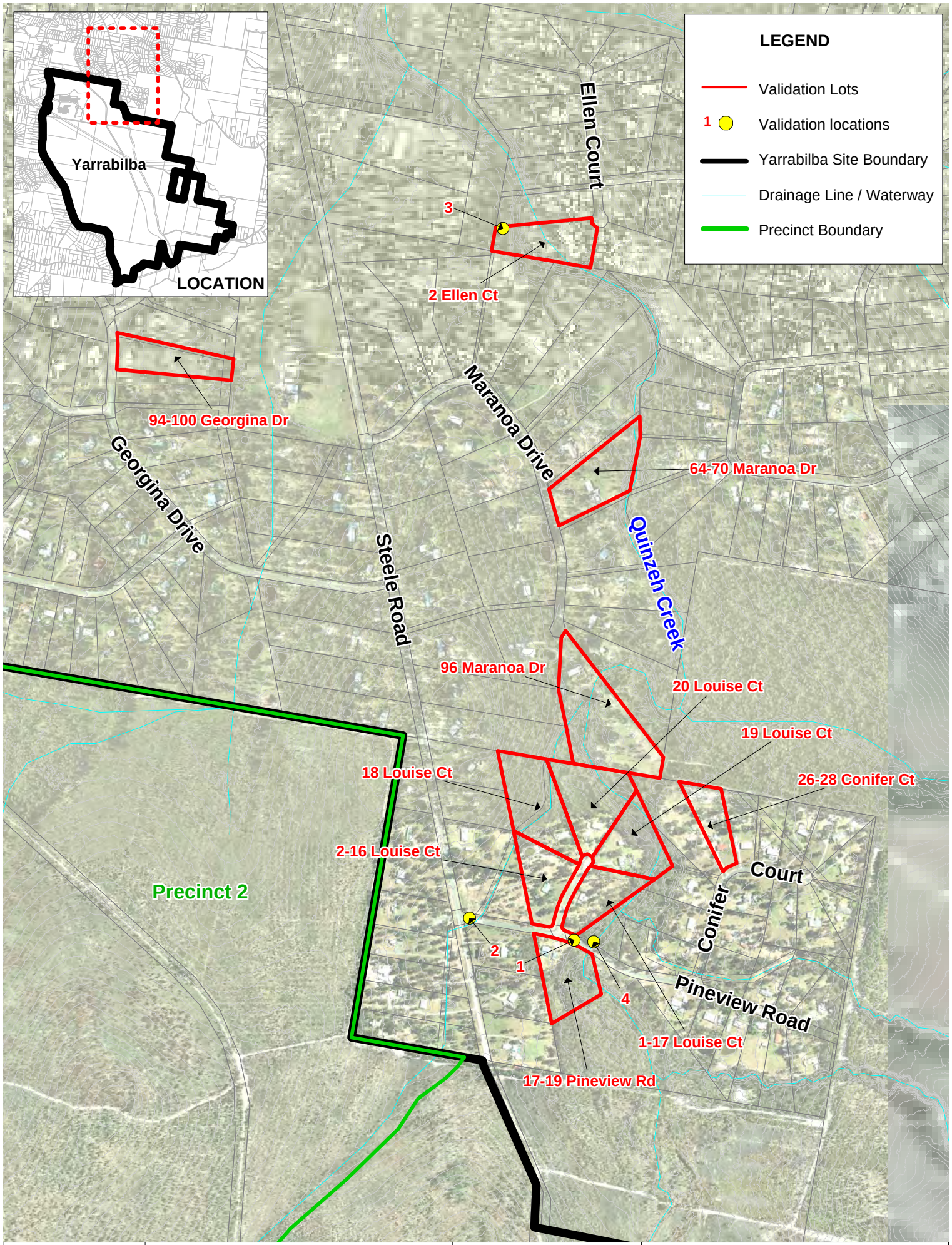
Table 31: Surveyed vs modelled flood level for January 2103 event

Location	Surveyed Flood Level* (mAHD)	Modelled Flood Level (mAHD)	
		Engeny (2013)	DesignFlow (2014)
1. Pineview Road/ Louise Court	21.63	21.63	21.57
2. Pineview Road/ Steele Road	21.19	21.19	21.15
3. Ellen Court	16.38	16.45	16.43**
4. Pineview Road (Dowsntream side of culvert)	21.62	21.50 ***	21.57 ***

* Surveyed flood levels understood to be based on water marks and/or flood debris measured some weeks after the flood event and therefore subject to some uncertainty. The localised effects of solid objects such as trees, railings and poles can impact the location and level of these indicators within the environment.

** DesignFlow flood extent is 5m from this reporting point (i.e. does not overlap this point) with almost equivalent level so minor discrepancy can be expected within the 3m grid size being modelled.

*** Reporting point 4 appears to be on the road which has a ground level of Approx. RL21.50 (i.e. not downstream of culvert as stated). Therefore Engeny flood level may be from very shallow 'wet' cell in TUFLOW. DesignFlow flood level is from nearest flood level on the upstream side of road.



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	Scale: 1 : 10,000 (A4)	**FIGURE 26** **Tuflow Model Validation Locations**
	Client: Lend Lease	Date: 21 July 2014	

Table 32: Peak flood level results at properties

Location	January 2013 Event Flood Level (mAHD)		100 year ARI (pre-development) Flood Level (mAHD)	
	Engeny (2013)	DesignFlow (2014)	Engeny (2013)	DesignFlow (2014)
20 Louise Ct	20.54	20.51	21.26	21.27
19 Louise Ct	20.78	20.75	21.44	21.45
18 Louise Ct	20.20	20.17	21.49	21.49
2-16 Louise Ct	20.97**	20.26**	22.17	22.20
1-17 Louise Ct	21.24	21.21	22.22	22.23
26-28 Conifer Ct	-	-	21.01	21.00
2 Ellen Ct	16.62	16.61	17.25	17.25
17-19 Pineview Rd	21.87	21.82	22.58	22.60
37 Maloo Ct	17.63	17.64	17.75	17.77
94-100 Georgina Dr	16.36	16.39	16.51	16.61
91-93 Culgoa Ct	-	-	-	25.59
96 Maranoa Dr	20.33	20.30	20.95	20.95
64-70 Maranoa Dr	18.05	18.00	18.91	18.91

* The Engeny January 2013 event was modelled with 10% blockage on the main culverts only with no justification provided. The DesignFlow (2014) results have adopted a consistent approach of zero blockage to all culverts for the purpose of comparative modelling as no justification could be found for the isolated blockage allowance at one culvert crossing.

** The Engeny level applies to mid-way along the western boundary of the lot where modelled flood extent only marginally crosses the lot boundary . The DesignFlow results have the flood extent just outside the lot boundary (by approx. 5m), with the flood level recording being in the very northern corner of the lot. Therefore these results are not in the same locatio but the flood extents are within acceptable model tolerance.

Hydraulic Validation Discussion

Based on the flood levels in Tables 31 and 32, the detailed Yarrabilba flood model (forming the upper part of the expanded Quinzeh Creek flood model) provides comparable results for both the January 2013 event and the 100 year ARI design event at the key locations of interest identified in the *Revised Quinzeh Creek Flood Study* (Engeny, 2013). This provides justification for the higher level of detail in terms of defining the site specific hydrological parameters for Yarrabilba which are important for detailed assessment of flood mitigation measures.

The major difference between the Engeny TUFLOW model and the current Yarrabilba model is that the discharge from the original Engeny XPRAFTS model representing the majority of the Yarrabilba site was input as a boundary condition at approximately 500m upstream of the validation location. Thus, the inflow hydrograph is derived from hydrological routing in XPRAFTS only which does not sufficiently account for the natural attenuation occurring within the site upstream (and was not specifically validated against any other peak flow assumption other than the WRM discharge estimation much further downstream). Thus, the higher loss values adopted by Council for the Yarrabilba site and the overall adoption of the storage coefficient multiplication factor (Bx) of 1.2 appear to be offsetting the lack of accounting for natural attenuation occurring within the broad drainage lines and natural wetland zones.

The expanded model however, utilises discharge with full hydraulic routing in TUFLOW for flows generated within Yarrabilba and considered more accurate representation of the catchment discharge.

Further, the peak flood levels derived from the current Yarrabilba – Quinzeh Creek model at the subject location occur from the 120 minute critical duration storm event whereas Engeny has adopted a 180 minute critical duration for flood mapping. A review and re-run of the original Engeny XPRAFTS model indicates that the 120 minute event results in a greater peak flow through this zone. In this instance, the increased flood level may require re-calibration of the hydrological parameters to provide a better fit to the surveyed flood levels. It is recommended that Council review this aspect of their current detailed flood model to ensure accuracy.

NOTE: There are a number of key locations within or just downstream of the Yarrabilba site where flood attenuation occurs within the natural topography as discussed previously in Section 9.4.9 and Figure 24 as part of the hydrological comparison to the Rational Method. The most critical of these for the hydraulic model validation locations near Pineview Road is the natural attenuation area B in Figure 24. This area causes the flood gradient from the southernmost catchment of Yarrabilba to flatten significantly, filling a wide flat drainage line and wetland, with discharge from this area constricted by the topography around the confluence with the western catchment drainage line. This natural attenuation influences the existing case site discharge from Yarrabilba and should be considered in the hydrological parameterisation of the site and downstream catchment.

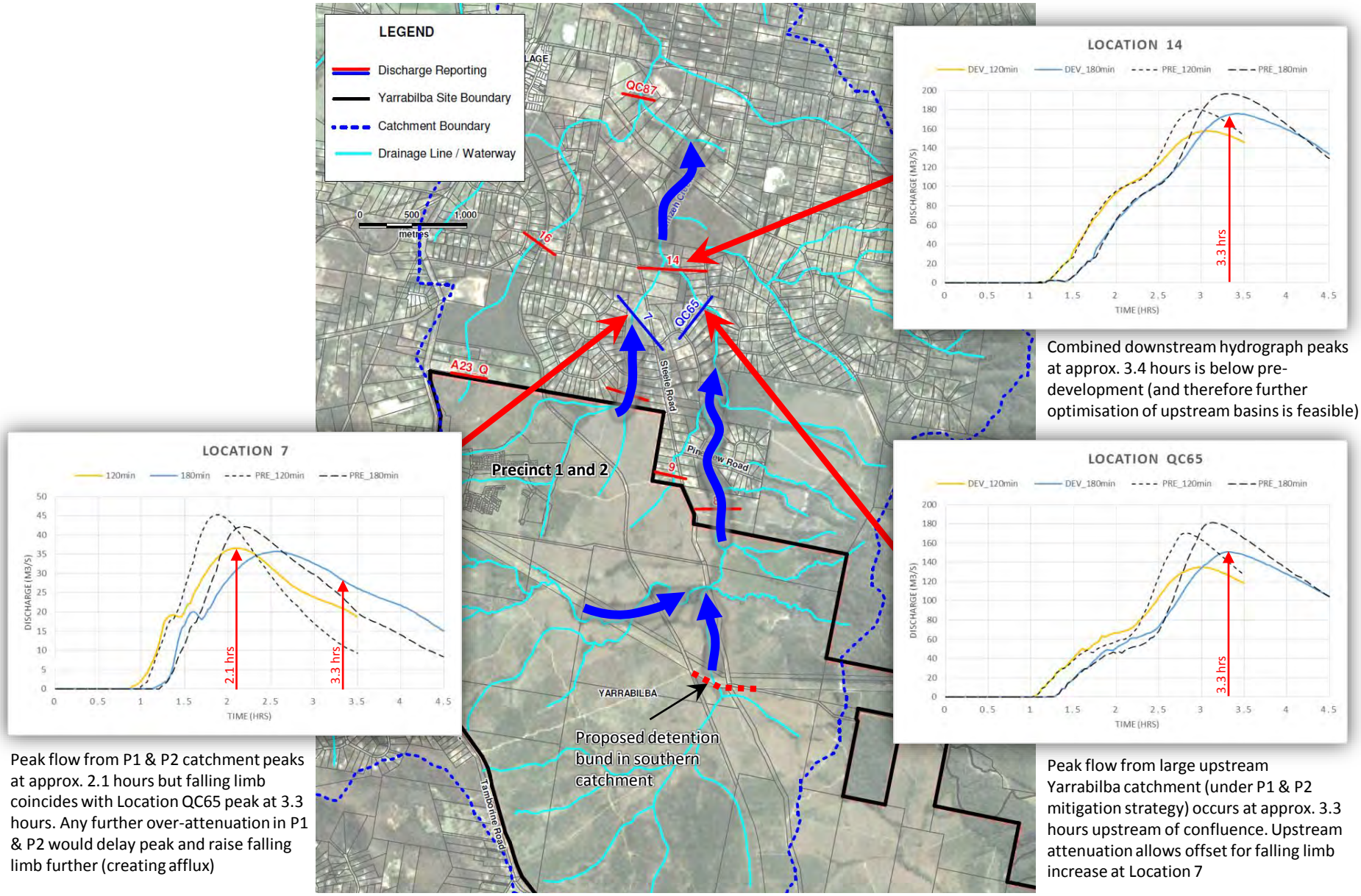
9.5.6 Hydrograph Timing in Upper Quinzeh Creek

One of the critical factors determined from this flooding assessment is the significance of discharge from Precinct 1 and 2 (at location 4 in Figure 28) and the resultant critical timing of this tributary in the context of the larger and undeveloped (at this stage) catchment to the south. It was determined form the detailed investigations across the Yarrabilba site and downstream tributaries that flood detention within Precinct 1 and 2 (to protect properties immediately downstream) resulted in a flood hydrograph falling

limb that combined with the largely undeveloped catchment to the south to result in minor afflux. As the issue was occurring on the falling limb of the local tributary hydrograph (from location 4), increasing detention upstream simply prolonged the falling limb coincidence effect and any reduction in detention meant adverse impacts to the properties immediately downstream (refer to Figure 27). Management of this coincidence issue was therefore targeted towards the upstream (undeveloped) catchment.

In a similar manner (but much smaller scale and flows), the previous *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2* (DesignFlow, February 2014) nominated two interim flood basins (former flood basins 10 and 11) on the southern extent of Precinct 2 to manage local increases in development runoff (until larger regional flood basins were in place as part of future development precincts). These two basins were also found to detain and delay peak discharge from Precinct 2 development such that it coincided adversely with the undeveloped catchment to the south.

The approach adopted to address this issue is to include a flood detention bund in the southern catchment to detain the undeveloped flood peak upstream and reduce the coincidence issue further downstream. This bund (referred to as Flood Fut-1) will ultimately form part of the future development flood mitigation but provides a solution (and flexibility) in the short to medium term to manage the complex hydrograph timing issues associated with progressive large scale development such as Yarrabilba spanning multiple sub-catchments and tributaries. Figure 27 provides a summary of the mitigation strategy in terms of the hydrograph timing in the two main tributaries from Yarrabilba. Discussion of the timing of detention basin construction is provided in Section 9.6.4.



Combined downstream hydrograph peaks at approx. 3.4 hours is below pre-development (and therefore further optimisation of upstream basins is feasible)

Peak flow from P1 & P2 catchment peaks at approx. 2.1 hours but falling limb coincides with Location QC65 peak at 3.3 hours. Any further over-attenuation in P1 & P2 would delay peak and raise falling limb further (creating afflux)

Peak flow from large upstream Yarrabilba catchment (under P1 & P2 mitigation strategy) occurs at approx. 3.3 hours upstream of confluence. Upstream attenuation allows offset for falling limb increase at Location 7

Figure 24: Hydrograph Timing Assessment

9.6 RESULTS

The expanded Yarrabilba – Quinzeh Creek TUFLOW model was run for a range of flood events and durations to estimate the flood discharge and inundation at a number of key locations at the site boundary as well as in the downstream catchment. Flow reporting locations are identified in Figure 28 and results from the pre and post development scenarios presented and discussed below.

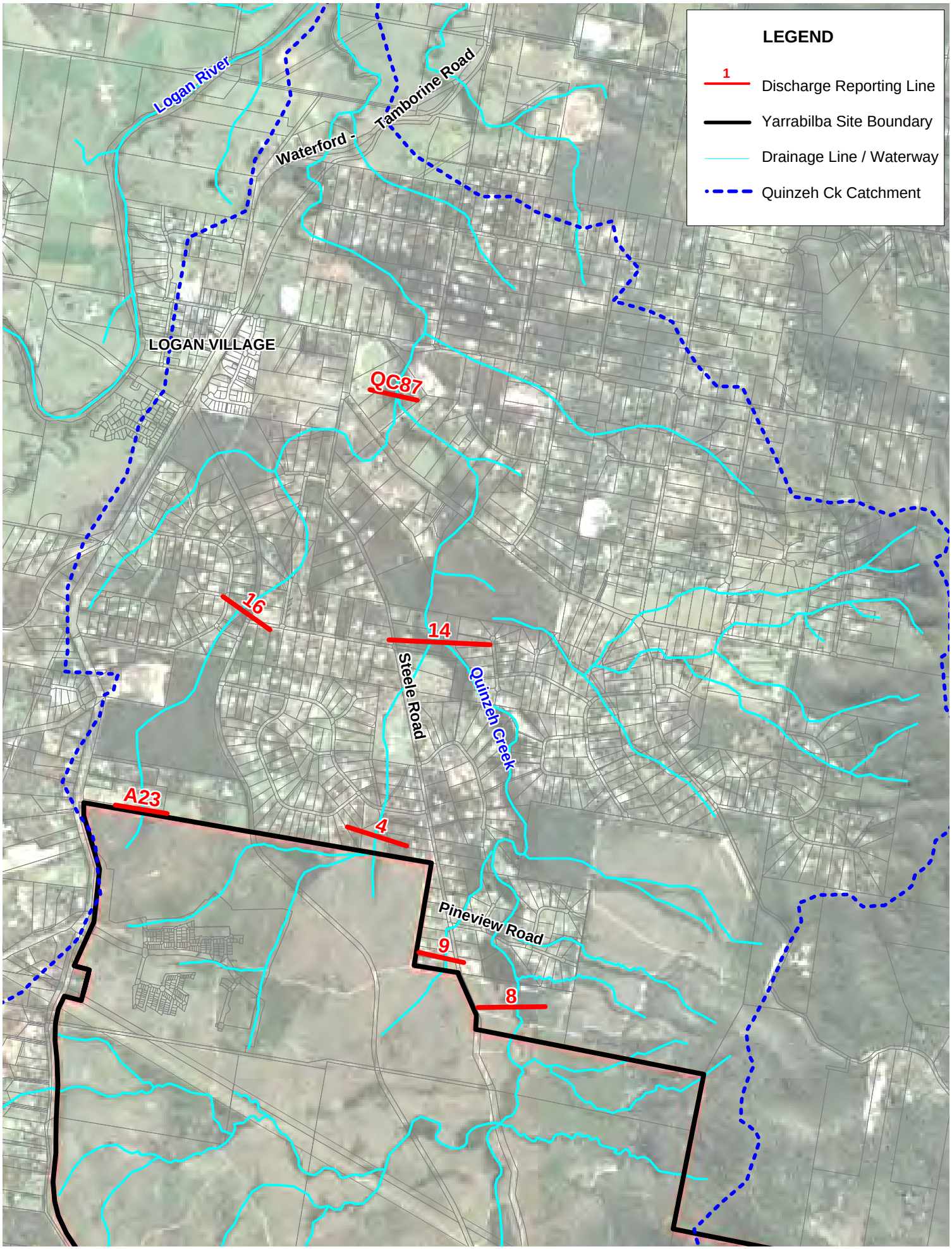
9.6.1 Summary

The results from the TUFLOW modelling are provided in Appendix B with the relevant flood maps in Appendix C. Tables 33 to 35 below provide summary results for the 2 and 100 year ARI events for key reporting locations downstream of the site. Results for locations within Precinct 1 and 2 (specifically detention basins) are discussed further in Section 9.6.3. Results pertaining to the 1 year ARI event for waterway stability assessment are addressed in Section 8.

Table 33: Peak discharge results

Location	Discharge m^3/s					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	9.65	6.91	-2.74	42.26	29.52	-12.74
9	1.81	1.09	-0.72	7.89	6.64	-1.25
A23	1.09	0.58	-0.51	4.67	2.57	-2.1
8	41.73	39.42	-2.31	169.14	134.03	-35.11 *
14	50.08	49.76	-0.32	196.31	175.7	-20.61 *
16	3.92	3.35	-0.57	20.26	17.51	-2.75
QC87	60.93	60.04	-0.89	251.74	229.46	-22.28 *

* Note that the large reductions in peak flow have resulted from a conservative approach to flood hydrograph timing management in the upstream (undeveloped) catchment in Yarrabilba as discussed in Section9.6.2. This strategy is subject to optimisation as part of detailed flood assessment and design.



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A4)	**FIGURE 28** **Quinzeh Creek Flow Reporting Locations**
	Client: Lend Lease	Date: 21 July 2014	

Table 34: Peak water Level results

Location	Water Level (mAHD)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	19.62	19.59	-0.03	20.65	20.37	-0.28
9	22.96	22.90	-0.07	23.09	23.07	-0.03
A23	37.60	37.59	-0.02	37.67	37.64	-0.03
8	22.80	22.78	-0.01	23.64	23.50	-0.14
14	15.35	15.33	-0.02	16.57	16.49	-0.08
16	20.21	20.19	-0.02	20.58	20.55	-0.03
QC87	11.04	11.03	-0.01	12.31	12.21	-0.10

Table 35: Peak velocity results

Location	Velocity (m/s)					
	2 year ARI			100 year ARI		
ID	PRE	DEV	Change	PRE	DEV	Change
4	0.59	0.58	-0.01	1.01	0.78	-0.22
9	0.51	0.44	-0.08	0.96	0.86	-0.10
A23	0.86	0.70	-0.16	1.27	1.08	-0.19
8	1.67	1.63	-0.05	1.78	1.72	-0.06
14	0.95	0.90	-0.05	1.57	1.45	-0.12
16	1.26	1.19	-0.08	1.75	1.75	0.01
QC87	1.57	1.57	0.00	1.42	1.44	0.02

9.6.2 Flood Mitigation Strategy

Due to the complex nature of the Yarrabilba site hydrology involving site discharge to multiple tributaries which in turn discharge at varying distances downstream into Quinzeh Creek, a flood mitigation strategy has been resolved for Precinct 1 and 2 that ensures:

(a) Protection of properties immediately downstream of the site (in tributaries) from increase in flooding impact

(b) Consideration of tributary discharge hydrograph timing impact (with main creek) to confirm no increase in flooding downstream of confluences while

recognizing that upstream catchments (in Yarrabilba) will continue to undergo development (and therefore hydrological modification) over time.

To achieve these outcomes, the following broad strategy components have been adopted for Precinct 1 and 2 (as identified previously in Section 9.2).

1. Flood detention basins throughout Precinct 1 and 2 formed upstream of road crossings or dedicated bunds

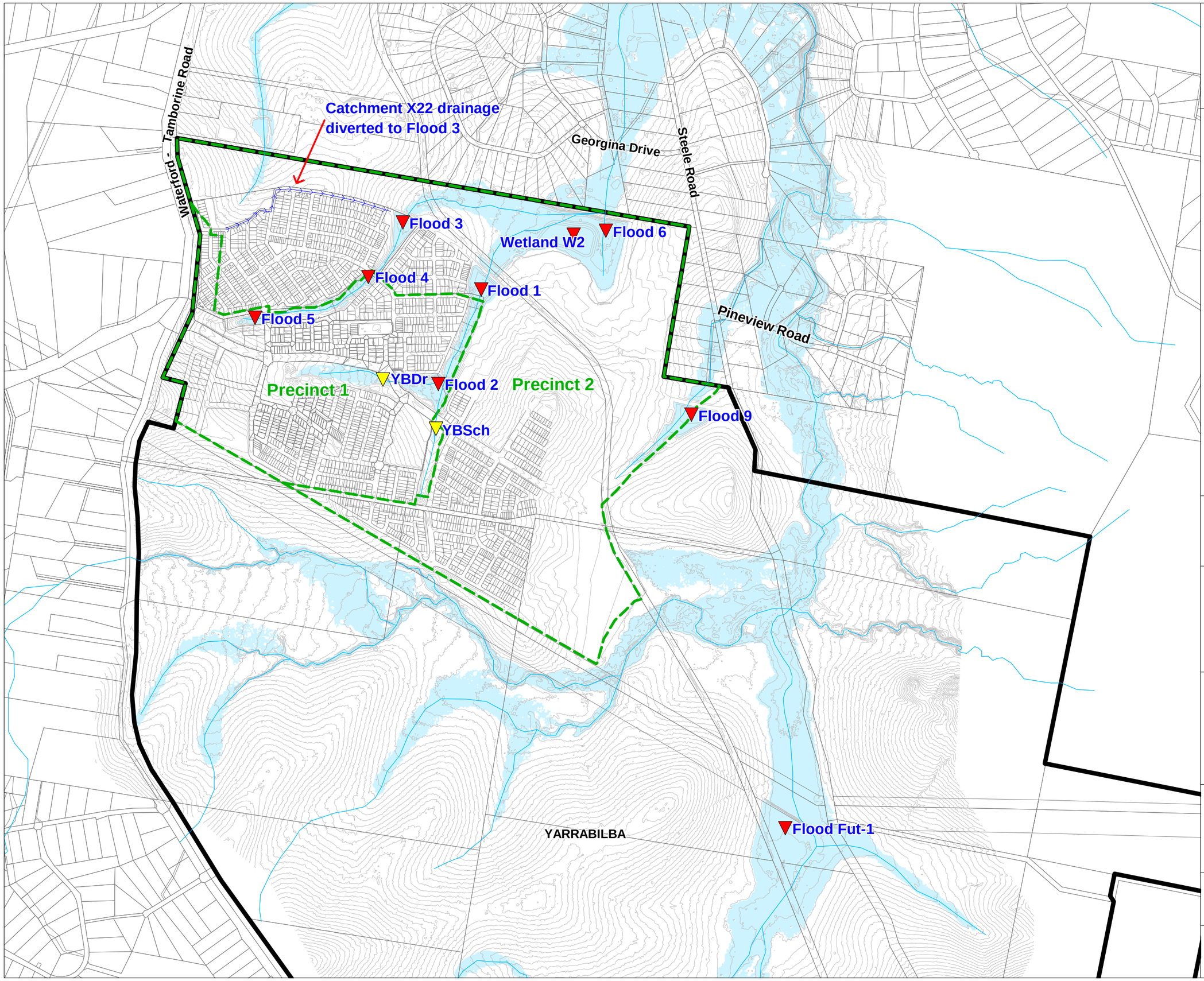
2. Diversion of developed catchment stormwater drainage where detention cannot feasibly be implemented

3. Provision of an upstream flood detention bund within the future development zone of Yarrabilba to manage flood peak timing (coincidence) with downstream detained flows in tributaries.

The location of these measures are shown in Figure 29.

9.6.3 Detention Basin Details

Flood attenuation is achieved via a number detention basins created upstream of road crossings or dedicated detention bunds across drainage lines. Discharge from detention basins is controlled by a range of outlet structures including pits, pipes, culverts and/or weirs. The location of these basins is shown in Figure 29 and briefly described in Table 36. The two locations italics (YBDr and YBSch) while not forming part of the formal detention basin network (as there is minimal detention volume upstream), are included in the hydraulic reporting as they are cross road culverts and influence the flow conveyance through the site. As discussed in the previous section, the flood detention bund (identified as 'Flood Fut-1') in the southern undeveloped catchment aims to control the coincident hydrograph timing issue that occurs downstream of the site at the confluence of Quinzeh Creek and the Precinct 1 and 2 tributaries. A brief description of each basin is provided in Table 36. A discussion on the timing of Flood Fut-1 construction is provided in Section 9.6.4.



DesignFlow

LEGEND

- Detention Basin
- Culvert (no formal detention)
- Yarrabilba Site Boundary
- Drainage Line / Waterway
- Precinct Boundary

Scale:
1 : 15,000 (A3)

FIGURE 29

Flood Mitigation Strategy Elements

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease

Table 36: Flood detention basin descriptions

Location	Description
Flood 1	Formed by bund upstream of future SIC in Catchment 2. Low flow pipes drain to Wetland W2, high flow outlets directly downstream to channel adjacent to Wetland W2 and ultimately to Flood 6 detention basin.
Flood 2	Formed upstream of a purpose built bund across waterway (already constructed) with low flow pipes and high flow weir.
Flood 3	Formed by bund upstream of future SIC in the northern waterway in Catchment 2. Discharges via pipe and weir to downstream vegetation zone and subsequently into Flood 6.
Flood 4	Upstream of Summerview Avenue road embankment across northern waterway in Catchment 2. Discharge via pipes under road.
Flood 5	Above bioretention basin B4a surface and upstream of Highland Street road embankment at the upper end of the northern waterway in Catchment 2. Discharge control via 2 stage pit.
Wetland W2	Primarily for water quality management. Receives low flow discharge from Flood 1 and acts as a perched flood basin within Flood 6 zone to provide attenuation for very minor flows. Weir overflow and flow balancing occurs to Flood 6 under high flows (and becomes inundated).
Flood 6	Formed by a proposed bund along northern site boundary to manage flows from Catchment 2. Targets management of minor flow discharge downstream (while the balance of the flood basins are targeting the major flows upstream in the catchment) Integrates Wetland W2 internal to the area. Discharge via multiple pits and pipes with high flow weirs.
Flood 9	Formed by bund upstream of future SIC in Catchment 3. Manages part of future Precinct 3 catchment to the east also.
Flood Fut-1	Formed by bund across the natural drainage line upstream of the power line easement/corridor. Discharge via pipes and high flow weir. Refinement of the design will occur as part of detailed design of development stages as well as assessment of the fully developed (ultimate) Yarrabilba site strategy.
YBDr	*Yarrabilba Drive cross road culverts in central waterway in Catchment 2. No significant flood detention occurs upstream of these culverts but included in hydraulic reporting.*
YBSch	*Yarrabilba Drive cross road culverts adjacent to proposed school in Catchment 2. No significant flood detention occurs upstream of these culverts but included in hydraulic reporting.*

Details of discharge control structures for the detention basins identified in Table 36 are provided in Table 37.

Table 37: Precinct 1 and 2 hydraulic structures

Name	ID	Type/Size	Level (mAHD)		
			Crest	USIL	DSIL
Flood 1	FL1_Lo	3 x 825 mm RCP	-	24.50	24.35
	FL1_Pit	10 m x 2.5 m pit	26.30	24.00	-
	FL1_Hi	4 x 1200 mm RCP	-	24.00	23.91
	FL1_Weir	25 m weir	26.90	-	-
Flood 2	FL2_Lo	4 x 1200 mm RCP	-	28.05	28.01
	FL2_Weir	20 m weir	29.85	29.85	-
Flood 3	FL3_Lo	3 x 1200 mm RCP	-	28.60	**28.45**
	FL3_Weir	20 m weir	31.00	-	-
Flood 4	FL4	3 x 1200 mm RCP	-	32.82	32.64
Flood 5*	FL5_Lo	0.9 m x 1.2 m pit	43.30	41.30	-
	FL5_Hi	1.5 m x 1.2 m pit	43.80	41.30	-
	FL5_pipe	1 x 1200 mm RCP	-	41.30	41.00
Wetland W2	W2_Lo	300 mm dia (in pit wall)	-	21.00	
	W2_Pit	3.0 m x 2.0 m pit	21.50	20.80	-
	W2_Pipe	2 x 900 mm RCP	-	20.80	20.60
	W2_Weir	20m weir	22.25	-	-
Flood 6	FL6_Lo_A	1200 x 900 mm RCBC (into pit)	-	20.27	20.26
(outlet A)	FL6_Pit_A	8 m x 2 m	22.30	20.26	-
	FL6_Pipe_A	3 x 1050 mm RCP	-	20.26	20.20
	FL6_Weir_A	50m weir	**23.00**		
(outlet B)	FL6_Lo_B	1200 x 900 mm RCBC (into pit)	-	20.27	20.26
Identical to A except	FL6_Pit_B	8 m x 2 m	22.30	20.26	
for weir length	FL6_Pipe_B	3 x 1050 mm RCP	-	20.26	20.20
	FL6_Weir_B	20m weir	**23.00**		-
Flood 9	FL9_Lo	600 mm RCP (into pit)	-	24.40	24.39
	FL9_Pit	2.5m x 1.5m pit	26.30	24.39	-
	FL9_Hi	2 x 825 mm RCP	-	24.39	24.24
	FL9_Weir	10m weir			
Flood Fut-1**	FLfut1_Pipe	10 x 1050 mm dia RCP	-	25.5	25.3
	FLFut1_Weir	50m weir	27.5	-	-
YB Dr Culverts	YBDr_out	3 x 2400 x 750 mm RCBC	-	32.01	31.91
YB School Culverts	YBSch_out	3 x 2700 x 600 mm RCBC	-	30.05	29.75

RCP = Reinforce concrete pipe (no. x diameter),

RCBC = reinforced concrete box culvert (no. x width x height)

* Flood 5 outlet structure comprises a two stage pit with a single discharge pipe. Combined pit modelled in TUFLOW with inlet rating curve.

** Flood Fut-1 is a nominal concept design at this stage to provide confirmation that sufficient flood storage and discharge control can be achieved in the upstream undeveloped catchment. Refinement of this outlet design is required as part of detailed design of Precinct 1 and 2 as well as assessment of the total Yarrabilba site strategy.

Table 38: Detention basin peak water levels

Location	Peak Water Level (mAHD)							Bund/ Road
ARI ->	1	2	5	10	20	50	100	(mAHD)
Flood 1	26.13	26.47	26.62	26.70	26.79	27.02	27.14	27.50
Flood 2	29.05	29.37	29.71	29.87	30.02	30.24	30.33	30.65
Flood 3	29.83	30.31	30.61	30.77	30.98	31.19	31.25	31.60
Flood 4	33.92	34.31	34.60	34.78	35.01	35.43	35.58	36.40
Flood 5	43.82	44.02	44.18	44.28	44.43	44.70	44.87	44.90
Flood 6	21.96	22.39	22.56	22.65	22.77	23.07	23.19	23.50
Wetland W2	22.30	22.46	22.57	22.65	22.77	23.06	23.18	22.50*
Flood 9	25.91	26.26	26.49	26.58	26.68	26.87	26.95	27.50
Flood Fut-1	26.32	26.66	27.07	27.29	27.56	27.77	27.89	28.20
YBDr **	*33.45*	*33.56*	*33.63*	*33.68*	*33.73*	*33.81*	*33.84*	*34.25*
YBSch **	*30.50*	*30.75*	*30.84*	*30.94*	*31.13*	*31.54*	*31.71*	*34.65*

* Wetland lies within flood Basin 6 and is inundated during flood detention.

** Yarrabilba Drive culverts not formally part of the flood detention strategy but upstream flood levels provided for clarity.

9.6.4 Detention Basin Depth Risk

As shown in Table 39 flood detention (specifically Flood 1) storage depths of up to 3.2 metres exist under 100 year ARI flood conditions. It should be noted however, that this maximum depth occurs in very localised depressions within the existing ephemeral wetland that exist within Flood Basin 1 and the majority of the flood basin is less than 3.0m depth in 100 year ARI.

Logan City Council requires detention basins to be designed in accordance with QUDM (2013) with regard to public safety. Specifically, it is desirable (where suitable land is available) to maintain flooded depths to 1.2m for the 1 in 20 AEP and greater if possible. However, (as QUDM states), '*in cases where this is neither practical nor economical, and the provision of a detention basin is considered to be better on safety grounds than other alternatives, greater depths may be acceptable. Notwithstanding this, designers are responsible for investigating the overall safety risks associated with the basin, design of the basin and the surrounding landscape in a manner that minimises safety risks and satisfying any safety requirements specified by the local government.*'

Table 39: Detention basin depth

Location	Maximum Depth (m)	
	20 year ARI	100 year ARI
Flood 1	2.81*	3.16*
Flood 2	2.31	2.62
Flood 3	2.12	2.39
Flood 4	2.20	2.77
Flood 5	1.43	1.87
Flood 6	2.48	2.89
Wetland W2	1.77	2.18
Flood 9	2.28	2.55
Flood Fut-1	2.31	2.65

* maximum depths occur in localised depressions within the existing ephemeral wetland in this Flood 1 zone. Localised depressions are up to 0.5m deep at centre of basin.

Given the topography of the Yarrabilba site and the conservative approach to hydrologic modelling (i.e. high initial loss for pre-development scenario vs zero initial loss for post developed), it is neither practical nor economical to achieve the 1.2m depth.

In order to quantify the areas onsite that exceed the preferred depth of 1.2m, Appendix D provides mapping of these areas for both the 20 year and 100 year ARI events. To manage safety risk in these areas the following has been adopted for design around the detention basins:

- 1 in 6 batters used where flood depths in are greater than 1.2m
- system will be planted out with vegetation and trees to discourage access
- warning signage provided
- depth indicators to be installed.
- Areas with slopes steeper than 1 in 4 will require steps and a handrail to assist egress (however this is an undesirable outcome and will be designed to meet dot point 1 as far as practical)

(Note: Fencing is not recommended by QUDM unless the flood risk is extreme)

There will be no passive or active recreation proposed 'within' in the low areas of flood detention basins that will be subject to flood depths greater than 1.2m or will have a velocity depth product (Vxd) greater than 0.6m²/s.

Detailed design of all flood detention zones will also be undertaken to ensure that safety is maintained under non-design operating conditions. Specifically, high level outlets, discharge weirs or road crossings (where applicable) will be designed to ensure that under 100% blockages of low level outlets and/or 50% blockage of screened road culverts (in accordance with QUDM) under the major design storm, the velocity x depth product of overflows at these locations does not exceed 0.6 m^2/s (see Section 9.6.8). Where this can't be achieved, public access must be restricted in accordance with QUDM.

9.6.5 Detention Basin Construction Timing

Flood detention basins have been and will continue to be constructed progressively throughout the catchment to match the rollout of development. Flood Basins 2, 4 and 5 have already been constructed and functioning as part of Precinct 1 development in the upper catchment.

As Precinct 2 development proceeds, flood basins 1, 3 and 6 will be constructed in conjunction with the civil earthworks and increase the flood mitigation capacity of the site to cater for the expanding impervious areas. Flood Basin 9 will be constructed when the portion of Precinct 2 in Catchment 3 proceeds. However, the full functioning capacity of this basin will not be engaged until Precinct 3 development proceeds in the eastern portion of the catchment.

The upstream flood basin (Flood Fut-1) will be constructed at such time as the area of development in Catchments 2 and 3 (refer Figure 19) reaches a critical threshold where the discharge from Flood basin 6 results in the commencement of the falling limb hydrograph coincidence issue discussed in Section 9.6.2. There is scope in the short to medium term to provide interim outlet structures (i.e. partially block the ultimate structure) on flood basins 1, 3 and 6 to 'throttle' the partially developed catchment flows to mitigate downstream impacts. However, prior to the critical development threshold in Catchment 2 being reached, the upstream flood bund Fut-1 will be required. This is subject to the schedule and spatial roll-out of stages (i.e. which flood basins would need to be throttled). A detailed assessment of this timing will be undertaken as part of the ongoing detailed design of development stages and stormwater infrastructure.

9.6.6 Outlet Stabilisation

Consideration of the outlet velocity from detention basin discharge control structures is important to ensure significant scour at and downstream of the outlet headwall does not occur. QUDM (Section 8.7 and 10.4.15) recommends scour protection with rock aprons on single and multiple pipe/culverts outlets based on the outlet velocity. Table 40 provides an overview of the peak outlet velocity expected at each of the major outlets or cross road culverts under the 100 year ARI event with the minimum recommended scour protection.

Each outlet will be assessed further as part of detailed design to ensure the final configuration and flow conditions are adequately addressed by scour protection. However, the information below indicates that all outlets are within the acceptable

range of outlet scour protection with rock aprons, and is provided to ensure the flood mitigation strategy does not create major potential for scour downstream of flood basins.

It should be noted that the velocities indicated are exit velocities which are subject to significant reduction a short distance downstream due to energy dissipation and flow spreading. In reality (as QUDM notes), it is likely that there will be some degree of soil erosion/scour downstream under high flow conditions, however scour protection can greatly reduce the severity of this.

Table 40: Outlet velocity and scour protection

Location	ID	Type/Size	100 year ARI Outlet Velocity (m/s)	Minimum Scour Protection (see notes below)
Flood 1	FL1_Lo	3 x 825 mm RCP	3.9	d_{50} = 500 mm, L_{min} = 6.0 m
	FL1_Hi	4 x 1200 mm RCP	4.0	d_{50} = 500 mm, L_{min} = 6.0 m
Flood 2	FL2_Lo	4 x 1200 mm RCP	3.6	d_{50} = 400 mm, L_{min} = 4.8 m
Flood 3	FL3_Lo	3 x 1200 mm RCP	3.8	d_{50} = 400 mm, L_{min} = 4.8 m
Flood 4	FL4	3 x 1200 mm RCP	3.7	d_{50} = 400 mm, L_{min} = 4.8 m
Flood 5	FL5_pipe	1 x 1200 mm RCP	3.9	d_{50} = 400 mm, L_{min} = 4.8 m
Wetland W2	W2_Pipe	2 x 900 mm RCP	2.4	d_{50} = 200 mm, L_{min} = 2.7 m
Flood 6				
outlet A	FL6_Pipe_A	3 x 1050 mm RCP	4.3	d_{50} = 500 mm, L_{min} = 5.3 m
outlet B	FL6_Pipe_B	3 x 1050 mm RCP	4.6	d_{50} = 600 mm, L_{min} = 5.3 m
Flood 9	FL9_Hi	2 x 825 mm RCP	4.0	d_{50} = 500 mm, L_{min} = 4.2 m
Flood Fut-1	FLfut1_Pipe	10 x 1050 mm RCP	4.0	d_{50} = 500 mm ,L_{min} = 5.3 m
YB Dr Culverts	YBDr_out	3 x 2400 x 750 mm RCBC	2.3	d_{50} = 200 mm, L_{min} = 2.3 m
YB School Culverts	YBSch_out	3 x 2700 x 600 mm RCBC	4.7	d_{50} = 600 mm, L_{min} = 3.0 m

Notes:
RCP = Reinforced concrete pipe
RCBC = Reinforced concrete box culvert
D_{50} = mean rock size
L_{min} = minimum roack apron length

9.6.7 Flood Warning Time

The 100 year ARI hydrographs for the four site discharge locations (refer to Figure 28) are provided in Figure 30. The plots indicate that the flood mitigation strategy preserves or delays the hydrograph peak, thereby providing increased warning time to peak flood events. The exception to this is Location 9, which (due to it being a small and relatively steep catchment) shows the peak discharge occurring marginally before the pre-development peak. However, this time difference is in the order of 5-10 minutes and the post-development peak flow at this time is no worse than the pre-development flow at the equivalent time and therefore does not present an increase risk to flooding.

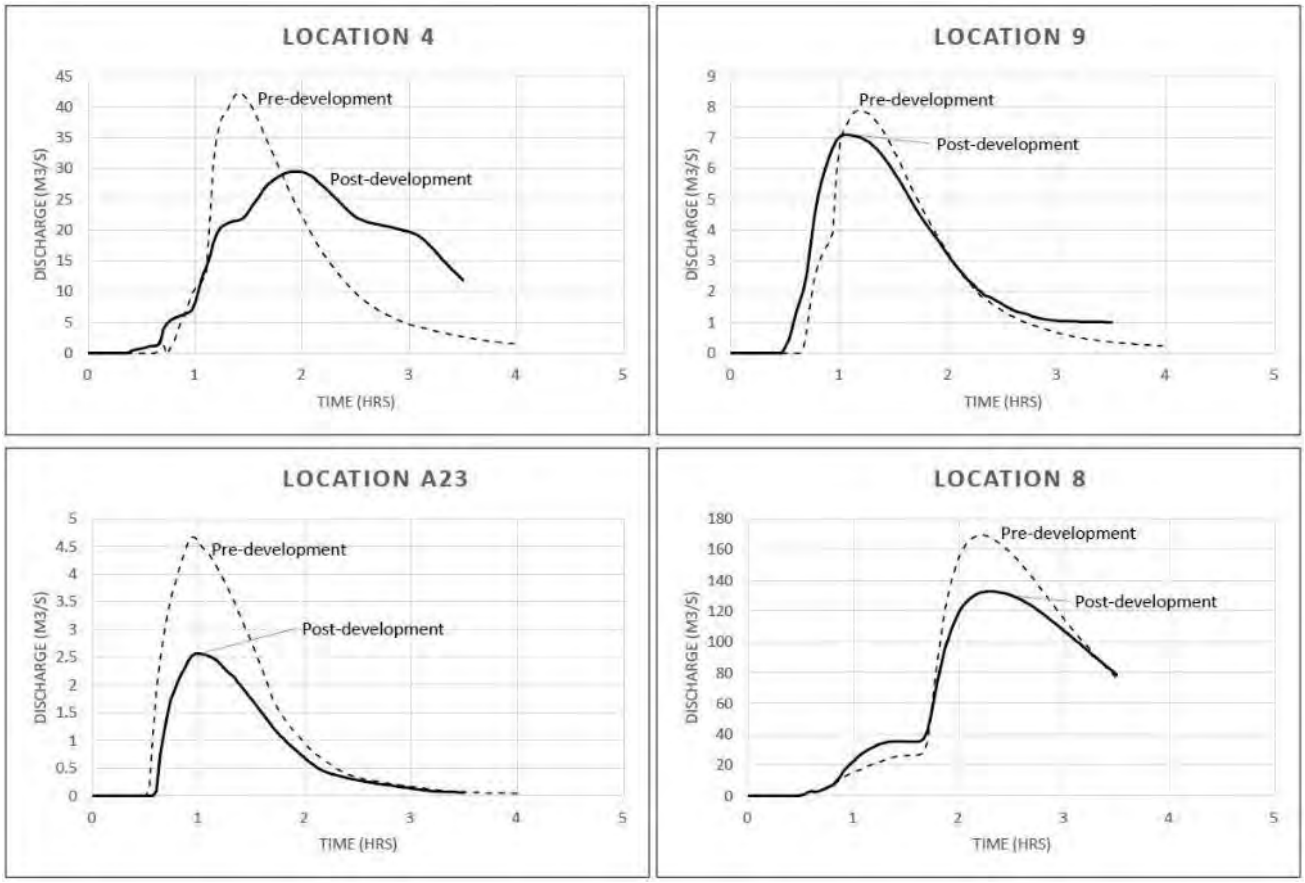


Figure 30: 100 year ARI peak flow warning time

9.6.8 Blockage Analysis

An analysis of the flood behaviour within Yarrabilba Precinct 1 and 2 was undertaken in TUFLOW to identify any risk areas associated with property flooding or infrastructure impacts.

Blockage factors adopted for the assessment are summarised in Table 41. These are consistent with QUDM (2013) Sections 5.8.2 and 10.4.10 and Table 7.1 in *Australian Rainfall and Runoff Project 11: Blockage of Hydraulic Structures* (Engineers Australia, 2013).

Table 41: Blockage factors for outlets and culverts

	Adopted Design Storm Blockage Factor
Low level detention basin outlets	100%
Grated pit structures (where not acting as low level outlet)	100% (≤1.5m square)* 50% (> 1.5m square)*
Culverts (with width < 3m, height < 5m)	20% unscreened 50% screened **
Weirs	No blockage

* These pit sizing blockage factors have been proposed for Yarrabilba to account for the higher likelihood of smaller grated pit structures becoming fully blocked and are not specifically stated in QUDM but adopted here based on conservative design approach.

** All pipe and box culverts have been assumed to be screened for the purpose of this assessment based on the requirement for screens at YBDr and Flood 4 culverts in Precinct 1 (already constructed)

The blockage analysis was carried out for the 100 year ARI event with durations between 60 and 120 minutes (representing the critical durations for the peak water level in the various detention basins within the site). The critical areas impacted by changes to the flood behaviour within Precinct 1 and 2 are provided in Table 42. The associated velocity x depth map for this analysis is in Appendix D (Figure D5).

Table 42: Blockage analysis impact

Location	100 year ARI Flood level (mAHD)		Increase (m)	Impact
	no blockage	with blockage		
Flood 1	27.14	27.45	0.31	0.05m below bund (overflow contained by weir), inundation of adjacent road to 0.45m, Vxd <0.05 m^2/s*
Flood 2	30.33	30.47	0.14	0.15m below bund, overflow contained by weir
Flood 3	31.25	31.26	0.02	0.35m below bund, overflow contained by weir
Flood 4	35.58	36.40	0.83	0.05m depth of flow over Summerview Avenue, Vxd <0.02 m^2/s
Flood 5	44.87	45.29	0.42	Up to 0.3m depth over Highland Street, Vxd <0.3 m^2/s
Flood 6	23.19	23.27	0.08	0.23m below bund, overflow contained by weirs
Wetland W2	23.18	23.25	0.07	contained within Flood 6
Flood 9	26.95	27.05	0.10	0.45m below bund, overflows contained by weir
YBDr	33.84	34.47	0.63	Overland flow along southern side of Yarrabilba Drive, max. depth 0.40m at sag over culverts east of school, Vxd <0.1 m^2/s
YBSch	31.71	32.66	0.95	Impacted by overland flow from Yarrabilba Drive (YBDr) culverts as above. Max. depth 0.40m at sag over culverts east of school, Vxd<0.1 m^2/s

* When future road connection occurs to development on the northern side of the SIC, overland flow will occur along road and ultimate depth at this location with be reduced.

10 CONCLUSIONS AND RECOMMENDATIONS

A stormwater management strategy has been developed for Yarrabilba Precincts 1 and 2 that delivers best practice objectives for urban stormwater quality improvement, waterway stability and remediation, frequent flow management and flood management. The strategy complies with the *Yarrabilba Stormwater Infrastructure Master Plan* (DesignFlow, 2012) and the *Yarrabilba Total Water Cycle Management Plan* (DesignFlow, 2012).

Key features of the strategy include:

- Local and regional erosion and sediment control during construction including regular auditing.
- Adoption of suitable waterway buffers to preserve key waterways.
- Remediation of all waterways through minor stabilisation and significant revegetation to create waterway systems endemic to the region.
- Creation of stormwater management systems which integrate with the existing waterways and form part of the remediation of the waterways. The treatment systems include sediment basins, remediated waterways, bioretention systems, constructed wetlands and ephemeral wetlands.
- A network of flood detention basins throughout the development to manage flood flow exiting the site to downstream private property and Quinzeh Creek.
- Stormwater harvesting and other drainage works to manage nuisance flows in downstream property.

Lend Lease do recognise that further work is required to refine the strategy. This will involve monitoring of boreholes recently installed in Catchment 2 to refine the frequent flow management strategy. Furthermore, a waterway remediation strategy is to be resolved for all the waterways in Precinct 1 and 2 which accounts for stabilisation requirements and revegetation of the poor and average reaches.

It is expected that minor adjustments to the stormwater management designs may occur as part of detailed design for the Operational Works certification process. Any changes will be clearly identified and explained in the form of "WSUD Functional Design Reports" for each of the development stages. The reports will provide detailed description of the design and associated calculations along with detailed MUSIC modelling. Design development and detailed design of the WSUD Strategy will be undertaken in accordance with WSUD Technical Design Guidelines for SEQ.

11 REFERENCES

Beaudesert Shire Council (1999), Design and Construction Manual (former Council document)

Bowler Geotechnical (2004) *Broad Scale Geotechnical Investigation.* Report for the Yarrabilba Development

Bureau of Meteorology Rainfall IFD Data System (online) [accessed 4 April 2013], http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

Cooperative Research Centre for Catchment Hydrology (CRCCH) (2005). *Model for Urban Stormwater Improvement Conceptualisation (MUSIC) User Guide*, Version 4, CRCCH, Monash University, Victoria

DesignFlow (2011) *Precinct A Water Sensitive Urban Design Preliminary Advice*. Prepared for Lend Lease lend Lease

DesignFlow (2014), *Yarrabilba Precinct 1 and 2 Stormwater Management Plan - Version 2*, prepared for Lend Lease, 25 February 2014.

Engeny (2013), *Revised Quinzeh Creek Flood Study,* Letter Report, 23 August 2013.

Engineers Australia (2005), *Australian Runoff Quality*, Wong, T.H.F. (ed).

Engineers Australia (2013), *Project 11: Blockage of Hydraulic Structures*. Australian Rainfall and Runoff Revision Projects, P11/S2/021, February 2013.

Ilahee, M (2005) *Modelling Losses in Flood Estimation*, QUT Thesis

Logan City Council (2010) *Draft Interim Standards for Stormwater, Overland Flow and Flood Plain management*

Logan City Council (undated), *Stormwater Quality Conceptual Design Guidelines*

QUDM (2013) *Queensland Urban Drainage Manual*. Department of Natural Resources and Water

Walsh. C, Fletcher. T, Hatt. B and Burns, M (2010) *New Generation Stormwater Management Objectives for Stream Protection: Stormwater as an Environmental Flow Problem* SIA Conference 2010

Water by Design - Healthy Waterways (2006), *WSUD Technical Design Guidelines for South East Queensland,* August 2006.

Water by Design - Healthy Waterways (2010), *MUSIC Modelling Guideline for SEQ*

Water Technology (2011) *Flood Management Plan – Yarrabilba Precinct A* Prepared for DesignFlow

WBM BMT (2012) *Yarrabilba - Development: Flood Risk Management Strategy*

WRM (2013) *Quinzeh Creek Design Discharge Estimate,* prepared for Logan City Council, September 2013.

APPENDIX A: RATIONAL METHOD COMPARISON

The XPRAFTS hydrologic 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 zero imperviousness) and for an unmitigated developed case.

The Rational Method assessment was carried out at selected discharge locations in order to compare the sub-catchment rainfall-runoff model at a range of scales and slopes. The application of the Rational Method has intentionally been avoided in parts of the catchment where significant natural attenuation exists as it is not suitable for such situations. Poor application of the Rational Method in these situations can result in the selection of loss and/or roughness parameters that are artificially high to offset the poor representation of in-stream flood attenuation.

Key data and components of the Rational Method applied to the site are discussed below.

Catchments

Pre-development catchment data (and grouping of catchments) is based on the data provided in Table 19 in the main report. The discharge location and corresponding catchments draining to these locations are shown in provided in Figure A1 and A2 with details provided in Table A1.

Table A1: Pre-development discharge comparison locations

Catchments	Contributing Area (ha)	Discharge Location
A01	17.03	A01
A01 - A05	59.99	A05
A07 - A09	33.34	A09
A07 - A14	106.42	A14
A16	19.82	A16
A_N32 - A_N33	50.26	A_N32
A_N8 - A_N15, A_N26 - A_N29	446.74	A_N10
A_N5 - A_N6	95.30	A_N5
A_N3	65.00	A_N3

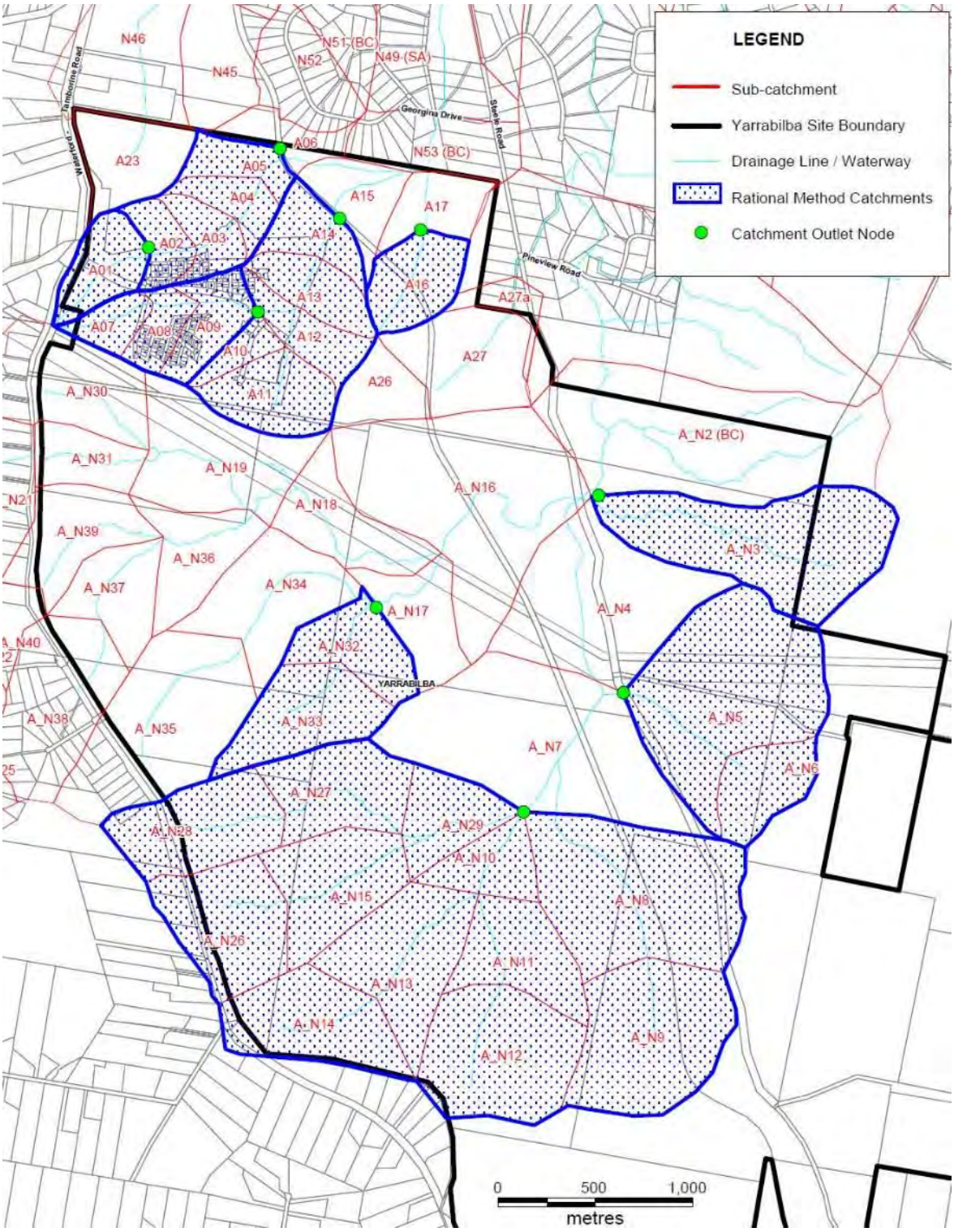


Figure A1: Pre-development Rational Method catchments and discharge locations

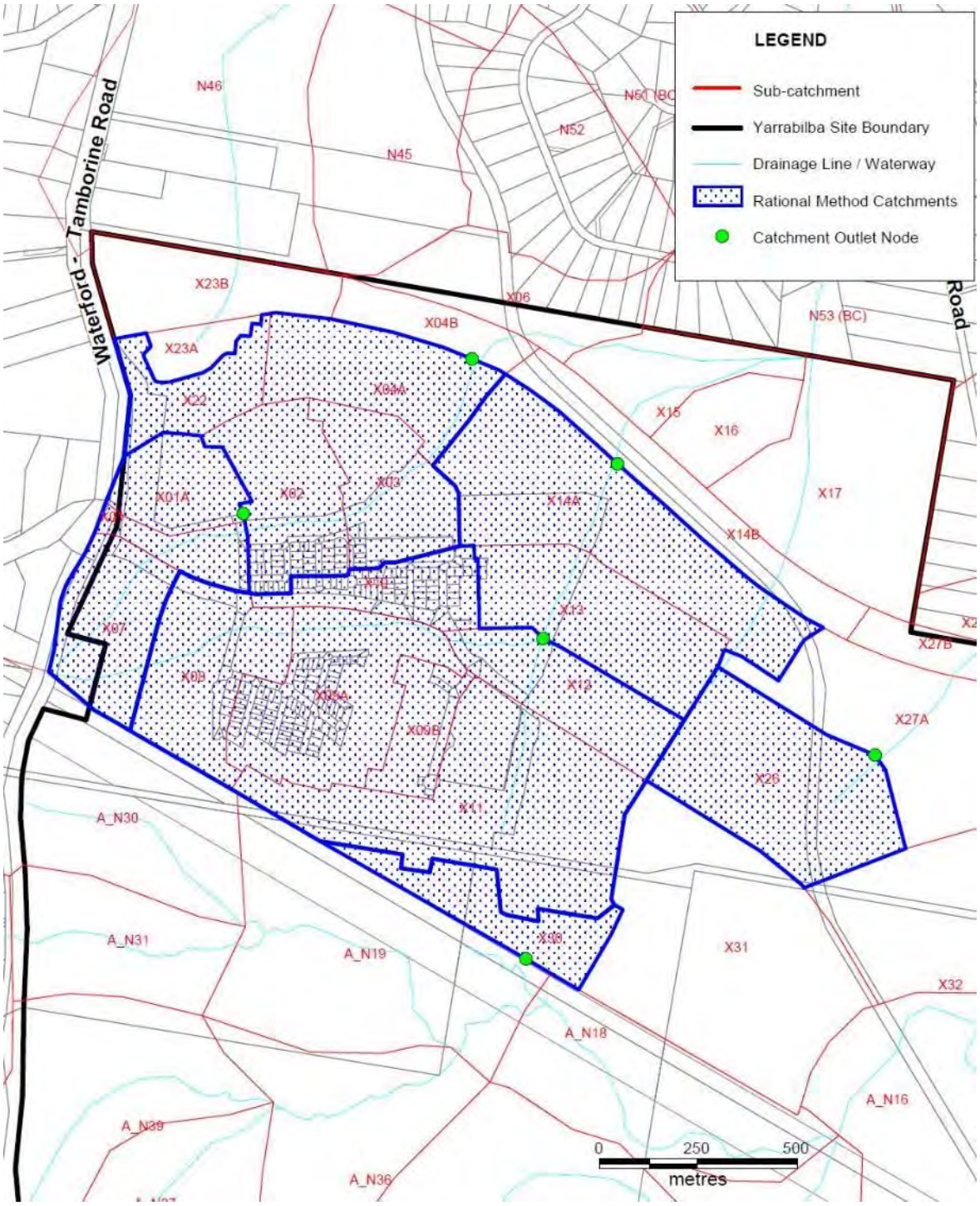


Figure A2: Post-development Rational Method locations

Table A2: Post-development (unmitigated) discharge comparison locations

Catchments	Contributing Area (ha)	Discharge Location
X01, X01A, X07	20.63	X01
X01-X04A, X07, X22	61.12	X04A
X08 - X12	79.28	X12
X08-X14a	118.87	X14A
X26	19.81	X26
X30	7.71	X30

Time of Concentration

The pre-development time of concentration for each reporting location was determined considering both sheet flow and concentrated flow in accordance with QUDM (2013) for bushland catchments without a defined creek with bed and banks. Sheet flow travel time is based on Friends Equation using a maximum sheet flow length of 100m (for medium gradient Bushland). Concentrated flow travel time was determined from review of actual flow velocities derived from the link routing in XPRAFTS model which uses actual channel section, length, slope and Manning's n. An average velocity was derived from the varying reach velocities within the model to provide a comparable travel time down the main flow path.

Table A3 provides the calculation summary for the existing (undeveloped) site time of concentration to the respective discharge locations.

Table A3: Pre-development time of concentration

CATCHMENT						SHEET FLOW				CONCENTRATED FLOW							
					MI	100	0.06										
						L	n	S	t	l	Average velocity in reach (for ARI)						
Catchment	outlet node	Area	Land Use	% Impervious	Total flow length	Sheet Flow	Horton s 'n'	Surface Slope	Sheet flow time	Channel flow length	1	2	5	10	20	50	100
		ha		%	m	m		%	min		m/s						
A01	A01	17.03	Grass/regrowth	0.5%	650	100	0.06	4.2	22.3	550	0.4	0.5	0.6	0.6	0.7	0.8	0.8
A01 - A05	A05	59.99	Grass/regrowth	0.1%	1530	100	0.06	4.2	22.4	1430	0.4	0.5	0.6	0.6	0.7	0.7	0.8
A07 - A09	A09	33.34	Grass/regrowth	0.0%	1080	100	0.06	5	21.6	980	0.4	0.5	0.5	0.5	0.6	0.7	0.7
A07 - A14	A14	106.42	Grass/regrowth	0.0%	1770	100	0.06	5	21.6	1670	0.4	0.5	0.5	0.6	0.6	0.7	0.8
A16	A16	19.82	Grass/regrowth	0.0%	620	100	0.06	3.5	23.2	520	0.2	0.2	0.3	0.3	0.4	0.4	0.4
A_N32 - A_N33	A_N32	50.26	Grass/regrowth	0.0%	1250	100	0.06	2.9	24.0	1150	0.4	0.4	0.5	0.6	0.6	0.6	0.7
A_N8 - A_N15, A_N26 - A_N29	A_N10	446.74	Grass/regrowth	0.3%	2300	100	0.06	3.7	23.0	2200	0.4	0.5	0.6	0.6	0.7	0.7	0.7
A_N5 - A_N6	A_N5	95.30	Grass/regrowth	0.0%	1100	100	0.06	4.85	21.7	1000	0.2	0.2	0.3	0.3	0.3	0.3	0.3
A_N3	A_N3	65.00	Grass/regrowth	0.0%	1510	100	0.06	3.9	22.7	1410	0.2	0.3	0.3	0.4	0.4	0.5	0.5

The developed case (unmitigated) time of concentration is derived from a combination of standard inlet time, pipe flow and concentrated flow through drainage lines to discharge locations. Standard inlet times were applied in accordance with QUDM based on developed gradients. Approximate pipe drainage lengths were derived from the preliminary development plan with an assumed velocity of 3 m/s in accordance with QUDM (2013). The balance of drainage through open natural drainage lines was again based on actual flow velocities derived from the link routing in the XPRAFTS model which were taken as an overage over the length of the channel.

Table A4 provides the calculation summary for the post developed (unmitigated) site time of concentration to the respective discharge locations.

Table A4: Post-development (unmitigated) time of concentration

CATCHMENT					Inlet Time		Pipe Flow Time			Channel Flow							
						13	400	3			RAFTS Average						
					S	t	n	V	t	l	Average velocity in reach (for ARI)						
Catchment	outlet Node	Area	Land Use	% Impervious	Upper catch. slope	Std Inlet time	Pipe length	Avg Pipe Vel.	Pipe Travel Time	Channel length	1	2	5	10	20	50	100
		ha		%	%	min	m	m/s	min		m/s						
X01, X01A, X07	X01	20.63	urban	71.5%	3-6%	13	400	3.0	2.2	0	-	-	-	-	-	-	-
X01-X04A, X07, X22	X04A	61.12	urba	57.6%	3-6%	13	400	3.0	2.2	790	1.0	1.1	1.2	1.2	1.3	1.4	1.4
X08 - X12	X12	79.28	urban	50.8%	3-6%	13	400	3.0	2.2	655	0.6	0.6	0.7	0.7	0.8	0.8	0.9
X08-X14a	X14A	118.87	urban	51.8%	3-6%	13	400	3.0	2.2	1150	0.6	0.7	0.8	0.8	0.8	0.9	0.9
X26	X26	19.81	urban	58.0%	3-6%	13	400	3.0	2.2	0	-	-	-	-	-	-	-
X30	X30	7.71	urban	45.0%	3-6%	13	400	3.0	2.2	0	-	-	-	-	-	-	-

Runoff Coefficient

Based on historical aerial photography, site inspections and the limited geotechnical data available, the site is considered to represent a mix of light/medium density bushland (partial regrowth pine plantation with localised regrowth vegetation) and good grass cover with medium permeability soils. The 1 hour rainfall intensity for the 1 in 10 year ARI (10% AEP) event is 64.5 mm/hr. From Table 4.5.4 (QUDM, 2013), a C10 runoff coefficient of **0.59** applies to the site.

(Note: the Intensity groups provided in QUDM table 4.5.4 inadvertently exclude the upper/lower limits from the ranges presents. Thus, 64.5 mm/hr lies between 60-64 and 65-69 mm/hr groupings. Conservatively for this assessment, the lower band was adopted which results in lower pre-development runoff).

Developed (unmitigated) case is based on the overall average impervious fraction of 50% across the developed catchments. From QUDM Table 4.5.3, C10 is interpolated as **0.78**. In this instance, the conservative post development approach of adopting the

upper band (65-69mm/hr) for C10 was selected. Simple sensitivity testing of this C10 value between 0.75 and 0.8 for the post development (unmitigated) assessment showed minimal impact on the overall peak flow estimation (<5% variation from the selected C10 value).

The results of the Rational Method calculations are provided in Table A5 and Table A6 for the respective cases with the XPRAFTS comparison flows shown in green. Discussion of these results follows the tables.

Table A5 Pre-development Rational Method peak flow comparison

	ARI	1				ARI	2				ARI	5				ARI	10				ARI	20				ARI	50				ARI	100			
	FFy	0.8				FFy	0.85				FFy	0.95				FFy	1				FFy	1.05				FFy	1.15				FFy	1.2			
	C10	0.59				C10	0.59				C10	0.59				C10	0.59				C10	0.59				C10	0.59				C10	0.59			
		I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q	
Catchment	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Peak Discharge	XPRAFTS
		mm/hr	-	m3/s			mm/hr	-	m3/s			mm/hr	-	m3/s			mm/hr	-	m3/s			mm/hr	-	m3/s			mm/hr	-	m3/s			mm/hr	-	m3/s	
A01	46.0	43.10	0.472	0.96	0.45	41.0	58.82	0.502	1.40	0.87	38.0	78.87	0.561	2.09	1.45	37.0	87.90	0.590	2.45	1.85	36.0	100.22	0.620	2.94	2.46	35.0	116.39	0.679	3.74	3.16	34.0	139.53	0.708	4.67	3.77
A01 - A05	78.0	31.56	0.472	2.48	1.49	70.0	42.12	0.502	3.52	2.85	63.0	57.94	0.561	5.41	4.81	62.0	64.69	0.590	6.36	6.18	59.0	77.81	0.620	8.03	8.08	57.0	90.51	0.679	10.23	10.39	52.0	105.94	0.708	12.50	12.28
A07 - A09	65.0	34.54	0.472	1.51	0.88	55.0	48.86	0.502	2.27	1.75	54.0	64.57	0.561	3.35	2.98	52.0	72.05	0.590	3.94	3.84	49.0	87.34	0.620	5.01	5.02	47.0	101.52	0.679	6.38	6.42	45.0	112.43	0.708	7.37	7.68
A07 - A14	91.0	28.04	0.472	3.91	2.65	81.0	38.69	0.502	5.74	5.10	73.0	52.71	0.561	8.73	8.62	70.0	58.88	0.590	10.27	10.98	66.0	70.42	0.620	12.90	14.32	63.0	85.99	0.679	17.25	18.42	59.0	100.28	0.708	20.99	22.00
A16	66.0	34.54	0.472	0.90	0.50	59.0	48.86	0.502	1.35	0.94	53.0	64.57	0.561	1.99	1.56	50.0	72.05	0.590	2.34	1.98	48.0	87.34	0.620	2.98	2.55	46.0	101.52	0.679	3.79	3.28	45.0	112.43	0.708	4.38	3.96
A_N32 - A_N33	79.0	31.56	0.472	2.08	1.14	69.0	44.11	0.502	3.09	2.10	62.0	57.94	0.561	4.53	3.86	59.0	68.14	0.590	5.61	4.46	55.0	77.81	0.620	6.73	5.77	54.0	95.64	0.679	9.06	7.15	54.0	105.94	0.708	10.47	8.88
A_N8 - A_N15, A_N26 - A_N29	115.0	23.81	0.472	13.95	9.09	96.0	34.59	0.502	21.53	16.63	84.0	48.46	0.561	33.71	27.27	81.0	54.16	0.590	39.65	34.30	78.0	64.48	0.620	49.57	44.51	76.0	75.08	0.679	63.22	57.71	75.0	83.24	0.708	73.13	69.01
A_N5 - A_N6	105.0	25.32	0.472	3.16	2.05	91.0	35.84	0.502	4.76	3.78	83.0	48.46	0.561	7.19	6.21	81.0	54.16	0.590	8.46	7.86	77.0	64.48	0.620	10.57	10.21	74.0	78.34	0.679	14.07	13.30	71.0	86.84	0.708	16.28	15.90
A_N3	140.0	20.81	0.472	1.77	1.47	117.0	30.45	0.502	2.76	2.61	101.0	41.94	0.561	4.24	4.40	90.0	50.23	0.590	5.35	5.51	81.0	61.92	0.620	6.93	7.12	75.0	75.08	0.679	9.20	9.30	70.0	86.84	0.708	11.10	11.05

Table A6: Developed (unmitigated) Rational Method peak flow comparison

	ARI	1				ARI	2				ARI	5				ARI	10				ARI	20				ARI	50				ARI	100			
	FFy	0.8				FFy	0.85				FFy	0.95				FFy	1				FFy	1.05				FFy	1.15				FFy	1.2			
	C10	0.78				C10	0.78				C10	0.78				C10	0.78				C10	0.78				C10	0.78				C10	0.78			
		I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q			I	C	Q	
Catchment	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS	Total tc	Rainfall Intensity	C	Discharge	XPRAFTS
	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s	min	mm/hr	-	m3/s	m3/s
X01, X01A, X07	15.0	75.67	0.624	2.71	4.41	15.0	96.32	0.663	3.66	5.75	15.0	119.32	0.74	5.07	7.33	15.0	132.64	0.780	5.93	8.27	15.0	150.86	0.819	7.08	9.66	15.0	174.78	0.897	8.98	11.13	15.0	193.12	0.936	10.36	12.38
X01-X04A, X07, X22	28.0	55.95	0.624	5.93	8.41	27.0	72.67	0.663	8.18	11.17	27.0	90.33	0.74	11.36	15.27	26.0	102.50	0.780	13.57	17.72	26.0	116.76	0.819	16.23	21.00	25.0	138.10	0.897	21.03	25.25	25.0	152.76	0.936	24.27	27.74
X08 - X12	35.0	49.66	0.624	6.82	10.85	33.0	68.79	0.663	10.04	15.02	31.0	85.58	0.74	13.96	19.72	30.0	95.32	0.780	16.37	22.50	29.0	110.52	0.819	19.93	26.35	28.0	130.56	0.897	25.79	31.83	28.0	144.46	0.936	29.78	35.69
X08-X14a	46.0	43.10	0.624	8.88	12.38	44.0	58.82	0.663	12.88	17.30	41.0	73.32	0.74	17.94	23.40	40.0	81.74	0.780	21.05	26.86	39.0	100.22	0.819	27.10	32.09	37.0	116.39	0.897	34.47	39.71	36.0	128.84	0.936	39.82	45.16
X26	15.0	75.67	0.624	2.60	3.68	15.0	96.32	0.663	3.51	4.55	15.0	119.32	0.74	4.87	5.95	15.0	132.64	0.780	5.69	6.86	15.0	150.86	0.819	6.80	8.02	15.0	174.78	0.897	8.63	9.40	15.0	193.12	0.936	9.95	10.47
X30	15.0	75.67	0.624	1.01	1.05	15.0	96.32	0.663	1.37	1.40	15.0	119.32	0.74	1.89	1.82	15.0	132.64	0.780	2.22	2.07	15.0	150.86	0.819	2.65	2.45	15.0	174.78	0.897	3.36	2.93	15.0	193.12	0.936	3.87	3.29

Discussion

The results indicate that for the existing case, the Rational Method appears to be over-estimating peak flows for the smaller 1 and 2 year ARI events with better agreement moving into the larger ARIs. Under Post development scenario, The Rational method is over-estimating peak flow for the low ARI events and under-estimating the larger ARI peak flows. However, while these variations occurred, the magnitude of peak flows estimated by the Rational Method were within reasonable limits compared to the XPRAFTS results and were considered to provide satisfactory agreement. As XPRAFTS generally provided more conservative results for the purposes of flood detention requirements (i.e. lower pre-development flows and higher post development flows), no further adjustments to the model parameters were undertaken based on the variable Rational Method findings.

The key hydrological parameters used in the XPRAFTS model in the final verification run against the Rational Method are provided in Table A7. In the absence of any gauged flow data, the Bx parameter was left as the default of 1.0.

Table A7: XPRAFTS parameters adopted from Rational Method comparison

	Existing/ Undeveloped Site	Developed Pervious	Developed Impervious
Catchment Manning's n	0.05	0.035	0.015
Initial Loss (mm)			
1 – 20 yr ARI	30	15	1
50 – 100 yr ARI	30	0	1
Continuing Loss (mm/h)			
1 – 20 yr ARI	2.5	2.5	0
50 – 100 yr ARI	2.5	2.5	0
Storage Coefficient 'Bx'	1.0	1.0	1.0

Summary

The comparison of Rational Method peak flow estimation with XPRAFTS indicates generally satisfactory agreement between peak flows with the exception of very minor ARIs under existing (fully pervious) catchment conditions. In these cases, the XPRAFTS model results in lower peaks and has therefore been adopted for the existing case (which defines the no-worsening basis). The developed (unmitigated) case Rational Method peak flows compare reasonably well with those from XPRAFTS across the full range of ARIs, with XPRAFTS adopted as the more conservative (for comparison against pre-development conditions).

APPENDIX B: TUFLOW RESULTS

Results are presented in Tables B1 to B5 below for pre and post development at the reporting locations identified in Figure 28 in the main report and at the respective detention basins (post-development only). The results from the blockage scenario (Section 9.6.8) are also presented in Table B4 and B5 to reflect the increase in flood level. Flood impact mapping is provided in Appendix C while the flood safety mapping is in Appendix D.

Results presented in the following sections are:

- Discharge (Table B1)
- Water level (Table B2)
- Velocity (Table B3)
- Detention Basin Water Level (Table B4)
- Detention Basin Depth (Table B5)

Table B1: Discharge

Location	Discharge m^3/s																				
ID	1 year			2 year			5 year			10 year			20 year			50 year			100 year		
	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.
4	4.82	4.51	-0.32	9.65	6.91	-2.74	16.35	12.72	-3.63	20.53	16.31	-4.22	26.15	19.57	-6.58	34.60	23.27	-11.33	42.26	29.52	-12.74
9	0.95	0.96	0.02	1.81	1.09	-0.72	3.13	2.04	-1.09	3.91	2.84	-1.07	5.02	3.80	-1.22	6.58	5.55	-1.03	7.89	6.64	-1.24
A23	0.57	0.30	-0.27	1.09	0.58	-0.52	1.84	0.99	-0.85	2.30	1.24	-1.05	2.99	1.62	-1.36	3.85	2.10	-1.75	4.67	2.57	-2.10
8	22.19	21.64	-0.55	41.73	39.42	-2.31	69.35	59.95	-9.40	86.65	72.91	-13.74	110.60	90.14	-20.46	140.61	112.41	-28.20	169.14	134.03	-35.12
14	24.27	26.77	2.50	50.08	49.76	-0.32	81.26	77.67	-3.59	95.91	86.40	-9.51	126.52	111.98	-14.54	165.92	148.11	-17.81	196.31	175.70	-20.61
16	1.39	1.11	-0.27	3.92	3.35	-0.57	7.22	6.07	-1.15	9.23	7.92	-1.31	12.51	10.37	-2.14	16.77	14.41	-2.35	20.26	17.51	-2.75
QC87	25.99	29.04	3.04	60.93	60.04	-0.88	104.43	100.25	-4.18	112.01	103.16	-8.85	151.98	139.41	-12.57	207.65	189.58	-18.07	251.74	229.46	-22.28

Table B2: Water Level

Location	Water Level (mAHD)																				
ARI ->	1 year			2 year			5 year			10 year			20 year			50 year			100 year		
	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.
4	19.53	19.56	0.02	19.62	19.59	-0.03	19.72	19.68	-0.04	19.91	19.71	-0.20	19.91	19.89	-0.02	20.39	19.92	-0.46	20.65	20.37	-0.28
9	22.90	22.90	0.00	22.96	22.90	-0.07	23.00	22.97	-0.03	23.01	22.99	-0.02	23.06	23.00	-0.05	23.07	23.06	-0.01	23.09	23.07	-0.03
A23	37.59	37.57	-0.01	37.60	37.59	-0.02	37.62	37.60	-0.02	37.64	37.62	-0.02	37.64	37.62	-0.03	37.66	37.63	-0.03	37.67	37.64	-0.03
8	22.55	22.55	0.00	22.80	22.78	-0.01	23.08	22.99	-0.09	23.22	23.12	-0.11	23.38	23.25	-0.13	23.53	23.39	-0.14	23.64	23.50	-0.14
14	14.63	14.68	0.05	15.35	15.33	-0.02	15.77	15.72	-0.05	15.90	15.81	-0.09	16.16	16.00	-0.16	16.47	16.34	-0.14	16.57	16.49	-0.08
16	20.00	19.91	-0.09	20.21	20.19	-0.02	20.32	20.28	-0.04	20.38	20.34	-0.04	20.46	20.41	-0.05	20.54	20.50	-0.04	20.58	20.55	-0.03
QC87	10.52	10.58	0.06	11.04	11.03	-0.01	11.42	11.38	-0.03	11.47	11.40	-0.07	11.78	11.69	-0.09	12.09	12.01	-0.09	12.31	12.21	-0.10

Table B3: Velocity

Location	Velocity (m/s)																				
ARI ->	1 year			2 year			5 year			10 year			20 year			50 year			100 year		
	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.	PRE	DEV	Diff.
4	0.56	0.49	-0.06	0.59	0.58	-0.01	0.69	0.66	-0.03	0.77	0.71	-0.06	0.87	0.72	-0.15	0.94	0.74	-0.20	1.01	0.78	-0.22
9	0.39	0.41	0.02	0.51	0.44	-0.08	0.64	0.56	-0.08	0.70	0.64	-0.06	0.76	0.71	-0.05	0.87	0.80	-0.07	0.96	0.86	-0.10
A23	0.69	0.54	-0.15	0.86	0.70	-0.16	0.99	0.83	-0.16	1.05	0.89	-0.16	1.13	0.96	-0.17	1.20	1.03	-0.17	1.27	1.08	-0.19
8	1.67	1.67	0.00	1.67	1.63	-0.05	1.69	1.65	-0.04	1.70	1.63	-0.06	1.73	1.67	-0.06	1.73	1.70	-0.04	1.78	1.72	-0.06
14	1.29	1.28	-0.01	0.95	0.90	-0.05	1.34	1.33	-0.01	1.28	1.50	0.21	1.43	1.44	0.00	1.52	1.40	-0.12	1.57	1.45	-0.12
16	0.99	0.94	-0.05	1.26	1.19	-0.08	1.50	1.34	-0.16	1.61	1.58	-0.03	1.61	1.61	0.00	1.69	1.69	0.01	1.75	1.75	0.01
QC87	1.51	1.52	0.01	1.57	1.57	0.00	1.43	1.58	0.15	1.42	1.46	0.03	1.43	1.46	0.03	1.41	1.45	0.04	1.42	1.44	0.02

Table B4: Detention Bain Water Level

Location	Water Level (mAHD)							
ARI ->	1 year	2 year	5 year	10 year	20 year	50 year	100 year	100 year Blockage Scenario
Flood 1	26.13	26.47	26.62	26.70	26.79	27.02	27.14	27.45
Flood 2	29.05	29.37	29.71	29.87	30.02	30.24	30.33	30.46
Flood 3	29.83	30.31	30.61	30.77	30.98	31.19	31.25	31.26
Flood 4	33.92	34.31	34.60	34.78	35.01	35.43	35.58	36.40
Flood 5	43.82	44.02	44.18	44.28	44.43	44.70	44.87	45.29
Flood 6	21.96	22.39	22.56	22.65	22.77	23.07	23.19	23.25
Wetland W2	22.30	22.46	22.57	22.65	22.77	23.06	23.18	23.24
Flood 9	25.91	26.26	26.49	26.58	26.68	26.87	26.95	27.05
Flood Fut-1	26.32	26.66	27.07	27.29	27.56	27.77	27.89	*27.89**
YBDr	33.45	33.56	33.63	33.68	33.73	33.81	33.84	34.47
YBSch	30.50	30.75	30.84	30.94	31.13	31.54	31.71	32.66

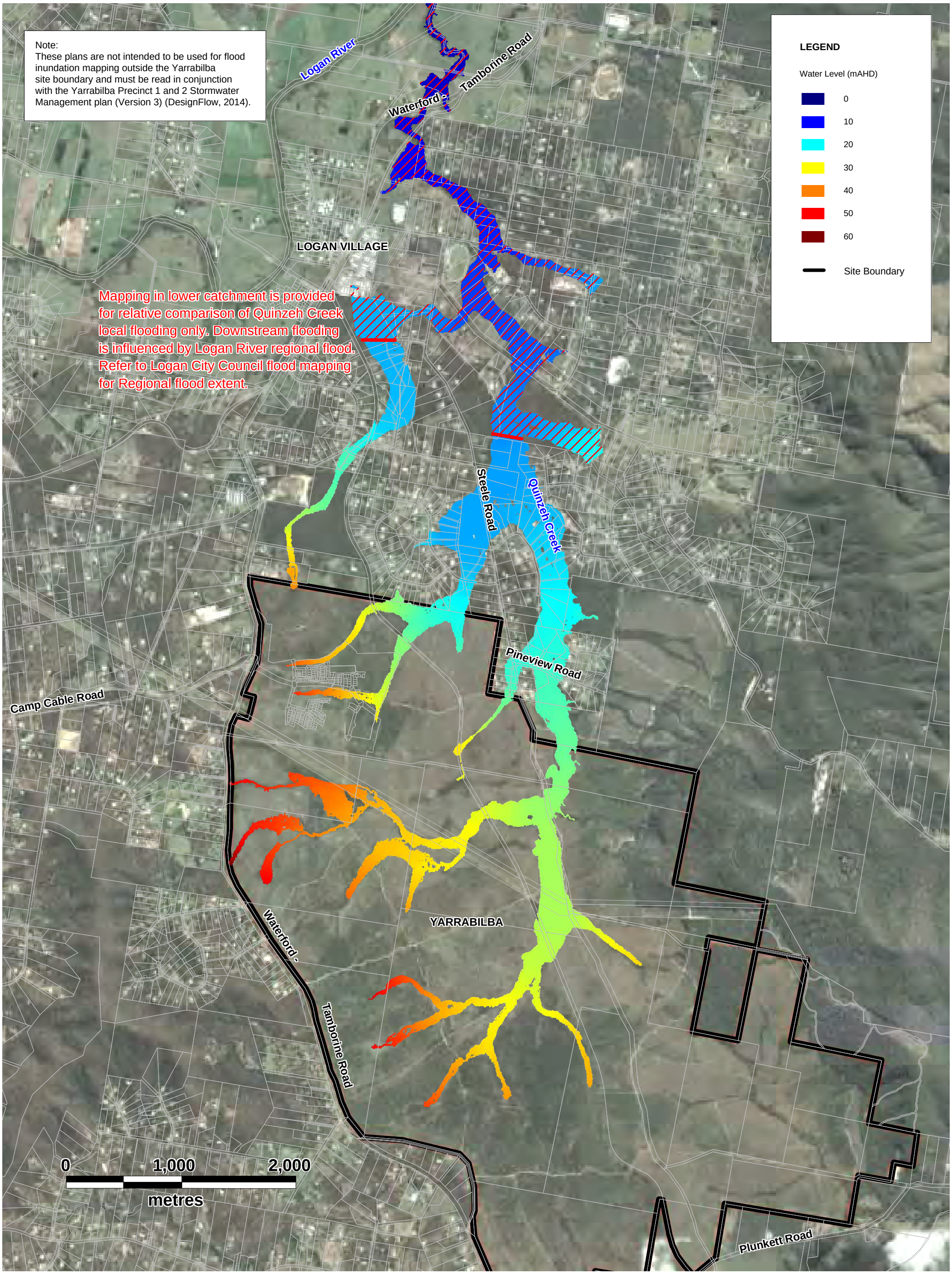
* Flood Fut-1 outlet was not included in the blockage scenario as there is no adjoining development to assess hazard against

Table B5: Detention Basin Water Depth

Location	Depth (m)							
ARI ->	1 year	2 year	5 year	10 year	20 year	50 year	100 year	100 year Blockage Scenario
Flood 1	2.15	2.50	2.65	2.72	2.81	3.04	3.16	3.47
Flood 2	1.34	1.66	2.00	2.16	2.31	2.53	2.62	2.75
Flood 3	0.97	1.45	1.76	1.92	2.12	2.34	2.39	2.41
Flood 4	1.10	1.50	1.79	1.97	2.20	2.62	2.77	3.60
Flood 5	0.82	1.03	1.18	1.28	1.43	1.70	1.87	2.29
Flood 6	1.66	2.10	2.27	2.35	2.48	2.77	2.89	2.95
Wetland W2	1.30	1.46	1.57	1.65	1.77	2.06	2.18	2.24
Flood 9	1.51	1.86	2.09	2.18	2.28	2.47	2.55	2.65
Flood Fut-1	1.07	1.41	1.82	2.04	2.31	2.52	2.65	*2.65**
YBDr	0.96	1.06	1.13	1.18	1.22	1.30	1.33	1.96
YBSch	0.45	0.64	0.75	0.86	1.02	1.40	1.61	2.56

* Flood Fut-1 outlet was not included in the blockage scenario as there is no adjoining development to assess hazard against

APPENDIX C: FLOOD IMPACT MAPPING



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C1** **Pre-Development** **100 year ARI Flood Extent**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C2

Pre-Development
50 year ARI Flood Extent

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

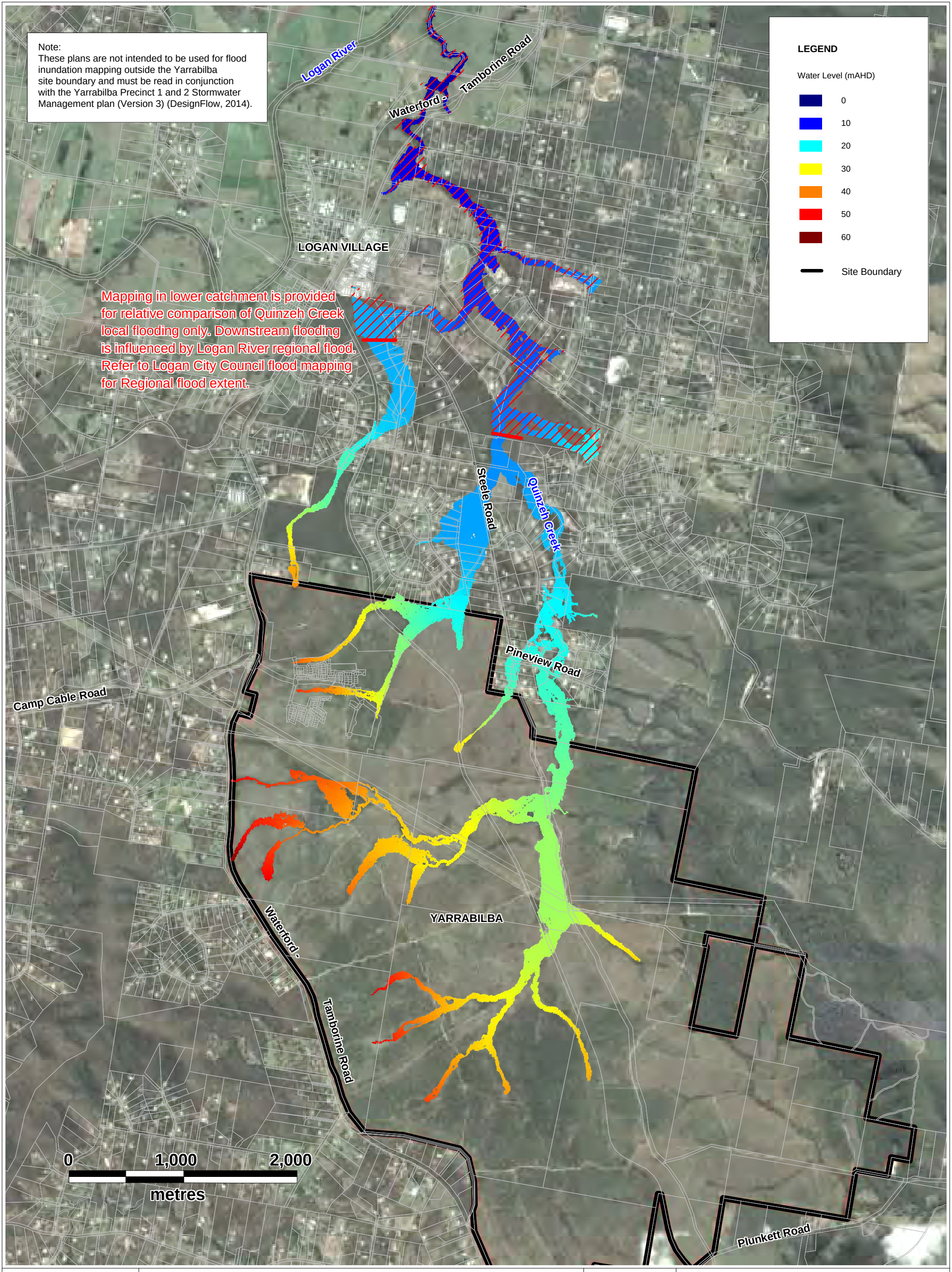
Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C3

Pre-Development
20 year ARI Flood Extent



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C4** **Pre-Development** **10 year ARI Flood Extent**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C5

Pre-Development
5 year ARI Flood Extent

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

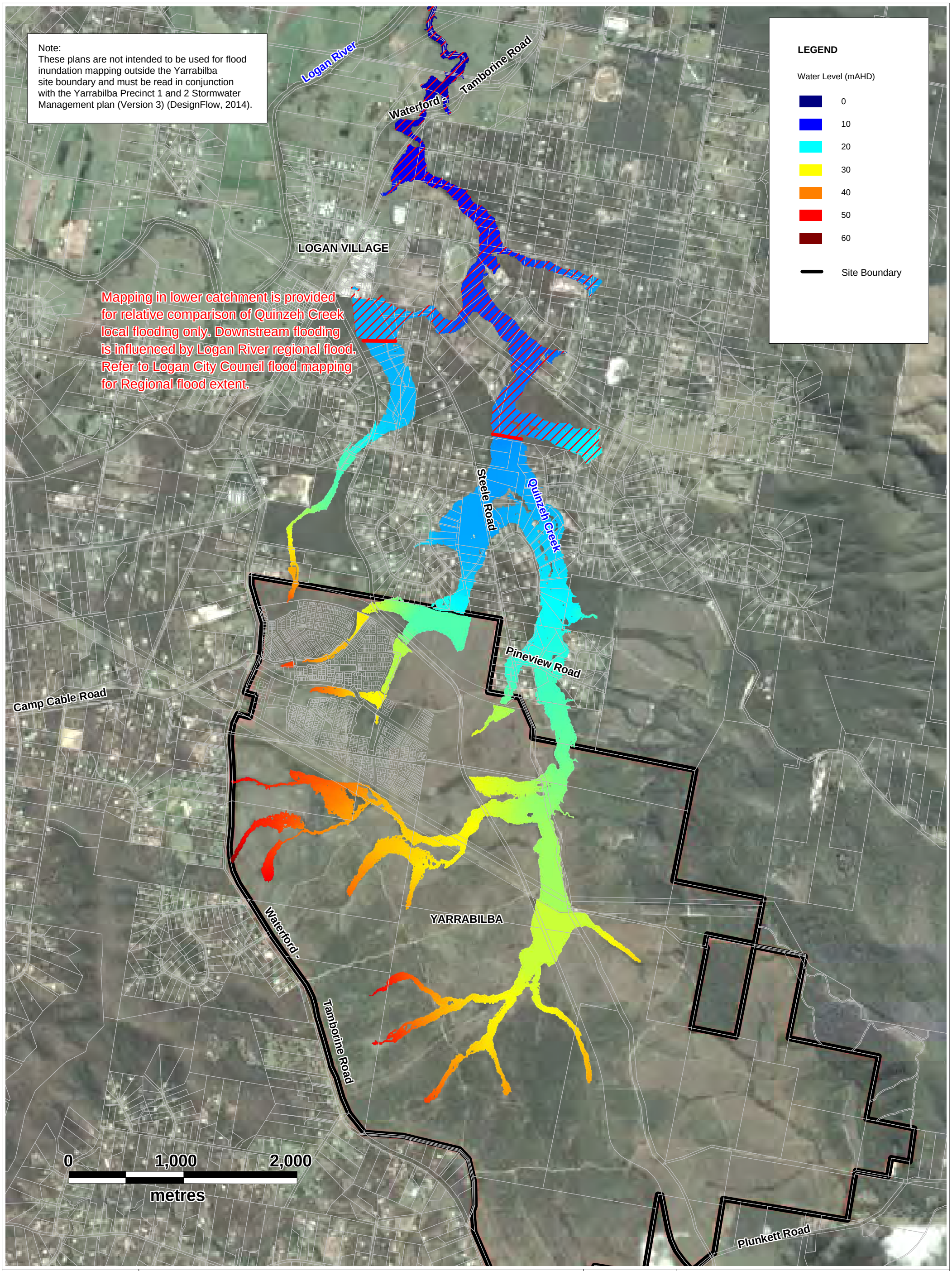
- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

0 1,000 2,000

metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A3)	**FIGURE C6** **Pre-Development** **2 year ARI Flood Extent**
	Client: Lend Lease Date: 28 July 2014		



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C7** **Post-Development (Mitigated)** **100 year ARI Flood Extent**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C8

**Post-Development (Mitigated)
50 year ARI Flood Extent**

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

0 1,000 2,000

metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A3)	**FIGURE C9** **Post-Development (Mitigated) 20 year ARI Flood Extent**
	Client: Lend Lease Date: 28 July 2014		

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C10

Post-Development (Mitigated)
10 year ARI Flood Extent

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Water Level (mAHD)

- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C11

Post-Development (Mitigated)
5 year ARI Flood Extent

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Water Level (mAHD)

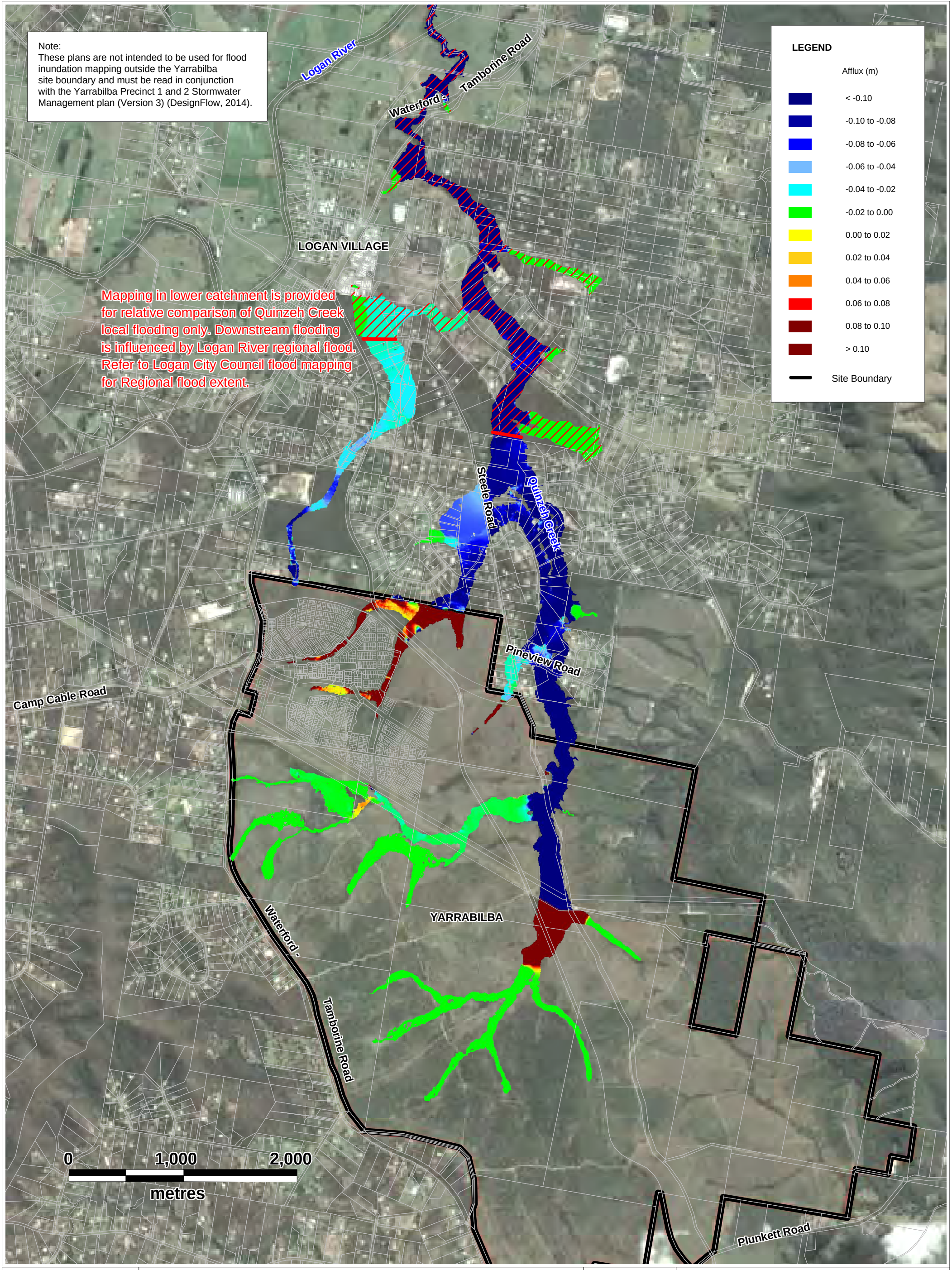
- 0
- 10
- 20
- 30
- 40
- 50
- 60

Site Boundary

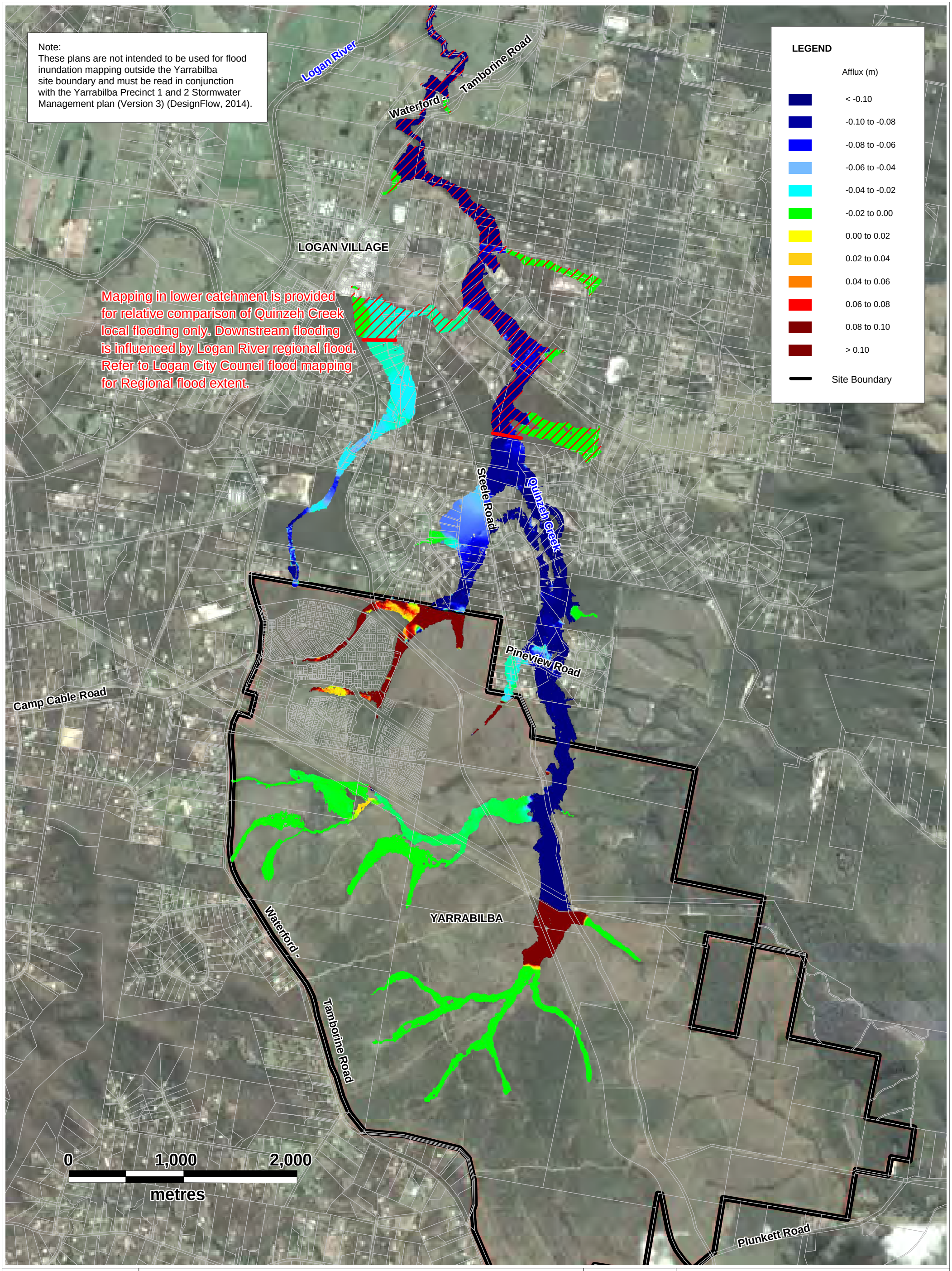
0 1,000 2,000

metres

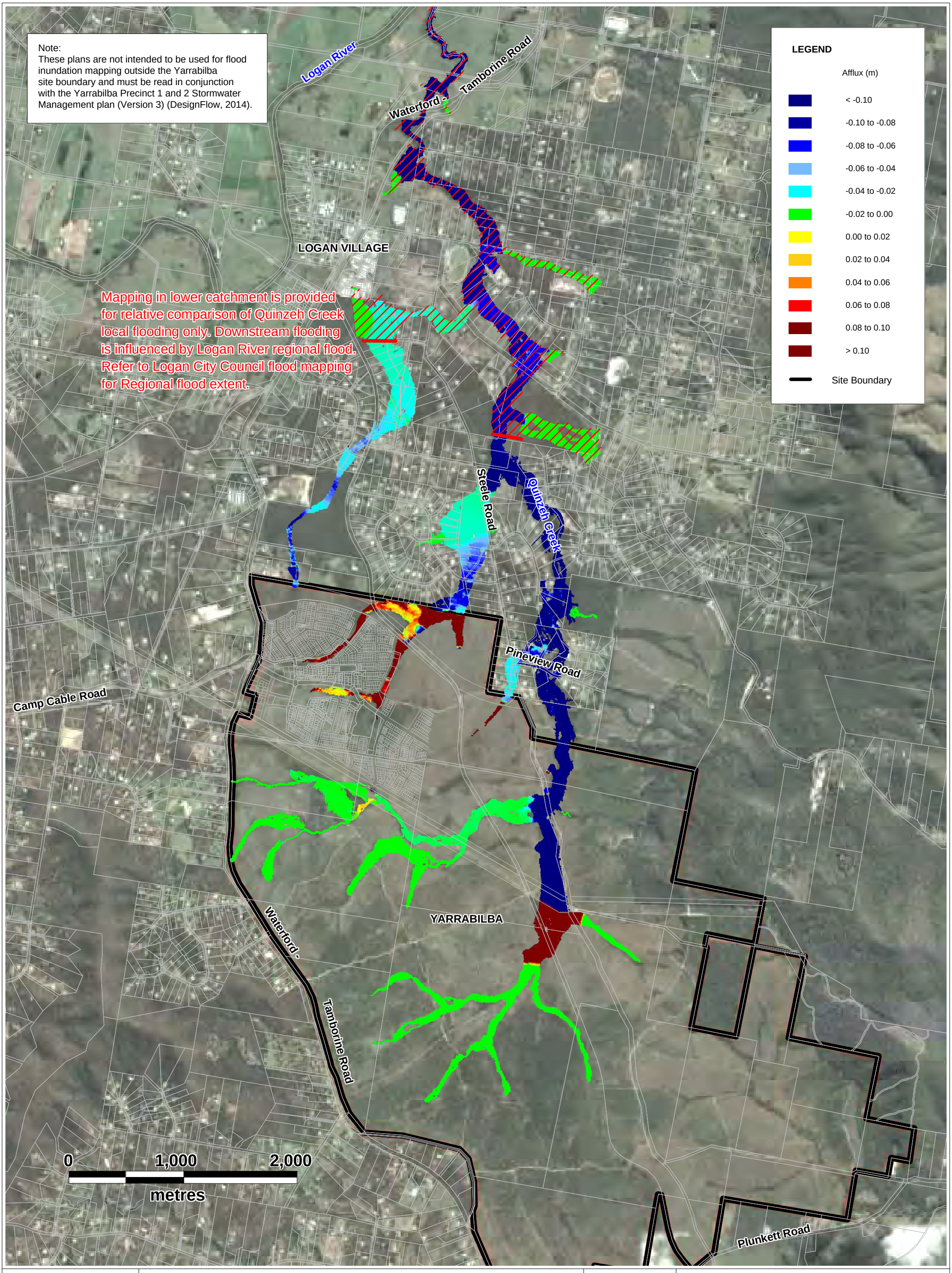
DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A3)	**FIGURE C12** **Post-Development (Mitigated) 2 year ARI Flood Extent**
	Client: Lend Lease Date: 28 July 2014		



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S Scale: 1 : 30,000 (A3)	**FIGURE C13** **Post-Development (Mitigated)** **100 year ARI Afflux**
	Client: Lend Lease	Date: 28 July 2014		



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C14** **Post-Development (Mitigated)** **50 year ARI Afflux**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	



DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N
W
E
S

Scale:
1 : 30,000 (A3)

FIGURE C15

Post-Development (Mitigated)
20 year ARI Afflux

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Afflux (m)

- < -0.10
- -0.10 to -0.08
- -0.08 to -0.06
- -0.06 to -0.04
- -0.04 to -0.02
- -0.02 to 0.00
- 0.00 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- > 0.10
- Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C16** **Post-Development (Mitigated)** **10 year ARI Afflux**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Afflux (m)

- < -0.10
- -0.10 to -0.08
- -0.08 to -0.06
- -0.06 to -0.04
- -0.04 to -0.02
- -0.02 to 0.00
- 0.00 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- > 0.10
- Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
Waterford -
Tamborine Road
YARRABILBA
Plunkett Road
0
1,000
2,000
metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C17** **Post-Development (Mitigated)** **5 year ARI Afflux**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Afflux (m)

- < -0.10
- -0.10 to -0.08
- -0.08 to -0.06
- -0.06 to -0.04
- -0.04 to -0.02
- -0.02 to 0.00
- 0.00 to 0.02
- 0.02 to 0.04
- 0.04 to 0.06
- 0.06 to 0.08
- 0.08 to 0.10
- > 0.10
- Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S Scale: 1 : 30,000 (A3)	**FIGURE C18** **Post-Development (Mitigated)** **2 year ARI Afflux**
	Client: Lend Lease	Date: 28 July 2014		

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
PineView Road
Camp Cable Road
YARRABILBA
Waterford -
Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C19

Pre-Development
100 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
PineView Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C20

Pre-Development
50 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
PineView Road
Camp Cable Road
YARRABILBA
Waterford -
Tamborine Road
Plunkett Road
0
1,000
2,000
metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S	**FIGURE C21** **Pre-Development** **20 year ARI Velocity**
	Client: Lend Lease	Date: 28 July 2014	Scale: 1 : 30,000 (A3)	

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

Waterford - Tamborine Road

YARRABILBA

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C22

Pre-Development
10 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

Waterford - Tamborine Road

YARRABILBA

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C23

Pre-Development
5 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

Logan River
Tamborine Road
Waterford -
LOGAN VILLAGE
Steele Road
Quinzeh Creek
Pineview Road
Camp Cable Road
YARRABILBA
Waterford - Tamborine Road
Plunkett Road

0 1,000 2,000
metres

DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan	N W E S Scale: 1 : 30,000 (A3)	**FIGURE C24** **Pre-Development 2 year ARI Velocity**
	Client: Lend Lease Date: 28 July 2014		

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford -

Tamborine Road

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C25

**Post-Development (Mitigated)
100 year ARI Velocity**

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford - Tamborine Road

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

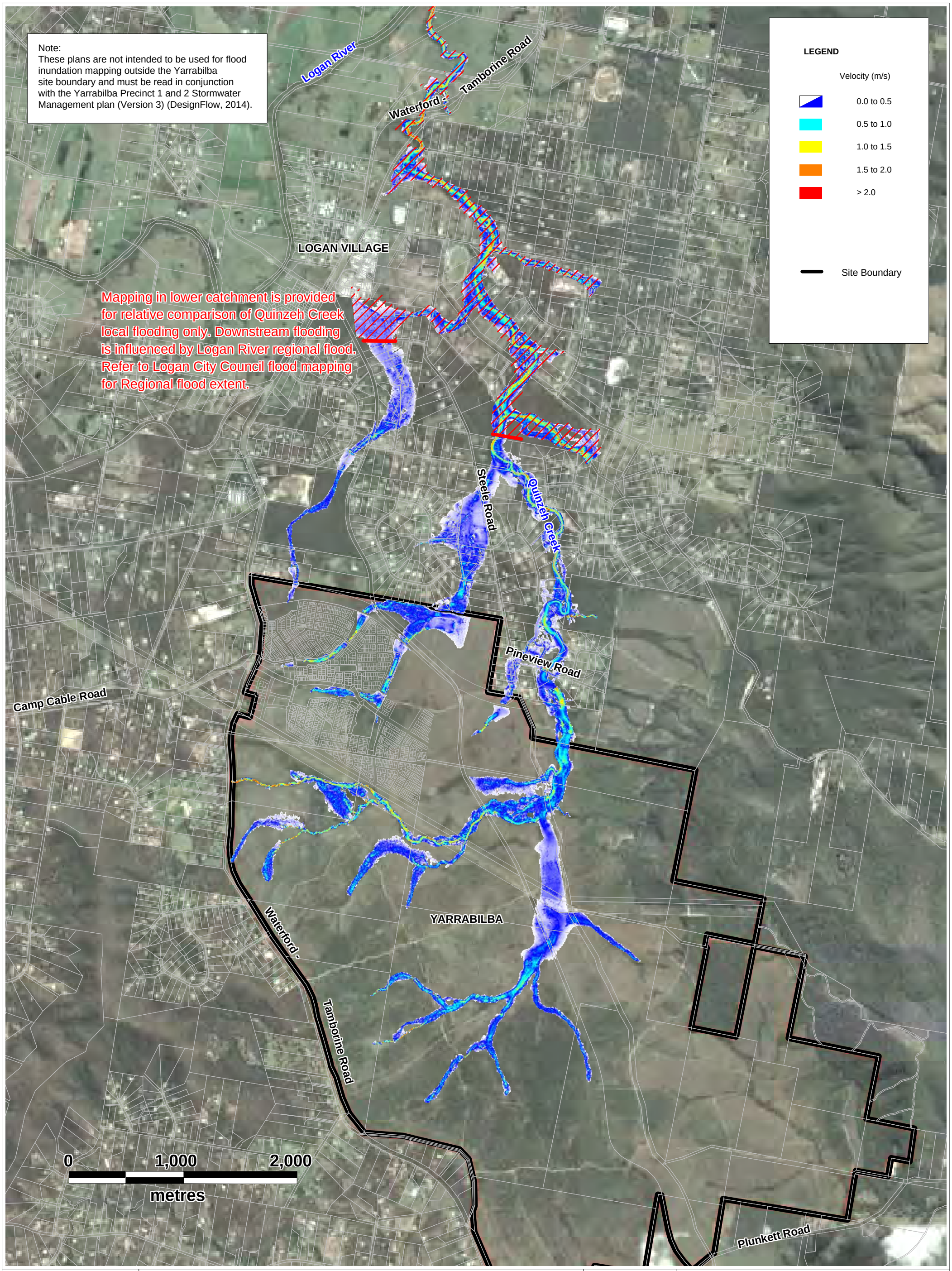
Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C26

Post-Development (Mitigated)
50 year ARI Velocity



DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

Scale:
1 : 30,000 (A3)

FIGURE C27

Post-Development (Mitigated)
20 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford - Tamborine Road

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

FIGURE C28

Post-Development (Mitigated)
10 year ARI Velocity

Note:
These plans are not intended to be used for flood inundation mapping outside the Yarrabilba site boundary and must be read in conjunction with the Yarrabilba Precinct 1 and 2 Stormwater Management plan (Version 3) (DesignFlow, 2014).

Logan River

Tamborine Road

Waterford -

LOGAN VILLAGE

Mapping in lower catchment is provided for relative comparison of Quinzeh Creek local flooding only. Downstream flooding is influenced by Logan River regional flood. Refer to Logan City Council flood mapping for Regional flood extent.

Steele Road

Quinzeh Creek

Pineview Road

Camp Cable Road

YARRABILBA

Waterford - Tamborine Road

Plunkett Road

LEGEND

Velocity (m/s)

- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Site Boundary

0 1,000 2,000

metres

DesignFlow

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Client:
Lend Lease

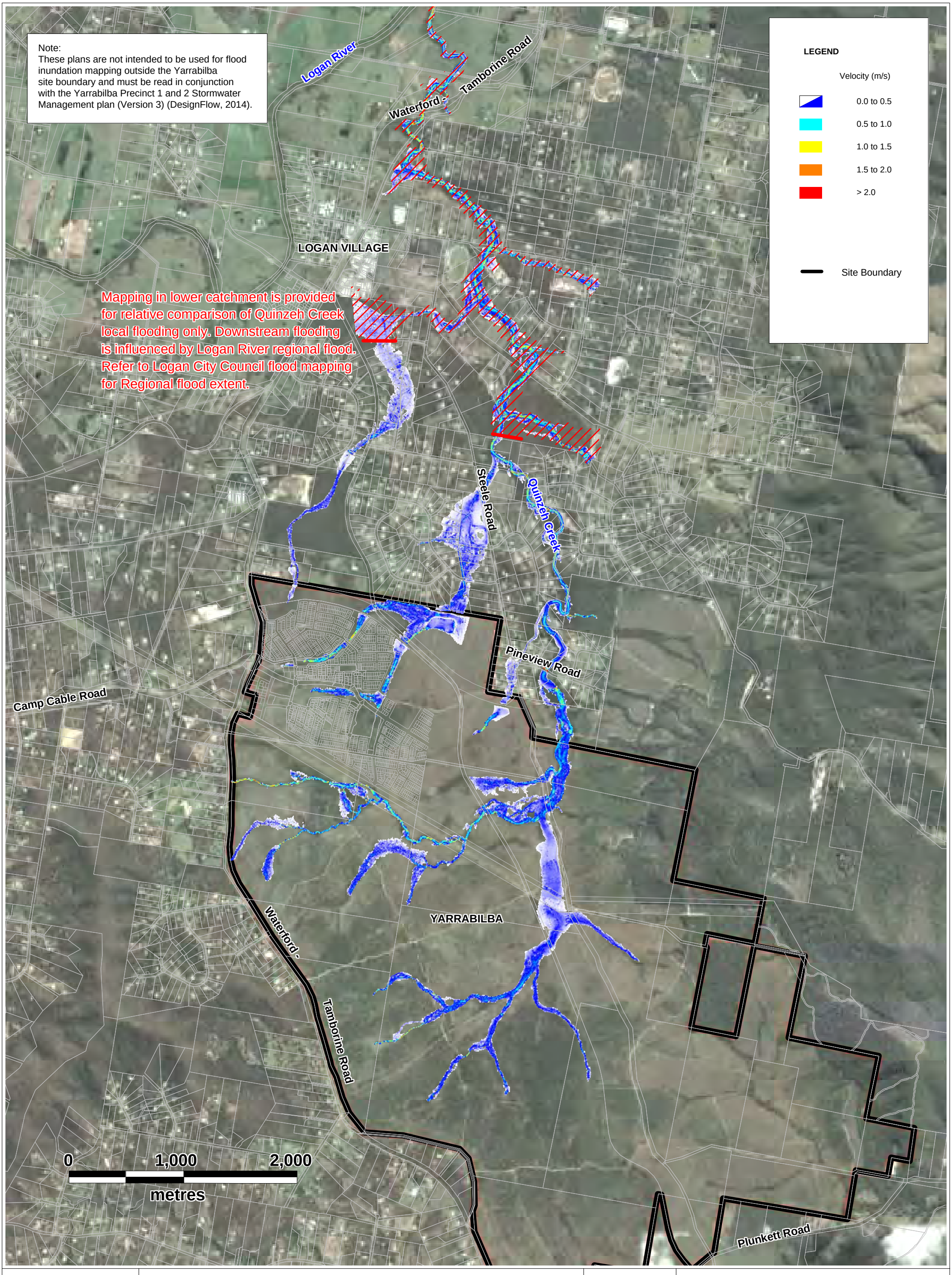
Date:
28 July 2014

N W E S

Scale:
1 : 30,000 (A3)

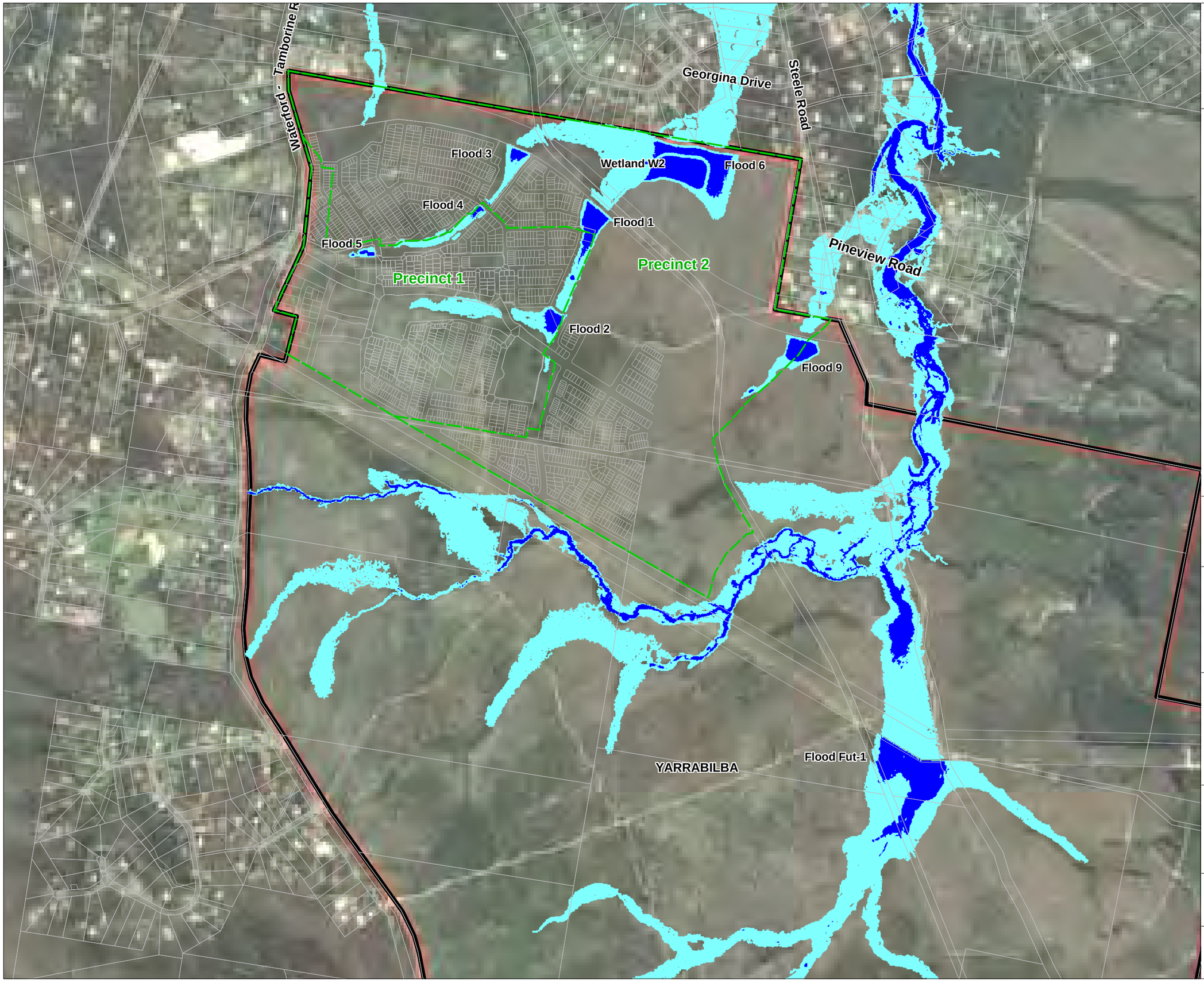
FIGURE C29

Post-Development (Mitigated)
5 year ARI Velocity



DesignFlow	Project: 4205 Yarrabilba Precinct 1 and 2 Stormwater Management Plan		N W E S Scale: 1 : 30,000 (A3)	**FIGURE C30** **Post-Development (Mitigated) 2 year ARI Velocity**
	Client: Lend Lease	Date: 28 July 2014		

APPENDIX D: FLOOD SAFETY MAPPING



DesignFlow

LEGEND

Depth (m)

< 1.2

> 1.2

Yarrabilba Site Boundary

Precinct Boundary

N W E S

Scale:

1 : 15,000 (A3)

FIGURE D1

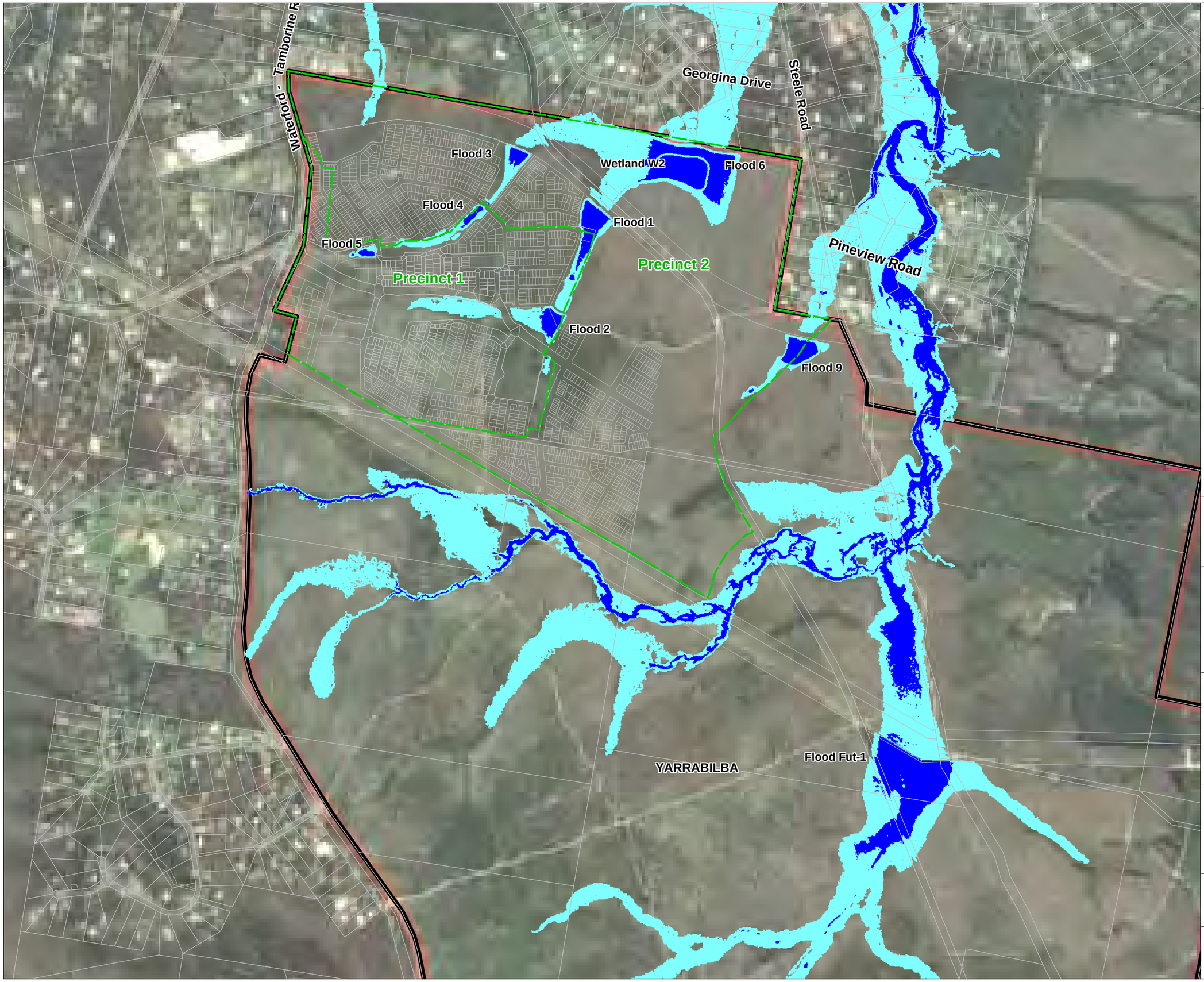
Post-Development (Mitigated) 20 year ARI Depth

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease



DesignFlow

LEGEND

Depth (m)

< 1.2

> 1.2

Yarrabilba Site Boundary

Precinct Boundary

N W E S

Scale:

1 : 15,000 (A3)

FIGURE D2

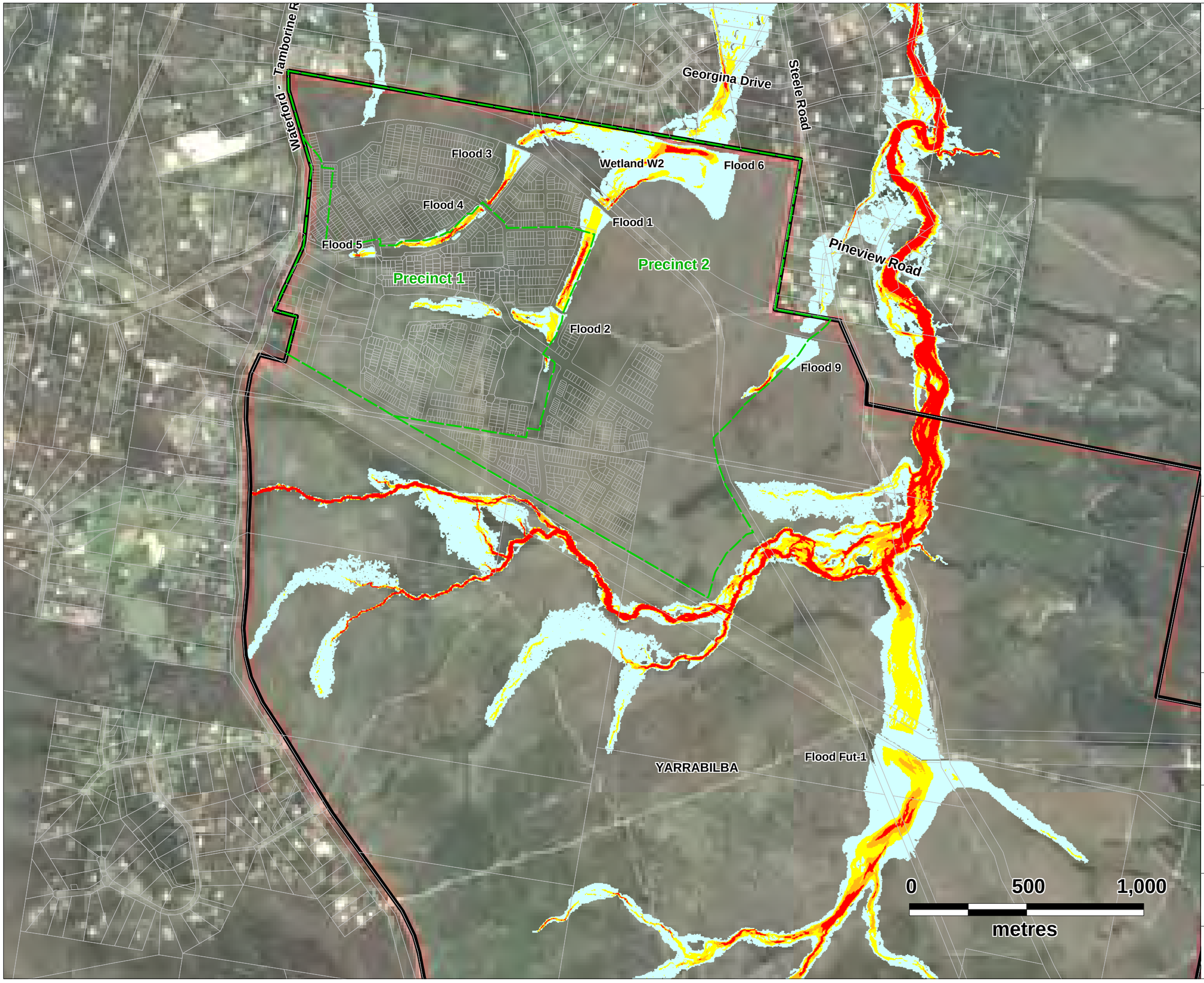
Post-Development (Mitigated) 100 year ARI Depth

Project: 4205

Yarrabilba Precinct 1 and 2 Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease



DesignFlow

LEGEND

Velocity x Depth (m2/s)

- < 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- > 0.6

- Yarrabilba Site Boundary
- Precinct Boundary

N W E S

Scale:
1 : 15,000 (A3)

FIGURE D3

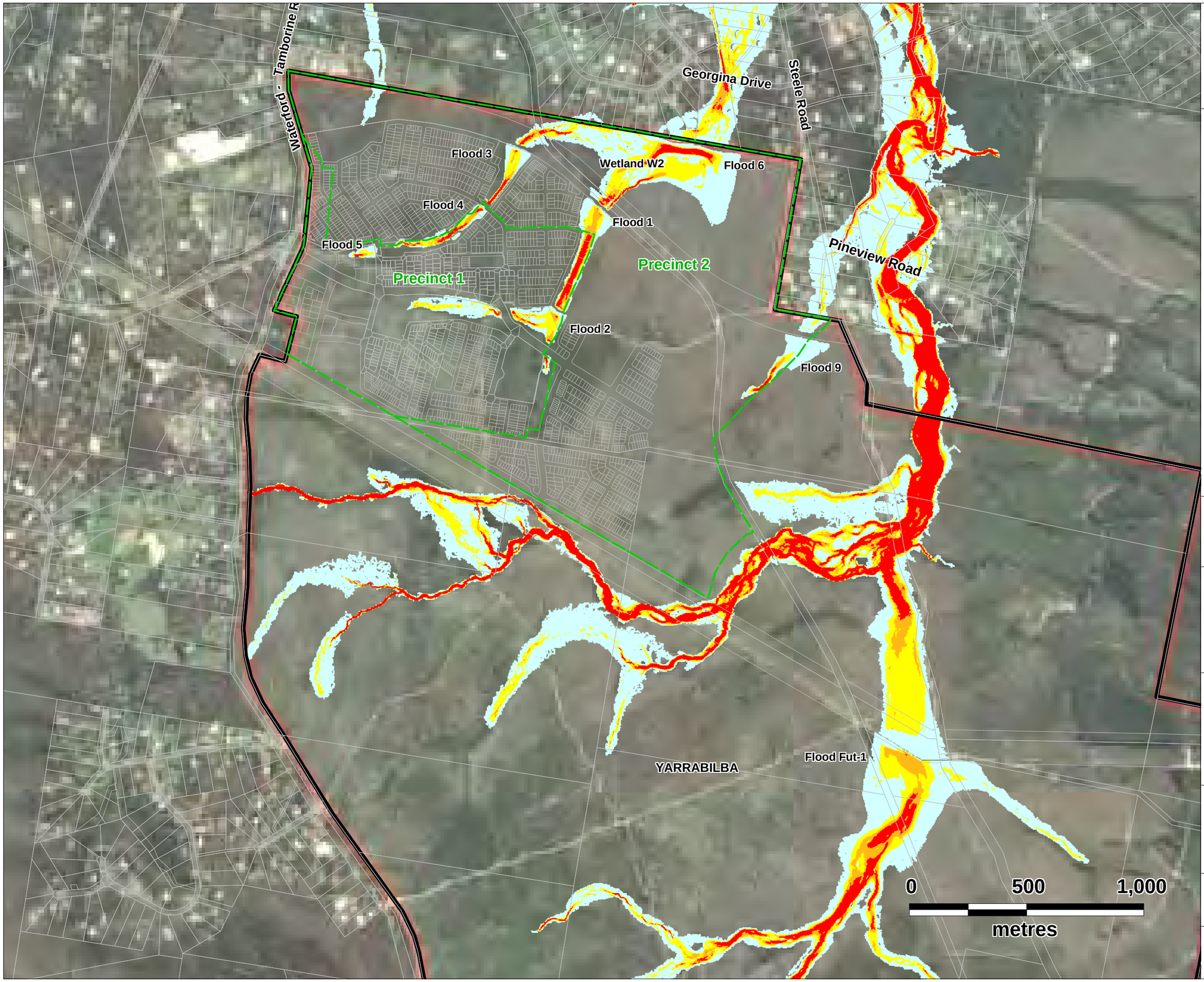
Post-Development (Mitigated)
20 year ARI Velocity x Depth

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease



DesignFlow

LEGEND

Velocity x Depth (m2/s)

- < 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- > 0.6

- Yarrabilba Site Boundary
- Precinct Boundary

N W E S

Scale:
1 : 15,000 (A3)

FIGURE D4

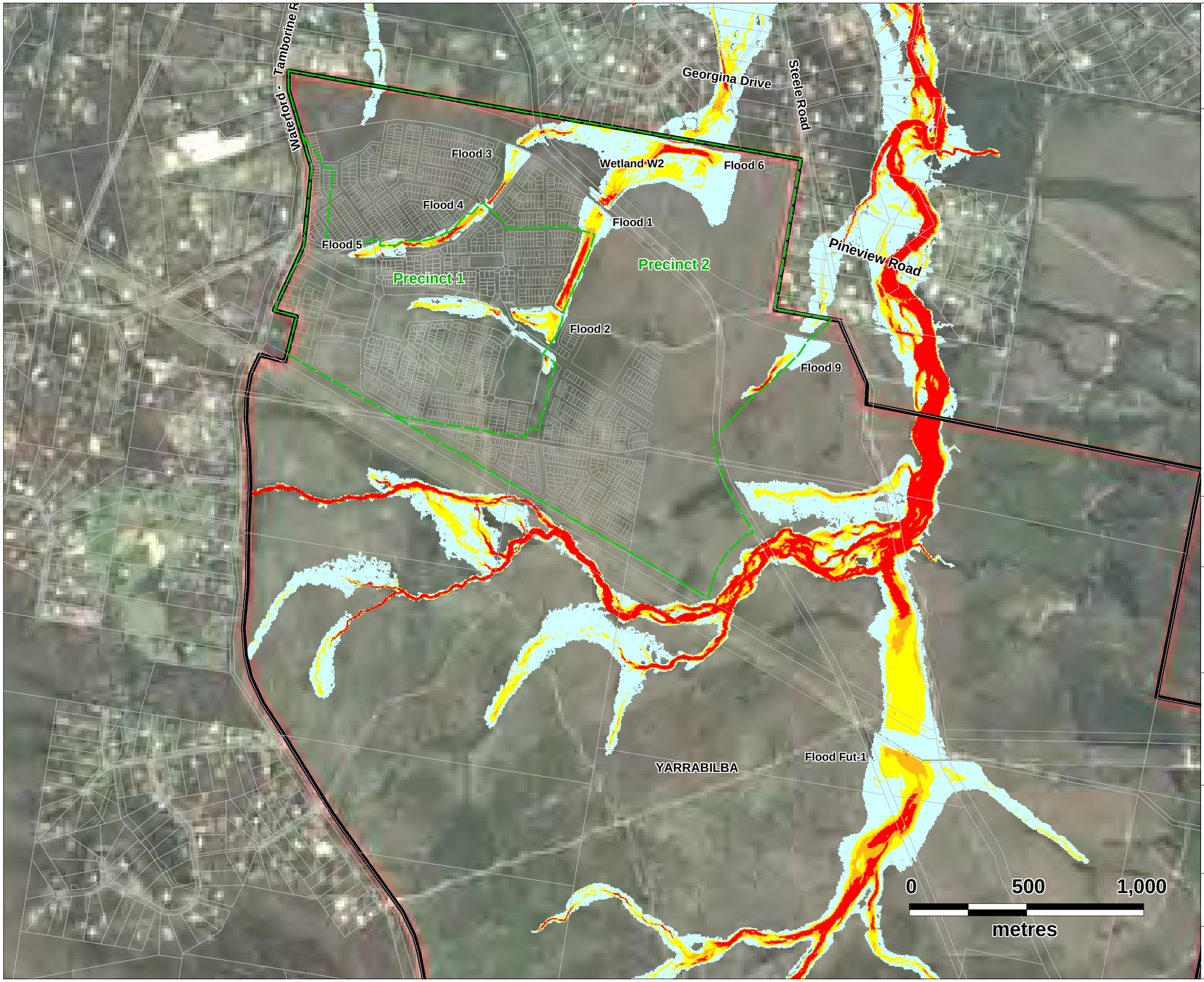
Post-Development (Mitigated)
100 year ARI Velocity x Depth

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease



DesignFlow

LEGEND

Velocity x Depth (m2/s)

- < 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- > 0.6

- Yarrabilba Site Boundary
- Precinct Boundary

N W E S

Scale:
1 : 15,000 (A3)

FIGURE D5

Post-Development (Mitigated)
Blockage Scenario
100 year ARI Velocity x Depth

Project: 4205

Yarrabilba Precinct 1 and 2
Stormwater Management Plan

Date:
28 July 2014

Client:
Lend Lease

APPENDIX E: REVIEW OF COUNCIL FLOOD MODEL AND DATA

Our Ref: projects/4239

DesignFlow

Rob Ball
Lend Lease Communities (Yarrabilba)
PO Box 1512
Milton QLD 4064

24 April 2014

Dear Rob

Re: Quinzeh Creek Regional Flood Model

Following receipt of the Quinzeh Creek Flood Model information from Logan City Council in mid-March, we have been working to ensure that these models are suitable for use in assessing Lend Leases requirement to achieve no worsening of flood impacts from pre to post development. Unfortunately, Council's models fall short of being able to be used directly for Yarrabilba site assessment for a number of reasons. Please find below a brief summary of our main concerns relating to Councils models with options for moving forward with the regional modelling approach to ensure development is not delayed by this process. The specific review of Council's model information relates to the following:

- **WRM RAFTS (hydrologic) model** (covering total Quinzeh Creek catchment)
- **Engeny RAFTS (hydrologic) model** (providing inputs to Engeny Tuflow model)
- **Engeny Tuflow (hydraulic) model** (covers a 3km reach and two tributaries of Quinzeh Creek mid-catchment only)

1. WRM RAFTS model

The WRM RAFTS model covers the total Quinzeh Creek catchment. We understand the work was completed to establish RAFTS modelling parameters and to broadly assess the potential impact of the Yarrabilba development on peak 100 year ARI discharges in Quinzeh Creek at its downstream end. The model was based on the Logan River RAFTS model developed by Engeny as part of the Logan-Albert Flood Modelling and Mapping Study 2011 (Engeny, 2011) but uses only the Quinzeh Creek portion of this larger model. Sub-catchment areas, slopes and channel routing/lagging parameters were adopted directly from the Engeny (2011) study. WRM then modified catchment roughness (PERN), initial/continuing losses and storage coefficients to validate the RAFTS model to a single location at the downstream end of the Quinzeh Creek catchment.

Priority concerns with WRM RAFTS model:

- Design rainfall data inconsistent with subsequent Engeny RAFTS model (2013)
- Assumption that Yarrabilba site (as existing case) is 'forested' rather than historically cleared

- Slope errors within 3 Yarrabilba sub-catchments (in the order of 4 to 6 times higher than actual)

- Channel routing K and X parameters were adopted for the catchments but remained fixed for all storm events and durations meaning routing in the 1-2 year ARI design storm is the same as the 100 year ARI storm event which is not correct.

- Use of single sub-catchment approach to developed case modelling (as opposed to recommended split impervious/pervious sub-catchment approach)

- Rational Method validation approach has a number of issues with the key ones listed below:

    - Model assumptions (specifically channel slope and runoff coefficients) that do not reflect the physical attributes of the Quinzeh Creek catchment.

    - Validation of modelled existing and developed case flows (for design events from 2 to 100 year ARI) at single location at the low end of the catchment (this concern is compounded by previous dot points).

    - Recognition in WRM report (September, 2013) that Rational Method validation parameters are not applicable at the sub-catchment scale.

- Reporting of 'validated' flows at locations in the mid-catchment (near Yarrabilba site boundary) that are not based on the critical storm duration at these locations (90 minute and 120 minute durations missing from model).

Additional issues are summarised in Table 1 attached. The overall outcome of these model assumptions is the underestimation of peak flows from the Yarrabilba site under existing (pre-development) conditions. This creates unrealistically high post development flood detention volumes to achieve no-worsening.

As noted in the last dot point above, WRM recognised that parameters validated at a sub-catchment scale would not match the catchment-wide scale validation. Despite this, the WRM recommendations were adopted for the Revised Quinzeh Creek Flood Study (Engeny, 2013) which was used for detailed flood mapping and calibration at locations in the mid catchment, just downstream of the Yarrabilba site boundary. This is discussed further in the following sections.

2. Engeny RAFTS Model

The Revised Quinzeh Creek Flood Study (Engeny, 2013) was undertaken to improve the accuracy of the flood mapping within parts of Quinzeh Creek catchment based on updated RAFTS hydrology and Tuflow hydraulic modelling. The revised study drew on the previous WRM (2013) hydrological assessment (discussed above) as well as flood data collected from the January 2013 event.

Priority concerns with Engeny RAFTS Model:

- Carryover of hydrological data recommendations from WRM (2013) (based on concerns outlined above)

- Design rainfall data inconsistent with WRM RAFTS model

- Channel routing parameters differ from WRM. In this case Engeny used cross sections inserted into the model to calculate the K and X routing factors.

- Sub-catchment slope errors (in Yarrabilba site) carried through from WRM model

- Single pervious initial loss of 39mm applied across total Quinzeh Creek catchment (regardless of existing land use in Yarrabilba and elsewhere in catchment).

- Validation of RAFTS model to Rational Method at Pineview Road based on different initial loss to WRM recommendations (and noting WRMs comment regarding the problem associated with applying their validation to a much smaller sub-catchment scale).

Additional issues are summarised in Table 2 attached. As noted previously for the WRM model, the impact of these model assumptions is the underestimation of existing case peak flows which imposes unrealistically high post development flood detention requirements on Lend Lease to achieve their non-worsening criteria.

The Revised Quinzeh Creek Flood Study letter report (August, 2013) notes that similar design storm flows were achieved to the WRM model when adopting similar model parameters, however, when comparing (for example) the Yarrabilba site, the WRM model uses an initial loss of predominantly 49mm while Engeny uses 39mm across all sub-catchments. **It is difficult to understand how these two modelling approaches can be considered equivalent or comparable when a critical runoff parameter such as initial loss is assumed to be significantly different for the same sub-catchment** (in conjunction with multiple other concerns above), **yet 'similar' peak storm event flows are produced downstream**.

3. Engeny Tuflow Model

The Revised Quinzeh Creek Flood Study letter report (Engeny, August 2013) notes that the detailed Tuflow modelling has been based on recommendations by the WRM (2013) study. This raises some concerns as to the validity of the Tuflow hydraulic outputs given the issues noted previously regarding the WRM hydrologic modelling parameters, validation approach and the carry-over of these into the subsequent Engeny hydrological modelling.

The Engeny Tuflow model is extremely limited in its extent, commencing near the northern boundary of the Yarrabilba site and extending downstream approximately 2km. Thus, it cannot be used (or accurately account for) existing or developed routing of flows through the broad and typically low gradient channels and waterways within the Yarrabilba site. Further, its limited downstream extent means it cannot be used (in current form) to assess pre and post development flow and afflux impacts at locations beyond the current extent (i.e. closer to Logan Village and the confluence with Logan River). This would require extension of the Tuflow model by an additional 5km downstream of the current model boundary.

In summary, concerns with the Engeny Tuflow modelling relate to:

- **The TUFLOW model only covers a small part of Quinzeh Creek** as illustrated in Figure 1. The extent of the model is insufficient for detailed catchment wide assessment of flood for Quinzeh Creek.

- Relies on hydrologic data input from Engeny RAFTS model (refer to concerns raised above)

- The TUFLOW model appears to have some strange water level results around Pineview Road (i.e. standing wave over the road and culverts). This may be caused by the method used by Engeny for inserting flows into the TUFLOW model from RAFTS or by the interaction between the 1D channel and the 2D grid.

- Review of the flood survey information for the January 2013 event provided by Council in GIS format appears to indicate recorded flood levels vary at a number of locations (i.e. a number of different flood levels at Pineview Road). However, as indicated Table 4 of the Engeny letter dated 23 August 2013, Engeny have only presented one flood level at each location. It is not clear how Engeny selected the validation levels they ended up adopting but it is clear there are other recorded levels at the same location which could be used to justify higher flood levels.

Additional issues are summarised in Table 3 attached. Council has adopted this model and produced 100 year ARI flood mapping for Quinzeh Creek, however, in its current form, the Quinzeh Creek Tuflow model does not allow the pre and post development flood impacts of the Yarrabilba site to be sufficiently assessed for the reasons listed above.

4. Conclusions

Based on discussions with Council we were assuming that between WRM and Engeny that a RAFTS and Tuflow model had been established for Quinzeh Creek. Lend Lease would simply adopt this model, with any small refinements for Yarrabilba, and developed a base case flooding condition to allow impact assessment across the **whole catchment**. Based on our review of the Engeny and WRM modelling it is clear that this is not the case for the following reasons:

- The Engeny TUFLOW model extent covers only a small portion of the creek.

- The Engeny RAFTs does not cover the full Quinzeh Creek catchment.

- The RAFTs models produced by WRM and Engeny are not consistent (routing method and initial loss assumption in particular).

Furthermore, our review of the WRM and Engeny RAFTS modelling indicates a number of concerns with the biggest issues being:

- The models do not reflect the current landuse in the Yarrabilba which is cleared or open woodland.

- The initial loss parameters have been justified using Rational Method at a single location. The Rational Method approach appears to have a number of incorrect assumptions (waterway slope and runoff coefficient).

- It is acknowledged by WRM that the RAFTS parameters derived using a Rational Method validation at a single location may/will not apply at a sub-catchment scale (i.e. Yarrabilba).

In our opinion, the flaws in the modelling completed by WRM and Engeny result in an under-prediction of flood flow from the Yarrabilba site. The problem for Lend Lease and Economic

Development Queensland is that Council have used the Engeny RAFTS and Tuflow model to generate a new 100 year ARI flood model for the areas directly downstream of Yarrabilba and presented this to the community. This flood mapping is now public and accepted by the community even though we have concerns with the modelling assumptions and approach (and so do Cardno based on their previous review of Council's models).

In terms of Lend Lease's position we provide the following conclusions:

- The are a number of concerns with the Engeny and WRM modelling of Quinzeh Creek meaning that the current models do not provide a suitable "base case" model of the entire catchment that allows consideration of future development on a sub-catchment basis.

- The Council hydrologic RAFTS parameters appear to conflict between WRM and Engeny, are based on a questionable Rational Method validation approach and do not reflect the existing conditions on Yarrabilba. These parameters should not be directly applied to the Yarrabilba site.

- Lend Lease should not take any responsibility for the modelling completed by WRM, Engeny and Council. The risk associated with their models and any future community and political liability with the flood mapping should be left with Council.

5. Recommended approach for a total Quinzeh Creek Base Case Flood Model

The options identified to allow assessment of Yarrabilba development relative flood impacts for the full extent of the Quinzeh Creek catchment are:

1. Merge DesignFlow, Engeny and WRM models. Council will retain responsibility for the accuracy of the modelling downstream of Yarrabilba and Lend Lease will take responsibility for the accuracy of the modelling within Yarrabilba.

2. Rebuild total Quinzeh Creek hydrologic and hydraulic models

These are discussed briefly below.

OPTION 1 involves rationalising the available data by using the following combined model approach which is illustrated in Figure 2:

(a) Use the existing Engeny Tuflow model (and RAFTS hydrology) for areas downstream of Yarrabilba northern site boundary to current Tuflow downstream boundary (Red area on Figure 1)

(b) Extending Tuflow model from Engeny boundary downstream to Logan River with hydrology based on WRM RAFTS catchment areas and slopes with Engeny generic 39mm/hr loss model (Green area in Figure 1)

(c) Extending Tuflow model upstream from Yarrabilba northern site boundary using Yarrabilba specific catchment data and loss model (Yellow area in Figure 1)

In adopting this approach, Council modelling and data would be retained and/or combined for all areas downstream of Yarrabilba. All sub-catchment areas within and upstream of Yarrabilba would be assessment and modelled based on site specific data and validation and essentially 'fed' into the downstream Council model. By doing so, the relative impacts of pre and post development can be assessed downstream. The Council's flood mapping would therefore only be valid within the Existing Engeny Tuflow model bounds with all Tuflow outputs downstream of here provided only for relative pre and post development 'no worsening' comparison (and not for absolute flood inundation or Council mapping). This approach ensures Council will retain responsibility for the accuracy of the modelling downstream of Yarrabilba and Lend Lease will take responsibility for the accuracy of the modelling within Yarrabilba.

OPTION 2 involves re-doing the WRM and Engeny work to develop a full hydrological (RAFTS) and hydraulic (Tuflow) model that covers the full extent of Quinzeh Creek ensuring that model parameter definition is more detailed and validation/calibration occurs at multiple locations throughout the catchment to verify applicability across all scales of assessment (as recommended in the WRM (2013) report). This represents a significant amount of work (and time) and should ultimately be the responsibility of Council. While Lend Lease may consider undertaking this remodelling approach, this should be with caution due to the ongoing community concerns with flooding in this catchment. The risk of revising current flood inundation mapping is best left to Logan City Council.

On the basis of maintaining as much of Council's data as possible, and in the interest of timing with regard to current development application scheduling, Option 1 is considered to be the most viable approach.

If you have any questions relating to the information provided above, please contact DesignFlow.

Yours Sincerely

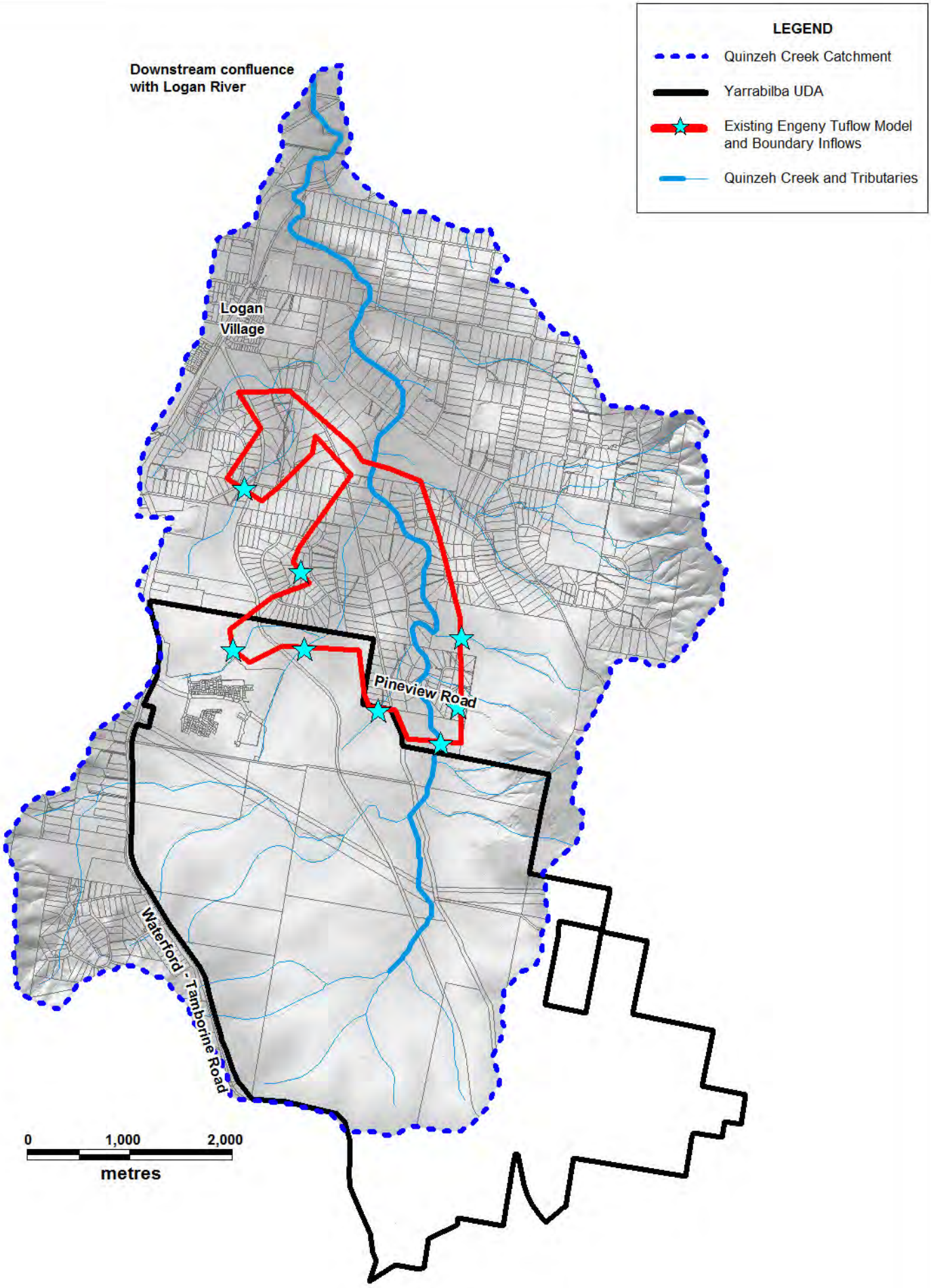


Shaun Leinster

DesignFlow

Attachments:

1. Figure 1: Existing Quinzeh Creek Tuflow Flood Model Extent (Engeny)
2. Figure 2: Proposed Quinzeh Creek Flood Model Extension – Option 1
3. Table 1: WRM Quinzeh Creek RAFTS Model Discrepancies
4. Table 2: Engeny Quinzeh Creek RAFTS Model Discrepancies
5. Table 3: Engeny Quinzeh Creek TUFLOW model Discrepancies



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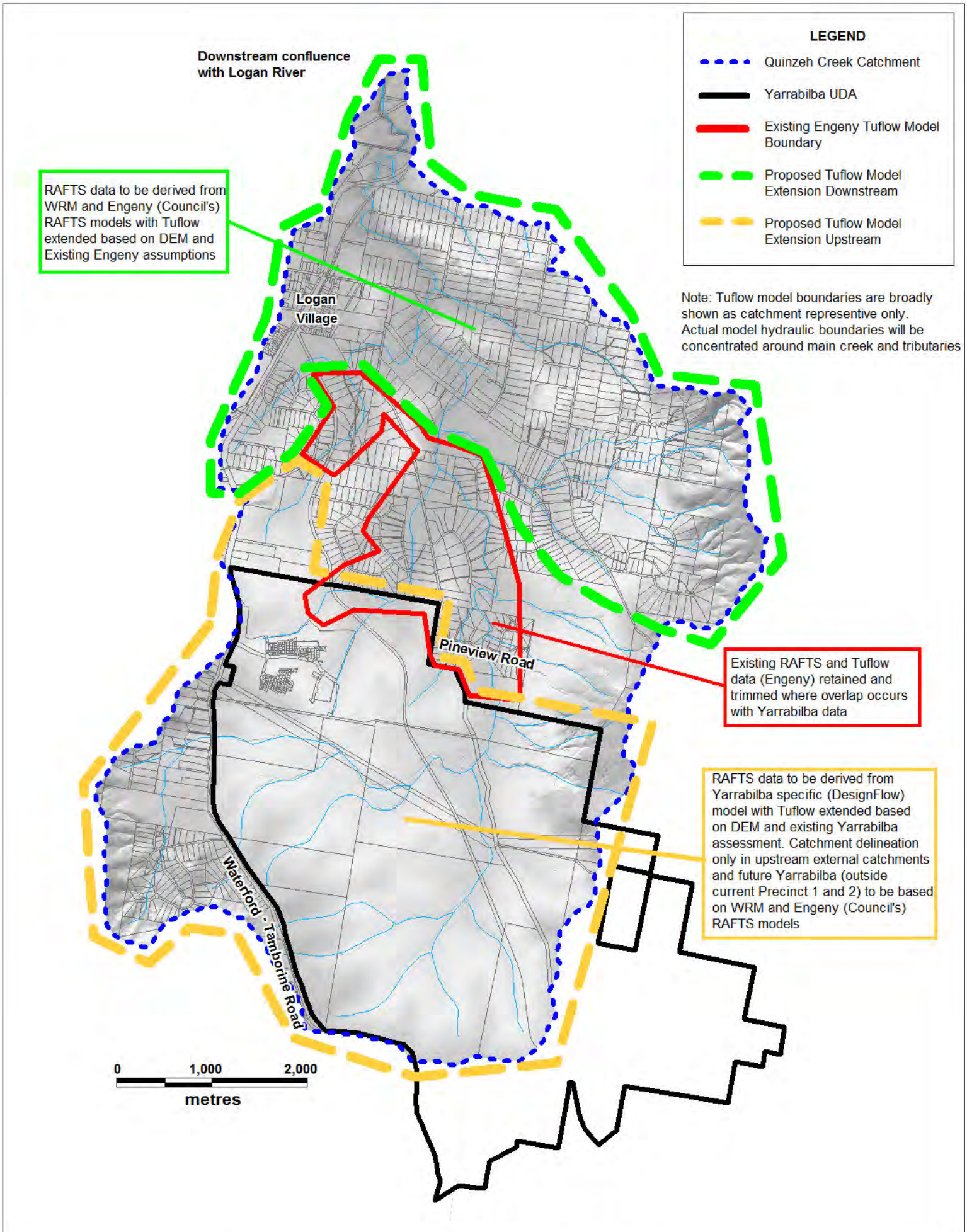
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SCALE:
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Date: 24 April 2014

FIGURE 1
Existing Quinzeh Creek Tuflow Flood Model Extent (Engeny)

Yarrabilba



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N
W E
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SCALE:
1 : 50,000

Date: 24 April 2014

FIGURE 2
Proposed Quinzeh Creek Tuflow Flood Model Extension - Option 1

Yarrabilba

Table 1: WRM Quinzeh Creek RAFTS Model Discrepancies

The items in Table 1 have been identified mainly from a review of the 100 year ARI existing case WRM RAFTS hydrologic model supplied by Council (with reference to other models where relevant). Some issues will carry across all other cases while additional items may arise from lower ARI models or developed case models (which time did not permit full review of). However, the items generally highlight main concerns identified with the method and/or data.

Note: Additional information that has been identified since the original issue of these tables on 24 April, 2014 is shown in *red italics*.

Issue	Comment	Importance
1. Direct input (fixed) values for Muskingum-Cunge K and X adopted from Logan-Albert River flood study (Engeny, 2011)	Does not vary K and X parameters with flow (in different storm durations or ARIs) and therefore not routing flows properly. This has a significant effect on peak flows when assessing a range of storm events in the model, particularly at the lower parts of the Quinzeh Creek Catchment under minor events	High
2. Slopes in catchments 43_N8, 43_N12 and 43_N13 are unrealistic ally high and incorrect.	The modelling of unrealistically steep slopes will result in higher runoff generation which in turn will force over-modification of loss parameters to attempt to match flows when validated against Rational Method.	Moderate
3. IFD data used is different from Engeny model.	While IFD data is typically only 1 or 2mm different, this creates a few cumecs difference at Yarrabilba site boundary and significant differences (~20m3/s in Q100) towards the downstream end of catchment.	High
4. Uses single sub-catchment with % impervious instead of separate sub-catchments for pervious and impervious fractions. Means that rainfall loss model applies to total catchment area (i.e. both pervious and impervious area).	Even though loss model is proportioned according to the % impervious, the routing of rainfall excess from impervious areas is incorrect as it has had full loss model applied to initial rainfall on both surface types. This will be more pronounced where % impervious is higher. (i.e. developed case)	Low (existing) High (Developed)
5. Uses combined PERN (catchment Manning's n) for each sub-catchment (rather than separate	Will not discreetly account for rapid runoff generation from impervious surfaces, particularly in rural residential and developed case.	Low (existing)

pervious/impervious values in the split catchment approach recommended with RAFTS)		High (Developed)
6. Catchments do not have consistent Manning's n (varying between 0.045 – 0.05)	Used as a calibration parameter but along with other catchment parameter errors (as noted in previous points), adjustments to Manning's n values may not be accurate.	Low
7. Validation of Rational Method has occurred at a single point in the catchment some 3.5km downstream from Yarrabilba using very broad catchment and channel assumptions (with some errors as noted above). This has assumed a uniformed channel slope and cross section for full 9.5km channel.	Margin of error in simplifying such a large catchment and channel reach to single parameters results in questionable 'validation'. (see also next item) WRM report acknowledges that this may not be representative of tributary flows at upstream locations which is the point DesignFlow has been concerned about for over 12 months.	High
8. Rational method channel slope assumption of0.2% (for entire catchment) is much lower than the majority of the 9.5km flow path	A flow path assessment from WRMs RAFTS model (using average reach velocity) found travel time over ~9.5km longest flow path to be ~125min for the Q100 (using model calculated Muskingum-Cunge parameters rather than the direct input parameters used by WRM). This is considerably faster than the Rational calculations for all land uses provided in the WRM report (Sept, 2013). This would indicate that the Rational Method is under estimating peak flow and that the existing case RAFTS model is being 'validated' against these under estimated flows.	High
9. The assumption that Yarrabilba site is forested is not considered appropriate given the historical clearing and subsequent use as a military camp then a pine plantation.	The existing case model should be revised to reflect relevant land use (historically) for Yarrabilba. This will inevitably result in higher modelled pre-development flows from Yarrabilba catchments, but may also impact the 'validated' catchment parameters for the balance of the Quinzeh Creek catchment.	High
10. No clear data is provided which clarifies the % impervious assumed for the rural residential land use. Thus, the IL/CL model is simply applied to the total sub-	As per previous comments, the over simplification of pervious portions of the catchment has implications for the Yarrabilba site when comparing the re and post development flows.	Low (existing)

catchment area rather than the pervious/impervious fractions separately.		High (Developed)
11. Adopting 19mm IL for low density residential (40% impervious) is equivalent to applying ~31mm IL to the pervious fraction of the site and 0mm IL to the impervious fraction (i.e. 19mm divided by 60%), but does not account for the different surface routing of these different surface types	See previous comment	
12. No 90 or 120 minute storms are included in RAFTS model which are critical for the Yarrabilba site under existing conditions.	The peak flows from Table 4.3 (for. Reporting Location 4) of WRM report for 'Existing conditions' are underestimated as the 90 minute storm produces a higher peak (by about 5%).	High
13. Storage coefficient 'Bx' assigned as 1.2	Based on the errors above and the validation of the existing model (with errors) to the Rational method, the Bx parameter may require review following error resolution. *Without flow gauging data, there is little justification in modifying the Bx parameter in RAFTS*	Low/ Moderate
14. Routing increment is 10 minutes	Differs from Engeny which uses 1 minute	

Table 2: Engeny Quinzeh Creek RAFTS Model Discrepancies

The items in Table2 have been identified mainly from a review of the 100 year ARI existing case Engeny RAFTS hydrologic model supplied by Council (with reference to other models where relevant). Some issues will carry across all other cases while additional items may arise from lower ARI models or developed case models (which time did not permit full review of). However, the items generally highlight main concerns identified with the method and/or data.

Note: Additional information that has been identified since the original issue of these tables on 24 April, 2014 is shown in *red italics*.

Issue	Comment	Importance
1. RAFTS model does not extend to downstream end of catchment	Unable to use for hydrological input to an extended Tuflow model *to cover the entire Quinzeh Creek extent*	High
2. Engeny sub-catchment names vary (in parts) to WRM RAFTS model	Confusing to compare models and data even though the reports state that one model was based on the other	Low
3. IFD data varies from WRM model	Impacts runoff and peak flow and therefore affects the 'validation' of model parameters to these peak flows	High
4. Uses model calculated K and C values for link routing (in contrast to WRM which uses fixed direct input values)	Model calculation is preferred method to the WRM approach as it accounts for variations in flow with different storm durations and ARIs.	High
5. Applies area weighted IL=39mm across total catchment to represent all land use types and attempts to reflect WRM derived losses of 49mm & 28mm for forested and rural res respectively	Results in the Yarrabilba site being modelled with two very different loss models for the WRM vs Engeny modelling while still arriving at 'comparative' flows at downstream reporting nodes. This highlights the inconsistency between the RAFTS models. How can the same flow be delivered when the IL is different.	High
6. Uses 1mm continuing loss model for channel links	Continually removes flow from the model (albeit relatively small) *which has not been specifically justified and may impact flow validation, particularly in minor events.*	Low

7. The Engeny model calibration to the January 2013 event was only undertaken for a very small number of locations compared to what was available *from the flood survey undertaken by Council*	This may bias the calibration to those sites which conveniently matched the model. For example there are a number of higher flood levels a Pineview Road than the one selected for validation.	~~High~~ *moderate*
8. Node N2 (BC) has area (96.89ha) equal to catchment N2 in Mapinfo. However, an additional catchment N2A(SA) (51.11ha) is also included downstream of N2(BC) but unable to determine where this catchment area was derived from.	Edit: Node N2A(SA) is actually a portion of catchment N1 with the 51.11ha being that portion of N1 (total 133.8ha) which is upstream of Pineview Road culverts. However, the balance area of N1 in RAFTS is given as 71.6 ha which does not equate to 133.8 – 51.11 (=82.69ha). Therefore, catchment N1 has been underestimated in Engeny RAFTS by 11ha.	High
9. Routing increment is 1 minute (compared to WRM 10 minutes)	Yet to be tested	
10. Catchment N2A (SA) loss model	*Catchment N2A (SA), which inputs flow directly upstream of Pineview Road, uses an impervious loss model (IL = 0, CL=1) over the entire 51.11ha forested / rural residential catchment existing case. This will significantly over-estimate the peak flows for all events at Pineview Road (affecting the validation of higher initial losses from Yarrabilba site).*	*High*
11. Calibration event (January 2013) rainfall data and routing increment	*The January 2013 rainfall data (72hrs) appears to be lumped into 3 hour blocks (despite rainfall being recorded in smaller intervals in the Enviromon system) and modelled with 3 hour routing increment. This routing increment would be expected to poorly represent rainfall-runoff generation from the catchment, particularly given this data was used to 'calibrate' the catchment parameters for Quinzeh Creek.*	*High*

Table 3: Engeny Quinzeh Creek TUFLOW model Discrepancies

The items in Table 3 have been identified mainly from a review of the 100 year ARI existing case Engeny Tuflow model supplied by Council (with reference to other models where relevant). Some issues will carry across all other cases while additional items may arise from lower ARI models or calibration case models (which time did not permit full review of). However, the items generally highlight main concerns identified with the method and/or data.

Note: Additional information that has been identified since the original issue of these tables on 24 April, 2014 is shown in *red italics*.

Issue	Comment	Importance
1. Model extent does not cover full catchment	Limits the use of Council's model for comparing flow and afflux impacts all the way down the catchment (without significant additional work to extend model) as well as not appropriately accounting for upstream channel attenuation (from Yarrabilba site)	High
2. RAFTS model hydrological input data quality and validation approach	The issues raised previously with regard to the Engeny RAFTS model previously translate into calibration of flood levels based on questionable hydrological data	High
3. Calibration of surveyed flood debris locations to the model only occurs in a very select small number of locations locally around Pineview Road and ignores others further downstream at Steel Road	This may bias the 'calibration' to sites where the water levels conveniently match the model	~~High~~ *Moderate*
4. No sensitivity testing for peak flow calibration location combined with relatively steep and wide water surface profile (from results plots received) at Pineview Road	Potentially lower/higher flow may be likely for very small difference in water surface level, therefore increasing margin of error for calibrated flow/parameters	High
5. The Q100 Logan River WSE results provided by Council (Tuflow) indicate that the Q100 (72hr) backwater from the Logan River dominates tailwater levels right up the catchment to just above Quinzeh Creek Road. However,	To be reviewed further,	TBA

the local event is dominated by the 3 hour event at which the Logan River levels are not influencing		
6. The inflow polygon associated with RAFTS catchment (node) N2A(SA) is very large and random in shape. Cannot determine impact on flows of this arrangement, particularly given it is adjacent to the 'calibration' location at Pineview Road.	May impact the input of flows to the hydraulic model 2d cells. To be assessed further,	Low (overall) Moderate (for calibration location)
7. Calibration event (January 2013) rainfall data and routing increment	*The January 2013 rainfall data (72hrs) in RAFTS appears to be lumped into 3 hour blocks (despite rainfall being recorded in smaller intervals in the Enviromon system) and modelled with 3hr routing increment. This routing increment would be expected to poorly represent rainfall-runoff generation from the catchment, particularly given this data was used to 'calibrate' the catchment parameters for Quinzeh Creek. The use of this data in Tuflow is then questionable in terms of accurately representing the hydrology of the catchment*	*High*
8. Flood inundation mapping in vicinity of Yarrabilba Site Boundary not based on local critical duration	*The flood inundation mapping in the vicinity of the Yarrabilba site boundary appears to be based on the 3 hr critical duration event whereas the actual critical duration here is in the order of 1.5-2 hrs (existing case). This means that Council's flood mapping is less than what the critical event will cause.*	*High* *(although flood levels may not change significantly)*

APPENDIX F: JANUARY 2013 EVENT SENSITIVITY TEST (ENGENY)

From: Mark Page [mailto:Mark.Page@engeny.com.au]
Sent: Friday, 7 February 2014 5:20 PM
To: Rob.Ball@lendlease.com; Shaun Leinster; Nic Smith
Cc: Khairul Alam (khairulalam@logan.qld.gov.au); (KamalRanaweera@logan.qld.gov.au); Michael Howe
Subject: Quinzeh Ck Sensitivity Analysis - Initial Loss

Rob/Shaun,

As requested, Engeny has undertaken a sensitivity analysis on the initial loss (IL) for the Quinzeh Creek RAFTS model whereby the IL has been adjusted for the January 2013 event from 38 mm (area weighted loss) to 5 mm, 30 mm and 49 mm for the entire catchment. As expected, the IL has little impact on catchment flows for the 2013 event including peak flows and associated timing of peaks. An increase in peak flow of 0.13 % was observed at the downstream extent of the model (near Quinzeh Ck Rd) when comparing modelled flows for the 5mm IL and 49mm IL scenarios. This analysis confirms that the initial rainfall loss has negligible impact on results for the historical 2013 flood event. A summary of results is provided below and the reporting locations are shown in the attached figure.

Summary of Results

Location	Existing (IL 38mm) Peak Flow (m^3/s)	Time of Peak	Sensitivity (IL 5mm) Peak Flow (m^3/s)	Time of Peak	Sensitivity (IL 30mm) Peak Flow (m^3/s)	Time of Peak	Sensitivity (IL 49mm) Peak Flow (m^3/s)	Time of Peak
Georgina Dr	10.46	27/01/2013 15:00	10.47	27/01/2013 15:00	10.47	27/01/2013 15:00	10.46	27/01/2013 15:00
Pineview Rd	2.67	27/01/2013 15:00	2.67	27/01/2013 15:00	2.66	27/01/2013 15:00	2.67	27/01/2013 15:00
Confluence DS Pineview Rd	72.29	27/01/2013 18:00	72.39	27/01/2013 18:00	72.39	27/01/2013 18:00	72.26	27/01/2013 18:00
Quinzeh Ck Confluence	96.47	27/01/2013 18:00	96.57	27/01/2013 18:00	96.57	27/01/2013 18:00	96.45	27/01/2013 18:00

Please don’t hesitate to contact me should you have any queries.

Regards,

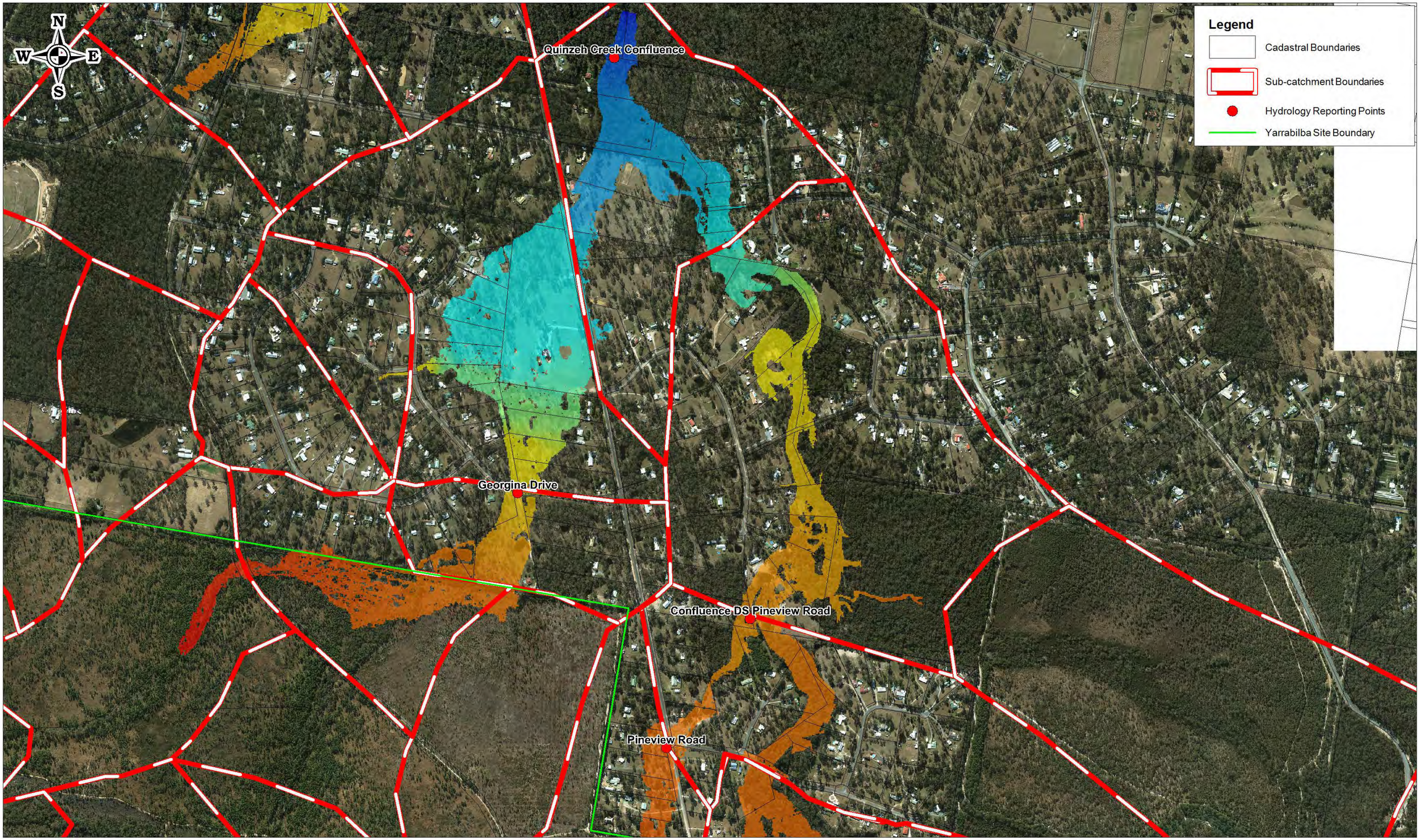
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ENGENY WATER MANAGEMENT

0 200 400

Scale in Metres (1:10,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 56

Quinzeh Creek Hydrology

Figure 1

Sensitivity Analysis - Initial Loss

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Drawn: MH
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