Upper South Creek Floodplain Risk Management Study and Plan

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Foreword

The NSW Government Flood Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following steps in the floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

   Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

   The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

   Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

   Evaluates management options for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

   Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

   Implementation of actions to manage flood risks for existing and new development.

This Floodplain Risk Management Study is in step 4 following the adoption of the Flood Study in 2012. This Study was prepared by Cardno for Camden Council, and was jointly funded by Council and the Office of Environment and Heritage.

Executive Summary

Cardno was commissioned by Camden Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Upper South Creek Study Area. This FRMSP has been prepared to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. It has been prepared in accordance with the NSW Government Floodplain Development Manual (2005).

The Study Area is in the upper catchment of South Creek from its headwaters down to Bringelly Road, being the boundary between the Camden and Liverpool LGAs. South Creek is the major waterway in the Study Area and its tributaries include Rileys Creek, Thompsons Creek, Lowes Creek, Kemps Creek, Scalibrini Creek and Bonds Creek.

The topography is low relief with undulating hills, broad floodplains and soft ridges lines. The waterways are typically open natural channels incised or excavated into depressions of the broad floodplain. Land use is in a state of transition from the historic rural residential uses to dense urban development. Urban development is generally undertaken on a precinct scale under the South West Growth Corridor strategy of the NSW state government. A key challenge of floodplain risk management is to identify the likely impact, if any, as a result of precinct development both for the Study Area and lands downstream of Bringelly Road.

The Flood Study of 2012 defined flood behaviour in the Study Area under existing conditions without consideration of the ongoing urban development in precincts such as Oran Park and Turner Road. The TUFLOW model prepared for the Flood Study was updated in this project to represent an Interim Development Scenario. The key changes made to the model were:

- Inclusion of the Bringelly Road upgrade design.
- South West Rail Line (SWRL) TUFLOW model DTM for ground topography of Kemps, Scalibrini and Bonds Creeks in addition to 1D elements of the bridge crossings.
- Upgrade of Camden Valley Way (CVW) at Rileys Creek.
- Addition of Bonds Creek to the Study Area which was not included in the Flood Study.
- Replication of urban development of the SWGC precincts Turner Road, Catherine Field, Leppington North and Oran Park by reducing initial loss, adjusting roughness and filling. The filling components involved delineation of the urban development extents that encroach onto the floodplain together with removal of farm dams. Significant regional storage facilities were retained in the model as shown in the flood maps.
- Inclusion of the Leppington Precinct (Preliminary Rezoning Phase) by reducing initial loss and adjusting roughness. No filling of the floodplain was included in this precinct.

The flood study based the initial water levels in the large farm dams on levels taken from the LiDAR data. As such, the dams were not a full supply during the original flood study runs, resulting in additional storage being available. In the current study, the dams were assumed to be full at the start of the storm event, in order to define the peak flood levels for the study area.

A significant flood event within the study area occurred in June 2016. The updated model, including the full farm dams, was used to model this rainfall event. The results showed a strong correlation with post-flood survey levels, which indicated that the updated model is accurately defining flood behaviour for the region.

An assessment was undertaken on the number of properties to be affected under different frequency storm events, as well as an estimate of the appropriate economic damage for that event. The following table summarises these results.

Table i Flood affected properties and damages under existing conditions

Flood Event	Properties with over-floor flooding	Properties with over-ground flooding	Flood Damages
5% AEP	51	66	$1,663,520
2% AEP	54	69	$1,850,554
1% AEP	57	72	$2,006,406
0.5% AEP	73	86	$2,602,236
0.2% AEP	75	91	$2,824,962
PMF	129	137	$6,108,345
Average Annual Damage			**$890,794**

Options to reduce or manage the effects of flooding in the catchment were investigated, and recommendations of a mix of strategies to manage the risks of flooding were developed.

Under the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (NSW Government, 2005), and in consultation with the community, Council and stakeholders, a number of potential options for the management of flooding and/or the associated risks to life and property were identified.

These options included:

- Flood modification measures
- Property modification measures
- Emergency response measures

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social). Hydraulic modelling of some of the flood modification options was undertaken to provide a comprehensive analysis of those options that would involve significant capital expenditure.

The following options were ranked as the top 10 and should be considered for further assessment and / or implementation:

Non-Structural Measures:

- P2 Building and Development Controls
- P1 LEP Update
- EM2 Preparation of Local Flood Plans and update of DISPLAN
- EM4 Public awareness and education
- EM1 Information transfer to SES
- EM5 Flood warning signs at critical locations

Structural Measures:

- FM7 Increase Regional Storage - Rileys Creek
- FMa Combination of FM2 and FM3
- FM1 Raise Masterfiled Street Levee – Rossmore

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring is not "absolute" and the proposed scoring and weighting should be reviewed in light of any additional future information.

Table of Contents

Appendices

Tables

Figures

In Report Body

In Attached Figures

1 Introduction

Cardno was commissioned by Camden Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Upper South Creek Study Area. This FRMSP has been prepared to refine the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. It has been prepared in accordance with the NSW Government Floodplain Development Manual (2005).

The Study Area is in the upper catchment of South Creek from its headwaters down to Bringelly Road, being the boundary between the Camden and Liverpool LGAs. South Creek is the major waterway in the Study Area and its tributaries include Rileys Creek, Thompsons Creek, Lowes Creek, Kemps Creek, Scalibrini Creek and Bonds Creek. **Figure 1.1** shows the general location of the Catchment and has a total area of 71km^2.

The topography is low relief with undulating hills, broad floodplains and soft ridges lines. The waterways are typically open natural channels incised or excavated into depressions of the broad floodplain. Land use is in a state of transition from the historic rural residential uses to dense urban development. Urban development is generally undertaken on a precinct scale under the South West Growth Corridor strategy of the NSW state government. A key challenge of floodplain risk management is to identify the likely impact, if any, as a result of precinct development both for the Study Area and lands downstream of Bringelly Road.

The Flood Study of 2012 defined flood behaviour in the Study Area under existing conditions without consideration of the ongoing urban development in precincts such as Oran Park and Turner Road. The TUFLOW model prepared for the Flood Study was updated in this project to represent an Interim Development Scenario. The initial levels in the regional farm dams were also revised so that the dams were modelled as full at the start of the storm event. The updated model was run for the 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP events and the Probable Maximum Flood (PMF).

The study area experienced a flood event in June 2016, which was used to validate the updated model, and the dam full assumption. The full assessment is presented in **Appendix B**. The assessment found that the updated model and dam full assumption showed a good correlation with the post-flood surveyed levels, with all model results within 0.2m of the surveyed levels.

1.1 Study Objectives

The overall objective of this study is to assess flooding risk, investigate flood mitigation options and develop a draft floodplain risk management plan that addresses the existing, future and continuing flood risk in Upper South Creek, in as detailed in the NSW Floodplain Development Manual (2005).

Objectives of the Floodplain Risk Management Study and Draft Plan are to:

- Update the hydraulic model within the study area for the full range of flood events under an Interim Development scenario, including flood flows, levels, depths, velocities, flood hazard extents, and hydraulic categories. The TUFLOW model of the Flood Study is to be updated for 5%, 2%, 1%, 0.5% and 0.2% AEP events and the Probable Maximum Flood (PMF).
- Update flood maps for the Study Area for the Interim Development scenario
- Review Council's existing planning policies and instruments of both Council and the state government.
- Identify works and measures aimed at reducing the social, environmental and economic impacts of flooding, over the full range of potential flood events.
- Evaluate the effectiveness of these works and measures for reducing the effects of flooding on the community and development.
- Examine and recommend measures to improved community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Prepare specific Development Controls for implementation in all types of development in the Study Area that can be integrated into state and local government planning instruments

1.2 Report Outline

In order to achieve the objectives above, the report is outlined as follows:

- Community consultation (**Section 3**);
- Environmental and social characteristics of the catchment (**Section 4**);
- Defining the existing flood behaviour, including flood levels, depths, velocities, hazard zones and hydraulic categories (**Section 5**);
- Assessment of economic impact of flooding (**Section 6**);
- Review of current emergency response arrangements (**Section 7**);
- Review of development controls (**Section 8**);
- Assessment of floodplain risk management options (**Section 9**);
- Economic assessment of options (**Section 10**);
- Multi-criteria assessment of options (**Section 11**); and
- Floodplain risk management plan (**Section 12**).

2 Data Collation and Inputs to the Study

2.1 Previous Reports

The Flood Study Report was prepared by WMAWater in 2012. The Flood Study defined flood behaviour in the Catchment under existing and future climate change conditions for the 5% AEP, 2% AEP, 1% AEP, 0.2% AEP and 0.5% AEP events and the Probable Maximum Flood (PMF).

A direct rainfall method was used in the TUFLOW software to estimate the flood behaviour of flows, peak water levels, peak depths and peak velocities for a range of storm events. The provisional hazard and hydraulic categories were determined for mainstream flooding in the catchment. Hydraulic structures included in the model were assumed to be 50% blocked throughout the Study Area. An in depth sensitivity analysis was undertaken to test the impact of:

- +/- 25% roughness
- 0% blockage and 100% blockage
- +/- 0.5m downstream boundary level
- change in infiltration (15mm/hr initial loss & 3mm/hr continuing loss, 1.4mm/hr initial loss & 1mm/hr continuing loss)
- + 5% impervious
- climate change (10%, 20% and 30% increase in rainfall intensity)

The 2012 Flood Study formed the basis for this Floodplain Risk Management Study.

2.2 Planning Documents

The Local Environmental Plan and Development Control Plan for the Study Area are reviewed in **Section 8**. The Local Flood Plan is reviewed in **Section 7**.

2.3 Available Data

The 2012 Flood Study is the basis for preparing this Floodplain Risk Management Study. Additional information for developing the flood models is described in **Section 5**.

3 Community Consultation

3.1 Community Questionnaire

In August 2012, Cardno distributed brochures and surveys to the local residents and land owners within the Upper South Creek Catchment in order to gain an understanding of the flooding issues that they may have experienced. A total of 1170 brochures and surveys were distributed, of which Cardno received 260 responses (approximately 22%).

The responses indicated that 44% of residents had experienced flooding in the catchment; however a relatively high number indicated that the flood didn't affect them and the comments emphasized that they did not think flooding would affect them in the future.

The least preferred floodplain management options were stormwater harvesting, such as rainwater tanks, levee banks and diversion of creeks and channels, as summarised in **Table 3-1**. The most preferred options involve the improvement of existing flowpaths and the augmentation of culverts/bridges.

The community indicated that their preferred option to stay informed and to give feedback and input would be through mail outs to all residents / business owners in the study area

Table 3-1 Mitigation Option Responses

Option	Proportion of Supporting Comments Received
Stormwater Harvesting	56%
Retarding or detention basins	67%
Improved flood flow paths	88%
Culvert / bridge / pipe enlarging	83%
Levee banks	55%
Diversion of creeks and channels	53%
Environmental channel improvements	89%
Planning and flood related development controls	77%
Education of community	63%
Flood forecasting, warning, evacuation planning and emergency response	62%

3.2 Public Exhibition

A draft of this Floodplain Risk Management Study was publicly exhibited from October to November 2018 to invite comments from the community and stakeholders. The Floodplain Risk Management Study & Plan was placed on the Council website, and weekly local newspaper advertisement were placed in community pages, commencing from 30th October during the exhibition period, to inform the community of the exhibition.

Community members were invited to view the plan and indicate the extent of their support for the plan. Community members were also able to provide comment on which options they support, which options they do not support and whether there were any other flood affected areas that had not been addressed in the plan. Written submissions from the community were requested to be received by close of business 23rd November 2018, no public submissions were received before this time period. One telephone enquiry on flood behaviour (flood extent and flood levels) changes on a property, compared to the Flood Study adopted in 2011 was received after close of exhibition. There were no changes to the flood behaviour on this property as a result of the Floodplain Risk Management Study.

4 Social and Environmental Characteristics

Environmental and social characteristics of the study area may influence the type and extent of flood mitigation options able to be implemented. Environmental characteristics, such as habitats, threatened species, topography and geology are constraints of structural flood mitigation sites.

Social characteristics such as housing and demographics may impact the communities response to flooding and therefore affect the type of flood mitigation options proposed.

The following environmental and social characteristics have been considered in the assessment:

- Social Characteristics;
- Topography;
- Geology and Soils;
- Contaminated land and licenced discharges;
- Flora and Fauna; and
- Aboriginal and Non-Aboriginal Cultural Heritage.

4.1 Social Characteristics

A knowledge of demographic character assists in the preparation and evaluation of management options which are appropriate for the local community. For example, the data is relevant in the consideration of emergency response or evacuation procedures as information may need to be presented in a range of languages or special arrangements made for less mobile members of the community.

The demographic characteristics of the Upper South Creek catchment presented in this report are based on suburbs of Bringelly, Rossmore, Leppington, Oran Park, Catherine Field, Harrington Park, Kirkham and Cobbitty. Due to the small population size, limited information was available for Gregory Hills and Smeaton Grange. There was no data available for Gledswood Hills. Population and income data was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census. The data was then aggregated to produce an overall summary for the region of interest.

In summary, the data revealed that:

- The Upper South Creek catchment population is typical of the NSW population, with the median age of 34. The region has quite a low proportion of people aged over 60 (**Table 4-1**). This results in a community who may be able to assist with emergency responses and evacuation during a flood event.
- In the Upper South Creek catchment, 73.9% of people were born in Australia. The most common countries of birth outside of Australia were England 3.1%, Italy 2.8%, China 2.1%, Malta 2.1% and Lebanon 2.1%. Indigenous (Aboriginal and Torres Strait Islander) people comprised of 1.4% of the region's population.
- English was the only language spoken in approximately 72.7% of homes in the Upper South Creek catchment. The remainder of languages spoken at home included Italian, German, Serbian, Hindi, Maltese, Tamil, Croatian, Cantonese, Mandarin, Spanish and Greek (**Table 4-2**).
- The average median weekly income for individuals in the region was $621, compared to the NSW average of $561. This trend of slightly above average income for the region compared to the NSW average was also evident for family and household incomes (**Table 4-3**). This may have implications for the economic damages incurred on property contents during a flood event (**Section 6**).
- The median house price is $509,930 (www.realestate.com.au, 2013), compared with a median property price for houses in NSW of $460,000 (APM, 2013). The median unit price is $367,815 (www.realestate.com.au, 2013), compared with a median unit price of $375,000 (APM, 2013). This information has implications for the economic damages incurred during a flood event (**Section 6**).

Table 4-1 Age Structure of Upper South Creek Catchment (ABS, 2011)

Age Group (Years)	Persons in Upper South Creek	% of total persons in Upper South Creek	% of total persons in NSW
0-9 years	2824	15%	12.9
10-19 years	3024	16%	12.7
20-29 years	2091	11%	13.3
30-39 years	2411	13%	13.9
40-49 years	2782	15%	14
50-59 years	2421	13%	12.9
60-69 years	1693	9%	10
70+ years	1113	6%	10.3
TOTAL	18,359	100	100

Table 4-2 Languages Spoken at Home in Upper South Creek Catchment (ABS, 2011)

Languages Spoken at Home	% of total homes in Upper South Creek Catchment	% of total homes in NSW
English Only	72.7	72.5
Italian	5.9	1.2
Maltese	2.2	0.2
Arabic	4.2	2.7
Croatian	1.1	2.0
Cantonese	3.4	0.2
Serbian	1.9	0.3
Mandarin	0.8	2.0
Hindi	0.8	0.7
Tamil	0.7	0.3
Greek	1.2	1.3
German	0.7	0.3
Spanish	1	8

Table 4-3 Average Median Income of Upper South Creek (ABS, 2011)

Income (For Population Aged 15 Years and Over)	Upper South Creek	New South Wales
Average Median Individual Income (weekly)	$621	$561
Average Median Family Income (weekly)	$1,779	$1,477
Average Median Household Income (weekly)	$1,660	$1,237

4.2 Environmental Characteristics

4.2.1 Topography

Camden LGA is characterised by broad river-flat floodplains and gently undulating hills. Slopes are generally <5%, but may exceed 10% on the edges of terraces (Hazelton and Tile, 1990). The levee banks are not distinctive but there are broad depressions with saline influence in the south-west of the catchment (Benson and Howell, 1993). The Nepean River is a major topographical feature of the LGA, and is situated to the west of the catchment.

4.2.2 Geology and Soils

The geology and soils of the area have been described and mapped by Hazelton and Tille (1990), and are shown on the Wollongong – Port Hacking 1: 100 000 map sheet.

Tertiary and Quaternary alluvium is the dominant geological unit covering the riparian areas of the Camden LGA, the floodplain and terraces of the Nepean River and its tributary creeks. Smaller tributaries higher up in the catchment are underlain with Bringelly shale of the Wianamatta group of shales, which is the dominant geological unit covering the surface of Camden LGA.

Three main soil landscapes are found within the Upper South Creek catchment, Luddenham, Blacktown and South Creek (Bannerman & Hazelton 1990). The characteristics of these soil landscapes are summarised in **Table 4-4** and shown on **Figure 4.1**.

Table 4-4 Soil Landscapes of the Upper South Creek Catchment (Bannerman & Hazelton 1990)

Soil Landscape	Landscape Type	Vegetation	Soil Material	Limitations
Luddenham	Erosional	Cumberland Plain Woodland	Yellow podzolic soils (loamy sand, clay) on lower slopes and drainage lines.	High soil erosion hazard, highly plastic and moderately reactive subsoils, potential mass movement hazard.
Blacktown	Residual	Cumberland Plain Woodland	Yellow podzolic soils (loam topsoil, yellow clay subsoil) on lower slopes and drainage lines.	Moderately reactive, highly plastic subsoils, low soil fertility, seasonal waterlogging, soils often saline.
South Creek	Fluvial	Cumberland Plain Woodland	Moderately acidic brown loam which lies over a hard setting dull brown clay loam and light to medium sandy clay	This landscape contains many areas of soil erosion and deposition. Stream bank erosion and sheet erosion of the floodplains are common.

4.2.3 Contaminated Land and Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the Contaminated Land Management Act 1997. The Office of Environment and Heritage (OEH) is authorised to regulate contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination.

A search of the OEH Contaminated Land Record on 20 August 2013 showed no known contaminated sites within the Camden LGA. The Contaminated Land Record is not an exhaustive index, and there may be unreported contamination present within the catchment. Given the predominance of residential and open space land-use in the catchment, there is no reason to suspect the presence of broad-scale contamination.

A search of the PoEO licensed premises public register on 20 August 2013 identified 15 licenced premises within or in close proximity to the Upper South Creek catchment (**Table 4-5**). **Figure 4.1** shows the premises within the catchment boundary.

Table 4-5 Items listed on the PoEO Licensed Premises Register (OEH, 2013)

Suburb/City	Organisation name	Location	Fee Based Activity	Shown on Figure
Narellan	GLENLEE COAL PREPARATION PLANT	1 Glenlee Road, Cnr Springs and Richardson	Waste disposal (application to land)	No
Catherine Field	THE RUGBY LEAGUE COUNTRY CLUB LTD	810 Camden Valley Way, Catherine Field	Sewage treatment processing by small plants.	Yes
Grasmere	WEST CAMDEN SEWAGE TREATMENT SYSTEM	Cnr of Sheathers and Fergusons Lanes	Sewage treatment processing by small plants.	No
Bringelly	BORAL BRICKS PTY LTD	Lot 2 Greendale Road	Ceramics production; Crushing, grinding or separating; Land-based extractive activity; and Mining for minerals.	Yes
Cobbitty	M COLLINS & SONS (CONTRACTORS) PTY LTD	Cut Hill Road	Other Land-Based Extraction.	No (no specific address given)
Catherine Field	KARYATES ENTERPRISE PTY LIMITED	108 Deepfields Road	Bird accommodation.	Yes
Spring Farm	SPRING FARM	214 Macarthur Road	Crushing, grinding or separating; Land-based extractive activity.	No
Camden	WATERWAYS OF CAMDEN LOCAL GOVERNMENT AREA		Other activities.	No
Spring Farm	JACKS GULLY WASTE & RECYCLING CENTRE	275 Richardson Road	Composting; Waste disposal by application to land; Waste storage - hazardous, restricted solid, liquid, clinical and related waste and asbestos waste; Waste storage - other types of waste; and Waste storage - waste tyres.	No
Narellan	WHITE LODGE / SPRINGS ROAD	Richardson Road	Land-based extractive activity.	No
Bringelly	VOLK HOLDINGS PTY LTD	765-769 The Northern Road	Composting.	Yes
Leppington	KOALA DEPOT	166 Ingleburn Road	Petroleum products storage.	Yes

Suburb/City	Organisation name	Location	Fee Based Activity	Shown on Figure
Spring Farm	ECOLIBRIUM MIXED WASTE AND ORGANICS FACILITY	Richardson Road	Composting; Generation of electrical power otherwise than from coal, diesel or gas; Non-thermal treatment of general waste; Recovery of general waste; Transport of category 1 trackable waste; and Transport of category 2 trackable waste.	No
Smeaton Grange	NARELLAN FIELD SUPPORT CENTRE	17 & 19a McPherson Road	Waste storage - hazardous, restricted solid, liquid, clinical and related waste and asbestos waste.	No
Oran Park	ORAN PARK TOWN	The Northern Road	Sewage treatment processing by small plants.	Yes

Flood modification works within the vicinity of these premises should both consider the protection of these facilities from flood damages and the compatibility of the flood works with the operations of the facilities.

4.2.4 Flora and Fauna

The Upper South Creek Catchment is comprised of a combination of primarily residential and open space land-uses.

4.2.4.1 Flora

The Upper South Creek Catchment is located within the Cumberland Plain Woodland habitat areas which is a part of the Sydney Basin Bioregion, and is associated with clay soils derived from Wianamatta Group geology (OEH, 2011). Cumberland Plain Woodland is characterised by a number of species and typically comprises an open tree canopy, a near-continuous groundcover dominated by grasses and herbs, sometimes with layers of shrubs and/or small trees (OEH, 2011).

Mapping undertaken by Tozer (2003) identified Cumberland Plain Woodland within the catchment, and is listed as an endangered ecological community under the *Threatened Species Conservation Act* 1995 (**Figure 4.2**).

A search of OEH's Atlas of NSW Wildlife on 20 August 2013 did not identify any further flora species as endangered, protected and/or vulnerable in the catchment area. However, it should be noted that there currently seems to be an issue with the Atlas and the lack of data may be incorrect.

A search of the EPBC Protected Matters Search Tool on 11 September 2013 revealed 14 threatened species listed as endangered or vulnerable in the Camden LGA. **Table 4-6** provides the details of these species.

4.2.4.2 Fauna

A search of OEH's Atlas of Wildlife on 20 August 2013 did not identify any species listed as endangered, protected and/or vulnerable in the catchment area. However, it should be noted that there currently seems to be an issue with the Atlas and the lack of data may be incorrect.

A search of the EPBC Protected Matters Search Tool on 11 September 2013 revealed 18 threatened species listed as endangered or vulnerable in the Camden LGA. **Table 4-7** provides the details of these species.

4.2.4.3 Fish

A desktop search of the Department of Primary Industries (Fishing and Aquaculture) database revealed that there are no known threatened species listed in this catchment (DPI, 2013). However, the EPBC Protected Matters Search tool revealed 2 species that may occur in the Camden LGA (**Table 4-7**).

Table 4-6 Vulnerable and Endangered Flora Species (SEWPAC, 2013)

Scientific Name	Common Name	Legal Status
Acacia pubescens	Downy Wattle, Hairy Stemmed Wattle	V
Allocasuarina glareicola		E
Clematis fawcettii	Stream Clematis	V
Cryptostylis hunteriana	Leafless Tongue-orchid	V
Cynanchum elegans	White-flowered Wax Plant	E
Eucalyptus benthamii	Camden White Gum, Nepean River Gum	V
Grevillea parviflora subsp. parviflora	Small-flower Grevillea	V
Lepidium hyssopifolium	Basalt Pepper-cress	E
Pelargonium sp. Striatellum	Omeo Stork's-bill	E
Pimelea spicata	Spiked Rice-flower	E
Pomaderris brunnea	Rufous Pomaderris	V
Pterostylis saxicola	Sydney Plains Greenhood	E
Streblus pendulinus	Siah's Backbone, Sia's Backbone, Isaac Wood	E
Thelymitra sp. Kangaloon	Kangaloon Sun-orchid	CE

Table 4-7 Vulnerable and Endangered Fauna Species (SEWPAC, 2013)

Scientific Name	Common Name	Legal Status
	Birds	
Anthochaera phrygia	Regent Honeyeater	E
Botaurus poiciloptilus	Australasian Bittern	E
Erythrotriorchis radiatus	Red Goshawk	V
Lathamus discolor	Swift Parrot	E
Rostratula australis	Australian Painted Snipe	E
	Fish	
Macquaria australasica	Macquarie Perch	E
Prototroctes maraena	Australian Grayling	V
	Frogs	
Heleioporus australiacus	Giant Burrowing Frog	V
Litoria aurea	Green and Golden Bell Frog	V
Litoria raniformis	Growling Grass Frog, Green and Golden Frog	V
	Mammals	
Chalinolobus dwyeri	Large-eared Pied Bat, Large Pied Bat	V
Dasyurus maculatus maculatus	Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll	E
Petrogale penicillata	Brush-tailed Rock-wallaby	V
Phascolarctos cinereus	Koala	V
Potorous tridactylus tridactylus	Long-nosed Potoroo	V
Pseudomys novaehollandiae	New Holland Mouse, Pookila	V
Pteropus poliocephalus	Grey-headed Flying-fox	V
	Reptiles	
Hoplocephalus bungaroides	Broad-headed Snake	V

4.2.5 Heritage

4.2.5.1 Aboriginal Heritage

The National Parks and Wildlife Act 1974 provides protection for Aboriginal heritage. The objective of the Act is to conserve heritage items of cultural significance to Aboriginal people and to promote public appreciation of these items. Proposed flood modification actions need to consider any potential impact on heritage items identified under this Act.

A preliminary investigation of indigenous heritage was undertaken by searching the NPWS Aboriginal Heritage Information Management System (AHIMS) in August 2013 for known or potential indigenous archaeological or cultural heritage sites within or surrounding the Upper South Creek catchment. The types of heritage items identified by AHIMS are presented in **Table 4-8**, with 305 listed Aboriginal sites within the catchment (**Figure 4.3**).

Table 4-8 Items Identified Under the NPWS Aboriginal Heritage Information Management System

Site Type	Number of sites within the Upper South Creek Catchment
Aboriginal Resource and Gathering	1
Artefacts	247
Potential Archaeological Deposit (PAD)	45
Art (Pigment or engraved)	1
Shell	1
Modified tree (Carved or scarred)	10

The following qualifications apply to an AHIMS search:

- AHIMS only includes information on Aboriginal objects and Aboriginal places that have been provided to OEH;
- Large areas of New South Wales have not been the subject of systematic survey or recording of Aboriginal history. These areas may contain Aboriginal objects and other heritage values which are not recorded on AHIMS;
- Recordings are provided from a variety of sources and may be variable in their accuracy. When an AHIMS search identifies Aboriginal objects in or near the area it is recommended that the exact location of the Aboriginal object be determined by re-location on the ground; and
- The criteria used to search AHIMS are derived from the information provided by the client and OEH assumes that this information is accurate.

Land Rights and Native Title Claims

Land rights and Native Title are two different forms in which traditional land owners can gain access to land or claim compensation for previous dispossession of their land.

Under the Aboriginal Land Rights Act 1983 local Aboriginal land councils can claim Crown lands provided the lands are vacant and not otherwise required for an essential public purpose. A search on the Land Claims Register on 27 August 2013 found one register of Native Title claim which encompasses the whole study area and no Land Use Agreements within the study area.

The Native Title Claim identified for the study area covers a total area of 18,675 km^2 and extends from the south of Katoomba to Goulburn. The claim was lodged in 1997 and the tribunal file number is NC1997/007. The claim was filed by Gundungurra Tribal Council Aboriginal Corporation and is registered and active.

If specific flood modification works were to proceed, any active claims in the development vicinity would need to be confirmed to ensure that an up-to-date evaluation of potential constraints is available.

4.2.5.2 Non-Aboriginal Heritage

There are three different types of statutory heritage listings of non-Aboriginal origin; local, state or national heritage items. A property is a heritage item if it falls into a listings category. The category of an item depends on whether it is considered to be significant to the nation, state or a local area. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Aboriginal heritage was undertaken for the catchment. Searches were undertaken on a number of databases to determine the cultural heritage within this area. Databases searched include:

- Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List; Register of the National Estate); and
- NSW Heritage Office – State Heritage Register.

A search of the Australian Heritage Database (DSEWPC, 2008) on 20 August 2013 identified 36 places within or in close proximity to the Upper South Creek catchment (**Table 4-9**). These place places were all included on the Register of National Estate, which means these places may not be removed from the register.

The State Heritage Register (OEH, 2013) listed 12 places within or in close proximity to the Upper South Creek Catchment, as indicated in **Table 4-10** and on **Figure 4.3**. There are a further 151 places that are listed under the Camden Local Environment Plan.

Table 4-9 Australian Heritage Database Listings (DSEWPC, 2013)

Name	Address	Register
Camden Airport	Airport Rd, Camden	(Indicative Place) Register of the National Estate
Camden Courthouse	31 John St, Camden	(Registered) Register of the National Estate
Camden Park	Camden Park Estate Rd, Camden Park	(Registered) Register of the National Estate
Camden Post Office	135 Argyle St, Camden	(Listed Place) Commonwealth Heritage List
Camelot	Kirkham La, Kirkham	(Registered) Register of the National Estate
Camelot Gardeners Lodge	Kirkham La, Kirkham	(Registered) Register of the National Estate
Camelot Stables	Kirkham La, Kirkham	(Registered) Register of the National Estate
Cobbitty Weir	Ellis La, Ellis Lane	(Indicative Place) Register of the National Estate
Cottage	39 JohnSt, Camden	(Registered) Register of the National Estate
Cottage near Macquarie Grove House	Macquarie Grove Rd, Camden	(Interim List) Register of the National Estate
Cottage near Macquarie Grove House	Macquarie Grove Rd, Camden	(Indicative Place) Commonwealth Heritage List
Denbigh including slab outbuildings and grounds	The Northern Rd, Cobbitty	(Registered) Register of the National Estate
Gledswood	Camden Valley Way, Catherine Field	(Registered) Register of the National Estate
Gledswood Garden	Camden Valley Way, Catherine Field	(Registered) Register of the National Estate

Name	Address	Register
Harrington Park Homestead	Camden Valley Way, Harrington Park	(Registered) Register of the National Estate
Heber Chapel	Cobbitty Rd, Cobbitty	(Registered) Register of the National Estate
Home Farmhouse	Camden Park Estate Rd, Camden South	(Registered) Register of the National Estate
John Street Group	John St, Camden	(Registered) Register of the National Estate
Kirkham Stables and Curtilage	Kirkham La, Kirkham	(Registered) Register of the National Estate
Macaria	37 John St, Camden	(Registered) Register of the National Estate
Macarthur Family Cemetery	Camden Park Estate Rd, Camden South	(Registered) Register of the National Estate
Macquarie Grove House	Macquarie Grove Rd, Cobbitty	(Registered) Register of the National Estate
Maryland Garden and Setting	The Northern Rd, Bringelly	(Registered) Register of the National Estate
Maryland and Outbuildings	The Northern Rd, Bringelly	(Registered) Register of the National Estate
Mount Hunter Rivulet Weir	Werombi Rd, Theresa Park	(Indicative Place) Register of the National Estate
National Australia Bank	Argyle St, Camden	(Registered) Register of the National Estate
Police Station and Residence	33-35 John St, Camden	(Registered) Register of the National Estate
St John the Evangelist Anglican Church	Menangle Rd, Camden	(Registered) Register of the National Estate
St Johns Hill and John Street Conservation Area	Camden	(Registered) Register of the National Estate
St Johns Rectory and Stables	Menangle Rd, Camden	(Registered) Register of the National Estate
St Pauls Anglican Church Group	Cobbitty Rd, Cobbitty	(Registered) Register of the National Estate
St Pauls Anglican Church and Graveyard	Cobbitty Rd, Cobbitty	(Registered) Register of the National Estate
St Pauls Catholic Church	John St, Camden	(Registered) Register of the National Estate
St Pauls Rectory	Cobbitty Rd, Cobbitty	(Registered) Register of the National Estate
Studley Park	Camden Valley Way, Narellan	(Registered) Register of the National Estate
Wivenhoe including Conservatory	Cobbitty	(Registered) Register of the National Estate

Table 4-10 State Heritage Register Listings (OEH, 2013)

Item name	Address
Camden Park	Elizabeth Macarthur Avenue, Camden Park
Camden Park Estate and Belgenny Farm	Elizabeth Macarthur Avenue, Camden South
Camelot	Kirkham Lane, Narellan
Denbigh	421 The Northern Road, Cobbitty
Gledswood	900 Camden Valley Way, Cobbitty
Harrington Park	1 Hickson Circuit, Harrington Park
Kirkham Stables and Precinct	Kirkham Lane, Narellan
Macquarie Grove Cottage	Aerodrome Road, Cobbitty
Nant Gwylan and Garden	Exeter Street, Camden
Orielton	179 Northern Road, Narellan
Raby	1025 Camden Valley Way, Narellan

4.3 Conclusions

The outcomes of this social and environmental assessment for the Upper South Creek Catchment have been utilised in the preparation of consultation materials, undertaking of damages assessments, development of appropriate emergency response recommendations and the impact / benefit assessment of floodplain modifications options.

The key environmental constraints identified in this assessment include:

- The presence of 15 licenced premises within the catchment. Flood modification works within the vicinity of these premises should both consider the protection of these facilities from flood damages and the compatibility of the flood works with the operations of the facilities.
- The presence of Cumberland Plain Woodland within the catchment (listed as an endangered ecological community under the Threatened Species Conservation Act 1995). Any impacts on this flora community should be considered in the assessment of potential floodplain management options.
- 305 Aboriginal sites are listed under the National Parks and Wildlife Act 1974. The impacts of floodplain management options on these items would need to be considered
- 36 non-Aboriginal heritage sites of national significance were identified and an additional 12 sites of state significance were identified. 151 places of local heritage significance are listed under the Camden Local Environment Plan.

Where possible, these key environmental constraints have been mapped (**Figures 4.1** and **4.3**) to assist in the assessment of potential floodplain management options.

5 Flood Behaviour

5.1 Background

The fully-dynamic hydraulic modelling system, TUFLOW, was utilised in the Flood Study (WMA 2012) to convert direct rainfall on the model terrain into water levels, depths and velocities in the study area. This was undertaken for the terrain recorded by the Aerial Laser Survey in 2008 using a 10m grid, which is representative of a broad scale study. The model was calibrated to historical events of 1988, 1991 and 1992.

Since the ALS was conducted there has been urban development progressing in the Oran Park and Turner Road precincts. Further development of neighbouring precincts is expected to initiate in the near future for Catherine Fields (Part Precinct), Leppington and Leppington North. In addition infrastructure projects are in progress for upgrade of Bringelly Road and construction of the South West Rail link. These changes prompted the revision of the TUFLOW model to represent a developed scenario to represent an updated existing condition.

The details of the updates, and the resultant flood data, are presented in **Appendix A**.

Part of the updates involved revising the initial water levels in the regional farm dams. Full details on the farm dam assessment are provided in **Appendix B**.

In June 2016, the Camden region experienced a significant storm event. Following this event, Council collected a number of post flood marks, which were used to validate the recently updated model and the Dam Full assumption.

The assessment found that the updated model provided results that closely matched those observed in the flood event, and confirmed that the dam full assumption adopted was suitable for the catchment.

Full details of the 2016 event analysis are provided in **Appendix C**.

5.2 Flood Hazard

Flood hazard can be defined as the risk to life caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain. The Floodplain Development Manual (NSW Government, 2005) describes various factors to be considered in determining the degree of hazard. These are:

- Size of the flood;
- Effective warning time;
- Flood readiness;
- Rate of rise of floodwaters;
- Duration of flooding;
- Ease of evacuation;
- Effective flood access; and
- Type of development in the floodplain.

Hazard categorisation based on all of the above factors is part of establishing a Floodplain Risk Management Plan. Flood hazard may be defined as either the provisional or true flood hazard. Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). True hazard is determined based on these hydraulic parameters as well as those factors listed above.

5.2.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). The hazard categories shown in the figure below and are defined as:

- High hazard – possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damage to buildings; and
- Low hazard – should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.

Provisional flood mapping is provided in **Appendix A** as part of the Flood Study update.

5.2.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

- Size of the flood;
- Effective warning time;
- Flood readiness;
- Rate of rise of floodwaters;
- Duration of flooding;
- Ease of evacuation;
- Effective flood access; and
- Type of development in the floodplain.

In the Upper South Creek floodplain many of the above factors are not applicable in terms of affecting hazard definition. However, all of the above factors have been considered in this report to provide a thorough assessment process.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. In order to define the "true" flood hazard in varied magnitudes of storm events, flood hazard has been assessed for the PMF, 1% AEP and 20% AEP events in this study.

Effective Warning Time

The effective warning time is the actual time available prior to a flood during which people may undertake appropriate mitigation actions (such as lift or transport belongings and/or evacuation). Effective warning time is always less than the total warning time available to emergency service agencies. This is related to the time needed to pass the flood warning to people located in the floodplain and for them to begin effective property protection and/or evacuation procedures. In general, the flood warning time needs to be in excess of 6 hours for any effective response to occur.

The Flood Study identified the critical duration within the catchment is 2 hours for all waterways except South Creek and its tributaries, having a 9 hour critical duration. For the PMF event, critical duration is between 30 minutes in the upstream areas and 1 hour in the downstream areas. The flow peak can take a couple of hours to occur in the Upper South Creek Floodplain however it is anticipated that the response time of the catchment would become shorter once urban development proliferates throughout the SWGC. Thus, the warning time is not considered to decrease the flood hazard.

Flood Readiness

Flood readiness or preparedness can greatly influence the time taken by flood-affected residents and visitors to respond in an efficient pattern to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. Responses from the community questionnaire (**Section 3.1**) indicated a high awareness of flooding noting the last major flood events occurred in mid 2012, but was only a 20% AEP event. Furthermore other recent floods were experienced in 1991 and 1992 and have been estimated to be in the order of the 10% AEP (WMA 2012). As a result an infrequent flood (~1% AEP) has not occurred in recent times, no particular part of the catchment is then likely to be any more prepared for a flood than another, thus flood readiness has not been considered in the preparation of hazard extents.

Rate of Rise of Floodwaters

The rate of rise of floodwater affects the magnitude of the consequences of a flood event. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The rate of rise of floodwaters is affected by catchment and floodplain characteristics.

A rate of rise of 0.5 m/hr has been adopted as indicative of high hazard. However, it is important to note that if an area has a rate of rise greater than 0.5 m/hr this does not automatically result in the area being categorised as high hazard. For instance, if the rate of rise is very high but flood depths only reach 200 mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

A flood depth of 500 mm was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr. A 500 mm flood depth is well within the range of available information as to when vehicles become unstable even with no velocity (Figure L1; NSW Government, 2005).

Depth and Velocity of Floodwaters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping is presented in **Appendix A**. This provisional hazard mapping has been used as the base to determine true flood hazard.

Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Because the Study Area is located in the Upper South Creek catchment the flooding durations, where peak flood levels are experienced, are generally less than 6hours, and as such this is not considered as a key issue for this Study Area.

Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult due to a number of factors, including:

- The number of people requiring assistance;
- Mobility of those being evacuated;
- Time of day; and
- Lack of suitable evacuation equipment.

A flood event in the catchment is likely to be a flash flood scenario, with limited warning time and a short period of exposure therefore evacuation may not be viable.

Effective Flood Access

The availability of effective access routes to or from flood affected areas can directly influence personal safety and potential damage reduction measures. Effective access implies that there is an exit route available that remains trafficable for sufficient time to evacuate people and possessions.

Flood access issues vary across the catchment. For this assessment, properties were identified as being in one of four flood access categories:

- Site is flooded and evacuation required through a high hazard flooded roadway;
- Site is flooded and evacuation is required through a flooded roadway;
- Site is flooded and evacuation is possible through a non-flooded roadway directly from site; and
- Site is flood free, however all road access is impeded by floodwaters.

To consolidate these categories and determine the implication of flood access issues on hazard mapping, criteria were set to establish effective flood access. It was determined that effective access is a road which is flooded by less than 300mm of water. For the purposes of this assessment 300mm is the threshold depth at which vehicles become unstable, even at very low velocities. However, further to this, a property or area is only considered to be without effective access, and hence has true high flood hazard, if the access is flooded by 300mm of water for more than 6 hours.

In a 1% AEP event, many of the local access roads within the floodplain are shown as within high hazard. The arterial roads are less affected by flooding in the 1% AEP event, however road crossings of waterways generally have a serviceability of less than the 1% AEP. In a PMF event the majority of road crossings are inaccessible.

Therefore identifying effective road access was undertaken with the intention of identifying those properties that would be able to use rising road access to evacuate high risk areas of the floodplain. Evacuation of properties to locations in the wider region was not identified at this point. Further discussion is provided in **Section 7.4**.

Type of Development

The degree of hazard to be managed is a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and may also change management strategies in existing development areas. The land-use in the Study Area is predominantly residential and does not have designated industrial or commercial areas. However the railway line and platforms are located in the floodplain but are not inundated in the 1% AEP event.

True Hazard Mapping

Figures 5-1 to 5-3 show the true hazard areas mapped in the PMF, 1% AEP and 5% AEP events. The results indicate that additional parts of the floodplain are classified as true hazard in the PMF, 1% and 5% AEP events as a result of isolated areas and regional storages. Properties along Masterfield Street that are protected by the existing levee are also allocated a high hazard dur to the increased risk of flooding there due to failure or overtopping of the levee. It should be noted that the lot size of properties in the floodplain is relatively large and as such the high true hazard identifies similar amounts of affected properties to the high provisional hazard. In this case the true hazard identification is most relevant for the identification of unsafe parts of the floodplain to avoid during urban development. The development controls take the high true hazard extent of the 1% AEP into consideration when outlining prescriptive requirements to the high risk precinct. More details are included in **Section 8**.

6 Current Economic Impact of Flooding

6.1 Background

Flooding is likely to cause significant social and economic damages to the community. Flood damages are classified into different categories as summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

Type of Flood Damage	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

Direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

6.2 Floor Level and Property Survey

A survey of properties was not available for the Upper South Creek catchment so the approach to estimating property levels comprised ground levels from the Aerial Laser Survey (ALS) and addition of 300mm to resemble floor levels of habitable buildings. This approach is considered suitable considering the land use of the catchment is predominantly rural and the number of properties within the floodplain is low, reflecting the low density of development.

6.3 Damage Analysis

A flood damage assessment for the existing conditions has been undertaken using the results of the Flood Study (WMA 2012).

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For this Study, generic spreadsheets have been used with the DECCW (now OEH) damage curves on the adoption of appropriate damage curves. The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchment is not available and recourse is generally made to damage curves from other catchments.

The Office of Environment and Heritage (OEH) has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data, which was used in this instance.

6.3.1 Residential Damage Curves

The draft DNR (now OEH) Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet that determines damage curves for three types of residential buildings:

- Single storey, slab-on-ground
- Two storey, slab-on-ground
- Single storey, high-set (i.e. on piers)

Damages are generally incurred on a property prior to any overfloor flooding. The OEH curves allow for a damage of $10,487 (May 2012 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.3m below the floor level for slab on ground). We have assumed that this remains constant until overfloor flooding occurs.

A nominal value of $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped by more than 0.3 metres of depth but only up to 0.3m below the floor of the house. This may occur on larger properties where the garden and fences may be impacted but the floodwaters do not reach the house.

There are a number of input parameters required for the damage curves including floor area and level of flood awareness. The following parameters were adopted:

- 200m^2 has been adopted as an estimate of the floor area for residential dwellings. With a floor area of 200m^2, the default contents value is $50,000 (based on November 2001 dollars);
- The Effective Warning Time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches), and;
- The Upper South Creek catchment is located on the outskirts of the Liverpool and Campbelltown metropolitan areas and as such it is not likely to be any post flood inflation. These inflation costs are generally experienced in small towns in regional areas, where re-construction resources are limited and large floods can cause a strain on these resources.

6.3.2 Industrial Damage Curves

Cardno conducted a survey of industrial properties in 1998 for Wollongong City Council as part of another project. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies and therefore have used these damage curves for the purpose of this assessment.

The curves were prepared for three categories:

- Low Value Industrial;
- Medium Value Industrial; and
- High Value Industrial.

For the purpose of this assessment all farmlands properties have been classified as low value industrial and business properties have been classified as medium value industrial to represent the rural land uses that involve storage of goods and crop management in large glass houses and farm sheds.

The damages calculation conducted only accounts for structural and contents damage to the property. Clean-up costs and indirect financial costs were estimated based on the FLDamage Manual. Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made if required.

The damage values were adjusted to May 2012 dollars using CPI statistics resulting in an increase of 49% compared to 1998 values.

6.3.3 Average Weekly Earnings

The DECCW curves are derived for late 2001 and were updated to represent May 2012 dollars. General recommendations by DECCW are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). DECCW proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for May 2012. Therefore all ordinates in the residential flood damage curves were updated to May 2012 dollars.

While not specified, it has been assumed that the curves provided by DECCW were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the DECC guidelines, and May 2012 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au) as shown in **Table 6-2**. Consequently, all ordinates on the damage curves were increased by 57%.

Table 6-2 AWE Statistics

Month	Year	AWE
November	2001	$676.40
May	2012	$1058.70
Change	57%	

6.3.4 Average Annual Damage

Flood damages (for a design event) are calculated by using the 'damage curves' described above. These damage curves define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

Average Annual Damage (AAD) is an estimation of the flood damage that a floodplain would receive on average during a single year. It is calculated on a probability approach using the flood damages calculated for each design event. A probability curve is developed based on the flood damages calculated for each design event (**Figure 6-1**). For example, the 1% AEP design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point on the AAD curve (**Figure 6-1**). AAD is then calculated by determining the area under this curve. Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (NSW Government, 2005). The average annual damage estimated for the floodplain under existing conditions is approximately $890,794.

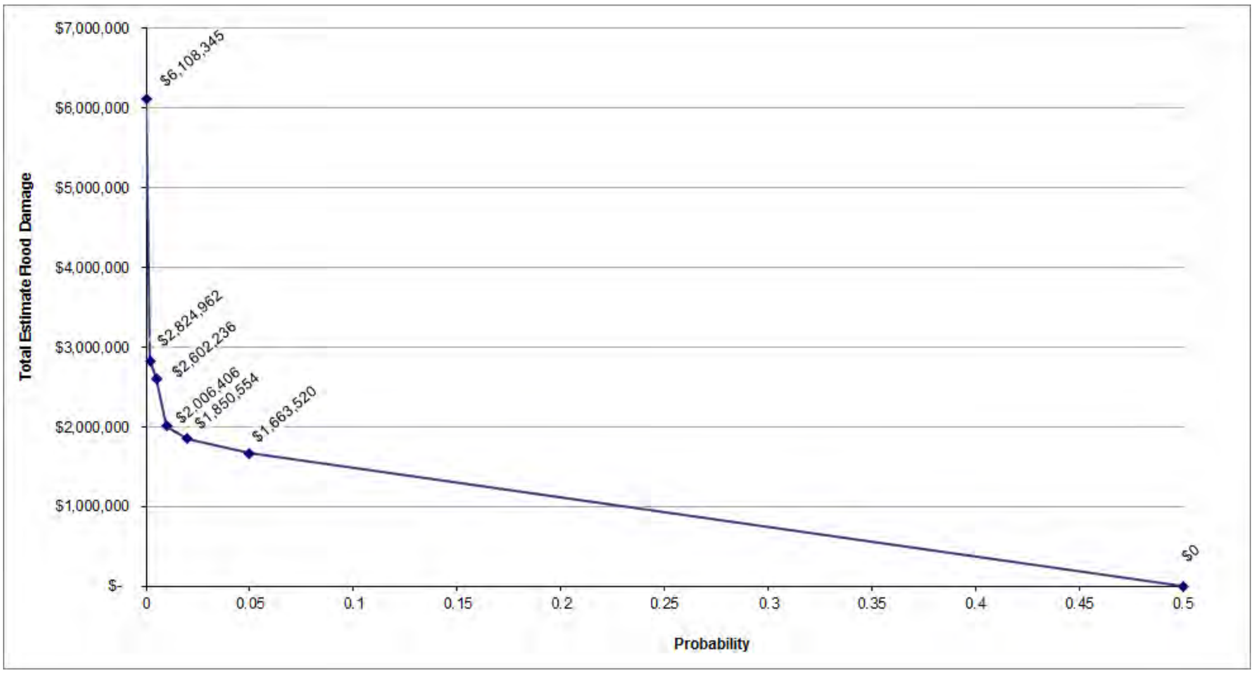


Figure 6-1 Annual Average Damage Curves for Upper South Creek

6.4 Discussion

Table 6-3 shows the results of the flood damage assessments for the modelled storm events.

Figure 6-2 outlines the properties affected by overfloor and over ground flooding in a 1% AEP event. There are 57 properties with overfloor flooding in 1% AEP event.

The average annual damage reflects the damages likely to occur as a result of an average storm event that is unlikely to occur. Whilst this is a useful tool for evaluating the benefit of flood management options in terms of flood damage reduction and assessing the flood damage to an area over a long period of time, it is also important to note the actual damages estimated to occur as a result of a specific design flood event. The cost to the community of flood damage is not incurred as an average annual amount. The costs will be borne at one time by the damage incurred by a specific flood event.

Financial and community attitude surveys and analysis undertaken in other areas of Sydney (e.g. the Hawkesbury Nepean Valley) (Gillespie et al, 2002) suggests that many people would have real difficulties dealing with the cost of recovering from severe flooding and there is an increasing awareness of the uncertainty of insurance cover for flooding.

6.5 Qualifications

Assumptions in the calculation of damage costs in this Study include:

- The flood level for a property was estimated by the flood level at the location of the building where damages where calculated
- The floor levels of properties were estimated to be 300mm above the level of the ALS in the centre of the building
- The type of building was estimated through interrogation of aerial photography and land use zoning of the Camden LEP 2010

Table 6-3 Flood Damage Assessment Summary

Property Type	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Estimated Damage ($ May 2012)
		PMF			
Residential	53	0.93	3.53	60	$4,252,684
Industrial	76	0.93	2.14	77	$1,855,661
PMF Total	**129**			**137**	**$6,108,345**
		0.2% AEP			
Residential	19	0.37	1.26	34	$1,763,814
Industrial	56	0.53	1.73	57	$1,061,148
0.2% AEP Total	**75**			**91**	**$2,824,962**
		0.5% AEP			
Residential	17	0.29	1.13	29	$1,603,986
Industrial	56	0.47	1.68	57	$998,250
0.5% AEP Total	**73**			**86**	**$2,602,236**
		1% AEP			
Residential	8	0.35	0.92	22	$1,159,948
Industrial	49	0.38	0.95	50	$846,458
1% AEP Total	**57**			**72**	**$2,006,406**
		2% AEP			
Residential	6	0.36	0.81	20	$1,046,799
Industrial	48	0.34	0.85	49	$803,755
2% AEP Total	**54**			**69**	**$1,850,554**
		5% AEP			
Residential	5	0.29	0.6	18	$913,919
Industrial	46	0.30	0.75	48	$749,602
5% AEP Total	**51**			**66**	**$1,663,520**

7 Flood Emergency Response Arrangements

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for the management of flooding in the Upper South Creek Catchment are discussed below.

7.1 Flood Emergency Response Documentation

7.1.1 DISPLAN

Camden has its own Camden Local Disaster Plan (DISPLAN) for the Camden Emergency Management District, being the LGA. Flood emergency management for the Camden is referred to in the DISPLAN as being managed by the Local Flood Plan as a sub-plan.

The DISPLAN provides a general description of arrangements at a district level to prevent, prepare for, respond to, and recover from incidents and emergencies, and also provides policy direction for the preparation of Local DISPLANs and District and Local Sub Plans and Supporting Plans within the district.

The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- Roles and strategies for prevention of disasters;
- Planning and preparation measures;
- Control, coordination and communication arrangements;
- Roles and responsibilities of agencies and officers;
- Conduct of response operations; and
- Co-ordination of immediate recovery measures.

7.1.2 Local Flood Plan

A sub-plan to the DISPLAN has been prepared by the SES in conjunction with Council. The Camden Local Flood Plan was prepared in 2010 and covers the preparation, response and recovery of flooding emergencies for the Camden LGA.

The Flood Plan focuses exclusively on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event.

This Local Flood Plan encompasses the key components as follows:

- Define the key responsibilities of the different response organisations in preparation for, response to and recovery from emergencies.
- Develop floodplain management plan and implementation strategies, and develop flood intelligence and warning systems, public education programs and training in preparing emergencies.
- Define the roles and procedures for different organisations in emergency response operations, including preliminary deployments, warning, evacuation, flood rescue, and evacuation.
- Details co-ordination, liaison between different organisations and resources arrangement.
- Develop the plan for long term recovery operations and implementation strategies.

The Local Flood Plan also notes key roads that can be flood affected and details evacuation centres for flood affected areas of Camden. The Flood Plan documents the need for update in response to floodplain risk management, changes in land use and improvements in flood intelligence. Therefore it is recommended that the Flood Plan be updated to reflect the outcomes of this current study, especially considering the ongoing and projected changes in land use. The Plan is due for review no later than August 2015 and with the preparation of this Floodplain Risk Management Study it is considered timely to update the Local Flood Plan to reflect the findings herein.

With respect to the Upper South Creek floodplains, areas of Rossmore are documented as being affected by flood and Camden Valley Way is cut off at the Cowpasture Bridge crossing. The construction of the Masterfield Street levee has mitigated the flood risk to properties of Rossmore up to the 1% AEP. However there is still flood affected buildings in the study area, which is broken down into two sectors:

Catherine Fields Sector

Delineated by Rileys Creek, South Creek and Chisholm/Springfield Road

Total population of 1954 people in the sector, 579 properties

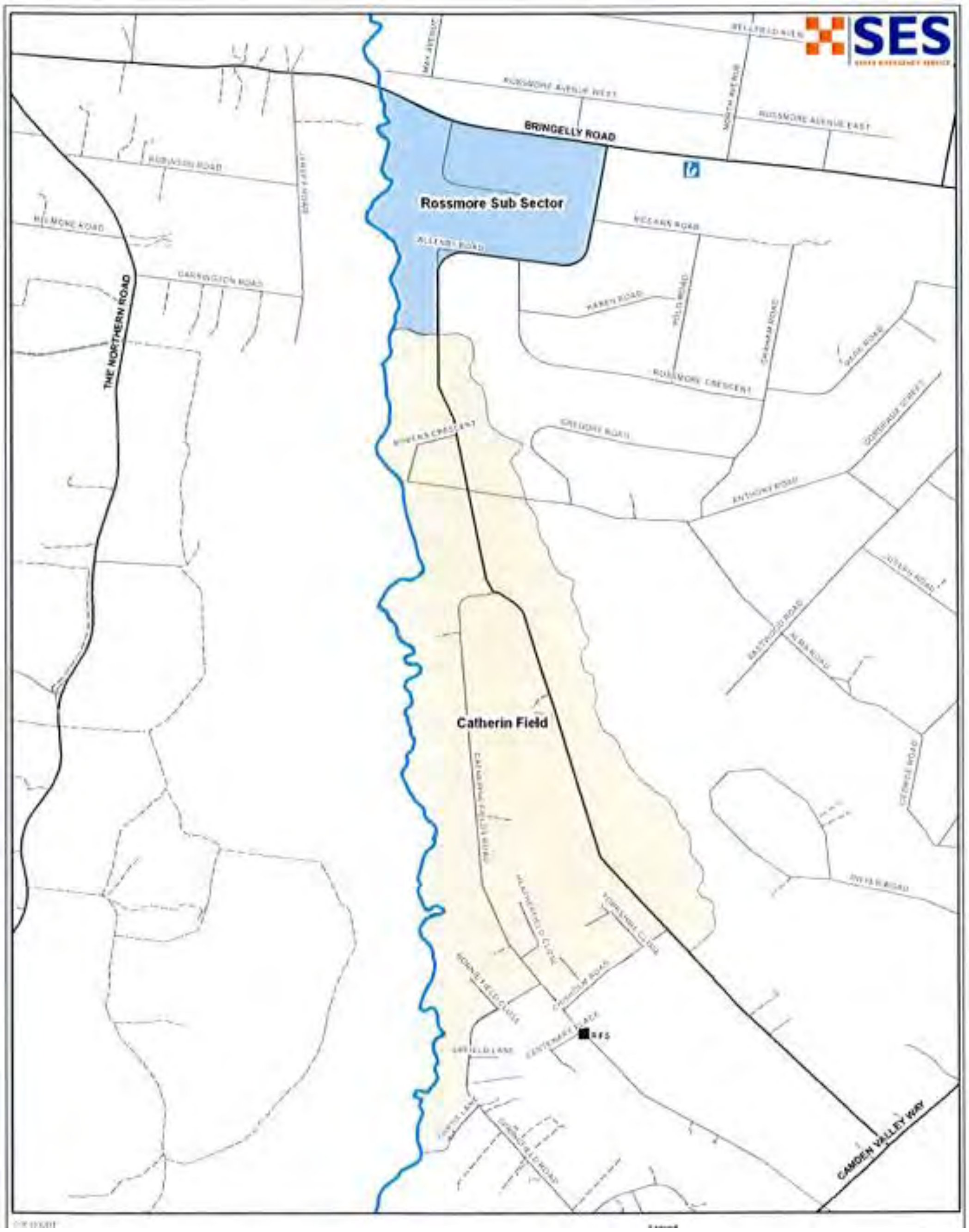
Evacuate to Catherine Fields Community Hall on Catherine Fields Road for those who are unable to take stock at home

Rossmore Sector

Delineated by South Creek, Bringelly Road, Allenby Road

Total population of 2197 people in the sector, 652 properties

Evacuate to Rossmore School on Bringelly Road for those who are unable to take stock at home



Evacuation areas nominated in the Local Flood Plan

The following amendments to the Flood Plan are recommended for the Upper South Creek floodplain:

- Include a section describing the flood behaviour and effects for the Upper South Creek floodplain
- Update the flood warning dissemination method to include the electronic media and television stations
- Update details of the population in the floodplain and subsequent service requirements for the flood refuge centres. It is likely that a far greater number of residents would be affected by an extreme flood following urban development in the study area.
- Identify additional flood refuge centres for parts of the floodplain that are unable to access the two existing flood refuge centres.
- The following key access roads/evacuation routes should be included (further details of accessing road flooding is provided below in **Section 7.4.1**):
  - The Northern Road – Northbound access is safe only from Georges Park
  - Camden Valley Way – Evacuation is only safe for motor vehicles northbound from the Deepfields Road intersection
  - Bringelly Road - Evacuate to the east from areas on the eastern side of South Creek only. The South Creek bridge is inaccessible during storm events of the 1% AEP and above.
- Provide a non-automated flood warning plan for the residents of Masterfield Street that are located behind the existing levee. See **Section 9.4.3**.

7.2 Emergency Service Operators

The Upper South Creek floodplain lies within the Sydney Southern Region of the State Emergency Service (SES). The SES is the legislated combat agency for floods and is responsible for the control of flood operations including the coordination of other agencies and organisations for flood management tasks. The Camden SES Local Controller is responsible for flood response in the study. The SES is primarily a volunteer organisation and in times of emergency operates a paging service for on-call volunteers.

The key emergency services for the Upper South Creek floodplain are outlined in **Table 7-1**.

Table 7-1 Emergency Service Providers Locations

Emergency Service	Location	Phone
Camden Hospital	Menangle Road, Camden	02 4634 3000
Ambulance		131 233
Narellan Community Health Centre	Corner Queen & Elyard Streets, Narellan	02 4640 3500
Narellan Police Station	278 Camden Valley Way, Narellan	000
Fire Station	12 Exchange Parade, Smeaton Grange	000
Camden State Emergency Service (SES)	19 Queen Street, Narellan	02 4647 0319

7.3 Flood Warning Systems

There is no official flood warning system for the Upper South Creek study area. However, sources of real-time flood intelligence during times of flooding are:

- Bureau of Meteorology (BoM):
  - Flood Watches: typically provide 24-48 hours notice that flooding is possible based upon current catchment conditions and future rainfall.
  - Severe Weather Warnings: provide warnings of possible flash flooding.
  - Severe Thunderstorm Warning: provide 0.5-2 hours notice of impending severe storms.
- Sydney Southern SES Region Headquarters provides information on flooding and its consequences including those in nearby council areas.
- Active reconnaissance. The SES Local Operations Controller coordinates the monitoring of known problem areas, predominantly in the Nepean River basin.

Warnings are provided as:

- BoM Flood Watches: If there are signs of impending floods, a Flood Watch may be incorporated in SES Flood Bulletins released to radio stations by the Illawarra South Coast SES Region Headquarters.
- BoM Severe Weather Warnings are issued when developing weather conditions indicate that flash flooding may occur. On receipt of such warnings, the SES Local Operations Controller will:
  - Advise Camden Council and the Camden Local Emergency Operations Controller.
  - Provide the Sydney Southern SES Region Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding.
- Evacuation Warnings are disseminated as follows:
  - Notification to Council Mayor
  - By reconnaissance
  - By direct access to community radio
  - In SES Flood Bulletins from regional to local offices
- Standard Emergency Warning Signal (SEWS).

7.4 Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood-free access, and the ease with which movement may be accomplished. Movement may comprise evacuation from flood-affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

7.4.1 Access Road Flooding

A summary of road flooding in the study area is listed in **Table 7-2**. The majority of the road crossings assessed are not accessible to motor vehicles for all design storm events. Bringelly Road (Kemps and Scalibrini Creek crossings) is the exception where there are accessible in design storms up to and including the 0.2% AEP. The Northern Road (location 1) is also accessible in design storms up to 1% AEP. The South Creek crossing (Bringelly Road) is accessible in the 5% AEP only. None of the road crossings are accessible during the PMF. Thus it is concluded that evacuation of the floodplain using major roads is not a safe emergency management strategy in the case of flood. It is recommended that flood depth gauges are installed as signs on all road crossings except Bringelly Road (Kemps and Scalibrini Creek crossings) and The Northern Road (location 1).

Refer to **Figure 7-1** for locations.

Table 7-2 Major Access Road Flooding

	Flood Depth (m)											
Road Name	**5% AEP**	**Safe**	**2% AEP**	**Safe**	**1% AEP**	**Safe**	**0.5% AEP**	**Safe**	**0.2% AEP**	**Safe**	**PMF**	**Safe**
Bringelly Road (South Creek)	0.054	yes	0.442	no	0.650	no	0.850	no	0.917	no	4.85	no
Bringelly Road(Kemps Creek)	0.00	yes	0.00	yes	0.00	yes	0.078	yes	0.154	yes	0.786	no
Bringelly Road (Scalabrini Creek)	0.070	yes	0.071	yes	0.072	yes	0.096	yes	0.177	yes	0.768	no
Northern Road(Location 1)	0.178	yes	0.188	yes	0.199	yes	0.443	no	0.467	no	0.449	no
Northern Road (Location 2)	1.505	no	1.557	no	1.614	no	1.727	no	1.793	no	2.551	no
Catherine Fields Rd (South Creek)	0.327	no	0.338	no	0.351	no	0.417	no	0.484	no	1.564	no
Barry Avenue (Rileys Creek)	2.717	no	2.793	no	2.869	no	2.992	no	3.095	no	4.035	no
Deepfields Road (Rileys Creek)	0.769	no	0.801	no	0.851	no	0.799	no	0.845	no	1.464	no
Camden Valley (Location1)	0.256	yes	0.297	yes	0.347	no	0.468	no	0.539	no	1.134	no
Camden Valley Way (Location 2)	0.370	no	0.397	no	0.416	no	0.464	no	0.487	no	0.617	no
Camden Valley Way (Location 3)	0.318	no	0.370	no	0.417	no	0.481	no	0.535	no	1.044	no
Ingleburn Road	0.127	yes	0.163	yes	0.193	yes	0.299	yes	0.365	no	0.893	no
Heath Road (Scalibrini Creek)	0.494	no	0.560	no	0.610	no	0.737	no	0.813	no	1.397	no

The safety criterion is defined by the inability for passenger vehicles to drive through flooding at a depth of 0.3m and above. Note that the flow velocity is generally 1m/s for all locations and it was found that the results for velocity x depth product were mostly identical to the depth results.

7.4.2 Refuge Centres

The Local Flood Plan identifies Catherine Fields Community Hall and Rossmore School as appropriate refuge centres for the study area. These centres are to be equipped with provisions for dealing with relocated residents for a minimum of 24 hours. It is not likely that residents cannot return to their homes, if structurally sound, for more than this duration because the length of flood inundation is commonly less than 12 hours. It is the responsibility of the SES and Council to ensure that adequate facilities and services are available to evacuated residents whilst they take refuge. The requirements for the refuge centres are documented in the Local Flood Plan. It has been recommended that additional flood refuge centres are identified to service flood affected residents that cannot safely access the two existing centres. This is particularly relevant for those residing on the western side of South Creek (Marylands, Lowes Creek and Bringelly) and in the Leppington area.

7.5 Flood Emergency Response Planning Classifications

To assist in the planning and implementation of response strategies the State Emergency Service (SES) classifies communities according to their flood impact. Flood affected communities are those in which the normal functioning of services is altered either directly or indirectly because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. The classifications adopted by the SES are (DECC, 2007):

- **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:
  - High Flood Island - the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground.
  - Low Flood Island - the flood island does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by flood waters.
- **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through floodprone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:
  - High Trapped Perimeter - the area contains enough flood-free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground.
  - Low Trapped Perimeter - the area does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by flood waters.
- **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
  - Areas with Overland Escape Route - access roads to flood free land cross lower lying flood prone land.
  - Areas with Rising Road Access - access roads rise steadily uphill and away from the rising floodwaters.
- **Indirectly Affected Areas.** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood-damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.
- **Overland Refuge Areas.** These are locations that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The flood emergency response planning classifications in a 1% AEP event for the floodplain are shown in **Figure 7-1**. It is predominantly classified as "Areas Able to be Evacuated", either as areas with overland escape route or areas with rising road access.

Table 7-3 outlines the response required for different flood emergency response planning classifications. Due to the predominant classification of the floodplain as areas with rising road access and overland escape routes the emergency response requirement is most likely evacuation to local refuge centres if the residents cannot take stock in their property.

Table 7-3 Emergency Response Requirements

Classification	Response Required		
	Resupply	**Rescue / Medivac**	**Evacuation**
High Flood Island	Yes	Possibly	Possibly
Low Flood Island	No	Yes	Yes
Area with Rising Road Access	No	Possibly	Yes
Area with Overland Escape Routes	No	Possibly	Yes
Low Trapped Perimeter	No	Yes	Yes
High Trapped Perimeter	Yes	Possibly	Possibly
Indirectly Affected Areas	Possibly	Possibly	Possibly

8 Current Development Zoning and Controls

8.1 Local Environmental Planning Instruments

The New South Wales Planning Reforms require all local governments to prepare their planning instruments in accordance with a new standard instrument LEP. The key features of these reforms are:

- An objective of reducing the number and layers of planning instruments;
- Provision of a standard LEP template for Councils to conform to;
- All mandatory controls to be included in the LEP;
- Mandatory timeframe for Council to prepare a new LEP (3-5 years);
- Rationalise and clarify the Development Control Plan (DCP) relationship to LEP; and
- Replace Master Plans with DCPs and staged development applications.

Under this process, Camden Council has developed an LEP which was gazetted in 2010. An important aspect of the LEP is to provide opportunities for controlling development within various land use zones so that it manages flood risk in a safe manner.

Land use zoning for the study area is indicated on **Figure 8-1**. The land use zonings designate the types of development that are permissible (either with or without consent) or not permissible in accordance with the objectives of each particular zone.

Flood planning is included Clause 7.1 of the LEP and generally outlines the objectives, areas of application and controls for floodplain management in the LGA. Clause 7.1 applies to areas within the extent of the Flood Planning Level (FPL), which is defined as the 1% AEP flood level plus 600mm freeboard. All land uses of the LEP are subject to the provisions of flood control if the land parcel, or a portion of it, is located within the FPL.

Further consideration of flooding and stormwater management in included in Clause 6.3 of the LEP. This clause requires that land development be undertaken under the provision of a Development Control Plan, which set out suitable plans and strategies to ameliorate environmental hazards such as flooding. This would appear to rely on separate planning instruments for more specific development controls, such as the Floodplain Risk Management Policy, reviewed in **Section 8.2**.

8.2 Camden Floodplain Risk Management Policy

The Camden Floodplain Risk Management Policy establishes flood risk management planning and development procedures for all flood prone land within the Camden Local Government Area (LGA). The primary method of Flood Risk Management in the Camden LGA is through the application of development controls, with the use of a development matrix, on flood prone lands up to the extent of the PMF. Council seeks to manage development on flood prone property that minimizes financial and personal risk to the community.

The aims and objectives of the flood risk management policy are to:

- Inform applicants of Council's Development Controls in flood risk areas;
- Adopt a Flood Planning Level (FPL);
- Alert the community to the extent and hazard of flooding in the Camden LGA;
- Reduce the impact of flooding on individual properties;
- Limit private and public liability resulting from flooding;
- Limit the potential risk to life and property resulting from flooding;
- Prevent non-compatible development in flood prone areas;
- Ensure development in flood prone areas is sympathetic with the character of the surrounding land uses;
- Ensure, where practical, that buildings and services required for evacuation and emergency needs are located above the Probable Maximum Flood (PMF);
- Assess all proposed developments on flood prone properties on a 'merits based' approach taking account of social, economic, environmental and flooding considerations.

Table 8-1 summarises our review of specific requirements of the Policy. We concur with requirements of the Policy that are not mentioned.

Table 8-1 Review of Requirements Relating to General Controls

Control	Comments
Floor Level: • Habitable floor levels to be the 1% AEP [100 year ARI] plus 600mm freeboard	• Most Council's in NSW use a freeboard of 500mm • A review of the FPL is undertaken in Section 8.4.
Local Overland Flooding: • Flood maps provided by the Policy generally include mainstream flooding and do not consider overland flow. The Policy identifies that there is a difference between flooding arising from overland and mainstream flows and discusses various types of overland flow examples. The Policy does not quantify what constitutes overland flow or how it should be identified by an Applicant.	• It would be expected that guidance would be provided on how to define overland flow. For example this may involve modelling to define flowpaths under existing conditions • Mapping of overland flow is recommended as part of the FRMSP with related development controls
Reliable Safe Flood Access: • Every development application on flood prone land, must demonstrate that effective warning time and reliable safe flood access for the evacuation of people to a communal refuge is available in the event of a flood event.	• This is considered onerous for some types of developed such as open space/recreation and single dwellings. In addition the provision of such access in certain locations may require unnecessary amounts of fill. • It is suggested that the inclusion of this requirement be reviewed. Consideration could also be given to assessing of the vulnerability of all roads throughout the LGA to PMF flooding and to identify those areas of the LGA where current or future residents / workers do not have reliable safe flood access to a communal refuge to inform the review.
Land Forming and Filling Operations • All applications on land below the 1% AEP flood level in flood fringe areas that propose to undertake land forming operations must be accompanied by a detailed submission, including a hydraulic report, prepared by a qualified engineer with suitable specialist experience in hydraulic engineering and flood risk management. • Any proposed filling on flood prone land will be given consideration on a merits based approach	• It is noted from the matrix that under Subdivision in Flood Storage that "All allotments in future subdivisions are to be a minimum of 300 mm above the 1% AEP flood level". This requirement is incompatible with this clause of the Policy. This suggests that Subdivision is not a compatible form of development in Flood Storage areas. • This inconsistency in Council's Policy should be resolved and either Subdivision removed as a compatible form of development in Flood Storage areas or this clause be modified to allow for balanced cut and fill works. Alternatively the impact of fill could be investigated through hydraulic modelling. • More specific filling thresholds are recommended for Upper South Creek, especially due to the number of Farm Dams and Regional Storages in the area.

Control	Comments
Hazard Categories • Taking all issues into account, particularly the limited warning time and generally rapid rise of water levels in the catchments within the Camden LGA, **all areas in the floodplain are considered to be High Hazard**. • This hazard rating is not intended to sterilise the land for any use. Rather, it is a signal that any development that occurs in the floodplain should be planned with due attention to the flood related issues and that strict implementation of flood related development controls is essential for the reduction of flood damages.	• Various development controls relating to high hazard rating of The Policy are considered onerous. Particularly for areas of the floodplain where low flood depth and low flood velocity is estimated. For example filling may be accommodated to a certain extent within such areas without impacting on neighbouring properties. • It is suggested that the approach to the designation of High Hazard throughout the floodplain be reviewed so that a more conventional designation of hazard be applied.
Flood Proofing Buildings • Engineers report required to prove that any portion of a structure can withstand the force of flood water, debris and buoyancy, up to and including the PMF flood event.	• This requirement applies to all areas of the floodplain ie. up to the PMF. The unintended consequence of this requirements is that almost all new residential building constructed in new growth centres which are affected by overland flooding in a PMF require an engineer's report. • The applicability of this requirement to development located above the 1% AEP flood extent and with floor levels at or higher than the Flood Planning Level needs to be reviewed.
Basement Parking • Accesses to basement car parks are to be above the level of the PMF. In addition evacuation routes from the basement car park is required.	• While this requirement applies to basement parking it is unclear what the requirements are for at-grade parking • Council needs to consider the intent of this requirement and the ramifications of applying this intent across the whole LGA. • The access level for the basement is recommended to be the 1% AEP plus 500mm or the PMF whichever is the lower. Otherwise basement carpark entries can be required to be higher than floor levels.

Control	Comments
Development Guideline Matrix • Council has prepared a development guidelines matrix that applies to a particular type of development based on the land use and hydraulic categories. • Three categories are identified based on the three hydraulic categories described in the 2005 Floodplain Development Manual as assessed in a 1% AEP flood while the fourth category is all land that lies between the 1% AEP flood level and the PMF. • Prior to identifying the development guideline standards, the flood categories should be determined at the location of the proposed development by a qualified engineer with suitable specialist experience in hydraulic engineering and flood risk management (engaged by the applicant). The flood category must be determined in accordance with the methods and definitions specified in the NSW Government Floodplain Management Manual.	• It is understood that the Policy was prepared as part of a Flood Risk Management Study and Plan (2001) for the Upper Nepean River Study area. Several other catchments exist within the LGA that do not appear to have been mapped to date. • The identification of the current adopted hydraulic categories can prove to be a challenge in areas outside of defined watercourses subject to overland flow and/or in developed areas with major/minor drainage systems. • In recent years a number of Councils have adopted a similar approach based on a matrix of development controls but have identified Flood Risk Precincts instead of hydraulic categories. This approach is recommended for Upper South Creek.

Other requirements that could be reviewed include:

1. The possibility for preparation of specific matrices for different catchments could be considered. This would be useful if the flood behaviour varies significantly between catchments where specific controls could be applied for safe levels of flood risk management.
2. The requirement for evacuation access and evacuation management plans for all developments should be reviewed. In some instances taking refuge or observation of precinct scale emergency management strategies may be more appropriate.
3. The inclusion of controls on ground levels should be reconsidered. These controls would most likely require filling to achieve a level 300mm above the 1% AEP and seems to preclude certain types of construction such as suspended floors above ground.
4. The section 149 certification should be reviewed as it currently states that the PMF triggers notification. Recent discussions with council suggest this may have been changed.
5. The requirement of a Flood Management Plan for residential development warrants further discussion, particularly if it is agreed with Council that refuge can be taken for residential properties in the place of evacuation in the case of the PMF.

8.3 Upper South Creek - Development Controls

Specific development controls have been prepared for the Upper South Creek floodplain through the mapping of Flood Risk Precincts and preparation of a Development Control Matrix that are located in **Appendix D**. More generic floodplain management controls have been documented by the recommended Policy revisions in **Section 8.2** and the Urban Stormwater Detention (USD) guidelines in **Appendix D**. The preparation of the development controls has been a high priority in order to manage the planned and ongoing land development in the Study Area. Stakeholders such as DP&I, OEH, Council, SES, RMS and Community Groups have been consulted and the Development Controls shall be put on public exhibition followed by subsequent review and endorsement by Council. As such the rigour applied to the refinement of the controls reflects the importance allocated to ensure that flood risk is managed appropriately for existing properties and future development.

8.4 Review of the Flood Planning Level

The Flood Planning Level (FPL) for the majority of areas across New South Wales has traditionally been based on the 1% AEP flood level plus a freeboard. The freeboard is generally set between 0.3m – 0.5m for habitable floor levels of residential properties, which comprise the majority of properties in Upper South Creek. In the 1% AEP event, under existing conditions, there are approximately 57 properties affected by overfloor flooding, and a further 72 affected by property flooding.

A variety of factors require consideration in determining an appropriate FPL. Of key consideration in the development of an FPL, is the flood behaviour, its sensitivity to changes in the catchment and the risk posed by the flood behaviour to life and property in different areas of the floodplain.

8.4.1 Likelihood of Flooding

As a guide, **Table 8-2** has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in **Table 8-2** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 8-2 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 Years)

Annual Exceedence Probability	Probability of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16

8.4.2 Current FPL

Based on the LEP, Council currently utilises the 1% AEP flood level plus a freeboard of 0.6m to define the Flood Planning Level for residential land use.

8.4.3 Incremental Height Difference between Events

Consideration of the average height difference between various flood levels can provide another measure for selecting an appropriate FPL.

Based on the existing flood behaviour, the incremental height difference between events is shown in **Table 8-3** for selected events. These are average height differences determined based on the flood levels at each of the flood affected properties within the catchment as part of the flood damages analysis.

Table 8-3 Relative Differences Between Design Flood Levels

Event	Diff to PMF (m)		Diff to 1% AEP (m)		Diff to 2% AEP (m)	
	Avg	SD	Avg	SD	Avg	SD
1% AEP	0.63	0.54	-	-	-	-
2% AEP	0.67	0.59	0.04	0.2	-	-
5% AEP	0.73	0.62	0.1	0.26	0.06	0.24

Table 8-3 indicates a larger difference in the flood level of the PMF event compared to other events. The adoption of the 1% AEP event as the flood planning level is only marginally different from that of the 2% AEP (on average 0.04m higher). Therefore, the adoption of the 1% AEP event would provide an increased level of risk reduction over the 2% AEP event, without a significant difference in the flood planning level height.

The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 1% AEP event (in the order of 0.63 metres) and may therefore potentially present an issue for the setting of flood planning levels in the catchment because the PMF represents an extreme event that may never occur.

With regards to an appropriate freeboard, the maximum difference between the PMF and the 1% AEP is 1.2m, but the average is 0.63m, indicating that basing the FPL on the 1% AEP level, with an appropriate freeboard would result in the protection of some properties in the PMF event.

8.4.4 Consequence of Adopting the PMF as a Flood Planning Level

The difference in average flood levels between the 1% AEP and the PMF event (**Table 8-3**) indicate that the use of the PMF as the FPL would result in higher levels (0.63 metres on average), and as a result higher economic costs and inconvenience to the community

The use of the PMF level as the FPL is not standard practice in NSW and may conflict with other development / building controls in the Councils DCP.

Given the risk of exposure outlined in **Table 8-2**, it is recommended that emergency response facilities be located outside of the floodplain and any other future planning ensure critical facilities be limited to areas outside of the floodplain. Modification to existing critical facilities within the floodplain are suggested to have a floor level at the PMF level.

8.4.5 Freeboard Selection

As outlined in **Section 8.4**, a freeboard ranging from 0.3 – 0.5 metres is commonly adopted in determining the FPL. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in the creek / channel vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
    - Local flood behaviour (due to local obstructions);
    - Wave action (e.g. wind induced waves or was from vehicles);
    - Culvert blockage;
    - Climate change (affecting both rainfall and ocean levels).

The various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood levels due to small local obstructions not accounted for in the modelling) (0.1m) (Gillespie, 2005).
- Local wave action (trucks and other vehicles) (allowances of ~0.1m are typical).
- Accuracy of ground / aerial survey (+/- 0.15m).
- Climate change impacts on rainfall intensity
- Sensitivity of the model to roughness and culvert blockage = /- 0.05m.

Based on this analysis, the total sum of the likely variations is in the order of 400mm, excluding climate change. This would suggest that a freeboard allowance of 500mm would be appropriate for Upper South Creek.

When applied to design events less than the PMF, the freeboard may still result in the FPL being higher than the PMF in certain cases. Council may wish to limit the FPL to the PMF in these cases and mapping of the FPL (**Figure 8-2)** has been undertaken on this basis.

8.4.6 Flood Planning Level Recommendation

The Flood Planning Level (FPL) for Upper South Creek is recommended to be the 1% AEP [100 year ARI] plus 500mm freeboard. A 500mm freeboard is standard practice in NSW and differs from the 600mm of freeboard required by the LEP. The philosophy behind the reduction in the amount of freeboard in this specific

Study Area is based on the topography and resulting flood behaviour. In general the difference in flood level between the design storm events is low and large differences in flow discharge do not directly relate to large increases in flood level. For example the difference in the average flood level between the 1% AEP and the PMF is approximately 630mm. Therefore adopting a 600mm freeboard in this case would mean that the majority of floor levels would be built at approximately the level of the PMF and theoretically never become inundated by flood. This is considered to be excessive in terms of freeboard and the lesser amount of 500mm is more appropriate.

Mapping of the FPL is included in **Figure 8-2** and is shown by the extent of the Medium Risk Precinct. It should be noted that the extent of the FPL is limited to the PMF where the 1% AEP + 500mm level exceeds that of the PMF.

The difference between the extent of the 1% AEP and the FPL does not sterilise land. That is, the difference between the two is accommodated within single lots, for the most part, and accommodation of the freeboard would be practical for residential properties built on flood prone land. The extent of the FPL also represents the outer edge of the Medium Flood Risk precinct, which has very similar controls as the Low Risk Precinct. Therefore the amount of freeboard has little bearing on the level of prescriptive controls for Upper South Creek.

9 Floodplain Risk Management Options

9.1 Overview of Available Measures

Flood risk can be defined as being existing, future or residual risk:

- Existing flood risk - the existing problem refers to existing buildings and developments on flood prone land. Such buildings and development by virtue of their presence and location are exposed to an 'existing' risk of flooding.
- Future flood risk - the future problem refers to buildings and developments that may be built on flood prone land in the future. Such buildings and developments may be exposed to a 'future' flood risk, i.e. a risk would not materialise until the developments occur.
- Continuing risk of flooding - the continuing problem refers to the 'residual' risk associated with floods that exceed management measures already in place, i.e. unless a floodplain management measure is designed to withstand the Probable Maximum Flood, it will be exceeded by a sufficiently large flood at some time in the future.

The alternate approaches to managing risk are outlined in **Table 9.1** (after SCARM, 2000):

Table 9-1 Flood Risk Management Alternatives

Alternative	Description
Preventing/Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. As a result, there are three types of measures for the management of flooding:

- Flood Modification Measures (for the existing risk)
- Property Modification Measures (for the future risk)
- Emergency Response Modification Measures (for the residual risk).

9.2 Flood Modification Measures

Modification of the floodplain using structural works can be an effective method of reducing risk of flood to residents located in the floodplain. A number a possible flood mitigation measures were identified in the community questionnaire and feedback to the structure measures therein have been summarised in **Section 3**. The identification of more specific options for flood mitigation has involved detailed review of flood behaviour, identification of properties most affected by flooding, review of urban development plans, liaison with the FMC and flood analysis.

Rural properties are for the most part more exposed to flood risk in the Upper South Creek floodplain than other land uses. Historically the rural land uses in the study area would have been undertaken either prior to flood planning controls or as development without consent. Residential and Commercial/Industrial uses have been developed more recently and would have been subject to modern planning controls. The rural properties that remain flood affected are located within broad floodplains where options to reduce flood risk may not be viable due to the vast extent of works required to protect a handful of homes or farm sheds. As a result it was decided that the selection of structural options would look to reduce flooding on existing properties, mitigate the impacts of ongoing urban development and provide improved flood behaviour for future urban developments.

Based on the flood study results, and field inspections of the catchment, seven structural options for various locations within the floodplain were identified and are listed in **Table 9-2**. The locations for these measures are shown in **Figure 9-1**.

Based on the flood study results, field inspections of the catchment and Precinct Development Plans twelve flood modification options for various locations within the floodplain were identified and are listed in **Table 9-2**. Eight of the options were chosen for further hydraulic assessment and a cost benefit analysis. Options FM6, FM11 and FM12 were not considered appropriate for further assessment because the locations where they are proposed conflicted with future precinct development. Thus options FM6, FM11 and FM 12 are not considered feasible and are not considered further. Cost estimation of the options is included in **Appendix C**.

Table 9-1: Summary of Flood Mitigation Options

Option	Description	Hydraulic Assessment Required?
FM1	Raise Masterfield Street Levee	Yes
FM2	Drainage Improvement on Rossmore Crescent	Yes
FM3	Increase Rileys Creek Capacity	Yes
FM4	Creek Revegetation in South Creek	Yes
FM5	Blockage Control Structure at South Creek	Yes
FM6	Catherine Fields Road Levee	No
FM7	Increase Regional Storage - Rileys Creek	Yes
FM8	New Regional Storage - Scalibrini Creek	Yes
FM9	New Regional Storage - Kemps Creek	Yes
FM10	Increase Regional Storage – South Creek	Yes
FM11	Increase Regional Storage – The Northern Road	No
FM12	New Regional Storage – South Creek	No
FMa	Combination of FM2 and FM3	Yes
FMb	Combination of FM2, FM3, FM4, FM7	Yes

9.2.1 FM1 – Raise Masterfield Street Levee

The risk of flooding is known for this area and a levee was constructed to prevent flooding in large storm events. It was found from modelling the developed scenario that the levee prevents flooding in design storm events up to and including the 0.2% AEP, however the 500mm freeboard requirement to the 1% AEP has been reduced. Thus this option proposes to increase the level of the levee to retain the required amount of freeboard and construct a piped 600mm local drainage network connecting to south creek with a flood gate to prevent backwater from South Creek.

Appropriate strategies are recommended in the case of an extreme flood event (PMF) where it has been predicted for the levee to overtop. These have been outlined for items to be included in update of the Local Flood Plan (EM2).

Figure 9-1 shows the design layout and **Figure 9-2** shows the afflux in the 1% AEP. The option has minimal effect on flood behaviour because the level of the levee does not affect flood behaviour in the 1% AEP. Minor improvements are shown behind the levee as a result of the local drainage network. It was not possible to improve the flood risk behind the levee to any significant degree because the drainage network is affected by the South Creek backwater both up and downstream of Bringelly Road.

9.2.2 FM2 – Drainage Improvement on Rossmore Crescent

The topography in this area is flat and overland flows make their way downstream to the Rileys and South Creek confluence via a myriad of flowpaths. This option attempts to reduce the extent of overland flow flooding in the area with the implementation of additional open channel and underground drainage networks on Rossmore Street. **Figure 9-3** shows the design layout, including a piped 900mm drainage network and two 3m wide by 1.2m high box culverts under existing roads. **Figure 9-4** shows the afflux in the 1% AEP. It was found that the option reduced flood levels by 0.1-0.3m in the vicinity of the drainage improvements, however further improvement would require regrading of large portions of floodplain in order to capture more overland flow. This level of works is not considered a viable addition to this option.

Minor increases in flood level are shown at the confluence as a result of the drainage improvement conveying flow at a greater rate to South Creek.

9.2.3 FM3 – Increase in Rileys Creek capacity

A number of rural residential properties are affected by flooding on the Rileys Creek floodplain. The flood behaviour is typical of the South Creek catchment where broad floodways carry the majority of flow and inset creek channels have an insignificant capacity in comparison. FM3 involved excavation of a creek channel into the broad floodway having an approximate width of 25m and a depth of 2m, over a length of 1630m.

Figure 9-5 shows the design layout and **Figure 9-6** shows the afflux in the 1% AEP. The option performs well in reducing water levels in Rileys Creek by up to 0.5m, however there is a maximum 0.1m increase at the South Creek confluence as a result. This option would require a significant amount of excavation in the existing floodway and loss of mature trees.

9.2.4 FM4 – Revegetation of South Creek

This option involves planting trees along the top of bank for South Creek extending from Bringelly Road up to the precinct boundaries of Oran Park and Catherine Fields, a total length of 9.5km. Revegetation is intended to retard flows in South Creek and reduce the volume of flow at Bringelly Road. In addition this option would improve flora habitat and increase the stability of the South Creek channel.

Figure 9-7 shows the design layout and **Figure 9-8** shows the afflux in the 1% AEP. It is shown that the increase in channel roughness increases flood levels to a maximum of 0.3m in South Creek. A reduction in flood level of 3cm downstream of Bringelly road is predicted, which is not significant. It is expected that the overall flood volume is contributing to flood levels at Bringelly Road more than the flow velocity and the retardation provided by the increase in roughness has little impact.

9.2.5 FM5 – Debris Control Structure for South Creek bridge

The modelling assumes a 50% blockage factor for Bringelly Road South Creek crossing to be consistent with the flood study. This option provides a structure upstream of the bridge in order to reduce the blockage allowance to 0%. This involves installation of a number of 300mm concrete poles/bollard in the creek channel to trap debris before it would make its way down to the bridge. This was replicated in the TUFLOW model by completely blocking one of the 1D cross sections of the creek upstream of the bridge at the top of bank level.

Figure 9-9 shows the design layout and **Figure 9-10** shows the afflux in the 1% AEP. It was found that the structure would have little impact on flood behaviour. Flooding in this location is controlled by Bringelly Road, Masefield Street levee and an expansive floodplain. Relocation of the blockage allowance to a point upstream shows little benefit.

The results of the hydraulic assessment proved that further damages analysis of this option was not feasible.

9.2.6 FM6 – Catherine Fields Road Levee

A number of existing rural residential properties along Catherine Fields Road are flood affected as a result of flows along the fringe of South Creek. An earth levee would be a simple means of preventing flows of south Creek entering these properties.

Options to prevent flooding for these properties are not considered feasible because they are located within a future precinct of the SWGC and investments of flood mitigation funding is not viable in this case.

9.2.7 FM7 – Increase Existing Storage at Rileys Creek

An existing Farm Dam is located on-line in Rileys Creek directly downstream of Camden Valley Way. The dam location is in the upper part of the Rileys Creek catchment, however its size is conducive to providing significant storage should the level of the detention bund be increased. The option was modelled by insertion of 1D breaklines to the TUFLOW model that would increase the level of the existing detention bund, expand the storage area and lower parts of the basin floor. In general the depth of excavation in the basin floor was approximately 0.6m and the top of the bund was increased by 1.5m. It is assumed that purchase of one property would be required for this option at a value of $600,000 ex GST. The outlet of the basin acts as the hydraulic control and no spillway above the outlet is included in the 1% AEP. The outlet is configured as shown below and includes an 8m wide by 0.4m high lower opening and a 12m wide by 0.4m high upper opening.

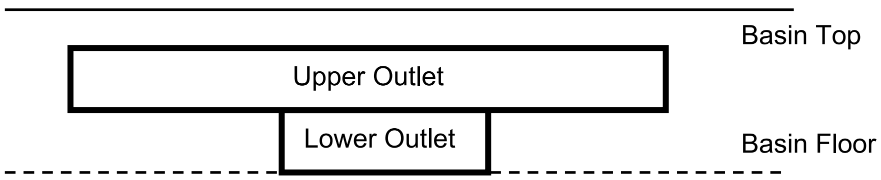


Figure 9-11 shows the design layout and **Figure 9-12** shows the afflux in the 1% AEP. The results show that flood levels are reduced from between 0.05-0.15m in Rileys Creek and by up to 0.2m in South Creek. This would effectively eliminate the 0.17m afflux in the development scenario at Bringelly Road.

9.2.8 FM8 – Construct Regional Storage for Scalibrini Creek

Precinct development for Leppington is in progress and preliminary versions of the ILP have been released. A number of on-line basins are proposed to control the increase in runoff as a result of urban development. This option investigates the performance of a significant on-line basin to reduce flood levels in the development scenario. It should be noted that this has been undertaken on a broad scale and assumes that the flows of the urban development have been controlled to pre-development levels. The location of the on-line basin has been proposed to align with open spaces and drainage infrastructure in the preliminary ILP. The outlet of the basin acts as the hydraulic control and no spillway above the outlet is included in the 1% AEP. The outlet is configured as shown above and includes a 9m wide by 0.4m high lower outlet and a 17m wide by 0.4m high upper outlet.

Figure 9-13 shows the design layout and **Figure 9-14** shows the afflux in the 1% AEP. The results show that flood levels are reduced by approximately 0.2m for the 1% AEP in Scalibrini Creek. A greater reduction in flood level of 0.25m is predicted at Bringelly Road. This would effectively reduce the 0.27 m afflux in the development scenario at Bringelly Road.

9.2.9 FM9 – Construct Regional Storage for Kemps Creek

FM9 has been designed in a similar manner to FM8 and is also located in the Leppington Precinct. The outlet of the basin acts as the hydraulic control and no spillway above the outlet is included in the 1% AEP. The outlet is configured as shown above and includes a 7m wide by 0.4m high lower opening and a 11m wide by 0.4m high upper opening.

Figure 9-15 shows the design layout and **Figure 9-16** shows the afflux in the 1% AEP. The results show that flood levels are reduced by approximately 0.2m for the 1% AEP in Kemps Creek. A greater reduction in flood level of 0.3m is predicted at Bringelly Road. This would assist in reducing the 0.54m afflux in the development scenario at Bringelly Road.

9.2.10 FM10 – Increase Existing Storage for South Creek

Three significant regional storage basins exist on the western side of South Creek that are used for crop irrigation. This option was proposed to increase the storage capacity in a similar manner to FM7. However this option was not considered feasible as precinct development in Oran Park proposed to reconfigure one of these existing storage basins and subsequent development of the Marylands precinct would most likely do the same. As a result this option was not considered further.

9.2.11 FM11 – Increase Existing Storage at The Northern Road

Three significant on-line storage basins are located on tributaries to Thomsons Creek in the vicinity of the Northern Road. This option was proposed to increase the storage capacity in a similar manner to FM10. However this option was not considered feasible as precinct development in Oran Park proposed to reconfigure one of these existing storage basins and subsequent development of the Marylands precinct would most likely do the same. As a result this option was not considered further.

9.2.12 FM12 – Construct Regional Storage for South Creek

FM12 was proposed to provide an large offline storage basin to divert flows from South Creek to a storage area located within open space proposed in the Catherine Fields Part Precinct ILP. It was not considered appropriate to proceed further with this option because it conflicted with a basin proposed in the Water Cycle Management plan of the precinct.

9.2.13 FMa – Combination of FM2 and FM3

This option was investigated to test the benefit of combining options FM2 and FM3. **Figure 9-17** shows that the combined options lower the flood levels in Rileys Creek by up to 0.5m. This is due to improvements in the drainage capacity in Rossmore Cr and Rileys Creek channel. However the improvement conveys flow to South Creek more efficiently and increases flood levels at the confluence by approximately 0.1m.

9.2.14 FMb – Combination of FM2, FM3, FM4 and FM7

FM2, FM3 and FM7 all have benefits to properties affected by overfloor flooding in Rileys Creek. However little benefit was shown for flood levels in South Creek for all of the options. As such it was anticipated that the combination of these options would reduce flood levels in South Creek and possibly alleviate the 0.17m flood level increase at Bringelly Road estimated by the developed scenario model in comparison to Flood Study results. Whilst FM4 was not found to have hydraulic benefits on its own, it was included in the combination of options in an attempt to retard flows in South Creek and reduce the impacts predicted at the Rileys Creek confluence in FMa. **Figure 9-18** shows that there is a benefit to flood levels both along Rileys Creek and in South Creek in the vicinity of Bringelly Road. However the increases in South Creek as a result of the increase in roughness (FM4) remain.

9.3 Property Modification Options

A number of property modification options were identified for consideration in the Upper South Creek floodplain. These are:

- LEP Update (P1)
- Building and Development Controls (P2)
- House Raising (P3)
- House Rebuilding (P4)
- Voluntary Purchase (P5)
- Land Swap (P6)
- Council Redevelopment (P7)
- Flood Proofing (P8)

These options are discussed in detail below.

9.3.1 P1 – LEP Update

Update of the Camden LEP would involve updating wording of the planning instrument to recognise the specific development controls prepared for Upper South Creek, as described in **Section 8** and in **Appendix B**. It is noted that urban development within the Upper South Creek floodplain would be subject to development controls that are different from other regions of the Camden LGA. For example the Nepean River flows through the LGA and has much different flood behaviour mechanisms than Upper South Creek. Therefore it should be recognised that the development controls herein are specific to the Upper South Creek catchment and should be treated as such in the respective planning instruments.

Recommendations for the update of the LEP are listed below:

- *Update section 7.1 to refer to Council's Flood Policy or relevant DCP for specific planning controls*
- *Change wording under section 7.1 clause 2 so that the flood planning requirements are applicable to the whole floodplain and not limited to the FPL*
- *Update Section 7.1 clause 5 to allow for alternative flood planning levels to the 1% AEP plus 600mm freeboard*
- *Consideration should be given to uses such as child care centres and aged care facilities that are permissible under rural, residential and recreation land use. These land uses are permitted in high to medium risk areas of the floodplain where child care centres and aged care facilities should not be located.*
- *Include general fill in land use zones RE1 and RE2*
- *Ensure that complying or exempt development includes provisions for the 'Concessional Development' definition included in the Development Controls (**Appendix B**)*

9.3.2 P2 – Building and Development Controls

Building and Development Controls should be included into a planning instrument, such as a DCP, for the Upper South Creek catchment. This would allow for the findings of the Floodplain Risk Management Study to be applied through improvements to existing development and consideration of flood planning controls for future development. Standard methods for administering the planning controls are with the use of a Flood Risk Precinct Map and associated Floodplain Development Matrix. This method was adopted for the Camden Flood Risk Management Policy for the Nepean River. A specific Flood Risk Precinct Map and associated Floodplain Development Matrix has been prepared for Upper South Creek that directly addresses the planning implications for the study area and intends to control precinct development in a manner that does not adversely affect flood behaviour. The Flood Risk Precinct map is shown in **Figure 8-2** and a review of the Flood Policy, with recommended changes, is included in **Section 8.2**. It is suggested that Council shall either update the Flood Policy to include Upper South Creek or prepare a separate DCP. The development controls for Upper South Creek are outlined in **Appendix B**.

9.3.3 P3 – House Raising

House raising is a possible option to reduce the incidence of over floor flooding in properties. However, whilst house raising can reduce the occurrence of over floor flooding, there are issues related to the practise, including:

- Difficulties in raising some houses, such as slab-on-ground buildings. In some slab-on-ground situations it may be possible to install a false floor, although this is limited by the ceiling heights;
- The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages, etc;
- Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists – i.e. there will still be a residual risk;
- Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounding a property;
- The need to ensure the new footings or piers can withstand flood-related forces; and
- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area.

For the above reasons, and because of the planned urban development as part of the SWGC, house raising is not recommended for Upper South Creek. As such no further economic consideration of this option has been undertaken.

9.3.4 P4 – House Rebuilding

Under a re-building scheme, the property owner would have the option of utilising the subsidy for house raising described above for re-construction instead. In a number of cases, the ability to raise properties can be difficult and therefore rebuilding may be the only option. The advantage of this option is that the new structure can also be built in a flood compatible way (such as including a second storey for flood refuge).

One of the issues associated with this option is that there is still a significant cost for the property owner to redevelop their land. In addition, this provides an inequitable situation for those properties that are subject to the subsidy and those that are not. It can have the effect of skewing the property development market, where those properties subject to the subsidy are made more attractive for development than those properties that are not.

House rebuilding is not recommended for Upper South Creek and no further economic consideration of this option has been undertaken because of the planned urban development as part of the SWGC.

9.3.5 P5 – Voluntary Purchase

An alternative to the construction of flood modification options and for properties where house raising is not possible is the voluntary purchase of existing properties. This option would free both residents and emergency service personnel from the hazard of future floods. This can be achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then be rezoned to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

However, this option should be considered after other, more practical options have been investigated and exhausted.

The recommended criteria to determine properties that are eligible for voluntary purchase are:

- Properties that were constructed prior to 1986;
- Flood risk is sufficient to endanger the lives of residents;
- Located in the high hazard zone for the 1% AEP flood event;
- Occurrence of above floor flooding in the 5% AEP flood event;
- Does not conflict with the flood risk reduction provided by other mitigation measures, and;
- Economic value of damages for a particular property is comparable to the property market value.

The costs for Voluntary Purchase has been used to involve purchase of the 51 properties affected by overfloor flooding in the 5% AEP at a value of $400,000 in addition to a demolition and rehabilitation cost of $50,000.

Table 9-1 Reduction in AAD Resulting from Different House Raising Scenarios*

Total Number of properties affected in 5% AEP	Properties with overfloor flooding in 5% AEP	AAD Reduction (per property)	Total Reduction in AAD	NPV (30 Years) of Reduction	Estimate Cost of VP
291	51	$3,061.04	$156,111.51	$1,937,194	$22,950,000

* Estimate based on “typical” property with overfloor flooding damage of $50,000

9.3.6 P6 – Land Swap

An alternative to pure voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area, such as an existing park, for the flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land rezoned to open space.

The costs for Land Swap has been used to involve provision of 51 properties for those affected by overfloor flooding in the 5% AEP at a value of $300,000 in addition to a demolition and rehabilitation cost of $50,000. This assumes that Council owns land that is available for building an average 3 bedroom home to compensate for the flood affected property loss. The reduction in AAD as a result of the option is consistent to the approach outlined in **Table 9-1**.

9.3.7 P7 – Council Redevelopment

This option also provides an alternative to the Voluntary Purchase scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and resell them with a break-even objective.

9.3.8 P8 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding.

These include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating, to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Examples of proofing measures include:

- All structural elements below the flood planning level shall be constructed from flood compatible materials;
- All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 1% AEP flood event. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF; and
- All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the flood planning level.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties.

These measures should be carried out according to a pre-arranged plan. These measures may include:

- Raising belongings by stacking them on shelves or taking them to a second storey of the building;
- Secure objects that are likely to float and cause damage;
- Re-locate waste containers, chemical and poisons well above floor level; and
- Install any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

The SES Business Flash Flood Tool Kit (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures.

The costs for flood proofing have been estimated based on the assumption that all properties affected by overfloor flooding in the 1% AEP would have works undertaken to the value of $50,000 for flood proofing.

9.4 Emergency Response Modification Options

A number of emergency response modification options are suitable for consideration within the Upper South Creek floodplain. These are:

- Information transfer to the SES (EM1);
- Preparation of Local Flood Plans and Update of DISPLAN (EM2);
- Flood warning system (EM3);
- Public awareness and education (EM4); and
- Flood warning signs at critical locations (EM5).

These options are discussed in detail below.

9.4.1 EM 1 – Information transfer to SES

The findings of the Flood Study and the Flood Risk Management Study and Plan provide an extremely useful data source for the State Emergency Service. All relevant data should be transferred to SES from Council.

9.4.2 EM 2 – Update of the Local Flood Plan

It is recommended that the Flood Plan be updated to reflect the outcomes of this current study. The Flood Plan has not been updated for six years thus this would be a suitable opportunity to update the Flood Plan for other recent studies within the LGA.

With respect to the Upper South Creek floodplain, the following amendments to the Flood Plan are recommended:

- Include a section describing the flood behaviour and effects for the Upper South Creek floodplain
- Update the flood warning dissemination method to include the electronic media and television stations
- Update details of the population in the floodplain and subsequent service requirements for the flood refuge centres. It is likely that a far greater number of residents would be affected by an extreme flood following urban development in the study area.
- Identify additional flood refuge centres for parts of the floodplain that are unable to access the two existing flood refuge centres.
- The following key access roads/evacuation routes should be included (further details of accessing road flooding is provided below in **Section 7.4.1**):
    - The Northern Road – Northbound access is safe only from Georges Park
    - Camden Valley Way – Evacuation is only safe for motor vehicles northbound from the Deepfields Road intersection
    - Bringelly Road - Evacuate to the east from areas on the eastern side of South Creek only. The South Creek bridge is inaccessible during storm events of the 2% AEP and above.
- Provide a non-automated flood warning plan for the residents of Masterfield Street that are located behind the existing levee. The flood depth sign recommended for Bringelly Road could act as an indicator for the risk of flooding to properties behind the Masterfield Street levee. The top of the levee is 60.5m AHD in existing conditions and designed to be 60.7m AHD for FM1 where 500mm freeboard is provided to the 1% AEP for the developed scenario. The level of the PMF is 61.9m AHD, which overtops the levee to a depth of more than 1m. Appropriate emergency management response triggers should be included in the update of the DISPLAN so that residents on Masterfield Street can be notified on the increase in flood risk and evacuate if needed. This should be based on a level reading at the flood depth sign corresponding to a certain amount of freeboard for the levee, probably based on the following:

    1. 500mm freeboard = warn residents of Masterfield Street that there is a major flood in South Creek and preparations for evacuation should be made
    2. 300mm freeboard = issue residents with an evacuation order to the nearest refuge location
    3. 150mm freeboard = issue residents with final evacuation order

9.4.3 EM 3 – Flood Warning System

The short critical duration and response times for the Upper South Creek floodplain limit the feasibility of an automated flood warning system implementation for most of the study area. The short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

However a non-automated flood warning system would be useful in reducing flood risk to residents of Masterfield Street Rossmore. These residents are located on the floodplain behind the Masterfield Street levee. The cost of the non-automated flood warning system for Masterfield Street would be covered through construction of flood signage (EM5), update of the Local Flood Plan (EM2) and raising of the levee (FM1).

Therefore no further cost implications are required for this option and flood warning systems are not recommended elsewhere.

9.4.4 EM 4 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for the area. This includes the defence of their property and their evacuation, if required, during the flood event.

Flood awareness campaigns should be an ongoing process and requires the continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area.

For effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment.

It is recommended that the following awareness campaigns be considered for the floodplain. These should be prepared together with the SES, as they have a responsibility for community awareness under the DISPLAN.

- Preparation of a FloodSafe brochure. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information. Once prepared, the FloodSafe brochure can then be uploaded to the Council and SES websites in a suitable format, where it would be made available under the flood information sections of the website. The brochures could also be made available at Council offices and community halls.
- Development of a Schools Package from existing material developed by the SES and distribution to schools accordingly. Education is not only useful in educating the students, but can be useful in dissemination of information to the wider community.
- A regular (annual) meeting of local community groups to arrange flood awareness programs on a regular basis.
- Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

9.4.5 EM 5 – Flood Warning Signs at Critical Locations

A number of public places in the catchment experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths. It is recommended that flood depth rulers are installed as signage on the following road crossings:

1. Bringelly Road (South Creek)
2. Northern Road (Location 2)
3. Catherine Fields Rd (South Creek)
4. Barry Avenue (Rileys Creek)
5. Deepfields Road (Rileys Creek)
6. Camden Valley (Location1)
7. Camden Valley Way (Location 2)
8. Camden Valley Way (Location 3)
9. Ingleburn Road
10. Heath Road (Scalibrini Creek)

*Refer to **Table 7-2** for details of the hydraulic results at these road crossings*

For locations other than road crossings, which are affected by high flood risk, these are likely to be redeveloped as part of the SWGC precincts. The need for signage would be revised during the flood risk assessment required by the precinct planning process.

10 Economic Assessment of Options

10.1 Damage Estimation for Options

Damage costs for each of the modelled flood modification options were estimated for the PMF, 0.2%, 0.5%, 1% AEP, 2% AEP, 5% AEP and 20% AEP events. The results of the damage assessment for the Options are summarised in **Table 10-1**.

The damage costs for each of the Options were estimated for the developed scenario based on the peak flood levels for 0.2%, 0.5%, 1% AEP, 2% AEP, 5% AEP events. It is noted that the damage costs for the PMF event were based on the 60 minute duration storm. For consistency the options modelling results were then compared to calculations of the developed scenario damages without the options in place. The damage estimations for the results of the Flood Study, reported in **Section 6,** were not used to assess the economic benefit of the options**.**

Option FM1 results in a decrease in damages for events of the 1% AEP and above. However an increase in damages is estimated for the 5% AEP. This shows that the option performs well for larger storm events but actually worsens the flood behaviour in more frequent events.

Options FM2 and FM3 both show a reasonable reduction to damages for all design storm events.

FM4 increases the damages for all storm events indicating that this option does not perform well hydraulically. The revegetation of the creek channel increases flood levels in the vicinity and does little to reduce flood levels elsewhere.

FM7 however improves hydraulic behaviour and lessens the flood damages for all design storm events. The storage provided reduces flood affectation for a number of properties downstream.

FM8 increases the damages for design storms up to and including the 1% AEP as a result of the basin locally increasing water levels on the eastern side of the basin. The hydraulic benefits are however reflected by a reduction in damages for the PMF.

FM9 improves hydraulic behaviour and lessens the flood damages for all design storm events. However the reduction in flood damages in insignificant in comparison to the capital cost for construction. Whilst the FM9 concept was prepared with reference to preliminary versions of the Leppington precinct ILP, it is no longer compatible with the proposed land use in this area. It is then not compatible with local precinct plans and policies because it is not supported by the current ILP.

FMa is a combination of FM2 and FM3 which both reduced damages independently and therefore it is expected that they would perform well in combination. The results reflect this and it is the option that has the greatest reduction in damages for design storms up to and including the 1% AEP.

FMb is a combination of FM2, FM3, FM4 and FM7. This option was anticipated to provide a large reduction in flood levels at Bringelly Road. The results however indicate that this combined option does not perform much better than FM7 or FMa. The reduction in damages for FMb is similar to those estimated for FMa.

It is then concluded that FM3 and FMa are the best performing options from a damage reduction perspective. It should be noted that the damage reduction for FMb would be significantly improved if FM4 was not included.

Table 10-1 The Results of Damage Assessment for Options

Scenario	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)	Reduction of Damage ($November 2012)
PMF						
FM1	137	1.105	1.15	291	$6,943,705.00	$18,699.30
FM2	137	1.095	1.14	291	$6,929,575.00	$32,829.30
FM3	136	1.09	1.13	291	$6,865,893.00	$96,511.30
FM4	137	1.11	1.16	291	$6,962,537.00	-$132.70
FM7	136	1.07	1.11	291	$6,815,645.00	$146,759.30
FM8	128	0.945	0.95	291	$6,061,272.00	$73,506.47
FM9	126	0.94	0.93	291	$5,963,624.00	$170,903.00
FMa	136	1.09	1.13	291	$6,857,430.00	$104,974.30
FMb	136	1.065	1.11	291	$6,774,789.00	$187,615.30
1% AEP						
FM1	56	0.4	0.37	291	$2,021,054.00	$12,190.47
FM2	56	0.345	0.37	291	$1,986,111.00	$47,133.47
FM3	55	0.34	0.35	291	$1,902,230.00	$131,014.47
FM4	56	0.365	0.4	291	$2,055,959.00	-$22,714.53
FM7	56	0.325	0.36	291	$1,977,700.00	$55,544.47
FM8	56	0.385	0.42	291	$2,020,444.00	-$10,142.89
FM9	57	0.38	0.41	291	$1,993,916.00	$47,489.00
FMa	54	0.34	0.35	291	$1,863,324.00	$169,920.47
FMb	52	0.355	0.38	291	$1,869,761.00	$163,483.47
5% AEP						
FM1	51	0.235	0.29	291	$1,722,310.00	-$2,231.16
FM2	51	0.24	0.28	291	$1,673,688.00	$46,390.84
FM3	48	0.24	0.29	291	$1,630,668.00	$89,410.84
FM4	51	0.26	0.31	291	$1,745,572.00	-$25,493.16
FM7	51	0.245	0.29	291	$1,708,216.00	$11,862.84
FM8	50	0.32	0.35	291	$1,682,287.00	-$13,937.11
FM9	50	0.315	0.34	291	$1,667,106.00	$5,902.73
FMa	48	0.23	0.28	291	$1,605,325.00	$114,753.84
FMb	48	0.245	0.30	291	$1,623,075.00	$97,003.84

*Note – The total damage for each option in the table was compared to the damage calculated for the developed scenario not for the existing damages reported in **Section 6**.*

10.2 Cost Estimate of Options

A preliminary cost estimate of the potential flood modification options has been prepared to assist with the comparative assessment. The costs were prepared with reference to the Cordell Building Cost Guide.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the options, these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost.

A benefit-cost ratio can be calculated to quantitatively assess the economic benefit of some of the options (i.e. those which are hydraulically modelled and those with known benefits).

Table 10-2 is a summary of the estimated costs for those options which have been quantitatively assessed. Details of these cost estimates are provided in **Appendix C**.

10.3 Average Annual Damage for Quantitatively Assessed Options

The total damage costs for each modelled option and an average annual damage (AAD) estimated as described in **Section 6**. **Table 10-2** lists the AAD for each option and a comparison to the AAD in the developed scenario.

10.4 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events to the cost of implementing the option.

The developed scenario was used as the base case to compare the performance of modelled options. Inputs for the assessment include the flood modelling results reported in **Section 5**. The PMF, 0.2%, 0.5%, 1% AEP, 2% AEP and 5% AEP events were considered for this evaluation. Preliminary costs of each option were estimated in **Appendix C** and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 10-4 summarises the overall economic assessment for each option that was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

- B/C greater than 1 indicates the economic benefits are greater than the cost of implementing the option;
- B/C less than 1 but greater than 0 indicates an economic benefit from implementing the option but the cost is greater than the economic benefit;
- B/C equal to zero indicates no economic benefit from implementing the option; and
- B/C less than zero indicates a negative economic impact of implementing the option.

Table 10-2 Benefit-Cost Ratio of Options

Option ID	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 30 years)	Reduction in AAD	NPV of Reduction in AAD	Benefit - Cost Ratio	Rank
FM1	$669,300.00	$6,000.00	$743,754	788	$9,778	0.01	**6**
FM2	$2,138,700.00	$6,375.00	$2,217,808	25516	$316,629	0.14	**1**
FM3	$8,800,400.00	$6,500.00	$8,881,059	48972	$607,696	0.07	**3**
FM4	$1,056,600.00	$19,000.00	$1,292,372	-12320	-$152,879	-0.12	**10**
FM5	$606,000.00	$5,000.00	$668,045	$0	$0	0.00	**8**
FM7	$3,646,100.00	$10,000.00	$3,770,190	8252	$102,399	0.03	**5**
FM8	$18,517,400.00	$15,000.00	$18,703,536	-6901	-$85,635	-0.005	**9**
FM9	$27,355,700.00	$20,000.00	$27,603,881	4720	$58,571	0.002	**7**
FMa	$9,552,000	$12,875	$9,711,766	62518	$775,788	0.08	**2**
FMb	$14,254,700	$41,875	$14,774,329	53401	$662,655	0.04	**4**

The benefit-cost analysis shows that all structural options (FM2 to FM7) have a benefit-cost ratio lower than 0.1. It suggests that these structural options may not be suitable as these options have a high cost compared with their potential economic benefit. It should be noted that if FM4 was not included in FMb, the potential ranking would be significantly different. Reduction in capital costs of over $1 million, reduction in ongoing costs of $20,000 (nearly 50%) and increased reduction in AAD to around $65,000.

10.5 Economic Assessment of Desktop Assessed Options

A detailed economic analysis was not prepared for the property modification and emergency response modification options. Economic benefits of these options was estimated as described in **Section 11**.

11 Multi-Criteria Assessment of Options

11.1 Overview

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach to assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute "right" answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion as shown in **Table 11-1**.

11.2 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain outlined in **Section 4** as well as the community preferences outlined in **Section 3**. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion.

The criterion adopted includes:

Economic	Benefit Cost Ratio Capital and Operating Costs Hydraulic Benefit
Social	Reduction in Social Disruption Reduction in Risk to Life Community Acceptance Compatibility with Policies and Plans
Environmental	Meeting of River Flow and Water Quality Objectives Fauna/ Flora

The scoring system is shown in **Table 11-1** for the above criteria.

Table 11-1 Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio	2	-1 to -0.5	-0.5 to 0	0	0 to 0.5	0.5 to 1
		Capital and Operating Costs	1	Extreme >$2 million	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Very Low $10,000 - $50,000
		Hydraulic Benefit	1	> 0.2 m increase in peak flood level at any location	> 0.1 m increase in average peak flood level at any location	Negligible Improvement or only local improvement	0.1 - 0.5 m decrease in peak average flood level across the floodplain	(>0.5 m decrease in peak average flood level across the floodplain
Social	1	Reduction in Risk to Life	1	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
		Community support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	1	Compatible with Water Quality and River Flow Objectives	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Fauna/Flora Impact	1	High negative impact	Slight negative impact	Neutral	Some benefit	Considerable benefit

11.2.1 Economic Assessment Overview

The economic assessment involved an appreciation of:

- Benefit Cost Ratio;
- Capital and Operating Costs; and
- Reduction in Risk to Property.

Capital and operating costs for major structural options were assessed as described in **Section 10.2**, whilst a judgement of the likely capital and recurrent costs was made for the remaining options by experienced engineers.

It is noted that the Benefit Cost Ratio incorporates both the capital & operating costs, and the reduction in the Risk to Property. However, these are included to provide an overall measure of both the affordability of an option (the magnitude of the cost) as well as the overall benefit of the option. The Benefit Cost Ratio, while providing a representation of the economic efficiency of the option, does not provide this information.

11.2.2 Social Impact Assessment

The social impact assessment involved an appreciation, based on the information collated in the questionnaire described in **Section 3** as well as **Section 4**, of:

- Reduction in Social Disruption;
- Reduction in Risk to Life;
- Council Attitude; and
- Community Support.

In general, there is a reasonable level of flood awareness in the community. The nature of the population in the area is such that the population is fairly stable with significant growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

The community support for a particular option was derived by converting the community responses received in the consultation period as discussed in **Section 3** into a numerical score.

The attitudes of Council to different options were subjectively assessed based on discussions with representatives over the course of the study.

11.2.3 Environmental Assessment

The environmental impact assessment involved an appreciation, based on the information collated in **Section 4**, of both:

- Compatibility of the option with Water Quality and River Flow Objectives; and
- Fauna/flora impact.

It is important to recognise that the watercourses of the area need to be managed in a sustainable way, in recognition of the modified nature of the system and the planned urban development.

11.3 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix D**. The score for each category (i.e. economic, environment and social) is determined by the score for each criterion, factored by a weighting as shown in **Table 11-1**. The overall score for the option is then calculated by the weights for each of the categories.

It is noted that the economic category is given more weight than either the environment or social categories. This is due to the economic category being the most direct measure of both the effectiveness of the option on flooding as well as its affordability. Options that rank highly on environmental or social categories do not necessarily provide significant flooding benefits.

A rank based on the total score was calculated to identify those options with the greatest potential for implementation. The total scores and ranks are also shown in **Appendix D**.

This ranking is proposed to be used as the basis for prioritising the components of the Floodplain Risk Management Plan. It must be emphasised that the scoring shown in **Appendix D** is not “absolute” and the proposed scoring and weighting should be reviewed carefully as part of the process of finalising the overall Floodplain Risk Management Plan.

12 Floodplain Risk Management Plan

12.1 Findings of Floodplain Risk Management Study

Both the Triple Bottom Line matrix (**Appendix D**) and the economic cost benefit analysis (**Table 10-4**) were used in the development of this Plan. The economic analysis, while limited to only the modelled options, provides a more detailed analysis of the financial cost benefit. Given the nature of the scoring system in the multi-criteria analysis, this detail reduces its significance. However, the Triple Bottom Line matrix provides a more thorough view of all the options. Therefore, both tables (**Appendix D** and **Table 10-4**) need to be viewed together, where possible, in order for a comprehensive analysis of the options.

Updates to both will be undertaken following the review process and the public exhibition period. These updates may affect the ranking of the options, which will affect the outcomes of this Plan.

The plan consists of a mixture of:

- Property modification options
- Emergency response modification options
- Flood modification options.

Triple Bottom Line and Economic Benefit / Cost Ratio analysis provide direction in the selection of various options. However, the final selection of options needs to consider other factors relevant to the floodplain and wider community. For the purpose of selecting a list of options for the Plan, the following criteria have been adopted:

- Overall ranking in the Triple Bottom Line matrix and Benefit/ Cost ratio where available
- Benefits to the wider community rather than localised benefits

The flood management options recommended in the plan are provided in **Table 12-1**.

12.2 Implementation Program

The implementation program essentially forms the action list for this Plan. This action list is shown in **Table 12.1**.

The benefit of following this sequence is that gradual improvement of the floodplain occurs, as the funds become available for implementation of these options.

Further steps in the floodplain management process from this point onwards are:

1. Floodplain Management Committee to consider and adopt recommendations of this Plan
2. Council considers the Floodplain Management Committee’s recommendations,
3. Exhibit the draft Plan Report and seek community comment,
4. Consider public comment, modify the Plan if and as required, and submit the final Plan to Council,
5. Council adopt the Plan and submit an application for funding assistance to OEH and other agencies as appropriate,
6. As funds become available from OEH, other state government agencies and/or Council’s own resources, implement the measures in accordance with the established priorities.

This plan should be regarded as a dynamic instrument requiring review and modification over time. The catalysts for change could include new flood events and experiences, legislative change, alterations in the availability of funding and reviews of the Council planning. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

12.3 Key Stakeholders

As a part of the implementation of the Plan and the detailed design phase of some of the options, liaison should be undertaken with key stakeholders. These key stakeholders should include, but are not limited to:

- Sydney Water - particularly with regards to any impacts on their assets within the catchment.
- SES - particularly in regards to Option EM1, EM2, EM3, EM4 and EM5
- OEH - as it is likely that funding would be sourced from OEH for a number of the options, they should be consulted as a part of the design process.
- RMS - to be consulted regarding options that impact on any RMS roads in the study area.
- Private Residents – in particular, those residents to be affected by the proposed works.

Table 12-1 Floodplain Risk Management Measures Recommended for Inclusion in the Upper South Creek Risk Management Plan

Option ID	Location	Description	Ranking	Estimated Capital Cost	Estimated Recurring Cost	Priority for Implementation
P2	Camden LGA	Building and Development Controls	1	$10,000	$1,500	High
P1	Camden LGA	LEP Update	2	$5,000	$1,000	High
EM2	Upper South Creek Floodplain	Update of Local Flood Plan and DISPLAN	3	$25,000	$1,500	High
EM4	Upper South Creek Floodplain	Public awareness and education	4	$5,000	$3,000	High
EM1	Upper South Creek Floodplain	Information Transfer to SES	5	$3,000	$1,000	High
EM5	Flood Affected Road Crossings	Flood warning signs at critical locations	6	$15,000	$300	High
FM7	Rileys Creek	Increase Regional Storage - Rileys Creek	7	$3,646,000	$10,000	Medium
FMa	Rileys Creek	combination of options FM2&3	8	$10,939,100	$12,875	Medium
FM1	Masterfield Street Rossmore	Raise Levee to 1% AEP plus 500mm freeboard	9	$669,000	$6,000	Low
Estimated Cost of Implementing the Plan				**$15,317,100**	**$37,175**	

13 Conclusion

This Floodplain Risk Management Study and Plan provides Council with critical information pertaining to floodplain management in the catchment including:

- Provisional Flood Hazard and additional hazard considerations such as effective flood access and rate of rise of flood waters.
- A review of existing emergency response arrangements and recommendations for updates.
- A review of planning considerations and recommendations for updates.
- The economic damages incurred in the catchment as a result of existing flood behaviour.

In order to assist Council and the relevant agencies in managing flood risk within the Upper South Creek study area, an assessment of potential floodplain risk management options has been undertaken. The outcome of the assessment identified a key role for planning related options to manage the existing flood risk. Several structural options were also identified as viable options for implementation.

The following options were ranked as the top 10 and should be considered for further assessment and / or implementation:

Non-Structural Measures:

- P2 Building and Development Controls
- P1 LEP Update
- EM2 Preparation of Local Flood Plans and update of DISPLAN
- EM4 Public awareness and education
- EM1 Information transfer to SES
- EM5 Flood warning signs at critical locations

Structural Measures-

- FM7 Increase Regional Storage - Rileys Creek
- FMa Combination of FM2 and FM3
- FM1 Raise Masterfiled Street Levee – Rossmore

The implementation strategy resulting from the assessment undertaken in this Floodplain Risk Management Study is outlined in the Floodplain Risk Management Plan.

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FIGURES

Cardno
Shaping the Future

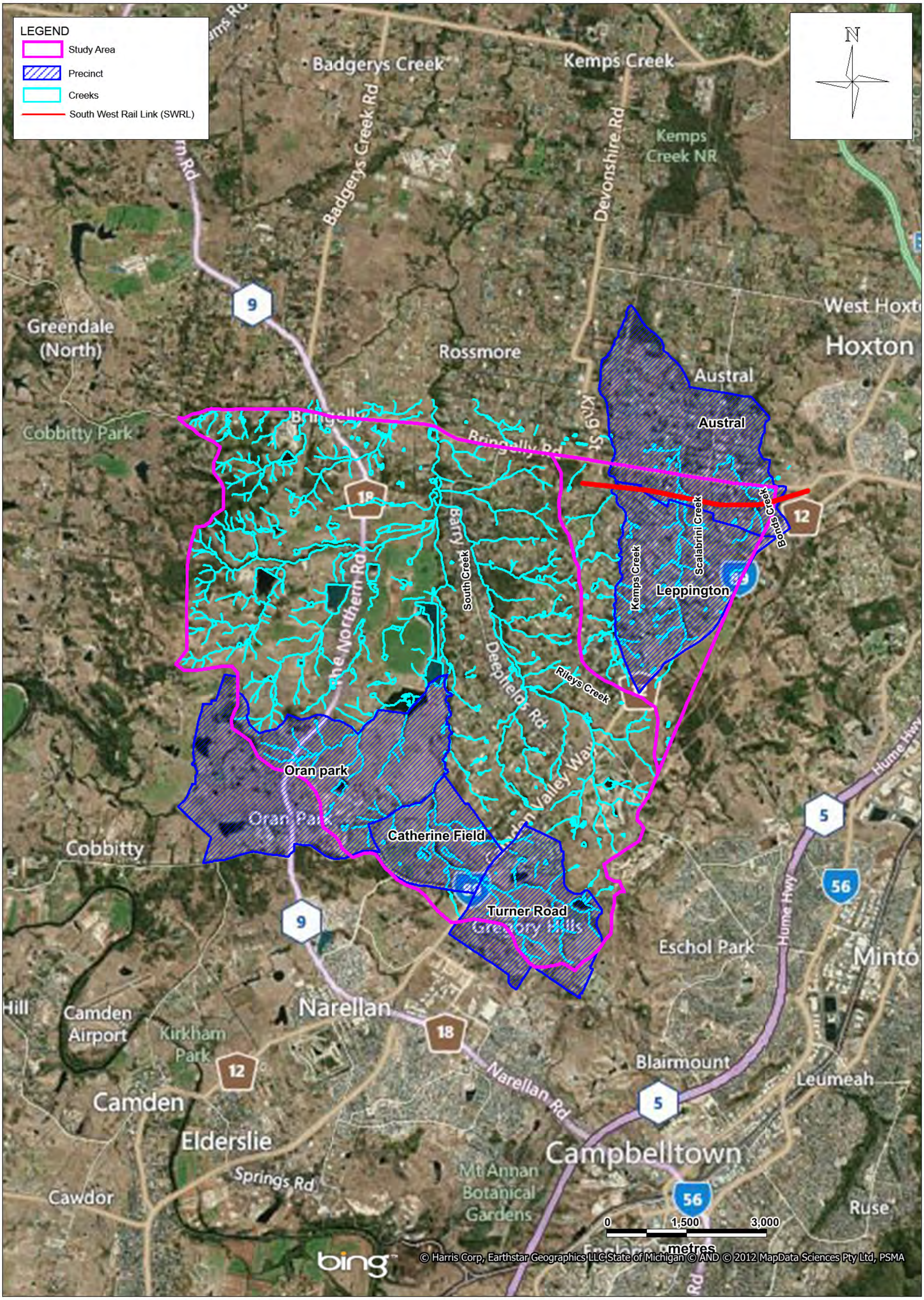
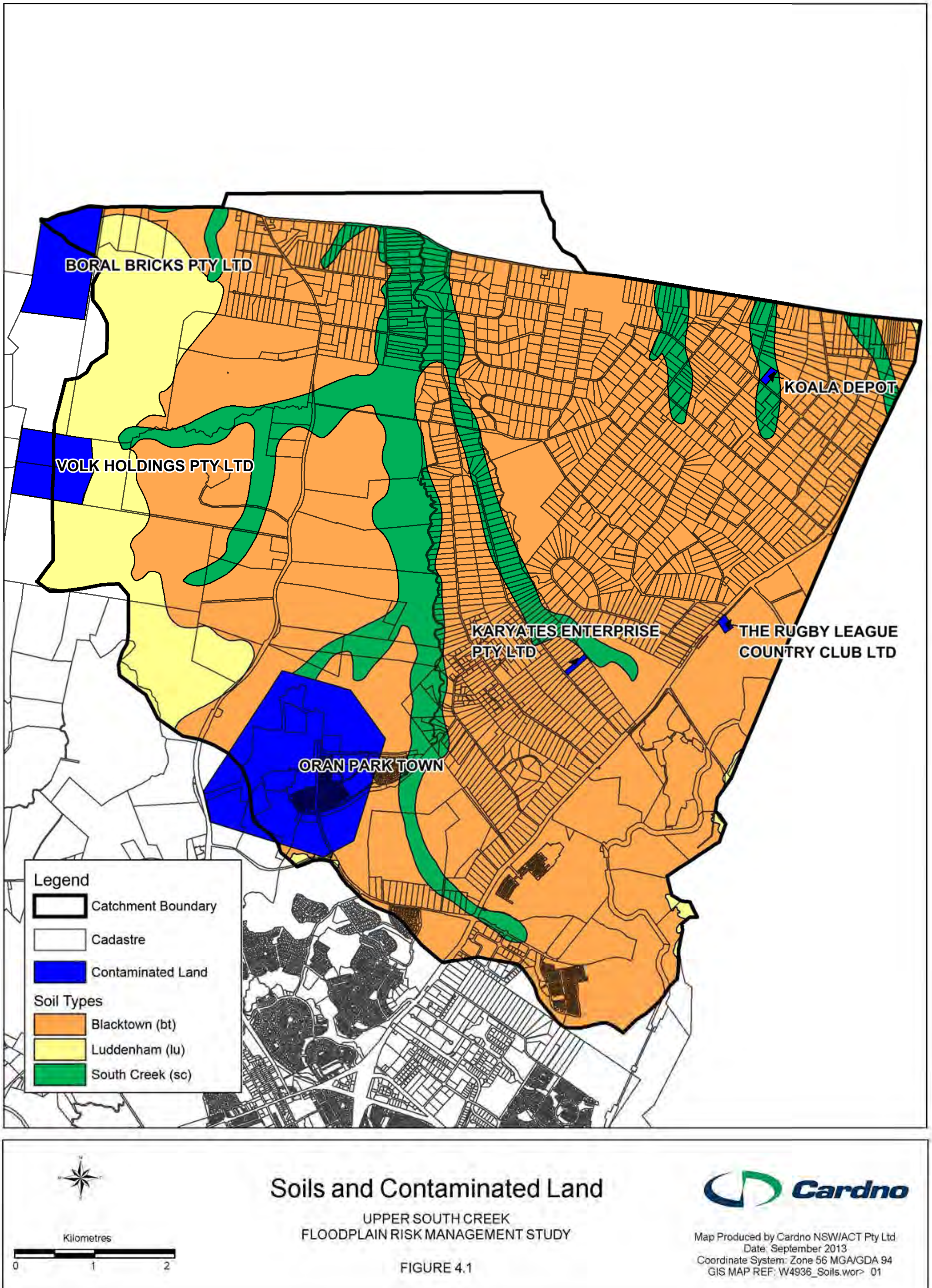


Figure 1-1
Catchment Locality



Soils and Contaminated Land

UPPER SOUTH CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE 4.1

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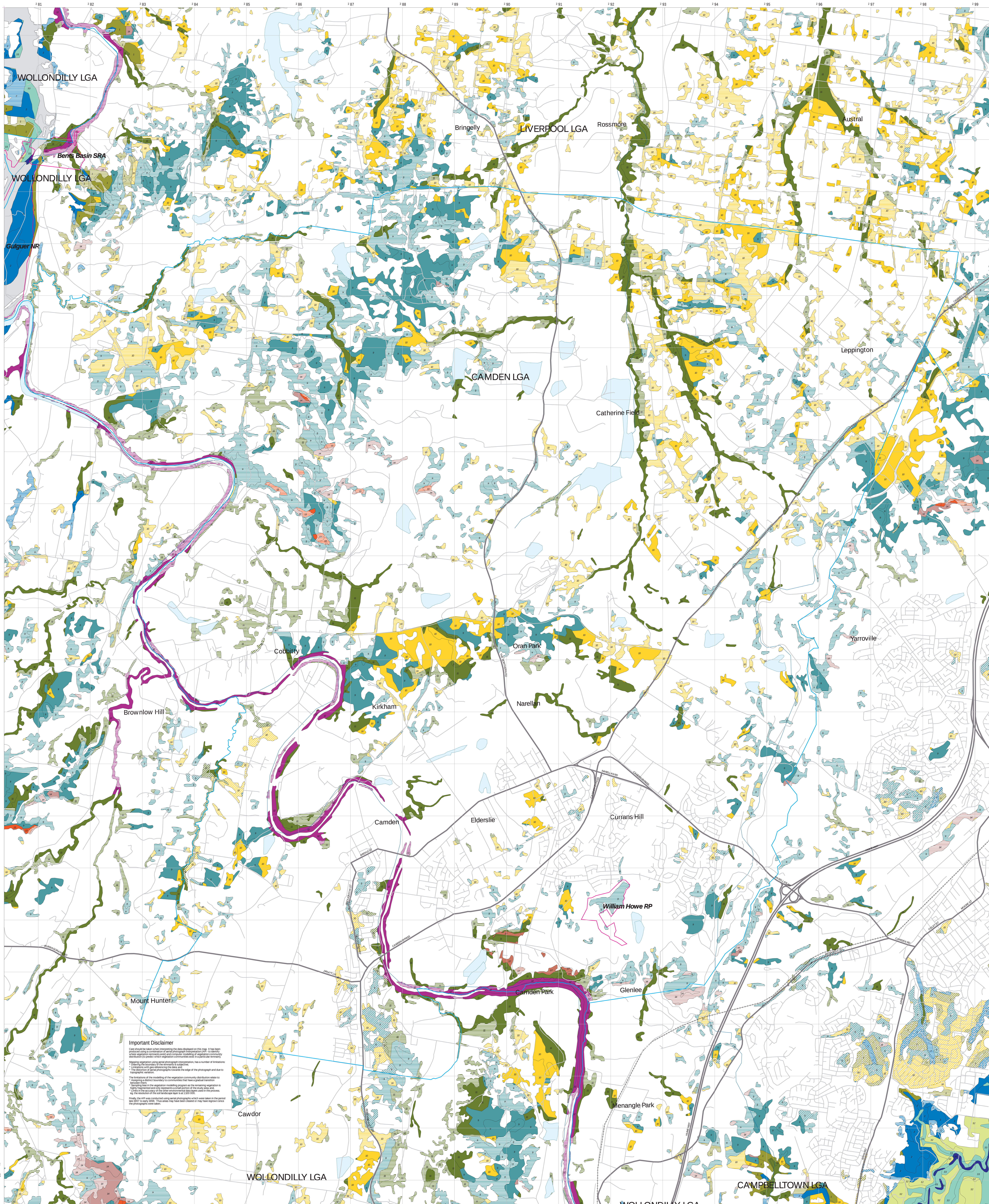
Map Produced by Cardno NSW/ACT Pty Ltd
Date: September 2013
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: W4936_Soils.wor> 01



Legend

Endangered ecological communities listed under the Threatened Species Conservation Act 1995 as of 1 June 2002

Shale/Sandstone Transition Forest
- 1 - Shale/Sandstone Transition Forest (Low Sandstone Influence)
- 2 - Shale/Sandstone Transition Forest (High Sandstone Influence)

Cooks River/Castlereagh Ironbark Forest
- 3 - Cooks River/Castlereagh Ironbark Forest

Castlereagh Swamp Woodland
- 4 - Castlereagh Swamp Woodland

Agnes Banks Woodland
- 8 - Agnes Banks Woodland

Cumberland Plain Woodland
- 9 - Shale Hills Woodland
- 10 - Shale Plains Woodland

Sydney Coastal River-flat Forest
- 11 - Alluvial Woodland
- 12 - Riparian Forest

Western Sydney Dry Rainforest
- 13 - Western Sydney Dry Rainforest

Moist Shale Woodland
- 14 - Moist Shale Woodland

Sydney Turpentine-Ironbark Forest
- 15 - Turpentine-Ironbark Forest
- 43 - Turpentine-Ironbark Margin Forest

Elderslie Banksia Scrub Forest
- 37 - Elderslie Banksia Scrub Forest

Shale Gravel Transition Forest
- 103 - Shale Gravel Transition Forest

Blue Gum High Forest
- 152 - Blue Gum High Forest

Ecological communities not listed under the Threatened Species Conservation Act 1995 as of 1 June 2002

- 6 - Castlereagh Scribbly Gum Woodland
- 31 - Sandstone Ridgetop Woodland
- 32 - Upper Georges River Sandstone Woodland
- 33 - Western Sandstone Gully Forest
- 34 - Mangrove/Saltmarsh Complex
- 35 - Riparian Scrub
- 36 - Freshwater Wetlands
- 61 - Eastern Gully Forest
- 62 - Woodland Heath Complex
- 67 - Vegetation Of Volcanic Substrates
- 9999 - Unclassified Vegetation, or outside study area
- No native vegetation overstorey
- Water body

Vegetation Condition Classes

- **Canopy Cover > 10% (Unless Remnant > 5ha, Where Canopy Cover > 5%)** (Areas mapped as classes: A, B, C, SA)
- **Canopy Cover < 10%** (Areas mapped as classes: Cmin, Tx, Txr)
- **Canopy Cover < 10% (Urban Areas)** (Areas mapped as class: Txu)

Note: Condition classes are shown as a shading over the ecological community color code. Example shown is for: 1 - Shale/Sandstone Transition Forest (Low Sandstone Influence)

- Study Area Boundary
- Local Government Area Boundary
- NPWS Estate boundary

Conservation Programs & Planning Division
Central Directorate
NSW National Parks and Wildlife Service
October 2002

PO Box 1967
Hurstville NSW 2220
Ph:(02) 9585 6444

Map Produced by Spatial Vision

Native Vegetation of the Cumberland Plain

Map 5 of 16
Camden LGA

Please view map in conjunction with report
"Interpretation Guidelines for the Native Vegetation of the Cumberland Plain, Western Sydney
NSW NPWS, Hurstville, October 2002"

Vegetation data compiled by the Conservation, Assessment and Data Unit, Central CPPD, and the Biodiversity Research Group, Biodiversity Research and Management Division, NSW NPWS.

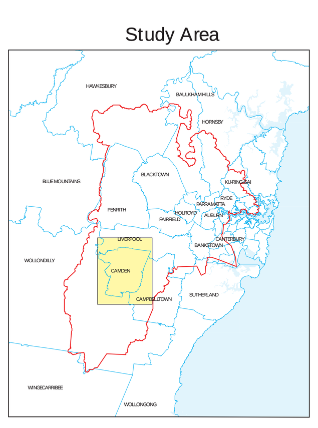
Base Mapping Data supplied by The Land Information Centre, Panorama Avenue, Bathurst 2795 NSW. (www.lic.gov.au)
Rail data provided by Australian Surveying & Land Information Group.

Project jointly sponsored by NPWS, Landcom, UDIA & DUAP.

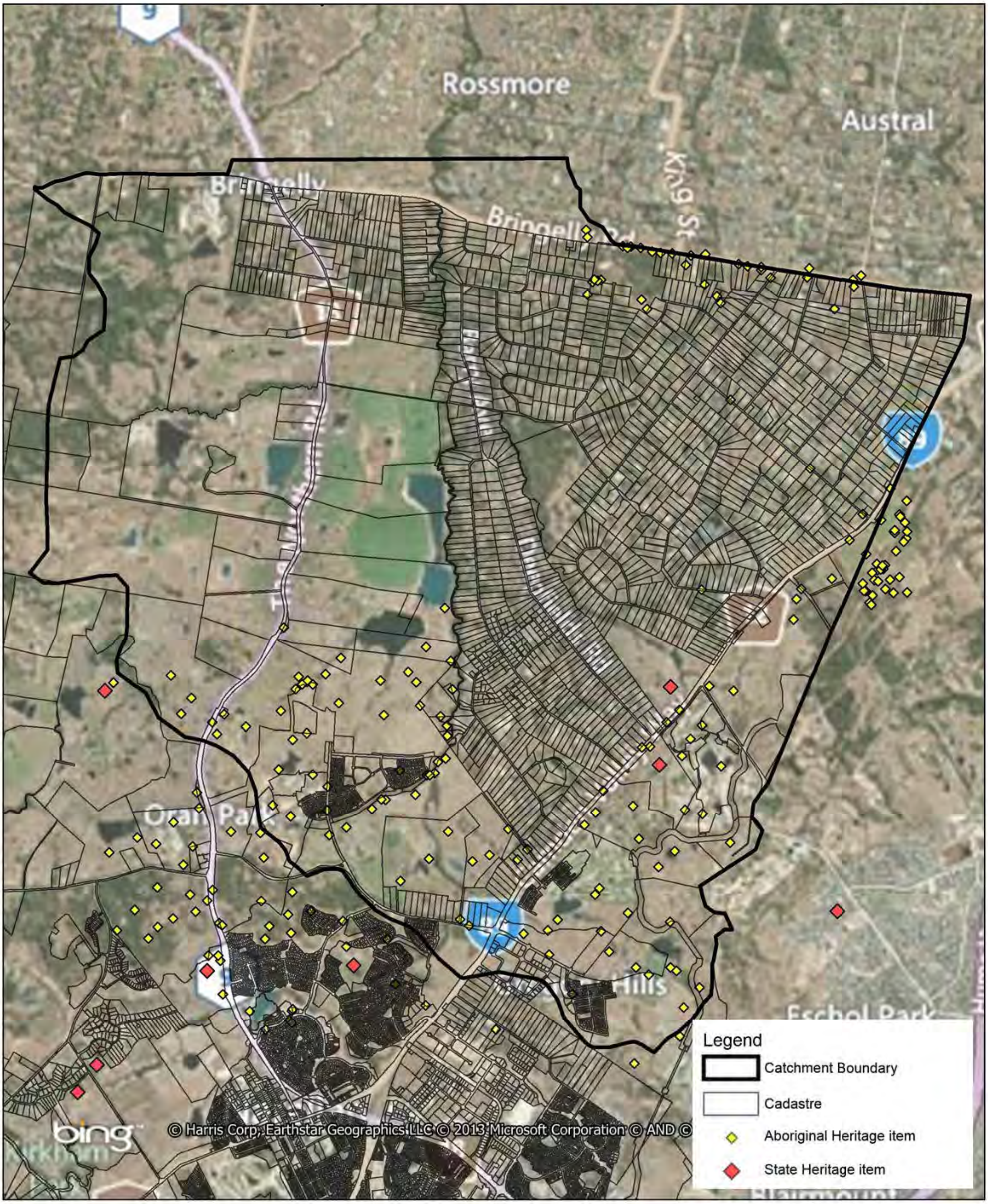
0 250 500 750 1000 1250 1500 1750 2000 2250 2500
metres

MAP ANGLE - GRID NORTH
HORIZONTAL DATUM: AUSTRALIAN GEODETIC DATUM 1966, ZONE 56
VERTICAL DATUM: AUSTRALIAN HEIGHT DATUM
TRANSVERSE MERCATOR PROJECTION
GRID INTERVAL 1000 METRES - ONE GRID SQUARE = 100 HECTARES

Study Area



Map Date: October 2002



Kilometres
0 1 2

Aboriginal and non-Aboriginal Heritage

UPPER SOUTH CREEK
FLOODPLAIN RISK MANAGEMENT STUDY

FIGURE 4.3

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: September 2013
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: W4936_Env.wor> 01

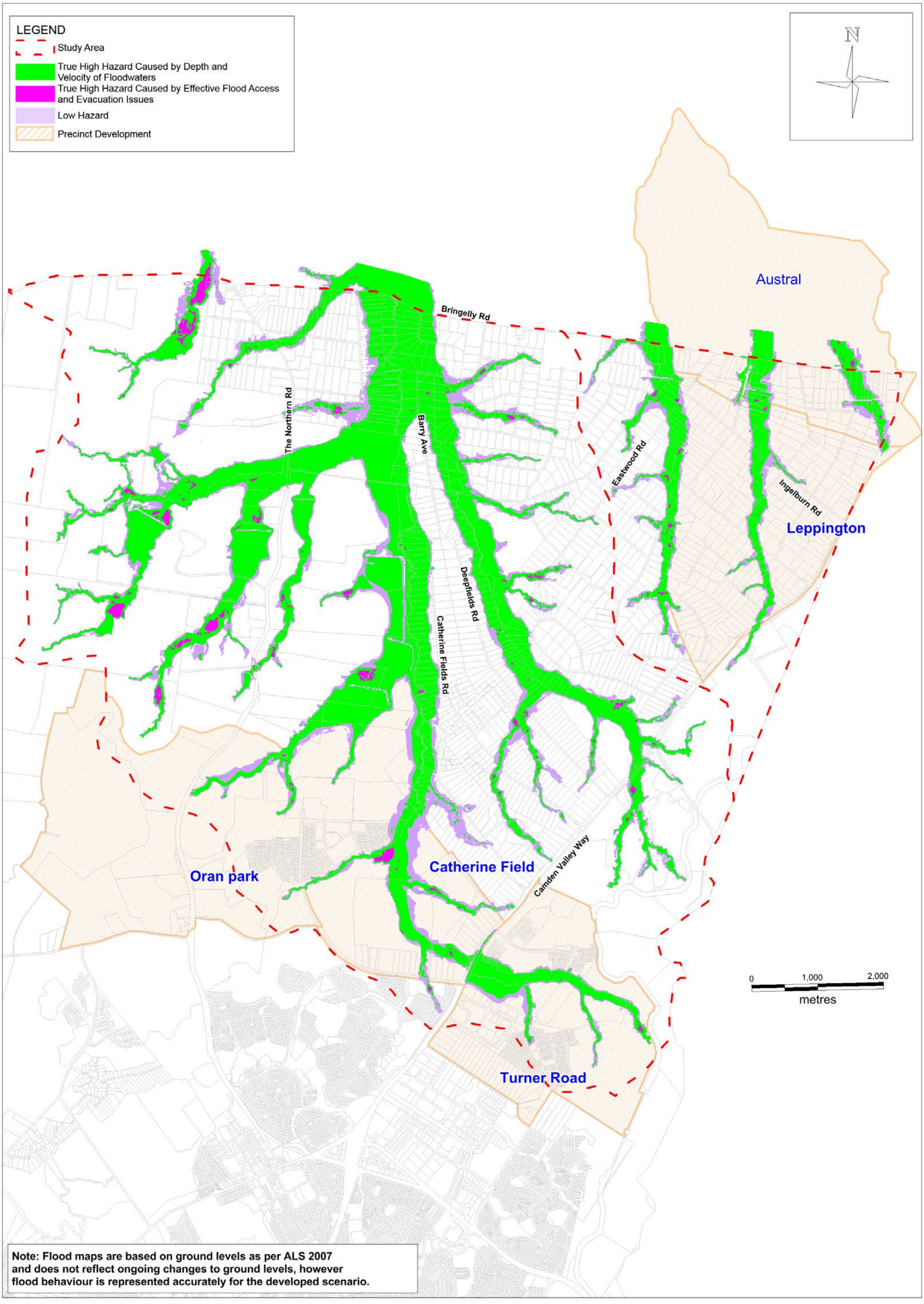


Figure 5-1
True Hazard - PMF
Developed Scenario

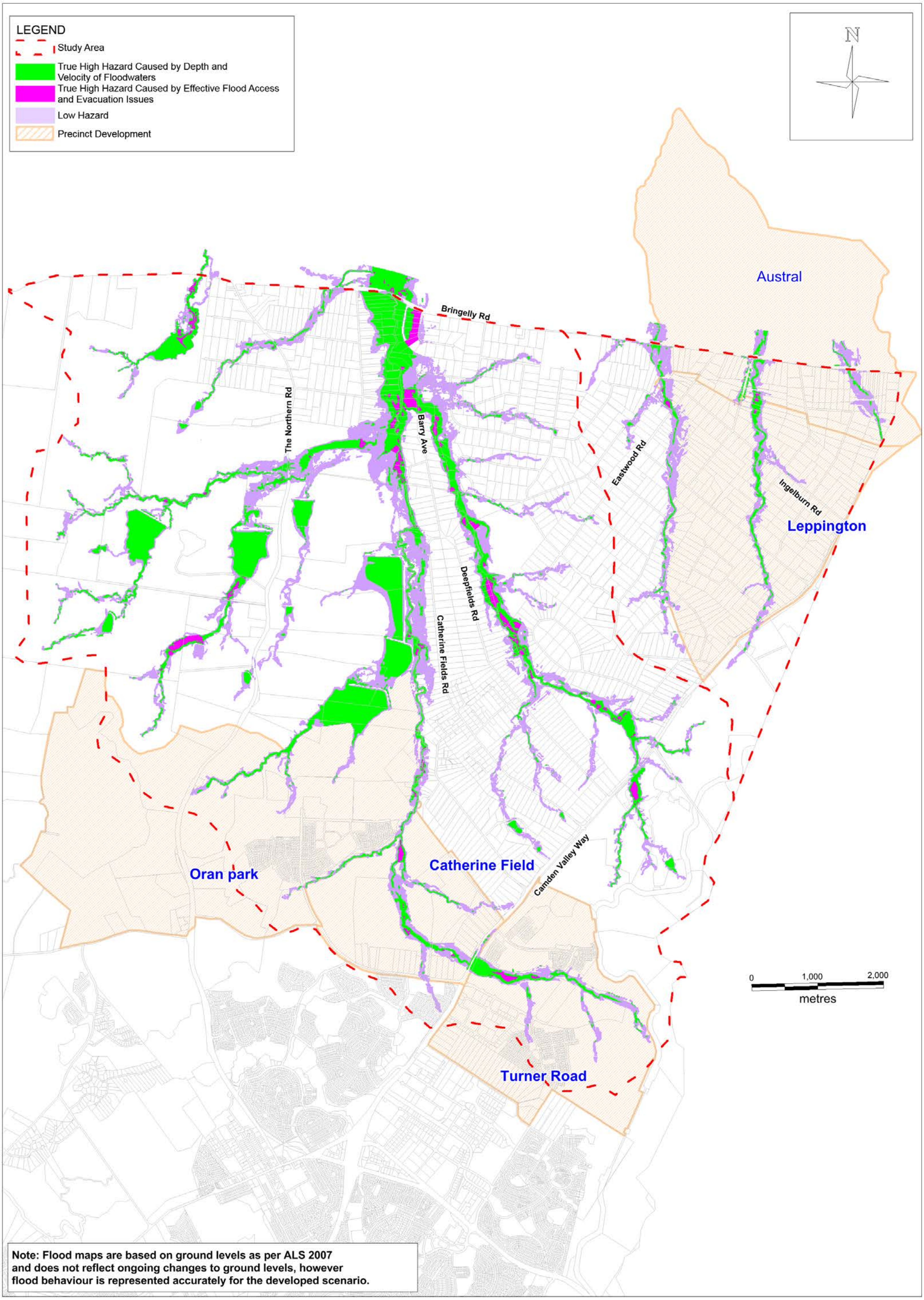


Figure 5-2
True Hazard - 1% AEP
Developed Scenario

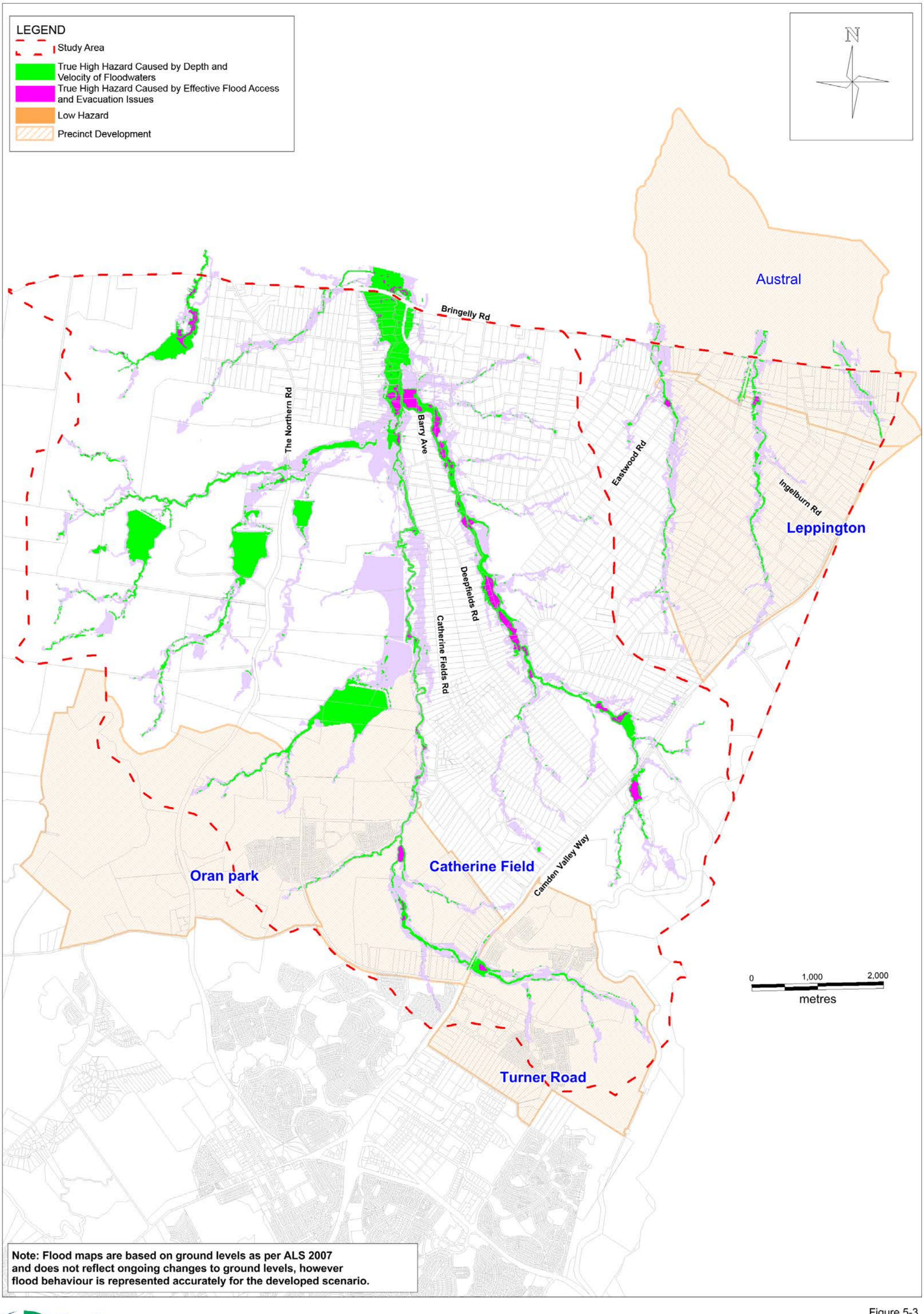


Figure 5-3
True Hazard - 5% AEP
Developed Scenario

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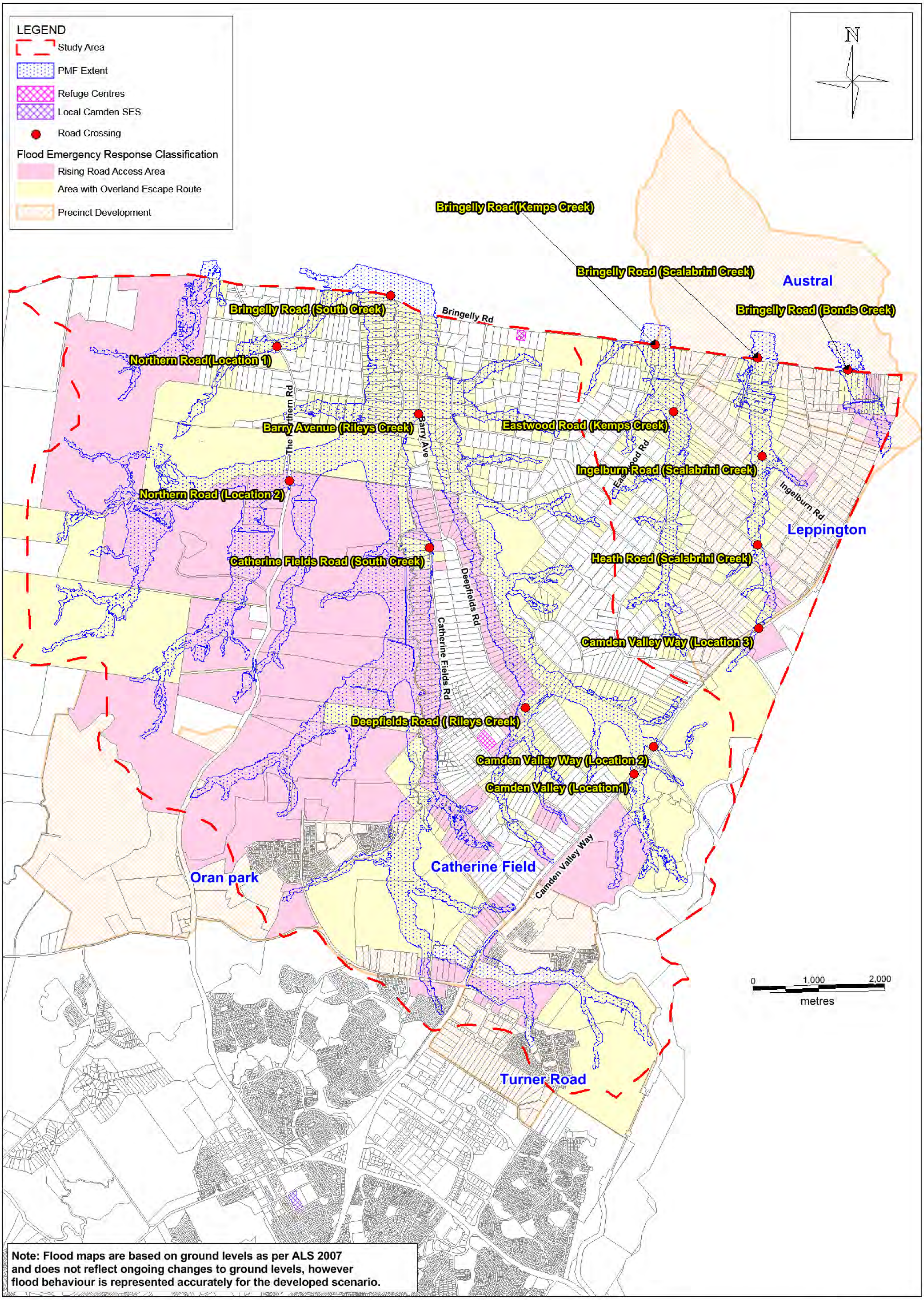

Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure 7-1
Flood Emergency Response Planning Classifications
Developed Scenario

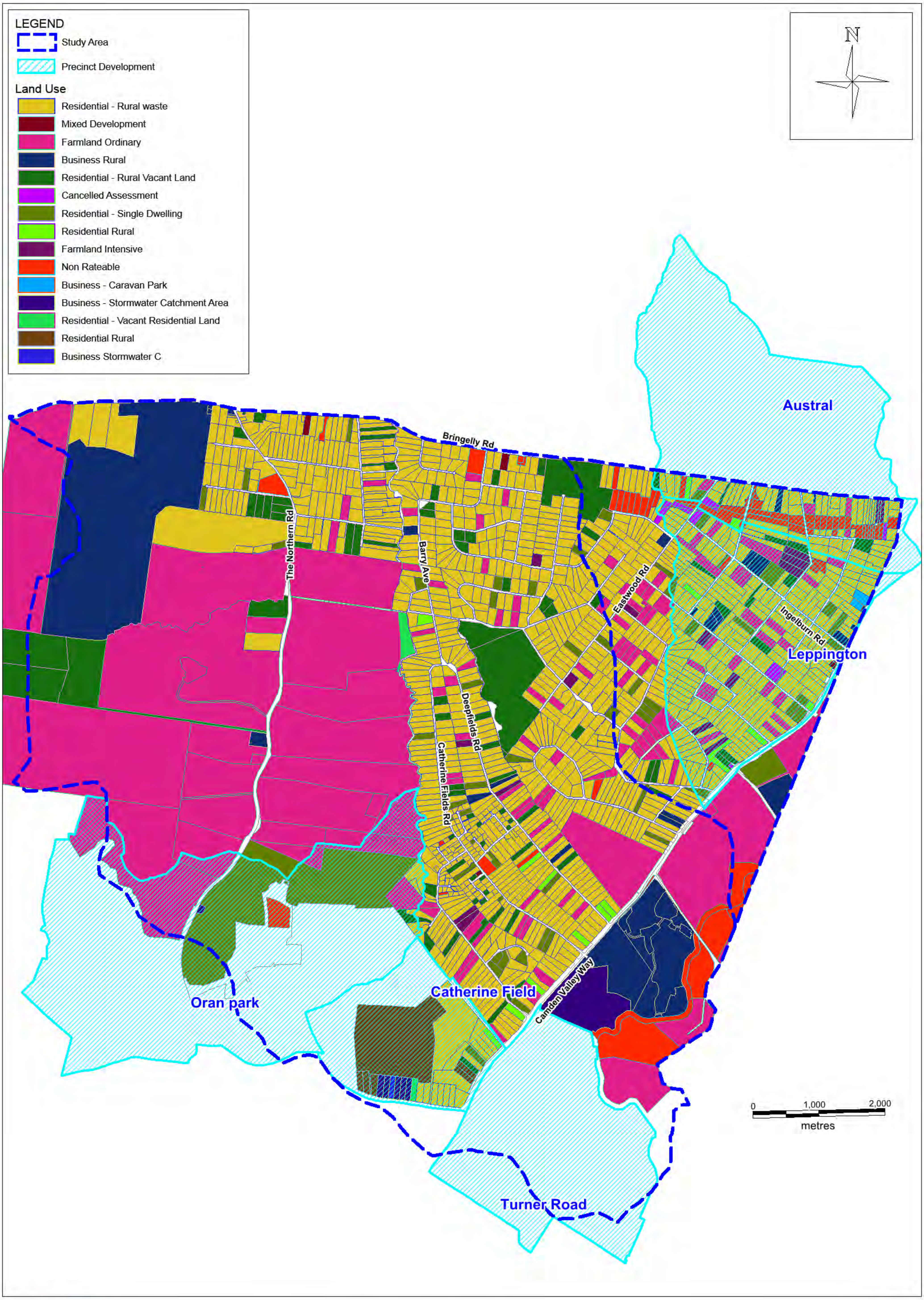

Figure 8-1
LEP Land-Use Zones

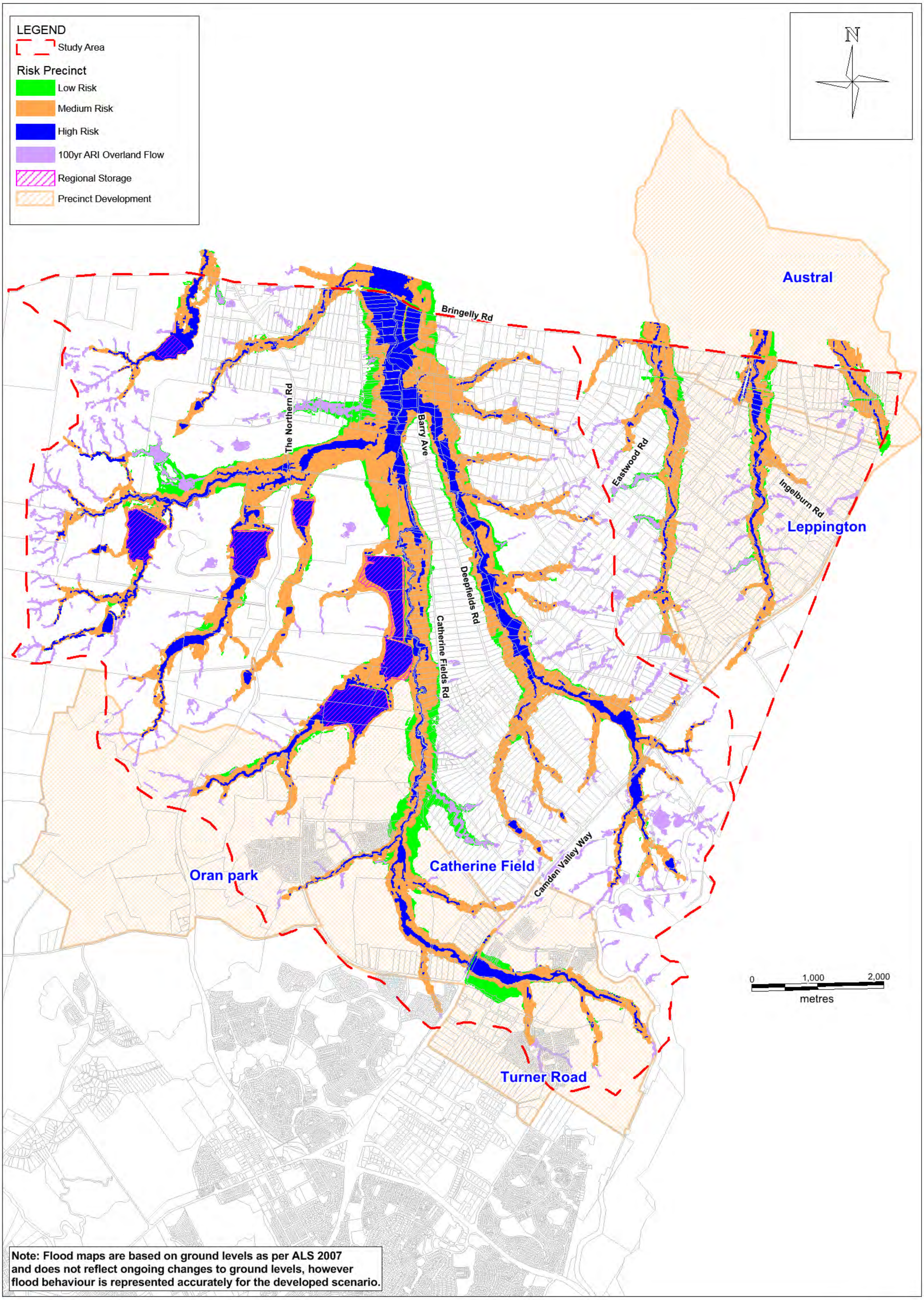

Figure 8-2
Flood Risk Precincts
Developed Scenario

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APPENDIX A
FLOOD STUDY UPDATE

Cardno
Shaping the Future

A Flood Study Update

The Upper South Creek Floodplain Risk Management Study and Plan (FRMS&P) project has been undertaken in order to assess the change in flood behaviour after the Flood Study was undertaken in 2012. The flood behaviour impacts as a result of ongoing land development on the study area as a whole has been investigated through update of the TUFLOW model of the Flood Study. The updates undertaken and a presentation of the revised flood results are provided below.

A.1 Hydrology

Hydrology and hydraulic models of the Oran Park precinct were made available by BROWNS consulting. The hydrology model used was XP_RAFTS and included both existing and developed conditions. The model was used to determine detention storage requirements for a number of offline retarding basins. The objective of the water quantity modelling was to retard the peak of post development flows back to predevelopment conditions for a range of design storm events. Through the achievement of this objective it was then considered that the hydrology of the predevelopment condition was maintained.

SOBEK was used to model the hydraulic behaviour of South Creek for predevelopment conditions and a quasi developed condition. The hydraulic model used direct inflow from the developed hydrology model without incorporating changes to the terrain or inclusion of tributaries to South Creek. The primary objective of the hydraulic model was to test the impact of the proposed development to flood behaviour in South Creek as a result of changes in hydrology.

Cardno then used the XP_RAFTS models of Oran Park and Catherine Fields to investigate the affects of development on hydrology and how they might be replicated in a rainfall on grid TUFLOW model. A tributary was chosen to South Creek where the whole catchment for that tributary would become developed. The tributary is shown in **Figure A-1** and locations are shown where hydrographs were extracted.

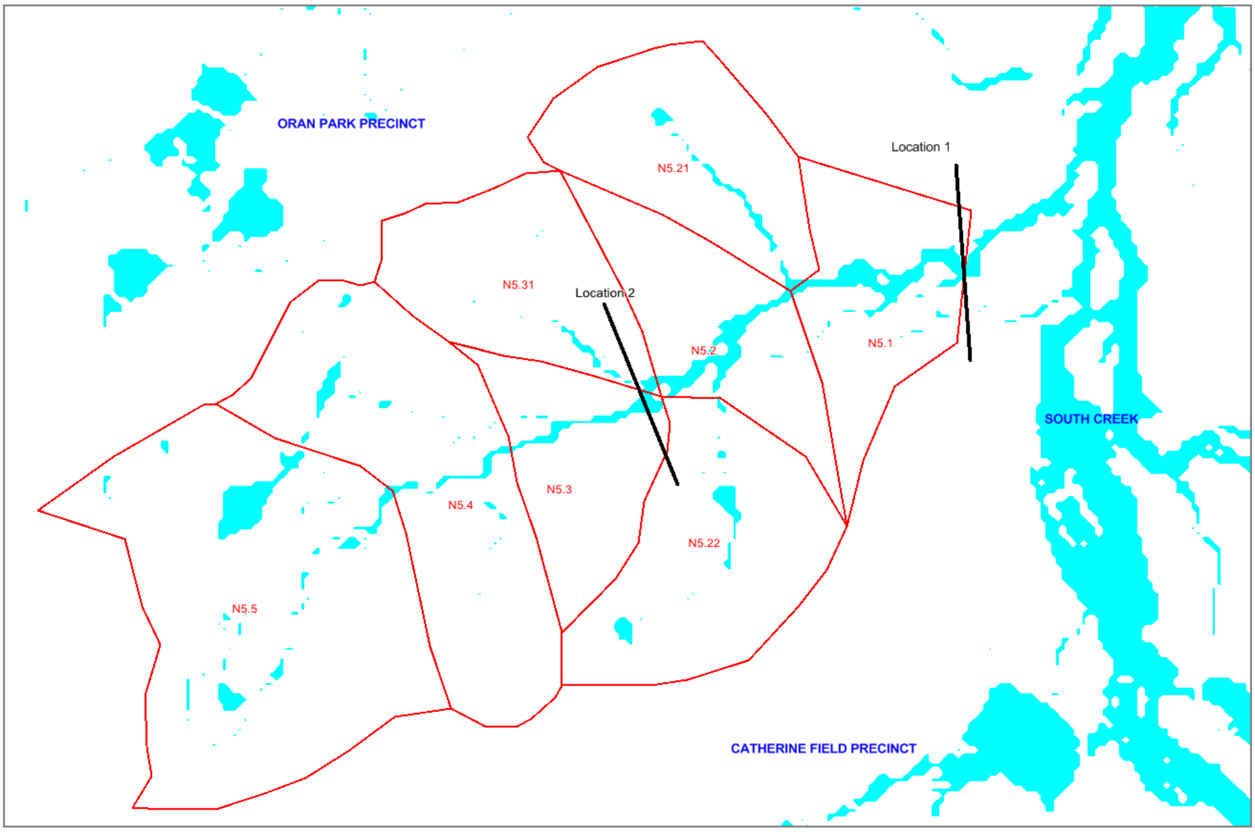


Figure A-1: Location of Hydrology Assessment

The BROWNS XP_RAFTS models were run in combination with the WMA Water TUFLOW model of the flood study and hydrographs were extracted for locations 1 and 2. The 9 hour duration storm is critical for South Creek for the 100 year ARI. Adjustments were made to the XP_RAFTS models so that consistent rainfall and initial/continuing losses were applied. This was necessary because the input parameters between the BROWNS and WMA Water hydrological models were different. Table 1 summarises a range of losses used for the study area. The parameters of the WMAWater flood study were adopted as the study is the most recent and includes calibration for three historical storm events.

Table 1: Hydrology parameters used in the study area

Author	Study	IL_P (mm/h)	CL_P (mm/h)	IL_{Imp} (mm/h)	CL_{Imp} (mm/h)	BX	Critical Duration(s) (hrs)
Perrens Consultants	Austral FPRMS&P	34 - 45	1	1	0	1.3	9 hours
WMAwater	Upper South Creek Flood Study	15	1.5	1	0	1.3	9 hours (south creek) 2 hours (Kemps/Bonds Ck)
Cardno	Austral and Leppington North Flooding Assessment	34 - 45	1	1	0	1.3	Existing = 9 hours Future = 2 or 9 hours
Cardno	East Leppington Flooding Assessment	34 - 45	1	1	0	1.3	Existing = 9 hours Future = 2 or 9 hours
Brown Consulting / GHD	Gregory Hills DA1 & DA2	15	2.5	2.5	0	1	2 hours
Brown Consulting	Oran Park	10	3	1.5	0	1	2 hours
Brown Consulting	Catherine Fields	10	3	1.5	0	1	2 hours

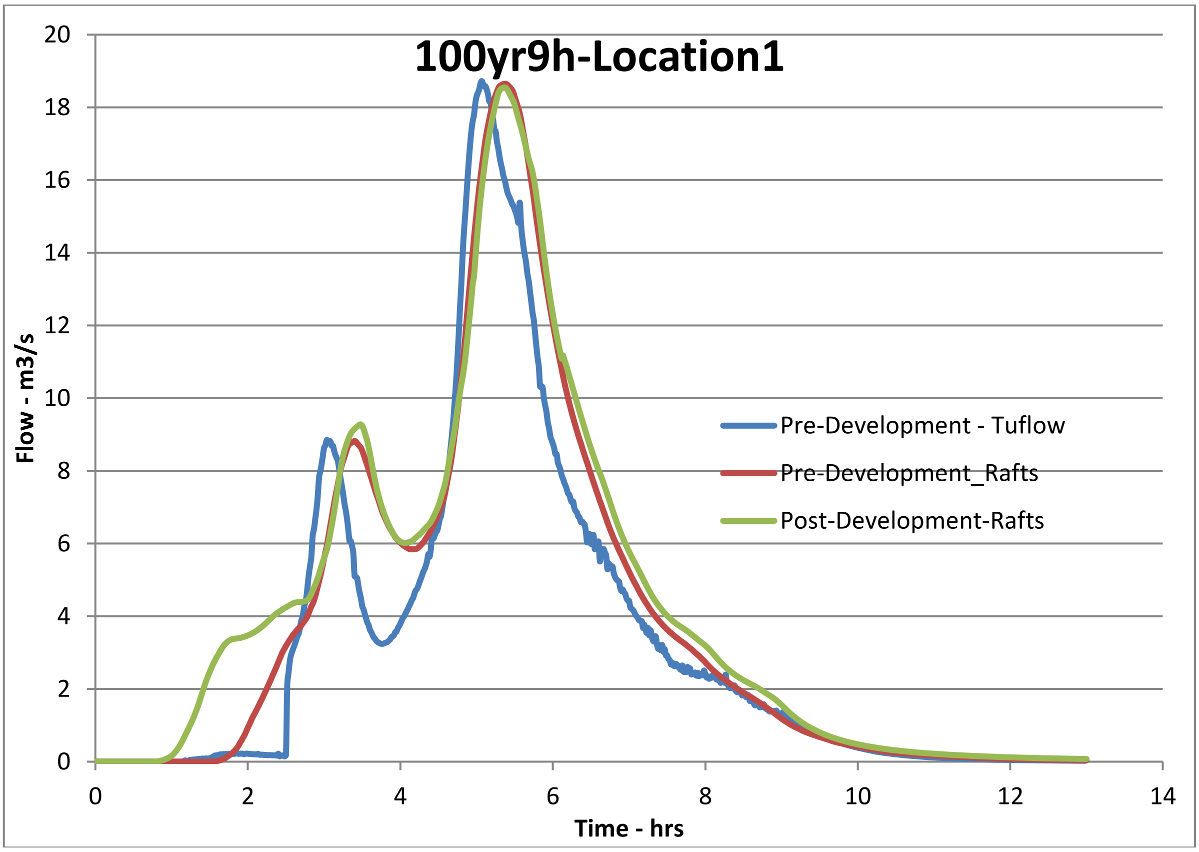


Figure A-2: Hydrographs at Location 1

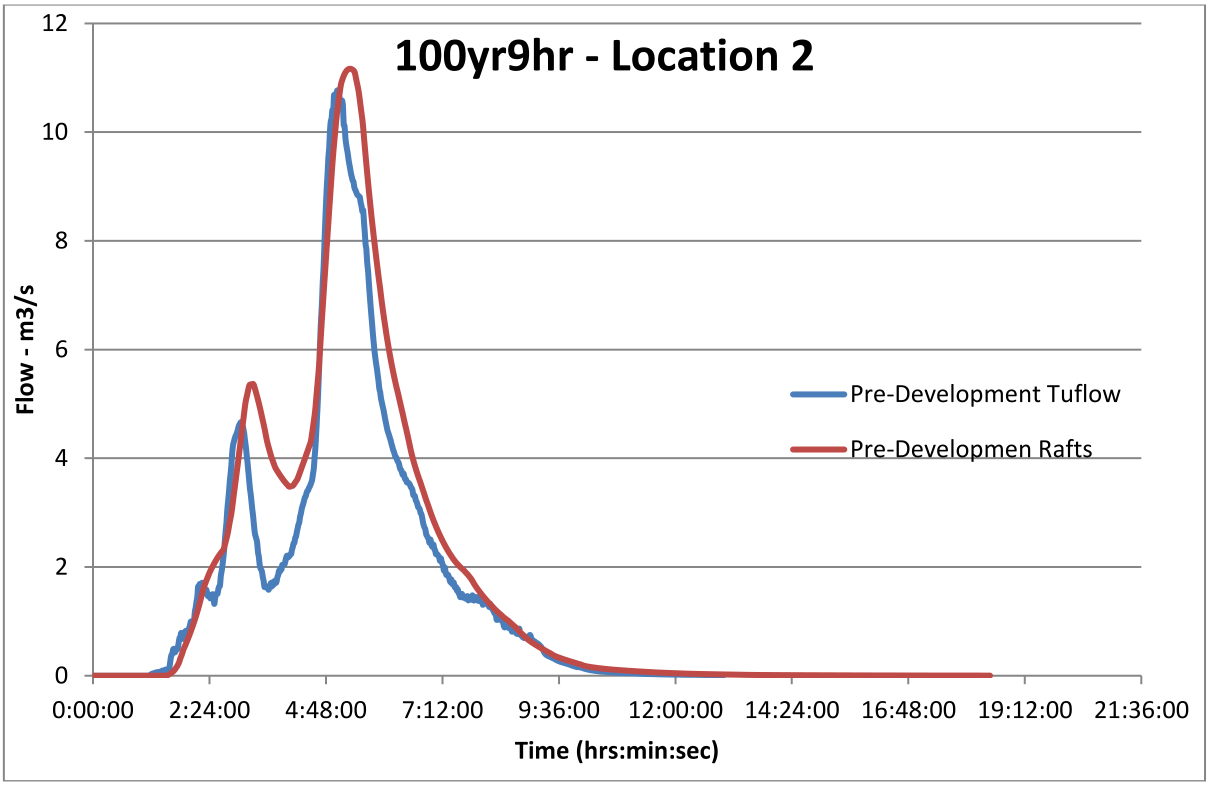


Figure A-3: Hydrographs at Location 1 for 2 hour duration

The hydrographs shown in **Figure A-2 and A-3** show that there is good correlation between the models for the existing condition when using consistent parameters. In addition it is evident that there are minor differences between the pre and post development hydrographs of XP_RAFTS in **Figure A-2**, mainly at the toe of the rising limb. The post development model includes retarding basins that have been incorporated into the precinct Masterplan (BROWNS 2009). It is then evident that the retarding basins of the XP_RAFTS models are performing according to their objects regardless of the updates to rainfall and initial/continuing losses. It is also noted that the shape of the TUFLOW hydrograph indicates a sharp response at the beginning of the rising limb, most likely as a result of storage effects of the direct rainfall modelling approach. There are numerous farm dams both offline and on-line in the catchment for Location 1. This is a common facet of the rural land use in the study area. The dams would be filled and replaced with urban land uses for offline basins and open channels for on-line basins. Therefore it is expected that the rising limb of the hydrograph would be more similar to that shown for XP_RAFTS post development.

In order to model the post development condition in TUFLOW, initial loss and roughness was adjusted to replicate the loss of storage (filling of small farm dams), increase in flow volume and surface modification. A range of initial losses were tested in the TUFLOW model so that the rising limb of the hydrograph achieved a better correlation to the post development XP_RAFTS hydrograph. The results in **Figures A-4** to **A-7** show that the TUFLOW hydrograph was more sensitive to the adjustment in losses for Location 2 than Location 1. This is assumed to be a result of retardation by farm dams indicated by puddles of flood extent in sub-catchment N5.22 shown in **Figure A-1** and detailed further in **Figure A-8**. Nonetheless it was concluded that the initial loss of 5mm/hr produced a post development hydrograph in TUFLOW that better replicated the impact to hydrology as a result of land development.

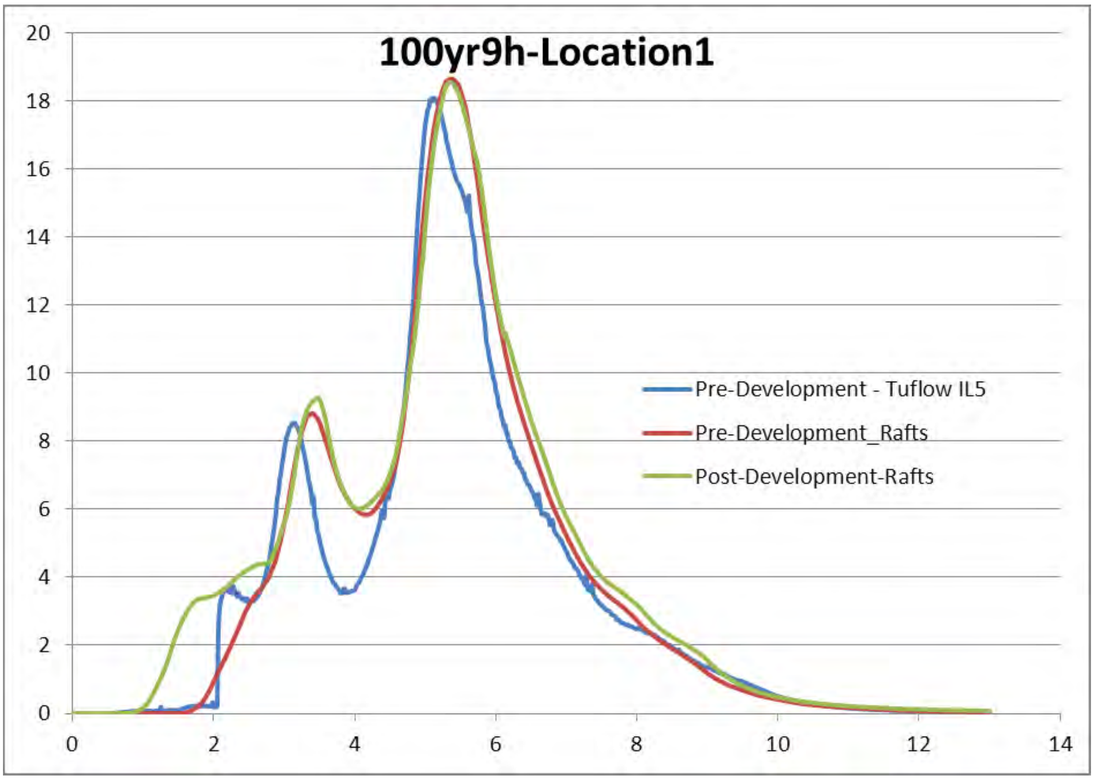


Figure A-4: Hydrographs at Location 1 with IL=5mm/hr

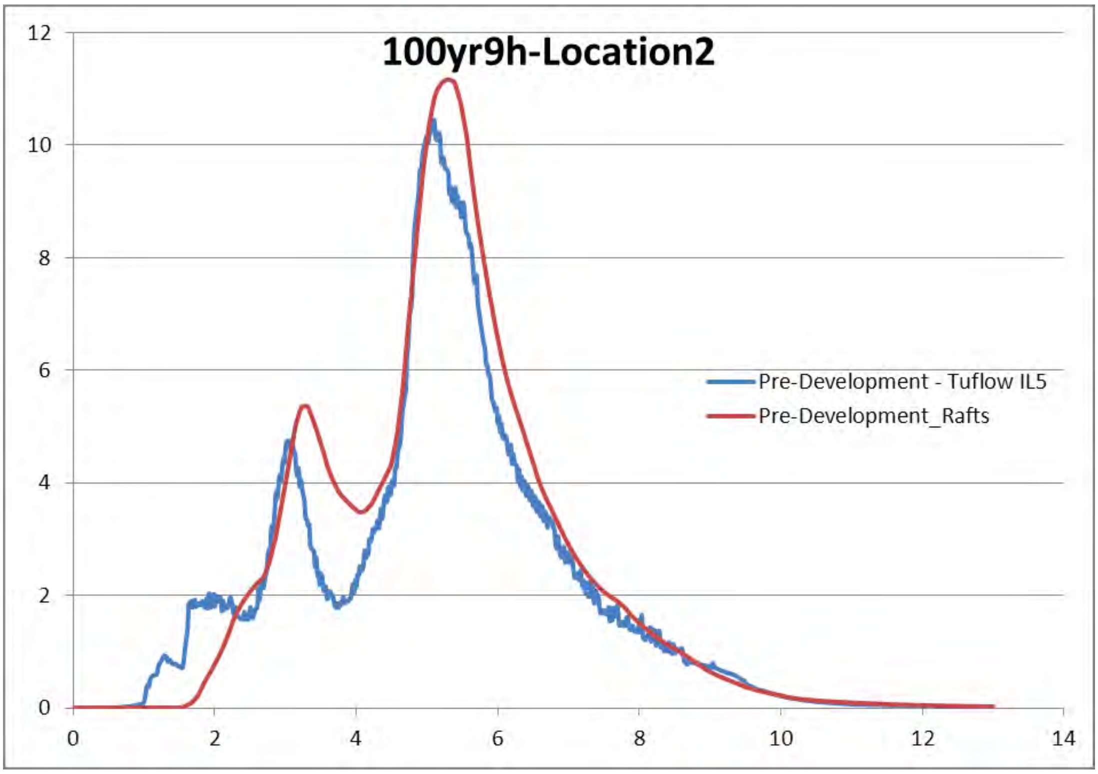


Figure A-5: Hydrographs at Location 2 with IL=5mm/hr

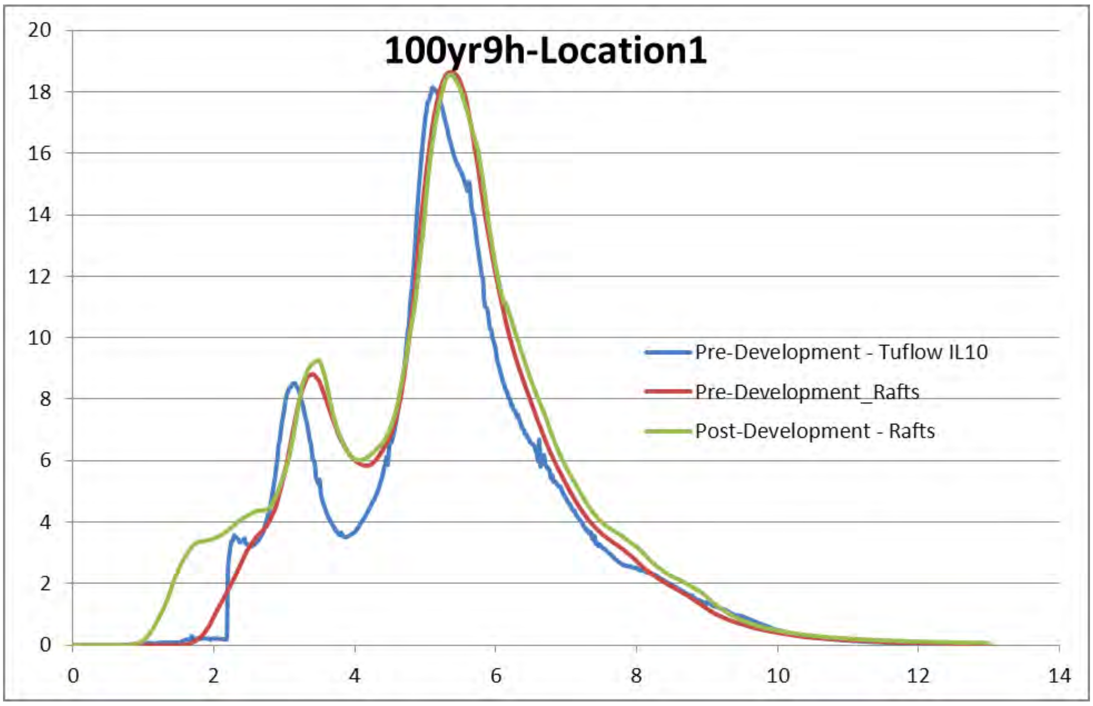


Figure A-6: Hydrographs at Location 1 with IL=10mm/hr

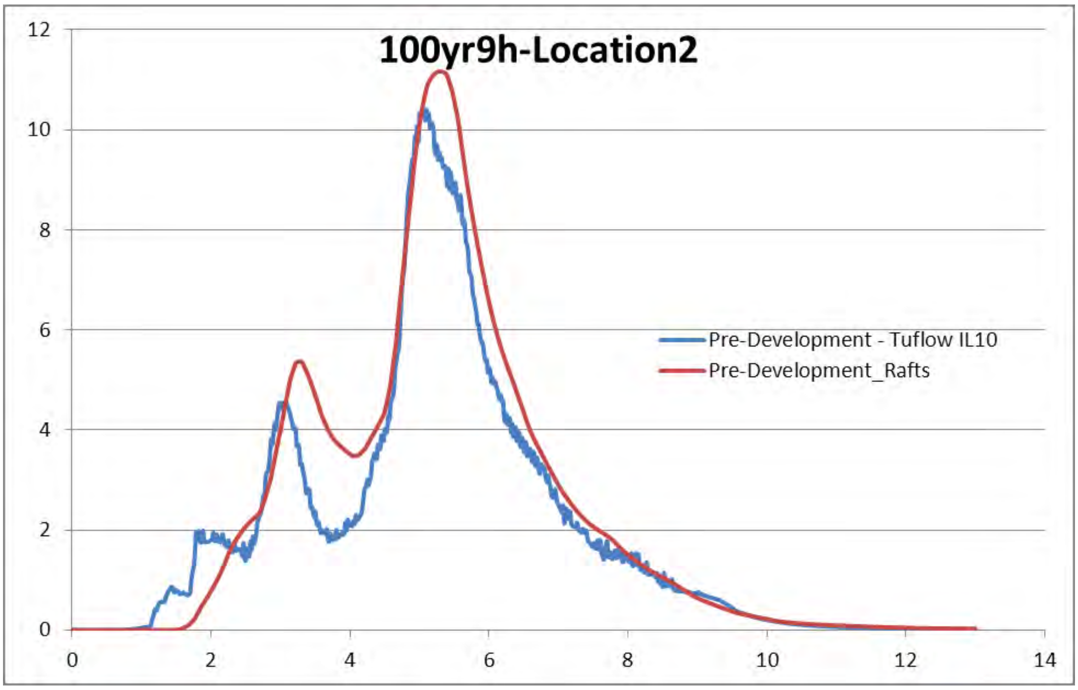


Figure A-7: Hydrographs at Location 2 with IL=10mm/hr

Figure A-8: Aerial photo of the hydrology testing area showing locations of farm dams

A.2 Hydraulics

Following the hydrological assessment, the 1D/2D TUFLOW model developed for the flood study was initially updated to include the following modifications:

- Bringelly Road upgrade design as per 80% detailed design model received from AECOM on 9th July 2013 under permission of RMS
- South West Rail Line (SWRL) TUFLOW model DTM for ground topography of Kemps, Scalibrini and Bonds Creeks in addition to 1D elements of the bridge crossings. Received from Council on 10th December 2012.
- 1D cross sections of South Creek from the BROWNS Sobek models extending from Bringelly Road to the upstream boundary of Oran Park. These cross sections are based on a ground survey undertaken as part of the precinct planning process for Department of Planning and Infrastructure. (BROWNS 2007)
- Upgrade of Camden Valley Way (CVW) at Rileys Creek crossing according to details of the CVW detailed road design DTM obtained from RMS website (RMS 2012)
- Addition of Bonds Creek to the Study Area which was not included in the Flood Study – inflows to the upstream boundary of the Study Area were extracted from the East Leppington TUFLOW model of Cardno, prepared for the DP&I. (Cardno 2012)
- Replication of urban development of the SWGC precincts; Turner Road, Catherine Field, Leppington North and Oran Park by reducing initial loss, adjusting roughness and filling. The filling components involved delineation of the urban development extents that encroach onto the floodplain together with removal of farm dams. Significant regional storage facilities were retained in the model as shown in the flood maps.
- Inclusion of the Leppington Precinct (Preliminary Rezoning Phase) by reducing initial loss and adjusting roughness. No filling of the floodplain was included in this precinct.

It was the aim of the modelling to estimate the flood behaviour of the development scenario without the need to insert detailed DEM's, flood management measures and drainage networks. Pilot testing was undertaken, using available models, to identify appropriate adjustments to roughness and design losses for inclusion of precinct developments to the model. Replication of precinct development including roads, drainage and detention basins/tanks was undertaken through adjustment of the rainfall/runoff losses and roughness parameters in TUFLOW. This approach was selected for a suitable method of modelling the urban development (including retardation) within the broad scale TUFLOW model.

The parameters adopted are shown in **Table A-1**.

Table A-1 Comparison of parameters for pervious areas in the TUFLOW model

Scenario	Initial Loss (mm/hr)	Continuing Loss (mm/hr)	Mannings Roughness
Flood Study – Rural Areas where future development is proposed by the SWGC Precincts	15	1.5	0.04
Interim Development – Revised parameters used to replicate urban development of SWGC Precincts	5	1.5	0.06

Note: Modelling of building footprints, roads, drainage and retarding basins is replicated through use of the above parameters i.e. percentage impervious was not updated.

The following figures show elements of the TUFLOW model:

- **Figure A-9** shows the SWGC precincts included in the developed scenario;
- **Figure A-10** shows the fill polygons included in the model;
- **Figure A-11** shows the one-dimensional culverts modelled, and;
- **Figure A-12** shows the surface roughness modelled.

Table A-2 Hydraulic structure updates to the TUFLOW model

Location	Size	Blockage Factor
Bringelly Road – Kemps Creek	9 (3.6m x1.5m)	50%
Bringelly Road – Scalabrini Creek	9 (3.6m x1.5m)	50%
Bringelly Road – Bonds Creek	9 (3.6m x1.2m)	50%
SWRL – Kemps Creek	72m x 2m	10%
SWRL – Scalabrini Creek	52m x 3.58m	0%
SWRL – Bonds Creek	84m x 7m	0%

Structures included in the table represent the changes included to the TUFLOW model since the Flood Study (WMA Water 2012)

A.4 Farm Dams Assessment

Following the initial revision of the model with updated terrain and structure details, further assessments were undertaken to examine the impacts on peak flood levels of adopting various assumptions of the initial water level in the large farm dams.

In the Flood Study, the adopted Starting Water Levels in the Regional Farm Dams are based on Aerial Laser Survey (ALS) and the Starting Water Levels in five farm dams are below the full supply level. As a result of this additional storage volume, the adopted Starting Water Levels underestimate the actual flood behavior.

A comprehensive assessment of the impacts of adopting Dam Full levels as the starting condition, as well as the staged removal of the regional dams was undertaken, and is provided in **Appendix B**.

The key outcome from the assessment was that assuming Dam Full levels at the commencement of the storm events is an appropriately conservative assumption to assess the potential peak flood levels that will occur in the study area.

A.5 2016 Event Analysis

In June 2016, the Camden region experienced a significant storm event. Following this event, Council collected a number of post flood marks, which were used to validate the recently updated model and the Dam Full assumption.

The assessment found that the updated model provided results that closely matched those observed in the flood event.

Further details are provided in **Appendix C**.

A.5 Modelled Flood Behaviour

The revised models, incorporating the Dam Full initial water levels, were run for a series of events and modelled peak water levels are listed in **Table A-3** for the hydraulic reference locations shown in **Figure A-13**.

The critical duration within the catchment for all AEPs is 9 hours in South and Kemps Creeks, and 2 hours for Scalibrini and Bonds Creeks. For the PMF event, critical duration is 60 minutes for all floodways in the study area.

The results of developed TUFLOW model are shown in the following figures for the PMF, 0.5% AEP, 0.2% AEP, 1% AEP, 2% AEP and 5% AEP events:

- Flood extents are shown in **Figures A-14 to A-19**.
- Flood depths are shown in **Figures A-20 to A-25**.

A comparison of the flood levels for a number of scenarios is included in **Table A-4**.

It was generally found that the existing flood extent receded in South Creek in the vicinity of Oran Park for the development scenario as a result of filling on the floodplain fringe. Flood depths and levels were generally similar between the existing and development conditions except where filling was proposed. The existing extent expanded in the lower reaches for the development scenario indicating that the loss of floodplain storage and discharge volume increase caused an amplification of flood levels, particularly upstream of hydraulic controls such as Bringelly Road and SWRL. Updated Flood mapping generally shows that:

- The storage of numerous small farm dams and the floodplain fringe assist in reducing peak discharges downstream, filling of these storages contributes to increased volume arriving at the SWRL and Bringelly Road.
- Construction of the SWRL involves multiple span bridges for the water way crossings and some creek training for Scalibrini and Kemps Creeks. As such the modelling showed that there was minimal impact on flood behaviour.
- In the location of floodplain filling the adjacent flood levels have locally increased in the floodway, in a holistic sense filling of the floodplain showed little impact to flood levels.

- In general there is a reduction in flood level for the areas of South Creek adjacent to Oran Park as a result of including the BROWNS ground survey as 1D cross sections
- Slight increases in flood level are observed in Rileys, Kemps and Scalibrini Creeks as a result of the Leppington Precinct change in losses and roughness
- The upgrade of Bringelly Road includes increase of the road crown level and amplification of existing culvert area. The increase in road crown above the 1% AEP level causes flood waters to back up behind the road before escaping through the culverts. Evidently this, in combination with urban development upstream, increases flood levels locally for the Scalibrini, Kemps and Bonds Creek crossings. No changes are proposed to the South Creek crossing, the existing bridge would be retained, and therefore the increase in flood level predicted is a result of changes in the catchment only.

In general there has been an increase in flood level for the lower part of the Study Area (in the vicinity of the SWRL and Bringelly Road). It is expected that this is a direct result of the increase in discharge as a result of precinct development and changes to the crown level of Bringelly Road.

Table A-3 Peak Water Levels at Reference Locations

Point	Location	Ground Elevation	PMF	0.2% AEP	0.5% AEP	1% AEP	5% AEP
1	DS_Huge Farm dams	64.63	65.95	65.09	65.02	64.88	64.72
2	Us BringellyRd SC	57.06	61.45	60.48	60.40	60.14	59.52
3	Ds BringellyRd SC	57.19	61.47	60.61	60.56	60.55	60.55
4	US_CVW	90.61	96.96	94.04	93.72	93.17	92.60
5	Junct_CathField_OranPk	76.37	79.68	78.57	78.45	78.29	78.17
6	US_Kemps_BringellyRd	72.92	75.73	75.11	75.02	74.86	74.83
7	US_Scalabrini_BringellyRd	74.10	75.30	74.57	74.45	74.34	74.33
8	US_Bonds_BringellyRd	72.77	75.13	74.580	74.578	74.577	74.574
9	US_Kemps_SWRL	75.57	78.29	77.82	77.68	77.62	77.57
10	US_Scalabrini_SWRL	74.41	77.46	76.71	76.66	76.58	76.49
11	US_Bonds_SWRL	74.62	80.33	79.93	79.90	79.87	79.84
12	DS_Oranpark_Precinct	68.87	73.09	71.95	71.86	71.73	71.63

Table A-4 Peak Water Levels Comparison at Reference Locations for the 1% AEP

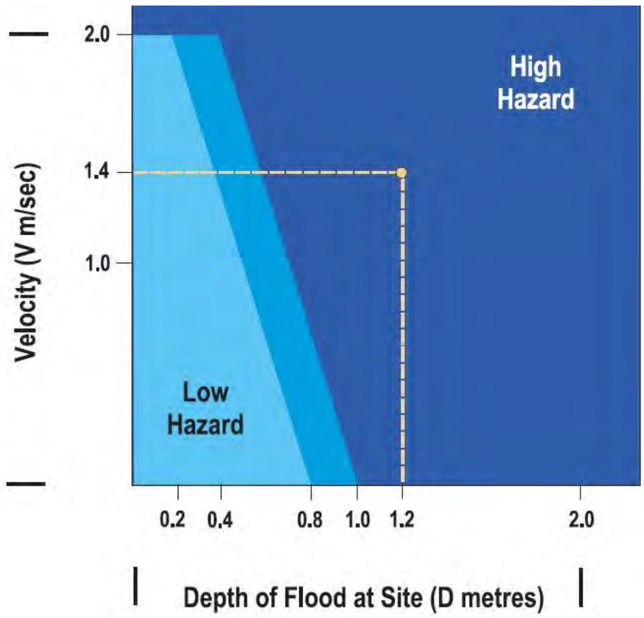
Point	Location	Flood Study	Development	Difference
1	DS_Huge Farm dams	65.10	64.81	-0.22
2	Us BringellyRd SC	59.86	60.1	0.28
3	Ds BringellyRd SC	57.93	60.55	2.62
4	US_CVW	92.68	93.17	0.49
5	Junct_CathField_OranPk	78.59	78.29	-0.3
6	US_Kemps_BringellyRd	74.31	74.86	0.55
7	US_Scalabrini_BringellyRd	73.86	74.34	0.48
8	US_Bonds_BringellyRd	NA	74.58	NA
9	US_Kemps_SWRL	76.66	77.62	0.96
10	US_Scalabrini_SWRL	76.54	76.58	0.04
11	US_Bonds_SWRL	NA	79.87	NA
12	DS_Oranpark_Precinct	71.71	71.66	0.02

Note – Bonds Creek was not modelled in the Flood Study thus results are not available

A.6 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). The hazard categories shown in the figure below and are defined as:

- High hazard – possible danger to personal safety, evacuation by trucks difficult, able-bodied adults would have difficulty in wading to safety, potential for significant structural damage to buildings; and
- Low hazard – should it be necessary, a truck could be used to evacuate people and their possessions, able-bodied adults would have little difficulty in wading to safety.



The provisional hazard was determined for each event magnitude based on the modelled peak flood depth and velocity for each recurrence interval. The transition zone between high and low is adopted as medium hazard. Provisional flood hazard for the PMF, 0.5% AEP, 0.2% AEP, 1% AEP, 2% AEP and 5% AEP events are shown in **Figures A-26 to A-31** respectively.

A.7 Hydraulic Categories

Hydraulic categorisation of the floodplain is used in the development of the Floodplain Risk Management Plan. The Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Floodways were determined for the 1% AEP event by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below (based on Howells et al, 2003).

As a minimum, the floodway was assumed to follow the creekline from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity x Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1m and/or would cause peak discharge anywhere to increase by more than 10%. The criteria were applied to the model results as described below.

To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m
- Not classified as floodway.

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, are represented as Flood Fringe.

The hydraulic categories for the PMF and the 1% AEP and 5% AEP events are provided in **Figure A-32** to **Figure A-34** respectively.

APPENDIX A FIGURES

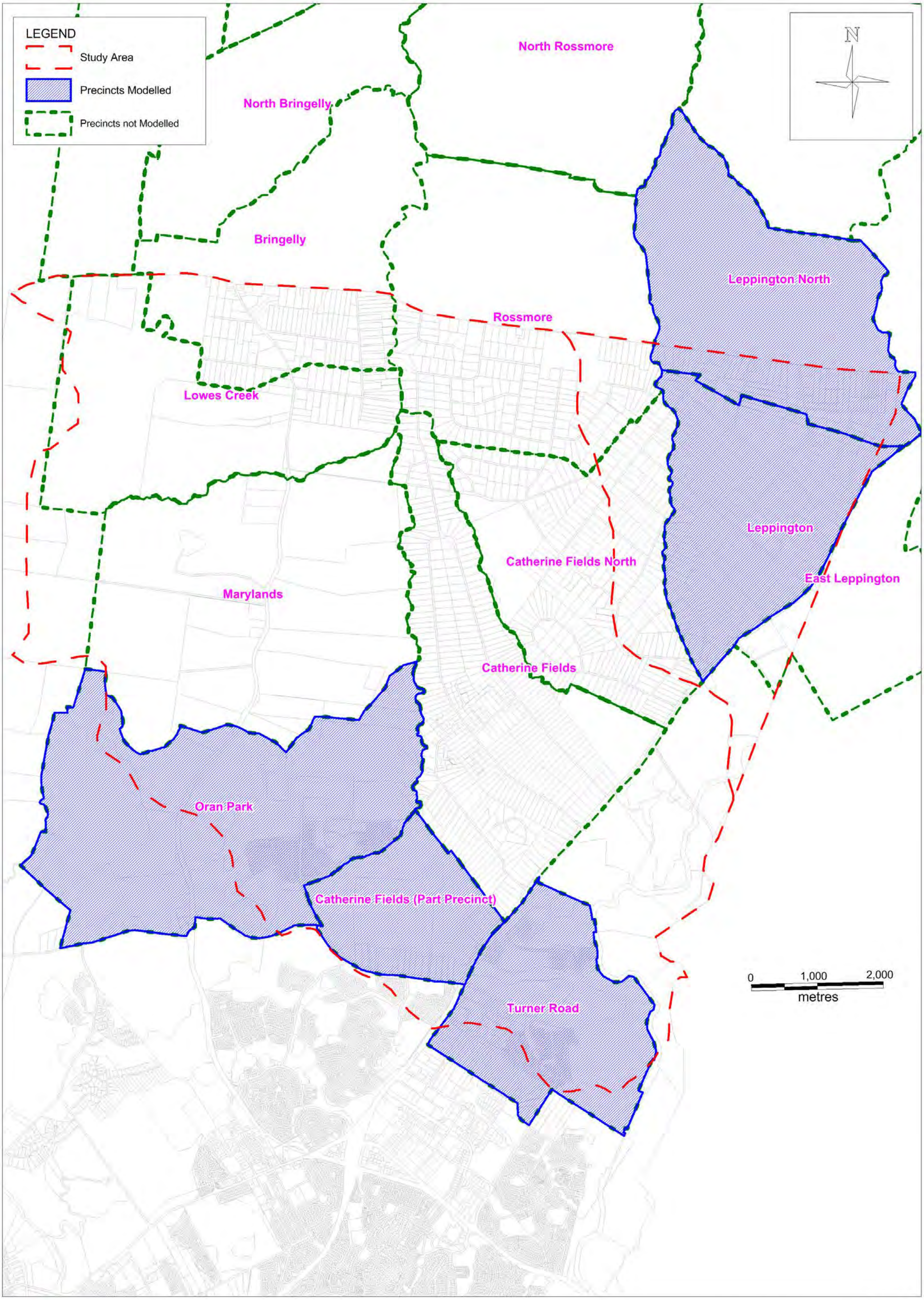
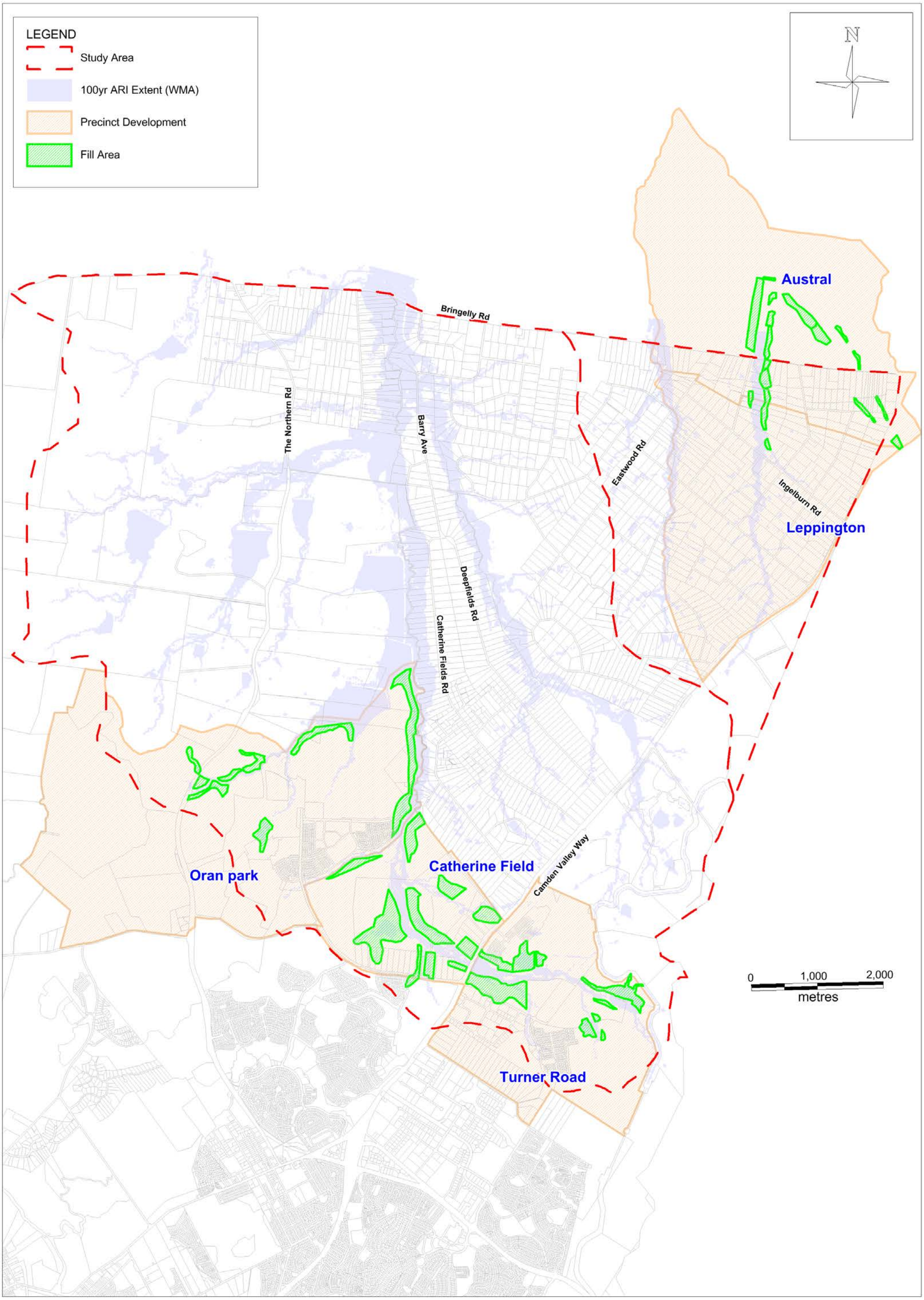


Figure A-9
SWGC Precincts included in the developed scenario TUFLOW model



Cardno

Upper South Creek FPRMS&P

Figure A-10
Fill Polygons included in the model

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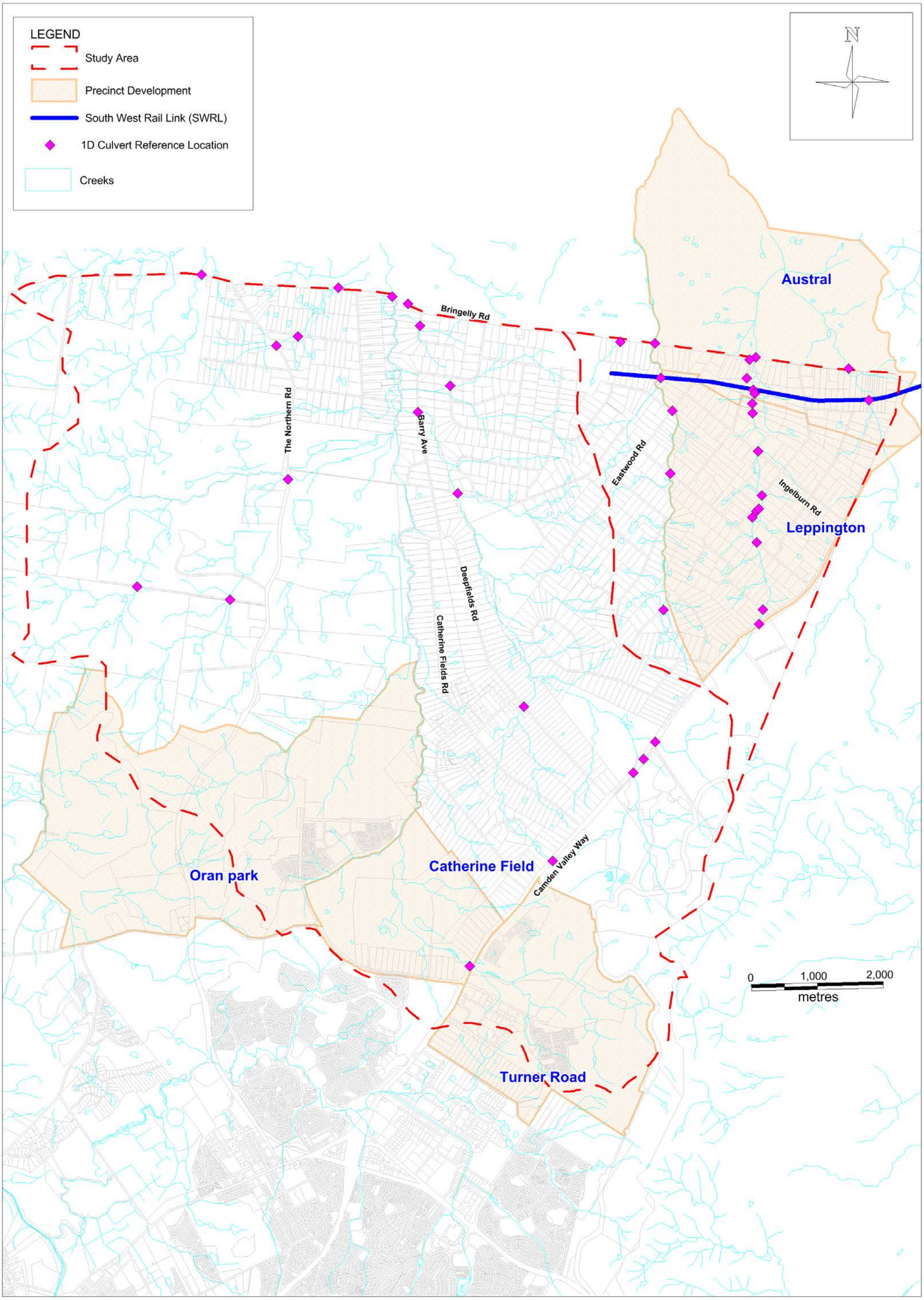
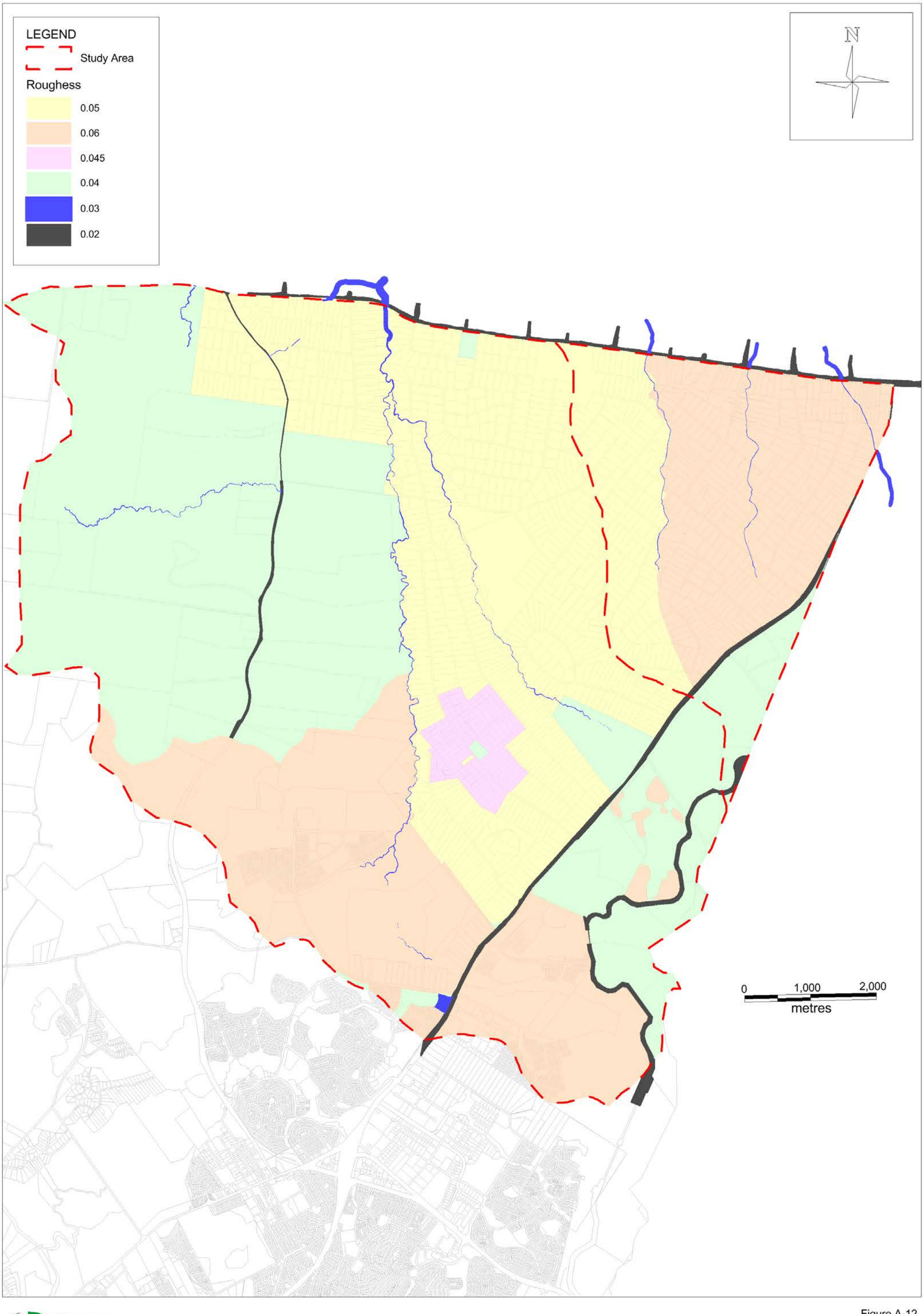

LEGEND
Study Area
Precinct Development
South West Rail Link (SWRL)
1D Culvert Reference Location
Creeks
N
Austral
Leppington
Oran park
Catherine Field
Turner Road
Bringelly Rd
The Northern Rd
Barry Ave
Eastwood Rd
Ingelburn Rd
Deepfields Rd
Catherine Fields Rd
Camden Valley Way
0
1,000
2,000
metres


LEGEND
Study Area
Roughess
0.05
0.06
0.045
0.04
0.03
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N
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1,000
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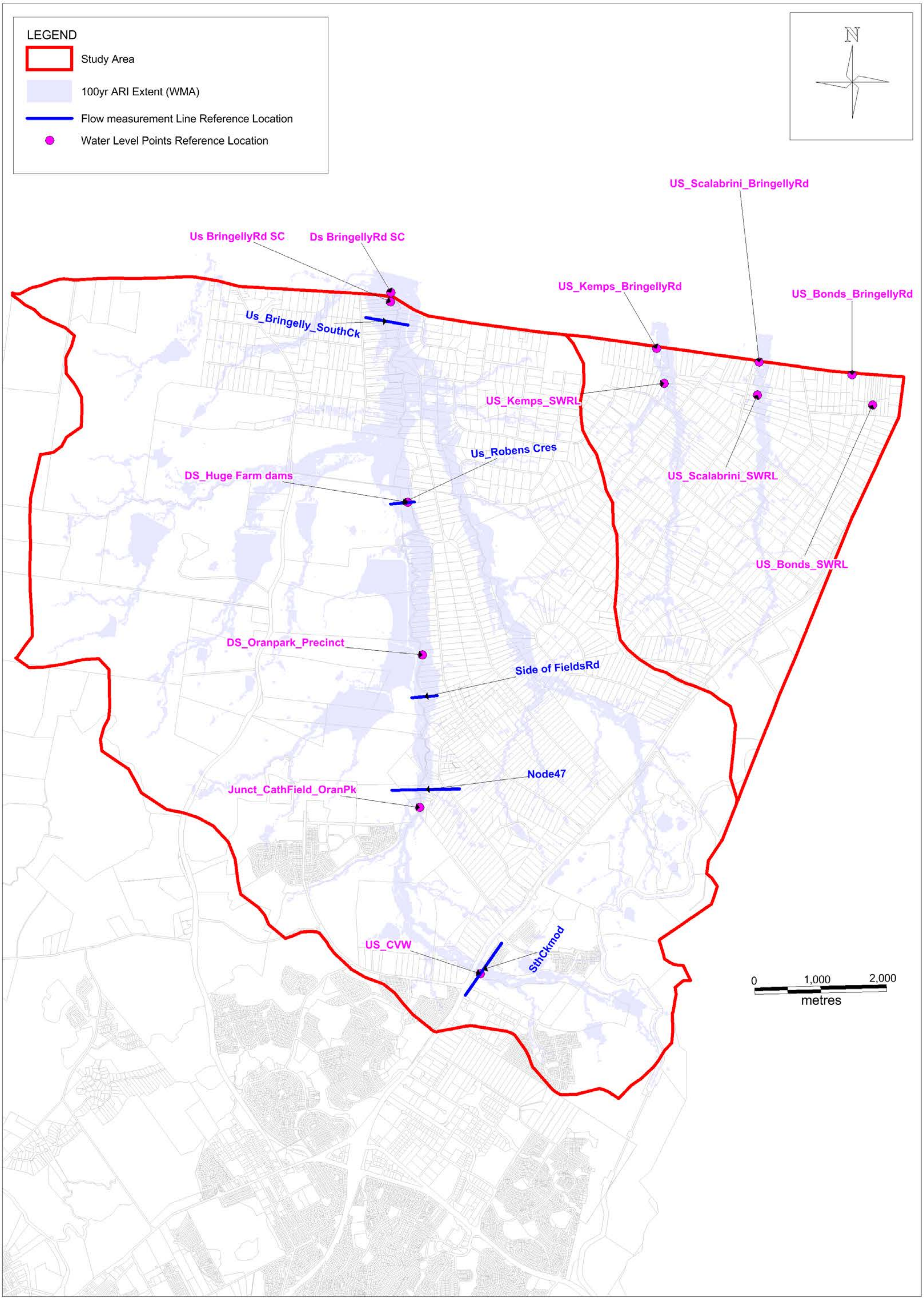
metres



Upper South Creek FPRMS&P

Figure A-13
Hydraulic Model Reference Points

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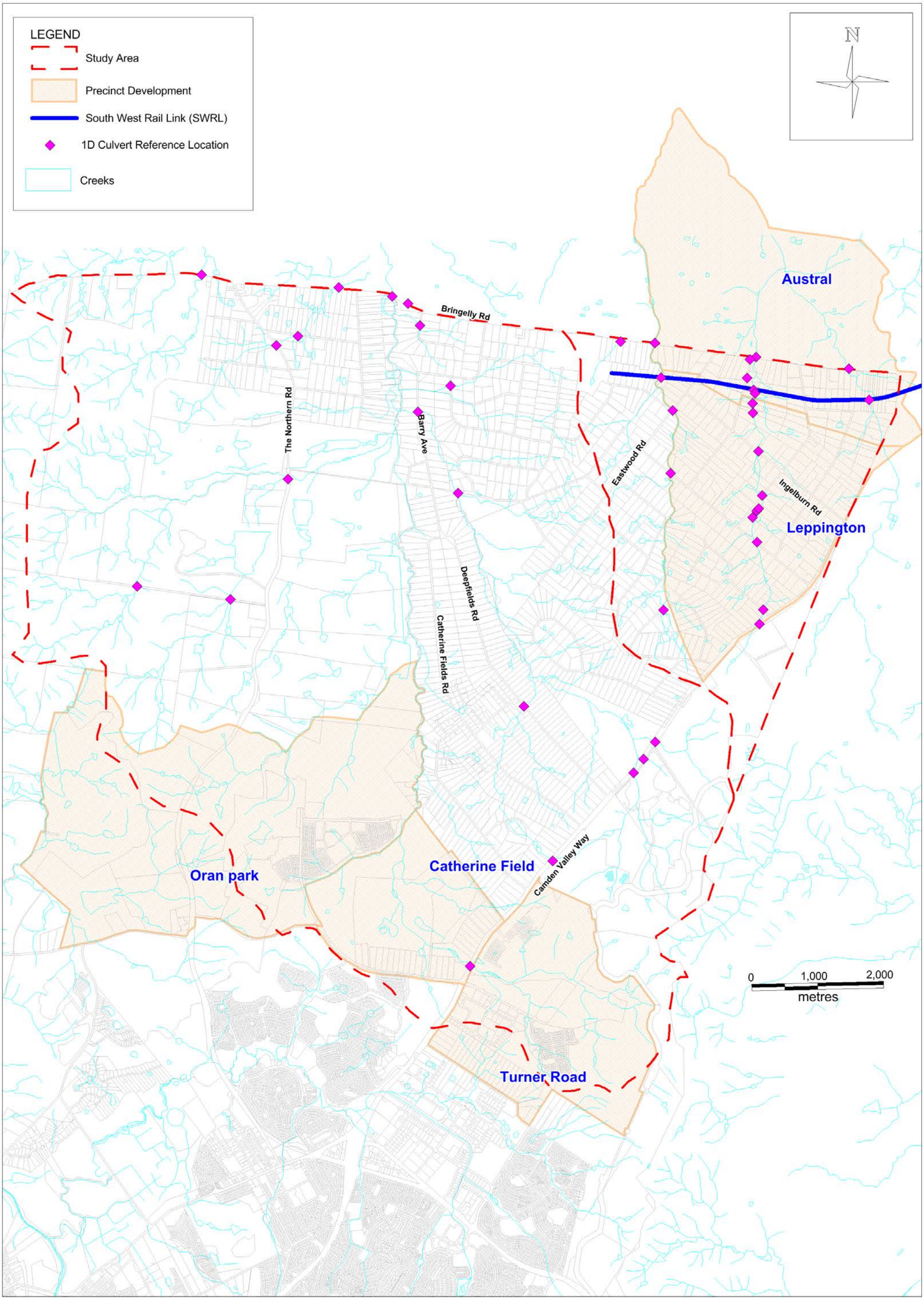
LEGEND
Study Area
Precinct Development
South West Rail Link (SWRL)
1D Culvert Reference Location
Creeks
N
Austral
Bringelly Rd
The Northern Rd
Barry Ave
Eastwood Rd
Ingelburn Rd
Leppington
Deepfields Rd
Catherine Fields Rd
Camden Valley Way
Oran park
Catherine Field
Turner Road
0
1,000
2,000
metres

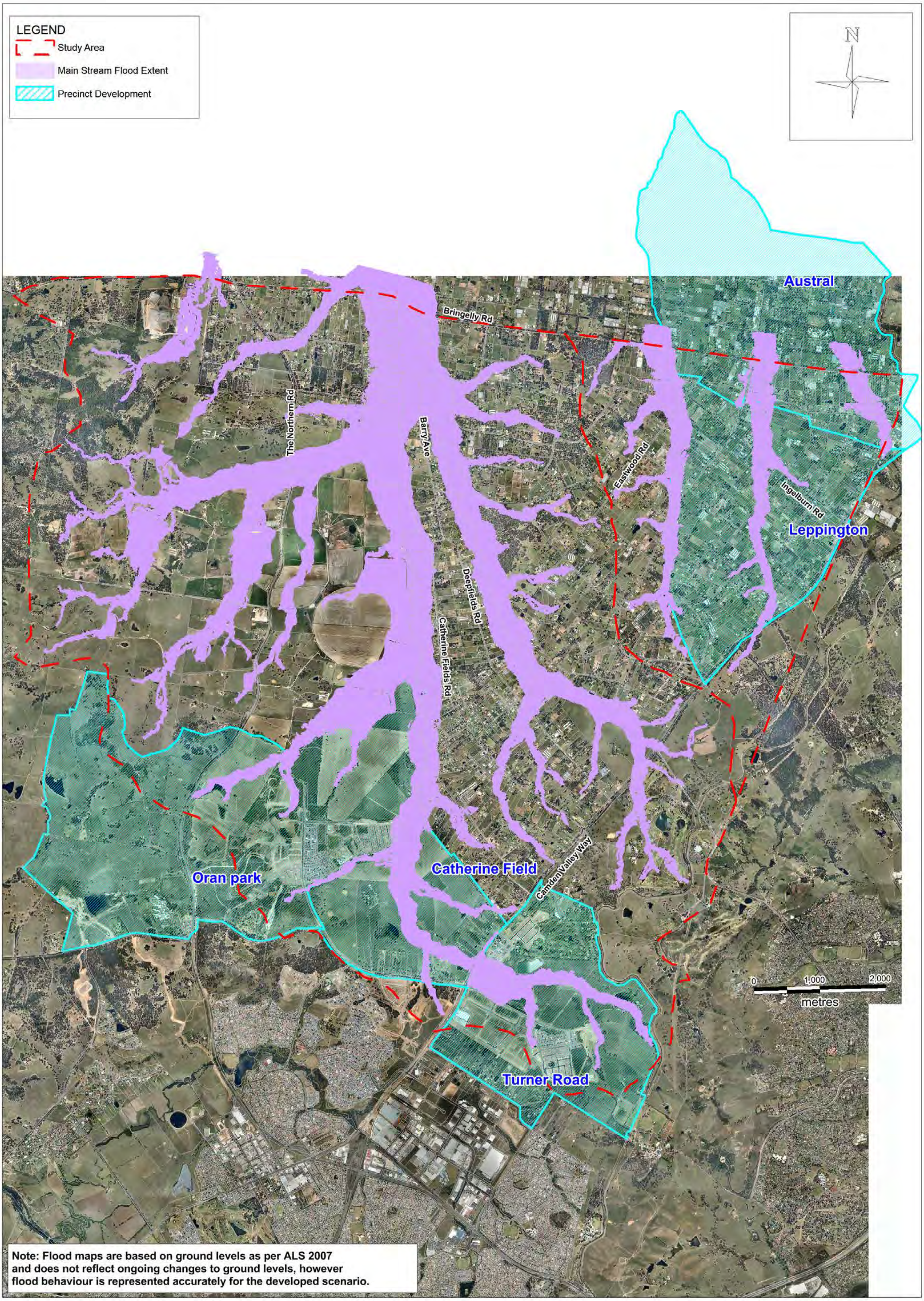

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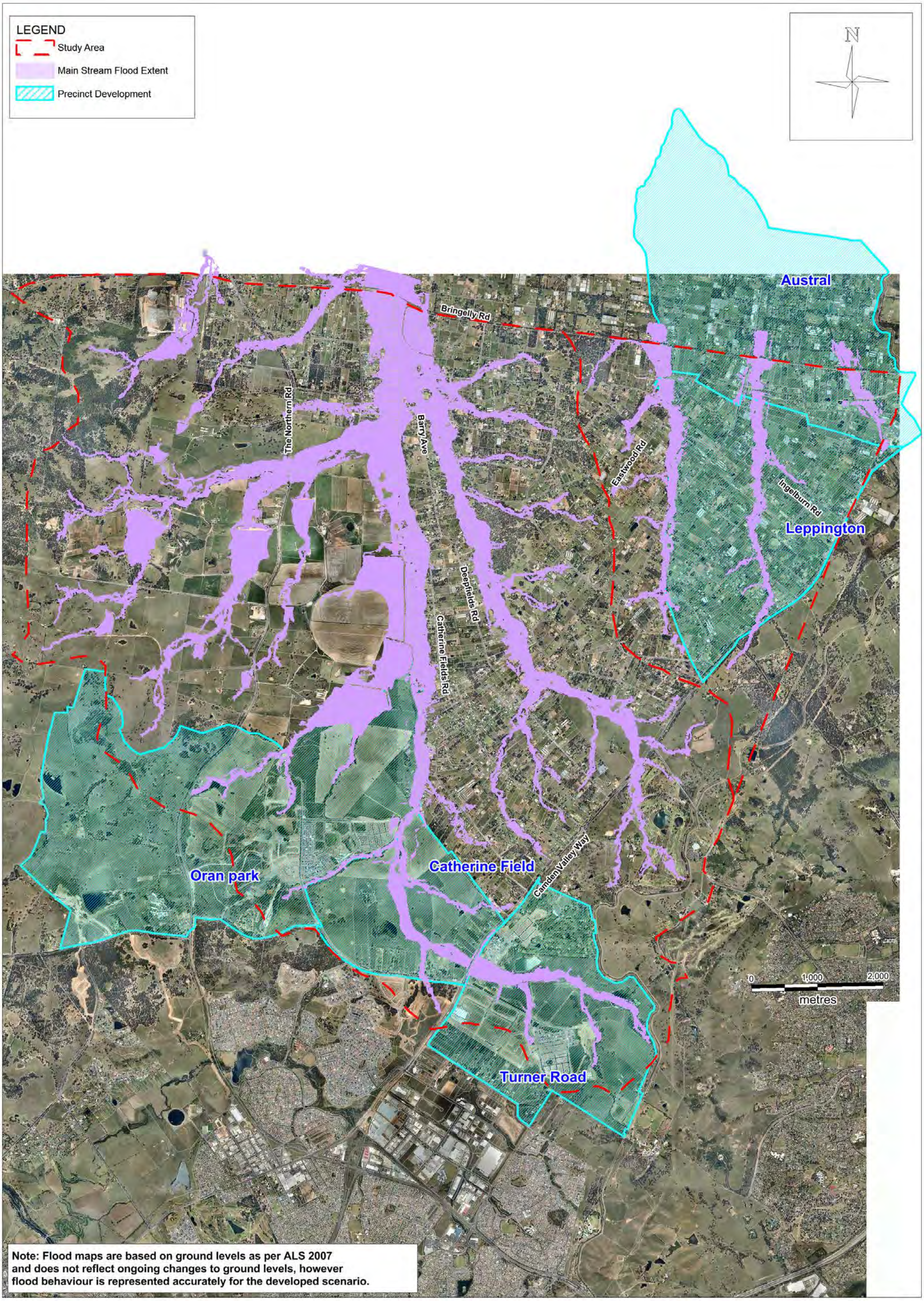
Figure A-15
Flood Extent - PMF
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure A-16
Flood Extent - 0.2% AEP
Developed Scenario

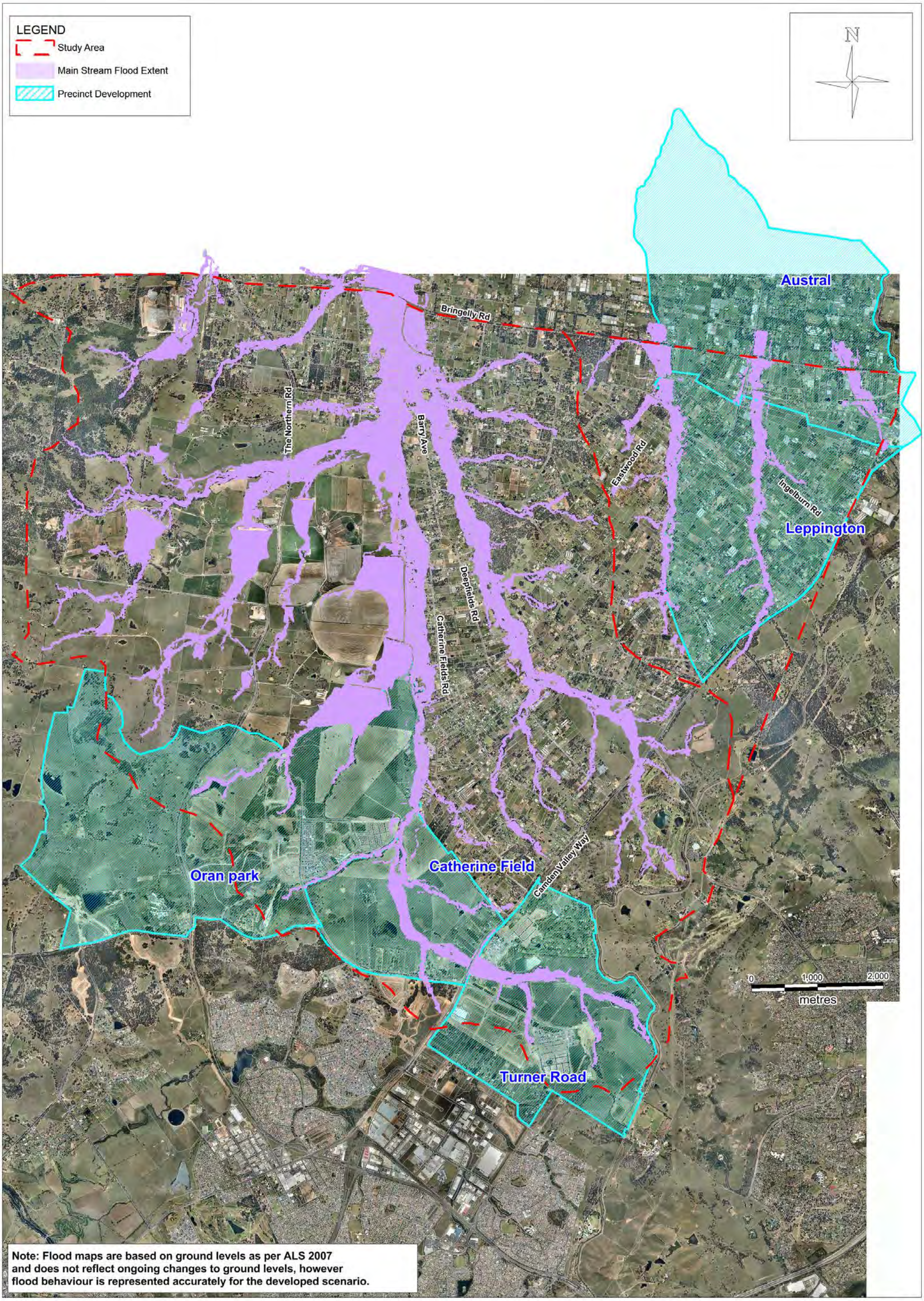


Figure A-17
Flood Extent - 0.5% AEP
Developed Scenario

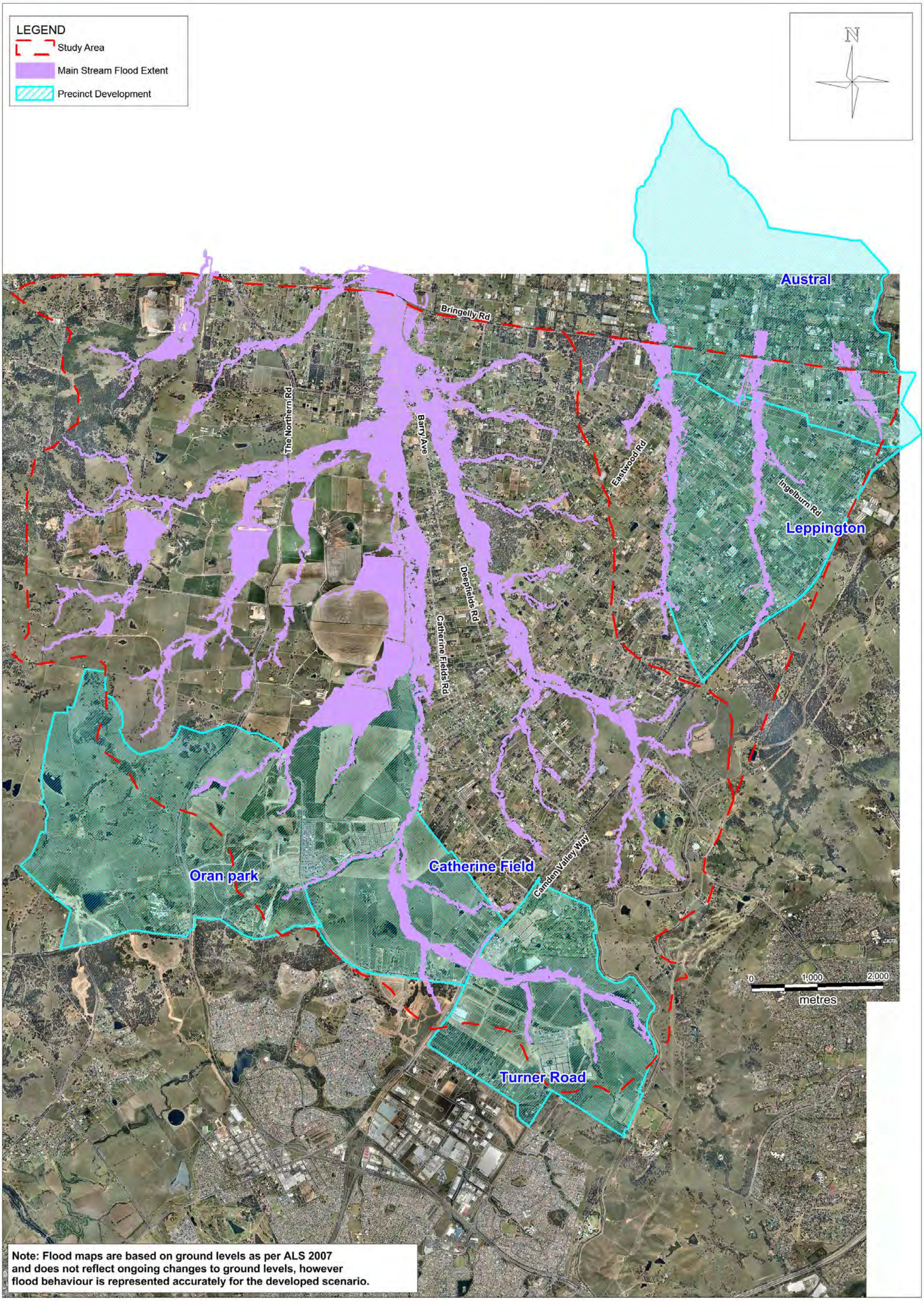
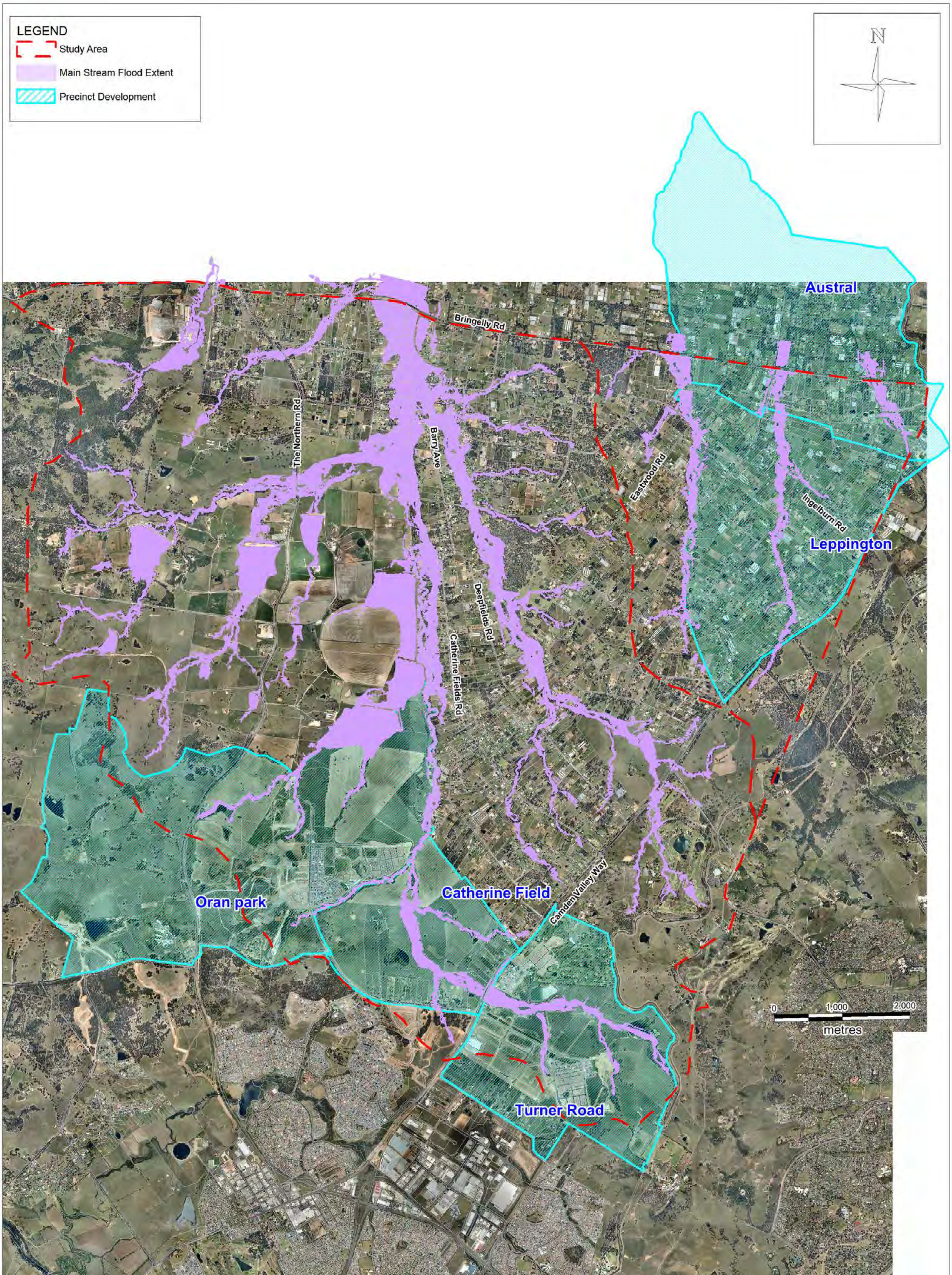


Figure A-18
Flood Extent - 1% AEP
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

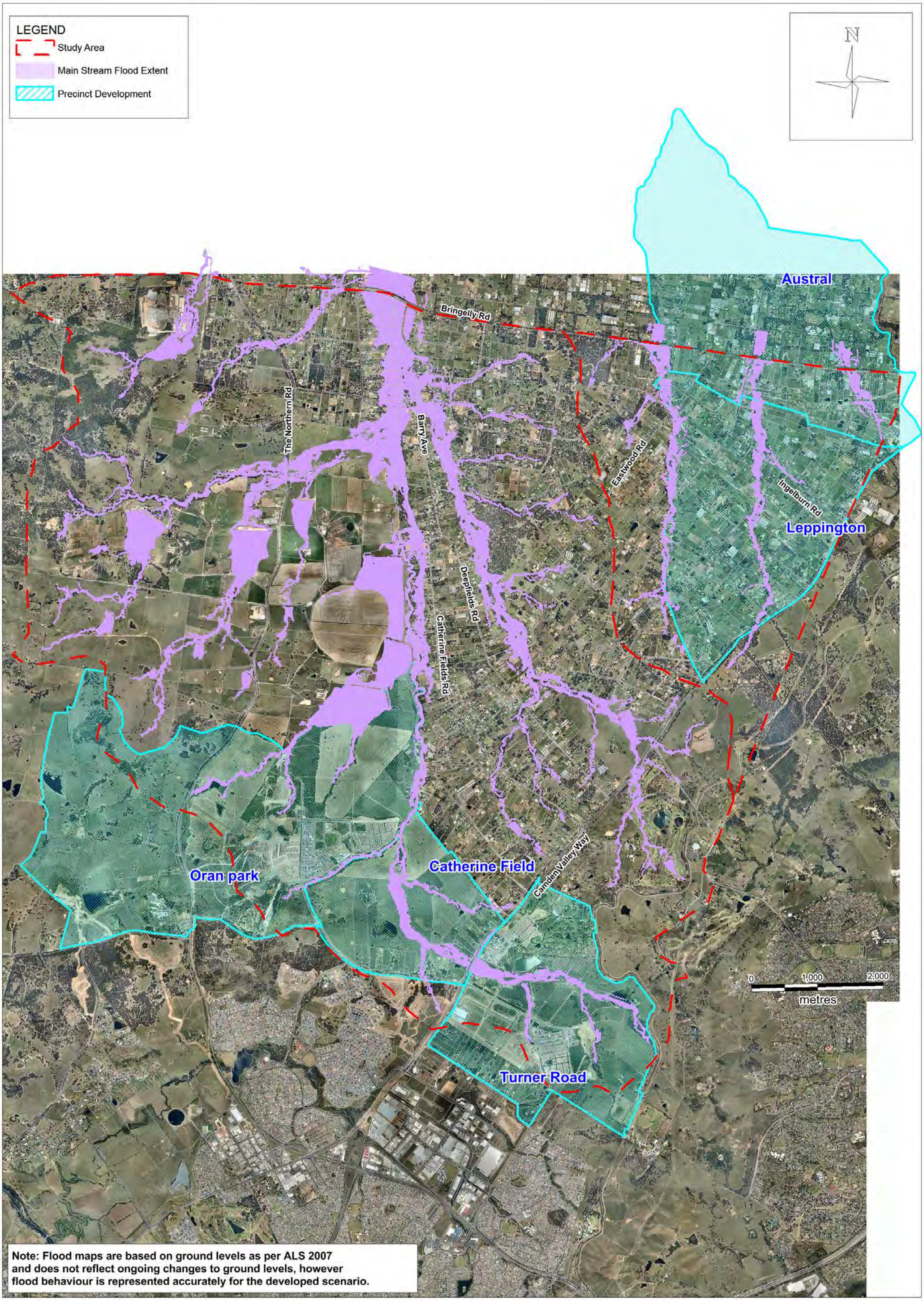
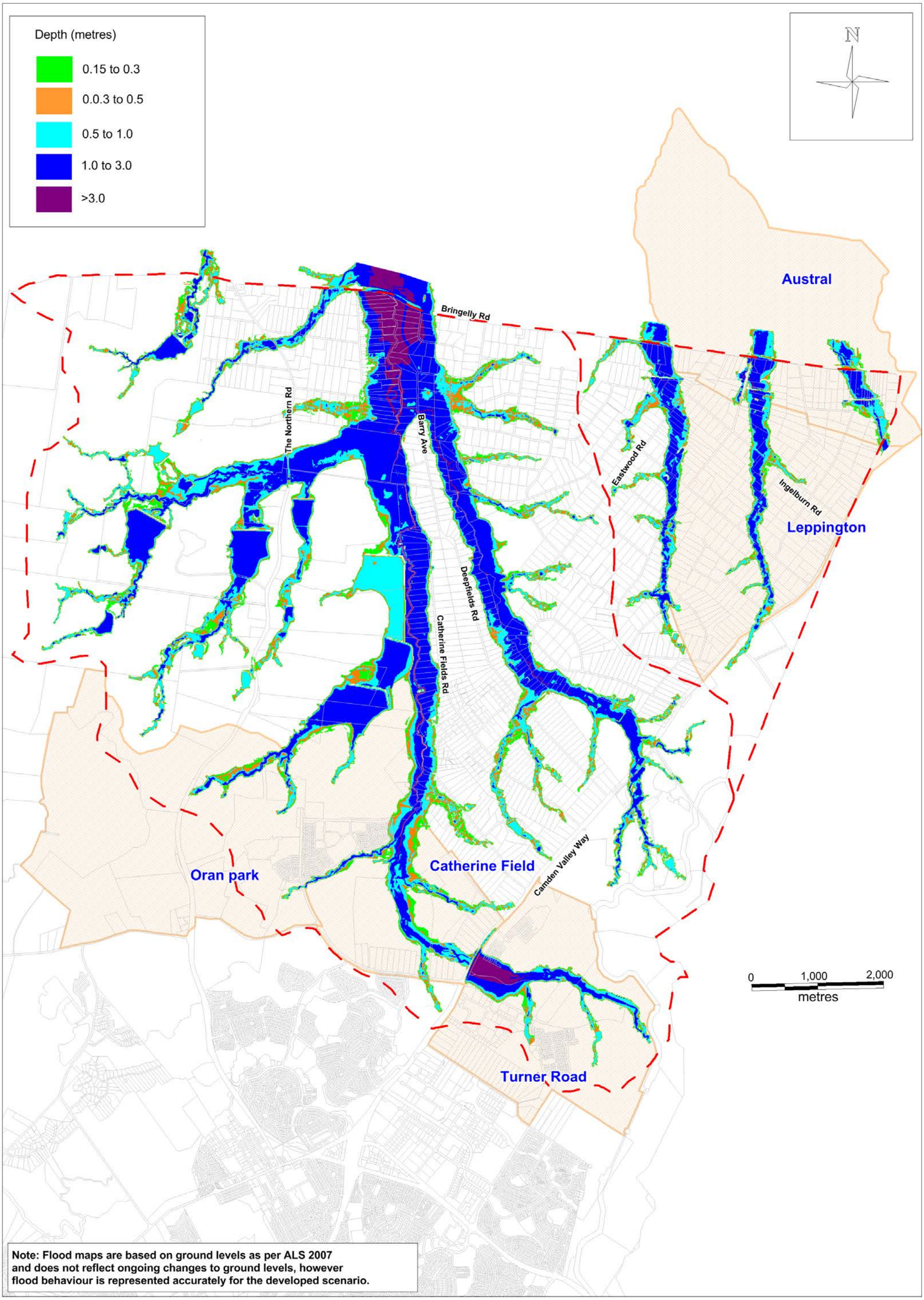
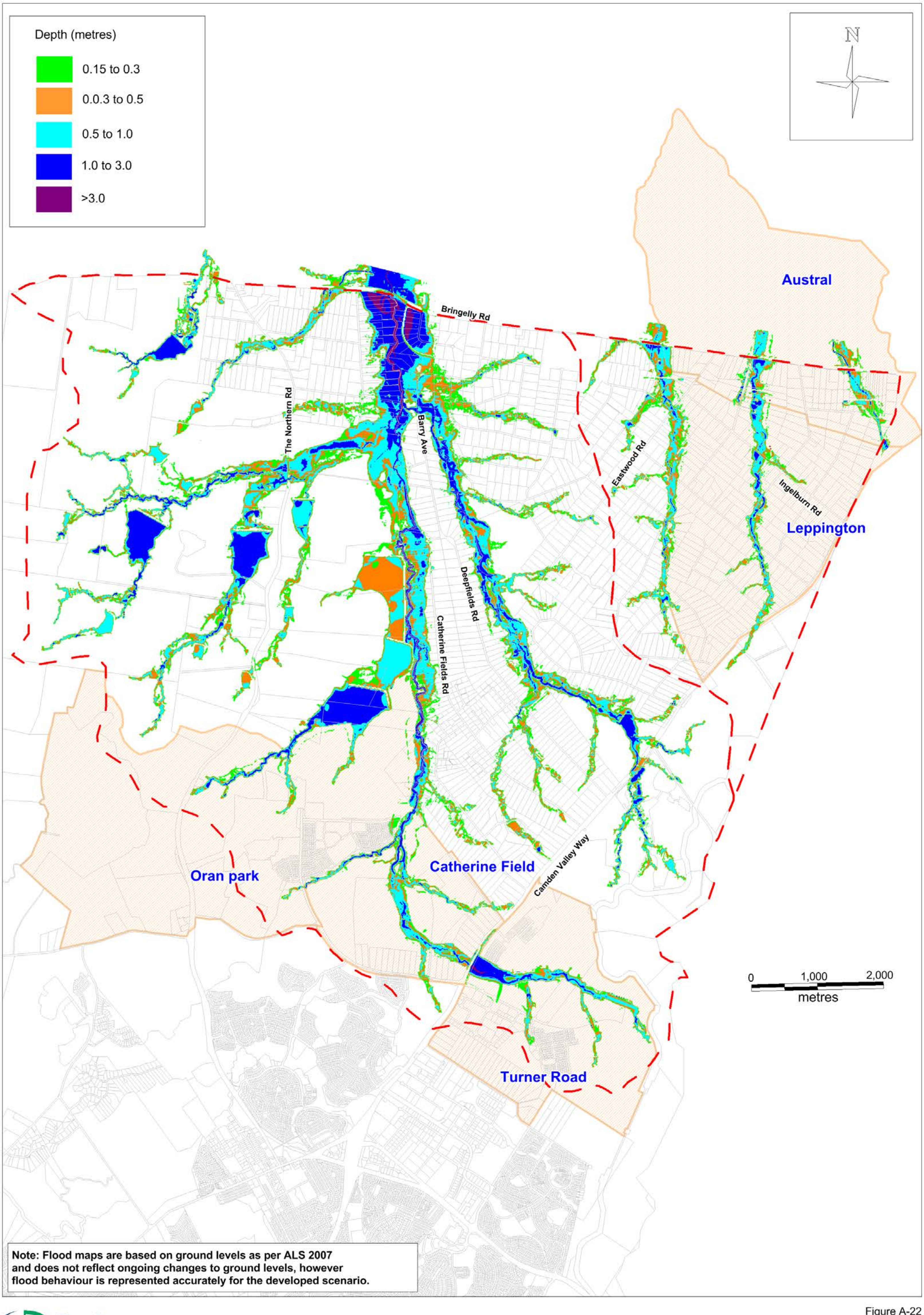


Figure A-20
Flood Extent - 5% AEP
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure A-21
Peak Flood Depths - PMF
Developed Scenario



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Upper South Creek FPRMS&P

Figure A-22
Peak Flood Depths - 0.2% AEP
Developed Scenario

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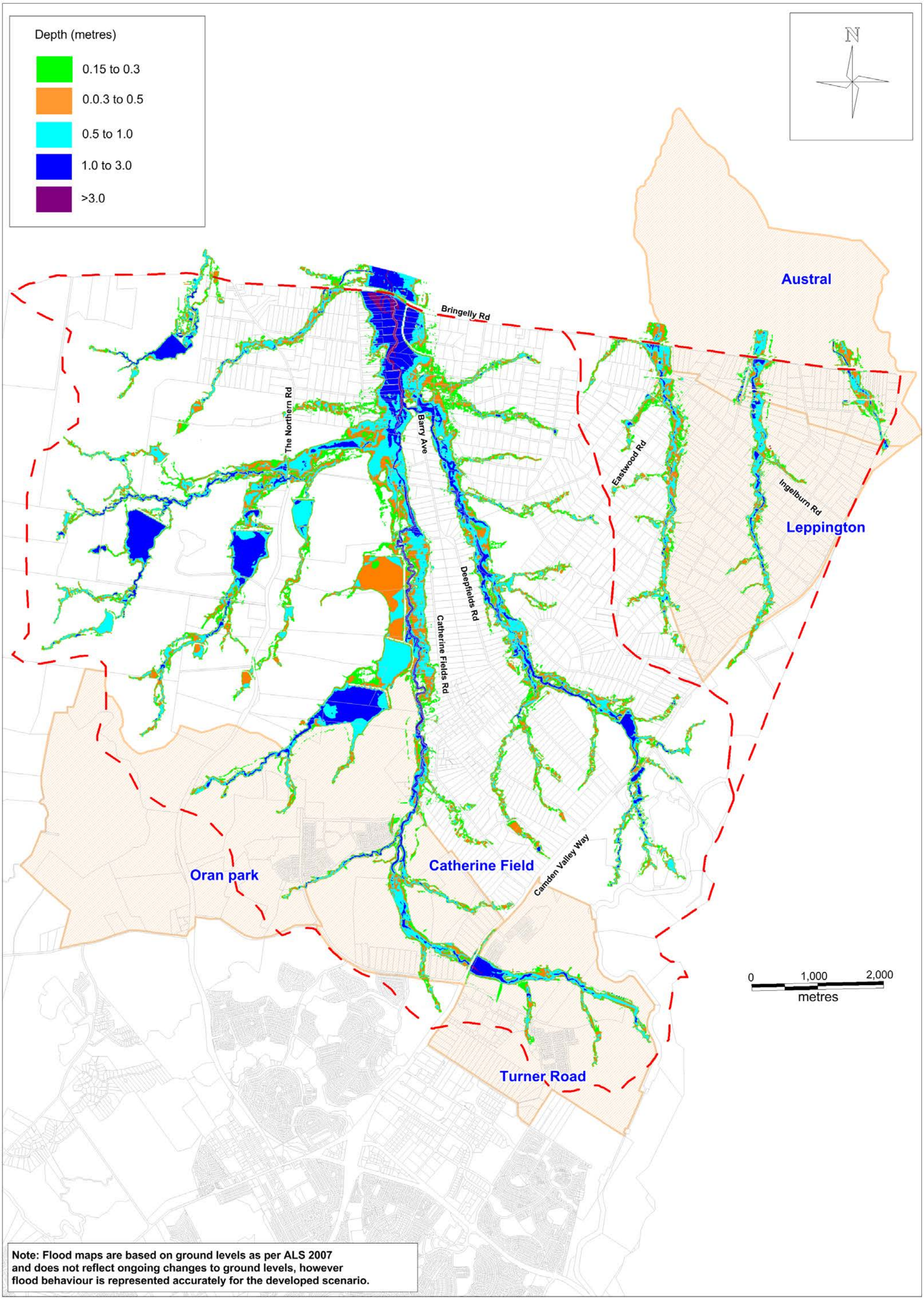


Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure A-23
Peak Flood Depths - 0.5% AEP
Developed Scenario

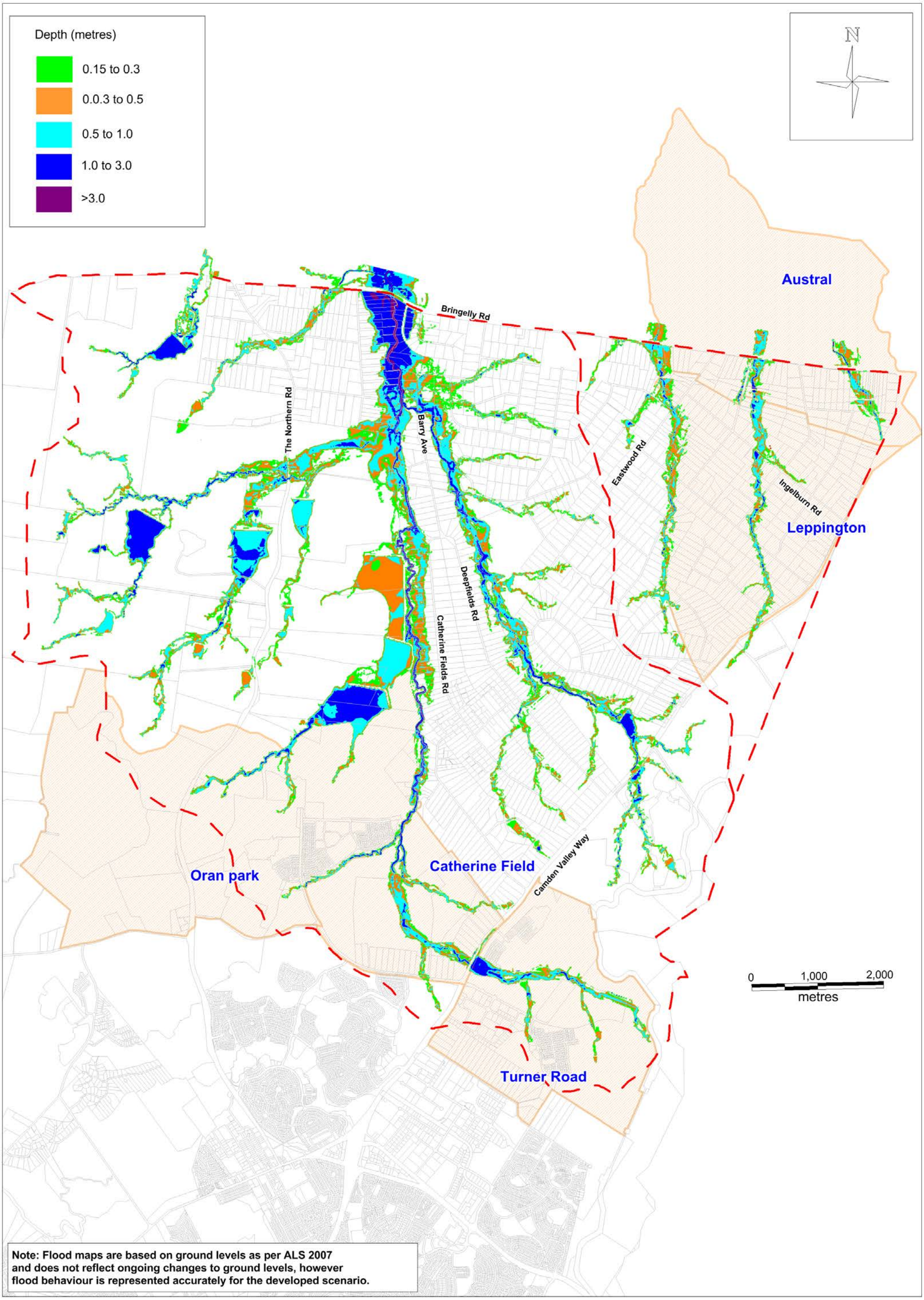
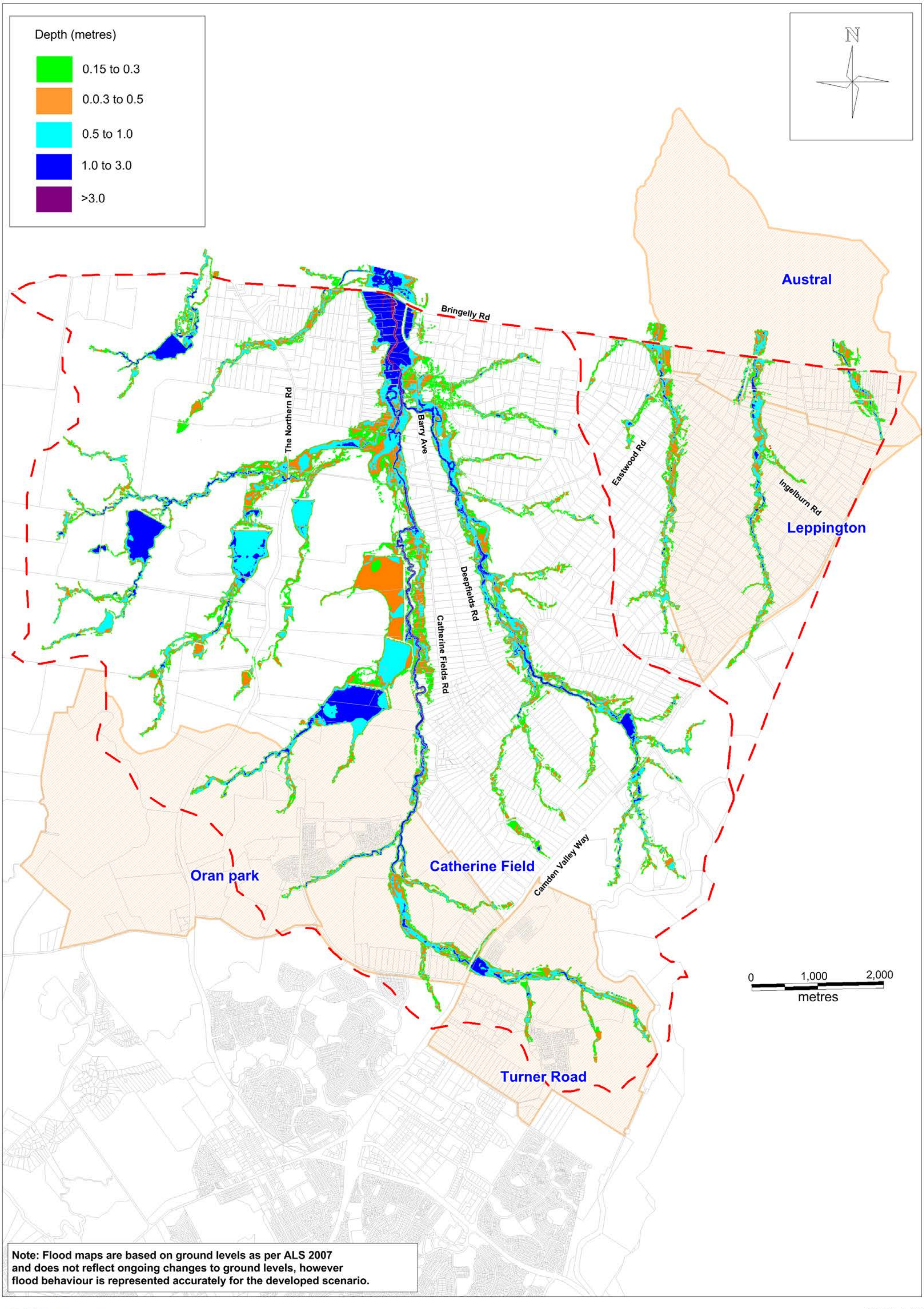
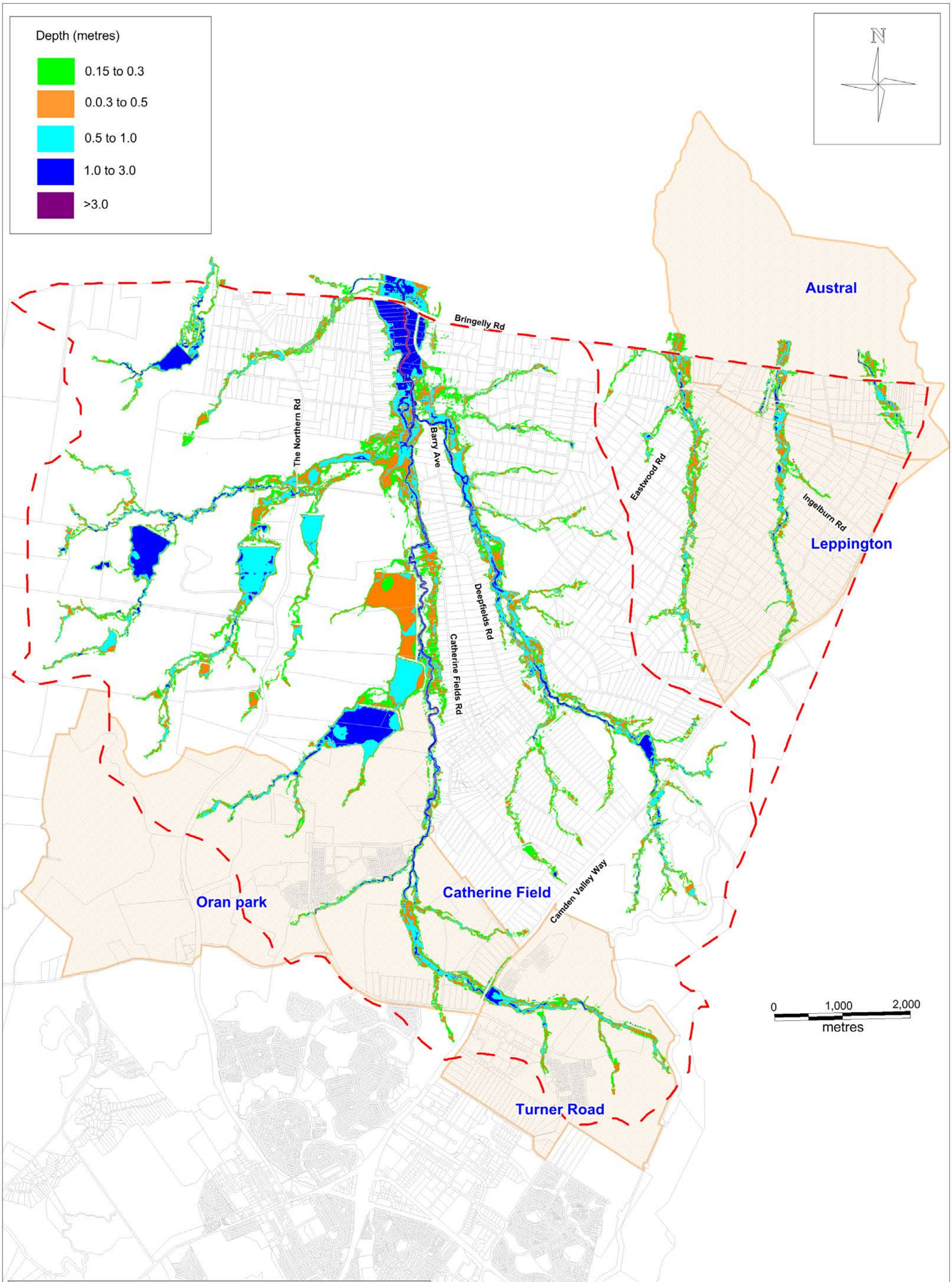


Figure A-24
Peak Flood Depths - 1% AEP
Developed Scenario

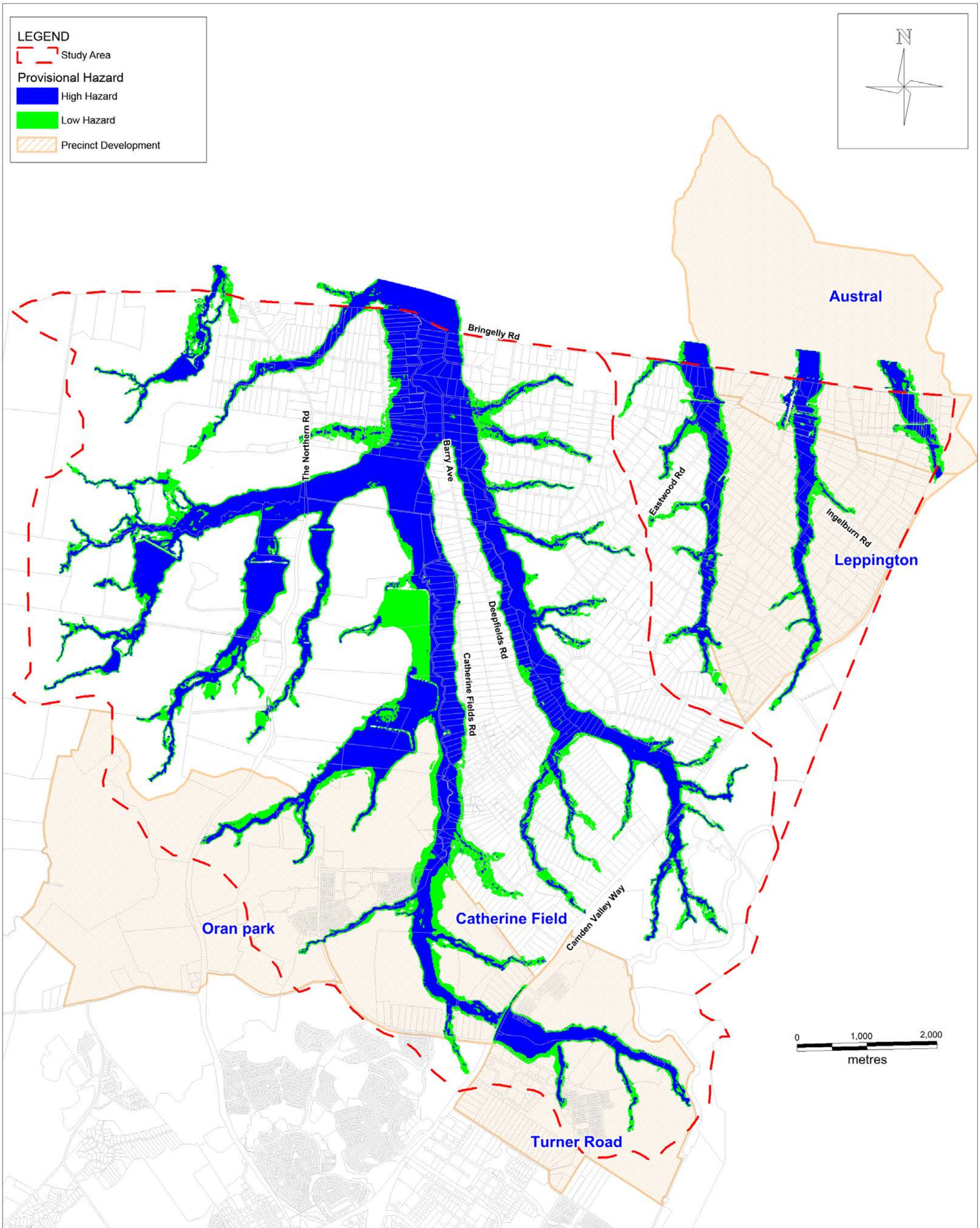


Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure A-26
Peak Flood Depths - 5% AEP
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

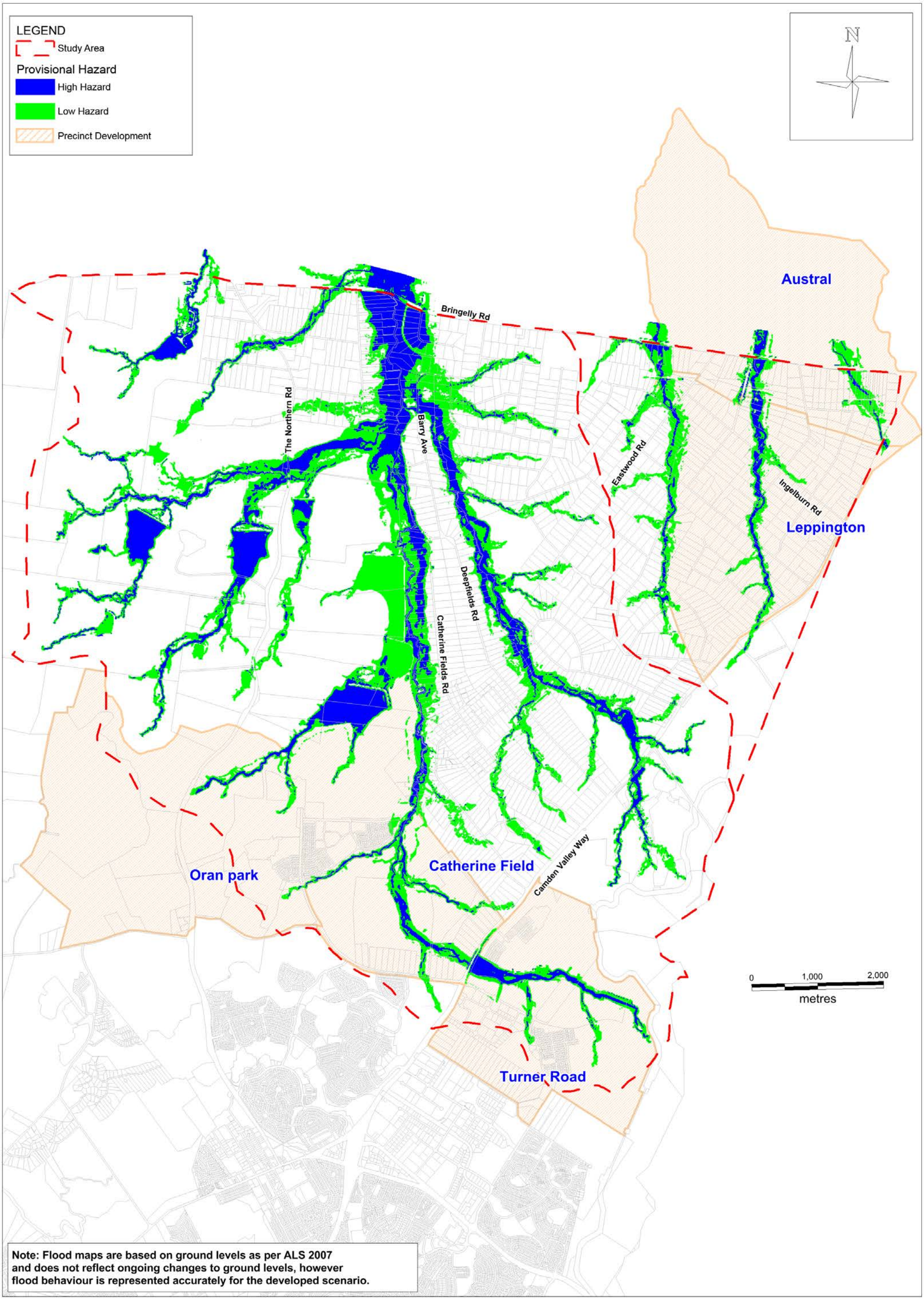
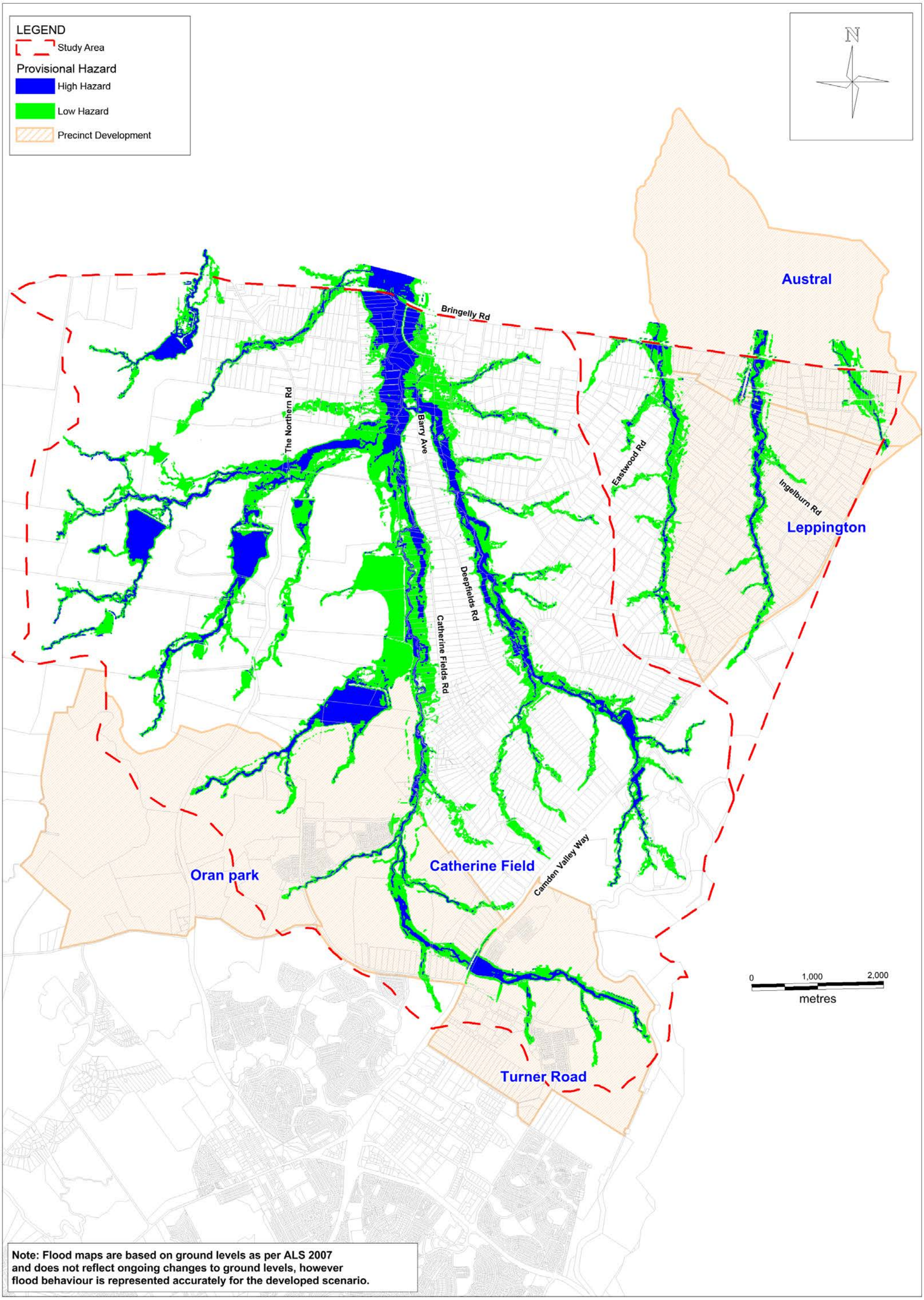


Figure A-28
Provisional Hazard - 0.2%
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

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Upper South Creek FPRMS&P

Figure A-29
Provisional Hazard - 0.5%
Developed Scenario

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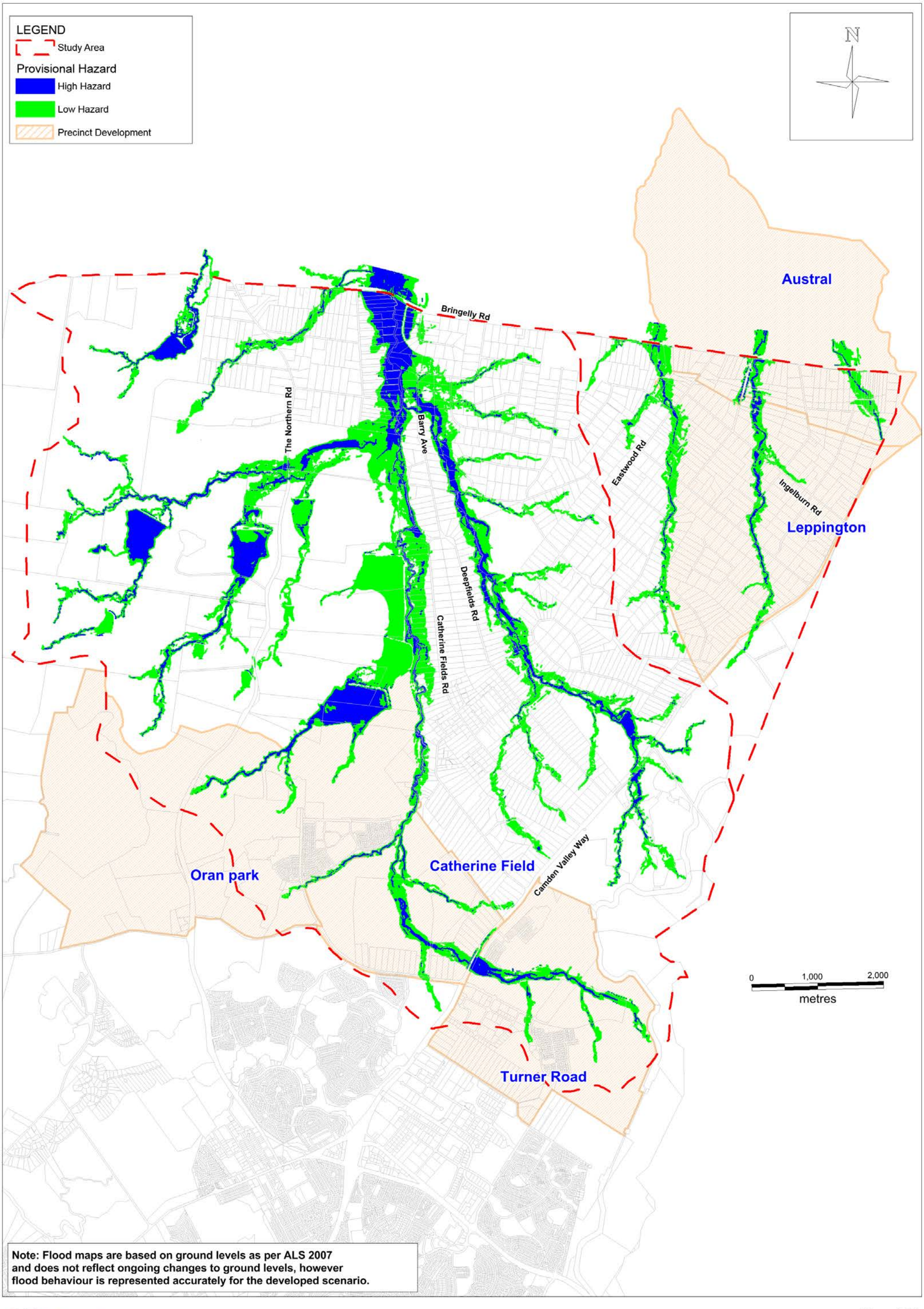


Figure A-30
Provisional Hazard - 1% AEP
Developed Scenario

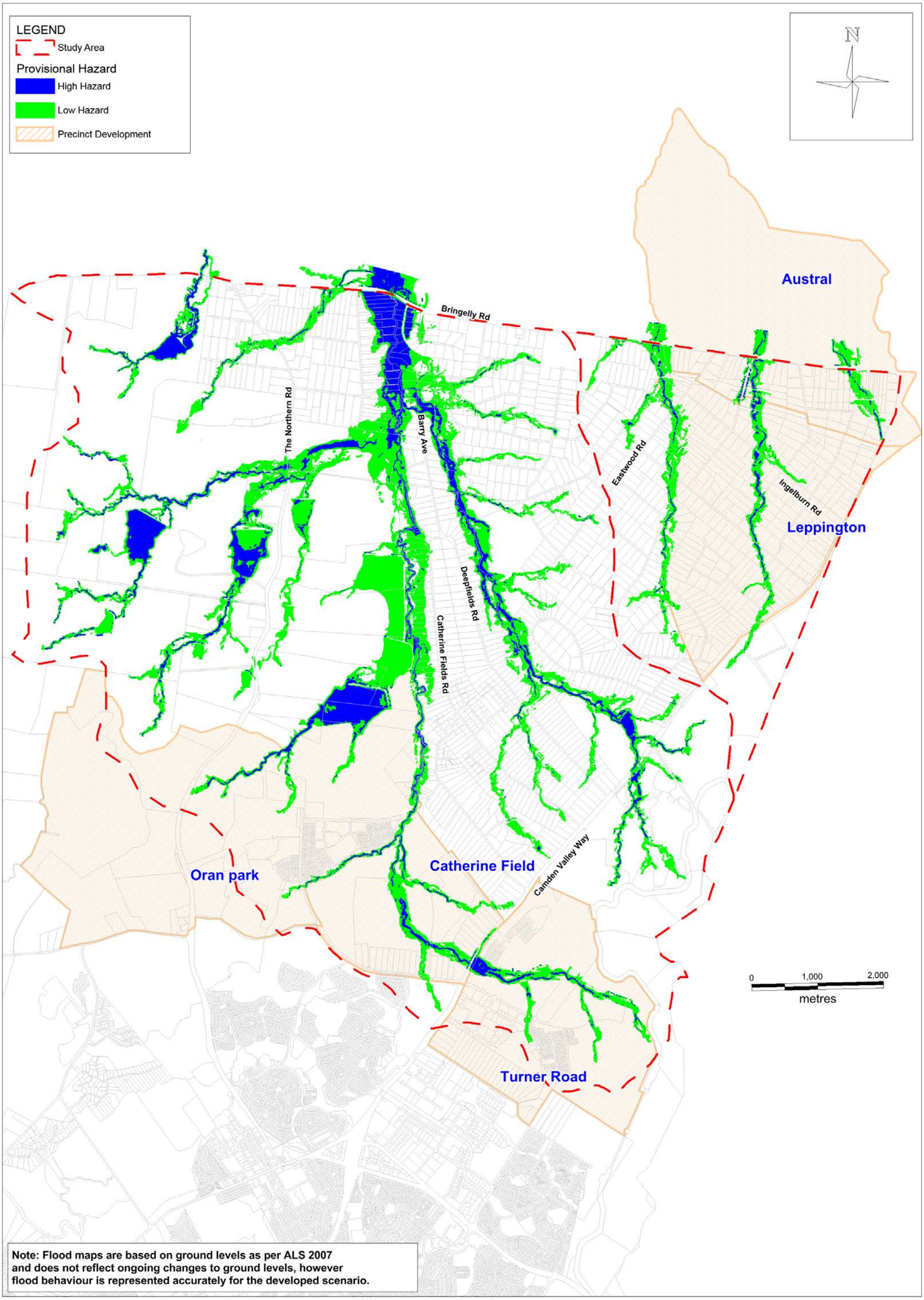


Figure A-31
Provisional Hazard - 2% AEP
Developed Scenario

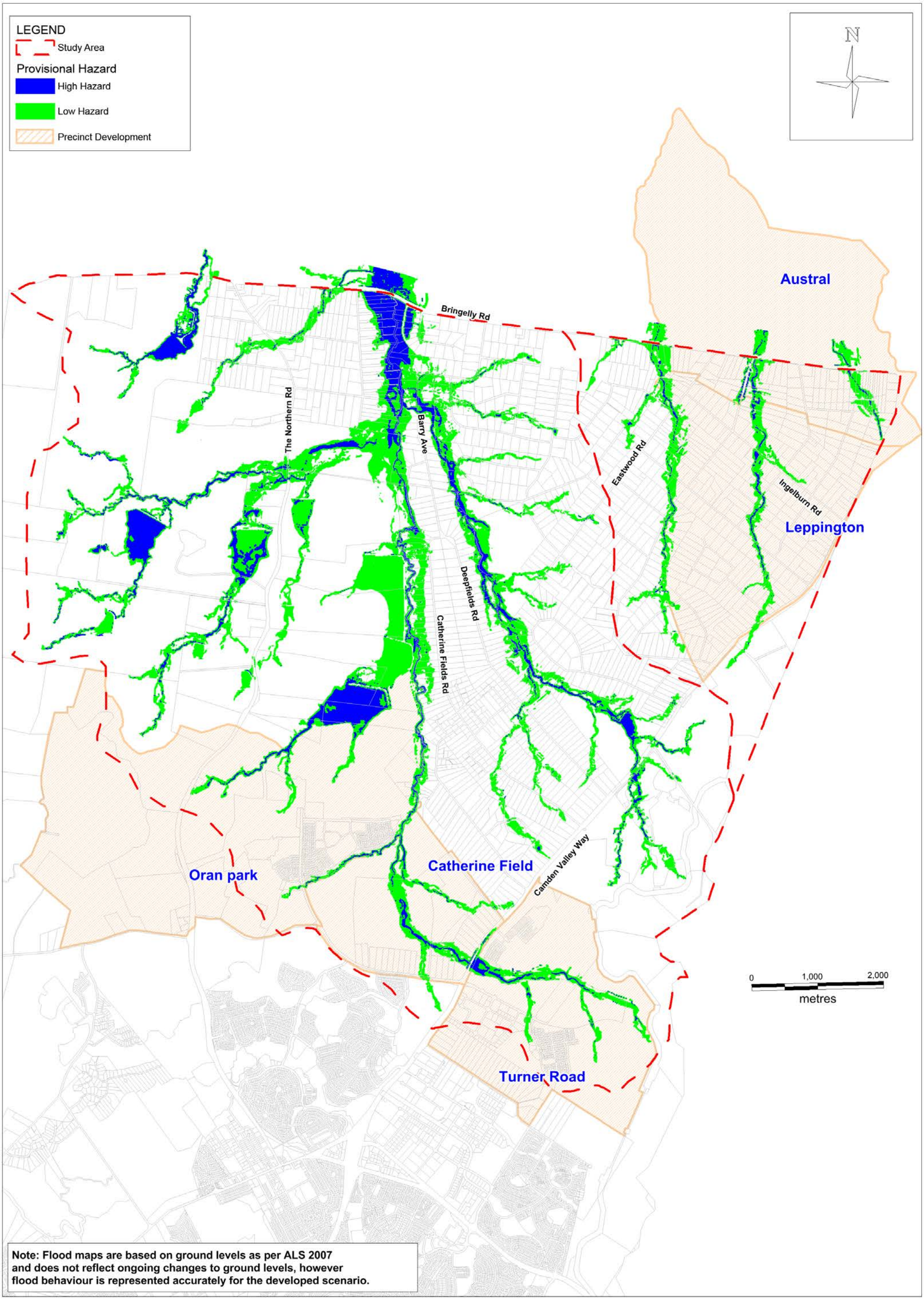
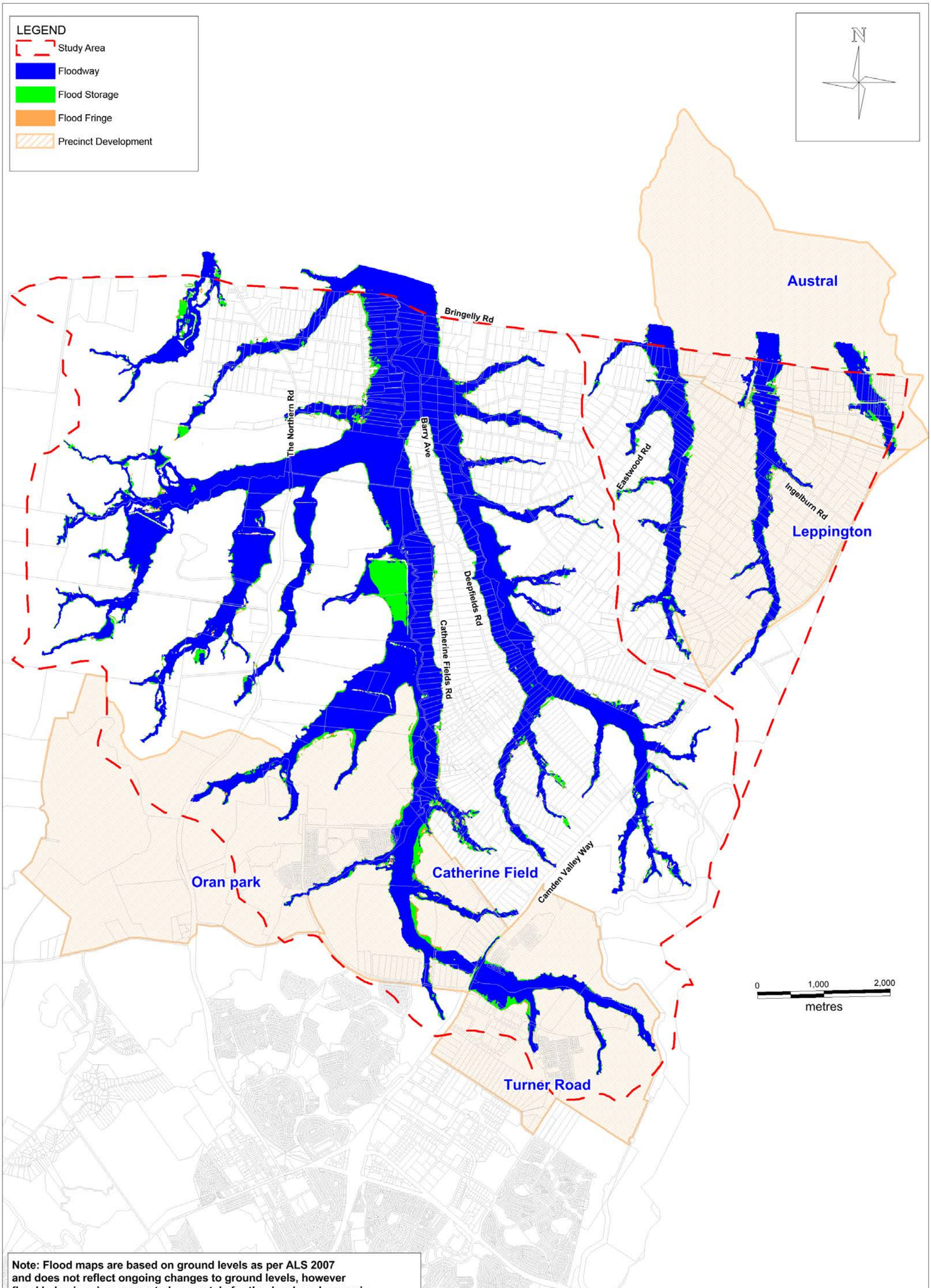
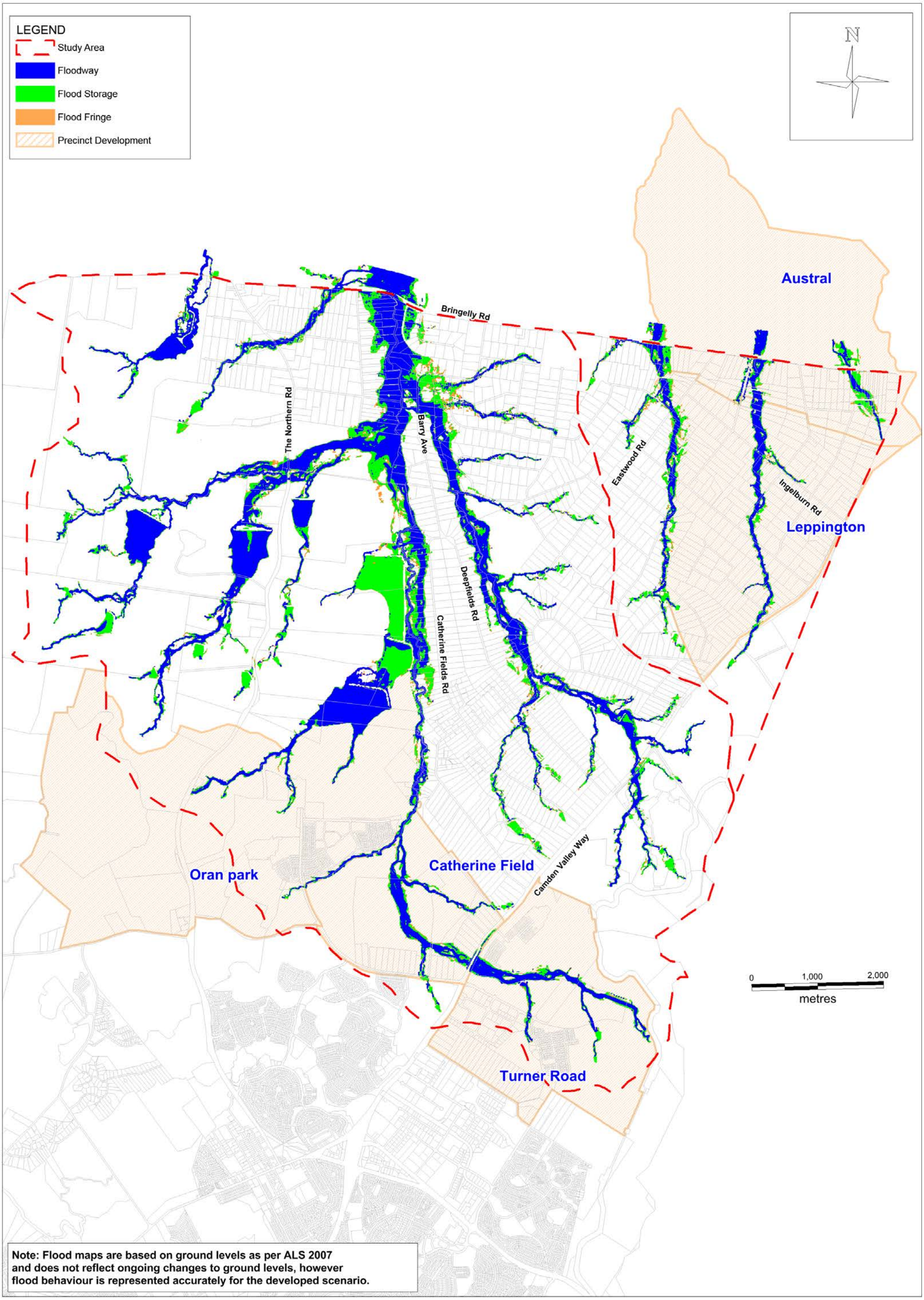


Figure A-32
Provisional Hazard - 5% AEP
Developed Scenario



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.



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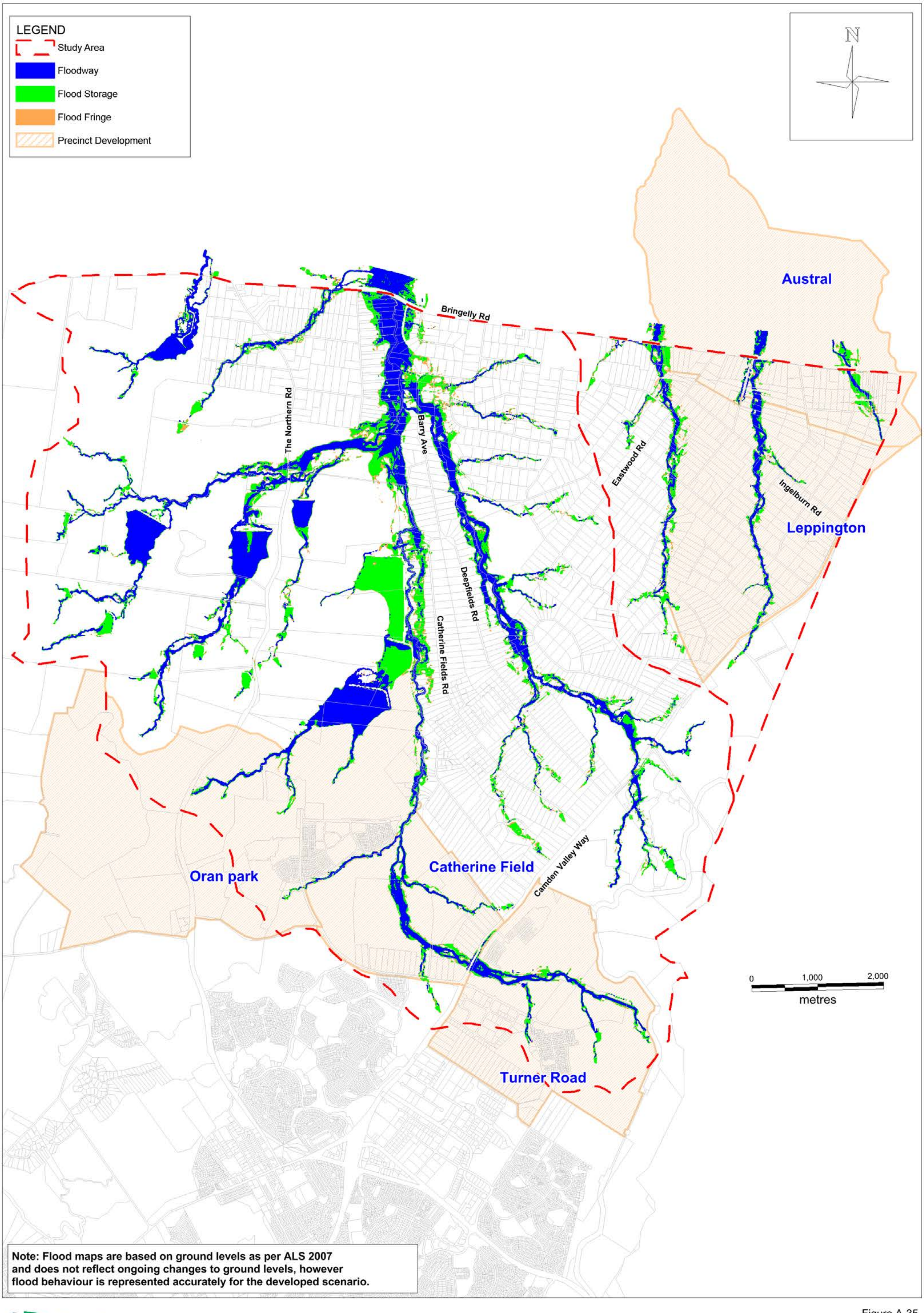
Upper South Creek FPRMS&P

Figure A-34
Hydraulic Category - 1% AEP
Developed Scenario

W4963



Note: Flood maps are based on ground levels as per ALS 2007 and does not reflect ongoing changes to ground levels, however flood behaviour is represented accurately for the developed scenario.

Figure A-35
Hydraulic Category - 5% AEP
Developed Scenario

APPENDIX B
FARM DAM ASSESSMENT

Cardno
Shaping the Future

Appendix B Farm Dam Assessment

The following is a summarised extract from the full Farm Dam Discussion Paper. Complete detailed can be found in “The Flooding Impact of Regional Farm Dams in the Upper South Creek Catchment”, *Discussion Paper, Version 4* (Cardno 2016), prepared for Camden Council, 12 September 2016.

The objective of the discussion paper was to assess the impact of regional farm dams in the upper South Creek catchment. The investigation sought to inform Camden Council and DPE of the amount of active storage in regional farm dams which should be retained to achieve minimal adverse impact on flood events up to the 1% AEP event at the boundary between the Camden and Liverpool LGAs (ie. downstream of Bringelly Road).

In 2015 an assessment was undertaken to identify the factors which influenced the current assessment of benchmark conditions and the potential impact of the removal of any or all of the regional farm dams. This was done to identify potential issues of concern, which should inform any decision regarding the benchmark condition for assessment of the impacts of planned development of the floodplain. The potential factors, which influenced the current assessment of benchmark conditions, include:

- The adopted approach to hydrological and hydraulic modelling, namely, the “rainfall on grid” approach; and
- The adopted water levels in each of the regional farm dams

With regard to the adopted starting water levels in the Regional Farm Dams, it was found that:

- The starting water levels in Dams C and D are currently modelled at full supply level;
- The starting water levels in Dams E and F are currently modelled at a level slightly lower than full supply level;
- The starting water levels in Dams A and B are currently modelled at a level lower than full supply level which creates depression storage volumes which are estimated to be 100% and 22% of the active storage respectively; and
- The starting water level in Dams G is currently modelled at a level significantly lower than full supply level which creates a depression storage volume which is estimated to be 10 times greater than the active storage.

With regard to rainfall losses, the TUFLOW floodplain model currently adopts an initial rainfall loss of 15 mm and a continuing rainfall loss of 1.5 mm/h for each dam water surface which in hydrological models is treated as an impervious surface with nil rainfall losses.

As a result of the starting water levels and rainfall losses, it was concluded that:

- The effective increase in active storage in all regional farm dams in a 2 hour storm burst is around 2% except for Dam G where the impact is greater because of the small active storage volume;
- The effective increase in active storage in Dams C and E in a 9 hour storm burst is around 5% -6%;
- The effective increase in active storage in Dams B and D in a 9 hour storm burst is around 10% - 12%;
- The effective increase in active storage in Dam A in a 9 hour storm burst is around 22%; and,
- The effective increase in active storage in Dam G in a 9 hour storm burst is more than five times greater than the small active storage volume.

A catchment hydrological model based on the Worley Parsons, 2015 model was used to assess the assessment of 1% AEP peak flows at Bringelly Road to the adopted storm burst duration, adopted rainfall loss, adopted catchment roughness, BX value and the inclusion of the regional farm dams.

The key findings were:

- The 2012 WMAwater assessment of flooding on the South Creek floodplain upstream of Bringelly Road was based on a 9 hour design storm burst;
- The 2015 Worley Parsons assessment of flooding on the South Creek floodplain downstream of Bringelly Road was based on a 36 hour design storm burst;
- It was found that the peak 9 hour storm burst embedded within the 36 hour ARR design storm has a depth with a severity greater than 1% AEP
- The difference between the critical storm burst durations in the two studies is due to the difference in the adopted rainfall losses;
- The 1% AEP peak flow at Bringelly Road estimated by Worley Parsons, 2015 is 312 m3/s;
- This is considered to be representative of the peak flow downstream of Bringelly Road because the Worley Parsons, 2015 floodplain model does not include storage upstream of Bringelly Road;
- The removal of the farm Dams A, B and G would not increase peak flows above the 2015 Worley Parsons peak flow; and,
- The removal of the farm Dams A, C, D and G matches the 2015 Worley Parsons peak flow.

A truncated floodplain model was used to assess the active storage in regional farm dams that needed to be retained to achieve minimal adverse impact on 1% AEP flood flows and flood levels downstream of Bringelly Road. It was noted that the 1% AEP peak flows estimated by the hydrological model (adjusted for the inclusion of the farm dams at full supply level) are in good agreement with the 1% AEP flows estimated downstream of Bringelly Road by the floodplain model.

The key findings were:

- The assessment of the impact of the removal of farm dams should be benchmarked against all farm dams at their full supply level;
- This benchmark gives higher 1% AEP flood levels in the South Creek tributary and the reach down to Bringelly Road than have been adopted by Council to date;
- The impact of removing or filling farm Dams C, D and E on the 1% AEP flood levels upstream and downstream of Bringelly Road are very similar. If the remaining farm dams are at full supply level then the 1% AEP flood level upstream of Bringelly Road would rise a further 0.06 m while the 1% AEP flood level downstream of Bringelly Road would rise a further 0.02 m.
- If farm Dams A and G only are removed then the impact on 1% AEP flood level upstream of Bringelly Road is minor (0.03 m) while the impact on the 1% AEP flood level downstream of Bringelly Road is negligible.
- If farm Dams A, C, D and G only are removed then the impact on 1% AEP flood level upstream of Bringelly Road is modest (0.11 m) while the impact on the 1% AEP flood level downstream of Bringelly Road is minor (0.06 m). These impacts are around half of the impact on 1% AEP flood levels upstream and downstream Bringelly Road of the removal all regional farm dams;
- Consideration should be given to partially retaining active storage at the location of farm Dams A and B or substantially at the location of farm Dam A or farm Dam B if the other is fully removed;
- Alternatively consideration could be given to a new on-line detention basin in the vicinity of the tributary confluence to mitigate the impacts of the removal of farm Dams A and B but this would be subject to the agreement of NOW and/or others to the siting of a new basin at this location within the riparian corridor; and
- Consideration could be given to removing farm Dams A, C, D and G if the minor impacts on 1% AEP flood levels are deemed acceptable.
- The estimated 1% AEP flood levels downstream of Bringelly Road are all lower than the 1% AEP flood levels estimated by Worley Parsons, 2015 under all scenarios which were assessed.

APPENDIX C
2016 EVENT ANALYSIS

Our Ref W4963_L004_LE

Contact Luke Evans

13 February 2017

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Maria Pinto
Camden Council
PO Box 183,
CAMDEN NSW 2570

Attention: Maria Pinto

Dear Maria

UPPER SOUTH CREEK – POST FLOOD ANALYSIS

In June 2016, the Camden LGA experienced significant rainfall that resulted in flooding occurring within the Upper South Creek system. As part of the 2012 Flood Study for this system, a TUFLOW model was developed for the Upper South Creek region. Following the flood event, Council collected a series of flood marks from within the catchment, in order to be able to compare the actual flood levels to those predicted by the TUFLOW model.

This letter report details the process and findings of this comparison.

1. THE RAINFALL EVENT

The rainfall record was provided by the Bureau of Meteorology (BoM) at 30min intervals. A plot of 30min rainfall depths is shown in Figure 1 at the end of this letter report.

The plot shows that the rainfall event lasted approximately 2 days, with the peak rainfall occurring 5 hours into the storm event. Subsequent peaks occurred at 12 and 15 hours into the storm event.

Rainfall depths were calculated for periods ranging from 30 minutes to 3 days, which were used to calculate average intensities across these periods. A comparison of these intensities against the design IFD data from the BoM website was undertaken to determine the recurrence interval of the rainfall event. This data is summarised in Table 1.

The table shows that the recurrence period for the storm event ranged from less than the 1 year ARI for the 30 minute rainfall, up to approximately the 100 year ARI for the 12 and 24 hour periods.

The critical duration for the Upper South Creek catchment is 6 hours. For this duration, the rainfall intensity was in the order of a 20 to 50 year ARI event.

The recurrence interval of the flood observed within the study area as a result of this rainfall is discussed in Section 3.

Table 1 Assessment of Rainfall Intensities

Duration (hours)	Peak Rainfall Depth in Period (mm)	Peak Period Intensity (mm / hr)	Equivalent ARI (from BoM IFD tool)
0.5	14.6	29.2	<1
1	27.8	27.8	1yr - 2yr
2	52	26.0	5yr - 10yr
3	66.2	22.1	5yr - 10yr
6	105.6	17.6	20yr - 50yr
12	169	14.1	~ 100yr
24	251.2	10.5	~ 100yr
48	287.8	6.0	50yr - 100yr
72	289.6	4.0	20yr - 50yr

3. SURVEY COLLECTION

Council surveyors collected survey data of the peak flood levels in the days following the flood event. A total of seven points were surveyed within the Upper South Creek study area.

Six of these points had a high confidence level, as they were based on debris lines or flood marks on walls. The final point, surveyed at Bringelly Road, was inferred from areas of flattened grass and debris caught in tree branches. This creates a high level of uncertainty in the surveyed level. As such, this point was removed from the assessment.

The location of the six survey points used in the assessment are shown in Figure 2 at the end of this letter report.

2. TUFLOW MODEL

The TUFLOW model developed for the Upper South Creek study area was calibrated against three historical events, namely 1988, 1991 and 1992, as part of the Flood Study (WMA 2012). The TUFLOW model was then used to define the existing flood behaviour of the study area in the Flood Study, and to develop and assess mitigation options in the Floodplain Risk Management Study and Plan. The model was recently updated to incorporate “dam full” conditions in the regional farm dams. The dams had previously been modelled as partly empty, with model levels based on the dam levels during the ALS survey. The updated “dam full” model was used in this assessment.

The model was set up as a rainfall on grid model, with the rainfall applied directly to the terrain grid in the hydraulic model. The model was revised to incorporate the 2016 rainfall event and re-run.

No other changes were made to the TUFLOW model.

3. RESULTS & DISCUSSION

The peak depths from this model are shown in Figure 2 at the end of this letter report, along with a comparison against the surveyed levels.

The figure shows that the TUFLOW model matches the surveyed levels for the majority of the catchment. All locations are within 0.2m of the surveyed levels, and of these locations, five of the six are within 0.1m.

Shown in Figure 3 is a comparison of the peak flood levels between the 2016 event and the 20 year ARI design event.

The figure shows that the 2016 event is a close match to the 20 year ARI event, with four of the five locations showing levels within 0.1m of the 20 year ARI design levels. The last location at Heath Road had an observed difference of 0.13m.

Levels along tributaries and upstream flowpaths are slightly below the 20 year ARI levels. The levels along Upper South Creek however are higher in the 2016 model that the 20 year ARI event. Overall, the 2016 event is broadly equivalent to the 20 year ARI design even.

4. CONCLUSION

The TUFLOW model for Upper South Creek was revised to incorporate the 2016 event rainfall data and run for this event. Results were compared against post flood survey data collected by Council. The assessment found that:

- The rainfall intensity of the 2016 event was between a 20 year and 50 year ARI event for the 6 hour critical duration of the study area;
- The updated "dam full" TUFLOW model showed a good correlation with the surveyed flood levels at all of the locations, which validates the changes made to update the model to current catchment conditions;
- The observed flooding was comparable to a 20 year ARI design event.

Overall, the assessment showed that the TUFLOW model provided a good representation of the 2016 flood event, with a reasonable match between modelled and surveyed levels throughout the study area.

The results also suggest that data collection following a flood event should also look to inspect major controls, such as culverts and bridges, in order to determine the level of blockage present in the event. As shown at Bringelly Road, the level of blockage adopted can have a significant impact on the model results, and consequently, the level of correlation between the survey and model data.

Should you have any queries regarding this letter, please do not hesitate to contact me on 9496 7700.

Yours sincerely

L Evans

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Luke Evans
Environmental Engineer, Water Engineering
for Cardno

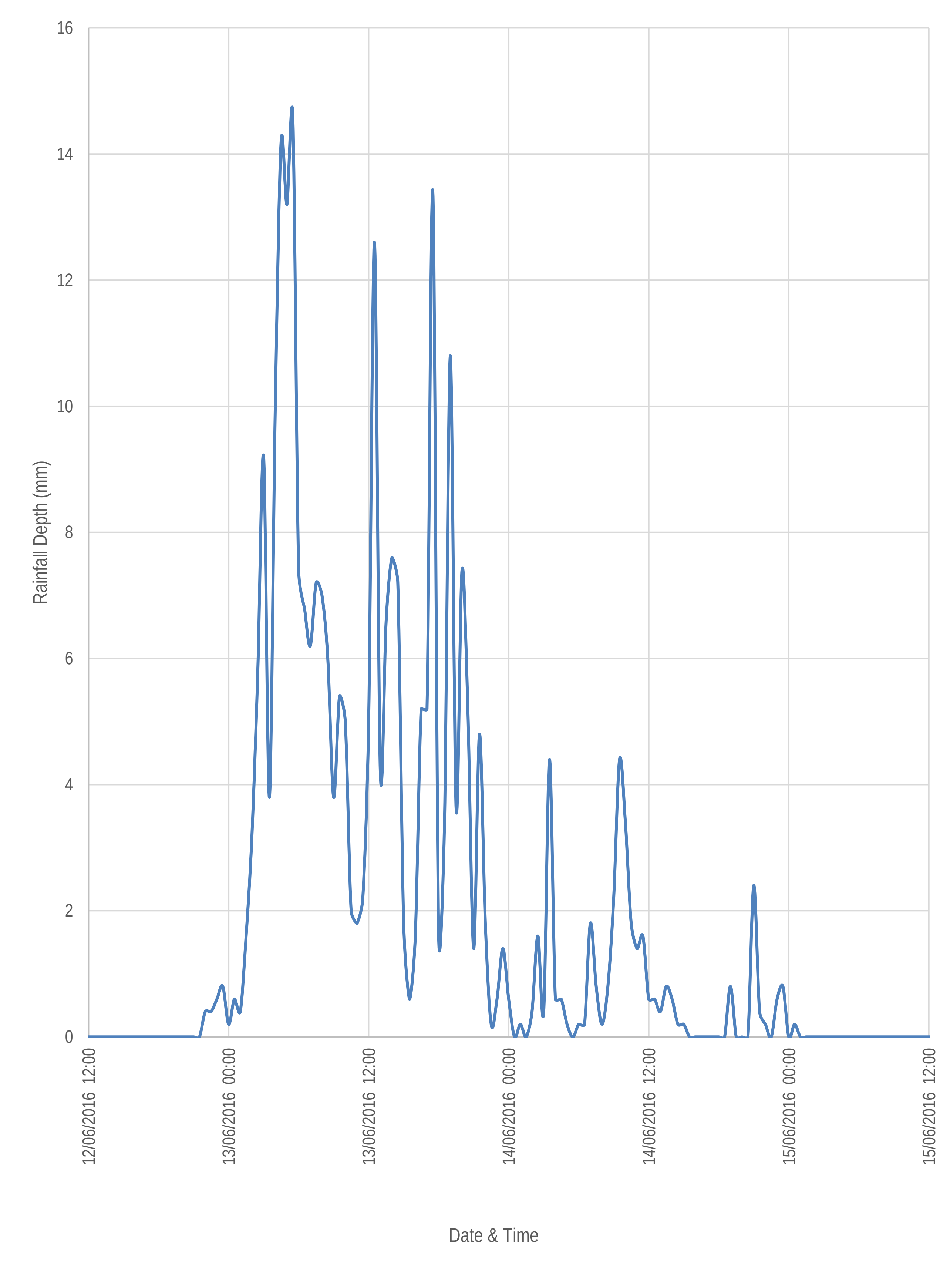


Figure 1 30 minute Rainfall Depths for 2016 Event

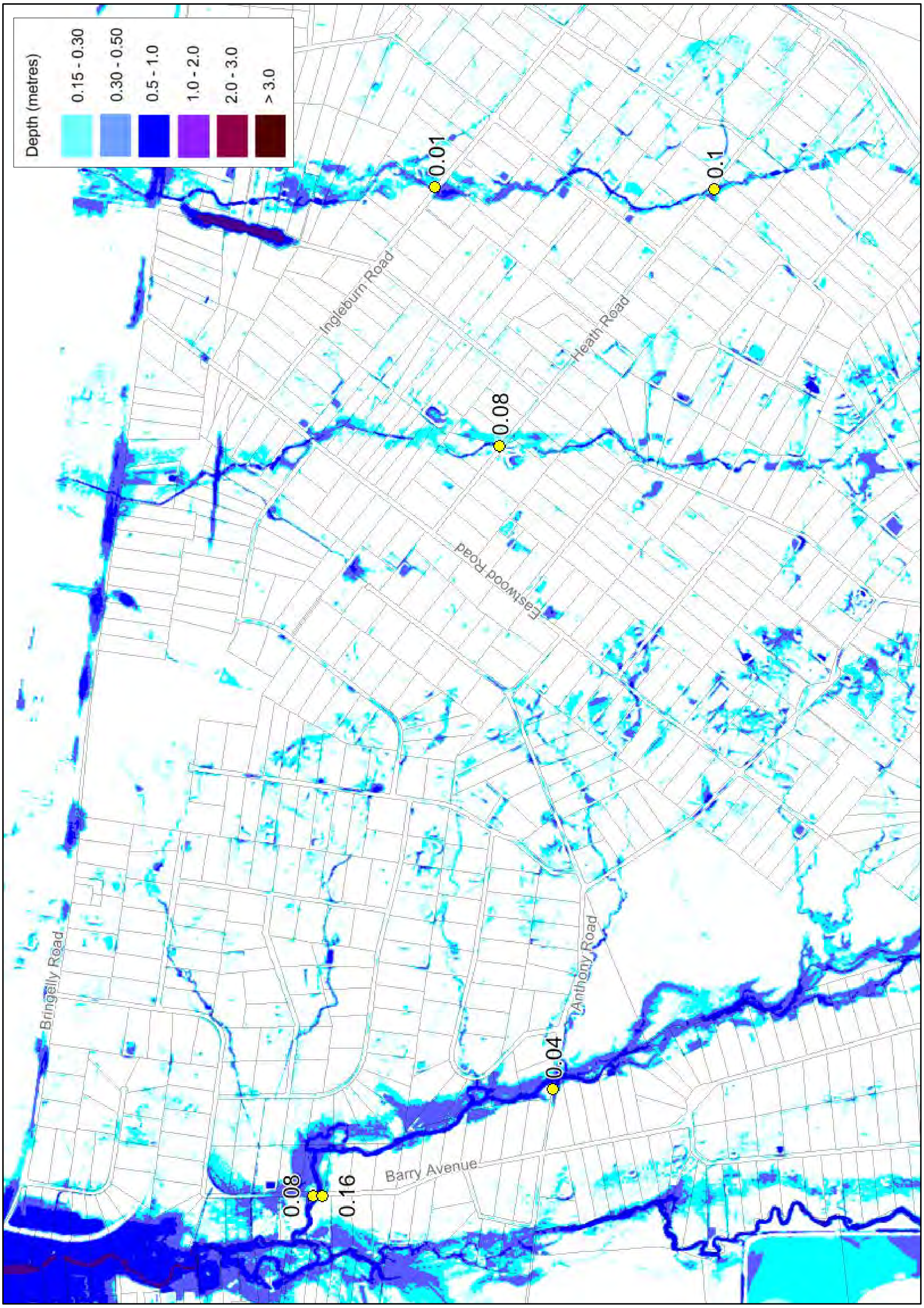


Figure 2 Peak 2016 Flood Depths, showing differences to surveyed levels (m)

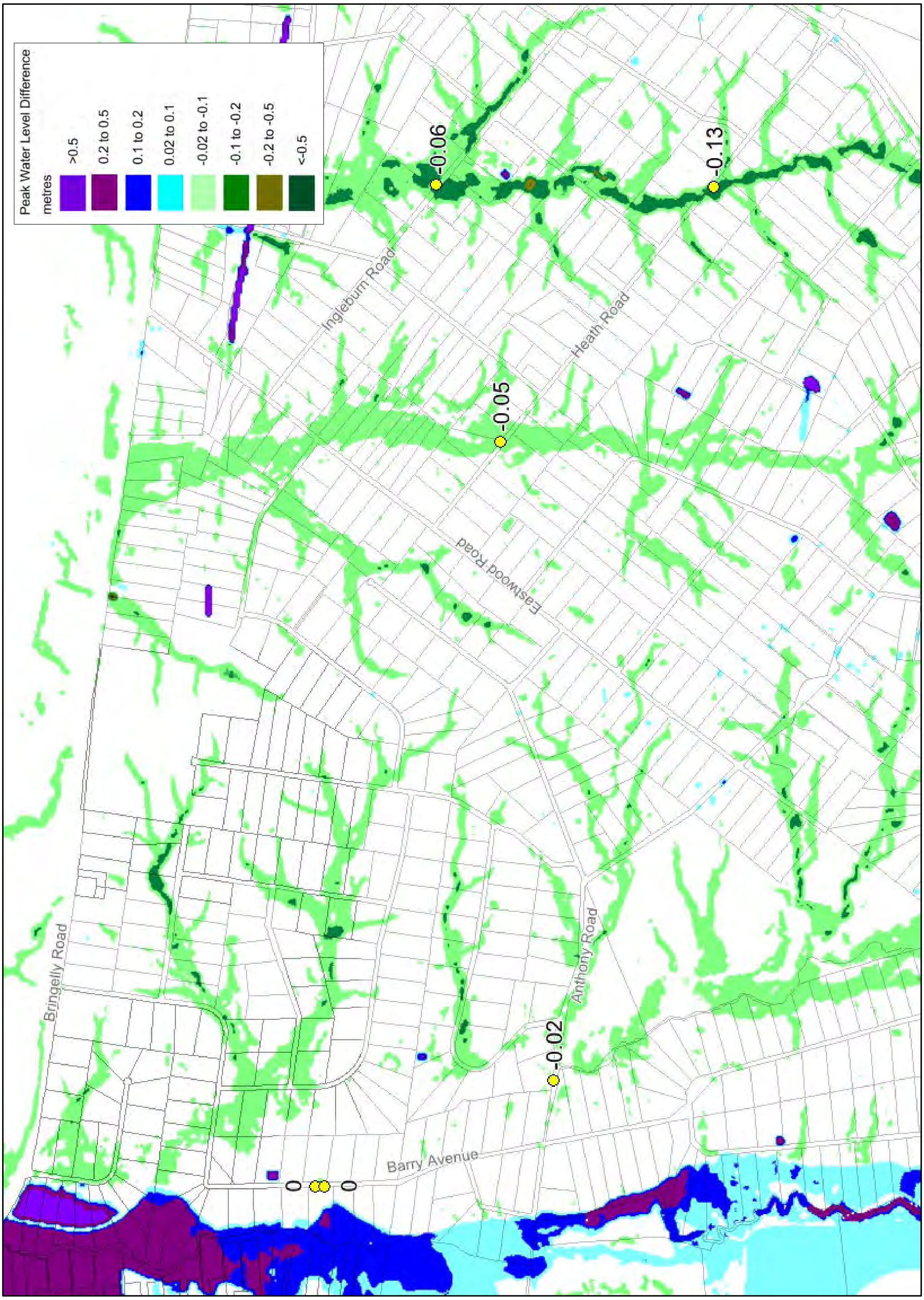


Figure 3 Difference between 2016 Event against 20 year ARI Design Event (m)

APPENDIX D
DEVELOPMENT CONTROLS

UPPER SOUTH CREEK – Development Controls

1 Land to which this Plan applies

This Plan applies to any development for which consent is required that is located on land affected by flooding (flood liable or flood prone land) within the Upper South Creek Catchment as illustrated on the map at Figure 1. Figure 2 is the Flood Risk Precinct Map for the Upper South Creek Area and defines High, Medium and Low Flood Risk Precincts as well as overland flow paths. This map(s) can be used to identify the flood risk precinct for individual properties within the Study Area.

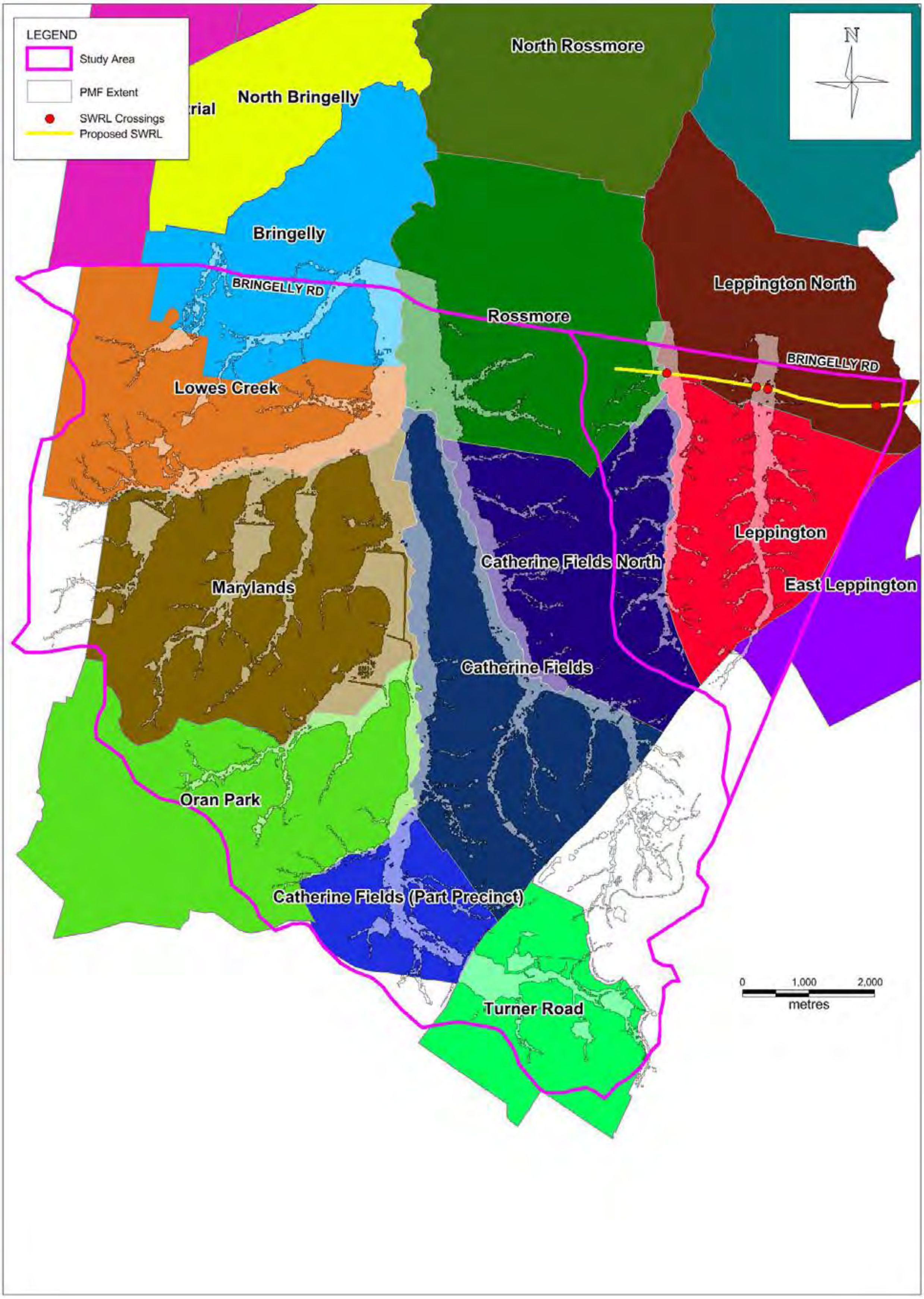


Figure 1 - Lands within the Upper South Creek Catchment

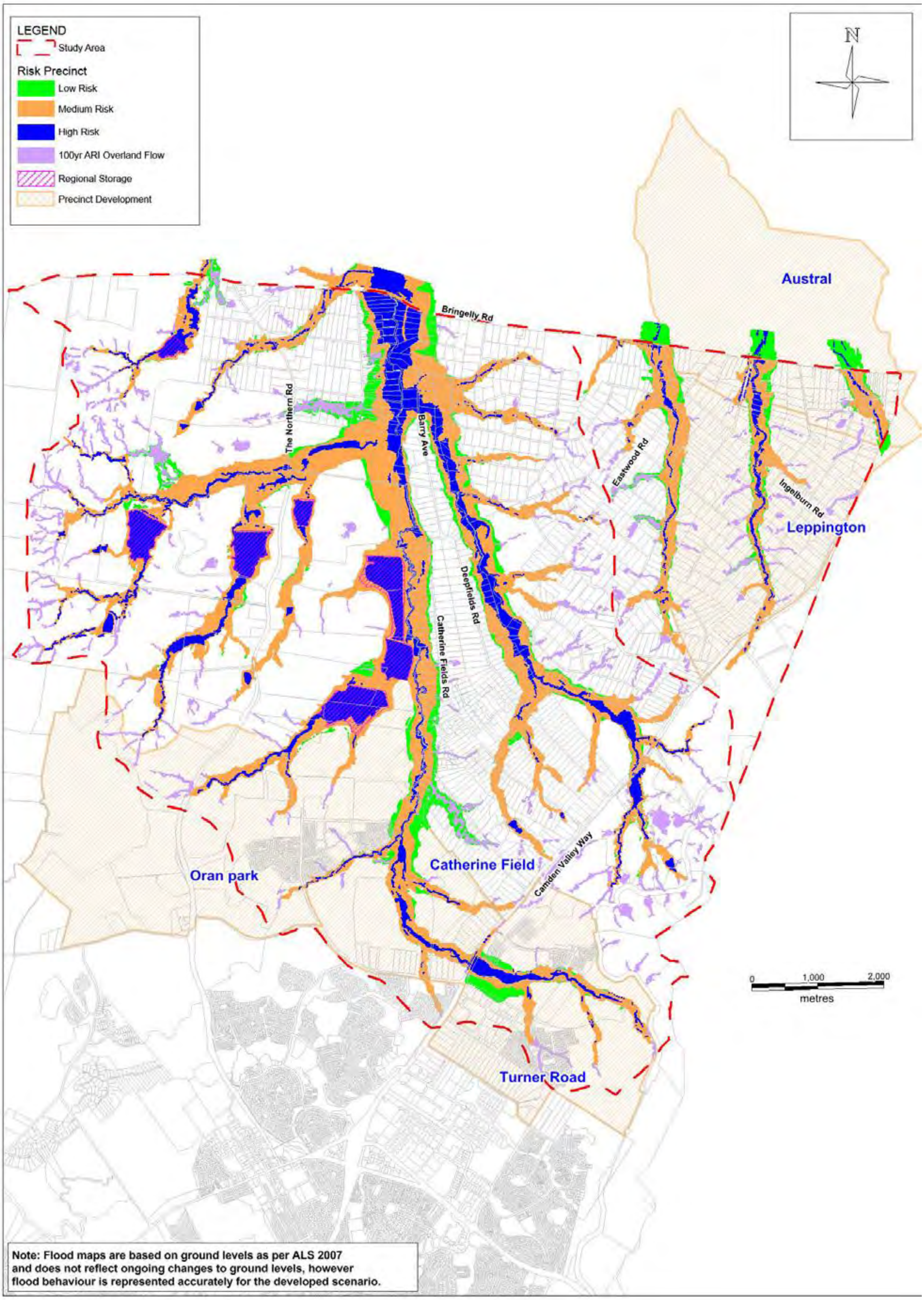


Figure 2 – FLOOD RISK PRECINCT MAP

2 Objectives of the Plan

The purpose of this Plan is to ensure development does not cause risk to life and property due to flooding in a manner consistent with the NSW Flood Policy and Floodplain manual and relevant local Council controls and guidelines. Specific objectives of the Plan are to:

- Provide a mechanism for the responsible control of development on flood prone land
- Ensure the safety of people and property from flood risk
- Provide detailed but user friendly controls for flood prone or flood liable lands for the preparation and assessment of development applications lodged under either the State Environmental Planning Policy *(Sydney Region Growth Centres) 2006* or Councils Local Environmental Plans.
- To ensure a sustainable and holistic catchment wide approach is taken to development on flood prone land within the upper south Creek Catchment

3 Land Use Categories

Different land uses carry with them a different level of potential risk from flooding. Consequently, land uses have been grouped into major land use categories based on their sensitivity to flood risks as follow:

Critical Infrastructure

Includes emergency services facilities such as Hospitals and administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events (e.g. SES Headquarters and Police Stations); Hospital.

Includes Camden LEP land zones SP2

Sensitive Uses and Facilities

Includes community facilities that would provide services to sensitive persons such as children and seniors which is essential to evacuation during periods of flood or if affected would unreasonably affect the ability of the community to return to normal activities after flood events. May include Seniors housing; Child Care Centre; Aged Care Centre; Schools; Liquid fuel depot; Public utility undertaking (including electricity generating works and utility installations).

Includes Camden LEP land use zones B1, B2, SP1

Land Subdivision

Refers to the subdivision of land for the purposes of urban development. This definition also pertains to the subdivision of land in Urban Release Areas where multiple land uses are proposed.

Includes all land use zones of the Camden LEP where relevant

Low Density Residential

Refers to the construction of dwellings for residential purposes on lots having a gross area no smaller than 450m^2 including rural-residential development and may include caravan park (approved long-term sites and/or "annuals"); exhibition home; home-based child care centre; home business; home industry; home occupancy; moveable dwelling; neighbourhood shop.

Includes LEP land use zone R1 and R2

Medium to High Density Residential

Refers to the construction of dwellings for residential purposes where a single dwelling is located on lots no greater than 450m^2. Includes detached, attached and multi-unit residential developments that include town houses, apartments, housing estates, villas and dense housing.

Includes Camden LEP land use zone R3

Commercial and Industrial

Refers to all commercial and industrial development, commercial additions and subdivision of land for commercial purposes. Tourist developments also fall within this category and will be given special consideration by Council given the potential risk.

Includes Camden LEP land use zone B4, B5, IN1 and IN2

Concessional Development

(a) In the case of commercial and residential (low-high density) development:

(i) an addition or alteration to an existing dwelling of not more than 10% or 50m^2 (whichever is the lesser) of the habitable floor area which existed at the date of commencement of this policy;

(ii) the construction of an outbuilding with a maximum floor area of 30m^2; or

(iii) rebuilt dwellings which substantially reduce the extent of flood affectation to the existing building.

(b) In the case of rural residential development:

(i) an addition to existing buildings of not more than additional 100m2 or 10% of the floor area which existed at the date of commencement of this Plan (whichever is the lesser);

(c) In the case of other development:

(i) rebuilding of a development which substantially reduces the extent of flood risks to the existing development;

(ii) a change of use which does not increase flood risk having regard to property damage and personal safety; or

(iii) subdivision that does not involve the creation of new allotments with potential for further development.

This is referenced in the LEP under exempt development or in general additions of residential development.

Rural & Recreation

Refers to primary production activities and large lot residential uses. Includes construction of farm sheds and non-habitable outbuildings, animal boarding establishment; agricultural facility; biosolid waste application; biosolids treatment facility; caravan park (with no approved long term sites and no “annuals”); environmental facility; environmental protection works; information facility; horticulture; environmental living; aquaculture; kiosk; landscape and garden supplies; bed and breakfast; recreation area; recreation facility; research station; water recreation structure; water recycling facility; water storage facility and flood mitigation works. General fill is also included where no change of land use is proposed.

Includes Camden LEP land use zone RU1, RU2, RU4, R5, RE1, RE2, E2 and E4

Recommendations to update for the LEP:

- *Update section 7.1 to refer to Council’s Flood Policy or relevant DCP for specific planning controls*
- *Change wording under section 7.1 clause 2 so that the flood planning requirements are applicable to the whole floodplain and not limited to the FPL*
- *Update Section 7.1 clause 5 to allow for alternative flood planning levels to the 1% AEP plus 600mm freeboard*
- *Remove uses such as child care centres and aged care facilities out of rural, residential and recreation land use and move to SP1 - Special Activities. This would eliminate the development of such uses in high to medium risk areas of the floodplain.*
- *Include general fill in land use zones RU1, RU2, RU4, R5, RE1, RE2, E2 and E4*
- *Ensure that complying or exempt development includes provisions for the ‘Concessional Development’ definition included above*

4 Terms

Freeboard means 500mm above the 1 in 100 year flood level for the Low to High Risk Precincts and 300mm for the Overland Flow Precinct where the flood depth in the 1% AEP is greater than 300mm

High Flood Risk Precinct "includes all floodways areas and all areas of the floodplain which would be provisionally high hazard in a 100 year flood (based on Figure L2 of the Floodplain Development Manual). In addition to including the 100 year provisionally high hazard areas in the high flood risk precinct, other parts of the floodplain are also included where:

(a) in a 100 year event, significant evacuation difficulties exist (e.g. islands surrounded by provisionally high hazard conditions);
(b) in floods rarer than a 100 year event, the potential for significant or extreme consequences exist which are not otherwise apparent from consideration of only the 100 year flood or more frequent flood events. Some events that may result in these consequences (depending on their scale) include catchment diversions, areas subject to overtopping of levees and embankments, areas subject to severe bank or bed erosion, or other conditions that can lead to unusually high depths, velocities or otherwise produce very dangerous flood conditions. Whilst the probabilities of these events might be low, the consequences can in some cases be extreme and thus produce a high risk.

Medium Flood Risk Precinct is the remaining area below the flood planning level FPL, not defined as the 'high' flood risk precinct. For reasons similar to those discussed above under (a) and (b), it is possible for some otherwise 'low' flood risk areas to be elevated to 'medium', when the flood conditions warrant it, though this is rarely required.

Low Flood Risk Precinct comprises all remaining areas of the floodplain above the flood planning level FPL to the limit of inundation in a but not identified as either a high flood risk or medium flood risk precinct, and where the risk of damages is low for most land uses.

Overland Flow Precinct means areas normally classified as 'low' provisional hazard under the Floodplain Development Manual and are located outside of the mainstream watercourses. The 1% AEP flood depth in this precinct is generally greater than 0.15m and no more than 0.5m.

Note that very shallow inundation may still occur in areas above the Overland Flow Precinct where depths would typically be less than 0.15m. These areas are not classified as either Overland Flow Precinct or a Flood Risk Precinct and would include areas referred to as 'Local Drainage' under the Floodplain Development Manual.

Flood Fringe refers to those areas of the floodplain where the depth of flooding is less than 200mm in the 1% AEP for single lots less than 10ha or where the depth of flooding is less than 300mm in the 1% AEP. Filling is only permitted of the flood fringe where flood modelling is conducted to demonstrate nil impact on flood behaviour. Filling of lots > 10 ha & all size multi lots is only permitted in the flood fringe where flood modelling is conducted to demonstrate nil impact on flood behaviour.

Farm Dam refers to above ground basins or informal storage facilities (detention bunds) located in the floodplain that temporarily, or permanently, store water.

Regional Storage is an existing feature of the floodplain that stores significant volumes of water and is shown in the flood risk precinct map.

5 Flood Risk Management Development Controls

5.1 The Development Control Matrix

The attached Development Control Matrix provides a correlation of the above land use categories, applicable controls and risk management measures to be followed in the preparation and assessment of development in the Catchment. The numbers in the matrix refer to those included in the Development Controls below.

5.2 Development controls

5.2.1 Floor Levels

1 = Flood Planning Level (FPL) for habitable floor levels is the 1% AEP flood level plus freeboard

2 = FPL for non-habitable floor levels is the 1% AEP flood level with no freeboard

3 = FPL for sensitive uses is the PMF flood level with no freeboard

4 = Where garages, sheds and minor additions are proposed floor levels lower than the above FPLs may be considered in cases that comply with the definitions of concessional development. The highest practical floor level is to be designed in all cases except in the case of minor additions where the existing floor level is to be maintained at a minimum.

5.2.2 Building Components

1 = Any part of a building, services, foundations and/or sub-structure located below the applicable FPL is to be constructed of flood compatible materials.

2 = Parts of a structure/building and its services, foundations and/or sub-structure are to be constructed of flood compatible materials below the 1% AEP flood level.

3 = All parts of a sensitive uses building are to be constructed of flood compatible materials below the level of the PMF.

5.2.3 Structural Soundness

1 = Structural engineering report is to be provided to ensure the structures can withstand floodwater forces including debris and buoyancy up to the 1% AEP plus freeboard or the PMF where a flood refuge or evacuation access is proposed.

2 = Applicant to demonstrate that the structure can withstand floodwater forces including debris and buoyancy up to the 1% AEP plus freeboard. An Engineers Report may be required.

3 = Applicant to demonstrate that the structure can withstand floodwater forces including debris and buoyancy up to the PMF. An Engineers Report may be required.

5.2.4 Flood Affectation

1 = Engineering report required to certify that development will not increase flood affectation elsewhere, having regard to a) loss of flood storage, b) changes in flood levels, flows and velocities upstream, downstream and adjacent to the site, c) cumulative impact of multiple development in the vicinity, d) negligible impact to flood hazard. Report to be prepared using a 2D floodplain model and user guide to be provided by Council where precinct developments are proposed or where sub-divisions increase the intensity of land use in the floodplain.

2 = Floodplain filling is only permissible on the floodplain fringe. Filling of lots > 10 ha & all size multi lots is only permitted in the flood fringe where flood modelling is conducted to demonstrate nil impact on flood behaviour.

3 = Requirements for Urban Stormwater Detention (USD) are to be prepared in accordance with the USD guidelines for Upper South Creek for developments of all sizes.

4 = The flood impact of the development is to be considered having regard to a) loss of flood storage, b) changes in flood levels, flows and velocities upstream, downstream and adjacent to the site, c) cumulative impact of multiple development in the vicinity, d) negligible impact to flood hazard as a result of development.

5 = Removal of Regional Storages and Farm Dams is only permitted where compensatory storage is provided elsewhere and does not cause adverse flood impact off-site. Demonstration of nil impact to flood level, flood velocity and redirection of flow is required by flood modelling for single lots greater than 10 hectares or where multiple single lot developments of all sizes are proposed.

5.2.5 Emergency Management

1 = Appropriate methods of reaching safety from flood waters during the PMF are to be demonstrated for habitable buildings with reference to the emergency management strategy of the wider Upper South Creek Floodplain Risk Management Study and Plan. An Engineer's report may be required.

2 = Engineer's report is to be provided demonstrating that permanent, failsafe, maintenance free measures are incorporated into the development so the occupants can either take refuge or evacuate from floodwaters in the case of events up to the PMF. A report is to be prepared by a suitably qualified Engineer/Hydrologist having regard to safe warning time, rate of rise and safe velocity and depth thresholds for evacuation by pedestrians and vehicles where evacuation is proposed.

3 = A Flood Emergency Management Response Plan (FERP) is to be developed by the business director/manager, in conjunction with the Council and the SES, with adequate documentation (signs) of the plan to be displayed around the premises. FERP is to be updated every 2 years.

4 = If the property is affected by the 1% AEP flood level then reliable access to a flood free refuge is to be provided for pedestrians and vehicles.

5.2.6 Car Parking

1 = Where basement car parking is proposed the entry level is to be the 1% AEP plus freeboard. If the level of the PMF is higher than the proposed entry level then a FREP is to be provided to manage flood risk in the carpark.

2 = Above ground car parks and garages are to be at a minimum level of 150mm below the 1% AEP flood level.

3 =Above ground car parking including carports are to be at the highest level practical and not more than 300mm below the 1% AEP flood level. Enclosed garages are to be at the highest level practical and not more than 500mm below the 1% AEP.

5.2.7 Management and Design

1 = Provision of adequate emergency response information and advice to residents, employees, attendants, guests and /or visitors

2 = Applicant to demonstrate that potential development as a consequence of the subdivision can be undertaken in accordance with Council's Flood Risk Management Policy

3 = Applicant to demonstrate that storage is available for goods above the 1% AEP plus freeboard

4 = Applicant to demonstrate that storage is available for goods above the level of the PMF

Urban Stormwater Detention (USD) Guidelines

Urban Development changes the hydrologic behaviour of the land to which it applies and can follow onto imposing adverse impact to existing Flood Behaviour. The Upper South Creek study area is located in the headwaters of South Creek and changes in hydrology could lead to flood affectation to downstream properties. It is therefore important to carefully plan and design stormwater management systems, including On-Site Detention systems, detention basins and regional storage to ensure that adequate storage and retardation of urban stormwater is provided to replicate, as far as possible, the existing hydrology. These guidelines have been provided as a general guide for urban development to assist in the preparation of Water Cycle Management plans and detention concept designs.

Objectives of guidelines

> To encourage an integrated approach to water cycle management to replicate, as far as possible, existing hydrology so that there is minimal impact on flood behaviour and stability of waterways
> To outline a set of parameters that guide urban development for an upper and lower limit so hydrology is replicated with reference to conditions of 2013. The upper limit aims to mitigate the effect of urban development on flooding whilst the lower limit aims to mitigate waterway stability impacts.
> Replication of hydrology is to be achieved through design of storage coupled with hydraulic controls to limit peak flows and overall discharge volume in the developed condition back to reference condition levels.
> To allow for urban developments to fill and reconfigure existing farm dams and regional storages providing that the floodplain storage benefits of the reference condition are maintained.

Guiding principles/documents

Applicants are required to refer to the following documents when preparing Development or Project Applications:

- *South West Growth Centres DCP 2012*
- *Camden Council Engineering Design Specification* (2009)
- *Camden Council DCP 2011 – Environmental Management*
- Camden Council's *Building in Saline Prone Environments Policy*
- Camden Council's *Flood Policy*
- *Upper South Creek Floodplain Development Matrix*

USD Requirements

(1) The maximum post-development discharge from the site shall not exceed the pre-development flows for the 50% AEP (lower) and 1% AEP (upper) for the critical duration storm duration under the pre development condition. The critical duration is to be determined through an examination of a full range of design storms durations;

(2) The stormwater drainage system (including surface grades, gutters, pipes, surface drains and overland flowpaths) for the property must:

- Be able to collect and convey all site runoff to the USD system in a 1% AEP event in the post-development critical duration storm; and
- Ensure that the all runoff from any upstream properties bypasses the USD storage in all storms up to and including the 1% AEP event.

The required USD storage can be achieved through either below ground or above ground storage or a combination of both and ideally should be integrated with other WSUD measures where possible. Any above ground storage is to be designed in such a manner that public safety and the integrity of property is not compromised and it does not interfere with overland flowpaths or adversely affect flood behavior.

(3) The required upper and lower limits for sizing the USD shall be informed by the following generic parameters:

Urban Stormwater Detention SSR and PSD Sizing Limits

Land Use	50% AEP SSR (m^3/ha)	50% AEP PSD (l/s/ha)	1% AEP SSR (m^3/ha)	1% AEP PSD (l/s/ha)
Residential	190	55	320	145
Commercial/Industrial	210	55	380	145

(4) All stormwater must drain by gravity to an approved drainage system. Discharge by use of mechanical pump system, or pressurised lines, is not allowed.

APPENDIX A

XP_RAFTS Modeling Methodology

Cardno have used the XP_RAFTS models prepared by BROWNS consulting as part of their precinct planning in Oran Park and Catherine Fields (Part Precinct) for the estimation of suitable USD parameters. These precincts are considered to be representative of conditions across the study area and the investigations aimed at selecting three sub areas within the two precincts in order to increase confidence that the result would be applicable.

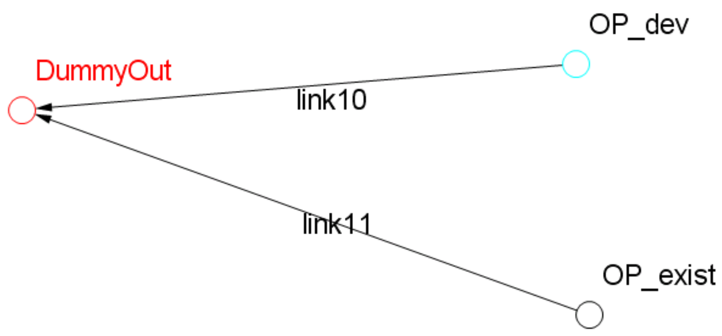
The following models were used to undertake the assessment:

1. Catherine Fields (Part Precinct) pre-development condition model: *X11286 Existing V2.xp*
2. Catherine Fields (Part Precinct) developed condition model: *X11286 Developed V2-1*
3. Oran Park developed condition model: *Proposed_with TownCenter_OSD_ Mar07.xp*

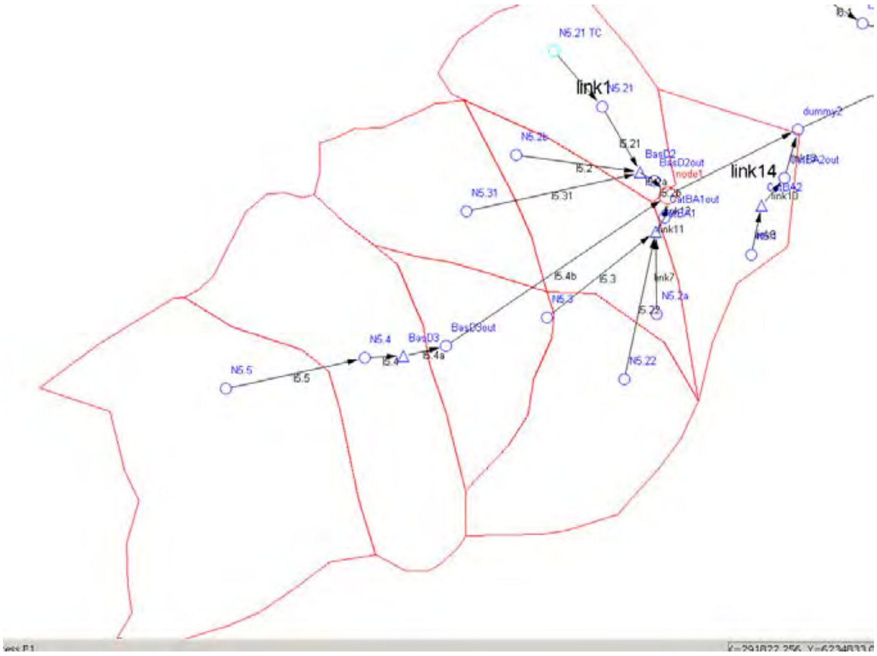
The above models included a combination of OSD tanks for the Oran Park town centre and retarding basins for replication of pre-development hydrology. The tanks and basins performed sufficiently to satisfy the requirement to reduce post development flow to pre development levels. Therefore it is considered that the xp rafts models are a sound basis for estimation of site storage requirements (SSR) and permissible site discharge (PSD) for Upper South Creek.

The general approach used was to initially add up the average storage and discharge control requirements of the retarding basins included in the BROWNS rafts models. Thereafter a basis for application of generic OSD parameters could be applied through the use of the OSD tool within the rafts software. The OSD tool allows the user to rapidly assess a post development scenario through inclusion of primary and secondary SSR and PSD parameters without the need to explicitly size and configure a basin. Three locations where chosen for the modelling and are described in the table below:

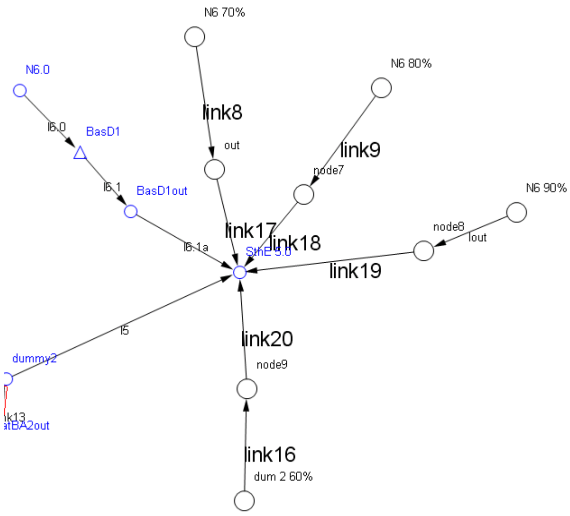
Location	Catchment Area (ha)	Description
1	640.7	The eastern segment of the Oran Park Precinct that drains to South Creek. The precinct drains to South Creek via three sub-catchments that includes two tributaries and an area draining directly to the creek. For simplicity the three sub-catchments were lumped together to get an understanding of the performance of the OSD tool on a precinct scale.
2	148	A catchment that includes a tributary delineating the boundary between the Oran Park and Catherine Fields Precincts. The structure of the rafts model included several sub-catchments draining to the tributary each with an offline retarding basin.
3	35	This location represents sub-catchment N6 of Oran Park and includes an offline retarding basin. A number of different impervious percentages were trialled for this area to gain an understanding of sensitivity for the SSR and PSD values estimated.



Location 1: Oran Park Precinct (Eastern)



Location 2: Tributary to South Creek delineating Oran Park/Catherine Fields boundary



Location 3: Subcatchment N6 of Oran Park with numerous impervious fractions

The BROWNS rafts models included retarding basins having a stage storage relationship for a retarding basin having a total depth of 1.5m and a depth to the spillway of 1m. Commonly a lower level culvert outlet and vertical slot spillway were included as the discharge controls. No stage discharge relationships were used. As a first pass of the modelling the BROWNS rafts models were run and the results for the total storage volume and peak discharge were recorded. The total storage and peak discharge were then converted into preliminary SSR and PSD values with reference to the catchment area. Then the OSD tool of the rafts model was used with the preliminary SSR and PSD values. Usually the results showed that the post development flow exceeded the predevelopment peak and the SSR values needed to be increased. In general it was the SSR that the results were most sensitive too, however in some cases increasing the PSD assisted in replication of the pre development flow rates.

Results

The results for each case are shown in the following tables. It is generally the case that the modelling of retarding basins requires slightly lower SSR and PSD parameters than in the case of the OSD tool. This is a result of the default assumption of the OSD tool where 80% of the catchment is assumed to be captured by the storage, whilst the remaining 20% is routed elsewhere. This is not the case for the BROWNS models that include retarding basins because there is a specific drainage strategy that accepts 100% of the catchment. Hence the slightly higher parameters estimated with the OSD tool are expected and compensate for the use of OSD parameters where parts of an urban development (such as roads) cannot be drained to the storage.

The parameters estimated through this methodology are intended for use in the Upper South Creek study area and would eventually be applied on both a small and large scale. Hence it is prudent to adopt parameters that would achieve a reasonable outcome considering the variety of catchments that would be planned in future. This leads to the selection of the parameters for Case 1 as having a higher importance than other cases due to its size. Adequately retarding development flows back to pre development levels would be of more importance to resulting flood behaviour than for smaller catchments such as cases 3 to 5. It is noted that the results for case 2 are lower than for case 1. This is most likely a result of the breakdown of sub-catchments for case 2 causing retardation naturally by lag times in the links of the model. Case 1 has the entire catchment area lumped into a single node that would not represent lagging in tributaries/overland flowpaths, however roughness was increased and slope was decreased in an effort to represent lagging.

The recommended SSR and PSD parameters for Upper South Creek are the weighted values highlighted in yellow. These results are in the ball park of values estimated by the UPRCT OSD guideline for subcatchments having a size of 100-200ha according to the sliding scale for catchment size.

	catchment area (ha)	Imp (%)	Parameters	Lower (OSD)	Lower (Basin)	Upper (OSD)	Upper (Basin)	Weighting
			SSR (m3/ha)	200	175	330	210	0.5
Case 1	640.7	67	PSD (l/s/ha)	50	45	130	115	0.5
			SSR	150	94	260	191	0.20
Case 2	148	61	PSD	60	55	160	158	0.20
			SSR	200	153	320	288	0.10
Case 3	35	71	PSD	60	54	160	140	0.10
			SSR	200	169	350	323	0.10
Case 4	35	80	PSD	60	54	160	140	0.10
			SSR	210	194	380	367	0.10
Case 5	35	90	PSD	60	54	160	140	0.10
			SSR	192	157	328	276	
Average			PSD	58	53	154	139	
				191		**322**		
Weighted				**55**		**145**		
			SSR	210		360		
UPRCT	100-200	100	PSD	40		150		

(Basin) = modelling results using retarding basins

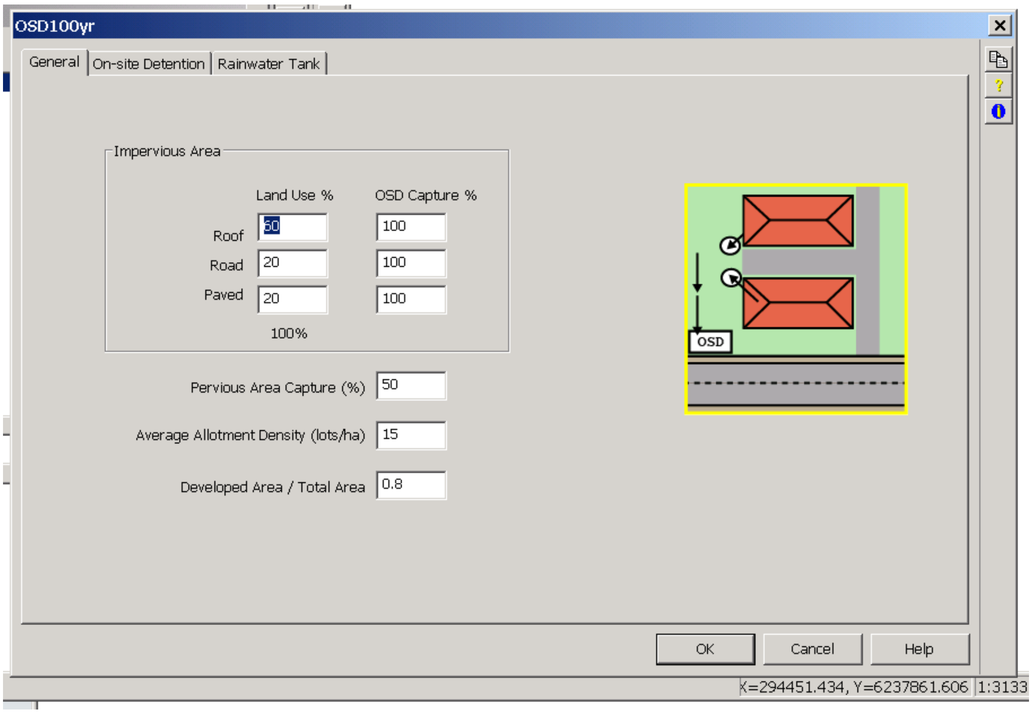
(OSD) = modelling results using the OSD tool of XP_RAFTS

	ARI	Existing Flow	Developed Flow	Developed with Basin	Developed with OSD
	2yr 9hr	23	36	-	21.7
Case 1	100yr 2hr	74	115.5	-	72
	2yr 9hr	8.2	9.4	8.4	6.5
Case 2	100yr 2hr	23.4	36.2	24.9	23.5
	2yr 9hr	1.9	2.5	1.8	1.7
Case 3	100yr 2hr	4.9	12.9	4.7	4.9
	2yr 9hr	1.9	2.5	1.8	1.7
Case 4	100yr 2hr	4.9	12.9	4.9	4.9
	2yr 9hr	1.9	2.5	1.8	1.7
Case 5	100yr2hr	4.9	12.9	4.9	4.8

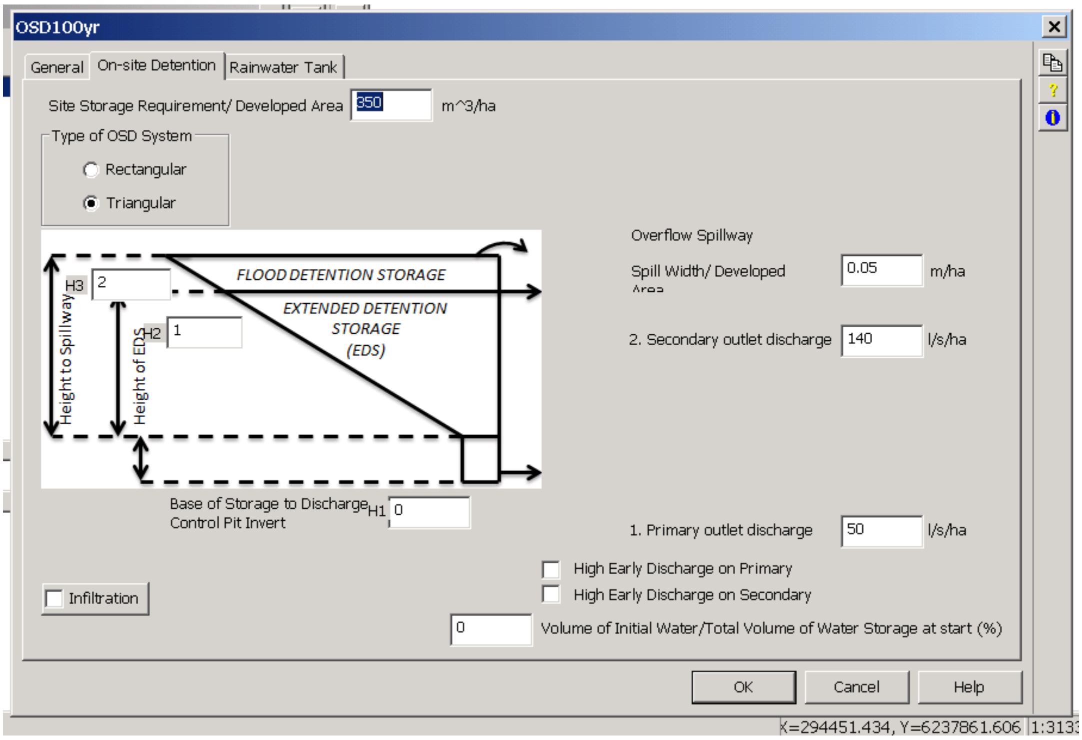
**results could not be reported for Case 1 Developed with Basin because the precent drains to south creek in a number of locations and it is not practical to extract flows from a number of locations for comparison purposes*

OSD Tool description

A basic explanation of the modelling approach with the OSD tool in included below:



- For larger catchments >50ha it is assumed that the retarding basins would be offline and as such the riparian area of the precinct would not be collected by drained to the basin. For catchments <50ha the pervious area capture was assumed to be 80%.
- The breaksdown of the roof, road and paved surfaces is consistent with default values and doesn't make much difference when it is assumed that there is 100% capture of these surfaces.
- No allowance has been made for use of air space in a rainwater tank for OSD.
- The developed area assumption stems from the case where the only 80% of a precinct is developable due to constraints such as flooding/riparian/significant vegetation/utility easements.



- The triangular setup of the basin replicates a large dry basin with earth embankments.
- The primary outlet was initially sized using the 50% AEP design storm. The seconday outlet discharge was then sized using the 1% AEP design storm.
- The primary outlet is located at the base of the basin, the sencandary outlet is located 1m above the basin base and the total depth of the basin is 2m.
- The spillway activates once the storage capacity of the basin has been exceeded, i.e. above the 2m depth, and flow would increase in depth over a fixed width. I have sized the storage requirement so that minimal amount of spill occurs. The width of the spillway is critical in controlling the flow rate that is allowed to be released as spill.
- High early discharges were trialled however they seemed to produce anomolous results.

Flood Risk Precincts

1 - Low Flood Risk

	Critical Infrastructure	Sensitive Uses and Facilities	Land Subdivision	Low Density Residential	Medium to High Density Res.	Commercial and Industrial	Concessional Development	Rural & Recreation
Floor Level		3						
Building Components		3						
Structural Soundness		3						
Flood Affectation		4	1			4	4	4
Emergency Management		1	1,2			1,3	1	1,3
Car Parking		1				1	1	1
Management & Design		1,4				1,3	1	1

2 - Medium Flood Risk

	Critical Infrastructure	Sensitive Uses and Facilities	Land Subdivision	Low Density Residential	Medium to High Density Res.	Commercial and Industrial Uses	Concessional Development	Rural & Recreation
Floor Level				1,2	1,2	1,2	1, 4	1,2
Building Components				1	1	1	2	2
Structural Soundness				2	1	1	2	2
Flood Affectation			1,2, 3,5	2,3, 4,5	1,2, 3,5	1,2, 3,5	2,4	2,3, 4,5
Emergency Management			2,4	1,4	2,4	2,3	1,4	1,4
Car Parking				2	1,2	1,2	1,3	1,2
Management & Design			2		1	1,3	1	1

3 - High Flood Risk

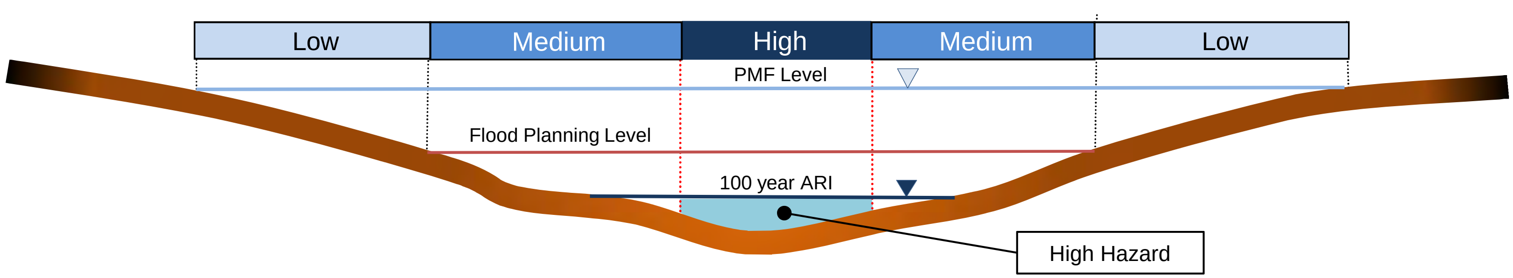
	Critical Infrastructure and Facilitie	Sensitive Uses and Facilities	Land Subdivision	Low Density Residential	Medium to High Density Residential	Commercial and Industrial Uses	Concessional Development	Rural & Recreation
Floor Level								1,2
Building Components								2
Structural Soundness								1
Flood Affectation								1,3, 5
Emergency Management								1,4
Car Parking								1,2
Management & Design								1

Overland Flow

	Critical Infrastructure and Facilitie	Sensitive Uses and Facilities	Land Subdivision	Low Density Residential	Medium to High Density Residential	Commercial and Industrial Uses	Concessional Development	Rural & Recreation
Floor Level				1,2	1,2	1,2	4	1,2
Building Components				1	1	1	2	2
Structural Soundness				2	1	1	2	2
Flood Affectation			1,2, 3,5	2,3, 4,5	1,2, 3,5	1,2, 3,5	2,4	2,3, 4,5
Emergency Management			1	1,4	2,4	2,3,4	1,4	1,4
Car Parking				2	1,2	1,2	1,3	1,2
Management & Design			2		1	1,3	1	1

Colour Legend

- Unsuitable land use- requires performance based assessment
- No Controls
- 1,2 Flood related controls apply



Flood Risk Precincts

APPENDIX E
COST ESTIMATION OF OPTIONS

Cardno®
Shaping the Future

ID	Option	Capital Cost	Ongoing Costs
FM1	Raise Masterfield Street Levee	669,300	6,000
FM2	Drainage Improvement on Rossmore Crescent	2,138,700	6,375
FM3	Increase Rileys Creek Capacity	8,800,400	6500
FM4	Creek Revegetation for South Creek	1,056,600	19000
FM5	Debris Control Structure at South Creek	606,000	5,000
FM7	Increase Regional Storage at Rileys Creek	3,646,100	10,000
FM8	New Regional Storage at Scalibrini Creek	18,517,400	15,000
FM9	New Regional Storage at Kemps Creek	27,355,700	20,000

Note: Maintenance costs taken as	
10,000	per basin
500	per 100m open channel
5,000	per culvert
750	per 100m pipe
250	per 100m levee
5,000	per debris blockage structure
200	per 100m revegetated creek

W4963 - UPPER SOUTH CREEK FRMS&P

FM1 - Raise Masterfield Street Levee
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**197,700**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	9,250	sq. m	10	92,500
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	1387.5	cu. m	20	27,750
2.3	Dispose of excess topsoil (nominal 10% allowance)	138.75	cu. m	50	6,938
	SUBTOTAL				**127,188**
3.0	**EARTHWORKS**				
3.1	Minor Earthworks - regrade to suit new design levels, including disposal / provision of excess cut / fill	1850	cu. m	75	138,750
	SUBTOTAL				**138,750**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for culverts	400	lin.m	2250	900,000
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for pipe network	103	lin.m	1000	103,000
4.3	Install new drainage / junction pit	4	each	4000	16,000
4.4	Install new oulet structure, including erosion protection and flood flap	1	each	10000	10,000
	SUBTOTAL				**1,029,000**
5.0	**MINOR LANDSCAPING**				
5.1	Hydro seed grass batters and repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	9,250	sq. m	2.5	23,125
	SUBTOTAL				**23,125**
	CONSTRUCTION SUB-TOTAL				**486,763**
6.0	**CONTINGENCIES**				
6.1	25% construction cost				**121,691**
	CONSTRUCTION TOTAL, excluding GST				**608,453**
	GST				**60,845**
	CONSTRUCTION TOTAL, including GST				**669,298**
	CONSTRUCTION TOTAL, rounded				**669,300**

DISCLAIMER:

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NOTES:

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2. Estimate / rates in 2013 dollars and does not allow for inflation

W4963 - UPPER SOUTH CREEK FRMS&P

Opt: FM2 - Drainage Improvement on Rossmore Crescent
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**126,700**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of vegatated areas (nominal allowance)	10,500	sq. m	7.5	78,750
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	1575	cu. m	25	39,375
2.3	Dispose of excess topsoil (nominal 10% allowance)	157.5	cu. m	60	9,450
2.4	Pull up and dispose existing road surface	200	sq.m	35	7,000
	SUBTOTAL				**134,575**
3.0	**EARTHWORKS**				
3.1	Excavation of channel in sand/clay	7,500	cu.m	30	225,000
3.2	Disposal of excess cut (assuming 30% of total excavation)	2,250	item	60	135,000
	SUBTOTAL				**360,000**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill concrete slot outlet	40	lin.m	2250	90,000
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for pipe network	350	lin.m	1000	350,000
4.3	Install new drainage / junction pit	3	each	4000	12,000
4.4	Install new oulet structure, including erosion protection as required	2	each	6000	12,000
	SUBTOTAL				**464,000**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	300	sq. m	120	36,000
	SUBTOTAL				**36,000**
6.0	**REHABILITATION WORKS**				
6.1	Stabilise new bank as required (nominal allowance)	10,500	sq.m	10	105,000
6.2	Reinstate topsoil	1575	cu.m	20	31,500
6.3	Reinstate / construct obstructions - rocks, logs, etc	420	item	30	12,600
6.4	Plant native species along bank and surrounds (bushes, shrubs, trees, etc)	7500	sq.m	10	75,000
	SUBTOTAL				**224,100**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	10,500	sq. m	20	210,000
	SUBTOTAL				**210,000**
	CONSTRUCTION SUB-TOTAL				**1,555,375**
8.0	**CONTINGENCIES**				
8.1	25% construction cost				**388,844**
	CONSTRUCTION TOTAL, excluding GST				**1,944,219**
	GST				**194,422**
	CONSTRUCTION TOTAL, including GST				**2,138,641**
	CONSTRUCTION TOTAL, rounded				**2,138,700**

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W4963 - UPPER SOUTH CREEK FRMS&P

Cardno
Shaping the Future

FM3 - Increase Rileys Creek Capacity
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**834,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	42,380	sq. m	10	423,800
2.2	Removal of dense vegetation / trees (nominal allowance)	2,000	item	25	50,000
2.3	Strip topsoil & stockpile for re-use (assuming 150mm depth)	6357	cu. m	20	127,140
2.4	Dispose of excess topsoil (nominal 10% allowance)	635.7	cu. m	50	31,785
	SUBTOTAL				**632,725**
3.0	**EARTHWORKS**				
3.1	Excavation of channel in sand/clay	66,830	cu.m	30	2,004,900
3.2	Disposal of excess cut (assuming 20% of total excavation)	13,366	item	60	801,960
	SUBTOTAL				**2,806,860**
4.0	**REHABILITATION WORKS**				
4.1	Stabilise new bank as required (nominal allowance)	42,380	sq.m	7.5	317,850
4.2	Reinstate topsoil	6357	cu.m	20	127,140
4.3	Reinstate / construct obstructions - rocks, logs, etc	1695.2	item	30	50,856
4.4	Plant native species along banks (reeds, grasses, trees, etc)	32,600	sq.m	10	326,000
	SUBTOTAL				**821,846**
5.0	**MINOR LANDSCAPING**				
5.1	Minor works to repair disturbed areas	130400	sq. m	10	1,304,000
	SUBTOTAL				**1,304,000**
	CONSTRUCTION SUB-TOTAL				**6,400,231**
6.0	**CONTINGENCIES**				
6.1	25% construction cost				**1,600,058**
	CONSTRUCTION TOTAL, excluding GST				**8,000,289**
	GST				**800,029**
	CONSTRUCTION TOTAL, including GST				**8,800,318**
	CONSTRUCTION TOTAL, rounded				**8,800,400**

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W4963 - UPPER SOUTH CREEK FRMS&P

FM4 - Creek Revegetation for South Creek
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	0	item		
1.3	Construction setout & survey	0	item		
1.4	Work as executed survey & documentation	0	item		
1.5	Geotechnical supervision, testing & certification	0	item		
	SUBTOTAL				**7,600**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing		sq. m	10	0
2.2	Removal of dense vegetation / trees (nominal allowance)		item	25	0
2.3	Strip topsoil & stockpile for re-use (assuming 150mm depth)		cu. m	20	0
2.4	Dispose of excess topsoil (nominal 10% allowance)		cu. m	50	0
	SUBTOTAL				**0**
3.0	**REHABILITATION WORKS**				
3.1	Stabilise new bank as required (nominal allowance)	0	sq.m	10	0
3.2	Reinstate topsoil	0	cu.m	20	0
3.3	Reinstate / construct obstructions - rocks, logs, etc	0	item	30	0
3.4	Plant native species along banks (1 per 9m2)	190200	sq.m	1.5	285,300
	SUBTOTAL				**285,300**
4.0	**MINOR LANDSCAPING**				
4.1	Establish plants (replacements, watering and weeding)	190200	sq. m	2.5	475,500
	SUBTOTAL				**475,500**
	CONSTRUCTION SUB-TOTAL				**768,400**
5.0	**CONTINGENCIES**				
5.1	25% construction cost				**192,100**
	CONSTRUCTION TOTAL, excluding GST				**960,500**
	GST				**96,050**
	CONSTRUCTION TOTAL, including GST				**1,056,550**
	CONSTRUCTION TOTAL, rounded				**1,056,600**

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W4963 - UPPER SOUTH CREEK FRMS&P

FM5 - Debris Control Structure at South Creek
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**57,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	286	sq. m	10	2,860
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	42.9	cu. m	20	858
2.3	Dispose of excess topsoil (nominal 10% allowance)	4.29	cu. m	50	215
	SUBTOTAL				**3,933**
3.0	**EARTHWORKS**				
3.1	Minor Earthworks - regrade to suit new design levels, including disposal / provision of excess cut / fill	16	cu. m	75	1,200
	SUBTOTAL				**1,200**
4.0	**DRAINAGE**				
4.1	Supply and install 300mm dia. piles	31	each	10000	310,000
4.2	Construct protection structures upstream and downstream	2	each	30000	60,000
	SUBTOTAL				**370,000**
5.0	**REHABILITATION WORKS**				
5.1	Stabilise new bank as required (nominal allowance)	286	sq.m	10	2,860
5.2	Reinstate topsoil	42.9	cu.m	20	858
5.3	Reinstate / construct obstructions - rocks, logs, etc	11	item	30	330
5.4	Plant native species along disturbed areas	200	lin.m	10	2,000
	SUBTOTAL				**6,048**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	200	sq. m	10	2,000
	SUBTOTAL				**2,000**
	CONSTRUCTION SUB-TOTAL				**440,681**
7.0	**CONTINGENCIES**				
7.1	25% construction cost				**110,170**
	CONSTRUCTION TOTAL, excluding GST				**550,851**
	GST				**55,085**
	CONSTRUCTION TOTAL, including GST				**605,936**

CONSTRUCTION TOTAL, rounded	**606,000**

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NOTES:

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2. Estimate / rates in 2010 dollars and does not allow for inflation

W4963 - UPPER SOUTH CREEK FRMS&P

FM7 - Increase Regional Storage at Rileys Creek
Cost Estimate

Cardno Shaping the Future

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**345,900**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	31,000	sq. m	10	310,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	4650	cu. m	20	93,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	465	cu. m	50	23,250
	SUBTOTAL				**426,250**
3.0	**EARTHWORKS**				
3.1	Bulk Earthworks - excavate to design levels (sand/clay)	18600	cu. m	30	558,000
3.2	Earthworks - Shape Bunds using excess cut from site	10500	cu. m	30	315,000
3.3	Spread remaining spoil to land surrounding basin	8100	cu. m	15	121,500
	SUBTOTAL				**994,500**
4.0	**VOLUNTARY PURCHASE**				
4.1	Purchase properties	600000	each	1	600,000
	SUBTOTAL				**600,000**
5.0	**DRAINAGE**				
5.1	Supply and construct concrete slot outlet structure	1	Item	30000	30,000
5.2	Construct and install custom inlet	1	each	50000	50,000
5.3	Construct and install custom outlet, including downsteam protection	1	each	50000	50,000
	SUBTOTAL				**130,000**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	31,000	sq. m	5	155,000
	SUBTOTAL				**155,000**
	CONSTRUCTION SUB-TOTAL				**2,651,650**
7.0	**CONTINGENCIES**				
7.1	25% construction cost				**662,913**
	CONSTRUCTION TOTAL, excluding GST				**3,314,563**

GST	331,456
CONSTRUCTION TOTAL, including GST	3,646,019
CONSTRUCTION TOTAL, rounded	3,646,100

W4963 - UPPER SOUTH CREEK FRMS&P

Cardno
Shaping the Future

FM8 - New Regional Storage at Scalibrini Creek
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**1,751,900**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	55,000	sq. m	10	550,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	8250	cu. m	20	165,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	825	cu. m	50	41,250
2.4	Pull up and dispose existing road surface	300	sq.m	35	10,500
	SUBTOTAL				**766,750**
3.0	**EARTHWORKS**				
3.1	Bulk Earthworks - excavate to design levels (sand/clay)	165000	cu. m	30	4,950,000
3.2	Earthworks - Shape Bunds using excess cut from site	25500	cu. m	30	765,000
3.3	Spread remaining spoil to land surrounding basin	139500	cu. m	15	2,092,500
	SUBTOTAL				**7,807,500**
4.0	**VOLUNTARY PURCHASE**				
4.1	Purchase properties	600000	each	4	2,400,000
4.2	Demolish and dispose of properties	10000	each	9	90,000
	SUBTOTAL				**2,490,000**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	300	sq. m	120	36,000
	SUBTOTAL				**36,000**
6.0	**DRAINAGE**				
6.1	Supply and construct concrete slot outlet structure	1	Item	40000	40,000
6.2	Construct and install custom inlet	3	each	50000	150,000
6.3	Construct and install custom outlet, including downsteam protection	3	each	50000	150,000
	SUBTOTAL				**340,000**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	55,000	sq. m	5	275,000
	SUBTOTAL				**275,000**
	CONSTRUCTION SUB-TOTAL				**13,467,150**

7.0	**CONTINGENCIES**	
7.1	25% construction cost	**3,366,788**
	CONSTRUCTION TOTAL, excluding GST	**16,833,938**
	GST	**1,683,394**
	CONSTRUCTION TOTAL, including GST	**18,517,331**
	CONSTRUCTION TOTAL, rounded	**18,517,400**

W4963 - UPPER SOUTH CREEK FRMS&P

Cardno Shaping the Future

FM9 - New Regional Storage at Kemps Creek
Cost Estimate

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL				**2,595,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	104,800	sq. m	10	1,048,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	15720	cu. m	20	314,400
2.3	Dispose of excess topsoil (nominal 10% allowance)	1572	cu. m	50	78,600
	SUBTOTAL				**1,441,000**
3.0	**EARTHWORKS**				
3.1	Bulk Earthworks - excavate to design levels (sand/clay)	262000	cu. m	30	7,860,000
3.2	Earthworks - Shape Bunds using excess cut from site	18000	cu. m	30	540,000
3.3	Spread remaining spoil to land surrounding basin	244000	cu. m	15	3,660,000
	SUBTOTAL				**12,060,000**
4.0	**VOLUNTARY PURCHASE**				
4.1	Purchase properties	600000	each	5	3,000,000
4.2	Demolish and dispose of properties	10000	each	15	150,000
	SUBTOTAL				**3,150,000**
5.0	**DRAINAGE**				
5.1	Supply and construct concrete slot outlet structure	1	item	25000	25,000
5.2	Construct and install custom inlet	1	each	50000	50,000
5.3	Construct and install custom outlet, including downsteam protection	1	each	50000	50,000
	SUBTOTAL				**125,000**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	104,800	sq. m	5	524,000
	SUBTOTAL				**524,000**
	CONSTRUCTION SUB-TOTAL				**19,895,000**
7.0	**CONTINGENCIES**				
7.1	25% construction cost				**4,973,750**
	CONSTRUCTION TOTAL, excluding GST				**24,868,750**
	GST				**2,486,875**

CONSTRUCTION TOTAL, including GST	**27,355,625**
CONSTRUCTION TOTAL, rounded	**27,355,700**

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APPENDIX F
MULTI CRITERIA ASSESSMENT

Cardno
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Multi-Criteria Matrix

ID	Category of Measure	Location	Description	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 30 years)	Reduction in AAD	% reduction in c.f. to base case	NPV of Reduction in AAD	Benefit - Cost Ratio	Score on Benefit Cost Ratio	Capital and Operating Costs	Likely Hydraulic Improvement	EconomicScore	Reduction in Risk to Life	Reduction in Social Disruption	Community Criteria	Compatible with Policies and Plans	Social Score	Water Quality and Flow	Fauna & Flora	Environmental Score	TOTAL SCORE	RANK on TOTAL SCORE
P1	Property Modification	Camden LGA	LEP Update	$5,000	$1,000	$17,409	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	1	1	2	**1.5**	0	0	**0.0**	**4.5**	**2**
P2	Property Modification	Camden LGA	Building and Development Controls	$10,000	$1,500	$28,614	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	1	2	2	**1.8**	0	0	**0.0**	**4.8**	**1**
P3	Property Modification	Upper South Creek Floodplain	House Raising	Not fasible in this case																				
P4	Property Modification	Upper South Creek Floodplain	House Rebuilding	Not feasible in this case																				
P5	Property Modification	Upper South Creek Floodplain	Voluntary Purchase	$22,950,000	$0	$22,950,000	$156,112	17.5%	$1,937,194	0.08	1	-2	0	**0.0**	2	2	0	-2	**0.5**	0	1	**0.5**	**1.0**	**11**
P6	Property Modification	Upper South Creek Floodplain	Land swap	$17,850,000	$0	$17,850,000	$156,112	17.5%	$1,937,194	0.11	1	-2	0	**0.0**	2	2	0	-2	**0.5**	0	1	**0.5**	**1.0**	**11**
P7	Property Modification	Upper South Creek Floodplain	Council Redevelopment	Not feasible in this case																				
P8	Property Modification	Upper South Creek Floodplain	Flood Proofing	$8,100,000	$5,000	$8,162,045	$165,302	18.6%	$2,051,239	0.25	1	-2	0	**0.0**	0	0	0	2	**0.5**	0	0	**0.0**	**0.5**	**16**
EM1	Emergency Response Modification	Upper South Creek Floodplain	Information Transfer to SES	$2,500	$1,000	$14,909	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	0	0	2	**1.0**	0	0	**0.0**	**4.0**	**5**
EM2	Emergency Response Modification	Upper South Creek Floodplain	Preparation of Local Flood Plans and Update of DISPLAN	$25,000	$1,500	$43,614	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	0	2	1	**1.3**	0	0	**0.0**	**4.3**	**3**
EM3	Emergency Response Modification	Upper South Creek Floodplain	Flood Warning System	Not feasible in this case																				
EM4	Emergency Response Modification	Upper South Creek Floodplain	Public awareness and education	$5,000	$3,000	$42,227	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	0	2	1	**1.3**	0	0	**0.0**	**4.3**	**3**
EM5	Emergency Response Modification	Flood Affected Road Crossings	Flood warning signs at critical locations	$15,000	$300	$18,723	NC	N/A	N/A	N/A	2	2	0	**1.5**	1	0	0	2	**0.8**	0	0	**0.0**	**3.8**	**6**
FM1	Flood Modification	Masterfield Street, Rossmore	Raise Masterfield Street Levee	$669,300.00	$6,000.00	$743,754	788	0.1%	$9,778	0.01	1	-1	1	**0.5**	0	0	0	2	**0.5**	0	0	**0.0**	**1.5**	**9**
FM2	Flood Modification	Rossmore Cres, Rossmore	Drainage Improvement on Rossmore Crescent	$2,138,700.00	$6,375.00	$2,217,808	25516	2.9%	$316,629	0.14	1	-2	1	**0.3**	1	1	2	0	**1.0**	0	-1	**-0.5**	**1.0**	**11**
FM3	Flood Modification	Rileys Creek - upstream of South Creek confluence	Increase Rileys Creek Capacity	$8,800,400.00	$6,500.00	$8,881,059	48972	5.5%	$607,696	0.07	1	-2	2	**0.5**	1	1	1	0	**0.8**	-2	0	**-1.0**	**0.8**	**15**
FM4	Flood Modification	South Creek	Creek Revegetation in South Creek	$1,056,600.00	$19,000.00	$1,292,372	-12320	-1.4%	-$152,879	-0.12	-1	-1	-2	**-1.3**	0	0	2	1	**0.8**	2	2	**2.0**	**0.3**	**17**
FM5	Flood Modification	Bringelly Road bridge over South Creek	Blockage Control Structure at South Creek	$606,000.00	$5,000.00	$668,045	$0	0.0%	$0	0.00	1	-1	-1	**0.0**	0	0	0	0	**0.0**	0	0	**0.0**	**0.0**	**18**
FM7	Flood Modification	Rileys Creek	Increase Regional Storage - Rileys Creek	$3,646,100.00	$10,000.00	$3,770,190	8252	0.9%	$102,399	0.03	1	-2	2	**0.5**	1	2	1	1	**1.3**	0	0	**0.0**	**2.3**	**7**
FM8	Flood Modification	Scalibrini Creek	New Regional Storage - Scalibrini Creek	$18,517,400.00	$15,000.00	$18,703,536	-6901	-0.8%	-$85,635	-0.005	-1	-2	2	**-0.5**	1	0	1	0	**0.5**	0	0	**0.0**	**-0.5**	**19**
FM9	Flood Modification	Kemps Creek	New Regional Storage - Kemps Creek	$27,355,700.00	$20,000.00	$27,603,881	4720	0.5%	$58,571	0.002	1	-2	2	**0.5**	1	0	1	-2	**0.0**	0	0	**0.0**	**1.0**	**11**
FMa	Flood Modification	Rossmore Cres, Rossmore	combination of options FM2&3	$10,939,100	$12,875	$11,098,866	62518	7.0%	$775,788	0.07	1	-2	1	**0.3**	1	1	2	1	**1.3**	0	0	**0.0**	**1.8**	**8**
FMb	Flood Modification	Rileys and South Creek	combination of options FM2,3,4 & 7	$15,641,800	$41,875	$16,161,429	53401	6.0%	$662,655	0.04	1	-2	0	**0.0**	2	2	1	0	**1.3**	-1	1	**0.0**	**1.3**	**10**

** Indicates hydraulic model and detailed economic assessment used*

NC - Not Costed