Floodplain Risk Management Study and Plan Report

Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

59915031

Prepared for
Blue Mountains City Council

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Shaping the Future

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Foreword

The NSW Government Flood Prone Land 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 modification measures.

The Policy identifies the following 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 floodplain management measures 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 Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan is founded on the outcomes of the Flood Study, prepared by Public Works Manly Hydraulics Laboratory in 2013 for Blue Mountains City Council.

Acknowledgement

Blue Mountains City Council has prepared this document with financial assistance from the NSW government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Office of Environment and Heritage.

Executive Summary

Flow Behaviour and Flood Risk

The Hazelbrook and Woodford Creeks floodplain contains of a series of ridges and steep valleys, forming a number distributed flow paths. Residential development is primarily located upon the ridges as well as within the upper parts of the valleys. There are number of road crossings across the streams within the catchment that subjected to regular inundation.

The key locations of flooding are the three major flow paths that have impact on both property and road crossings are Hall – Pine, Luchetti – Oaklands and Park Oaklands. The majority for risk issues are contained within these sub catchments.

Impact of Flooding

The impact of flooding across the catchment is localised and generally impacts isolated properties. There are 58 properties affected by over floor flooding in the Probable Maximum Flood. Economic impacts of flooding as a result of overfloor flooding and garden damage of residential properties is estimated to be $375,000. The table below shows the estimated total damage for events ranging between the 20% AEP to the PMF.

Design Event	Properties with Overfloor Flooding	Total Damage ($)
PMF	57	$3,375,000
0.5% AEP	25	$1,412,000
1% AEP	23	$1,316,000
2% AEP	22	$1,194,000
10% AEP	17	$1,014,000
20% AEP	15	$880,000

Emergency Response Arrangements

When determining the risk to life associated with flooding, the flood hazard for an area does not directly imply the danger posed to people in the floodplain. The capacity for people to respond and react to flooding is a component of the risk of life associated with flooding. Flood emergency response is the formal and informal means of responding to flooding when it occurs.

A review of the existing emergency response arrangements for the catchment conclude that due to the fast rate of rise of flood waters experienced throughout the floodplain where time available for evacuation is less than an hour, that co-ordinated SES assisted regional evacuation is not possible.

However, for catchments such as this, evacuation may occur at a more localised level through a different sequence of events; occupants visually see flooding in their vicinity and respond instinctively by moving to higher ground. This sequence relies less on warning systems and emergency services co-ordination and more on the common sense and preparedness of the resident to respond to observed flooding through evacuation.

Flow paths within the floodplain are relatively confined, as proven by the fact that the maximum distance to flood free land does not exceed 50 metres for the majority of the floodplain. A review of shelter-in-place potential for the floodplain shows that this form of emergency response could be suitable for the area due to the relatively short duration of isolation.

Emergency response to flooding can be enhanced through the implementation of educations programs communicating flood risk and appropriate response, flood warning systems and provision of facilities and services to assist in a flood event. Opportunities to enhance emergency response within the Hazelbrook and Woodford Creeks floodplain have been assessed and incorporated into the flood management options considered.

Flood Related Planning Controls

A review of Flood Planning Levels for the floodplain was conducted to assess the currently adopted levels and any potential alternative levels that could be adopted. This assessment was done through an assessment of the flood risk associated with the various alternatives including consideration of climate change, the adopted freeboard level and the Flood Planning Area that assigns planning controls to properties. The outcome of the review was that Council's currently adopted Flood Planning Level of the 1% AEP plus 0.5 metre freeboard was appropriate for the Hazelbrook and Woodford Creeks floodplain.

A wider review of the Council's flood related development controls was also conducted. Recommendations were made to be considered as part of future amendments to the Blue Mountains Local Environment Plan and Blue Mountains Development Control Plan.

Flood Model Update

During the development of this Floodplain Risk Management Study and Plan, a subdivision application was being assessed at 54 Luchetti Avenue. As the development impacted upon the flooding behaviour both upstream and downstream of the site, the flood study model was updated to reflect changes to the topography and piped drainage system.

Flood Risk Management Options

For the Hazelbrook and Woodford Creeks floodplain, a range of flood risk management options were considered including flood modification, emergency response modification, and property modification measures.

Flood modification measures are measures aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment. Options considered were confined to overland flow modifications by way of berms, swales or detention basins. Significant upgrade of the stormwater drainage system options were not considered as part of this assessment as the underground network in generally intended to address up to the 5% AEP flood event.

A total of 10 flood modification options were modelled. Red Gum Avenue / Blue Hills Road Berms (FM1) and flow path from Luchetti Avenue (FM3) proved to reduce flood depths in multiple properties and hence providing a positive economic benefit. Cost benefit ratios of 4.74 and 8.02 respectively were produced for these options, substantially greater than other options considered.

Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than modifying the flood behaviour, these measures aim to modify properties so that there is a reduction in flood risk. A review of property modification measures including Voluntary House Raising and Voluntary Purchase found that these modification options were not feasible for the Hazelbrook and Woodford Creeks catchment .No properties in the catchment met the flood risk and hazard criteria for consideration under these schemes as set-out by the NSW Office of Environment and Heritage (OEH).

Flood proofing involves undertaking structural changes and other procedures in order to reduce the damage caused to the property 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. This approach to property modification is much more appropriate for the Hazelbrook and Woodford Creeks floodplain as the majority of properties affect by over floor flooding are contained within a low hazard area.

Emergency response modification measures aim to reduce the consequences of flood risks, by modifying the behaviour of people during a flood event. A range of emergency response options were assessed, namely:

- Local evacuation measures;
- Public awareness and education;
- School education program; and
- Flood markers and signage.

Inundation of road crossings was identified as an issue in the catchment. In most cases, the duration of inundation is short and the depth flow generally less than 300mm in the 1% AEP event. The depth of water

can be difficult for the community to assess in a flood event. The installation of flood markers can provide information to the community such that they can make an informed decision when crossing a flooded road.

All of the viable flood risk management options were assessed using a Multi-Criteria Assessment (MCA). This assessment provided for a triple bottom line approach to account for the performance of the various options with respect to economic, social and environmental criteria. The highest ranking option is the flow path from Luchetti Avenue (FM3). This option significantly reduced the flood depth in multiple properties providing a substantial economic benefit.

To assist Council with their implementation program, each of the recommended options has been given a priority (high, medium or low) corresponding to their ranking.

Floodplain Risk Management Plan

The plan (**Section 13**) has been developed to direct and co-ordinate the future management of flood prone land within the Hazelbrook and Woodford Creeks floodplain. It also aims to educate the community about flood risks so that they can make more informed decisions regarding their individual exposure and responses.

Implementation and Funding

In order to achieve the implementation of relevant recommendations of the plan, a program of implementation has been developed. This FRMSP report is finalised and the remaining steps in progressing the floodplain risk management process are:

- The Floodplain Management Committee will consider and support relevant recommendations of this Plan for adoption by Council;
- Council will adopt the final Plan and submit applications for funding assistance to relevant State and Commonwealth agencies, as appropriate;
- The flood management actions will be prioritised for funding through the Integrated Planning and Reporting Process; and
- As funds become available from OEH, the Commonwealth, other state government agencies, and/or from Council's own resources, recommended management actions will be implemented in accordance with the established priorities.

The estimated cost of implementing the plan by Council and relevant State Agencies include approximately $1,000,000 in capital costs and $25,400 in annualised recurrent costs.

Outcomes and Recommendations

The review and analysis undertaken as part of this FRMS&P has identified the flood only isolated cases of property inundation that can be effectively managed by structural flood modification measures (FM1 and FM3). Road overtopping has been identified as a problem within the catchment as communities could become isolated during large storm events, although the duration of inaccessibility is short and can be managed with emergency management processes.

Glossary and Abbreviations

Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Exceedance Probability (AEP)	The probability of exceedance of a given discharge within a period of one year. X? or 1 in Y.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Acid Sulfate Soils (ASS)	Acid sulfate soils (ASS) are naturally occurring sediments and soils containing iron sulfides (mostly pyrite). When these sediments are exposed to the air by excavation or drainage of overlying water, the iron sulfides oxidise and form sulphuric acid. ASSs are widespread among low lying coastal areas of NSW, in estuarine floodplains and coastal lowlands.
BMCC	Blue Mountains City Council
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
DCP	Development Control Plan
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.

Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as depth and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
LEP	Local Environment Plan
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
NSW	New South Wales
NSW SES	NSW State Emergency Service
OEM	Office of Emergency Management
Overland Flow	Overland flow is flooding that is not mainstream and deals with surcharging pipes and flow via roads.

Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation, see Average Recurrence Interval.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
REOCON	Regional Emergency Operations Controller
SEOCON	State Emergency Operations Controller
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stormwater Flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface that defines the ground level of a chosen area.

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Additional figures are included in **Appendix D**

1 Introduction

Cardno were commissioned by Blue Mountains City Council (BMCC) to prepare the Floodplain Risk Management Study and Plan for Hazelbrook and Woodford Creeks. The study has been undertaken to define existing flood behaviour and associated hazards of the study area, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure community concerns were addressed. The plan takes the possible mitigation options and forms the proposed approach for BMCC to manage floodplain risk.

1.1 Project Context

The NSW Floodplain Management process progresses through six steps in an iterative process:

1. Formation of a Floodplain Management Committee
2. Data Collection
3. Flood Study
4. **Floodplain Risk Management Study**
5. **Floodplain Risk Management Plan**
6. Implementation of the Floodplain Risk Management Plan

This report addresses aspects of steps four and step five.

1.2 Project Objectives

The overall objective of the project is to develop a Floodplain Risk Management Study (FRMS) where management issues are assessed, management options are investigated, and recommendations are made, and prepare a Floodplain Risk Management Plan (FRMP) detailing how flood prone land within the floodplain is to be managed based on the findings of the study.

The specific objectives of the Floodplain Risk Management Study are:

> Review the current Hazelbrook and Woodford Catchments Mainstream and Overland Flow Flood Study (NSW Public Works, 2013);

> Review Council's existing environmental planning policies and instruments including Council's long term planning strategies for the study area, particularly in the light of the potential impact of climate change and in terms of consistency with the principles of the Floodplain Development Manual (2005).

> Identify residential flood planning levels and flood planning area

> Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events and taking into account the potential impacts of climate change.

> To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future and taking into account the potential impacts of climate change;

> To consider whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised;

> In terms of the Department of Planning Circular PS 07-003 and "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual", determine if and where exceptional circumstance are appropriate for flood related development controls on residential development on land outside the residential flood planning area.

- In consultation with the NSW SES, review the local flood plan, identify deficiencies in information and address the issues identified in the DECCW Guideline “NSW SES Requirements from the FRM Process.”
- Examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Examine ways in which the river and floodplain environment may be enhanced without having a detrimental effect on flooding; and,
- Identify modifications required to current policies in the light of investigations.

The objective of the Stages 3, 4, 5 and 6 report is to provide a draft floodplain risk management study and draft floodplain risk management plan.

2 Catchment and Floodplain Description

The physical, environmental and social characteristics of the study area may influence the type and extent/location of floodplain management options able to be implemented under the FRMP.

Environmental characteristics, such as topography, sensitive environments, the presence of threatened species, and soils are constraints for any structural flood modification works proposed under the FRMS.

Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood management options proposed.

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

- Catchment topography;
- Land use;
- Demographic characteristics;
- Geology and soils;
- Flora and fauna; and
- Aboriginal and non-Aboriginal cultural heritage.

A review has been undertaken of environmental characteristics in the catchment and floodplain. It is important to consider environmental characteristics in the evaluation of floodplain risk management options, particularly structural flood modification measures.

2.1 Catchment Topography and Waterway

The study area includes a number of sub-catchments with a combined area of approximately 7.6 km^2, located on the northern side of a ridge line coinciding largely with the alignment of the Great Western Highway at an elevation of approximately 670 m AHD. The study area is shown in **Figure 2-1** and the topography of the catchment in **Figure 2-2**. The area consists of a series of ridges and steep valleys, forming a number distributed flow paths and sub catchments. Residential development is primarily located upon the ridges as well as within the upper parts of the valleys. The sub-catchments drain north and north-east into the upper reaches and tributaries of Hazelbrook, Woodford and Bulls Creeks. Woodford and Bulls Creeks (a tributary of the Hawkesbury Nepean River System) flow into Lake Woodford before merging with Hazelbrook Creek which flows to the Grose River.

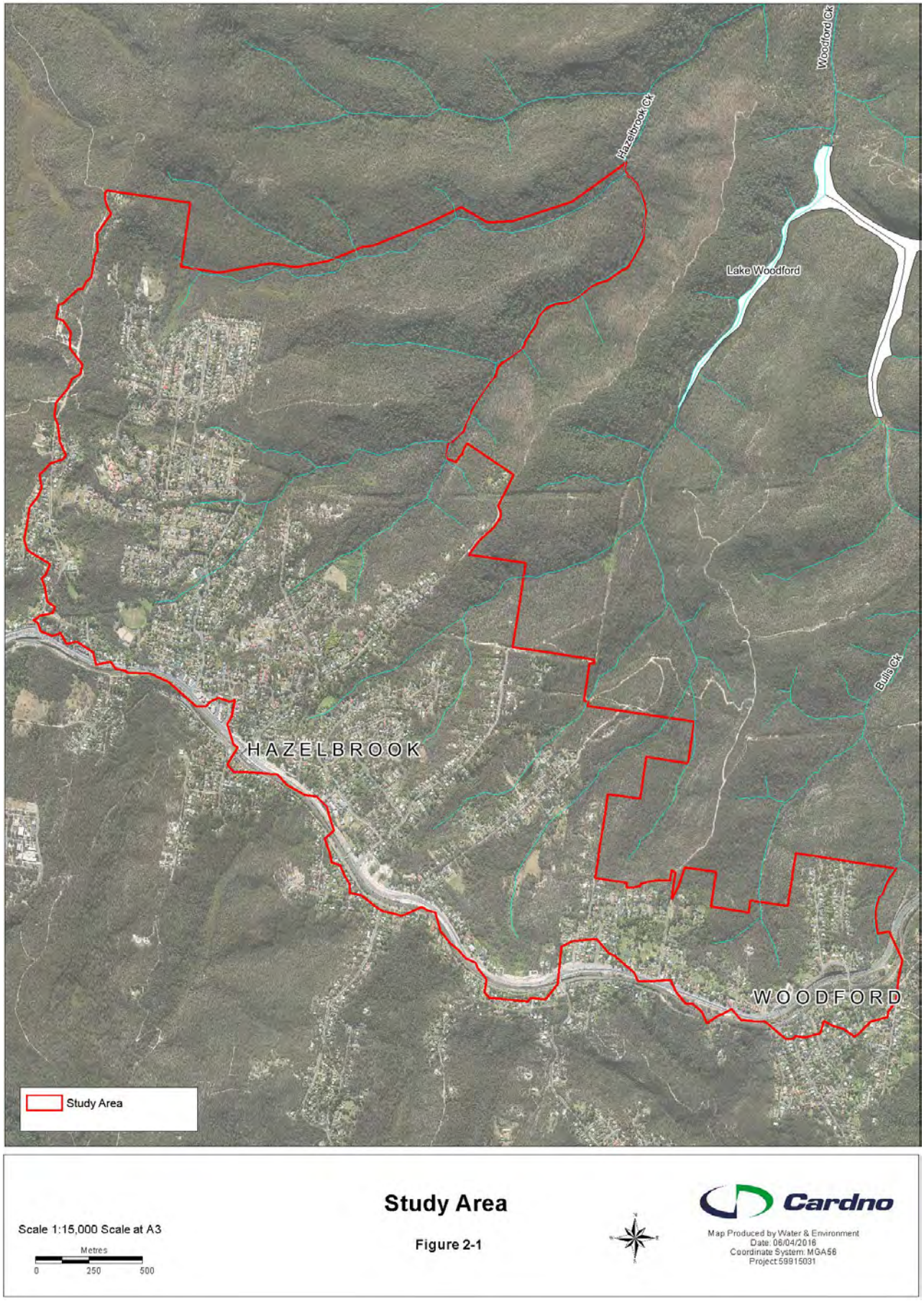


Figure 2-1 Study Area

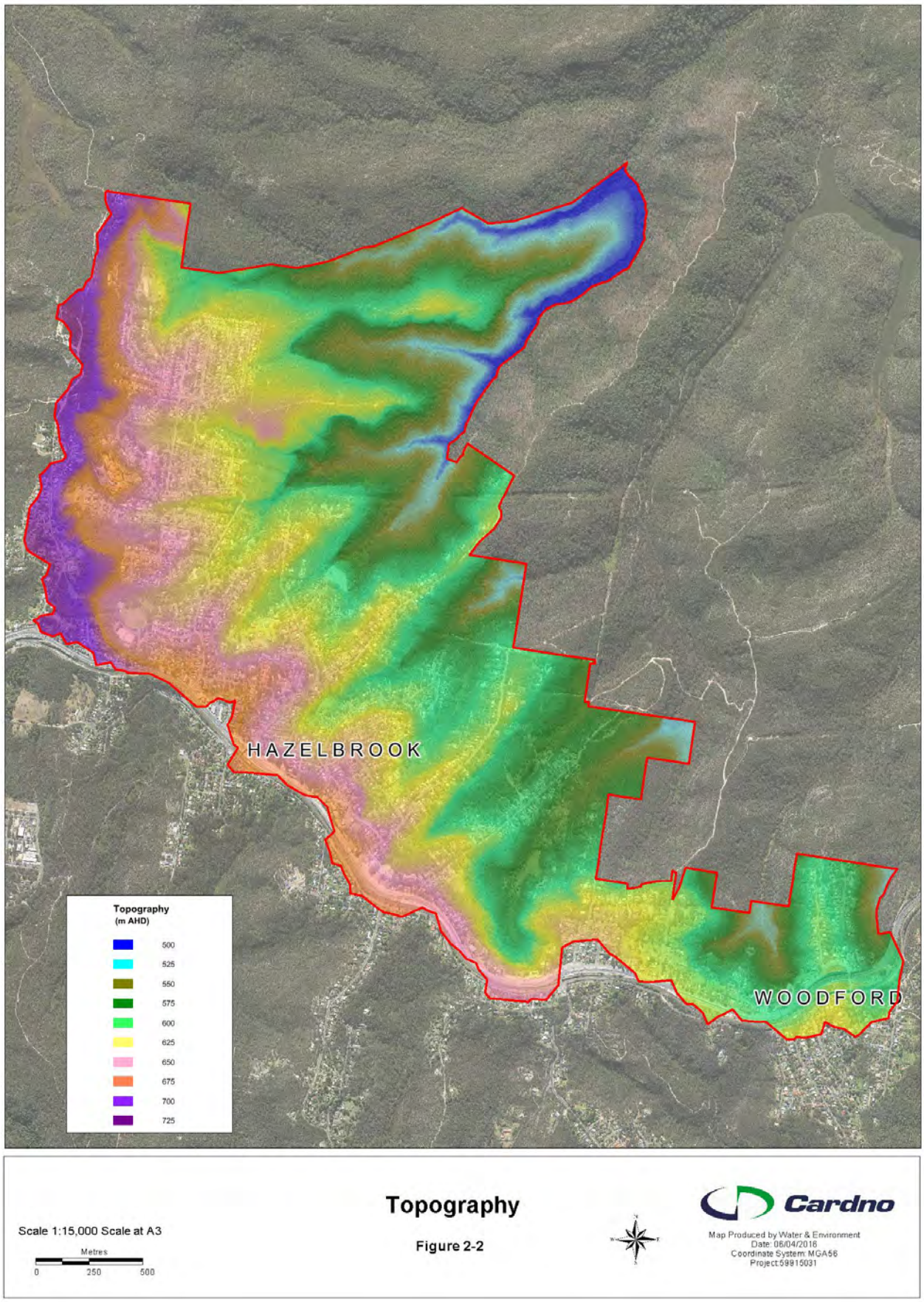


Figure 2-2 Topography

2.2 Land Use

The catchment contains land uses of predominantly environmental living (under the Blue Mountains City Council Local Environment Plan (LEP), 2015) with comparatively smaller regions of medium and low density residential. The more compact development is located adjacent to the highway and to the north-west of the study area. The downstream areas to the north and north-east are all zoned as Environmental Conservation. The land uses are shown in **Figure 2-3** as per the 2015 LEP. A more detailed discussion around land use within the study area are provided in **Section 8.2.**

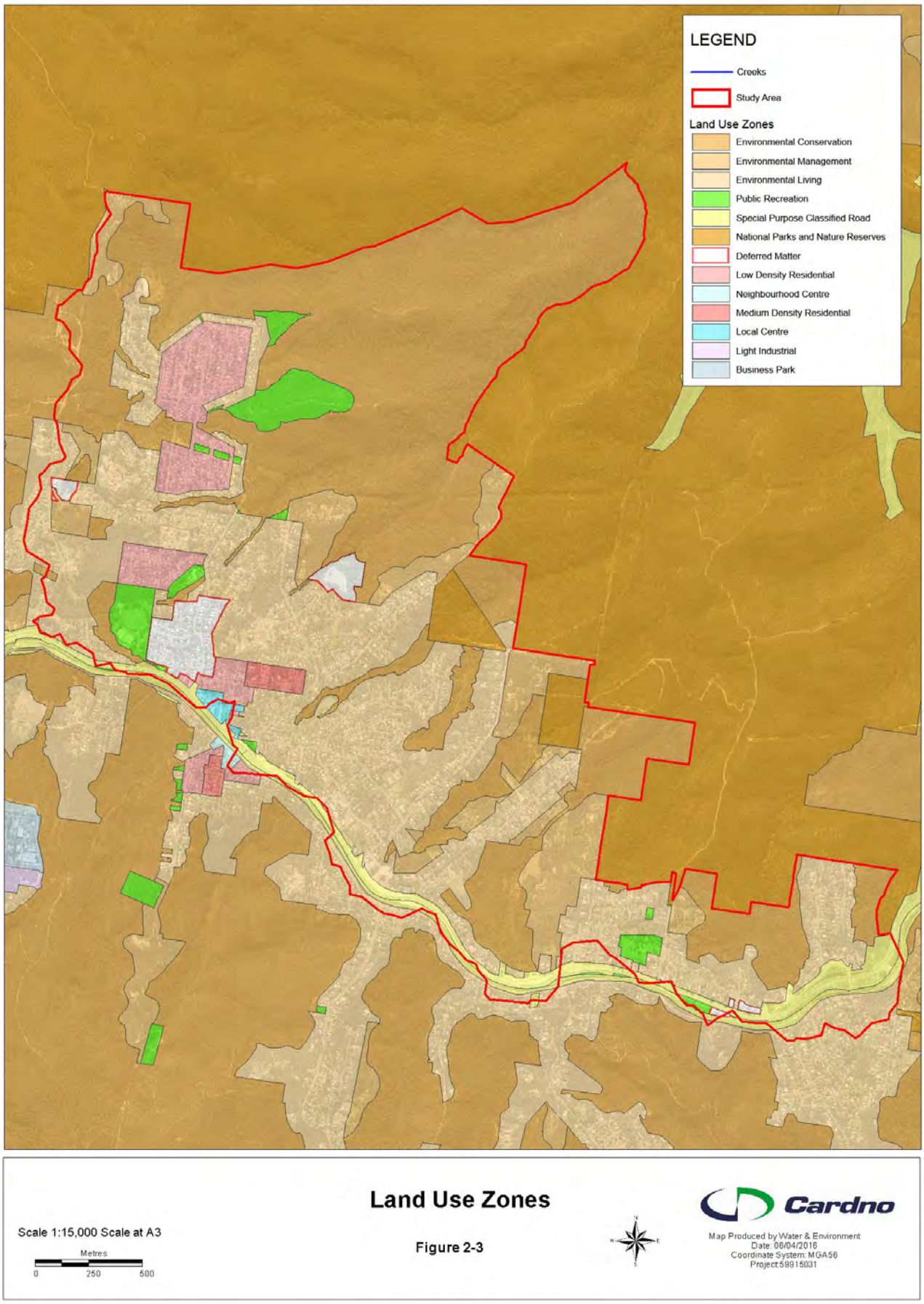


Figure 2-3 Land Use Zones (Blue Mountains Local Environment Plan, 2015)

2.3 Demographic Profile

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

The demographic characteristics of the survey area presented in this report was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census and are based on results for the Lawson - Hazelbrook - Linden (Statistical Area Level 2). Data on property values were sourced from Australian Property Monitor (APM 2015).

In summary, the data revealed that:

> The population within the Lawson-Hazelbrook-Linden statistical area (encompassing the Hazelbrook Woodford catchment) has a population median age of 40 and is typical of the NSW population. In total 74% of the population are aged below 55 years (**Table 2-1**), which indicates a community which is likely to be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures during a flood event. However, 22% of respondents are aged 14 years or younger. Younger children in particular will require specific assistance during a flood event.

> Of all respondents, 91% speak only English at home. The remainder of languages spoken at home include German, Spanish, Italian, Hungarian and Dutch (**Table 2-2**). This data indicates English would be the dominant language for material used for any flood communication.

> 80% of respondents have an internet connection, the majority having broadband. This indicates that internet based communications may be an effective means of communication with residents (except when power is cut).

> The Median weekly individual income is $581 for the combined statistical area of Lawson, Hazelbrook and Woodford and above the average of $561 for NSW. This trend of slightly above average income for the region compared to the NSW average was also evident for family and household incomes (**Table 2-3**). This may have implications for the economic damages incurred on property contents during a flood event.

> The median property price is $400,000 (www.pricefinder.com.au, 2015) compared with a median property price for houses in NSW of $540,000 (APM, 2015). This data is based on the previous 12 months of sales data up until November 2014. The majority (97%) of dwellings comprised separate houses (**Table 2-5**).

Table 2-1 Age Structure of the Survey Area (ABS 2011)

Age Group (Years)	Persons in the Statistical Area	% of Total Persons in the Statistical Area	% of Total Persons in NSW
0-4 years	475	7.4	6.3
5-14 years	953	14.9	14.1
15-19 years	436	6.8	6.7
20-24 years	263	4.1	4.3
25-34 years	641	10.1	8.6
35-44 years	970	15.2	12.7
45-54 years	1,010	15.8	15.2
55-64 years	885	13.9	14.7
65-74 years	459	7.2	10.5
75-84 years	220	3.5	5.4
85 years and over	64	1	1.6
Total	6,376	100	100

Table 2-2 Languages spoken at home in the survey area (ABS 2011)

Languages Spoken at Home	% of Total Persons in the Statistical Area	% of Total Persons in NSW
English only	91.2	72.5
German	0.7	0.3
Spanish	0.5	0.8
Italian	0.3	1.2
Hungarian	0.3	0.1
Dutch	0.2	0.1

Table 2-3 Average weekly income for people 15 and over in the survey area (ABS 2011)

Income (For Population Aged 15 Years+)	Statistical Area	NSW
Average Median Individual Income (weekly)	$581	$561
Average Median Family Income (weekly)	$1,534	$1,477
Average Median Household Income (weekly)	$1,256	$1,237

Table 2-4 Household composition in the survey area (ABS 2011)

Household Composition	% of Total Persons in the Statistical Area	% of Total Persons in NSW
Family households	71.7	71.9
Single (or lone) persons households	25.2	24.2
Group households	3.1	3.8

Table 2-5 Dwelling structure of occupied private dwellings in the survey area (ABS 2011)

Dwelling Structure	% of Total Persons in the Statistical Area	% of Total Persons in NSW
Separate house	97.0	69.5
Semi-detached, row or terrace house, townhouse etc.	1.5	10.7
Flat, unit or apartment	1.5	18.8
Other dwelling	0.1	0.9

Table 2-6 Median house and unit prices in the survey area for 2014 (APM 2015)

Suburb	Median House Price	Median Unit Price
Hazelbrook	$400,000	$322,000

2.4 Geology and Soils

The geology and soil landscape of a catchment can greatly influence the flood modification measures that can be implemented to minimise flood risk. For example, an area consisting predominantly of rock may not be compatible with the construction of detention storage, as the construction cost will increase dramatically if

excavation is required. It is important to have an understanding of these catchment features throughout the floodplain risk management process. Geology and soils are shown in **Figure 2-4** and **Figure 2-5** in **Appendix D.**

2.4.1 Geology

The geology of the majority of the study area is comprised of the Narrabeen Group (a sedimentary siliciclastic). The geology of southern-most area of the study area near Woodford is comprised of Hawkesbury Sandstone (a quartz rich arenite to rudite).

2.4.2 Soils

The study area is comprised of several soil landscapes and some limitations to development may be present (Table 2-7). Geotechnical and soil investigations may be required for larger-scale structural floodplain risk management options that are proposed to ensure that environmental risks are considered and mitigated. Anecdotal evidence suggests that erosion is a significant problem in some areas of the catchment. Soils with a high erosion hazard can exacerbate flooding. Any flood modification works should consider the impacts of these soil landscapes.

Table 2-7 Soil Landscapes in the Study Area

Soil landscape	Process	Limitations
Deanes Creek variant a	Swamp	Permanently high water tables and periodic to permanent waterlogging, acid soils of low fertility, high foundation hazard
Faulconbridge	Residual	Shallow soils and rock outcrops
Gymea	Erosional	Localised steep slopes, localised rockfall hazard, high erosion hazard, rock outcrop, shallow highly permeable soil, very low soil fertility
Hawkesbury	Colluvial	Very high erosion hazard and mass movement (rock fall) hazard, very low soil fertility
Warragamba	Colluvial	Mass movement hazard, steep slopes, severe water erosion hazard, rock fall hazard, stony soils of low fertility and rock outcrop

2.4.3 Acid Sulfate Soils

Acid Sulfate Soils (ASS) occur when soils containing iron sulfides are exposed to air, and the sulfides oxidise, producing sulphuric acid. This usually occurs when soils are disturbed through excavation or drainage works. The production of sulfuric acid results in numerous environmental problems. A review of the Blue Mountains Local Environment Plan 2015 shows that no ASS is known to occur within the study area.

2.4.4 Contaminated Land and Licensed Premises

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 Environmental Protection Authority (EPA) is authorised to regulate contaminated land sites and maintains a record of written notices issued in relation to the investigation or remediation of site contamination.

A search of the 'List of NSW contaminated sites notified to the EPA' on 23 February 2016 showed one potentially contaminated sites within the study area (Hazelbrook Caltex Service Station, 198 Great Western Highway), and a search of the Contaminated Land Record showed no contaminated sites reported within the study area. A search of the Protection of the Environment Operations act (PoEO) licensed premises public register on 23 February 2016 identified no licenced premises within the study area.

2.5 Flora and Fauna

The study area is comprised of primarily residential land extending along the Great Western Highway from Lawson to Woodford, bordered mostly by forest and woodland with areas of modified bushland. The study area is bordered to the north by the World Heritage Listed Blue Mountains National Park.

The Bionet Atlas of NSW Wildlife (OEH, 2015a) was searched for fauna and flora species listed under the Threatened Species Conservation (TSC) Act and the Commonwealth's Environment Protection and

Biodiversity Conservation (EPBC) database was searched for fauna and flora species listed under the EPBC Act within a 10 km by 10 km area around the study area.

Databases searches conducted in February 2015 showed a combined total of 234 known fauna species and 139 flora species within or near the study area that are listed under one or both of the Acts. The database searches unavoidably included areas outside of the study area and within the Blue Mountains National Park. **Figure 2-6** in **Appendix D** shows the locations of flora and fauna. A full list of Fauna and Flora species in included in **Appendix B.**

Flora and Fauna mapping has been used in this study to ensure the flood modification measures proposed do not adversely impact threatened flora and fauna.

2.5.1 Native Vegetation

Mapping of the study area provided by Council indicate that Blue Mountains Swamps are present in numerous locations within the study area and in close proximity to residential areas (**Figure 2-6**). This vegetation community is listed as a vulnerable ecological community under the Threatened Species Conservation (TSC) Act 1995 and an endangered ecological community under the Commonwealth's EPBC Act 1999. Other significant communities present within the study area include Rainforest, Blue Mountain Riparians Complex and Blue Mountains Escarpment Complex communities (**Figure 2-6**, **Table 2-8**). Although not listed under the TSC or the EPBC Acts, these communities are recognised as significant (referred to as "scheduled vegetation") under the Blue Mountains Local Environmental Plan (2015).

Table 2-8 Significant vegetation communities and protection status under the EPBC Act, TSC Act and Blue Mountains LEP 2015

Common Name	Scientific Name	EPBC (Comm.)	TSC (NSW)	Local (Blue Mountains LEP)
Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion	*Blue Mountains Shale Cap Forest in the Sydney Basin Bioregion*	CE	E	
Blue Mountains Swamps in the Sydney Basin Bioregion	*Blue Mountains Swamps in the Sydney Basin Bioregion*	E	V	S
Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions	*Montane Peatlands and Swamps of the New England Tableland, NSW North Coast, Sydney Basin, South East Corner, South Eastern Highlands and Australian Alps bioregions*	E	E	S
Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion	*Newnes Plateau Shrub Swamp in the Sydney Basin Bioregion*	E	E	S
Blue Mountains Heath and Scrub	*Blue Mountains Heath and Scrub*			S
River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions	*River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions*		E	
Shale Sandstone Transition Forest in the Sydney Basin Bioregion	*Shale Sandstone Transition Forest in the Sydney Basin Bioregion*	E	CE	
Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion	*Southern Sydney sheltered forest on transitional sandstone soils in the Sydney Basin Bioregion*		E	

Common Name	Scientific Name	EPBC (Comm.)	TSC (NSW)	Local (Blue Mountains LEP)
Sun Valley Cabbage Gum Forest in the Sydney Basin Bioregion	*Sun Valley Cabbage Gum Forest in the Sydney Basin Bioregion*		CE	
Western Sydney Dry Rainforest in the Sydney Basin Bioregion	*Western Sydney Dry Rainforest in the Sydney Basin Bioregion*	CE	E	
White Box Yellow Box Blakely's Red Gum Woodland	*White Box Yellow Box Blakely's Red Gum Woodland*	CE	E	
Blue Mountains Riparian complex	*Blue Mountains Riparian complex*	E		S
Blue Mountains Escarpment Complex	*Blue Mountains Escarpment Complex*			S
Rainforest				S
Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion		E		

P = Protected; V = Vulnerable; CE = Critically Endangered, E = Endangered, S= Scheduled

2.6 Aboriginal and Non-Aboriginal Cultural Heritage

It is important to recognise locations of Aboriginal and non-Aboriginal cultural heritage in determining the flood modification options. For the information available, maps have been produced highlighting known cultural heritage locations and compared to the proposed locations of options. Heritage locations are shown in in **Figure 2-6** in **Appendix D.**

2.6.1 Aboriginal Cultural 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 Aboriginal heritage was undertaken by searching the NPWS Aboriginal Heritage Information Management System (AHIMS) (OEH, 2015b) in February 2015 for known or potential Aboriginal archaeological or cultural heritage sites within a 20 km^2 rectangular area defined around the Hazelbrook/Woodford Creek study area (note that this preliminary search unavoidably included surrounding areas within the Blue Mountains National Park. The AHIMS search revealed that 25 Aboriginal sites were recorded in or near the study area. Given the high number of heritage items, it is recommended that a more detailed heritage assessment be undertaken prior to implementation of any management actions to ensure that the impacts of any proposed flood mitigation works on these sites can be appropriately managed.

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 maintained by the Office of the Registrar, Aboriginal Land Rights Act 1983 (ORALRA) on 5 February 2015 found no Native Title claim and no Land Use Agreements within the study area.

There was however one Native Title claim directly bordering the Great Western Highway to the south of the study area. The Native Title Claim identified near the study area covers a total area of 18,675 km2 and extends from the south of Katoomba to Goulburn. The claim was lodged in 1997 and the tribunal file number is NC1997/7. 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.

2.6.2 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 an item falls into 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 study area. Searches were undertaken on the following databases to investigate the non-Aboriginal cultural heritage present within this area:

> Australian Heritage Database (incorporates World Heritage List; National Heritage List; Commonwealth Heritage List);

> NSW Heritage Office – State Heritage Register (OEH, 2015c);

> Blue Mountains Council LEP (2015) Local Heritage listings; and

> Roads and Maritime Services S170 Heritage and Conservation Register.

A total of 25 heritage items are listed within the study area, comprising 23 items listed in the Blue Mountains LEP (2015), one item listed on the NSW State Heritage Register, and one item listed in the Roads and Maritime Services S170 Heritage and Conservation Register (**Table 2-9**). The provisions that must be followed in relation to heritage items in the study area are outlined in Part 5, Clause 5.10 of the Blue Mountains LEP (2015).

Table 2-9 Heritage Items within the study area

Name	Address	Suburb	Register
Masonry Retaining Wall	Great Western Highway, North Side East of Falcon Street	Hazelbrook	Heritage Act - s.170 NSW State agency heritage register
Hazelbrook Railway Station	Main Western Railway (Near Addington Road)	Hazelbrook	Local Government
Railway Parade Conservation Area	Main Western Railway (Near Addington Road)	Hazelbrook	Local Government
Selwood House and Grounds	4 Addington Road and 41 Railway Parade	Hazelbrook	Local Government
Ortona	46 Railway Parade	Hazelbrook	Local Government
Railway Parade Group	46, 47, 49, 51 Railway Parade	Hazelbrook	Local Government
Oaklands, Pumphouse and Dam	62 Hall Parade and 78 Oaklands Road and 3-19 Sulman Road	Hazelbrook	Local Government
Gloria Park and War Memorial	21 Lester Avenue	Hazelbrook	Local Government
Rainbow Lodge and Grounds	123-125 Great Western Highway	Hazelbrook	Local Government
Gardener's Cottage to Kihilla	230 Great Western Highway	Lawson	Local Government
House	241 Great Western Highway,	Lawson	Local Government

Name	Address	Suburb	Register
Kihilla and Grounds	236-238 Great Western Highway,	Lawson	Local Government
Woodford Academy and Grounds	88-89, 90-92 Great Western Highway and 10, 12, 20-26 Woodford Avenue	Woodford	Register of the National Estate (Non-statutory archive) NSW State Heritage Register
Garden - Stoney Hill	127 Great Western Highway	Woodford	Local Government
Tyn-y-Coed (site only)	107 Great Western Highway and 14, 16 Woodbury Street	Woodford	Local Government
Twenty Mile Hollow Lock-up Site	88-89, 90-92 Great Western Highway and 10, 12, 20-26 Woodford Avenue	Woodford	Local Government
Weroona and Grounds	21 Woodford Avenue	Woodford	Local Government
Former St Paul's Anglican Church	78A Great Western Highway	Woodford	Local Government
Woodford Uniting Church	68A, 68B Great Western Highway	Woodford	Local Government
Woodford House	69 Great Western Highway	Woodford	Local Government
Memorial Park	70, 70A, 75A Great Western Highway	Woodford	Local Government
Woodford Railway Station	55P Great Western Highway	Woodford	Local Government
Abandoned Railway Cuttings	25 Station Street	Woodford	Local Government
Cox's Road	Great Western Hwy	Woodford	Local Government
Birralee and Garden	11 The Appian Way	Woodford	Local Government

2.7 Summary of Environmental and Social Issues

The key environmental and social issues to be considered in the development of floodplain management strategies for the Hazelbrook and Woodford catchments include:

> English was the only language spoken in approximately 91% of homes in the catchment. The most common languages spoken at home other than English were German, Spanish, Italian, Hungarian and Dutch;

> The soil types that are present may potentially pose issues related to mass earth movement and high erosion risk, as well as low fertility.

> At least 25 Aboriginal heritage items were recorded in or near the study area; and

> One non-Aboriginal heritage item was found within the catchment area which was listed under the *NSW Heritage Act 1977*, and one listed under Section 170 of *NSW Heritage Act 1977.* A further 23 items are listed under the Blue Mountains LEP 2015 that feature in the study area.

3 Review of Available Data

3.1 Previous Reports and Studies

The main study of relevance conducted concerning the Hazelbrook and Woodford Creek catchments is the Hazelbrook and Woodford Catchments Mainstream and Overland Flow Flood Study (NSW Public Works Manly, 2013). Modelling undertaken as part of this study has been reviewed and has been utilised to inform the floodplain risk management study.

3.2 Survey Information

Survey was undertaken to collect property floor and ground levels for the flood damage assessment. This survey was completed by Cardno (NSW/ACT) Pty Ltd in June 2015.

3.3 GIS Data

As part of the study the following Geographic Information System (GIS) datasets were provided by Blue Mountains City Council:

- Pipes, Pits, Study Area, Creek Lines, Land Use Zones, Contaminate Land Zones, Vegetation, Heritage, Conservation Areas and Cadastral in .TAB format; and
- 2012 Aerial Imagery in .ecw format.

3.4 Previous Modelling

The flood study undertaken in 2013 (NSW Public Works, 2013) developed hydrologic and hydraulic models to assess the flood behaviour of the study area. Hydrological and hydraulic modelling (rainfall on grid) was undertaken using the TUFLOW software. Further verification of hydrology was undertaking using the WBNM software.

The TUFLOW output layers for the 0.5%, 1%, 2%, 10% AEP and the PMF event were converted to GIS format and imported into Mapinfo for use in this Study.

The TUFLOW flood model was reviewed and the 1% AEP 120 minute catchment model was rerun producing the same results as those provided as outputs from the 2013 Flood Study. The model is therefore considered suitable for the purpose of evaluating options.

3.4.1 Hydrology

The hydrologic parameters used for the TUFLOW model are as follows:

- Considering the steep nature of the study catchment and hence little opportunity for infiltration, no initial losses were applied to the catchment and a continuing loss value of 2.5 mm/hr was adopted for pervious areas. No losses were applied to impervious areas.

3.4.2 Hydraulics

As described above, a TUFLOW model was developed as part of the flood study to assess flood behaviour in the region. The primary calibration method for the hydraulic model was information gathered through a community consultation process (NSW Public Works, 2013). A high level of correlation exists between the substantiated flood depth and peak modelled flood depth.

3.4.2.1 Model Extent

The hydraulic model extends from the Great Western Highway toward the low lying areas to the north east. The extent covers critical locations within the study and is deemed to be suitable to assess flood mitigation options.

3.4.2.2 Model Digital Elevation Model

A digital elevation model captured via Airborne Laser Scanning (ALS) in 1999 was initially evaluated by NSW Public Works as part of the Hazelbrook and Woodford Catchments Mainstream and Overland Flow Flood Study (2013).

This data was used to create a high resolution (1 m grid) digital elevation model (DEM), although upon review it was discovered that significant noise was present in the ALS data. Further investigation uncovered large discrepancies between overlapping ALS datasets.

A second ALS data set was captured by Photomapping Services in June 2012. NSW Public Works carried out an independent verification of the data and found the data meet the level of coverage and accuracy to achieve suitable representation of flood behaviour. The data was used to create a DEM of the study area.

The DEM ranges in elevation from 470 m AHD at the downstream end to 730 m AHD along the ridge forming the western study boundary. The majority of the development in the towns of Hazelbrook and Woodford lies between the elevations of approximately 580 m AHD to 670 m AHD.

3.4.2.3 Model Roughness

The roughness values adopted in the model are summarised in the Hazelbrook and Woodford Catchments Mainstream and Overland Flow Flood Study (NSW Public Works, 2013). The model roughness adopted is considered to be reasonable.

3.4.2.4 Hydraulic Structures

The model consists of 18 hydraulic structures. These are detailed in the Hazelbrook and Woodford Catchments Mainstream and Overland Flow Flood Study (NSW Public Works, 2013).

3.5 Flood Model Update

A subdivision application was being assessed in Luchetti Avenue during the development of this Floodplain Risk Management Study and Plan. The flood study model has been updated to reflect changes to both the terrain and piped drainage system as a result of the proposed subdivision. The changes included:

- Changes to the natural topography (cut and fill) to allow for the development;
- Installation of cut-off drains upstream of the development to direct flow to defined channels;
- Piping of overland flow paths through the development;
- Installation of detention structure to manage increased flows as a result of the development; and
- Changes to roughness and rainfall losses attributed to new roads and residential development.

The updated flood model was run for the required design events and flood mapping results revised accordingly.

4 Community Consultation

4.1 Community Consultation Process

Community consultation is an important component in the development of a Floodplain Risk Management Study and Plan. Consultation provides an opportunity to collect feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

The main consultation elements for this project are:

- A project website keeping the community informed about the progress of the project;
- A call for information from all affected stakeholders within the catchment;
- A community newsletter including a brochure and questionnaire;
- Community workshops to discuss flood affected and potential management options of the community's preferred options; and
- Public exhibition of draft Floodplain Risk Management Study and Plan.

This process ensures that there is opportunity for community participation during the development of the plan.

4.2 Project Website

A project website was developed and launched in March 2015 using the platform extranet.cardno.com/HazelbrookWoodfordFRMS. The purpose of the website was to provide a central point of information for the community on:

- The purpose of the study;
- The study area;
- The NSW floodplain management process;
- Flood behaviour; and
- Details as to how they can get involved in the study.

4.3 Stakeholder Consultation

Consultation with key stakeholders such as local community groups, sporting groups, utility providers and schools was undertaken on a variety of issues relevant to the specific organisation. Stakeholders were contacted by letter and followed up by either phone call or email. Information requested included:

- Identification of existing or future projects in the catchment;
- Location and flood affectation of their assets within the catchment;
- Emergency management and historical floods;
- Meteorological data; and
- Sensitive locations within the study area (e.g. ecologically or with respect to cultural heritage).

4.4 Information Brochure and Questionnaire

4.4.1 Background

As part of the community consultation process, an information brochure about the study and a questionnaire designed to gauge community awareness to flood related issues and to request feedback were produced (included in **Appendix A**). Together with a covering letter, these were delivered to almost 500 flood affected property owners on 5 November 2015.

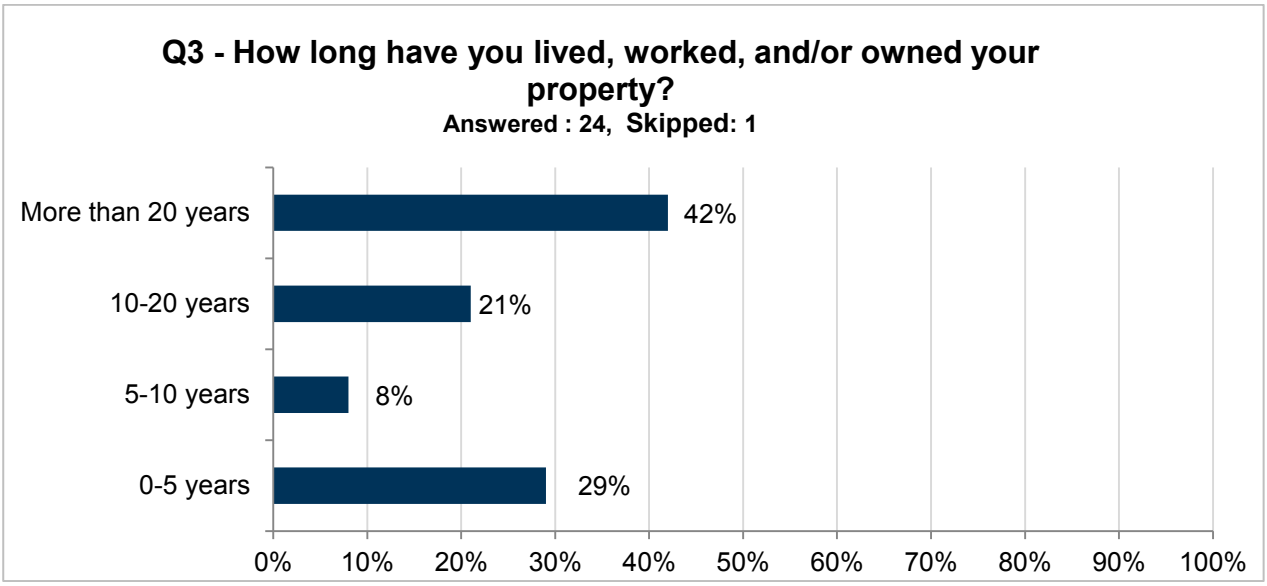
At the close of the survey period on 12 December 2015, 25 submissions had been received, with one respondent sending an attachment to council. Of the submissions received, 16 were received in hardcopy and nine were received via the online survey portal.

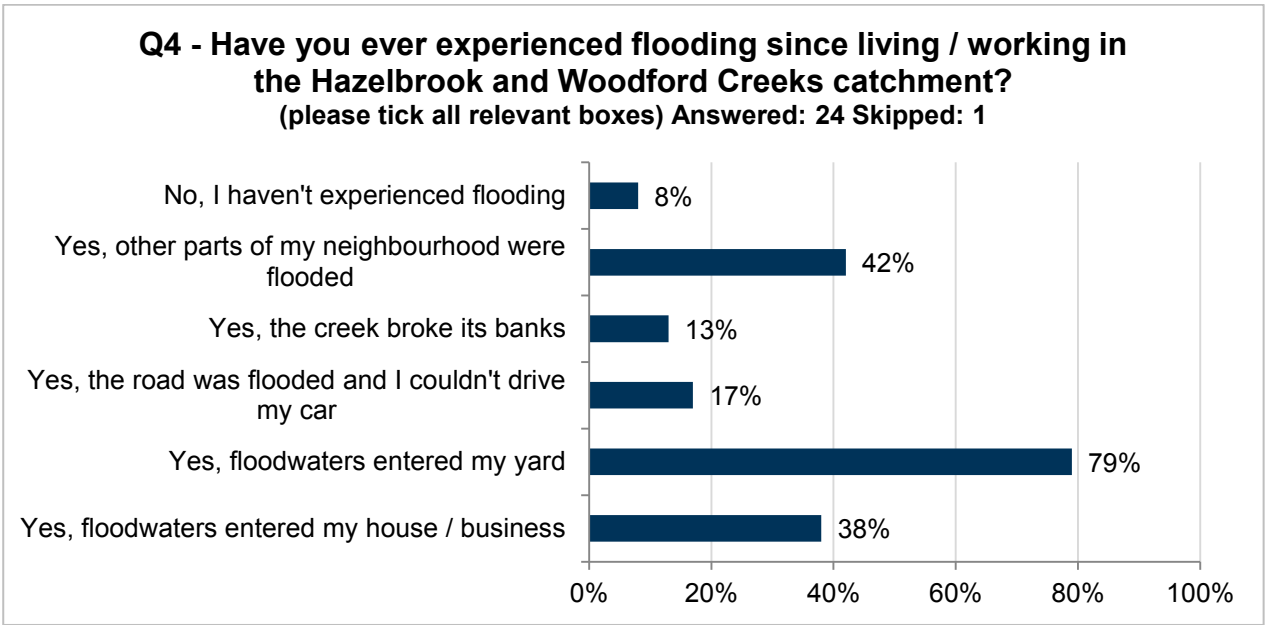
4.4.2 Submission Results

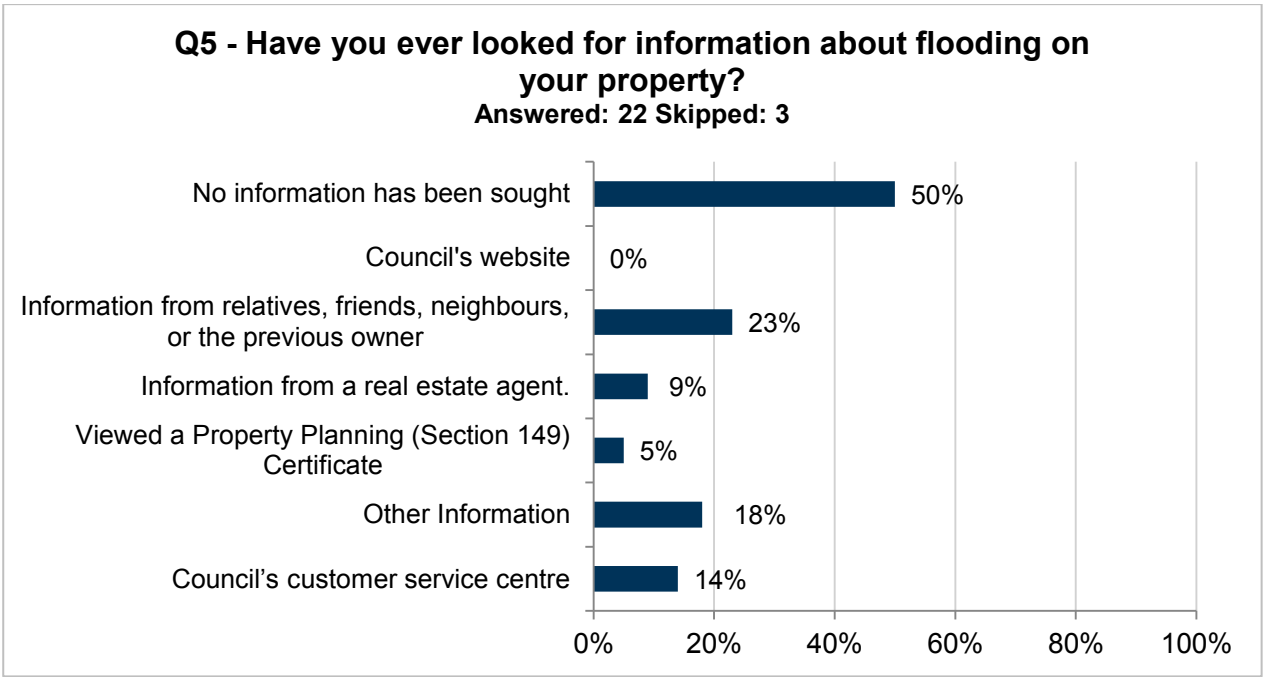
A summary of the submissions is shown in the charts below. All community responses have been collated in spreadsheet format and supplied to council.

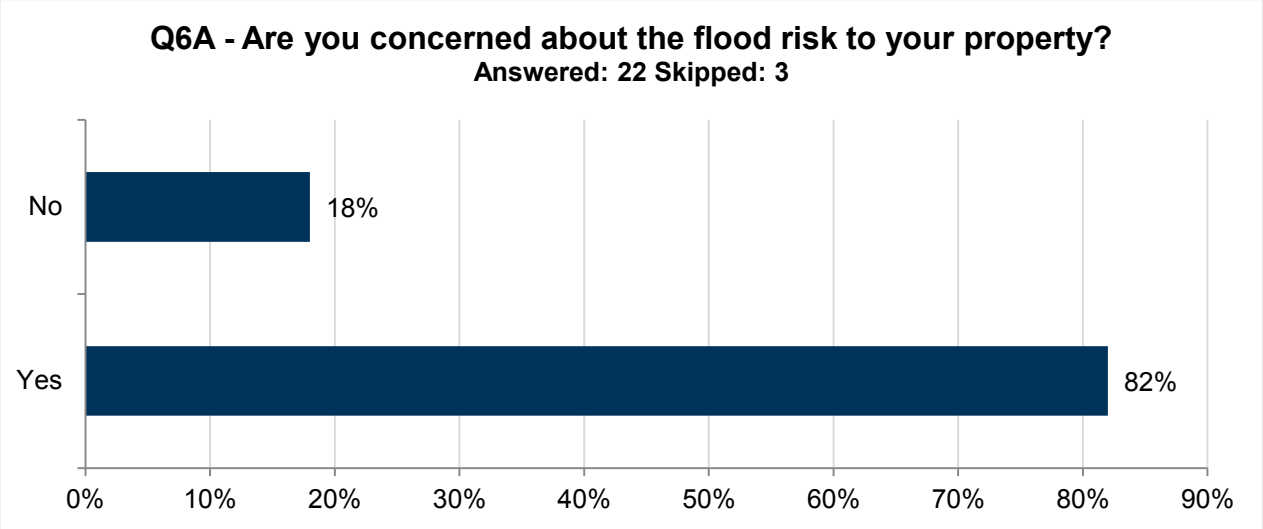
Question four of the survey required the community to identify whether they have ever experienced flooding. Nearly all (24 of 25 responses) answered this question with only two residents indicating that they have never experienced flooding since living/working in the Hazelbrook and Woodford Creeks catchment.

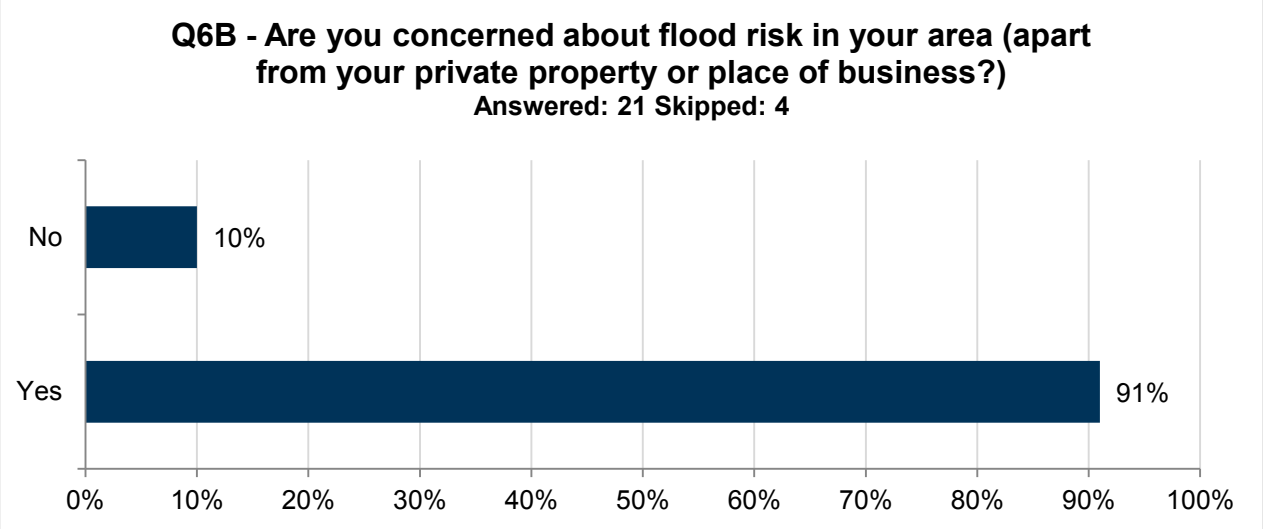
Respondents believe that the main cause of flooding in their area is due to a lack of capacity in the stormwater network causing drainage systems to surcharge (**Q7**).

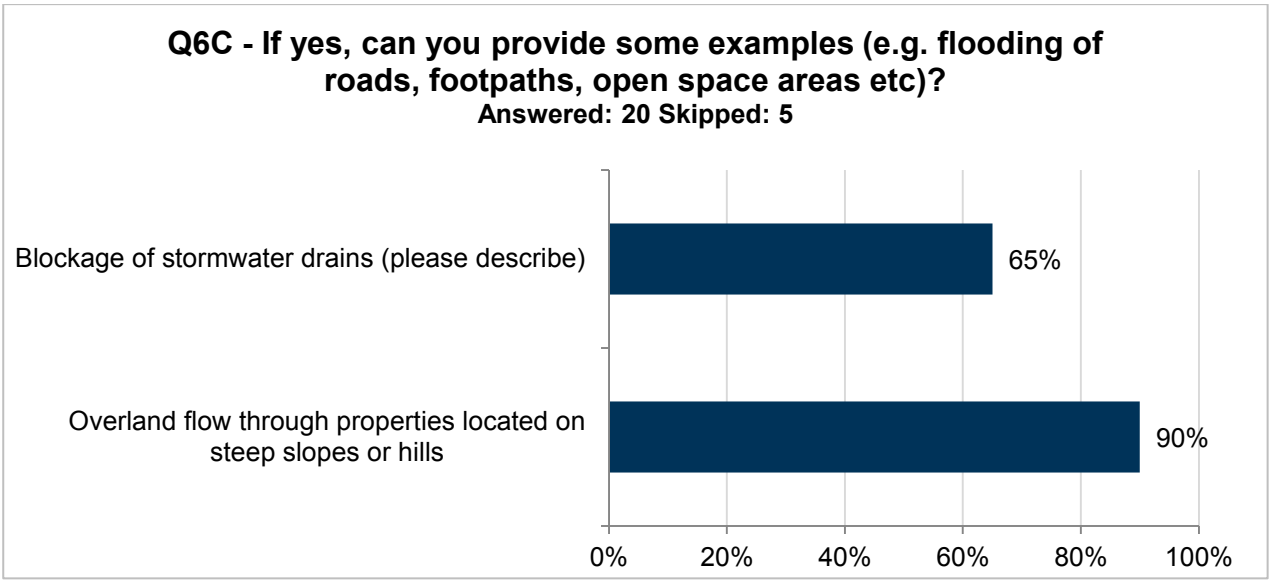


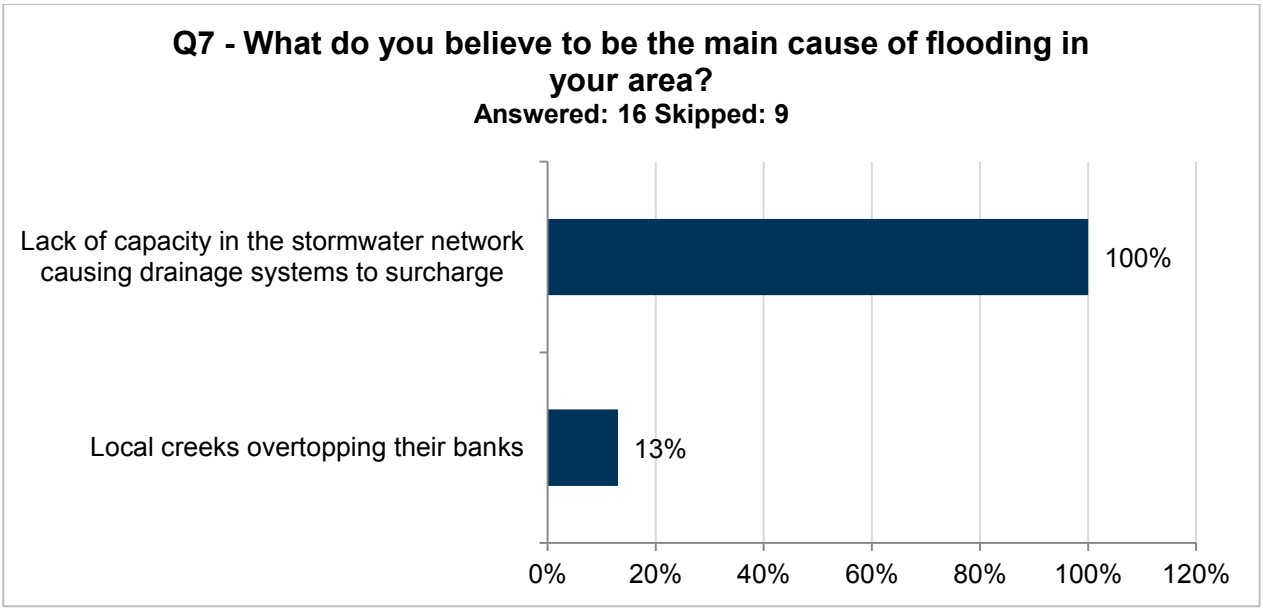


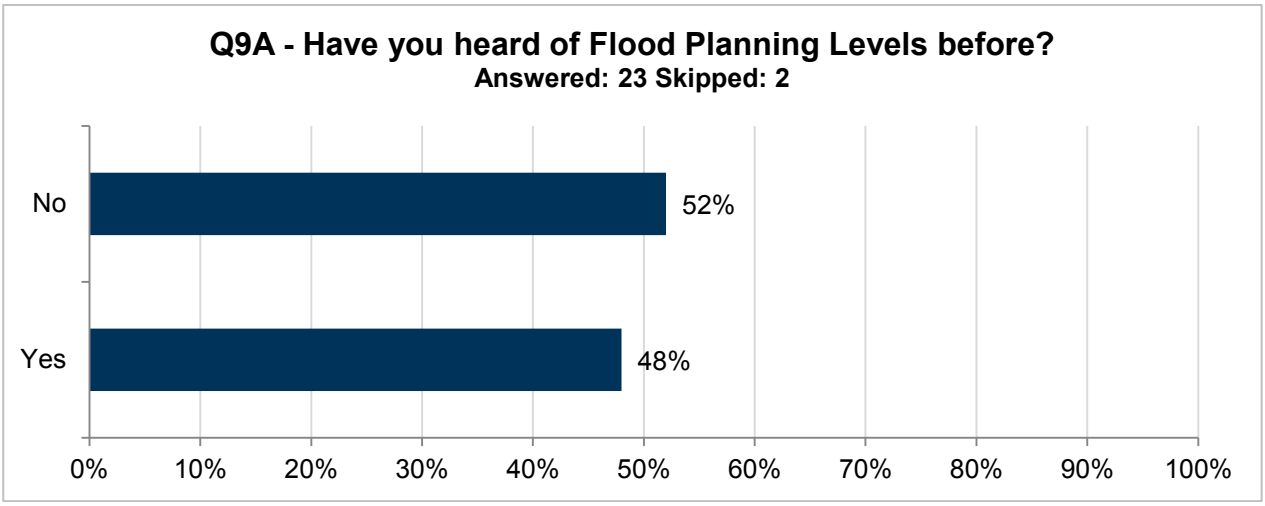

Q5 - Have you ever looked for information about flooding on your property?
Answered: 22 Skipped: 3
No information has been sought
50%
Council's website
0%
Information from relatives, friends, neighbours, or the previous owner
23%
Information from a real estate agent.
9%
Viewed a Property Planning (Section 149) Certificate
5%
Other Information
18%
Council's customer service centre
14%
0%
20%
40%
60%
80%
100%

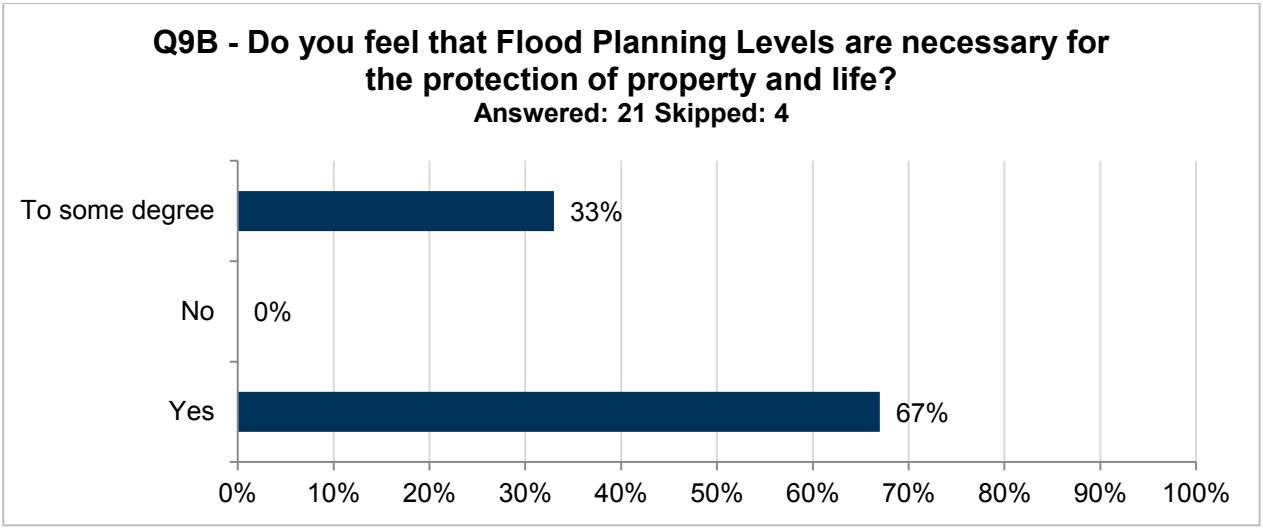

Q6A - Are you concerned about the flood risk to your property?
Answered: 22 Skipped: 3
No
18%
Yes
82%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%

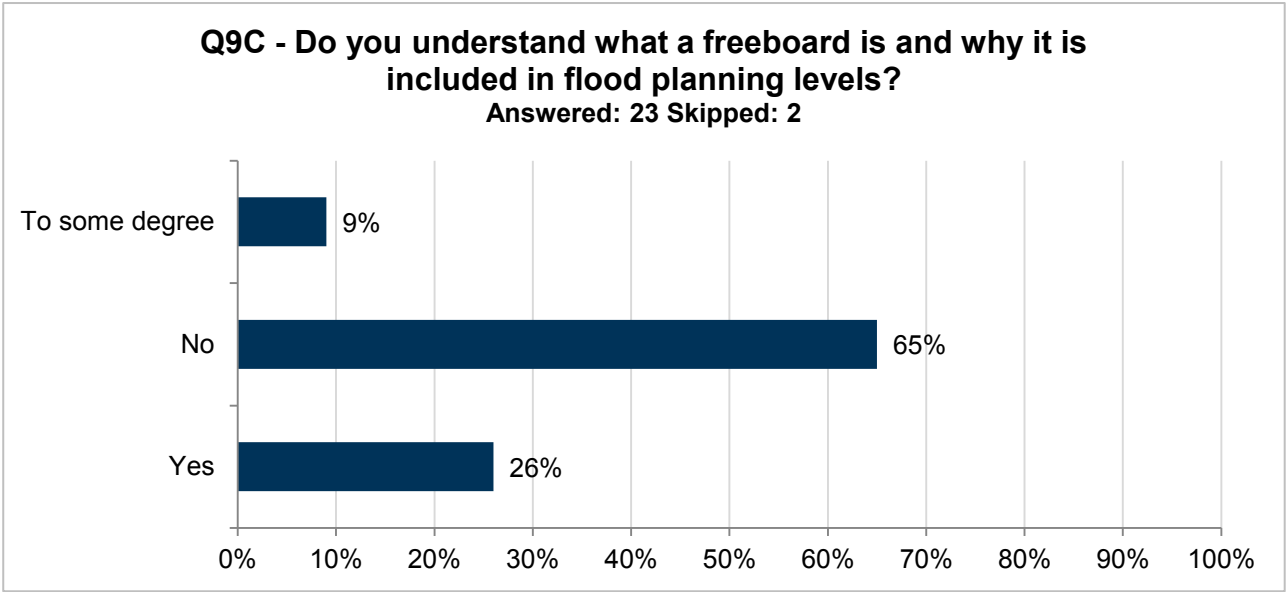

Q6B - Are you concerned about flood risk in your area (apart from your private property or place of business?)
Answered: 21 Skipped: 4
No
10%
Yes
91%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

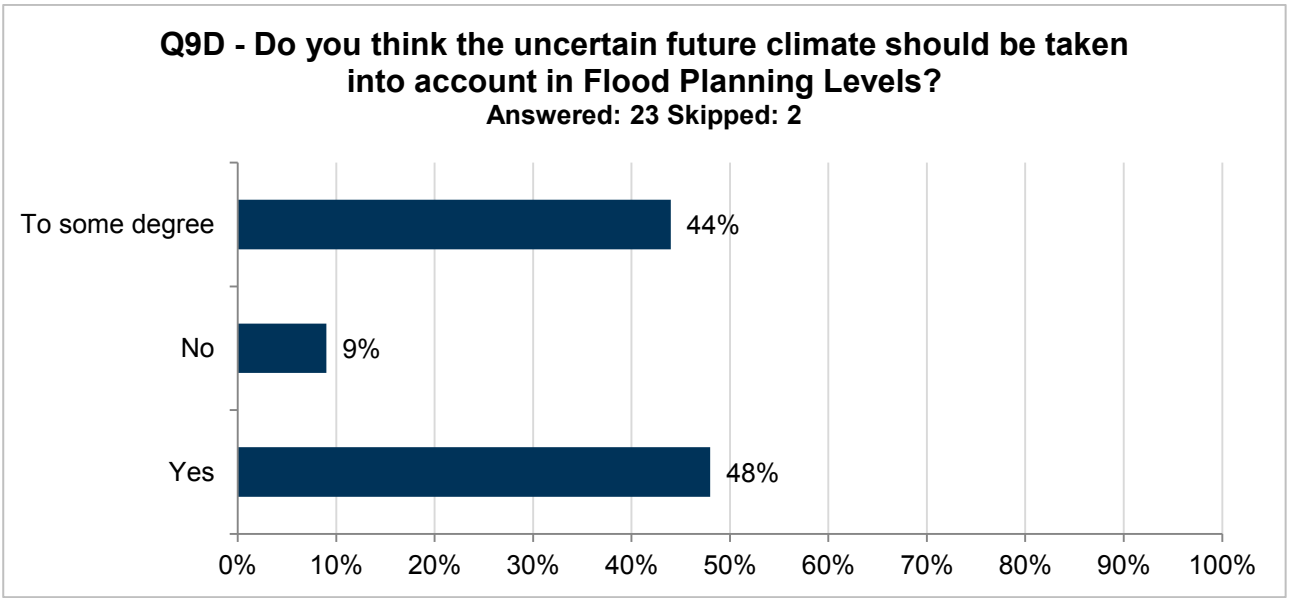

Q6C - If yes, can you provide some examples (e.g. flooding of roads, footpaths, open space areas etc)?
Answered: 20 Skipped: 5
Blockage of stormwater drains (please describe)
65%
Overland flow through properties located on steep slopes or hills
90%
0%
20%
40%
60%
80%
100%


Q7 - What do you believe to be the main cause of flooding in your area?
Answered: 16 Skipped: 9
Lack of capacity in the stormwater network causing drainage systems to surcharge
100%
Local creeks overtopping their banks
13%
0%
20%
40%
60%
80%
100%
120%


Q9A - Have you heard of Flood Planning Levels before?
Answered: 23 Skipped: 2
No
52%
Yes
48%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q9B - Do you feel that Flood Planning Levels are necessary for the protection of property and life?
Answered: 21 Skipped: 4
To some degree
33%
No
0%
Yes
67%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q9C - Do you understand what a freeboard is and why it is included in flood planning levels?
Answered: 23 Skipped: 2
To some degree
9%
No
65%
Yes
26%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%


Q9D - Do you think the uncertain future climate should be taken into account in Flood Planning Levels?
Answered: 23 Skipped: 2
To some degree
44%
No
9%
Yes
48%
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

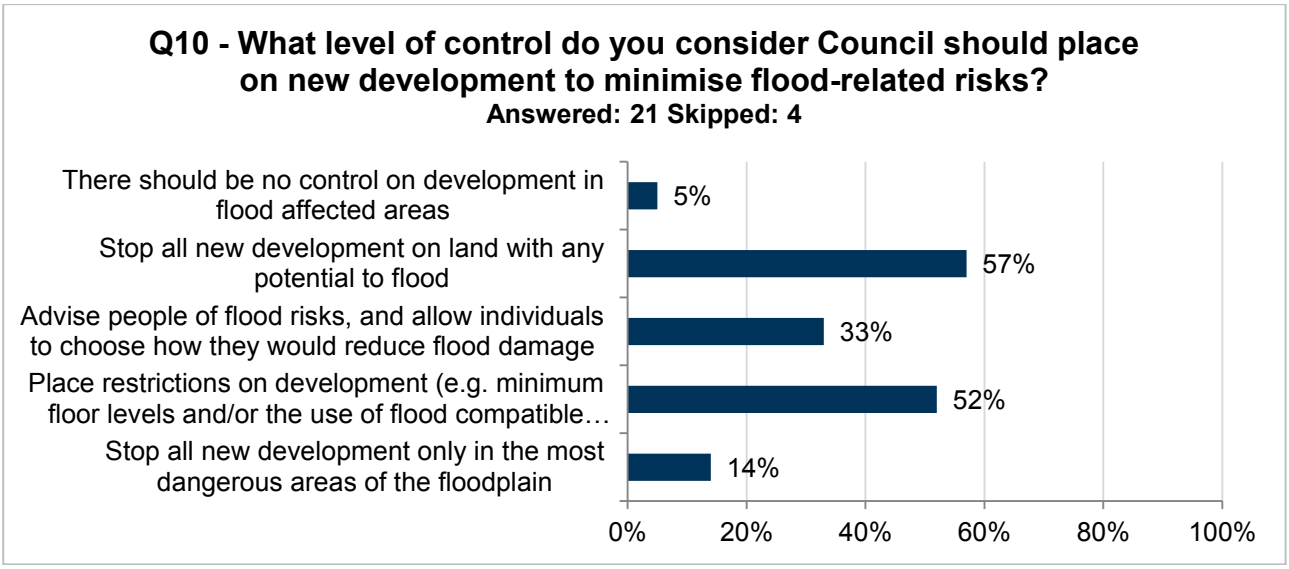


Table 4-1 (Question 8 in survey) highlights the preferred mitigation options based on the responses to the community questionnaire. Each option had its total score calculated based on the responses received and ranked from lowest to highest score.

Table 4-1 Preferred Floodplain Management Options

Floodplain Management Option	Rank
Regrade road and overland flowpath (eg Falcon St and Talbot Rd)	1
Other	2
Construct berms behind properties to redirect flowpath (eg Low Bridge Pl)	3
Construct berm and improve channel / flowpath (eg Alexander Avenue near Log Bridge Pl)	4
Flood forecasting, floodwarning, evacuation planning and emergency response	5
Construct detention basin and channel improvements (eg Gloria Park)	6
Construct berms in channel to create detention storage (eg Log Bridge Pl)	6
Culvert and pipe upgrades	8
Education of community, providing greater awareness of potential hazards	9
Clear overland flowpath to drain road to downstream (eg Oaklands Rd near Hall Pde)	10
Regrade road and overland flowpath (eg Lester Ave and Oaklands Rd)	11
Construct berm and improve channel / flowpath (eg Oaklands Rd near Derain Cres)	11
Create overland flowpath to drain road to downstream and create additional detention storage upstream (eg Blue Hills Rd and Grove St)	13
Clear overland flowpath to drain road to downstream (eg Rocklea St)	14
Construct bund / flood deflector and create overland flowpath to drain road to downstream (eg Luchetti Avenue)	15
House raising / voluntary purchase	16

These results are based on the respondents providing the correct weighting for their preferred option with 1 being the most preferred and 5 being the least preferred (21 respondents answered this question).

It should be noted that culvert and pipe upgrades had the most respondents with 61.54% stating it was their most preferred option (8 respondents stated it was the most preferred option).

4.4.3 Outcomes of Community Questionnaire

Based on the feedback provided within the completed questionnaires received the following key outcomes have been derived:

> There is a general consensus within the community that the Hazelbrook/Woodford Catchment is subject to flooding, with 90% indicating concern for flooding in their local area. A total of 82% of respondents indicate concern about the flood risk to their own property.

> Most respondents (100%) believe that flooding in their area is primarily attributable to a lack of capacity in the stormwater network causing drainage systems to surcharge, with few (12.5%) respondents believing local creeks overtopping their banks is the key contributor.

- Most respondents (92%) have experienced flooding in the Hazelbrook/Woodford Creeks catchment.
- Flooding in the area is thought to be as a result of overland flow through properties located on steep slopes or hills (89%) and blockage of stormwater drains (63%). Other comments were accepted as an option with a few respondents indicating flooding is a result of new developments and infrastructure.
- Respondents were equally spread for their awareness of Flood Planning Levels (48% aware). All respondents (100%) agreeing that Flood Planning Levels are a necessary method of flood risk management at least to some extent. Most respondents (65%) do not know what freeboard is and why it is included in flood planning levels.
- 91% of respondents believe that uncertain climate should be taken into account in Flood Planning Levels.
- Respondents are mixed as to the best approach to the level of control Council should place on new development to minimise flood-related risks with 52% believing placing restrictions on development (e.g. minimum floor levels and/or the use of flood compatible building materials) is appropriate. A total of 33% responded that Council should advise people of flood risks, and allow individuals to choose how they would reduce flood damage and 71% believing all new development should be restricted depending on location.

It is noted that some of these questions were skipped by survey respondents.

These outcomes were taken into account during the formulation and assessment of potential flood mitigation options (**Section 10**).

4.5 Community Workshops

Two meetings were held at Hazelbrook Bowling Club on the 23rd and 25th November 2015 whereby attendees could view model results for flood affectation at their property, and discuss their flood experience and recommendations for management one-on-one. Flooding at about 11 locations were discussed at the two meetings.

4.5.1 Overall Response Summary

Responses from the questionnaire and community workshops are summarised for each of the sub catchment flowpaths as shown below . Not all sub catchments were identified to have flooding issues based on the community responses received.

4.5.1.1 Rocklea

No comments received for this sub catchment.

4.5.1.2 Hall

No comments received for this sub catchment.

4.5.1.3 Fern

No comments received for this sub catchment.

4.5.1.4 Hall – Pine

The natural flow path at the rear of properties on Grove Street has, on several occasions, flooded nearby properties. A lack of weed management within the flow path may have exacerbated flooding. Properties in Grove Street were reported to have been subjected to flooding (dwelling and land) multiple times.

4.5.1.5 Luchetti – Oaklands

A local drain on private property between Roberts Road and Lyons Place has, on several occasions, been filled / blocked, which may impact on flooding to neighbouring properties. Previously Council has cleared the drain to restore the flowpath.

The bush regeneration team at Kihilla (on Queens Road) has enquired as to if they are able to assist in flood management.

Properties in Scullin Circuit are inundated by runoff from that is reported to be sourced from Korowal School. Council has advised that this is a natural flowpath.

A small footbridge on private property over the natural watercourse at the rear of properties on Luchetti Avenue has been damaged several times and is not covered by insurance.

There is a natural watercourse through a property in Oaklands Road which is reported to have flooded resulting in damage to the property. Flow at the Oaklands Road frontage is constrained by pipe capacity and vegetation growth in the vicinity. Clearing of the outlet on the downstream side of Oaklands Road may not assist.

Access is restricted at some properties in Oaklands Road during flooding. Resident have noted they could not drive their car due to flooded road. Pipe beneath driveway access at 78 Oaklands Road surcharges and causes flooding.

4.5.1.6 Park – Oaklands

Resident are concerned about impact of flooding and any works around Gloria Park affecting sporting teams and the bowls club.

Several open channels on the eastern side of Gloria Park overflow and inundate properties (e.g. properties in Park Road). Flow can occur in the channel for several days after a storm event. Inundation is exacerbated by blockage to the pipe crossing the watercourse and limited maintenance to remove debris.

Inundation of properties in Oaklands Road (on opposite side to watercourse from Gloria Park) is potentially due to local overland flow rather than mainstream overland flooding.

Properties on the eastern side of Oaklands Road (at the intersection with Derain Crescent) experiences runoff from the road during intense storms. However, dwellings have not been inundated and generally flooding is more of an issue from Oaklands Road rather than the nearby creekline.

The open watercourse at Origma Avenue is reported to be regularly blocked by debris at the pipe under the road. Some flooding of the road has been observed but residents did not consider this to be a major issue as runoff is generally confined to the channel during large storms. Resident has undertaken works to stabilise the channel with rock to prevent erosion.

4.5.1.7 Log Bridge

Runoff from Glendarrah Street (near intersection with Rosedale Ave) overflows through properties to the rear of properties on Log Bridge Place. This runoff results in flooding of dwellings on Log Bridge Place as a small berm originally constructed at the rear of the properties is not sufficient to convey flow. Development upstream, on Glendarrah Street for example, is considered by residents to potentially have exacerbated flooding.

4.5.1.8 Hazel

No comments received for this sub catchment.

4.5.1.9 Falcon

Runoff ponds on Albert Road (near the intersection with Falcon Street) creating a potential hazard. Runoff overflows through properties (toward the natural watercourse to the south) and has flooded close to floor level in the past.

The bottom of the Falcon Street hill floods.

4.5.1.10 Cunningham

An overflowing storm drain flooded the sheds and rear yards of Talbot Road in either 2010 or 2011. Flow from the road way banks up in the kerb and almost flows down driveway. The driveways in this area have been built up over time.

The stormwater drain on some properties is eroding and silting. Sections of the drain are considered to be ponding, posing a hazard. Residents suggested that the channel has moved over time by way of erosion.

4.5.1.11 Clearview

No comments received for this sub catchment.

4.5.1.12 Mountview

No comments received for this sub catchment.

4.5.1.13 Weroona

No comments received for this sub catchment.

4.5.1.14 Woodford

No comments received for this sub catchment.

4.5.1.15 Station

No comments received for this sub catchment.

4.5.1.16 Beauford

No comments received for this sub catchment.

4.6 Public Exhibition

The draft Floodplain Risk Management Study and Plan (FRMSP) was on public exhibition from 1 September to 10 October 2017. The Council held two facilitated Community Information Sessions during the public exhibition period.

The community was informed of the public exhibition by:

- Advertisement in the Blue Mountains Gazette on 31 August and 21 September 2017;
- Information and copy of the draft FRMSP on the Council's Website and Have Your Say; and
- Reference copies of the draft FRMSP available to residents for review at Katoomba Council office, and libraries at Springwood, Katoomba, Wentworth Falls and Lawson.

There were no submissions made during the public exhibition of the final draft FRMSP. It is noted that community consultation was undertaken in earlier phases of the project with a high level of participation.

5 Existing Flood Behaviour

5.1 Flooding Behaviour

The study area features a number of steep ridges and valleys forming well defined flow paths draining north east. The area contributing to each flow path can be described as a sub-catchment. The breakup of sub catchments is shown in **Table 5-1** and **Figure 5-1**. The flooding behaviour for each sub catchment is explained in the following sections.

Table 5-1 Sub catchment Breakup

Sub Catchment	Area (km^2)
Hall	0.199
Rocklea	0.498
Fern	0.557
Hall - Pine	0.431
Luchetti - Oaklands	0.41
Park - Oaklands	0.647
Log Bridge	0.321
Hazel	0.302
Falcon	0.507
Cunningham	0.44
Clearview	0.521
Mountview	0.748
Weroona	0.3
Woodford	0.468
Station	0.383
Beauford	0.321

Given the nature of the sub catchments (steep, narrow and short), and development is generally confined to the upper parts of the catchment, Short duration storms are likely to be of most concern with regard to the management of flood risk.

Flood extents for the following events are shown in **Appendix D.** The mapped flood extents are filtered using the same methodology adopted for the Flood Study (2013).

- 20% AEP Flood Extent – Figure 5-3
- 10% AEP Flood Extent – Figure 5-4
- 2% AEP Flood Extent – Figure 5-5
- 1% AEP Flood Extent – Figure 5-6
- 0.5% AEP Flood Extent – Figure 5-7
- PMF Flood Extent – Figure 5-8.

5.1.2 Hall

A small area of the upper section of the Hall sub catchment is developed. A low point in the road on Hall Avenue collects flow, and with little storage in the road, overland flow will develop through properties in Hall Avenue. This flow then contributes to flows from the Rocklea sub catchment.

5.1.3 Rocklea

A large proportion of this sub catchment is bush land and zoned as environmental conservation. Properties in Cliff Avenue and Rocklea Street appear to be subject to overland flow from the land above and to the west as flow drains towards defined natural flow paths.

There is currently no development nor zoning to suggest future development in the region where mainstream flow forms.

5.1.4 Fern

The upper parts of the Fern sub catchment are developed with lower sections consisting mainly of bushland. Overland flow appears to develop downstream of the development and hence only minor localised issues would be evident upstream. The arrangement of the development is such that roads are aligned perpendicular to the flow path.

A defined flow path is not present within the area developed as residential. The flow path begins to form downstream of the residential development.

The mainstream flow is well-confined as it drains towards the eastern edge of the study boundary.

5.1.5 Hall-Pine

The Hall Pine sub catchment consists of a main flow path through the centre of the sub catchment with isolated pockets of flooding throughout. The road infrastructure has been constructed such that it is perpendicular to the flow (Red Gum Avenue and Blue Hills Road). Modelling suggests that these roads will somewhat impacted in the 20% AEP and will overtop in the 1% AEP.

The flow path contains thick vegetation with only development present on the flood extent fringe. Notably, properties in Hall Parade, and properties on the northern side of Grove and Brook Street are impacted by mainstream flooding, possibly as low as the 20% AEP event.

The downstream flow path does not impact any property or buildings as such although peak flow velocities approach 2 m/s.

5.1.6 Luchetti-Oaklands

The Luchetti-Oaklands sub catchment contains a small pocket development zoned as environmental living.

A piped drainage system collects flow from properties west of Queens Road. This piped system runs from Roberts Road, along Luchetti Avenue before discharging into an open channel just downstream of Scullin Court. This piped drainage system forms the basis of drainage within this sub catchment with overland flow generally confined to Luchetti Avenue and nearby properties.

Properties at the eastern end of Luchetti Avenue are impacted by overland flow from the upstream catchment. The subdivision under assessment at Luchetti Avenue will divert flows away from impacted properties and reduce the incidence of flooding.

This flow path crosses Oaklands Road and will likely overtop in storm events.

Part of the land south of Luchetti Avenue (where overland flow develops) is zoned as environmental living. Any development in this region would likely increase the flood impact on downstream properties as overland flow already affects these properties and introducing impervious surfaces will introduce increased runoff.

5.1.7 Park-Oaklands

The Park – Oaklands sub catchment contains one major flow path through the centre of the sub catchment. Overland flow begins to develop just north of the sports oval. A number of properties are likely to be impacted by flooding but most likely land areas rather than buildings.

The flow path intersects with Oaklands Road adjacent to KU Children's Services. The road does not appear to become in undated in the 20% AEP event. Flood mapping for the 1% AEP event suggests the road will overtop. Flooding here will result in access problems for Oaklands Road and may impact access to the childcare centre. It should also be noted that bus stops are located here.

Downstream of Oaklands Road the flow path is well contained by the natural formation of the land. A number of properties on Burwood Place and Origma Avenue are positioned within this low lying area and are likely to be impacted by flooding (some properties as frequent as the 20% AEP event).

5.1.8 Log Bridge

The upstream area of the Log Bridge sub catchment contains a mix of land uses namely low and medium density residential, and local centre. This, combined with the highway at the top end of the catchment creates a region of relatively high imperviousness. Flow from this region generally drains to Log Bridge Place

where overland flow begins to develop. The flow path is well defined and is generally confined to one flow path through the centre of the catchment.

Log Bridge place is a relatively new development and contains offline stormwater detention. The flow path passes through this development but does not appear to impact any buildings.

There is minimal existing development downstream of Alexander Avenue with isolated cases of flood inundation.

The flood extent does impact an area zoned as 'deferred matter'. This is discussed in **Section 8.**

5.1.9 Hazel

The top end of the Hazel sub catchment consists of a small pocket of medium density residential and environmental living zoned land. Drainage from the medium density residential land is piped and discharges at the rear of 7 Alexander Avenue. This combined with natural runoff from surrounding areas contributes to the formation of overland flow upstream of properties on Hazel Avenue.

There are some properties in Hazel Avenue that are positioned in a low lying area and are subject to overland flow in the 20% AEP event. Flood depths in the order of 0.5 m are observed here with velocities of approximately 1.5 m/s for the 1% AEP event.

A drainage pipe (diameter 750 mm) is positioned within the flow path with the likely intent of passing flow in lieu of an overland flow path.

Downstream of Hazel Avenue the flow path passes through area zoned as 'deferred matter'. This is discussed in **Section 8.**

5.1.10 Falcon

The top end of the Falcon sub catchment contains a developed environmental living area serviced by a piped drainage system. This drainage system also collects runoff from the highway. Flow is discharged to the main flow path. There are a number of point discharges to the flow path as the flow path extends downstream, mainly collection from road drainage.

The issue for flooding within this sub catchment is properties constructed adjacent to the major flow path. Four piped discharges are located within close vicinity of each other.

The flow path downstream of Talbot Road is contained and has no impact on existing developments.

Flow here joins with the outfall of the Cunningham sub catchment.

5.1.11 Cunningham

The main flooding feature within the Cunningham sub catchment is the main flow path through the centre of the sub catchment. Only isolated cases of flooding are observed elsewhere.

Overland flow begins to develop at the low point of Cunningham Street.

A 600 mm diameter pipe is positioned between two properties in an attempt to pass flow, although flooding of the roadway and properties will occur in the 1% AEP event.

Further downstream a property at the end of the Falcon Street cul de sac is impacted by flooding.

An isolated instance of flooding is also observed at the end of Talbot Road. The low point is serviced by two gully pits. Properties on the southern end of Talbot Road are likely to be impacted by flood waters if these pits fail or inflows exceed pit capacity / pipe capacity.

5.1.12 Clearview

The Clearview sub catchment contains a single flow path through the centre of the sub catchment. Development is generally constrained to the ridge line of the sub catchment boundary with the flow path only impacting properties in a small number of instances where development extends into the valley.

5.1.13 Mountview

Development within the Mountview sub catchment exists adjacent to the Great Western Highway. The flow extends through the centre of the sub catchment with only minor instances of private property inundation.

5.1.14 Weroona

Only a small proportion of the Weroona sub catchment is contained within the study area. Only minor instances of building flooding are observed.

5.1.15 Woodford

The main flow path in the Woodford sub catchment drains west to east. The top end of the sub catchment consists of park land. This is where overland flow begins to develop. Woodford Avenue runs perpendicular to the flow path, although it does not appear to be inundated in the 1% AEP event.

No structures appear to be present in the downstream flow path and the land is zoned as environmental conservation.

5.1.16 Station

Development within the Station sub catchment is confined to the area adjacent to the northern side of the Great Western Highway and the eastern sub catchment ridge line.

The main flow path through the centre of the sub catchment does not appear to impact any properties.

A section of Station Road appears to flood in the 20% AEP event although depths only in the order of 200 mm are observed.

The study area also includes a region to the south of the Great Western Highway. The land drains towards the south and is intersected by the rail corridor. Flood depths in the order of 0.5 m to 1.0 m for the 1% AEP are observed here over the railway line.

5.1.17 Beauford

The Beauford sub catchment consist of regions both north and south of the Great Western Highway. The major concern here is the effect the rail corridor and the highway have on flow draining towards the south with flooding occurring residential zoned land just south of the railway line.

Only minor, isolated instances of flooding occur north of the highway.

5.2 Critical Infrastructure and Vulnerable Developments

Critical infrastructure and vulnerable developments can include but not limited to the following:

- Aged Care Facilities;
- Ambulance / Fire Brigade;
- Caravan Park;
- Childcare;
- Hospital / Medical Centre;
- Police Station;
- Pre School;
- Retirement Village; and
- School.

Critical infrastructure and vulnerable developments within the study area are highlighted in **Figure 5-2** in **Appendix D**. Generally, these developments are clear from the flood extent up to the PMF but access to and from the facilities could be impacted. KU Hazelbrook Preschool is located adjacent to a flow path. The facility is not impacted at the 1% AEP event but access is somewhat restricted on Oaklands Road from the south. Roads impacted by floodwaters are discussed in **Section 7.5.**

5.3 Historical Flooding

The Flood Study (NSW Public Works, 2013) identified 11 February 2012 and 6 February 2010 as significant events within the catchment.

5.4 Infrastructure Blockage

Blockages of the stormwater drainage system, such as inlet pits, pipes, open channels and culverts, can cause significant reduction of the system capacity and consequently exacerbate flooding as additional stormwater runoff is conveyed overland. Blockages of major culverts and road crossings have historically occurred during large storm events, as observed in Wollongong in 1998 and Newcastle in 2007. In some cases, stormwater culverts were completely blocked by debris in these locations.

Several modes of blockage of the stormwater drainage system may occur. Blockage may result from a build-up of debris comprising leaves, litter, and/or sediment over a period of time. During storm events debris from building sites, unsecured items from properties, tree branches and even vehicles can cause blockages.

As part of the *Hazelbrook and Woodford Creeks Flood Study* (NSW Public Works, 2013) a sensitivity test of the impact of infrastructure blockage was conducted. Detail of the assessment undertaken can be found in Section 8.7 of the Flood Study (NSW Public Works, 2013).

The sensitivity test for infrastructure blockage produced localised peak flood height increases of generally less than 0.2 m in the 1% AEP design flood event. The blockage scenario did not significantly alter flow paths although it was recognised that in some cases a small number of properties would be affected.

5.5 Flood Hazard

5.5.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (Figure L2, NSW Government, 2005). The Floodplain Development Manual (2005) defines two categories for provisional hazard - High and Low.

> 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 definition of these categories is shown in **Figure 5-1**.

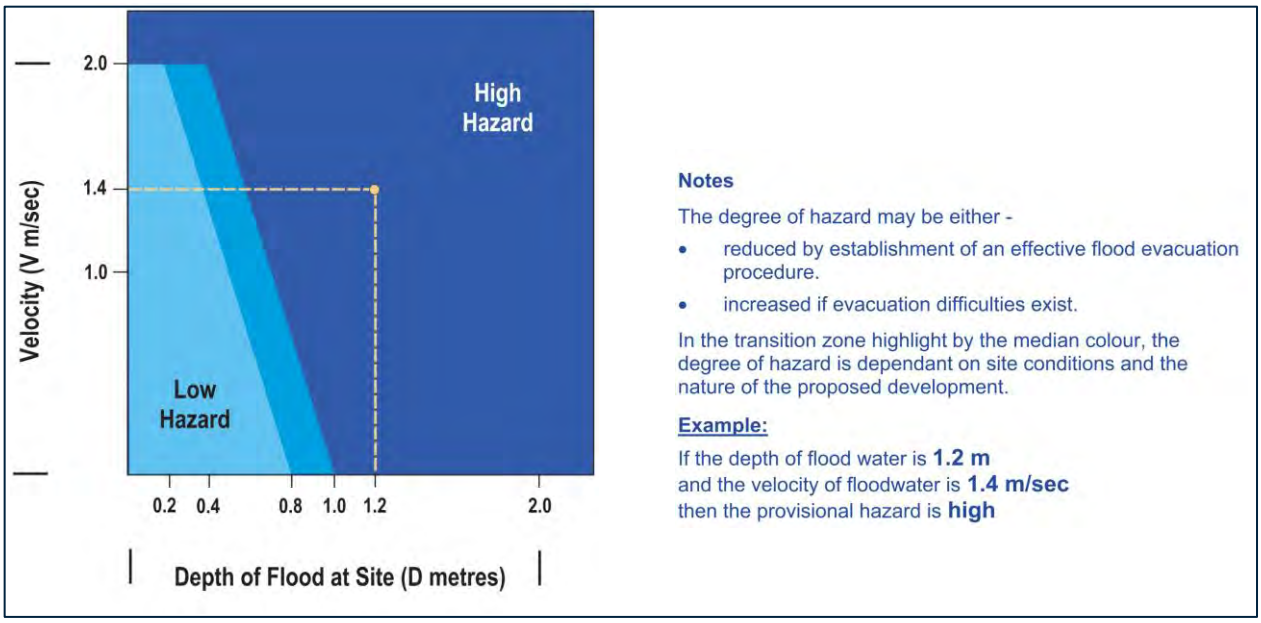


Figure 5-1 Provisional Hazard Categories (from Appendix L of the Floodplain Development Manual)

The provisional hazard maps in the Hazelbrook and Woodford Creeks Mainstream and Overland Flow Flood Study (NSW Public Works, 2013) were prepared using the methodology set out in the Floodplain Development Manual (NSW Government, 2005), and has been used as the base to determine true flood hazard for this study.

5.5.2 True Flood Hazard

Provisional flood hazard categorisation based around 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 the:

> Size of the flood;

> Effective warning time;

> Flood readiness;

> Rate of rise of floodwaters;

> Duration of flooding;

> Ease of evacuation; and,

> Effective flood access.

In the Hazelbrook and Woodford Creeks floodplain, many of the above factors are not applicable in terms of affecting hazard identification. However, consideration of the above listed factors is an important process to identify the particular issues which may result in hazardous conditions for specific locations or the entire study area.

5.5.3 Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, flood hazard has been mapped for the PMF event as well as the 0.5%, 1%, 2%, 10% and 20% AEP events.

The flood extents were defined using the methodology presented in Table 8.1 of the Hazelbrook and Woodford Creeks Mainstream and Overland Flow Flood Study (NSW Public Works, 2013).

5.5.4 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). The 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.

The critical storm duration for the study area is generally between 90 and 120 minutes (NSW Public Works, 2013). These short critical durations suggest that there is insufficient time to warn residents to take action.

As critical durations are fairly homogenous throughout the floodplain, all regions are subject to flash flooding, and consequently no region is more at risk due to warning time than any other. As such, no changes to the hazard mapping have been recommended as an outcome of effective warning time.

5.5.5 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. Based on the responses from the resident survey (NSW Public Works, 2013) the most prominent flooding events occurred on 11 February 2012 and 6 February 2010.

Based on the available information it is assumed that flood awareness across the study area is likely to be relatively consistent no particular part of the catchment appears to have more flood awareness than another. As a result, the provisional high hazard extents are not recommended to be altered as a result of flood readiness. Strategies around flood readiness are discussed in **Section 10.**

5.5.6 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 hazardous conditions. There are no conclusive guidelines on this parameter. As such this value has been selected arbitrarily to provide an indication of locations where waters can reach hazardous depths in a relatively short period of time.

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 0.2 m, 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 identifying hazardous areas.

A flood depth of 0.5 m 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 0.5 m flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (NSW Government, 2005).

In the study area, there are no properties with flow behaviour within these constraints which are not already encompassed by the provisional high hazard criteria. (**Section 5.5.1**). Roads are subjected to rapid rise of flood waters. Affected roads are discussed in **Section 7.5.**

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. Flooding durations are generally less than a couple of hours, even in the longer duration events. Those properties affected by longer periods of inundation are already flagged by the provisional high hazard criteria.

5.5.7 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 because of a number of factors, including:

> The number of people requiring assistance;

> Mobility of people;

> 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 (refer to **Section 5.5.4**) and exposure time, therefore evacuation may not be viable.

As discussed in **Section 2.3,** the population within the Lawson-Hazelbrook-Linden statistical area (encompassing the Hazelbrook Woodford catchment) has a median age of 40. In total 74% of the population are aged below 55 years, which indicates a community which is likely to be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures during a flood event. However, 22% of respondents are aged 14 years or younger. Younger children in particular could require assistance during a flood event.

A number of childcare facilities and preschools are located within the floodplain. Notably Clever Ducks Family Day Care and KU Children's Services. The facilities are located in an area classified as provisional low hazard. Floor levels are greater than the PMF flood level negating the requirement for evacuation.

Evacuation is a key issue with regards to flood risk and hazard within the LGA. This issue has been reviewed in more detail in **Section 10**. However, the provisional hazard mapping is not recommended to be modified as an outcome of evacuation issues in the study area.

5.5.8 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.

Access issues vary across the floodplain. For the purposes of this assessment properties were identified as being in one of these 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 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 0.3m of water. For the purposes of this assessment 0.3m is the threshold depth at which vehicles become unstable, even at very low velocities.

A location identified that may have effective flood access issues are properties north of 53 Oaklands Road. The 1% AEP event results in a peak flood depth of approximately 0.35m across Oaklands Road resulting in approximately 400 properties with restricted access. Since the flood depth is only just above the 0.3m threshold and the duration of inundation is likely to be less than an hour, the impact to residents is only minor but it should be recognised that Oaklands Road and Origma Avenue are the only access roads from Hazelbrook and are impacted somewhat by flood water.

The impact of climate change (increase in intensity of rainfall) could increase depth and velocity across the road, although the time to which the road is inundated will not increase substantially to warrant an increase in flood hazard.

It is recommended to install flood markers at this location and other similar locations to give the public an indication of flood depths (**Table 5-2** and **Section 10.4.4**)

5.5.9 Outcome of Hazard Assessment

The provisional hazard mapping was reviewed against the factors for True Hazard. Several key issues were identified relating to flood hazard and risk as a result of this review.

The effective flood access assessment identified the northern region of the study area may have access issues although it is recognised that the time to which the community has restricted access is relatively short (flood depth over 0.3m less than one hour).

The flood hazard mapping is included in **Appendix D**:

> 20% AEP True Hazard – Figure 5-10

> 10% AEP True Hazard – Figure 5-11

> 2% AEP True Hazard – Figure 5-12

> 1% AEP True Hazard – Figure 5-13

> 0.5% AEP True Hazard – Figure 5-14

> PMF True Hazard – Figure 5-15.

The following strategies identified to reduce flood risk within the true hazard process have been included in the floodplain risk management options (**Section 10**) and are detailed in **Table 5-2.**

Table 5-2 Management Options from True Hazard Assessment

True Hazard Category	Strategy	Management Option

Flood Readiness	Education program to ensure the community are aware of the flood behavior in the community.	EM2 and EM3
Effective Flood Access	Installation of flood marker at locations where flood water overtops roads. Locations are identified in **Section 7.5**	EM4
Effective Warning Time	The flash flooding nature of the catchment results in minimal warning time. Community should be aware of the flood behavior to understand how to respond.	EM2 and EM3

5.6 Hydraulic Categories

Hydraulic category mapping has been undertaken as for the 20%, 10%, 2%, 1%, 0.5% and PMF event. The criteria to which the mapping was undertaken is based on methodology stated in the Hazelbrook and Woodford Creeks Mainstream and Overland Flow Flood Study (NSW Public Works, 2013). Hydraulic Category Mapping is shown in **Appendix D:**

> 20% AEP Hydraulic Categories – Figure 5-16
> 10% AEP Hydraulic Categories – Figure 5-17
> 2% AEP Hydraulic Categories – Figure 5-18
> 1% AEP Hydraulic Categories – Figure 5-19
> 0.5% AEP Hydraulic Categories – Figure 5-20
> PMF Hydraulic Categories – Figure 5-21.

5.7 Property Flooding

The number of properties affected by flooding in the Hazelbrook and Woodford Creeks floodplain is shown in **Table 5-3.**

Table 5-3 Flood Affected Properties

Flood Event	Number of Flood Affected Properties	Number of Properties with Overfloor Flooding
20% AEP	192	44
10% AEP	193	52
2% AEP	198	63
1% AEP	199	66
0.5% AEP	199	67
PMF	207	103

6 Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. The various types of flood damages are categorised in **Table 6-1**.

Table 6-1 Flood Damages Categories

Type of Flood Damages	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc.) Infrastructure
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 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.

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 floodplain for which the study is being carried out. However, local damage data in most floodplains is not available and recourse is generally made to damage curves from other catchments, which is the case for this assessment.

A separate assessment of the economic impact of flooding on roads in the study area has also been undertaken.

6.2 Floor Level and Property Survey

A combined floor level and property survey has been utilised for the flood damage estimation. This consists of survey data from the following sources:

> A detailed floor level and property survey undertaken for 205 properties in June 2015; and

> Property data provided by Council.

6.3 Property Damage Analysis

A flood damage assessment for the existing floodplain conditions has been undertaken as part of the study to quantify the existing economic impact of flooding and to assist with comparing the benefit of the option. The assessment is based on damage curves that relate the depth of flooding on a property, to the potential damage within the property.

As described above, ideally the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and recourse is generally made to damage curves from other catchments. The NSW Office of Environment and Heritage (OEH) has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. The OEH guidelines include a template spreadsheet program that determines damage curves for residential properties including:

> Single storey, slab on ground;

> Two storey, slab on ground; and

> Single storey, high set.

The methodology for determination of flood damages within the study area is outlined in the following sections.

6.3.1 Residential Damage Curves

There are a number of input parameters required to calculate the damage to a property including floor area and level of flood awareness. The following parameters were adopted in developing the residential damage curves for the Hazelbrook and Woodford Creek Catchment:

> Damages are generally incurred on a property prior to any overfloor flooding. The default OEH curves allow for external damage of $11,256 (2015 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined to be 0.5m below the floor level for slab on ground). This has been adjusted so that a nominal value of $5,000 (2015 dollars) is used to represent external damage (eg. damage to gardens), where the ground level of the property is overtopped.

> All single storey properties have been conservatively classified as “slab-on ground”,

> The Effective Warning Time has been assumed to be zero due to the absence of any flood warning systems in the Hazelbrook and Woodford Creeks 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

> Residential damage curves have been used for all properties assessed.

6.3.2 Average Weekly Earnings

The OEH damage curves were derived for late 2001. To convert damages to today’s dollars, it is recommended that values in residential damage curves are adjusted by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). AWE is considered a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home.

The most recent data from the Australian Bureau of Statistics website (www.abs.gov.au) at the time of the damage assessment is for November 2015. November 2001 AWE is shown in Table D1 of the DECC (now OEH) guidelines, and November 2015 AWE were taken from the Australian Bureau of Statistics website ‘All employees average weekly total earnings’ as shown in **Table 6-2**. Consequently, all ordinates on the residential damage curves have been increased by 69%. In addition, all damage curves include GST as per OEH recommendations.

Table 6-2 AWE Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$676.40
November	2015	$1,145.60
Changes	69%	

6.4 Results

Properties from the floor level survey have been reviewed against flood depth results for the 1% AEP and PMF events. The inundation of properties can be classified as contiguous overland flow or isolated ponding behind buildings. The ponding behind buildings is cause by sheet flow from an upstream slope being “captured” behind the building. This produces an un representative reflection of the “true” damages.

In order to distinguish between the two cases and provide a representative reflection on flood damage, properties affected by a contiguous overland flow path in the 1% AEP scenario were adopted for damage calculations in all rainfall events up to the PMF. Properties affected by a contiguous overland flow path in the PMF for considered by damage calculation for the PMF.

It was found of the 208 properties surveyed, that 97 were affected by overland flow-paths in the PMF, and 62 were affected by overland flow paths in the 1% AEP event.

The results of the flood damage assessment are shown in **Table 6-3.** The average annual damage within the floodplain under existing catchment conditions is estimated at **$215,000**.

These results are based upon the updated flood model developed in April 2017.

Table 6-3 Flood Damage Assessment Summary

Event / Property type	Properties with Overfloor Flooding	Maximum Overfloor Flooding Depth (m)	Properties with Overground Flooding	Estimated Total Damage ($2015)
PMF				
Residential	57	1.2	97	$3,375,000
0.5% AEP				
Residential	25	0.7	62	$1,412,400
1% AEP				
Residential	23	0.7	62	$1,316,000
2% AEP				
Residential	22	0.7	62	$1,194,000
10% AEP				
Residential	17	0.6	60	$1,014,000
20% AEP				
Residential	15	0.54	61	$880,000

7 Flood Emergency Response Assessment

7.1 Flood Emergency Response

Flooding in the Hazelbrook and Woodford Creek catchment is mainly “flash” flooding. That is, flood inundation characteristically occurs quickly resulting in rapid onset of increased flood levels that may be elevated for only short periods of time. This flooding behaviour results in a limited time period in which to provide a flood warning or to arrange for evacuations.

When determining the risk to life associated with flooding, the flood hazard for an area does not directly imply the danger posed to people in the floodplain. The capacity for people to respond and react to flooding is a component of the risk of life associated with flooding. Flood emergency response is the formal and informal means of responding to flooding when it occurs.

To help minimise the risk to life associated with flooding, it is important that there are provisions for flood emergency response. There are two main forms of flood emergency response that may be adopted:

- Evacuation: The movement of people out of the floodplain before the property becomes flooded;
- Shelter-in-place: The movement of people to a building, or within a building, that provides vertical refuge on the site or near the site before their property becomes flood affected.

The following sections review the current emergency response systems that are in place and the feasibility for evacuation based on critical infrastructure and vulnerable developments (**Section 5.2**) and key road location overtopping (**Section 7.5**).

7.2 Flood Emergency Response Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. There are a number of documents relating to emergency preparedness and response for flood events, including:

- New South Wales State Emergency Management Plan (EMPLAN) (OEM, 2012);
- New South Wales State Storm Plan (SES, 2015)
- Blue Mountains Local Emergency Management Plan (EMPLAN); and
- North West Metropolitan Emergency Management District DISPLAN (Interim) (North-West Metropolitan Regional Emergency Management Commitee, 2011).

Current flood emergency response arrangements for flooding in the Hazelbrook and Woodford Creeks floodplain are discussed with reference to the key documents below.

7.2.1 North West Metropolitan Emergency Management District DISPLAN

The North West Metropolitan Emergency Management District covers the City of Blue Mountains, and many other local government areas (LGAs) from Hawkesbury, and Parramatta to the Northern Beaches. The aim of the North West Metropolitan Emergency Management District DISPLAN (2011) is for a coordinated and efficient management of the prevention, preparation, response and recovery arrangements for emergencies within the District. It describes the arrangements and agency responsibilities and provides policy direction for the preparation of supporting plans.

The DISPLAN lists significant assets and risks within the District located. The following list identifies assets that are contained within the study area, including:

- Motorways/Freeways/Highways – Great Western Highway.
- Significant rail line passing through district – Blue Mountains Line.
- Waterways – none.
- Water Storage Areas / Prescribed Dams – none.
- Correctional Centres – none.

> Industry and Critical Infrastructure – The Blue Mountains National park is listed, although this is located adjacent to the study area and therefore has not been considered. Specific reference is made to critical infrastructure in **Section 5.2**.

The primary hazards which could require district level response related to this Floodplain Risk Management Study are listed in **Table 7-1.**

Table 7-1 Primary Hazards

Hazard	Threat level			Comments
	Likelihood	Consequence	Risk Rating	
Severe Storms	Likely	Major	High	General threat throughout the District.
Flash Flood	Likely	Major	High	General threat throughout the District
Riverine Flood	Likely	Major	High	Refer to NSW SES Flood Plans

The agencies, organisations and/or committees with responsibilities to facilitate prevention and mitigation measures in potential flood disaster situations are listed in **Table 7-2**.

Table 7-2 Agencies Responsible for Flood Prevention and Mitigation

Hazard	Agency Responsible	Mitigation / Prevention Strategies
Flood	Local Councils	> Regulate property development & building construction through LEPs & DCPs > Development & maintenance of flood mitigation works. > Preparation of floodplain management plans.
	OEH	> Preparation of mitigation schemes and floodplain management studies and plans.

Responsibility for the conduct and coordination of public education in relation to flooding and severe storms is the NSW State Emergency Service (SES) as listed in **Table 7-3.**

Table 7-3 Agencies Responsible for Public Education on Flooding

Hazard	Agency Responsible
Flooding	NSW SES is responsible for ensuring that residents are aware of the flood threat and how to protect themselves against it.
Severe Storm	NSW SES is responsible for ensuring that the residents of their divisions are aware of the likely effects of storm impact and how to protect themselves against it.

Responsibility for the provision of warnings to the community, participating organisations and other agencies in relation to flood hazards or threats are listed in **Table 7-4**.

Table 7-4 Agencies Responsible for Provision of Warnings for Flood Hazards

Hazard	Agency Responsible	Warning Provided
Flooding	NSW SES Region Controllers	Local Flood Bulletins & Evacuation Warnings to: > Flood affected communities via the electronic Media; > the DEOCON; and > relevant Agencies and Functional Areas.
	Bureau of Meteorology	Local Flood Advices and Warnings

The Standard Emergency Warning Signal (SEWS) is a nationally adopted distinctive sound which may be broadcast over radio or television immediately before an urgent public safety message. The SEWS is designed to attract the attention of the public to an urgent safety message. The NSW Government Office of Emergency Management (OEM) advises "Following the signal there will be a message, pay immediate attention, listen to the announcement, and follow any instructions given. As part of a coordinated national emergency plan, an audio signal has been adopted to alert the community to an urgent safety message relating to an identified emergency such as a flood, fire, or earthquake aftershocks."

The OEM also advises of the Emergency Alert telephone warning system as "one of a number of ways we can warn the community of NSW about an emergency threat or emergency situation. If a decision is made to issue a warning via telephone during an emergency, an Emergency Alert would be sent to landline telephones based on the location of the handset, and to mobile phones based on the billing address within an area defined as under threat or affected by the situation. Emergency Alerts will only be used as a complement to other existing warning mechanisms such as door-knocking, broadcasts via local media outlets such as television, radio and newspapers and public address systems.

Evacuation of persons or animals from an area of danger or potential danger is a possible strategy in combating a flood event. **Table 7-5** is an extract from the DISPLAN (NWMREMC, 2011) and lists some individuals and organisations which have authority to order an evacuation of persons or animals and under which circumstances they have this authority. Disseminating warnings and advice to the public is generally through electronic media, but if urgently required, evacuation warnings will be reinforced by public address systems fitted to emergency services vehicles and door knocks of affected areas by evacuation teams (emergency services personnel and others as necessary). The NSW State Flood Plan (SES, 2015) does not list locations in (or near) the Hazelbrook and Woodford Creeks floodplain recommended for use as flood evacuation centres.

Table 7-5 Extract from DISPLAN (Evacuation Authority)

Individual / Organisation	Circumstances	Authority
A member of the Police Force	If satisfied that there are reasonable grounds for doing so for the purpose of protecting persons from injury or death.	The protection of persons from injury or death whether arising from criminal acts or in any other way. (S 6 (3) (b) *Police Service Act*.
A Police officer, and all other members of emergency service organisations	Emergency operation related to flood or storm or when directed by SEOCON.	Recognise authority of the Director-General NSW SES and emergency officers acting under the orders of the Director-General, division controller or local controller (S. 21 - *State Emergency Services Act*).
The Commissioner, NSW SES; or "Emergency Service Officer" (as defined) when authorised by the Commissioner	Emergency related to flood or storm; or when directed by SEOCON	Direct a person to: leave premises and move out of an emergency area or part thereof; taking any persons in their care with them; and/or not to enter an emergency area or part thereof, including doing all such things as are reasonably necessary to ensure compliance, including use of reasonable force (S. 22 - *State Emergency Service Act*).

7.2.2 City of Blue Mountains Local Disaster Plan

The aim of the City of Blue Mountains Local Disaster Plan is to detail arrangements for preparing for, responding to and recovering from emergencies within the City of Blue Mountains. The DISPLAN contains five key components:

- Introduction;
- Prevention;
- Preparedness;
- Response; and
- Recovery.

The following details the key components of the above sections on how that relate to flooding within the Hazelbrook and Woodford Creeks floodplain.

The DISPLAN identifies hazards and high risks. **Table 7-6** shows the interpretation of flooding as part of the DISPLAN. Flooding behaviour in the Hazelbrook and Woodford Creeks floodplain can be described as flash flooding (i.e. “some isolated locations”).

Table 7-6 Hazard and High Risk Areas

Type	Level	Responsibility	Remarks
Flooding	Minor	SES	Wentworth Falls Dam, some isolated locations (flash flooding)

The SES is identified as the combat agency for dealing with storms and flooding and are to coordinate the evacuation and immediate welfare of affected communities.

Responsibility for the development and implementation of prevention and mitigation measures in relation to flooding and storms is the NSW SES with assistance from Blue Mountains City Council (BMCC) as detailed in **Table 7-7.**

Table 7-7 Prevention Responsibilities and Strategies

Hazard	Rating	Remarks
Storm	High Likelihood Moderate to high consequence	Combat agency – SES, with assistance from emergency services and BMCC through MOUs
Flood	Low Likelihood Moderate consequence	Combat agency – SES, with assistance from emergency services and BMCC through MOUs

Preparedness generally consists of warning of an imminent storm or flood event for the Hazelbrook and Woodford Creeks floodplain. **Table 7-8** identifies the warnings to be provided for the stated event.

Table 7-8 Warnings Provided

Hazard	Responsibilities	Warning Provided
Flooding	Bureau of Meteorology	Onset of weather likely to cause flooding.
	State Emergency Service	Pump and stock warning, local flood advice, flood bulletins, flood heights and evacuation warnings to the Local Emergency Operations Controller (LEOCon) and relevant emergency services and functional areas.
Severe Storms	Bureau of Meteorology	General advice to wider community via the electronic media
	State Emergency Service	General advice and warnings to the LEOCon, and relevant emergency services and functional areas.

7.3 Emergency Response Guideline for Flash Flooding

In 2013, the Australian Fire and Emergency Service Authorities Council (AFAC) released a guideline on emergency planning for flash flood events providing a useful insight into the position of the emergency services authorities council, of which the NSW SES is a member. The guideline reflects a consensus on best practice for managing flash flooding, focussing on risk to life. The AFAC (2013) defines flash flooding as: flooding that occurs within six hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterised by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity.

The flood behaviour in the Hazelbrook and Woodford Creeks floodplain can be described as flash flooding as there is a rapid rate of rise of flood waters and affected roads can be inundated in under six hours

The guideline provides the following comments relating to appropriate emergency response in relation to flash flooding:

- The safest place to be in a flash flood is well away from the affected area. Accordingly, pre-event planning for flash floods should commence with an assumption that evacuation is the most effective strategy, provided evacuation can be safely implemented;
- Evacuation too late may be worse than not evacuating at all because of the dangers inherent in moving through flood waters. The timescale at which flash floods occur may limit the feasibility of evacuation as a response measure;
- A structurally suitable building means a building which is strong enough to withstand lateral flood flow, buoyancy, and suction effects and debris impact load;
- In the absence of a more detailed engineering-based code the following observations can be made regarding structural suitability for shelter-in-place buildings:
  - Single storey slab-on-ground dwellings, and relocatable homes and caravans are unlikely to be suitable;
  - Reinforced concrete or steel-framed multi-level buildings are more likely to be suitable; and,

  - Ideally the building should have sufficient area of habitable floor that will be flood free in a Probable Maximum Flood (PMF) event to accommodate the likely number of occupants,
- The pre-incident planning of evacuation must include operational contingency plans for the rescue of individuals who do not evacuate in a timely manner;
- Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (less than 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation;
- The dangers to be considered in relation to evacuation include evacuees being overwhelmed by floodwaters, and exposure to adverse weather such as lightning, hail, heavy rain, strong winds, flying debris, or falling trees and power lines;
- The dangers to be considered for shelter-in-place include risks resulting from:
  - Their own decision making (drowning if they change their mind);
  - Their mobility (not being able to reach the highest part of the building);
  - Their personal safety within the building (fire and accident); and,
  - Their health while isolated (pre-existing condition or sudden onset).

For these reasons, remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning. Where the available warning time and resources permit, evacuation should be the primary response strategy.

7.4 Flood Information Systems

Flooding in the catchments would be the result of overland flow flooding. Overland flow flooding in the catchment is of a flash flooding nature, where the warning time is less than six hours. The time to the peak of a flooding event and potential response times limits the implementation of a flood warning system.

In the case of flash flood catchments, the BoM provides general warning services, including:

- Severe Thunderstorm Warnings;
- Severe Weather Warnings; and
- Flood Watches.

These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. In some cases, two to three days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

7.5 Road Overtopping

Throughout the Hazelbrook and Woodford Creeks floodplain there are high importance local roads that are affected by flooding. These access roads are important when considering evacuation as a flood emergency response. A total of nine road overtopping locations have been identified as shown in **Figure 5-9.**

A summary of the flood affectation for key road locations is included in **Table 7-9**. Included in the table is the peak depth of overtopping for the 20% AEP, 1% AEP and PMF. In addition, the 1% AEP peak velocity is provided to give an indication of hazard (refer to **Section 5.5** for flood hazard).

Table 7-9 Summary of Roads Affected by Flood Inundation

ID	Name	Road Level (m AHD)	20% AEP Depth (m)	1% AEP Depth (m)	PMF Depth (m)	1% AEP Velocity (m/s)
1	Rocklea Road	634.5	0.25	0.32	0.52	1.8
2	Red Gum Road	633.5	0.28	0.36	0.66	2.2
3	Blue Hills Road	628.8	0.25	0.36	0.62	1.8
4	Oaklands Road 1	619.3	0.34	0.45	0.85	2.0
5	Oaklands Road 2	628.8	0.23	0.34	0.65	2.0
6	Log Bridge Place	630.8	0.23	0.29	0.47	0.9
7	Origma Avenue	616.9	0.30	0.5	0.87	1.1
8	Alexander Road	613.8	0.26	0.32	0.57	1.1
9	Hazel Avenue	602.8	0.35	0.43	0.73	1.6

The road overtopping at the two locations on Oaklands Road and Origma Avenue have potential to cause problems with flood access to and from the northern part of Hazelbrook.

Oaklands Road is the only road that provides access to and from the northern Hazelbrook area, therefore road closure as a result of flood inundation could result in major disruption.

7.6 Evacuation Timeline

When considering flood evacuation, the most important areas to consider are the flood affected neighbourhoods as these are the areas that are most at risk. Therefore this analysis focusses on the key road locations.

The *NSW SES Timeline Evacuation Model* has been the de facto standard for evacuation calculations in NSW since it was first developed for evacuation planning in the Hawkesbury Nepean Valley. Though the guideline has not yet been released, the paper *Technical Guideline for SES Timeline Evacuation Model* was prepared by Molino et al (2013) to brief the industry on the application of the guideline.

The timeline assessment of evacuation potential relates to the time required for regional evacuation of floodplains from doorknocking by SES volunteers through to the evacuation of all occupants from the region.

At the centre of the timeline methodology is the following concept:

Surplus Time = Time Available – Time Required

If surplus time is positive then evacuation of all occupants is feasible, while a negative value implies evacuation of all occupants is not likely to be achieved. The determination of the two times; Time Available, and Time Required is summarised in the following sections.

7.6.1 Time Available

The time available is dependent upon the rate of rise of waters, meaning it varies for each scenario. As an example, the time to peak for various storms at Oaklands Road (Site 5, shown in **Table 7-9**) is shown in **Figure 7-1**.

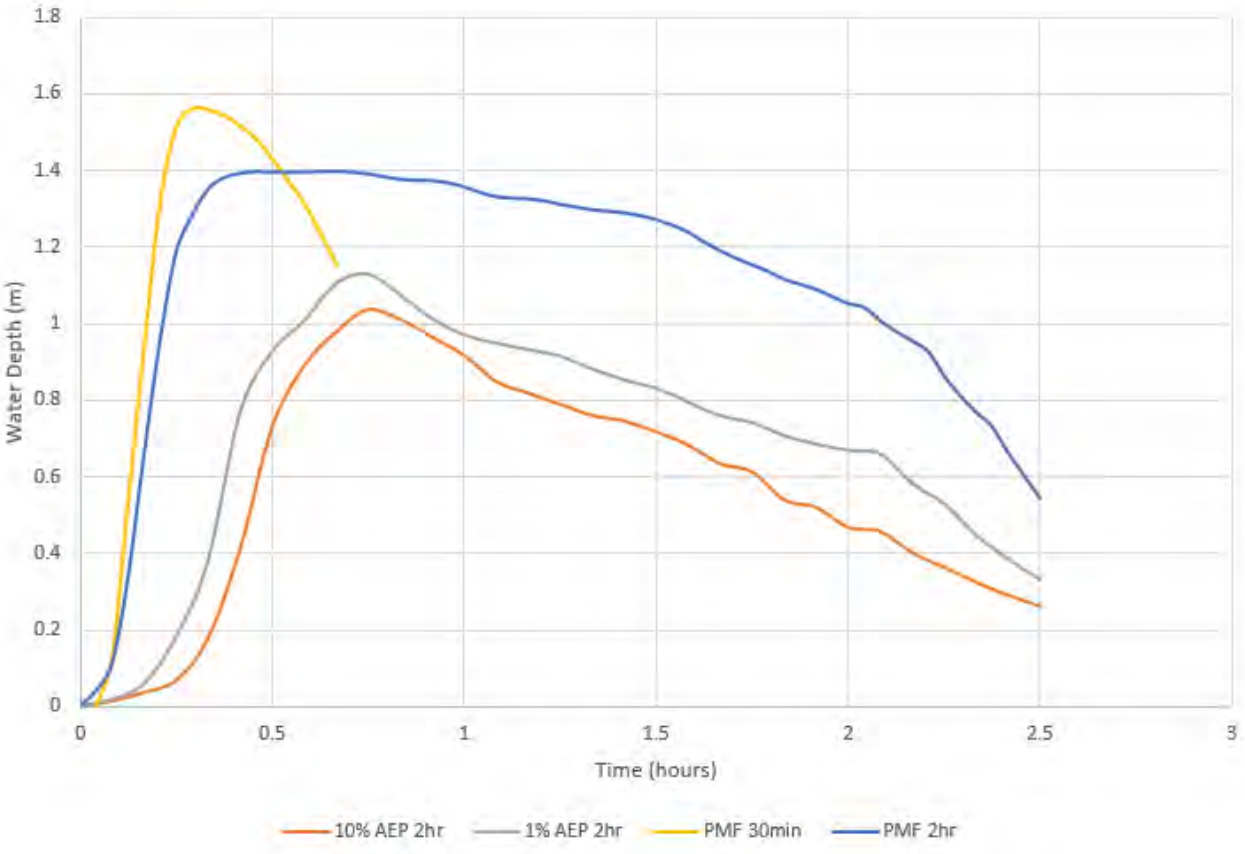


Figure 7-1 Water Depth Time Series for Oaklands Road

The figure is intended to give an indication of time to flood peak within the catchment by presenting a representative location. The water level depths to do not correlate the road flood depth but rather the depth of the stream immediately upstream of the road crossing.

As presented, the time to peak is less than one hour, for all the design flood events considered.

7.6.2 Time Required

The SES evacuation timeline model uses the following equation to calculate Time Required:

Time Required = Warning Acceptance Factor (WAF) + Warning Lag Time (WLT) + Travel Time (TT) + Travel Safety Factor (TSF)

Where the following values are recommended in the guideline:

WAF = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.

WLT = 1 hour – an allowance for the time taken by occupants to prepare for evacuation.

TT = Variable – the number of hours taken for the evacuation of all vehicles based on road capacity. NSW SES recommend a road lane capacity of 600 vehicles per hour.

TSF = Variable – added to travel time to account for any delays along the evacuation route for example resulting from accidents, this value is a variable of TT between 1 hour and 3.5 hours.

Before considering variable factors of time available, it is apparent both the WAF time and WLT already surpasses the time available. Therefore, the evacuation timeline suggests that evacuation is not feasible for the Hazelbrook and Woodford Creeks floodplain.

7.7 Shelter-in-Place Potential

The implementation of appropriate shelter-in-place strategies to effectively reduce flood risk to life requires consideration of the following:

> The feasibility of provision of a flood free refuge area;

> The duration of isolation of the refuge area.

The potential for shelter-in-place to be implemented for the Hazelbrook and Woodford Creeks floodplain based on these two factors is investigated in the following sections.

7.7.1 Flood Free Refuge

Flood hazard exposure is the main risk to life related to flooding. Therefore if shelter-in-place is implemented where occupants will remain on site for the duration of the flooding event, it is essential that the refuge not expose them to any direct flood hazard, i.e. that the refuge is flood free.

This applies for all possible flood events, therefore as for evacuation, the Probable Maximum Flood (PMF) has been adopted as the design event. The peak flood extents in the PMF event for the Hazelbrook and Woodford Creeks floodplain are shown in **Figure 5-8.** Given the steep nature of the catchment and well defined channels, a large proportion of existing building floor levels are outside the PMF extent.

7.7.2 Duration of Inundation

This duration of inundation relates to the length of isolation of any shelter-in-place refuges within the floodplain. Isolation results in the following sources of risk to life to occupants:

> Isolation from medical services: In the event of a medical emergency, a pre-existing condition, injury, or sudden onset event such as heart attack, medical services may not be accessible. This is a particularly high risk for vulnerable developments where residents are more likely to experience a medical emergency at any given time than other demographics;

> Isolation from supplies: Isolation from drinking water, food, amenities, and communication lines. This becomes a particular concern when the period of isolation exceeds 24 hours.

The duration of inundation (the time for which the location is submerged) for the critical duration events for the Hazelbrook and Woodford Creeks floodplain is less than one hour. Therefore isolation from services and supplies is not considered to be a major issue.

7.8 Evacuation vs Shelter-in-Place

7.8.1 Local Evacuation

The SES timeline approach to assess time required to evacuate is based on a specific sequence of events; SES monitor, and notify occupants of a region to evacuate following initial reluctance. However, evacuation may occur at a more localised level through a different sequence of events; occupants visually see flooding in their vicinity and respond instinctively by moving to higher ground.

This sequence relies less on emergency services co-ordination and more on the common sense of the resident to respond to observed flooding through evacuation. It is not dissimilar to the expected sequence of events for shelter-in-place with the exception that occupants evacuate to higher ground rather than elevated buildings. This means that a high level of flood awareness would be required for this strategy to be feasible.

The time available for evacuation is in the order of one hour. At this time, a number of roads begin to overtop making movement within the catchment difficult and hazardous. Furthermore the duration of flooding is short (less than one hour), implying by the time evacuation is arranged and implemented, it is likely that the flood may have passed.

7.8.2 Shelter-in-Place

While not the preferred form of emergency response, in **Section 7.7** it was found that shelter-in-place is a feasible form of emergency response for the Hazelbrook and Woodford Creek catchments. Therefore in accordance with the AFAC (2013) guideline, shelter-in-place is seen as an acceptable solution if approached appropriately. This is discussed in **Section 10.4.1**

7.9 Flood Emergency Response Classification

Flood emergency response classification mapping was undertaken in accordance with the New South Wales Floodplain Risk Management Guideline (NSW Government, 2005) and is included in **Appendix D** as **Figure 7-2**.

The mapping identifies an area to the northern region of the study area as a 'High Trapped Perimeter Area' as a result of road overtopping at multiple locations along Oaklands Road. As previously discussed in **Sections 5.5.8** and **7.5**, road overtopping at these locations is at threshold where the flood depth could be considered to be unsafe. Given the flash flooding nature of the catchment, the time at which residents lose access to outside services is relatively short (less than one hour).

8 Policies and Planning

The Hazelbrook and Woodford Creeks floodplain is located in the Blue Mountains Local Government Area (LGA) where development is controlled by the Blue Mountains Local Environment Plan (LEP) and various development control plans (DCPs). The LEP is a planning instrument which designates land uses and development in the LGA, while DCPs regulate developments with specific guidelines and parameters.

8.1 Blue Mountains Local Environment Plan (2015)

The Blue Mountains Local Environment Plan (BMLEP) came in to effect on 15 February 2016.

The BMLEP adopts the Department of Planning and Environment's model flood planning clause as clause 6.10. The objectives of clause 6.10 Flood Planning are to:

- Minimise the flood risk to life and property associated with the use of land;
- Allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change; and
- Avoid significant adverse impacts of flood behaviour on the community.

The land to which this is applied to is the land at our below the flood planning level (1% AEP plus 0.5 m freeboard).

The BMLEP makes provision for 'Floodplain Risk Management' (clause 6.11). The objectives of floodplain risk management are:

- In relation to development with particular evacuation or emergency response issues, to enable evacuation of land subject to flooding events exceeding the flood planning level; and
- To protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

The land to which this clause applies to is land between the flood planning area and the level of the probable maximum flood, and land surrounded by the flood planning area.

8.2 Current Land Use and Zoning

As part of this study, Council has supplied the land use mapping adopted within the BMLEP.

The Hazelbrook and Woodford Creeks floodplain are predominately comprised of bushland and residential development north and north-east of the Great Western Highway. Development is denser on the catchment boundary north of Hazelbrook.

The land use within the Hazelbrook and Woodford Creeks catchments is controlled by the BMLEP. The zoning of the study area is shown in **Figure 2-3** and zone objectives are described in **Table 8-1** (BMLEP 2015).

Table 8-1 Hazelbrook and Woodford Creek Catchments Land Use Zones

Zone	Land Use	Zone Objectives
Environmental	E1 National Parks and Nature Reserves	> To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values.
	E2 Environmental Conservation	> To protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values. > To prevent development that could destroy, damage or otherwise have an adverse effect on those values. > To encourage land restoration works on disturbed bushland areas. > To restrict the development of private land that would be inappropriate because of physical characteristics or high

Zone	Land Use	Zone Objectives
		bush fire hazards, but only where less restricted development is permitted elsewhere on the land due to split zoning. > To maintain biodiversity in the Blue Mountains.
	E3 Environmental Management	> To protect, manage and restore areas with special ecological, scientific, cultural or aesthetic values. > To provide for a limited range of development that does not have an adverse effect on those values. > To protect the natural bushland buffer between towns, to avoid ribbon development and to conserve vistas of bushland obtained from public places and the Blue Mountains National Park. > To ensure that the form and siting of buildings, colours, landscaping and building materials are appropriate for, and harmonise with, the bushland character of the area. > To encourage landscaping and regeneration of natural bushland in areas with sparse tree or canopy cover.
	E4 Environmental Living	> To provide for low-impact residential development in areas with special ecological, scientific or aesthetic values. > To ensure that residential development does not have an adverse effect on those values. > To preserve and re-establish native bushland in those areas that exhibit a predominantly bushland character, where consistent with the protection of assets from bush fire. > To ensure that the form and siting of buildings are appropriate for, and harmonise with, the bushland character of the locality.
Residential	R2 Low Density Residential	> To provide for the housing needs of the community within a low density residential environment. > To enable other land uses that provide facilities or services to meet the day to day needs of residents. > To promote residential development in locations that are accessible to services and facilities. > To ensure that development maintains and improves the character of residential areas in a manner that minimises impacts on existing amenity and environmental quality. > To allow a range of non-residential land uses that are consistent with the predominant scale and height of adjoining buildings and do not unreasonably detract from the amenity of adjacent residents.
	R3 Medium Density Residential	> To provide for the housing needs of the community within a medium density residential environment. > To provide a variety of housing types within a medium density residential environment. > To enable other land uses that provide facilities or services to meet the day to day needs of residents.

Zone	Land Use	Zone Objectives
		> To consolidate residential opportunities in accessible localities within close proximity to commercial centres and railway stations. > To ensure that residential development contributes to the streetscape and has a scale and character that is consistent with adjoining residential land uses and minimises any adverse impact on the amenity of residents.
Recreation	RE1 Public Recreation	> To enable land to be used for public open space or recreational purposes. > To provide a range of recreational settings and activities and compatible land uses. > To protect and enhance the natural environment for recreational purposes. > To enhance the quality of life of residents and visitors and improve the amenity of the villages in the Blue Mountains through the provision and management of open space.
Business	B2 Local Centre	> To provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area. > To encourage employment opportunities in accessible locations. > To maximize public transport patronage and encourage walking and cycling. > To promote the unique character of each of the towns and villages of the Blue Mountains. > To maintain the economic viability of the towns and villages of the Blue Mountains. > To promote high quality urban design of built forms.
Special Purpose	SP2 Infrastructure (SP2 rd and SP2 rl)	> To provide for infrastructure and related uses. > To prevent development that is not compatible with or that may detract from the provision of infrastructure.

Two land use areas that were previously zoned in the 2013 LEP as environmental conservation and residential character conservation feature in the 2015 LEP as deferred matter. The change from the 2013 LEP to the 2015 LEP was a result of mapping anomalies and is likely to be resolved in future amendments of the LEP. The purpose of the 2015 LEP was to bring Council's older LEP's into the standard instrument.

These changes are not expected to have an impact upon this study.

8.2.1 Flood Affected Land Use Zones

A number of land uses are affected by the 1% AEP event and the PMF event. The percentage of flood affected zones within the study area is shown in **Table 8-2.**

Table 8-2 Flood Affected Land Use Zones

Land Use	Percent Affected 1% AEP	Area Affected 1% AEP (ha)	Percent Affected PMF	Area Affected PMF (ha)
E1 National Parks and Nature Reserves	10	1.5	19	2.8

E2 Environmental Conservation	10	31.2	16	53.2
E3 Environmental Management	4	2.6	8	5.3
E4 Environmental Living	3	7.7	9	24.0
R2 Low Density Residential	2	0.7	8	2.9
R3 Medium Density Residential	0	0	1	0.04
RE1 Public Recreation	3	6.5	11	2.6
B2 Local Centre	0	0	0	0
SP2 Infrastructure (SP2 rd)	6	1.2	11	2.1
SP2 Infrastructure (SP2 rl)	16	1.1	25	1.6
DM Deferred Matter	5	0.7	9	1.4

Streams are generally contained within land zoned as E2 Environmental Conservation (the greatest proportion of affected land).

Zones, with relevant development potential, affected by the 1% AEP event are predominantly E4 Environmental Living as these zones are generally located adjacent to streams.Although some locations are not directly impacted by flooding, flooding in nearby locations can restrict access into and out of that location. **Section 5.5.8** addresses these areas which are primarily zoned low density residential and environmental living.

8.3 Development Control Plan

A Development Control Plan (DCP) is prepared by Council and applied to specific types of development or areas of land and provide detailed development guidelines and controls. A DCP outlines specific controls and parameters that apply to development proposals. The current DCP for the Blue Mountains was adopted on 26 March 2015 and became effective on 15 February 2016.

The following sections of the DCP have relevance to floodplain management.

8.3.1 Section C6.4. Flooding

Section C6.4 is the primary source of flood controls within the DCP. The controls apply to:

> All development on land below the 1% AEP flood plus the required freeboard;

> Development of critical facilities on land below the PMF plus the required freeboard;

> Development on all land affected by or adjacent to a stormwater drainage system; and

> Development on land within a catchment that has not been the subject of a Floodplain Risk Management Study, but due to its location and topography, it is considered reasonable to expect that the land may be subject to an overland flow path and/or flood impacts.

The objectives of section C6.4 are:

> To control development at risk of flooding in accordance with the NSW Government's Floodplain Development Manual;

> To ensure that the economic and social costs which may arise from damage to property by flooding is minimised and can be reasonably managed by the property owner and general community;

> To reduce the risk to human life and damage to property caused by flooding by controlling development on land impacted by potential floods; and

> To ensure that development is appropriately sited and designed according to the site's sensitivity to flood risk.

Key controls with the DCP are:

> Building floor levels shall comply with conditions as detailed in **Table 8-3** (non habitable includes areas such as sheds or laundries, but excludes garages).

Table 8-3 Floor Levels for Buildings (from Blue Mountains DCP, Part C6 – Table 2)

Scenario	Floor Level
Habitable Floors - all development (excluding critical facilities)	
Inundated by flooding	1% AEP + 0.5m freeboard
Inundated by overland flow path	1% AEP + 0.5m freeboard
Habitable floors - Critical facilities	
Inundated by flooding	PMF + 0.5m freeboard
Inundated by overland flow path	1% AEP + 0.5m freeboard
Non-habitable floors – residential outbuildings (excluding garages)	
Gross floor area less than or equal to 10 square metres	1% AEP but not less than 0.15m above surrounding ground level
Gross floor area greater than 10 square metres	The applicable habitable floor level
Non-habitable floors – Industrial and commercial	
Located on flooding or overland flow path	1% AEP but not less than 0.15m above surrounding ground level
Material storage locations – all development	
Materials sensitive to flood damage, or which may cause pollution or be potentially hazardous during flooding	1% AEP + 0.5m freeboard

> All development that is in 'cut' is to address the impacts of overland flow path from upstream catchments, and ensure that there is adequate provision for flows paths around the structure, stepping up at least 225mm from the finished ground level to the floor level of the structure.

> The level of the driveway between the road and the car park shall be no lower than 0.3m below the 1% AEP flood, or such that the depth of inundation during the 1% AEP flood is no greater than the depth of flooding at either the car park or the road where the site is accessed.

> Car park floor levels shall comply with the conditions detailed in **Table 8-4**.

Table 8-4 Floor Levels for Car Parking (from Blue Mountains DCP, Part C6 – Table 3)

Scenario	Floor Level
Above ground level open car parking, car ports and garages	
Open car parking spaces and car ports	5% AEP flood
Residential garages with up to two spaces	1% AEP but not less than 0.15m above surrounding ground level
Residential garages with more than two spaces	Applicable residential habitable floor level requirement (Table 2 of the DCP)
Enclosed industrial/ Commercial parking spaces	Applicable residential habitable floor level requirement (Table 2 of the DCP)
Underground car park (where floor level is more than 0.8m below surrounding ground level)	
All driveways	1% AEP plus 0.3m freeboard at its highest point
All emergency exits	All underground garages and car parks to have emergency exits protected from inundation up to the 1% AEP flood plus 0.5m freeboard with a minimum of 0.2m freeboard from vehicle entry point.
All other openings inundated by flooding or local overland flow path	All openings to be sealed up to 1% AEP + 0.5m freeboard with a minimum of 0.3m above the surrounding ground level

8.4 Flood Risk for Future Development

Blue Mountains City Council were contacted to provide information on possible future development within the Hazelbrook and Woodford Creeks catchment and floodplain that may have an impact on hydrology. There is no obvious development planned within the study area that will have impact upon the hydrology of the catchment.

8.5 Other Relevant Policies and Plans

8.5.1 Blue Mountains City Council Climate Change Risk Assessment (Climate Risk, 2009)

This document is not a council adopted report but does provide insight into the hazards the BMCC may face in the future with regard to climate change and is relevant to the management of flood risk.

Climate change is a serious and critical issue for local government councils. The BMCC faces a number of risks that will be exacerbated by climate change. The risks are presented in the hazard categories:

> Primary (precipitation)

> Secondary (regulation and policy change)

> Tertiary (behavioural change)

With regard to flooding, the Climate Change Risk Assessment identifies extreme weather events as a primary hazard. Within the categories of governance, social, economic and environment, the following risks have been identified as extreme:

> House damage/ litigation increase from flooding;

- Road flooding;
- Risk to assets; and
- Pressure on emergency services.

The Blue Mountains City Council Climate Change Risk Assessment states:

"In light of recent science it is anticipated that the intensity of these storms will increase with a warming of Australian average temperatures. The resultant impacts would likely include an increase in disruption to key services such as electricity and transport, increased damage to infrastructure, higher accident rates including water and aviation sectors, and increased outbreaks of post-event disease and water-borne diseases from extreme rainfall (Department of Climate Change 2008)."

8.6 Summary of Recommendations for Hazelbrook and Woodford Creek

Based on a review of the relevant flood-related planning controls the following recommendations are provided:

- All documentation adopt consistent terminology, primarily with respect to naming conventions for design flood events. It is understood that both Australian Rainfall and Runoff (ARR) and OEH is now using AEP rather than ARI, and it may be prudent to adopt a consistent approach. It is noted that the BMLEP and the Flood Liable Land Policy (now superseded by the DCP) use ARI terminology;
- Clause 6.10 of the BMLEP makes reference to a flood planning level but a flood planning level is not stated. Clause 6.11 implies the flood planning level to be the 1% AEP plus 0.5m freeboard. It is recommended the definition of the flood planning level in clause 6.10 be clarified.
- The LEP defines the FPL as the 1% AEP event plus 0.5 m freeboard. The DCP provides a number of conditions to which an alternate flood planning level applies. To provide agreement between both the LEP and DCP it is recommended to rephrase the terminology in the LEP to reflect all conditions.
- As identified in the true hazard assessment, development north of Hall Parade is likely to be indirectly impacted by flooding due road inundation at Oaklands Road resulting in flood access issues. There is no specific provision for development within areas where their access is impacted by flooding.
- For defining the FPL for various scenarios, either 'flooding' or 'overland flow path' are termed. Part K: definitions of the BMDCP provides a definition of the term 'overland flow path' but is not well defined. It is recommended to provide a definition of 'overland flow' and clearly distinguish between the flooding and overland flow.

Recommendations of flood planning levels can be found in **Section 9**.

9 Flood Planning Levels

As stated within Appendix K of the Floodplain Development Manual (NSW Government, 2005):

> *Flood Planning Levels (FPL's) are an important tool in the management of flood risk. They are derived from a combination of a flood event, and a freeboard.*

The Flood Planning Level (FPL) for the majority of flood prone areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard which is generally set at 0.5 m for habitable floor levels. Both the BMLEP and DCP refer to a Flood Planning Level (FPL) of 1% AEP plus 0.5m freeboard. The DCP adds further detail to the FPL by identifying structures that deviate from this condition as detailed in **Section 8.3**.

With the completion of the Hazelbrook and Woodford Creeks Overland Flow Study (Public Works, 2013), recent data is available to inform the consideration of flood planning levels.

Factors for consideration in determining an appropriate FPL for a particular floodplain include:

- The Flood Planning Levels and minimum floor level requirements currently adopted by Blue Mountains City Council, and how this approach compares to other Councils in NSW;
- The design event adopted for the Flood Planning Level, including consideration of duration of inundation and the impacts this has on flood risk;
- The freeboard adopted within the Flood Planning Level which accounts for modelling uncertainties, local flooding effects and potentially climate change; and
- The determination of the Flood Planning Area and the number of flood affected properties.

9.1 Other Council Flood Planning Levels

To assist with benchmarking the current planning arrangements for Hazelbrook and Woodford Creeks study area, a comparison of Flood Planning Level and minimum floor levels approaches adopted by other selected Councils within the Sydney region and surrounds is shown in **Table 9-1.**

Table 9-1 Comparison of FPL and Minimum Floor Level Approaches for Selected Councils in NSW (As at March 2015)

Council	FPL Design Event	FPL Freeboard	Minimum Floor Level			Consideration of Flood Risk / Hazard Category
			Residential	Commercial / Industrial	Vulnerable / Critical	
Pittwater (now Northern Beaches Council)	Narrabeen Lagoon - 1% AEP (with coincident 5% AEP ocean event)	0.5m (0.3m for OLF*)	FPL (+ climate change for intensification)	FPL (+ climate change for intensification)	The greater of PMF/FPL (+ climate change for intensification)	Not specifically. Design provisions included in DCP.
Warringah (now Northern Beaches Council)	Narrabeen Lagoon - 1% AEP (with coincident 5% AEP ocean event)	0.5m	1% AEP plus 0.5m (PMF for high risk)	FPL (or PMF for high risk)	PMF or FPL whichever is greater	For high flood risk areas, a merits based approach to floor levels is required)
Manly (now Northern Beaches Council)	1% AEP (with coincident 5% AEP ocean event)	0.5m	FPL	FPL	FPL	No
City of Sydney	1% AEP	0.5m (0.3m min for OLF)	FPL (1% AEP for non-habitable floors)	1% AEP minimum (merit based assessment)	PMF or FPL whichever is greater	No
Randwick	1% AEP	0.5m (0.3m min for OLF)	FPL	FPL (1% AEP for non-habitable floors)	PMF plus freeboard	No
Leichhardt	1% AEP	0.5m	FPL	FPL (1% AEP accepted where impractical)	PMF or FPL whichever is greater	For high hazard areas, floor underside to PMF or FPL whichever is greater

Council	FPL Design Event	FPL Freeboard	Minimum Floor Level			Consideration of Flood Risk / Hazard Category
			Residential	Commercial / Industrial	Vulnerable / Critical	
Gosford	1% AEP (inclusion of climate change dependent on catchment)	0.5m	FPL (300mm above ground level for non-habitable)	FPL (300mm above ground level for non-habitable)	PMF	"If consequences are high, then consider raising floor levels above the FPL"
Woollahra	1% AEP	0.5m (0.3m for non-habitable)	FPL	FPL	FPL	No vulnerable developments permitted in medium and high risk precincts
Hornsby	1% AEP (0.9m SLR for habitable, 0.4m SLR for non-habitable)	0.5m	FPL	FPL	FPL	No
Wollongong	1% AEP (5% AEP for open space / non-urban) (plus design blockage of structures)	0.5m	FPL	FPL	PMF plus 0.5m freeboard	No development in high flood risk areas
Newcastle	1% AEP	0.5m	FPL (1% AEP for Garages)	FPL	FPL	No development in high risk areas
Parramatta	1% AEP (5% AEP for open space / non-urban)	0.5m	FPL	FPL	PMF plus 0.5m freeboard	No development in high flood risk areas
Wyong	1% AEP (all design events must consider mine subsidence)	0.5m	FPL (5% AEP for non-habitable)	FPL (5% AEP for non-habitable)	PMF	No development in high hazard areas

*OLF – Overland flow

9.2 Consideration of Flood Risk

9.2.1 Likelihood of Flooding

As a guide, **Table 9-2** has been reproduced from the NSW Floodplain Development Manual (NSW Government, 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 9-2** 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 0.5% AEP 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 9-2 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (AEP)	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
0.5%	30	5

9.2.2 Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels can be increased.

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. Part C6.4.2 - flood effects, of the current BMCC DCP restricts development that results in loss of storage or induces a change in flood level.

Given this, and other current controls within the DCP (**Section 8.3**), incorporating specific allowances for changes in land use in the FPL is not considered to be a significant issue within the catchment.

9.3 Freeboard

As outlined above, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL for overland flow (OLF) or mainstream flooding respectively. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin within the adopted FPL. This consideration may result in the adopted FPL being higher than the PMF in certain cases.

The *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013) discusses preliminary flood planning areas and levels. The preliminary adopted levels are:

- **Preliminary Flood Planning Area –** the lesser of the PMF extent (where depth is greater or equal to 0.1m), and the extent at which the 1% AEP + 0.5m level intersects with the topography. Small 'islands' of flooding (areas less than 250 m^2) with a low flood hazard are likely to be caused by local ponding or sheet flow, were removed from the planning area. This provides a simple, logical and scientifically justifiable means of determining the lateral extent of the flood planning area.
- **Preliminary Flood Planning Level –** the lesser of the PMF level and the 1% AEP +0.5m level within the Preliminary Flood Planning Area.

9.3.1 Factors Accounted for in Freeboard

As outlined above, the concept of a freeboard is to account for uncertainties in deriving design flood levels or local effects beyond the scope of the method of estimation and as such is generally used as a 'safety factor' to ensure that the design flood event that is planned for is not exacerbated due to uncertainties or local effects. The uncertainties are:

- Accuracy of model input data (ground survey): The flood model compromised of LiDAR data captured in June 2012. According to the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works,2013), The survey was verified against 17 ground points and was found to be accurate to + / - 0.1m. NSW Public works undertook an independent verification utilising survey control points and found the vertical accuracy to be slightly lower (detail on accuracy not provided in the report), however some control points were located in dense vegetation.
- Model Sensitivity: A sensitivity analysis was undertaken as part of the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013) and included the assessment of the following parameters:
  - Hydraulic structure blockage: The blockage scenario adopted in the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013) is as follows
    - 100% blockage of structure with opening width less than 0.9m;
    - 20% blockage of structure with opening width 0.9m and greater
    - 10% blockage of structure with opening width 2.7less than 0.9m;

    This results in changes of the order of + / - 0.02 m with localised changes of + 0.06 m
  - Hydraulic roughness: hydraulic roughness of the model was increased and decreased by 20%. The decrease in hydraulic roughness resulted a decrease in flood level in the order of 0.02 m to 0.05 m. highly localised increases of 0.1 m were observed. The increase in hydraulic roughness produced

increased flood levels in the order of 0.02 m to 0.05m. Localised increases and decreases of 0.1 m were also observed.

> Local factors that can result in differences in water levels across the floodplain. These factors can often not be determined in flood modelling, because they are too difficult, complex or expensive to incorporate. The Hazelbrook and Woodford Creeks flood model covers a relatively small area and as such, is was able to account for most local factors such as retaining walls and other structures. The model comprised of a 2 x 2m grid and included local stormwater drainage systems meaning localised flood issues should have been accounted for in the flood modelling.

> The cumulative effect of subsequent infill development of existing zoned land: This is not expected to be a significant factor as the floodplain is already significantly developed and the potential loss of flood storage and additional blockage of flowpaths is expected to be negligible compared to the existing scenario which is significantly obstructed.

Therefore for the majority of the catchment the flood model is not particularly sensitive to the underlying assumptions in the model (water level increases at most locations are less than 0.2 metres).

9.3.2 Climate Change

Climate change sensitivity modelling was undertaken as part of the Hazelbrook and Woodford Creek Flood Study in terms of increased rainfall intensity. Generally increases in flood level in the upper catchment are small (less than 0.2m). Flood levels in the lower catchment increased by 0.75m in land zoned as environmental conservation. These large increases are isolated within the study area and lesser increases in the upper catchment are more relevant for the assessment of flood planning levels.

The impacts of climate change can be accounted for within freeboard, such that climate change scenarios do not need to be adopted as the design event. The existing scenarios are appropriate.

9.3.3 Comparison of 0.3 and 0.5 Metre Freeboard

As part of this Floodplain Risk Management Study, two freeboards were assessed in detail:

> 0.5 metre freeboard which is commonly adopted in NSW; and

> 0.3 metre freeboard which was assessed due to the overland flow nature of flooding (i.e. lower depth of flooding and hence lower risk of uncertainty in the flood levels).

The key factor in comparing the freeboards is to understand the number of properties removed from the flood planning area as a result of a reduction in freeboard.

The comparison identified only a small number of properties to be removed from the flood planning area. This is likely due to the steep nature of the study area. A decrease of 0.2 metres would result in only a small reduction in the horizontal extent.

9.3.4 Freeboard Recommendations

A freeboard of 0.5m is recommended for the Hazelbrook and Woodford Creeks catchment based on the following:

> Model sensitivities are generally in the order of 0.2m;

> Flood level impacts of as a result of increased rainfall due to climate change are not likely to exceed 0.3m.

> The impact of selecting a freeboard of 0.5m over a freeboard of 0.3m does not result in a significant increase in the number of properties impacted by flood related controls.

Given the above, a freeboard allowance of 0.5m is recommended for adoption.

9.4 Consideration of Overland Flow

The BMDCP uses the terms ‘inundated by flooding’ and ‘inundated by overland flow path’ in determining minimum floor levels for development. The BMDCP defines the overland flow path as:

“Overland Flow Path means the path of rain-induced surface run-off that is not part of a defined watercourse or natural flow path, including run-off in excess of the capacity of the road and property drainage system.”

The BMDCP species different flood planning levels based upon whether the flooding is classified as 'overland flow' or 'flooding'. In most cases, the conditions are identical for 'flooding' and 'overland flow'. The only condition that specifies a different FPL for 'overland flow' is critical facilities where the flood planning level is based upon the 1% AEP event for 'overland flow' and the PMF event for 'flooding'.

9.5 Flood Planning Level Recommendation

The *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013) provided a preliminary flood planning area that sought to build on the what was initially provided in the BMDCP. The flood planning area is based upon a flood planning level of the 1% AEP flood level plus 0.5 m freeboard. The key factors in developing the flood planning area are:

- The 1% AEP flood extent based on the flood mapping filter in Table 8.1 of the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013)
- If the extent of the 1% AEP flood level plus 0.5m freeboard exceed the PMF extent, the 1% AEP flood level plus 0.5m freeboard exceed will be confined to the PMF Extent;
- The flood planning level is to be the lesser of the 1% AEP flood level plus 0.5m freeboard or the PMF flood level; and
- Flood islands (areas less than 250 m^2) and areas mapped as low hazard are removed from the flood planning area.

The key difference between the flood planning area method stated in the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013) and the DCP is that a filter is applied to the 1% AEP flood level to only consider 'real' flooding (to remove model 'noise' from the results). Since the flood mapping results were developed utilising a rainfall on grid model, filtering of results is required to enable the appropriate presentation of information.

The filtering method outlined in the Flood Study is sound and justifiable and should be adopted in the development of flood planning areas.

The proposed flood planning area is the lesser of the PMF extent or the filtered 1% AEP flood level plus 0.5 m. The influence of the PMF extent is minimal as the filtering applied to the 1% AEP extent generally removes any areas that are caused by local ponding or sheet flow.

Given the steep nature of the study area, an increase in flood planning level generally does not result in a large increase in area. As such, by confining the flood planning area to the PMF extent does not reduce the number of properties impacted.

Based on the assessment undertaken it is recommended to adopt the preliminary flood planning area and flood planning level proposed in the *Hazelbrook and Woodford Creek Overland Flow Study* (NSW Public Works, 2013).

10 Floodplain Risk Management Options

10.1 Managing Flood Risk

Flood risk can be categorised as existing, future or residual risk:

> **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding;

> **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built; or

> **Residual Flood Risk** – buildings and developments that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 10-1**.

Table 10-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
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. There are three broad categories of management;

- **Flood modification measures** – Flood modification measures are structural options aimed at preventing / avoiding or reducing the likelihood of flood risks through modifying the flood behaviour
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks through modifying the way the community and emergency services respond during a flood event.

10.2 Base Case

In order to assess various mitigation options, it is necessary to define a base case. This base case provides a reference against which the effectiveness of various options can be assessed. In this case, the base case is the existing Hazelbrook and Woodford Creek catchments, as defined in the flood study (NSW Public Works, 2013) and described in **Section 3** of this report.

10.3 Flood Modification Measures

Based on the flood model results, historical information, community feedback and engineering judgement, possible flood modification options (i.e. structural options) for the study area were identified. These options are outlined in **Table 10-2** and shown in **Figure 10-1**.

A range of option types are presented. These include:

> Berm – small earth levee designed to divert flow or detain flow.

> Swale / flow path / flow path augmentation – a channel or constructed depression designed to drain flow away from flooded area.

> Detention Basin – a large basin designed to detain flow and release it at a controlled rate.

> Pipe upgrade – the upgrade of an existing piped drainage system to increase to drainage capacity.

The intention of this analysis is to determine benefits associated with options. The flood model provides a representation of the proposed options.

The benefits of these options are discussed further in **Section 11**.

Table 10-2 Flood Modification Options

Sub Catchment	Option ID	Option	Details	Expected Benefit	Major Constraints	Assess in Hydraulic Model
Hall – Pine	FM1	Red Gum Avenue and Blue Hills Road Berms	Detention storage at Blue Hills Road and Red Gum Road; and Raise driveways on Grove Street, created flow path from road to channel, clear vegetation.	A reduction of peak flood flows and overtopping of Red Gum Road and Blue Hills Road. A reduction in peak flood level for properties on Grove Street	Berms on upstream of road crossing will introduce flooding upstream	Yes
Luchetti – Oaklands	FM3	Flow path from Luchetti Avenue	Divert flow from Luchetti Avenue from roadway to creek upstream of impacted properties. Possibly through nature strip	A reduction in peak flood level for properties on Luchetti Avenue	Space restriction on Luchetti Avenue nature strip.	Yes
	FM4	Oaklands Road Berm (Luchetti-Oaklands)	Construct berm upstream of Oaklands Road and clear downstream watercourse Berm/storage on upstream side of road and increase flow capacity across road	Reduction of peak flood flows and overtopping of Oaklands Road.	Minimal area upstream of Oaklands Road to detain flow	Yes
Park – Oaklands	FM5	New flow path Park Road	Drain flow from pipe outlet to Park Road and improve drainage across Park Road	Reduction in flood level of properties on Oaklands Road south of Park Road	Constructing and maintaining a flow path within private property.	Yes
	FM6	Gloria Park detention basin and upstream flow path augmentation	New basin to detain flows including drainage augmentation upstream to divert flows to basin	A reduction in peak flood level for properties on Park Road and downstream of basin	Basin wall may take up a large amount of space	Yes
	FM7	Oaklands Road Berm (Park-Oaklands)	Construction of berms to create flood storage prior to spilling onto Oaklands Road. Channel improvements upstream and downstream	A reduction in frequency of road inundation at Oaklands Road	Berms on upstream of road crossing will introduce flooding upstream	Yes
	FM11	Vegetation management downstream of Origma Avenue	Clearing of flow path to reduce flood hazard at Origma Avenue	Improved conveyance through channel and reduction in frequency of road overtopping	None identified	No

Sub Catchment	Option ID	Option	Details	Expected Benefit	Major Constraints	Assess in Hydraulic Model
Log Bridge	FM8	Log Bridge Place Detention Basin	Berm in channel and berm / flood deflector adjacent Log Bridge. Provide additional detention upstream of road to reduce flood peak downstream	A reduction in flood peak downstream	Basin wall may take up a large amount of space	Yes
	FM9	Alexander Avenue Berm	Berm and clear upstream and downstream road crossing. Modification of driveway in Alexander Avenue	Reduce the flood impact at property Alexander Avenue	Limited space to construct berm	Yes
	FM12	Glendarrah Road Swale / Berm	Reconstruction of swale at rear of properties on Glendarrah Road	Removal / reduction of flooding from south for properties on southern side of Log Bridge Avenue	Constructing and maintaining a flow path within private property.	No
Falcon	FM10	Falcon Street Pipe Upgrade	Diversion of flows from Hazelbrook Street and Talbot Road to Creek.	Reduction of flooding for properties on Talbot Road	Pipe is positioned in private property. Difficult to renew	Yes

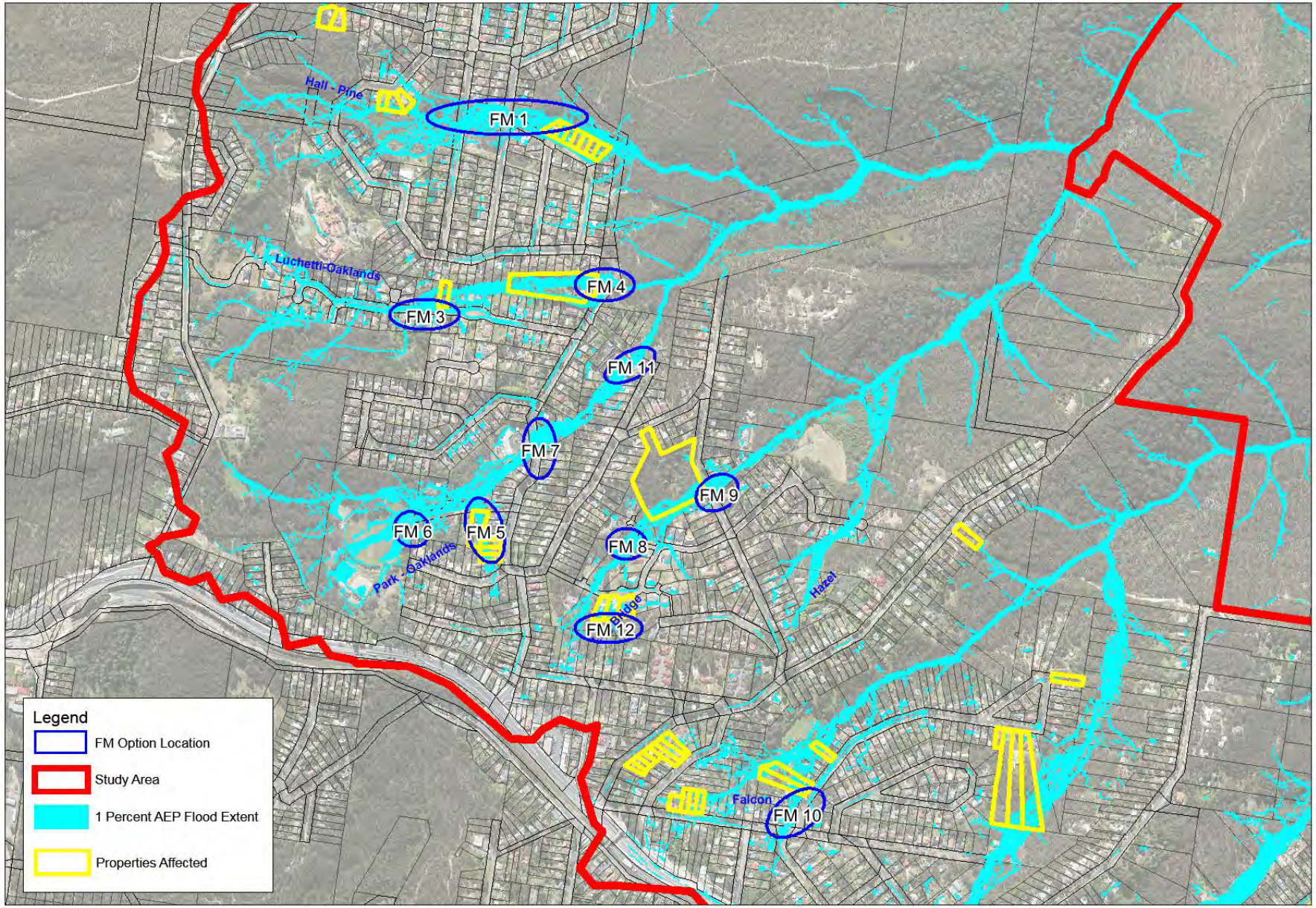


Figure 10-1 Flood Modification Measures

Furthermore, as part of the assessment of flood modification measures, recent pipe upgrade works in Falcon Avenue undertaken by council were assessed (option FM10).

The following sections provide the following:

> Location of the option and the proposed modification measures;

> Discussion of the problem and how the modification measure addresses the flooding issue; and

> Flood level differences for the 20% AEP event.

10.3.2 FM1 – Red Gum Avenue and Blue Hills Road Berms

The Hall Pine sub catchment consists of a main flow path through the centre of the sub catchment with isolated pockets of flooding throughout. The road infrastructure is constructed such that it is perpendicular to the flow (Red Gum Avenue and Blue Hills Road).

Both Red Gum Road and Blue Hills Road are subject to inundation in the 20% AEP event. Furthermore, as the flow continues downstream, properties on Grove Street become affected. The purpose of this option is to reduce the frequency of inundation on Red Gum Road and Blue Hills Road, and to mitigate flooding of properties on Grove Street.

Figure 10-2 shows the proposed locations of berms to mitigate flooding. The intention is for the frequency of flooding of roads to be reduced and to divert water away from properties on Grove Street.

Figure 10-3 shows the flood level difference as a result of the flood mitigation works for the 20% AEP event.

Berms constructed upstream of roads may not provide the required storage in rare storm events. Therefore it is important to consider a spillway on these structures to ensure a suddenly failure does not occur as a result of erosion.

10.3.3 FM3 – Flow Path from Luchetti Avenue

Overland flow develops upstream of properties on the southern side of Luchetti Avenue. This flow ultimately drains to Luchetti Avenue and poses a flood risk to those properties on the northern side of Luchetti Avenue.

The proposed option is to modify ground levels such that the overland flow can drain to the creek located between Luchetti Avenue and Hall Parade with minimal impact upon property. **Figure 10-4** shows a combination of raised and lowered nature strip to divert flow to the creek prior to properties becoming impacted.

Figure 10-5 shows a water level reduction through properties as result of the option.

In addition, increasing the kerb height and introducing standard driveway layback profiles for properties on the northern side of Luchetti Avenue will reduce the frequency of flooding of properties.

10.3.4 FM4 – Oaklands Road Berm (Luchetti-Oaklands)

Modelling suggests that in frequent events Oaklands Road will over top. This option is to install a berm on the upstream side of Oaklands Road to detain flow and reduce flood risk associated with flooded roads. The location of the berm is shown in **Figure 10-6**.

The option assessment indicates that in the 20% AEP flood event, flood level reductions of the order of 50 mm are observed (**Figure 10-7**). Although, this option will have negligible effect on larger storms, it will reduce the frequency of road overtopping in more frequent storm events.

The detention of flow results in increased flood levels on a private lot upstream. This is to be considered upon on the assessment of the suitability of the option.

Figure 10-7 also shows the flood level reduction attributed to option **FM6**.

10.3.5 FM5 – Flow Path Park Road

A piped stormwater system collects flow from Lester Avenue and discharges into the rear of properties on Oaklands Road. Flooding modelling suggests a number of properties are impacted by flooding. The option is to improve conveyance through properties by formalising the open channel through private property (as shown in **Figure 10-8**)

The water level reduction in **Figure 10-9** shows a reduction in flood level throughout the rear of properties on Oaklands Road. It should be noted that this reduction in peak water level is partly due to the reduced ground level to represent the channel in the model.

10.3.6 FM6 – Gloria Park Detention Basin and Upstream Flow Path Augmentation

Open space in the upper Park – Oaklands Catchment provides a good opportunity to utilise space as stormwater detention to reduce peak flows downstream.

The area identified in **Figure 10-10** shows the area adopted for the detention basin. For the basin to operate, flow to the north is to be directed into the basin. A nominal basin depth of 1.5 m is adopted.

The Basin provides a reduction in flood depth for the entire flow path with reductions in flood depth for private property. The flood level reduction as a result of the basin immediately downstream for the 20% AEP event is shown in **Figure 10-11**. The detention basin also provides a reduction in flood depth at Oaklands Road and Origma Avenue. A reduction of approximately 80mm and 150mm is observed (respectively). A combination of this option and berms downstream could result in a more beneficial outcome at Oaklands Road.

A detailed assessment of this basin should be undertaken to determine the optimal basin arrangement to mitigate flooding downstream.

10.3.7 FM7 – Oaklands Road Berm (Park-Oaklands)

Overtopping at Oaklands Road has the potential to cause problems with access during floods to and from the northern parts of Hazelbrook. The aim of this option is to reduce the frequency of flooding on Oaklands Road. A berm is proposed to be installed on the upstream side of Oaklands Road, downstream of the childcare centre. Clearing of vegetation upstream and downstream of the road is also recommended as this will provide the culvert maximum opportunity to operate at its capacity. The location of the proposed berm is shown in **Figure 10-12**.

The flood level difference is shown in **Figure 10-13**. It is noted that the increase in flood level on the road is a function of raising the terrain to model the berm, rather than increasing the flood inundation on the road. The option shows a minor reduction in flood levels downstream.

As discussed previously, this option combined with the implementation of the Gloria Park Detention Basin will result in a more substantial flood level reduction on Oaklands Road. The location would need to be optimised during further concept and detailed design to avoid impacts on the childcare centre.

10.3.8 FM8 – Log Bridge Place Detention Basin

The upstream area of the Log Bridge sub catchment contains a mix of land uses namely low and medium density residential, and local centre. This, combined with the highway at the top end of the catchment, creates a region of relatively high imperviousness. Flow from this region generally drains to Log Bridge Place where overland flow begins to develop. The flow path is well defined and is generally confined to one flow path through the centre of the catchment.

This option proposes to install a floodwall / berm upstream of Log Bridge Place (location of berm shown in **Figure 10-14**).

The purpose of this option is detain flow such that the frequency of flooding of properties downstream on Alexander Avenue is reduced, and the frequency of road overtopping is reduced.

The flood level difference plot shown in **Figure 10-15** demonstrates a minor flood level reduction downstream near properties on Alexander Avenue.

The basin wall will need to extend towards the south to ensure the basin does not spill around the side as is shown in **Figure 10-15**.

A detailed assessment of the basin is required to determine the maximum possible storage.

10.3.9 FM9 – Alexander Avenue Berm

Figure 10-16 shows the location of the berm upstream of Alexander Avenue. The berm level has been set at 614.5 m AHD which results in a maximum wall height of 1 m relative to the road level.

This option will generally adversely impact the property immediately south of the berm as the detained flow is likely to inundate the property if additional berms are not included (see **Figure 10-17**). The addition of a berm along northern boundary of the property could impede drainage from the south.

This option should only be considered in conjunction with **FM8**.

10.3.10 FM10 – Falcon Street Pipe Upgrade

The piped drainage system has previously been upgraded from the corner of Talbot Road and Falcon Street to the natural drainage channel at the rear of properties on Talbot Road. **Figure 10-18** shows the extent of the pipe upgrade works (already completed) and the raised nature strip adjacent to the pit on Falcon Street.

The nature strip is raised by approximately 400 mm at its highest point.

The option reduces flood levels for the 20% AEP event ranging from 50 mm to 200 mm for properties on Falcon Street and Talbot Road. The increased surface levels on the nature strip will ensure the pit operates to its capacity.

Flood depths on the road are calculated to be 150 mm in the 20% AEP event and up to 200 mm in the 1% AEP event. Some minor increase in flood depth along Talbot Road but flow remains within the road reserve.

Figure 10-19 shows the flood level decrease through properties on Talbot Road.

10.3.11 FM11 – Vegetation Management Downstream of Origma Avenue

The reduction of vegetation both upstream and downstream of the Origma Avenue road crossing could not be modelled to the detail required to represent the benefits this option may have. However, clearing of the vegetation around the culvert 10 metres upstream and downstream will reduce the risk of blockage and allow the culvert to operate at capacity. This will reduce the frequency of road overtopping.

10.3.12 FM12 – Glendarrah Road Swale / Berm

The base case modelling undertaken does not show any property inundation, although the community consultation process identified a flood issue at Glendarrah Avenue. As such flood modelling would not show a benefit and has not been undertaken as part of this assessment.

The option proposes to construct a small berm or swale at the rear of properties in Log Bridge Place. The intention of the berm is to divert flow away from properties on Log Bridge Place.

Figure 10-20 shows a contour plan (1 metre interval). The figure shows land slopes towards properties on Log Bridge Place land parallel to the rear fence is relatively flat. Therefore, to allow the swale / berm to drain, some minor earth works may be required.

The swale / berm is intended to drain flow to the west towards vacant land. The acquisition of an easement may be required.

It is recognised that the land upstream of the berm may be suitable for future development and any downstream flooding modification measures should consider future development.

10.4 Emergency Response Modification Measures

A number of emergency response options are suitable for consideration within the Hazelbrook and Woodford Creek catchments. These are:

- Shelter in place measures EM1
- Public awareness and education EM2
- School education programs EM3
- Flood Warning Signs EM4.

10.4.1 EM1 – Shelter in Place Measures

The conclusion of the review of evacuation timeline from **Section 7.6** was that the flood affected neighbourhoods are not compatible with evacuation measures due to the flash flooding nature of the catchment. A shelter-in-place approach is recommended.

To establish a shelter in place strategy a risk to life assessment should be undertaken. The case study titled *Risk to Life Policy – Shelter or Flee? A Case Study in Pittwater Council* highlights the approach undertaken by Pittwater Council to shelter in place.

10.4.2 EM2 – 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 need to be an ongoing process and requires the continuous effort of related organisations (e.g. Council and NSW SES). A 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, awareness among long-term residents is maintained, and to allow for changing flood behaviour and new developments.

The community consultation undertaken as part of this study (**Section 4**) identified the level of understanding and awareness of flooding within the Hazelbrook and Woodford Creeks floodplain. The consultation identified 62% of respondents were living in the Hazelbrook and Woodford Creek floodplain at the time of the February 2010 flood event.

The aim of educational and awareness programs is to improve and then maintain the level of flood awareness within the community. This is best approached by identifying strategies in the short, medium and long term.

10.4.2.1 Short Term Measures

Develop FloodSafe Brochure and FloodSafe Toolkit

The SES has developed Local FloodSafe Guides, which give specific information for areas at risk of floods. These guides are produced in collaboration with Council and regional and local SES units. The SES recommends that these guides are reviewed every five years.

The SES has also prepared templates allowing Local Guides to be prepared for individual regions. Different guides may be prepared for general township flooding, flash flooding and rural flooding. Development of the forms can be organised through contacting the SES.

Develop a Post-Flood Data Collection Strategy

The collection of data post flood can provide valuable information to provide the community with a better understanding of the flood event and provide perspective of what flooding the catchment may be capable of producing. Data to be collected could include:

- The approximate recurrence interval of the rainfall event and peak river / creek flows;
- A comparison of the storm event with previous historical events and design events. Comparison could be mage against rainfall depth, creek level and creek flows;
- Timings of peak flows or levels in creeks; and
- The timing and duration of road overtopping / closures.

In additional to providing the community with information, this information could also be utilised by the council to inform future flood related capital works and operational response to flood emergencies.

10.4.2.2 Medium Term Measures

Hold a FloodSafe Launch Event

Following the development of the Flood Safe documents, a public launch may be held to inform the community of the availability of this material and provide an opportunity for the community to discuss flooding issues with Council staff.

Develop a Flood Information Package for New Residents

The documents prepared for the Flood Safe initiative will provide new residents an introduction to flood behaviour and risks within the study area. It is recommended that an information package be distributed to new residents that contains a short letter from Council discussing the current flood management program, the flood safe documents, links to further information, and contact details of Council staff should they have any further queries or concerns.

Council may already have a welcome package that they provide to new residents, which would provide an existing process that can be expanded to include flood related information.

Develop a Post Flood Information Mail-Out

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 2% or 1% AEP event, would give the community a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event.

10.4.3 EM3 – School Education Programs

The school education program should align with strategies identified within EM2 where appropriate to provide a consistent approach to flood education and awareness.

It is important that education and awareness programs target everyone within the community. Children are an important part of a community and can also be influential members of the family unit. They are also a high risk population during a flood event. As such, it is important that children are educated about flood risks and appropriate behaviour during a flood. Furthermore, staff and managers of schools and childcare centres should be made aware of flood risks at their sites, and encouraged and supported in identify and maintaining appropriate flood risk strategies.

The SES has developed a tailored program for school children in primary schools. The program, which includes teacher's resources, newsletters, activities and games, is designed to deliver knowledge and awareness of floods to young children. SES personnel are also available to visit schools to talk about flooding and flood response.

Further details of these programs are available on the SES StormSafe website (www.stormsafe.com.au/informationfor-schools)

It is recommended that local schools be informed of these initiatives, and encouraged to take part in them.

It is also recommended that Council contact schools to investigate opportunities for students to be informed of flood hazards and appropriate responses. For example, schools run fire drills frequently to ensure students know how to respond during fires. It may be possible to expand this emergency response training to include a discussion on flood risks and responses. Alternatively, opportunities could be investigated to make presentations concerning flooding to students studying waterways, the environment or natural disasters as part of their school curriculum.

10.4.4 EM4 – Flood Warning Signs

Flood warning signs are commonly located in locations that are periodically inundated and present a traffic or pedestrian hazard. In some cases, it may be difficult to pedestrian or motorist to assess the flood depth. A number of public places and roads in the catchment experience flood inundation to some degree in the 20% AEP event. It is therefore important that appropriate flood warnings 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.

Potential locations for flood warning signs include:

- Rocklea Street
- Red Gum Road

- Blue Hills Road
- Oaklands Road (two locations)
- Log Bridge Place
- Origma Avenue
- Alexander Road
- Hazel Avenue.

10.5 Property Modification Measures

A number of property modification options were identified for consideration in the Hazelbrook and Woodford Creeks floodplain. These options fall into two categories; those for which OEH support is available, and those which would be required to be implemented fully by Council.

Options for which funding may be available from OEH are:

> House Raising P1

> Voluntary Purchase P2

Details of the OEH grants available may be found at: www.environment.nsw.gov.au/coasts/Floodgrants.htm

Additional property modification options that may be pursued by council are:

> Building and Development Controls P3

> Land Swap P4

> Council Redevelopment P5

> Flood Proofing P6.

These options are discussed in detail below.

10.5.1 P1 – House Raising

House raising is a measure to reduce the incidence of over-floor flooding of existing buildings by raising them, with the works funded by Council, with assistance from the NSW Office of Environment and Heritage (OEH). The *Guidelines for voluntary house raising schemes* (OEH, 2013a) sets out ineligibility criteria for house raising under the Voluntary House Raising (VHR) scheme which includes:

> Properties which are benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee or those that will be – will not be funded for VHR.

> VHR should generally return a positive new benefit in damage reduction relative to its cost (benefit–cost ratio greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial social and community benefits or VHR is compensatory work for the adverse impacts of other mitigation works.

> The scheme should involve raising residential properties above a minimum design level, generally the council's flood planning level (FPL) and comply with the council's relevant development control requirements.

> VHR is not considered suitable in floodways and areas of high hydraulic hazard.

Based on the costs involved, estimated to be in the range of $40,000 for a standard residential house the key constraint for whether house raising would be viable is for a positive cost benefit analysis from house raising. There are a number of additional obstacles to be considered for making house raising viable, some of the issues related to this approach include:

> Difficulties in raising some houses, such as slab on ground buildings. For some slab on ground houses it may be possible to install a false floor, although this is limited by the ceiling heights, but it is assumed slab on ground properties are generally not viable;

> The potential for damage to items on a property other than the raised dwelling (such as gardens, sheds, garages, etc.) are not reduced;

> Unless a dwelling is raised above the level of the PMF, the potential for over-floor flooding still exists (i.e. there will still be a residual risk);

> The need to ensure the new footings or piers can withstand flood-related forces;

> There is potential for conflict with height restrictions imposed for a specific zone or locality within the LGA; or,

> Potential heritage constraints.

In consideration of the above factors, as well as the likely costs involved with any house raising works it is assumed that house raising is not a viable option for the Hazelbrook and Woodford Creek floodplain. Therefore the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

10.5.2 P2 – Voluntary Purchase

The voluntary purchase of existing flood affected properties is an alternative to the construction of flood modification measures for properties where house raising is not possible. Option P2 would free both residents and emergency services personnel from the hazard of future floods by removing the risk. 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 need to be re-zoned under the LEP to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

However, due to the expense associated with purchase of properties in the study area (based on Bureau of Statistics figures from **Section 2.3** median house prices for Hazelbrook were $400,000) this measure should be considered only after other, more practical measures have been investigated and exhausted.

The OEH has prepared the *Guidelines for voluntary purchase schemes* (OEH, 2013b) for voluntary purchase schemes that detail the objectives, eligibility criteria, funding and implementation procedure. Based on these guidelines a potential criteria to determine properties that are eligible for voluntary purchase are:

- Located in the high hazard zone for the 1% AEP flood event; and
- Occurrence of over-floor flooding in the 20% AEP flood event; and
- Economic value of damages for a particular property is comparable to the property market value.

Of the properties with over-floor flooding in the 20% AEP event, no buildings lie within the 1% AEP high hazard areas.

Therefore, the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

10.5.3 P3 – Building and Development Controls

Recommendations for changes to building and development controls are detailed in **Section 8**

10.5.4 P4 – Land Swap

An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land outside of the flood prone area, such as an existing park, for a parcel of 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 re-zoned under the LEP to open space.

Note that land swap could also raise several issues relating to moving of existing public open space which could be a potentially contentious issue for the community.

There are no lots sufficiently affected by frequent events to warrant further consideration of the land swap option. This option is not considered viable for the Hazelbrook and Woodford Creeks floodplain.

10.5.5 P5 – Council Redevelopment

This option also provides an alternative to the Voluntary Purchase scheme (**Section 10.5.2**). While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them with a break even objective.

This option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

10.5.6 P6 – Flood Proofing

Flood proofing involves undertaking structural changes and other procedures to an individual dwelling in order to reduce the damage caused to the property 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; 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.

Flood proofing 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.

11 Costing and Economic Assessment of Options

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated. This calculation is described below. For other options it may not be possible to specifically calculate benefits. In this case, those options have only been assessed using a multi criteria matrix approach (**Section 12**)

11.1 Preliminary Costing of Options

11.1.1 Flood Modification Options

Preliminary cost estimates have been prepared for the flood modification options (**Table 11-1)** being those options that allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages. Detailed costings are presented in **Appendix C**. For other measures, approximate cost estimates were made for the purpose of comparison in the multi-criteria assessments detailed in **Section 12**.

Prior to an option proceeding, it is recommended that in addition to detailed analysis and design of the option, that these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities will also be required at the detailed design phase.

Table 11-1 Cost Estimates for Flood Modification Options

Option ID	Option	Capital Cost	Ongoing Cost (per year)
FM1	Red Gum Avenue and Blue Hills Road Berms	$120,000	$1,000
FM3	Flow path from Luchetti Avenue	$44,000	$1,000
FM4	Oaklands Road Berm (Luchetti-Oaklands)	$65,000	$1,500
FM5	Flow Path Park Road	$155,000	$1000
FM6	Gloria Park detention basin and upstream flow path augmentation	$640,000	$10,000
FM7	Oaklands Road Berm (Park-Oaklands)	$75,000	$1,500
FM8	Log Bridge Place Detention Basin	$190,000	$5,000
FM9	Alexander Avenue Berm	$40,000	$1,000
FM10	Falcon Street Pipe Upgrade	$238,000	$1,000
FM11	Vegetation management downstream of Origma Avenue	$67,000	$1,500
FM12	Glendarrah Road Swale / Berm	$105,000	$1,500

11.1.2 Property Modification Options

An estimate of $10,000 was applied to the review of building and development controls (P3) with an ongoing cost of $500 per year

To establish flood proofing guidelines (P6) an estimate of $15,000 has been adopted with an ongoing cost of $1,000 per year.

11.1.3 Emergency Response Modifications Options

To undertake a risk to life assessment with the Hazelbrook and Woodford Creeks study area, a cost of $50,000 is estimated with an ongoing cost of $1,000 per year.

To implement both a public education and school education program (EM2 and EM3 respectively) an indicative cost to establish the program has been estimated to be $10,000 initially and an ongoing cost of $2,000 per year for each program.

For signage in EM4 a unit cost of $1,500 per sign has been assumed, with two signs at each location (for each direction of traffic) and 9 locations in total. On-going maintenance has been assumed to be $300 per sign annually.

11.2 Annual Average Damages Assessment

An assessment of damages for the existing condition is presented in **Section 6**. As the flood modification options selected are predominantly concerned with the reduction of local flood impacts, rather than assess the catchment wide damages, the reduction in damages resulting from local decreases in flood depths and extents has been considered. The reductions in properties affected by overground and over floor flooding, total damages and AAD are presented in **Table 11-2**.

A number of options featured are intended to reduce the flood level on critical roads, therefore the damage assessment will not show economic benefit for these options as the costs only relate to property damage.

Table 11-2 Reduction in Damages Associated with Flood Modification Options

Option No.	Description	Reduction in Damages for 1% AEP ($)	Total Reduction in AAD ($)
FM1	Red Gum Avenue and Blue Hills Road Berms	$143,800	$45,400
FM3	Flow path from Luchetti Avenue	$117,800	$33,200
FM4	Oaklands Road Berm (Luchetti-Oaklands)	$ -	$ -
FM5	Flow Path Park Road	$37,500	$3,900
FM6	Gloria Park detention basin and upstream flow path augmentation	$13,600	$5,800
FM7	Oaklands Road Berm (Park-Oaklands)	$900	$1,700
FM8	Log Bridge Place Detention Basin	$0	$1,200
FM9	Alexander Avenue Berm	$ -	$ -
FM10	Falcon Street Pipe Upgrade	$4,200	$5,600

For those options did not allow for a damages assessment to be undertaken (FM11 and FM12), a short description of the expected benefit is provided below.

11.2.1 FM11 – Vegetation Management Downstream of Origma Avenue

The reduction of vegetation both upstream and downstream of the Origma Avenue road crossing could not be modelled to the detail required to represent the benefits this option may have. Clearing of the culvert upstream and downstream will reduce the risk of blockage and allow for the culvert to operate at capacity. This will reduce the frequency of road overtopping.

11.2.2 FM 12 – Swale / Berm Glendarrah Avenue

The base case modelling undertaken does not show any property inundation, although the community consultation process identified a flood issue at Glendarrah Avenue. If options modelling were to be

undertaken here, no quantifiable benefit would be produced, discounting the option. For the option to be considered a qualitative approach was taken.

The option proposes to construct a berm at the rear of properties in Log Bridge Place. The berm will protect these properties from flooding and divert flows.

It is recognised that the land upstream of the berm is suitable for future development and any downstream flooding modification measures could adversely influence this land.

11.3 Benefit to Cost Ratio of Options

The economic evaluation of each modelled option was performed by considering the reduction in the amount of flood damages incurred for the design flood events and then comparing this value with the cost of implementing the option.

The existing condition was used as the base case to compare the performance of modelled options (FM1-FM10). Inputs for the assessment include those data derived from the floor levels and property survey along with damage curves for other similar areas. The preliminary costs of each measure were used to undertake a benefit-cost analysis on a purely economic basis.

Table 11-3 summarises the results of the economic assessment of each of the flood management options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C), which is based on the net present worth (NPW) of the benefits (reduction in AAD) and the costs (of implementation), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance:

> Where the benefit-cost ratio is greater than one the economic benefits are greater than the cost of implementing the measure.

> Where the benefit-cost is less thanone1 but greater than zero there is still an economic benefit from implementing the measure, but the cost of implementing the measure is greater than the economic benefit.

> Where the benefit-cost is equal to zero, there is no economic benefit from implementing the measure.

> Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

Table 11-3 Summary of Economic Assessment of Flood Management Options

Option No.	NPW of Reduction in AAD (excl. GST)	NPW of Cost of Implementation (excl. GST)	B/C Ratio	Economic Ranking
FM1	$626,443	$132,101	4.74	2
FM3	$458,728	$57,201	8.02	1
FM4	$3	$85,301	0.00	8
FM5	$53,896	$166,801	0.32	3
FM6	$79,902	$773,807	0.10	6
FM7	$23,637	$94,101	0.25	5
FM8	$16,135	$255,304	0.06	7
FM9	-$2,491	$59,501	-0.04	9
FM10	$77,269	$258,701	0.30	4

The three highest ranking flood management options are:

> Option FM3 – Flow path from Luchetti Avenue; and

> Option FM1 – Red Gum Avenue and Blue Hills road Berm; and

> Option FM5 – Flow path Park Road.

Option FM3 has the highest economic benefit cost ratio due to the ability to protect several floor levels from flooding in the 20% AEP and above.

Similarly, option FM1 provides a significant reduction in flood damage due to the ability of the option to modify flood behaviour such that it does not substantially impact property.

It should be noted that the economic analysis has only incorporated changes to economic damages to properties, and does not consider social factors, risk to life and environmental factors. These types of benefits are difficult to quantify in dollar terms. The multi criteria analysis (**Section 12**) incorporates some of these non-quantifiable impacts into the decision making process.

12 Multi-Criteria Assessment

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* (NSW Government, 2005). This approach to assessing the merits of various options uses a subjective scoring system. The principal 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 **Section 12.1**

12.1 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. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion. The scoring system summary is provided in **Table 12-1**. The criteria used are:

Economic	Benefit cost ratio
	Capital and operating costs
	Reduction in risk to property
	Feasibility
	Protection of Vulnerable Developments and Critical Infrastructure
Social	Reduction in risk to life in 1% AEP
	Reduction in social disruption
	Community support
	Compatibility with policies and plans
Environmental	Compatibility with surface water quality objectives
	Fauna / Flora impacts

Table 12-1 Scoring System

Category	Criteria	Description of Criteria Assessment	Score				
			-2	-1	0	1	2
Economic	Benefit Cost Ratio	The cost effectiveness of the scheme, i.e. the tangible return on investment	0 to 0.2	0.2 to 1	1	1 to 1.5	>1.5
	Capital and Operating Costs	Consideration of the initial capital costs and ongoing operation costs to Council	Extreme >$2 million	High $500,000 – $2 million	Medium $200,000 – $500,000	Low $50,000 – $200,000	Very Low $0 – $50,000
	Reduction in Risk to Property	Based on reduction in AAD, it establishes the tangible benefit of an option	Major increase in AAD (>$20,000)	Slight increase in AAD (<$20,000)	No Improvement	Slight decrease in AAD (<$20,000)	Major decrease in AAD ($>20,000)
	Feasibility	Establishes the feasibility of options based on constructability, and bureaucratic difficulties such as land acquisition and agreements with external agencies	Very unlikely to be feasible	Unlikely to be feasible	May or may not be feasible	Likely to be feasible	Very likely to be feasible
	Protection of Vulnerable Development and Critical Infrastructure	Assesses the flood risk implications for existing vulnerable developments and critical infrastructure in the floodplain (as identified in **Section 5.2**)	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
Social	Reduction in Risk to Life in 1% AEP event	The impact on risk to life for the flood planning event, which is the design event for most structural options	Widespread or significant increase in risk to life	Localised or slight increase in risk to life	No change in risk to life	Localised or slight reduction of risk to life	Widespread or significant reduction of risk to life
	Reduction in Social Disruption	Social disruption of flooding has been based on reduction in road overtopping, with emphasis on regional roads, and access roads for isolated communities (as outlined in **Section 7.5**)	Major increase in social disruption (road overtopping increased by >0.2m)	Slight increase in social disruption (road overtopping increased by <0.2m)	No change to social disruption	Slight reduction of social disruption (road overtopping reduced by <0.2m)	Major reduction of social disruption (road overtopping reduced by >0.2m)
	Community Support	Guided by community questionnaire and consultation session	Very unlikely to be supported	Unlikely to be supported	Neutral	Likely to be supported	Very likely to be supported
	Compatible with Policies and Plans	The compatibility with Council's policies and plans	Amendment required to either Council's current policies or plans	Slightly incompatible with Council's current policies or plans	Slightly incompatible with Council's current policies or plans, but could be grounds for reviewing policies or plans	Compatible with both Council's policies and plans	In line with and supported by Council's current policies or plans
Environment	Compatibility with Water Quality Objectives	Impacts to quality of catchment inflows or reduction in water exchange with ocean and freshwater inputs	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
	Fauna/Flora Impact	Likely impacts on Threatened Ecological Communities and Threatened Species based on recorded locations identified in **Section 2.5**	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit

The assignment of a score for each criterion for each option is shown in the completed matrix in **Appendix E**. The total score of each option was calculated by equally weighting criteria and summing the total.

Each of the options was then ranked against each other based on the total scores, allowing identification of the preferred options, namely those that provide the greatest benefit to the community. These total scores and rankings are also shown in **Appendix E**.

The rankings are proposed as the basis for selecting management options for inclusion in the FRMP, and for prioritising their implementation.

12.2 Summary of Options Assessment Outcomes

Table 12-2 provides a ranked list of management options for consideration for inclusion in the FRMP. The options selected for inclusion should be based on both their likely benefits and the likely funding available from Council and the State Government.

The modifications option on Luchetti Avenue (FM3) is identified as the option most likely to provide significant improvement (albeit localised). These option provides a cost effective approach to substantially minimise property damage as a result of flooding.

Options were modelled such that a single option was assessed independently. In some cases, the benefit of one option can be altered based upon the outcome of an upstream option. The reduction in flood depth as a result of the implementation of the Gloria Park Detention Basin is widespread throughout the catchment. This option could provide additional benefit to options downstream that are not being considered as part of this analysis.

Two of the upstream road berm options (FM9, and FM7) only provided minor reductions in flood level and hence have not ranked well in the MCA. These options are not recommended for implementation in their current form.

Table 12-2 Summary of MCA Ranking and Options Implementation Preferences

Option ID	Option Description	MCA Score	Overall MCA Rank	Implementation Priority
FM3	Flow path from Luchetti Avenue	2.85	1	High
P3	Building and Development Controls	2.05	2	High
FM1	Red Gum Avenue and Blue Hills Road Berms	1.90	3	Medium
FM7	Oaklands Road Berm (Park-Oaklands)	1.90	3	Medium
FM6	Gloria Park detention basin and upstream flow path augmentation	1.80	5	Medium
EM4	Flood warning signs at critical locations	1.80	5	Medium
EM1	Shelter in Place Strategy	1.60	7	Medium
EM2	Public awareness and education	1.55	8	Medium

EM3	School Education Program	1.55	10	Medium
P6	Flood Proofing Guidelines	1.55	10	Medium
FM8	Log Bridge Place Detention Basin	1.45	11	Low
FM4	Oaklands Road Berm (Luchetti-Oaklands)	1.25	12	Low
FM9	Alexander Avenue Berm	1.15	12	Low
FM11	Vegetation management downstream of Origma Avenue	0.95	14	Low
FM10	Falcon Street Pipe Upgrade	0.65	15	Low
FM5	Flow Path Park Road	0.45	16	Low
FM12	Glendarrah Road Swale / Berm	0.45	16	Low

12.3 Potential Funding Sources

The NSW Government has established the Floodplain Management Program to provide financial support to Local Government for the implementation of the Flood Prone Land Policy, as described in the Floodplain Development Manual (NSW Government, 2005). The primary objective is “to reduce the impacts of flooding and flood liability on communities as well as the private and public losses resulting from floods, using ecologically positive methods wherever possible”.

Floodplain management grants from the NSW Government are available for implementation of actions listed in FRMPs, which include (but are not limited to), the following:

- structural works, such as levees, detention basins, flood gates and improved flow conveyance;
- flood warning systems;
- evacuation management; and
- voluntary purchase or house raising.

This grant program is administered by OEH.

13 Floodplain Risk Management Plan

13.1 Overview

The floodplain management options outlined in **Section 12.2** that have a priority of high or medium are recommended for implementation. In order to achieve the implementation of relevant management actions, a program of implementation has been developed. This section attempts to achieve the objectives of the Floodplain Risk Management Plan component as outlined in **Section 1.2**.

The steps in progressing the floodplain risk management process from this point onwards are:

- Council will adopt the final Study and Plan and submit applications for funding assistance to relevant State and Commonwealth agencies, as appropriate;
- As funds become available from OEH, the Commonwealth, other state government agencies and/or from Council's own resources, recommended management actions will be implemented in accordance with the established priorities.
- Implementation will require in some cases more detailed cost benefit analysis, assessment and mitigation of environmental impacts and / or detailed design.

13.2 Implementation Planning Horizons

Table 13-1 provides the following information relevant to the implementation of the management actions:

- An estimate of capital and recurrent costs for each action (this may, in some cases, include existing staff and funding);
- The agency or organisation likely to be responsible for the action;
- The priority for implementation (high, medium or low) as an outcome of the FRMS (refer to **Section 12.2** for further details); and
- Performance measures to allow for the evaluation of the implementation of the FRMS&P.

13.3 NSW Floodplain Management Authority Project Assessment and Priority Ranking

The informing Floodplain Risk Management Study for this plan utilised a multi criteria assessment approach to better understand the reduction in flood risk and other benefits and impacts of various options. This plan is based on the outcomes of this assessment. However, funding and implementation of these recommendations will not necessarily be undertaken in accordance with the ranking of the options, hence actions have been assigned a priority of high or medium rather than a specific order.

The NSW Government's floodplain management grants support local government to manage flood risk. The funding for these grants comes from two programs, the NSW Floodplain Management Program and the Floodplain Risk Management Grants Scheme (jointly funded by the NSW Office of Emergency Management and the Commonwealth Government).

Applications for funding can be made by Council for the implementation of actions identified in this floodplain risk management plan. The information provided in the applications for each management action is used to rank the priority for funding of all actions across NSW.

The information presented in this plan and informing Floodplain Risk Management Study can be used to complete the relevant applications for funding.

Table 13-1 Implementation Program

Option ID	Action	Capital Cost	Ongoing Cost (Annual)	Potential Funding Source / Responsibility	Priority	Performance Measure
FM3	Flow path from Luchetti Avenue	$44,000	$1,000	Council / OEH	High	Flood modification works are complete
P3	Building and Development Controls	$10,000	$500	Council	High	DCP and LEP are updated as per recommendations
FM1	Red Gum Avenue and Blue Hills Road Berms	$120,000	$1,000	Council / OEH	Medium	Flood modification works are complete
FM7	Oaklands Road Berm (Park-Oaklands)	$75,000	$1,500	Council / OEH	Medium	Flood modification works are complete
FM6	Gloria Park detention basin and upstream flow path augmentation	$640,000	$10,000	Council / OEH	Medium	Detention basin is constructed and operational
EM4	Flood warning signs at critical locations	$27,000	$5,400	Council / OEH	Medium	Signs are installed and maintained
EM2	Public awareness and education	$10,000	$2,000	Council / SES	Medium	Education program is undertaken and documented.
EM3	School Education Program	$10,000	$2,000	Council / SES	Medium	Education program is undertaken and documented.
P6	Flood Proofing Guidelines	$15,000	$1,000	Council / SES	Medium	Guidelines are produced and implemented
EM1	Shelter in Place Strategy	$50,000	$1,000	Council / SES	Medium	Strategy is developed and implemented
TOTAL		**$1,001,000**	**$25,400**			

14 Conclusions

This FRMS&P for the Hazelbrook and Woodford Creeks Catchment follows on from the overland flow study undertaken in 2013 (NSW Public Works, 2013). The early sections of this report provide context through a description of the environmental, social and economic character of the catchment (**Section 2**), review of the data available for the study area (**Section 3**), and outline of the community consultation process undertaken as part of this study (**Section 4**).

Further assessment of the existing flood behaviour has been undertaken, including an assessment of flood hazard (**Section 5**). In addition, current average annual flood damage for the Hazelbrook and Woodford Creeks floodplain has been estimated to be approximately $375,000 (**Section 6**).

A review of existing emergency management arrangement (**Section 7**), current flood policies (**Section 8**) and flood planning levels (**Section 9**) was used to develop a range of flood mitigation options (**Section 10**). A detailed economic assessment of the options' costs and benefits has been conducted (**Section 11**); informing a multi-criteria assessment and review of the feasibility of the options (**Section 12**). The MCA scores of the emergency management and flood modification options have been combined to produce rankings of options (**Table 12-2**).

The Floodplain Risk Management Plan (**Section 13**) is the recommended approach to managing flood risk in the floodplain.

The review and analysis undertaken as part of this FRMS&P has identified the isolated cases of property inundation that can be effectively managed by structural flood modification measures (FM1 and FM3). Road overtopping has been identified as an issue within the catchment as communities could become isolated during large storm events, although the duration of inaccessibility is short and can be managed with emergency management processes.

15 Qualifications

This report has been prepared by Cardno for Blue Mountains City Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided.

Study results should not be used for purposes other than those for which they were prepared.

16 References

Australasian Fire and Emergency Services Authorities Council (AFAC) (2013) *Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events*

Australian Bureau of Statistics (2011) *2011 Census Data* from: *http://www.abs.gov.au/websitedbs/censushome.nsf/home/quickstats?opendocument&navpos=220* accessed 2015

Australian Property Monitors (2015) *APM Price Finder* from: *http://apm.com.au/* accessed 2015

Blue Mountains City Council (2008), *City of Blue Mountains Flood Liable Land Policy*

Blue Mountains City Council (2013), *Blue Mountains Local Environment Plan 2013*

Blue Mountains City Council (2015), *Blue Mountains Development Control Plan 2015*

Blue Mountains City Council (2015), *Blue Mountains Local Environment Plan 2015*

Blue Mountains Local Emergency Management Committee (2016), *City of Blue Mountains Local Emergency Management Plan*

Climate Risk (2009), *Blue Mountains City Council Climate Change Risk Assessment*

Molino S., Morrison T., Howard M., Opper S. (2013) *A technical guideline for the use of the SES timeline evacuation model in flood evacuation planning*, 2013 NSW Floodplain Management Conference

North-West Metropolitan Regional Emergency Management Committee (2011) *North West Metropolitan Emergency Management District DISPLAN (Interim)*

NSW Government (2005) *NSW Floodplain Development Manual: The Management of Flood Liable Land*.

NSW Government (2007) *SES Requirements from the Floodplain Risk Management Process*

NSW Government (2007) *Flood Emergency Response Planning Classification of Communities Guideline*, October, Version 1.01

NSW Government (2015) *NSW State Flood Plan*

NSW Government (2012) *NSW State Emergency Management Plan*

NSW Public Works (2013), *Hazelbrook and Woodford Catchments Mainstream and Overland Flow Study, Stage 5 – Final Flood Study Report*

OEH (2013a) *Floodplain Management Program*, *Guidelines for voluntary house raising schemes*

OEH (2013b) *Floodplain Management Program, Guidelines for voluntary purchase schemes*

OEH (2015a) *Bionet Atlas of NSW Wildlife,* NSW Government. Retrieved February 2015, from: http://www.bionet.nsw.gov.au/

OEH (2015b) *Aboriginal Heritage Information Management System (AHIMS) Web Services*. Retrieved February 2015 from http://www.environment.nsw.gov.au/awssapp/Login.aspx?ReturnUrl=%2fawssapp%2ftimeout.aspx

OEH (2015c) *State Heritage Database*. Retrieved February 2015, from http://www.environment.nsw.gov.au/heritageapp/heritagesearch.aspx

SCARM (2000) *Floodplain Management in Australia: best practice principles and guidelines.* Agriculture and Resource Management Council of Australia and New Zealand, SCARM Report 73, CSIRO.

SES (2012) *Business FloodSafe Toolkit and Plan*

Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

APPENDIX

A

COMMUNITY CONSULTATION MATERIALS

Cardno
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Floodplain Risk Management Options

The following list of Floodplain Risk Management options presents some strategies that could be considered to minimise the risk and reduce the impact of flooding throughout the Hazelbrook and Woodford floodplain. These options will be considered in further detail during the preparation of the Risk Management Study and Plan.

Examples of Flood Management Options	
	Description
Flood Modification Options	• Construction of levees where properties are most at risk • Upgrading drainage systems i.e. construction of detention/retarding basins • Stabilisation works along drainage channels
Property Modification and Planning Control Options	• Building and development controls • Voluntary house raising program (for selected properties) • Voluntary house rebuilding subsidy scheme (for selected properties) • Voluntary property purchase program (for selected properties)
Emergency Response Modification Options	• Revision of the Local Disaster Plan (DISPLAN) • Public awareness and education - locality based flooding information for residents • Public awareness and education - flooding information for schools • Flood depth markers at major (flood affected) road crossings • Continuation of existing public awareness and education campaigns • Data collection strategies for future floods

Consultation

The communtiy will be invited to view and comment on the Draft Study and Plan. The exhibition period will be advertised and residents notified in advance.

Blue Mountains City Council recognise the important role that the community has in the development of viable options to manage flood risk. The Councils' goals for community consultation are to inform the community about the study, identify community concerns and attitudes, gather information from the community, obtain community opinions on possible risk management options and develop and maintain community confidence in the study results.

The following consultation activities will be undertaken as part of the Hazelbrook and Woodford Creek Floodplain Risk Management Study and Plan.

A website, which will be available for the duration of the study preparation and will be updated regularly through the project to inform the community of the project status and upcoming activities that they may be involved in.

This community brochure and survey will be undertaken to obtain opinions on possible options to manage the flood risks.

Press releases at key stages in the study.

Public exhibition would be undertaken of the draft documents to obtain feedback from the community for incorporation into the finalisation of the Study and Plan.

Please complete the attached questionnaire and return it in the reply paid envelope. If you have any further questions or would like further details, please contact Council via the details below or visit our website: *https://extranet.cardno.com/HazelbrookWoodfordFRMS*

Contact Us

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Hazelbrook and Woodford Creek Catchments Floodplain Risk Management Study and Draft Plan

Information Brochure

Blue Mountains City Council has engaged Cardno to assist with the preparation of a Floodplain Risk Management Study and Draft Plan.

The Risk Management Study and Plan follows on from the Flood Study, completed in 2013, which identified existing flooding behaviour in the Hazelbrook and Woodford Creek catchments. The purpose of the Risk Management Study and Plan is to identify and recommend appropriate actions to manage flood risks in the Hazelbrook and Woodford Creek catchments.

This brochure provides an update to the Risk Management Study and Plan and sets out the remaining steps to complete the study and plan.

FLOODPLAIN MANAGEMENT PROCESS | Formation of a Committee | Data Collection | Overland Flow Study | **Floodplain Risk Management Study** | **Floodplain Risk Management Plan** | Implementation of Plan

Floodplain Management Process

Councils Floodplain Management Committee (the Committee) oversees the Floodplain Management process. The Committee includes representatives from Council, NSW Office of Environment and Heritage (OEH), State Emergency Service (SES), NSW Department of Primary Industries (DPI), and representatives of the local commuity.

Objectives

The objectives of the study and plan are:

Floodplain Risk Management Study

Find an appropriate mix of management measures and strategies to effectively manage the full range of flood risk in accordance with the NSW Government Floodplain Development Manual (2005) through an effective public participation and community consultation program. The information from this study will enable Council to formulate a Floodplain Risk Management Plan for the study area.

Floodplain Risk Management Plan

Formulate a cost effective plan for the study area based on the findings of the Floodplain Risk Management Study and provide a priority program for implementation of the recommended works and measures in accordance with the Floodplain Development Manual. The plan will detail how the existing and future flood risk within the study area will be managed.

The Study Area

The Floodplain Risk Management Study has been undertaken for the Hazelbrook and Woodford Creek catchments.

Hazelbrook, with a population of 4,447 people is located approximately 17 kilometres east of Katoomba in the Blue Mountains on the Great Western Highway. Two creeks; the Hazelbrook Creek and Woodford Creek Creeks; flow through Hazelbrook and merge to form the mainstream Hazelbrook Creek before joining into the Grose River.

Existing Flooding Issues

Properties at Hazelbrook have been built on the ridges as well as the "valleys", and therefore has been identified by Council as the highest flood related issues within the Blue Mountains LGA.

This was shown during the February 2010 storm where a significant number of flood damages have been reported across a number of properties within Hazelbrook.

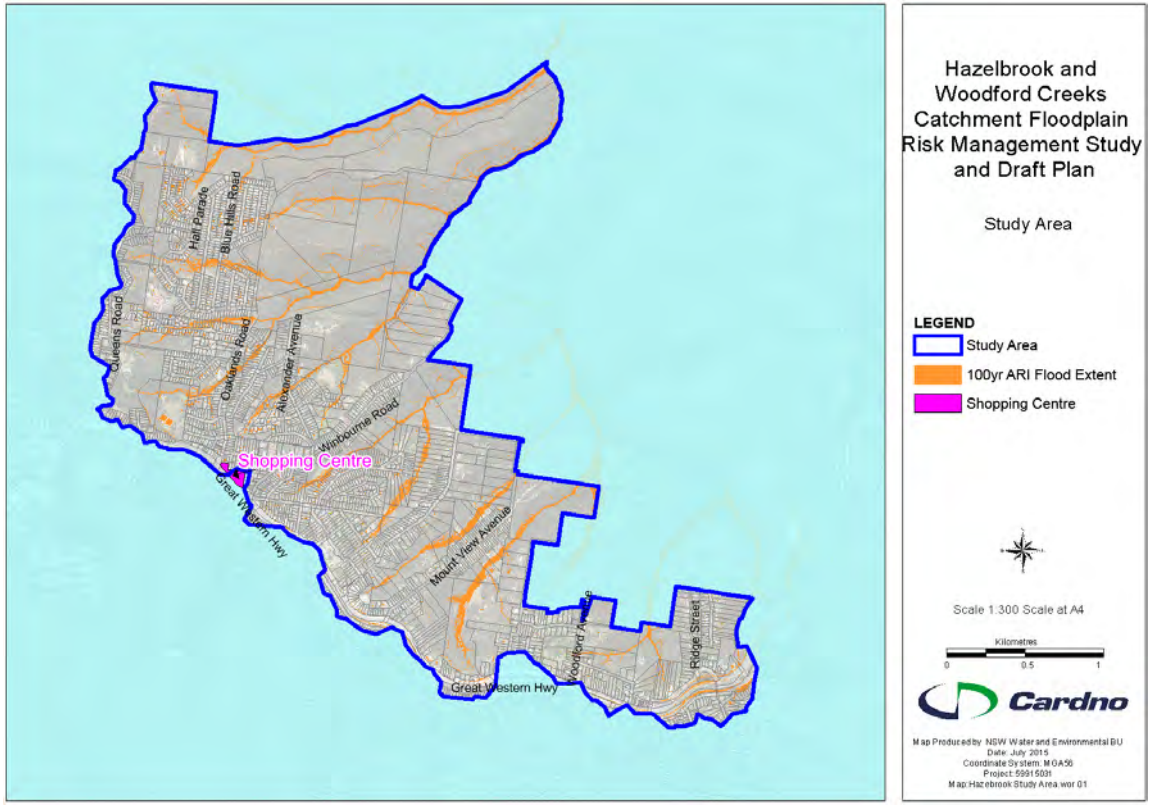

Figure 1: Study Area

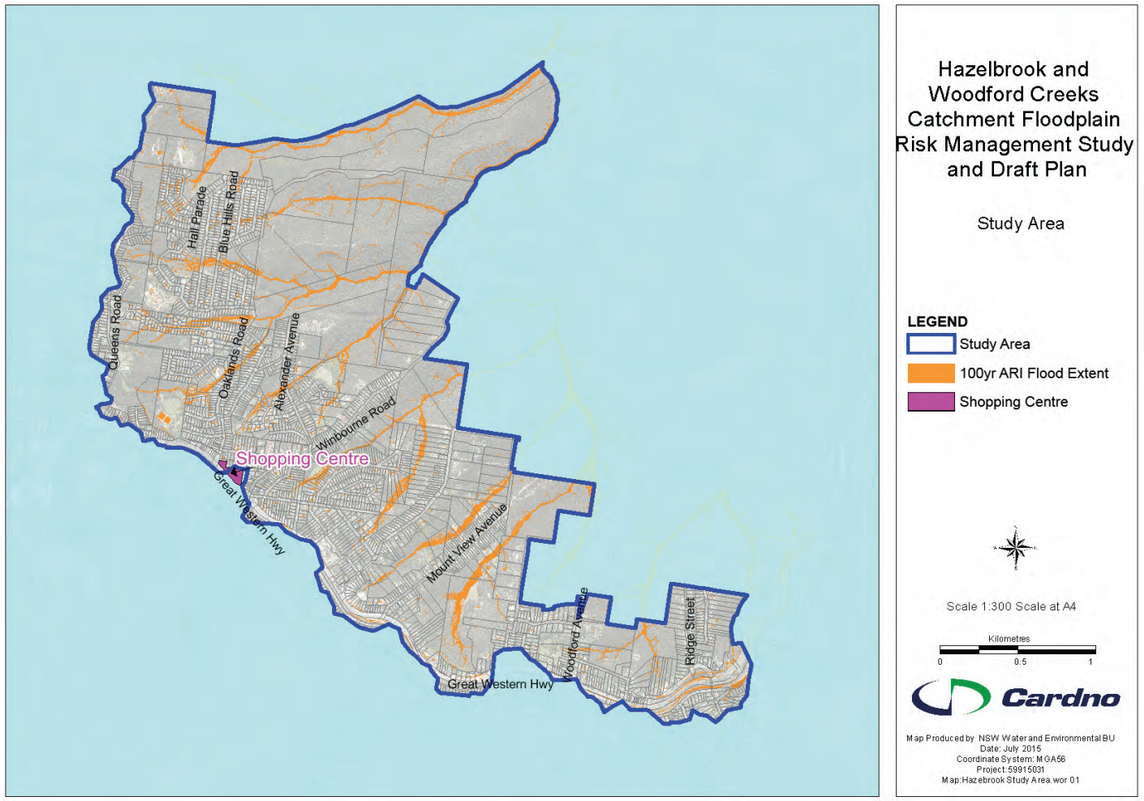

Figure: The Study Area

If you have any further comments that relate to the Management Study and Draft Plan, please provide them in the space below (or attach any additional pages if necessary):

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.....

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Thank you for providing the above information. Please return all pages in the the reply paid envelope by 25 September 2015. A representative from Cardno or Council may contact you in the near future to discuss your response.

Contact Us

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact

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blue mountains City Council | NSW GOVERNMENT Office of Environment & Heritage | Cardno Shaping the Future

This project is supported by the NSW Government's Floodplain Management Program.

Hazelbrook and Woodford Creeks Catchment Floodplain Risk Management Study and Draft Plan

Resident / Landowner Survey | August 2015

Cardno was commissioned by Blue Mountains City Council to undertake a Floodplain Risk Management Study and Floodplain Risk Management Draft Plan (FRMS&P) for the Hazelbrook and Woodford Creeks catchments. The FRMS&P is being undertaken in order to define existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. The tasks will be undertaken alongside community consultation to ensure that community concerns are addressed.

The overall objective of this study is to develop a FRMS&P that addresses the existing, future and continuing flood problems, taking into account the potential impacts of climate change.

The Floodplain Management Process progresses through six stages:

1. Formation of a Floodplain Risk Management Committee
2. Data Collection
3. Flood Study
4. Floodplain Risk Management Study
5. Floodplain Risk Management Plan
6. Implementation of the Floodplain Risk Management Plan

This study will be addressing Stages 4 and 5.

blue mountains City Council | NSW GOVERNMENT Office of Environment & Heritage | Cardno Shaping the Future

This project is supported by the NSW Government's Floodplain Management Program.

Q1. Could you please provide us with the following details, as this allows us to locate specifically where your comments and responses relate to?
This information will not be shared without your consent. If you do not provide these details, please feel free to complete the survey anyway.

Name: .....

Address: .....

.....

Daytime Ph: .....

Email: .....

Q 2. Is your property (please tick)

- ☐ Owner occupied
- ☐ Occupied by a tenant
- ☐ Holiday home
- ☐ A business
- ☐ Other .....

Q 3. How long have you lived, worked and/or owned your property?

- ☐ 0 - 5 years
- ☐ 10 - 20 years
- ☐ 5 - 10 years
- ☐ More than 20 years

Q 4. How many people live / work at your property?

.....

Number of permanent residents at this address aged:

- ☐ Less than 5 years
- ☐ 5 - 65 years
- ☐ 65+ years

Q 5. Have you ever experienced flooding since living/working in the Hazelbrook and Woodford Creeks catchment? (please tick relevant boxes)

- ☐ Yes, floodwaters entered my house/business
- ☐ Yes floodwaters entered my yard
- ☐ Yes, the road was flooded and I couldn't drive my car
- ☐ Yes, the creek broke its banks
- ☐ Yes, other parts of my neighbourhood were flooded
- ☐ No, I haven't experienced flooding

Q 6. Which of the following catchment values do you feel are most important in the Hazelbrook and Woodford Creeks catchment? (where 1 = low importance, 5 = high importance)

Catchment Value	Importance Low → High
Clean creeks and waterways	1 2 3 4 5
Minimise impact to flora and fauna	1 2 3 4 5
Maintenance of stormwater drainage infrastructure (including weed removal in drains)	1 2 3 4 5
Stormwater harvesting and reuse	1 2 3 4 5
Character and aesthetic of area	1 2 3 4 5
Reduction in property damage	1 2 3 4 5
Improved safety / reduced risk to life	1 2 3 4 5
Cost benefit ratio (total cost compared to benefits)	1 2 3 4 5
Impacts to water quality and environmental flows	1 2 3 4 5
Potential inconvenience / social disruption	1 2 3 4 5
Flood planning and development controls	1 2 3 4 5

Q 7. As a local resident who may have witnessed flooding problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for the Hazelbrook and Woodford Creeks catchment (where 1 = low preference, 5 = high preference)?
Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please tick) Low → High	Potential Location	Comments - suggested location or details
Culvert / bridge / pipe upgrades	1 2 3 4 5	Luchetti Avenue Oaklands Road Rocklea Street	
Overland flowpath improvement	1 2 3 4 5	Grove Street Lester Avenue	
Planning and flood related development controls	1 2 3 4 5		
Channel improvements including removal of weeds and bank stabilisation	1 2 3 4 5	Oaklands Road Park Road Luchetti Avenue	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5		
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5		
Retarding / detention basins – to temporarily hold water and reduce peak flood flows	1 2 3 4 5	Gloria Park (Park Avenue) Log Bridge Place Blue Hills Road	
Levee banks	1 2 3 4 5	Alexander Avenue	
House raising / voluntary purchase	1 2 3 4 5	Oaklands Road	
Other - please specify (attach extra pages as necessary)	1 2 3 4 5		

Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

APPENDIX

B

FLORA AND FAUNA OF THE FLOODPLAIN

Cardno
Shaping the Future

Kingdom	Class	Family	Common Name	Scientific Name	Comm. status	NSW status	Species Code
Animalia	Amphibia	Myobatrachidae	Common Eastern Froglet	*Crinia signifera*		P	3134
Animalia	Amphibia	Myobatrachidae	Giant Burrowing Frog	*Heleioporus australiacus*	V	V,P	3042
Animalia	Amphibia	Myobatrachidae	Brown-striped Frog	*Limnodynastes peronii*		P	3061
Animalia	Amphibia	Myobatrachidae	Great Barred Frog	*Mixophyes fasciolatus*		P	3074
Animalia	Amphibia	Myobatrachidae	Red-crowned Toadlet	*Pseudophryne australis*		V,P	3116
Animalia	Amphibia	Myobatrachidae	Smooth Toadlet	*Uperoleia laevigata*		P	3158
Animalia	Amphibia	Hylidae	Blue Mountains Tree Frog	*Litoria citropa*		P	3175
Animalia	Amphibia	Hylidae	Bleating Tree Frog	*Litoria dentata*		P	3180
Animalia	Amphibia	Hylidae	Freycinet's Frog	*Litoria freycineti*		P	3184
Animalia	Amphibia	Hylidae	Lesueur's Frog	*Litoria lesueuri*		P	3316
Animalia	Amphibia	Hylidae	Peron's Tree Frog	*Litoria peronii*		P	3204
Animalia	Amphibia	Hylidae	Leaf-green Tree Frog	*Litoria phyllochroa*		P	3206
Animalia	Amphibia	Hylidae	Tyler's Tree Frog	*Litoria tyleri*		P	3214
Animalia	Amphibia	Hylidae	Verreaux's Frog	*Litoria verreauxii*		P	3215
Animalia	Amphibia	Hylidae		*Litoria wilcoxii*		P	3314
Animalia	Reptilia	Gekkonidae	Wood Gecko	*Diplodactylus vittatus*		P	2077
Animalia	Reptilia	Gekkonidae	Lesueur's Velvet Gecko	*Oedura lesueurii*		P	2118
Animalia	Reptilia	Gekkonidae	Broad-tailed Gecko	*Phyllurus platurus*		P	2129
Animalia	Reptilia	Scincidae	Red-throated Skink	*Acritoscincus platynota*		P	2464
Animalia	Reptilia	Scincidae	Cream-striped Shinning-skink	*Cryptoblepharus virgatus*		P	2331
Animalia	Reptilia	Scincidae	Copper-tailed Skink	*Ctenotus taeniolatus*		P	2386
Animalia	Reptilia	Scincidae	Cunningham's Skink	*Egernia cunninghami*		P	2408
Animalia	Reptilia	Scincidae	Yellow-bellied Water-skink	*Eulamprus heatwolei*		P	2214
Animalia	Reptilia	Scincidae	Blue Mountains Water skink	*Eulamprus leuraensis*	E	E1,P	2215
Animalia	Reptilia	Scincidae	Eastern Water-skink	*Eulamprus quoyii*		P	2557
Animalia	Reptilia	Scincidae	Dark-flecked Garden Sunskink	*Lampropholis delicata*		P	2450
Animalia	Reptilia	Scincidae	Pale-flecked Garden Sunskink	*Lampropholis guichenoti*		P	2451
Animalia	Reptilia	Scincidae	White's Skink	*Liopholis whitii*		P	2430
Animalia	Reptilia	Scincidae	Tussock Cool-skink	*Pseudemoia entrecasteauxii*		P	2459
Animalia	Reptilia	Scincidae	Tussock Skink	*Pseudemoia pagenstecheri*		P	2879
Animalia	Reptilia	Scincidae	Weasel Skink	*Saproscincus mustelinus*		P	2452
Animalia	Reptilia	Scincidae	Blotched Blue-tongue	*Tiliqua nigrolutea*		P	2578
Animalia	Reptilia	Scincidae	Eastern Blue-tongue	*Tiliqua scincoides*		P	2580
Animalia	Reptilia	Agamidae	Jacky Lizard	*Amphibolurus muricatus*		P	2194
Animalia	Reptilia	Agamidae	Eastern Water Dragon	*Intellagama lesueurii*		P	2252
Animalia	Reptilia	Agamidae	Mountain Dragon	*Rankinia diemensis*		P	2182
Animalia	Reptilia	Typhlopidae	Blackish Blind Snake	*Ramphotyphlops nigrescens*		P	2599
Animalia	Reptilia	Boidae	Diamond Python	*Morelia spilota spilota*		P	5096
Animalia	Reptilia	Elapidae	Golden-crowned Snake	*Cacophis squamulosus*		P	2647
Animalia	Reptilia	Elapidae	Eastern Small-eyed Snake	*Cryptophis nigrescens*		P	5136
Animalia	Reptilia	Elapidae	Yellow-faced Whip Snake	*Demansia psammophis*		P	2655
Animalia	Reptilia	Elapidae	Mustard-bellied Snake	*Drysdalia rhodogaster*		P	2805
Animalia	Reptilia	Elapidae	Broad-headed Snake	*^Hoplocephalus bungaroides*	V	E1,P,2	2676
Animalia	Reptilia	Elapidae	Tiger Snake	*Notechis scutatus*		P	2681
Animalia	Reptilia	Elapidae	Red-bellied Black Snake	*Pseudechis porphyriacus*		P	2693
Animalia	Aves	Phasianidae	Stubble Quail	*Coturnix pectoralis*		P	0009
Animalia	Aves	Phasianidae	Unidentified Quail	*Coturnix sp.*		P	9046
Animalia	Aves	Phasianidae	King Quail	*Excalfactoria chinensis*		P	0012
Animalia	Aves	Anatidae	Pacific Black Duck	*Anas superciliosa*		P	0208
Animalia	Aves	Anatidae	Australian Wood Duck	*Chenonetta jubata*		P	0202
Animalia	Aves	Podicipedidae	Australasian Grebe	*Tachybaptus novaehollandiae*		P	0061
Animalia	Aves	Columbidae	White-headed Pigeon	*Columba leucomela*		P	0028
Animalia	Aves	Columbidae	Bar-shouldered Dove	*Geopelia humeralis*		P	0032
Animalia	Aves	Columbidae	Peaceful Dove	*Geopelia striata*		P	9931
Animalia	Aves	Columbidae	Wonga Pigeon	*Leucosarcia melanoleuca*		P	0044
Animalia	Aves	Columbidae	Brown Cuckoo-Dove	*Macropygia amboinensis*		P	0029
Animalia	Aves	Columbidae	Crested Pigeon	*Ocyphaps lophotes*		P	0043
Animalia	Aves	Columbidae	Common Bronzewing	*Phaps chalcoptera*		P	0034
Animalia	Aves	Columbidae	Brush Bronzewing	*Phaps elegans*		P	0035
Animalia	Aves	Podargidae	Tawny Frogmouth	*Podargus strigoides*		P	0313
Animalia	Aves	Caprimulgidae	White-throated Nightjar	*Eurostopodus mystacalis*		P	0330
Animalia	Aves	Aegothelidae	Australian Owlet-nightjar	*Aegotheles cristatus*		P	0317
Animalia	Aves	Apodidae	White-throated Needletail	*Hirundapus caudacutus*	C,J,K	P	0334
Animalia	Aves	Phalacrocoracidae	Little Pied Cormorant	*Microcarbo melanoleucos*		P	0100
Animalia	Aves	Phalacrocoracidae	Great Cormorant	*Phalacrocorax carbo*		P	0096
Animalia	Aves	Ardeidae	White-necked Heron	*Ardea pacifica*		P	0189
Animalia	Aves	Ardeidae	White-faced Heron	*Egretta novaehollandiae*		P	0188
Animalia	Aves	Accipitridae	Collared Sparrowhawk	*Accipiter cirrocephalus*		P	0222
Animalia	Aves	Accipitridae	Brown Goshawk	*Accipiter fasciatus*		P	0221
Animalia	Aves	Accipitridae	Wedge-tailed Eagle	*Aquila audax*		P	0224
Animalia	Aves	Accipitridae	Swamp Harrier	*Circus approximans*		P	0219
Animalia	Aves	Falconidae	Nankeen Kestrel	*Falco cenchroides*		P	0240
Animalia	Aves	Rallidae	Purple Swamphen	*Porphyrio porphyrio*		P	0058
Animalia	Aves	Charadriidae	Masked Lapwing	*Vanellus miles*		P	0133

Animalia	Aves	Cacatuidae	Sulphur-crested Cockatoo	*Cacatua galerita*	P	0269
Animalia	Aves	Cacatuidae	Gang-gang Cockatoo	*^^Callocephalon fimbriatum*	V,P,3	0268
Animalia	Aves	Cacatuidae	Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*	P	0267
Animalia	Aves	Cacatuidae	Glossy Black-Cockatoo	*^Calyptorhynchus lathami*	V,P,2	0265
Animalia	Aves	Cacatuidae	Galah	*Eolophus roseicapillus*	P	0273
Animalia	Aves	Cacatuidae	Cockatiel	*Nymphicus hollandicus*	P	0274
Animalia	Aves	Psittacidae	Australian King-Parrot	*Alisterus scapularis*	P	0281
Animalia	Aves	Psittacidae	Little Lorikeet	*Glossopsitta pusilla*	V,P	0260
Animalia	Aves	Psittacidae	Crimson Rosella	*Platycercus elegans*	P	0282
Animalia	Aves	Psittacidae	Eastern Rosella	*Platycercus eximius*	P	0288
Animalia	Aves	Psittacidae	Scaly-breasted Lorikeet	*Trichoglossus chlorolepidotus*	P	0256
Animalia	Aves	Psittacidae	Rainbow Lorikeet	*Trichoglossus haematodus*	P	9947
Animalia	Aves	Psittacidae		*Trichoglossus haematodus moluccanus*	P	8882
Animalia	Aves	Cuculidae	Fan-tailed Cuckoo	*Cacomantis flabelliformis*	P	0338
Animalia	Aves	Cuculidae	Brush Cuckoo	*Cacomantis variolosus*	P	0339
Animalia	Aves	Cuculidae	Horsfield's Bronze-Cuckoo	*Chalcites basalis*	P	0342
Animalia	Aves	Cuculidae	Shining Bronze-Cuckoo	*Chalcites lucidus*	P	0343
Animalia	Aves	Cuculidae	Oriental Cuckoo	*Cuculus optatus*	P	8922
Animalia	Aves	Cuculidae	Eastern Koel	*Eudynamys orientalis*	P	0347
Animalia	Aves	Cuculidae	Channel-billed Cuckoo	*Scythrops novaehollandiae*	P	0348
Animalia	Aves	Strigidae	Southern Boobook	*Ninox novaeseelandiae*	P	9922
Animalia	Aves	Strigidae	Powerful Owl	*^^Ninox strenua*	V,P,3	0248
Animalia	Aves	Alcedinidae	Azure Kingfisher	*Ceyx azureus*	P	0319
Animalia	Aves	Alcedinidae	Laughing Kookaburra	*Dacelo novaeguineae*	P	0322
Animalia	Aves	Alcedinidae	Sacred Kingfisher	*Todiramphus sanctus*	P	0326
Animalia	Aves	Menuridae	Superb Lyrebird	*Menura novaehollandiae*	P	0350
Animalia	Aves	Climacteridae	Red-browed Treecreeper	*Climacteris erythrops*	P	0560
Animalia	Aves	Climacteridae	White-throated Treecreeper	*Cormobates leucophaea*	P	0558
Animalia	Aves	Ptilonorhynchidae	Green Catbird	*Ailuroedus crassirostris*	P	0676
Animalia	Aves	Ptilonorhynchidae	Satin Bowerbird	*Ptilonorhynchus violaceus*	P	0679
Animalia	Aves	Maluridae	Superb Fairy-wren	*Malurus cyaneus*	P	0529
Animalia	Aves	Maluridae	Variegated Fairy-wren	*Malurus lamberti*	P	0536
Animalia	Aves	Maluridae	Southern Emu-wren	*Stipiturus malachurus*	P	0526
Animalia	Aves	Dasyornithidae	Pilotbird	*Pycnoptilus floccosus*	P	0506
Animalia	Aves	Acanthizidae	Western Thornbill	*Acanthiza inornata*	P	0472
Animalia	Aves	Acanthizidae	Striated Thornbill	*Acanthiza lineata*	P	0470
Animalia	Aves	Acanthizidae	Yellow Thornbill	*Acanthiza nana*	P	0471
Animalia	Aves	Acanthizidae	Brown Thornbill	*Acanthiza pusilla*	P	0475
Animalia	Aves	Acanthizidae	Buff-rumped Thornbill	*Acanthiza reguloides*	P	0484
Animalia	Aves	Acanthizidae	Brown Gerygone	*Gerygone mouki*	P	0454
Animalia	Aves	Acanthizidae	Chestnut-rumped Heathwren	*Hylacola pyrrhopygia*	P	0498
Animalia	Aves	Acanthizidae	Rockwarbler	*Origma solitaria*	P	0505
Animalia	Aves	Acanthizidae	Yellow-throated Scrubwren	*Sericornis citreogularis*	P	0493
Animalia	Aves	Acanthizidae	White-browed Scrubwren	*Sericornis frontalis*	P	0488
Animalia	Aves	Acanthizidae	Large-billed Scrubwren	*Sericornis magnirostra*	P	0494
Animalia	Aves	Pardalotidae	Spotted Pardalote	*Pardalotus punctatus*	P	0565
Animalia	Aves	Pardalotidae	Striated Pardalote	*Pardalotus striatus*	P	0976
Animalia	Aves	Meliphagidae	Eastern Spinebill	*Acanthorhynchus tenuirostris*	P	0591
Animalia	Aves	Meliphagidae	Red Wattlebird	*Anthochaera carunculata*	P	0638
Animalia	Aves	Meliphagidae	Little Wattlebird	*Anthochaera chrysoptera*	P	0710
Animalia	Aves	Meliphagidae	Yellow-faced Honeyeater	*Caligavis chrysops*	P	0614
Animalia	Aves	Meliphagidae	White-eared Honeyeater	*Lichenostomus leucotis*	P	0617
Animalia	Aves	Meliphagidae	White-plumed Honeyeater	*Lichenostomus penicillatus*	P	0625
Animalia	Aves	Meliphagidae	Noisy Miner	*Manorina melanocephala*	P	0634
Animalia	Aves	Meliphagidae	Bell Miner	*Manorina melanophrys*	P	0633
Animalia	Aves	Meliphagidae	Lewin's Honeyeater	*Meliphaga lewinii*	P	0605
Animalia	Aves	Meliphagidae	Brown-headed Honeyeater	*Melithreptus brevirostris*	P	0583
Animalia	Aves	Meliphagidae	White-naped Honeyeater	*Melithreptus lunatus*	P	0578
Animalia	Aves	Meliphagidae	Scarlet Honeyeater	*Myzomela sanguinolenta*	P	0586
Animalia	Aves	Meliphagidae	Little Friarbird	*Philemon citreogularis*	P	0646
Animalia	Aves	Meliphagidae	Noisy Friarbird	*Philemon corniculatus*	P	0645
Animalia	Aves	Meliphagidae	White-cheeked Honeyeater	*Phylidonyris niger*	P	0632
Animalia	Aves	Meliphagidae	New Holland Honeyeater	*Phylidonyris novaehollandiae*	P	0631
Animalia	Aves	Meliphagidae	Crescent Honeyeater	*Phylidonyris pyrrhoptera*	P	0630
Animalia	Aves	Psophodidae	Eastern Whipbird	*Psophodes olivaceus*	P	0421
Animalia	Aves	Neosittidae	Varied Sittella	*Daphoenositta chrysoptera*	V,P	0549
Animalia	Aves	Campephagidae	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	P	0424
Animalia	Aves	Campephagidae		*Coracina novaehollandiae melanops*	P	8525
Animalia	Aves	Campephagidae	White-bellied Cuckoo-shrike	*Coracina papuensis*	P	0425
Animalia	Aves	Campephagidae	Cicadabird	*Coracina tenuirostris*	P	0429
Animalia	Aves	Pachycephalidae	Grey Shrike-thrush	*Colluricincla harmonica*	P	0408
Animalia	Aves	Pachycephalidae	Eastern Shrike-tit	*Falcunculus frontatus frontatus*	P	0416

Animalia	Aves	Pachycephalidae	Golden Whistler	*Pachycephala pectoralis*		P	0398
Animalia	Aves	Pachycephalidae	Rufous Whistler	*Pachycephala rufiventris*		P	0401
Animalia	Aves	Artamidae	Australian Magpie	*Cracticus tibicen*		P	0705
Animalia	Aves	Artamidae		*Cracticus tibicen tibicen*		P	8499
Animalia	Aves	Artamidae	Grey Butcherbird	*Cracticus torquatus*		P	0702
Animalia	Aves	Artamidae		*Cracticus torquatus torquatus*		P	8489
Animalia	Aves	Artamidae	Pied Currawong	*Strepera graculina*		P	0694
Animalia	Aves	Artamidae	Grey Currawong	*Strepera versicolor*		P	0697
Animalia	Aves	Dicruridae	Spangled Drongo	*Dicrurus bracteatus*		P	0673
Animalia	Aves	Rhipiduridae	Grey Fantail	*Rhipidura albiscapa*		P	0361
Animalia	Aves	Rhipiduridae		*Rhipidura albiscapa alisteri*		P	8447
Animalia	Aves	Rhipiduridae	Willie Wagtail	*Rhipidura leucophrys*		P	0364
Animalia	Aves	Rhipiduridae	Rufous Fantail	*Rhipidura rufifrons*		P	0362
Animalia	Aves	Corvidae	Australian Raven	*Corvus coronoides*		P	0930
Animalia	Aves	Monarchidae	Magpie-lark	*Grallina cyanoleuca*		P	0415
Animalia	Aves	Monarchidae	Black-faced Monarch	*Monarcha melanopsis*		P	0373
Animalia	Aves	Monarchidae	Leaden Flycatcher	*Myiagra rubecula*		P	0365
Animalia	Aves	Petroicidae	Eastern Yellow Robin	*Eopsaltria australis*		P	0392
Animalia	Aves	Petroicidae	Rose Robin	*Petroica rosea*		P	0384
Animalia	Aves	Cisticolidae	Golden-headed Cisticola	*Cisticola exilis*		P	0525
Animalia	Aves	Acrocephalidae	Australian Reed-Warbler	*Acrocephalus australis*		P	0524
Animalia	Aves	Timaliidae	Silvereye	*Zosterops lateralis*		P	0574
Animalia	Aves	Hirundinidae	Welcome Swallow	*Hirundo neoxena*		P	0357
Animalia	Aves	Hirundinidae	Fairy Martin	*Petrochelidon ariel*		P	0360
Animalia	Aves	Hirundinidae	Tree Martin	*Petrochelidon nigricans*		P	0359
Animalia	Aves	Nectariniidae	Mistletoebird	*Dicaeum hirundinaceum*		P	0564
Animalia	Aves	Estrildidae	Red-browed Finch	*Neochmia temporalis*		P	0662
Animalia	Aves	Estrildidae	Beautiful Firetail	*Stagonopleura bella*		P	0650
Animalia	Mammalia	Ornithorhynchidae	Platypus	*Ornithorhynchus anatinus*		P	1001
Animalia	Mammalia	Tachyglossidae	Short-beaked Echidna	*Tachyglossus aculeatus*		P	1003
Animalia	Mammalia	Dasyuridae	Brown Antechinus	*Antechinus stuartii*		P	1674
Animalia	Mammalia	Dasyuridae	Dusky Antechinus	*Antechinus swainsonii*		P	1033
Animalia	Mammalia	Dasyuridae	Spotted-tailed Quoll	*Dasyurus maculatus*	E	V,P	1008
Animalia	Mammalia	Peramelidae	unidentified Bandicoot	*Isoodon/Perameles sp.*		P	T081
Animalia	Mammalia	Peramelidae	Long-nosed Bandicoot	*Perameles nasuta*		P	1097
Animalia	Mammalia	Vombatidae	Common Wombat	*Vombatus ursinus*		P	1165
Animalia	Mammalia	Petauridae	Sugar Glider	*Petaurus breviceps*		P	1138
Animalia	Mammalia	Pseudocheiridae	Greater Glider	*Petauroides volans*		P	1133
Animalia	Mammalia	Pseudocheiridae	Common Ringtail Possum	*Pseudocheirus peregrinus*		P	1129
Animalia	Mammalia	Phalangeridae	brushtail possum	*Trichosurus sp.*		P	T082
Animalia	Mammalia	Phalangeridae	Common Brushtail Possum	*Trichosurus vulpecula*		P	1113
Animalia	Mammalia	Macropodidae	Swamp Wallaby	*Wallabia bicolor*		P	1242
Animalia	Mammalia	Pteropodidae	Grey-headed Flying-fox	*Pteropus poliocephalus*	V	V,P	1280
Animalia	Mammalia	Rhinolophidae	Eastern Horseshoe-bat	*Rhinolophus megaphyllus*		P	1303
Animalia	Mammalia	Molossidae	White-striped Freetail-bat	*Austronomus australis*		P	1324
Animalia	Mammalia	Vespertilionidae	Gould's Wattled Bat	*Chalinolobus gouldii*		P	1349
Animalia	Mammalia	Vespertilionidae	Chocolate Wattled Bat	*Chalinolobus morio*		P	1351
Animalia	Mammalia	Vespertilionidae	Eastern False Pipistrelle	*Falsistrellus tasmaniensis*		V,P	1372
Animalia	Mammalia	Vespertilionidae	Eastern Bentwing-bat	*Miniopterus schreibersii oceanensis*		V,P	1834
Animalia	Mammalia	Vespertilionidae	long-eared bat	*Nyctophilus sp.*		P	T092
Animalia	Mammalia	Vespertilionidae	Greater Broad-nosed Bat	*Scoteanax rueppellii*		V,P	1361
Animalia	Mammalia	Vespertilionidae	Eastern Broad-nosed Bat	*Scotorepens orion*		P	1365
Animalia	Mammalia	Vespertilionidae	Large Forest Bat	*Vespadelus darlingtoni*		P	1022
Animalia	Mammalia	Vespertilionidae	Southern Forest Bat	*Vespadelus regulus*		P	1378
Animalia	Mammalia	Vespertilionidae	Unidentified Eptesicus	*Vespadelus sp.*		P	T088
Animalia	Mammalia	Vespertilionidae	Little Forest Bat	*Vespadelus vulturnus*		P	1379
Animalia	Mammalia	Muridae	Bush Rat	*Rattus fuscipes*		P	1395
Animalia	Mammalia	Muridae	Swamp Rat	*Rattus lutreolus*		P	1398
Animalia	Insecta	Petaluridae	Giant Dragonfly	*Petalura gigantea*		E1	I007
Plantae	Flora	Adiantaceae	Common Maidenhair	*Adiantum aethiopicum*		P	7997
Plantae	Flora	Adiantaceae	Rough Maidenhair	*Adiantum hispidulum*		P	8000
Plantae	Flora	Adiantaceae		*Adiantum silvaticum*		P	8001
Plantae	Flora	Apiaceae	Flannel Flower	*Actinotus helianthi*		P	1094
Plantae	Flora	Asteraceae		*Cassinia aureonitens*		P	1363
Plantae	Flora	Blandfordiaceae		*Blandfordia cunninghamii*		P	3527
Plantae	Flora	Blandfordiaceae	Christmas Bells	*Blandfordia grandiflora*		P	3528
Plantae	Flora	Cunoniaceae		*Acrophyllum australe*	V	V,P	2265
Plantae	Flora	Cunoniaceae	Christmas Bush	*Ceratopetalum gummiferum*		P	2272
Plantae	Flora	Cyatheaceae	Rough Treefern	*Cyathea australis*		P	8074
Plantae	Flora	Cyperaceae	Curly Wig	*Caustis flexuosa*		P	2341
Plantae	Flora	Cyperaceae	Thick Twist Rush	*Caustis pentandra*		P	2342
Plantae	Flora	Cyperaceae		*Caustis recurvata*		P	2343
Plantae	Flora	Cyperaceae		*Caustis recurvata var. recurvata*		P	9315
Plantae	Flora	Cyperaceae	Red-fruit Saw-sedge	*Gahnia sieberiana*		P	2442
Plantae	Flora	Dicksoniaceae	Soft Treefern	*Dicksonia antarctica*		P	8082
Plantae	Flora	Ericaceae	Pink Swamp Heath	*Sprengelia incarnata*		P	2654
Plantae	Flora	Ericaceae		*Sprengelia incarnata f. 'incarnata'*		P	12949
Plantae	Flora	Fabaceae (Faboideae)		*Dillwynia tenuifolia*		V,P	2853

Plantae	Flora	Fabaceae (Faboideae)	Smooth Bush-Pea	*Pultenaea glabra*	V	V,P	2995
Plantae	Flora	Fabaceae (Mimosoideae)	Bynoe's Wattle	*Acacia bynoeana*	V	E1,P	3728
Plantae	Flora	Fabaceae (Mimosoideae)		*Acacia gordonii*	E	E1,P	7229
Plantae	Flora	Fabaceae (Mimosoideae)	Downy Wattle	*Acacia pubescens*	V	V,P	3860
Plantae	Flora	Gleicheniaceae	Umbrella Fern	*Sticherus flabellatus var. flabellatus*		P	11175
Plantae	Flora	Lycopodiaceae	Bushy Clubmoss	*Lycopodium deuterodensum*		P	6409
Plantae	Flora	Myrtaceae	Weeping Baeckea	*Baeckea linifolia*		P	3997
Plantae	Flora	Myrtaceae		*Darwinia biflora*	V	V,P	4024
Plantae	Flora	Myrtaceae	Tick Bush	*Kunzea ambigua*		P	4204
Plantae	Flora	Myrtaceae		*Kunzea capitata*		P	4207
Plantae	Flora	Myrtaceae	Woolly Teatree	*Leptospermum lanigerum*		P	4223
Plantae	Flora	Orchidaceae	Mosquito Orchid	*Acianthus exsertus*		P	4352
Plantae	Flora	Orchidaceae	Pixie Caps	*Acianthus fornicatus*		P	4353
Plantae	Flora	Orchidaceae	Mosquito Orchid	*Acianthus spp.*		P	ACIA
Plantae	Flora	Orchidaceae		*Adenochilus nortonii*		P	4356
Plantae	Flora	Orchidaceae		*Caladenia dimorpha*		P	4379
Plantae	Flora	Orchidaceae	Musky Caladenia	*Caladenia gracilis*		P	9123
Plantae	Flora	Orchidaceae	Bronzed Caladenia	*Caladenia transitoria*		P	13313
Plantae	Flora	Orchidaceae	Large Duck Orchid	*Caleana major*		P	4389
Plantae	Flora	Orchidaceae	Slender Beard Orchid	*Calochilus gracillimus*		P	4391
Plantae	Flora	Orchidaceae	Red Beard Orchid	*Calochilus paludosus*		P	4394
Plantae	Flora	Orchidaceae	Purplish Beard Orchid	*Calochilus robertsonii*		P	4395
Plantae	Flora	Orchidaceae		*Calochilus spp.*		P	CALO
Plantae	Flora	Orchidaceae		*Chiloglottis reflexa*		P	4402
Plantae	Flora	Orchidaceae		*Chiloglottis seminuda*		P	10291
Plantae	Flora	Orchidaceae		*Chiloglottis sylvestris*		P	6881
Plantae	Flora	Orchidaceae		*Chiloglottis trilabra*		P	6525
Plantae	Flora	Orchidaceae	Spurred Helmet Orchid	*Corybas aconitiflorus*		P	4404
Plantae	Flora	Orchidaceae		*Corybas spp.*		P	CORY
Plantae	Flora	Orchidaceae	Tartan Tongue Orchid	*Cryptostylis erecta*		P	4414
Plantae	Flora	Orchidaceae		*Cryptostylis spp.*		P	CRYT
Plantae	Flora	Orchidaceae	Large Tongue Orchid	*Cryptostylis subulata*		P	4417
Plantae	Flora	Orchidaceae	Snake Orchid	*Cymbidium suave*		P	4419
Plantae	Flora	Orchidaceae		*Cyrtostylis spp.*		P	CYRO
Plantae	Flora	Orchidaceae	Streaked Rock Orchid	*Dendrobium striolatum*		P	4433
Plantae	Flora	Orchidaceae		*Dipodium spp.*		P	DIPO
Plantae	Flora	Orchidaceae		*Diuris platichila*		P	4451
Plantae	Flora	Orchidaceae	Parson's Bands	*Eriochilus cucullatus*		P	4460
Plantae	Flora	Orchidaceae		*Genoplesium apostasioides*		P	9783
Plantae	Flora	Orchidaceae	Variable Midge Orchid	*Genoplesium archeri*		P	9197
Plantae	Flora	Orchidaceae		*Genoplesium citriodorum*		P	9559
Plantae	Flora	Orchidaceae	Fringed Midge Orchid	*Genoplesium fimbriatum*		P	8872
Plantae	Flora	Orchidaceae	Bearded Midge Orchid	*Genoplesium morrisii*		P	9785
Plantae	Flora	Orchidaceae	Dense Midge Orchid	*Genoplesium nudiscapum*		P	8873
Plantae	Flora	Orchidaceae	Green Midge Orchid	*Genoplesium pumilum*		P	9200
Plantae	Flora	Orchidaceae	Red Midge Orchid	*Genoplesium rufum*		P	9201
Plantae	Flora	Orchidaceae		*Genoplesium sagittiferum*		P	9543
Plantae	Flora	Orchidaceae		*Genoplesium simulans*		P	9784
Plantae	Flora	Orchidaceae		*Microtis spp.*		P	MICO
Plantae	Flora	Orchidaceae	Tall Leek Orchid	*Prasophyllum elatum*		P	4497
Plantae	Flora	Orchidaceae	Yellow Leek Orchid	*Prasophyllum flavum*		P	4502
Plantae	Flora	Orchidaceae		*Prasophyllum spp.*		P	PRAS
Plantae	Flora	Orchidaceae	Streaked Leek Orchid	*Prasophyllum striatum*		P	4524
Plantae	Flora	Orchidaceae	Pointed Greenhood	*Pterostylis acuminata*		P	4535
Plantae	Flora	Orchidaceae		*Pterostylis chocolatinus*		P	13348
Plantae	Flora	Orchidaceae		*Pterostylis daintreana*		P	4546
Plantae	Flora	Orchidaceae	Cobra Greenhood	*Pterostylis grandiflora*		P	4554
Plantae	Flora	Orchidaceae	Small Nodding Greenhood	*Pterostylis hispidula*		P	7616
Plantae	Flora	Orchidaceae	Tall Greenhood	*Pterostylis longifolia*		P	4559
Plantae	Flora	Orchidaceae	Nodding Greenhood	*Pterostylis nutans*		P	4562
Plantae	Flora	Orchidaceae	Tiny Greenhood	*Pterostylis parviflora*		P	4566
Plantae	Flora	Orchidaceae	Maroonhood	*Pterostylis pedunculata*		P	4568
Plantae	Flora	Orchidaceae		*Pterostylis sp. aff. tunstallii*		P	11402
Plantae	Flora	Orchidaceae	Greenhood	*Pterostylis spp.*		P	PTER
Plantae	Flora	Orchidaceae	Green Rock Orchid	*Rimacola elliptica*		P	4578
Plantae	Flora	Orchidaceae	Ladies' Tresses	*Spiranthes australis*		P	11877
Plantae	Flora	Orchidaceae		*Thelymitra angustifolia*		P	11449
Plantae	Flora	Orchidaceae	Tiny Sun Orchid	*Thelymitra carnea*		P	4592

Plantae	Flora	Orchidaceae	Dotted Sun Orchid	*Thelymitra ixioides var. ixioides*		P	8968
Plantae	Flora	Orchidaceae	Tall Sun Orchid	*Thelymitra media var. media*		P	10275
Plantae	Flora	Orchidaceae	Red Sun Orchid	*Thelymitra rubra*		P	10277
Plantae	Flora	Orchidaceae		*Thelymitra spp.*		P	THEL
Plantae	Flora	Orchidaceae	Large Veined Sun Orchid	*Thelymitra venosa*		P	4604
Plantae	Flora	Osmundaceae	King Fern	*Todea barbara*		P	8151
Plantae	Flora	Podocarpaceae	Dwarf Mountain Pine	*Pherosphaera fitzgeraldii*	E	E1,P	12430
Plantae	Flora	Proteaceae	Hairpin Banksia	*Banksia spinulosa*		P	5349
Plantae	Flora	Proteaceae		*Banksia spinulosa var. spinulosa*		P	7488
Plantae	Flora	Proteaceae		*Grevillea longifolia*		P	5382
Plantae	Flora	Proteaceae	Broad-leaf Drumsticks	*Isopogon anemonifolius*		P	5433
Plantae	Flora	Proteaceae	Crinkle Bush	*Lomatia silaifolia*		P	5445
Plantae	Flora	Proteaceae	Needle Geebung	*Persoonia acerosa*	V	V,P	5450
Plantae	Flora	Proteaceae	Mountain Geebung	*Persoonia chamaepitys*		P	5453
Plantae	Flora	Proteaceae	Lance Leaf Geebung	*Persoonia lanceolata*		P	5460
Plantae	Flora	Proteaceae	Laurel Geebung	*Persoonia laurina*		P	5461
Plantae	Flora	Proteaceae		*Persoonia laurina subsp. laurina*		P	9823
Plantae	Flora	Proteaceae	Broad-leaved Geebung	*Persoonia levis*		P	5462
Plantae	Flora	Proteaceae	Narrow-leaved Geebung	*Persoonia linearis*		P	5463
Plantae	Flora	Proteaceae	Soft Geebung	*Persoonia mollis*		P	5465
Plantae	Flora	Proteaceae		*Persoonia mollis subsp. mollis*		P	9000
Plantae	Flora	Proteaceae	Pine-leaved Geebung	*Persoonia pinifolia*		P	5469
Plantae	Flora	Proteaceae		*Persoonia spp.*		P	PERS
Plantae	Flora	Proteaceae		*Petrophile pedunculata*		P	5478
Plantae	Flora	Proteaceae	Conesticks	*Petrophile pulchella*		P	5479
Plantae	Flora	Proteaceae		*Petrophile sessilis*		P	5480
Plantae	Flora	Proteaceae		*Petrophile spp.*		P	PETO
Plantae	Flora	Proteaceae	Waratah	*Telopea speciosissima*		P	5488
Plantae	Flora	Proteaceae	Woody Pear	*Xylomelum pyriforme*		P	5490
Plantae	Flora	Psilotaceae		*Tmesipteris truncata*		P	8170
Plantae	Flora	Rutaceae		*Asterolasia buxifolia*		E1,P	10885
Plantae	Flora	Rutaceae	Pale-pink Boronia	*Boronia floribunda*		P	5740
Plantae	Flora	Rutaceae	Sydney Boronia	*Boronia ledifolia*		P	5744
Plantae	Flora	Rutaceae		*Boronia pinnata*		P	5750
Plantae	Flora	Rutaceae		*Phebalium squamulosum subsp. squamulosum*		P	8374
Plantae	Flora	Rutaceae		*Philotheca hispidula*		P	10586
Plantae	Flora	Xanthorrhoeaceae		*Xanthorrhoea arborea*		P	6315
Plantae	Flora	Xanthorrhoeaceae		*Xanthorrhoea media*		P	6319
Plantae	Flora	Xanthorrhoeaceae		*Xanthorrhoea minor*		P	6320
Plantae	Flora	Xanthorrhoeaceae		*Xanthorrhoea resinosa*		P	6321
Plantae	Flora	Xanthorrhoeaceae		*Xanthorrhoea spp.*		P	XANT

NSW status

1	Sensitivity Class 1 (Sensitive Species Data Policy)
2	Sensitivity Class 2 (Sensitive Species Data Policy)
3	Sensitivity Class 3 (Sensitive Species Data Policy)
CH	Critical Habitat (Threatened Species Conservation Act 1995)
E1	Endangered (Threatened Species Conservation Act 1995)
E2	Endangered Population (Threatened Species Conservation Act 1995)
E3	Endangered Ecological Community (Threatened Species Conservation Act 1995)
E4	Presumed Extinct (Threatened Species Conservation Act 1995)
E4A	Critically Endangered (Threatened Species Conservation Act 1995)
E4B	Critically Endangered Ecological Community (Threatened Species Conservation Act 1995)
FCE	Critically Endangered Fish (Fisheries Management Act 1994)
FE	Endangered Fish (Fisheries Management Act 1994)
FEC	Endangered Ecological Community of Fish (Fisheries Management Act 1994)
FEP	Endangered Population of Fish (Fisheries Management Act 1994)
FKTP	Key Threatening Process of Fish (Fisheries Management Act 1994)
FP	Protected Fish (Fisheries Management Act 1994)
FV	Vulnerable Fish (Fisheries Management Act 1994)
FX	Extinct Fish (Fisheries Management Act 1994)
KTP	Key Threatening Process (Threatened Species Conservation Act 1995)
P	Protected (National Parks & Wildlife Act 1974)
V	Vulnerable (Threatened Species Conservation Act 1995)
V2	Vulnerable Ecological Community (Threatened Species Conservation Act 1995)

Commonwealth status

C	Listed on China Australia Migratory Bird Agreement
CD	Conservation Dependent (Commonwealth EPBC Act 1999)
CE	Critically Endangered (Commonwealth EPBC Act 1999)
E	Endangered (Commonwealth EPBC Act 1999)
J	Listed on Japan Australia Migratory Bird Agreement
K	Listed on Republic of Korea Australia Migratory Bird Agreement
KTP	Key Threatening Process (Commonwealth EPBC Act 1999)
V	Vulnerable (Commonwealth EPBC Act 1999)
X	Extinct (Commonwealth EPBC Act 1999)
XW	Extinct in the Wild (Commonwealth EPBC Act 1999)

Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

APPENDIX C

OPTIONS COST ESTIMATES

Cardno
Shaping the Future

59915031 - Hazelbrook and Woodford Creek FRMSP

FM1 Red Gum Avenue and Blue Hills Road Berms
Cost Estimate

Cardno
Shaping the Future

18/03/2016

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)				**9,200**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing (all)	1,000	sq. m	10	10,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	150	cu. m	20	3,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	15	cu. m	50	750
	SUBTOTAL				**13,750**
3.0	**EARTHWORKS**				
3.1	Construction of Berm 1 - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	750	cu. m	50	37,500
3.2	Construction of Berm 2 - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	1400	cu. m	50	70,000
3.3	Construction of Berm 3 - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill.	750	cu. m	50	37,500
	SUBTOTAL				**37,500**
4.0	**ROAD WORKS**				
4.1	Local reshaping of naturestrip on grove road to divert flow towards creek	60	m	20	1,200
	SUBTOTAL				**1,200**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	1,000	sq. m	10	10,000
	SUBTOTAL				**10,000**
	CONSTRUCTION SUB-TOTAL				**71,650**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**35,825**
	CONSTRUCTION TOTAL, excluding GST				**107,475**
	GST				**10,748**
	CONSTRUCTION TOTAL, including GST				**118,223**
	CONSTRUCTION TOTAL, rounded				**120,000**

DISCLAIMER:

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NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM3 Flow path from Luchetti Avenue
Cost Estimate

19/03/2016

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)				**3,500**
2.0	**CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	400	sq. m	10	4,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	60	cu. m	20	1,200
2.3	Dispose of excess topsoil (nominal 10% allowance)	6	cu. m	50	300
	SUBTOTAL				**5,500**
3.0	**EARTHWORKS**				
3.1	Construction of Berm - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill. Length 50m height 600mm	75	cu. m	50	3,750
3.2	Import fill to construct berm	40	cu. m	50	2,000
3.3	Construction of flow path from Luchetti Avenue to natrual flow path. Nominal 250mm deep 4 m wide	50	m	50	2,500
3.4	Kerb modifications to allow flow from road onto constructed flow path	1	item	5000	5,000
	SUBTOTAL				**13,250**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	400	sq. m	10	4,000
	SUBTOTAL				**4,000**
	CONSTRUCTION SUB-TOTAL				**26,250**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**13,125**
	CONSTRUCTION TOTAL, excluding GST				**39,375**
	GST				**3,938**
	CONSTRUCTION TOTAL, including GST				**43,313**
	CONSTRUCTION TOTAL, rounded				**44,000**

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NOTES:

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3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

Cardno
Shaping the Future

FM4 Oaklands Road Berm (Luchetti-Oaklands)
Cost Estimate

19/03/2016

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)				**5,100**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	400	sq. m	10	4,000
2.2	Removal of Trees	1	item	5000	5,000
2.3	Strip topsoil & stockpile for re-use (assuming 150mm depth)	600	cu. m	20	12,000
2.4	Dispose of excess topsoil (nominal 10% allowance)	60	cu. m	50	3,000
	SUBTOTAL				**24,000**
3.0	**EARTHWORKS**				
3.1	Construction of Berm 1 - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill. 50m long at 620m RL.	120	cu. m	50	6,000
	SUBTOTAL				**6,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	400	sq. m	10	4,000
	SUBTOTAL				**4,000**
	CONSTRUCTION SUB-TOTAL				**39,100**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**19,550**
	CONSTRUCTION TOTAL, excluding GST				**58,650**
	GST				**5,865**
	CONSTRUCTION TOTAL, including GST				**64,515**
	CONSTRUCTION TOTAL, rounded				**65,000**

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NOTES:

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2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM5 Flow Path Park Road
Cost Estimate

21/03/2016

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)				**12,100**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	1,500	sq. m	10	15,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	225	cu. m	20	4,500
2.3	Dispose of excess topsoil (nominal 10% allowance)	22.5	cu. m	50	1,125
	SUBTOTAL				**20,625**
3.0	**EARTHWORKS**				
3.1	Excavate channels - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill. Shallow swal approximately 0.3m deep at 10m	300	cu. m	50	15,000
3.2	Inlet pit improvement at Park Road.	1	item	2500	2,500
	SUBTOTAL				**15,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	1,500	sq. m	30	45,000
	SUBTOTAL				**45,000**
	CONSTRUCTION SUB-TOTAL				**92,725**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**46,363**
	CONSTRUCTION TOTAL, excluding GST				**139,088**
	GST				**13,909**
	CONSTRUCTION TOTAL, including GST				**152,996**
	CONSTRUCTION TOTAL, rounded				**155,000**

DISCLAIMER:

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NOTES:

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2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM6 Gloria Park Detention Basin
Cost Estimate

21/03/2016

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)				**50,300**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	4,000	sq. m	10	40,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	600	cu. m	20	12,000
2.3	Dispose of excess topsoil (nominal 10% allowance)	60	cu. m	50	3,000
2.4	Clear channel to south of new detention basin	800	m	15	12,000
	SUBTOTAL				**55,000**
3.0	**EARTHWORKS**				
3.1	Excavate basin - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	4500	cu. m	50	225,000
3.2	Augmentation of northern tributary to flow to new basin	250	m	50	12,500
	SUBTOTAL				**225,000**
4.0	**DETENTION BASIN DRAIANGE**				
3.1	Instal entry and exit weirs, construct drainage and conect to existing network (nominal cost)	1	item	15000	15,000
	SUBTOTAL				**15,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	4,000	sq. m	10	40,000
	SUBTOTAL				**40,000**
	CONSTRUCTION SUB-TOTAL				**385,300**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**192,650**
	CONSTRUCTION TOTAL, excluding GST				**577,950**
	GST				**57,795**
	CONSTRUCTION TOTAL, including GST				**635,745**
	CONSTRUCTION TOTAL, rounded				**640,000**

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NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM7 Oaklands Road Berm (Park-Oaklands)
Cost Estimate

19/03/2016

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)				**5,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	150	sq. m	10	1,500
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	225	cu. m	20	4,500
2.3	Dispose of excess topsoil (nominal 10% allowance)	22.5	cu. m	50	1,125
	SUBTOTAL				**7,125**
3.0	**EARTHWORKS**				
3.1	Construction of Berm 1 - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill. 200m long at 629m RL.	600	cu. m	50	30,000
	SUBTOTAL				**30,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	150	sq. m	10	1,500
	SUBTOTAL				**1,500**
	CONSTRUCTION SUB-TOTAL				**44,425**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**22,213**
	CONSTRUCTION TOTAL, excluding GST				**66,638**
	GST				**6,664**
	CONSTRUCTION TOTAL, including GST				**73,301**
	CONSTRUCTION TOTAL, rounded				**75,000**

DISCLAIMER:

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NOTES:

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2. Assume existing drainage at sufficiently deep level to remain undisturbed.
3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM8 Log Bridge Place Detention Basin
Cost Estimate

21/03/2016

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)				**14,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	550	sq. m	10	5,500
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	82.5	cu. m	20	1,650
2.3	Dispose of excess topsoil (nominal 10% allowance)	8.25	cu. m	50	413
	SUBTOTAL				**7,563**
3.0	**EARTHWORKS**				
3.1	Construction of Basin Wall - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	1500	cu. m	50	75,000
	SUBTOTAL				**75,000**
4.0	**DETENTION BASIN DRAINAGE**				
3.1	Instal entry and exit weirs, construct drainage and conect to existing network (nominal cost)	1	item	10000	10,000
	SUBTOTAL				**10,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	550	sq. m	10	5,500
	SUBTOTAL				**5,500**
	CONSTRUCTION SUB-TOTAL				**112,863**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**56,431**
	CONSTRUCTION TOTAL, excluding GST				**169,294**
	GST				**16,929**
	CONSTRUCTION TOTAL, including GST				**186,223**
	CONSTRUCTION TOTAL, rounded				**190,000**

DISCLAIMER:

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NOTES:

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3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM9 Alexander Avenue Berm
Cost Estimate

22/03/2016

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)				**3,100**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	100	sq. m	10	1,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	15	cu. m	20	300
2.3	Dispose of excess topsoil (nominal 10% allowance)	1.5	cu. m	50	75
	SUBTOTAL				**1,375**
3.0	**EARTHWORKS**				
3.1	Excavate basin - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	600	cu. m	30	18,000
	SUBTOTAL				**18,000**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	100	sq. m	10	1,000
	SUBTOTAL				**1,000**
	CONSTRUCTION SUB-TOTAL				**23,475**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**11,738**
	CONSTRUCTION TOTAL, excluding GST				**35,213**
	GST				**3,521**
	CONSTRUCTION TOTAL, including GST				**38,734**
	CONSTRUCTION TOTAL, rounded				**40,000**

DISCLAIMER:

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NOTES:

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3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

FM10 - Falcon Street Pipe Upgrade
Cost Estimate

12/04/2016

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)				**18,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	400	sq. m	10	4,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	60	cu. m	20	1,200
2.3	Dispose of excess topsoil (nominal 10% allowance)	6	cu. m	50	300
	SUBTOTAL				**5,500**
3.0	**EARTHWORKS**				
3.1	Nominal cost for minor earthworks at headwalls	1	item	25000	25,000
	SUBTOTAL				**25,000**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø900mm RIBLOK Pipe	50	lin.m	900	45,000
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø750mm RCP including demolition and disposal of existing pipe.	45	lin.m	750	33,750
4.3	Removal of concrete channel and disposal offsite	15	lin.m	750	11,250
4.4	Upgrade of existing pits	5	item	1000	5,000
4.5	Installation of new pits	1	Item	1500	1,500
4.6	Installation of headwall including removing of existing trees and vegetation and stabilising outlet with rock	1	item	7500	7,500
	SUBTOTAL				**90,000**
5.0	**CHANNEL WORKS**				
5.1	Widening existing channel at rear of properties on Talbot Road to 2 m	90	m	50	4,500
5.2	Rock line channel	90	m	75	6,750
	SUBTOTAL				**4,500**
	CONSTRUCTION SUB-TOTAL				**143,800**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**71,900**
	CONSTRUCTION TOTAL, excluding GST				**215,700**
	GST				**21,570**
	CONSTRUCTION TOTAL, including GST				**237,270**
	CONSTRUCTION TOTAL, rounded				**238,000**

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NOTES:

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59915031 - Hazelbrook and Woodford Creek FRMSP

FM11 Vegetation Management Origma Avenue
Cost Estimate

21/03/2016

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)				**5,300**
2.0	**CLEARING AND WEEDING**				
2.1	Removal of trees and debris from within flow path (nominal cost)	1	item	15,000	15,000
2.2	Weeding / clearing of creek sections with overgrown banks or invasive / exotic species.	300	m	50	15,000
	SUBTOTAL				**30,000**
3.0	**MINOR LANDSCAPING**				
3.1	Repair disturbed bank areas (nominal allowance)	500	sq. m	10	5,000
	SUBTOTAL				**5,000**
	CONSTRUCTION SUB-TOTAL				**40,300**
4.0	**CONTINGENCIES**				
4.1	50% construction cost				**20,150**
	CONSTRUCTION TOTAL, excluding GST				**60,450**
	GST				**6,045**
	CONSTRUCTION TOTAL, including GST				**66,495**
	CONSTRUCTION TOTAL, rounded				**67,000**

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NOTES:

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3. Estimate / rates in 2016 dollars and does not allow for inflation

59915031 - Hazelbrook and Woodford Creek FRMSP

Cardno
Shaping the Future

FM12 Glendarrah Road Swale / Berm
Cost Estimate

30.03.2014

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)				**8,300**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	1,300	sq. m	10	13,000
2.2	Removal of trees	1	item	7500	7,500
2.3	Strip topsoil & stockpile for re-use (assuming 150mm depth)	195	cu. m	20	3,900
2.4	Dispose of excess topsoil (nominal 10% allowance)	19.5	cu. m	50	975
	SUBTOTAL				**25,375**
3.0	**EARTHWORKS**				
3.1	Excavate for swale and berm - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill.	550	cu. m	30	16,500
	SUBTOTAL				**16,500**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas (nominal allowance)	1,300	sq. m	10	13,000
	SUBTOTAL				**13,000**
	CONSTRUCTION SUB-TOTAL				**63,175**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**31,588**
	CONSTRUCTION TOTAL, excluding GST				**94,763**
	GST				**9,476**
	CONSTRUCTION TOTAL, including GST				**104,239**
	CONSTRUCTION TOTAL, rounded				**105,000**

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NOTES:

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3. Estimate / rates in 2016 dollars and does not allow for inflation

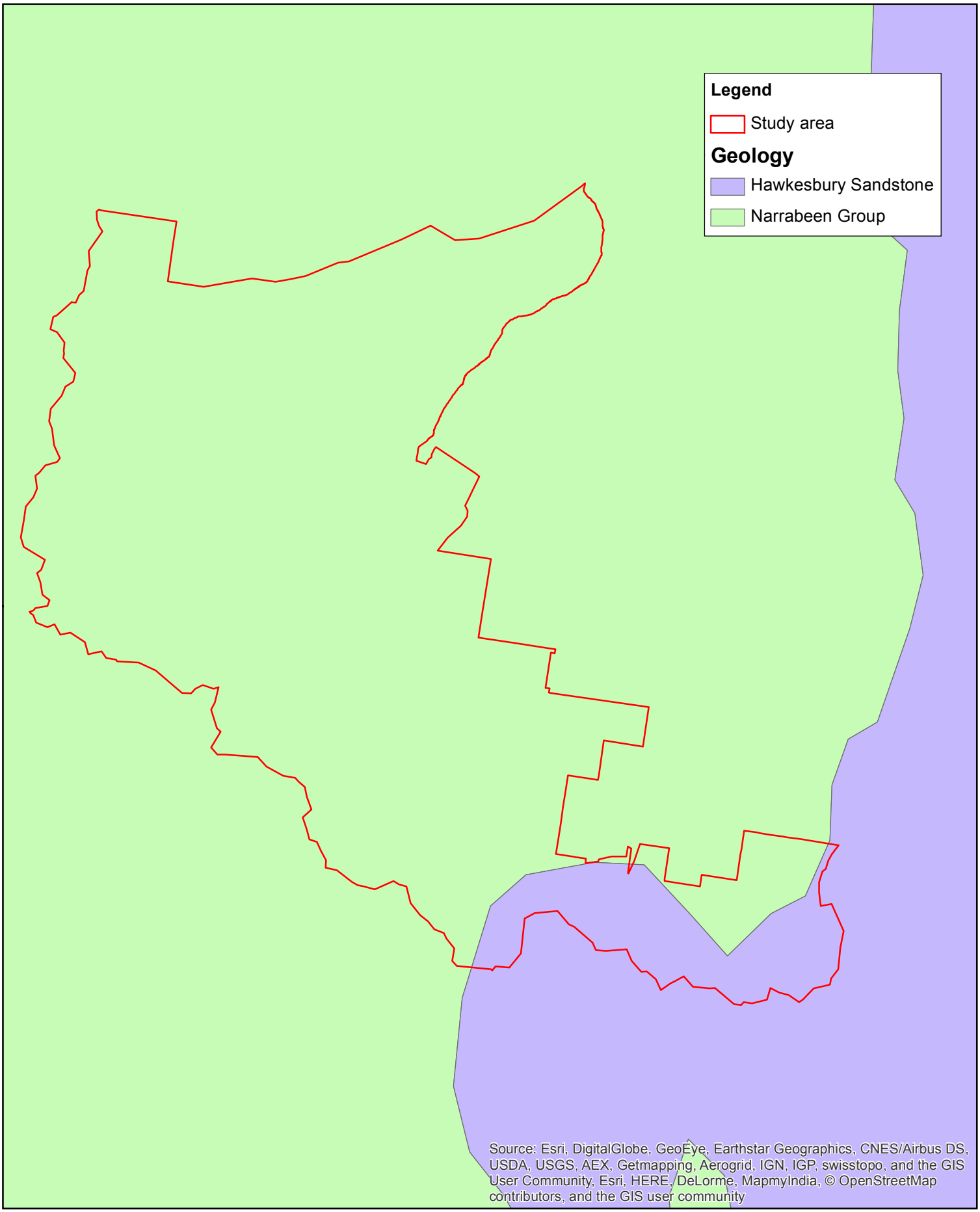
Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

APPENDIX

D

FIGURES

Cardno
Shaping the Future



Geology

Figure 2-4

1:25,000 Scale at A4

Metres

0 200 400 600 800

N W E S

Cardno

Map Produced by NSW/ACT (2304)
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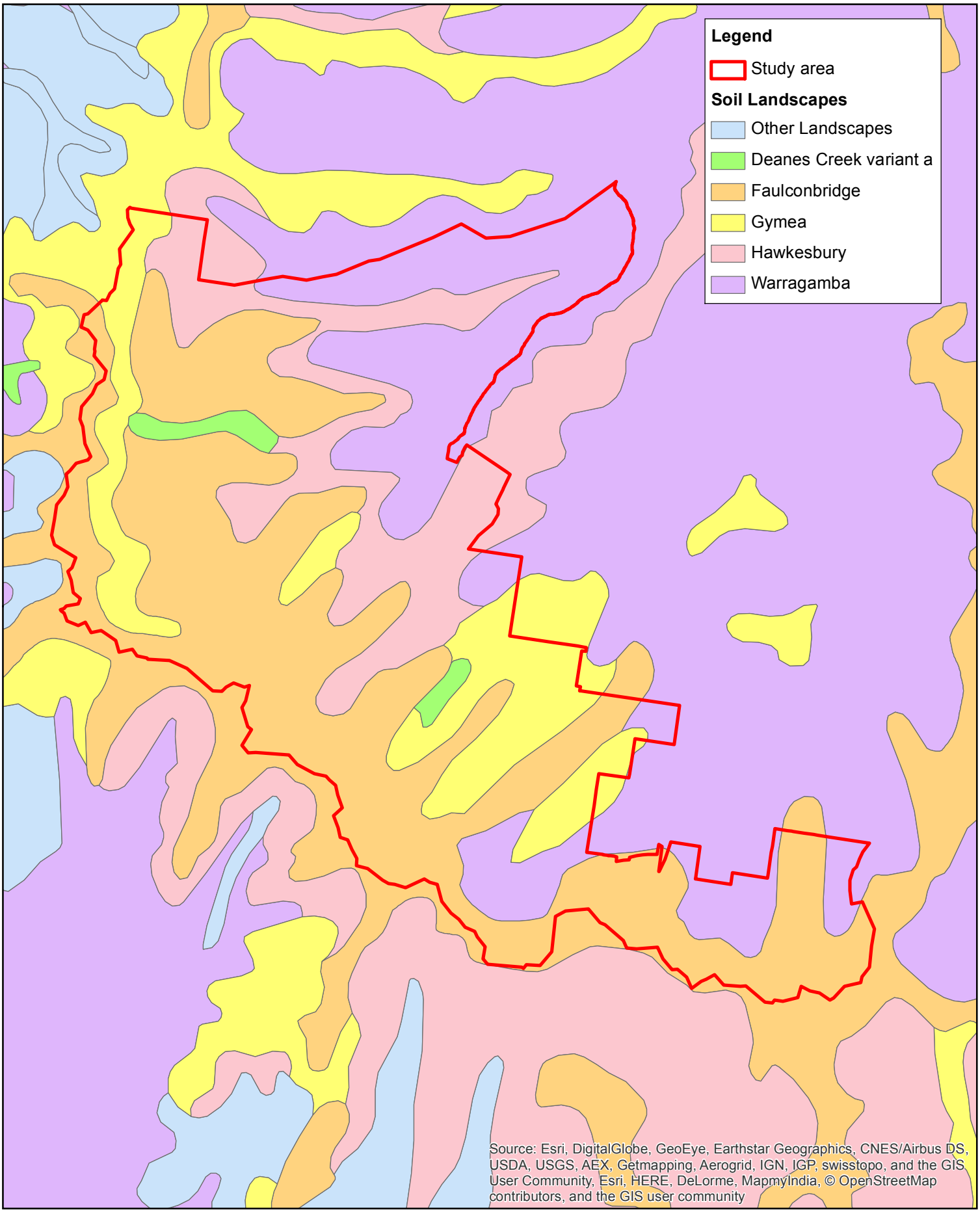
Coordinate System: GDA 1994 MGA Zone 56
Project: 59915031
Map: 59915031-GS-003-GeoSoils.mxd 01



Soil Landscapes

Figure 2-5

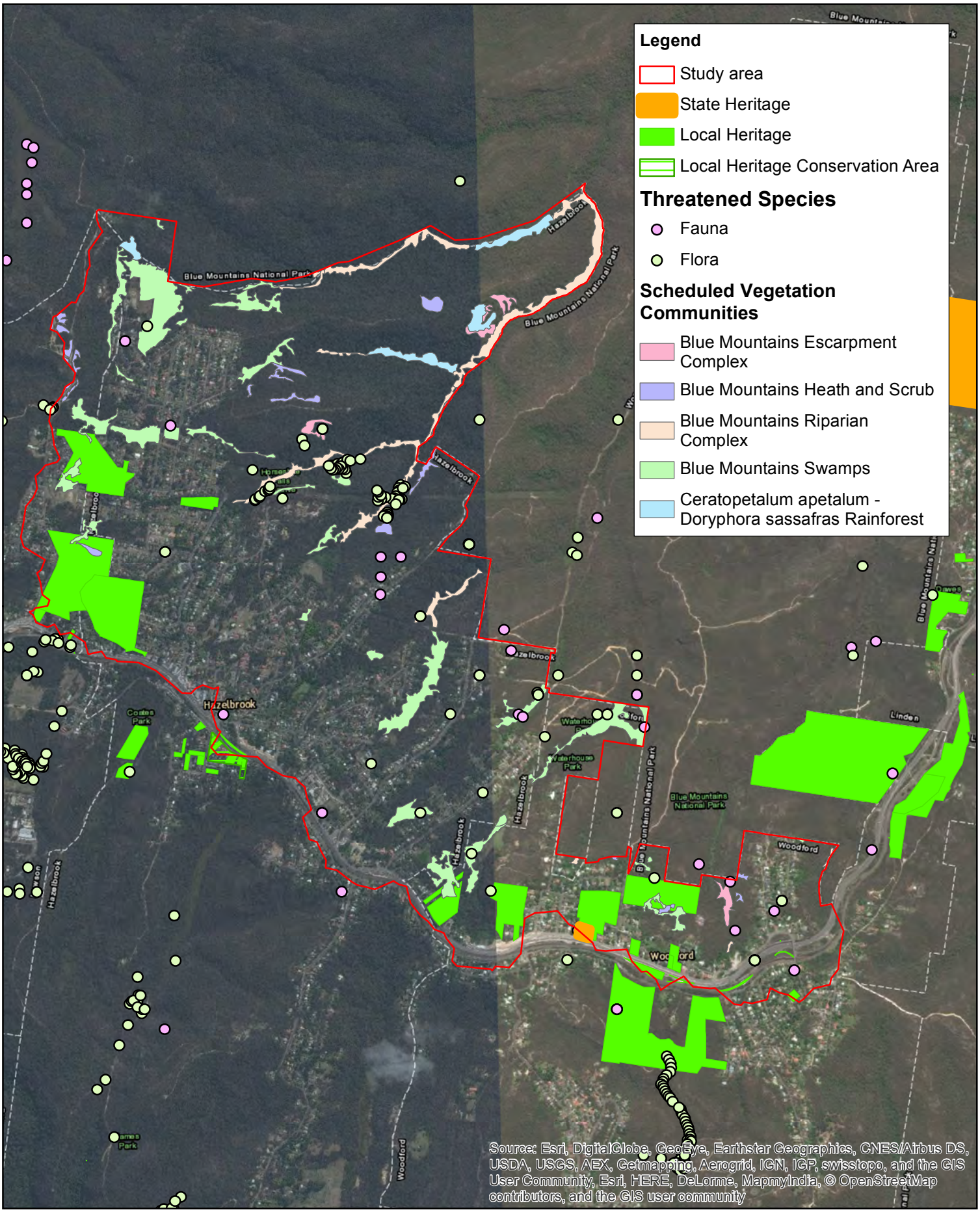
1:25,000 Scale at A4

Metres

0 200 400 600 800

Cardno

Map Produced by NSW/ACT (2304)
Date: 2016-03-16
Coordinate System: GDA 1994 MGA Zone 56
Project: 59915031
Map: 59915031-GS-004-Soils.mxd 01



Flora, Fauna and Heritage

Figure 2-6

1:25,000 Scale at A4

Metres

0 200 400 600 800

Cardno

Map Produced by NSW/ACT (2304)
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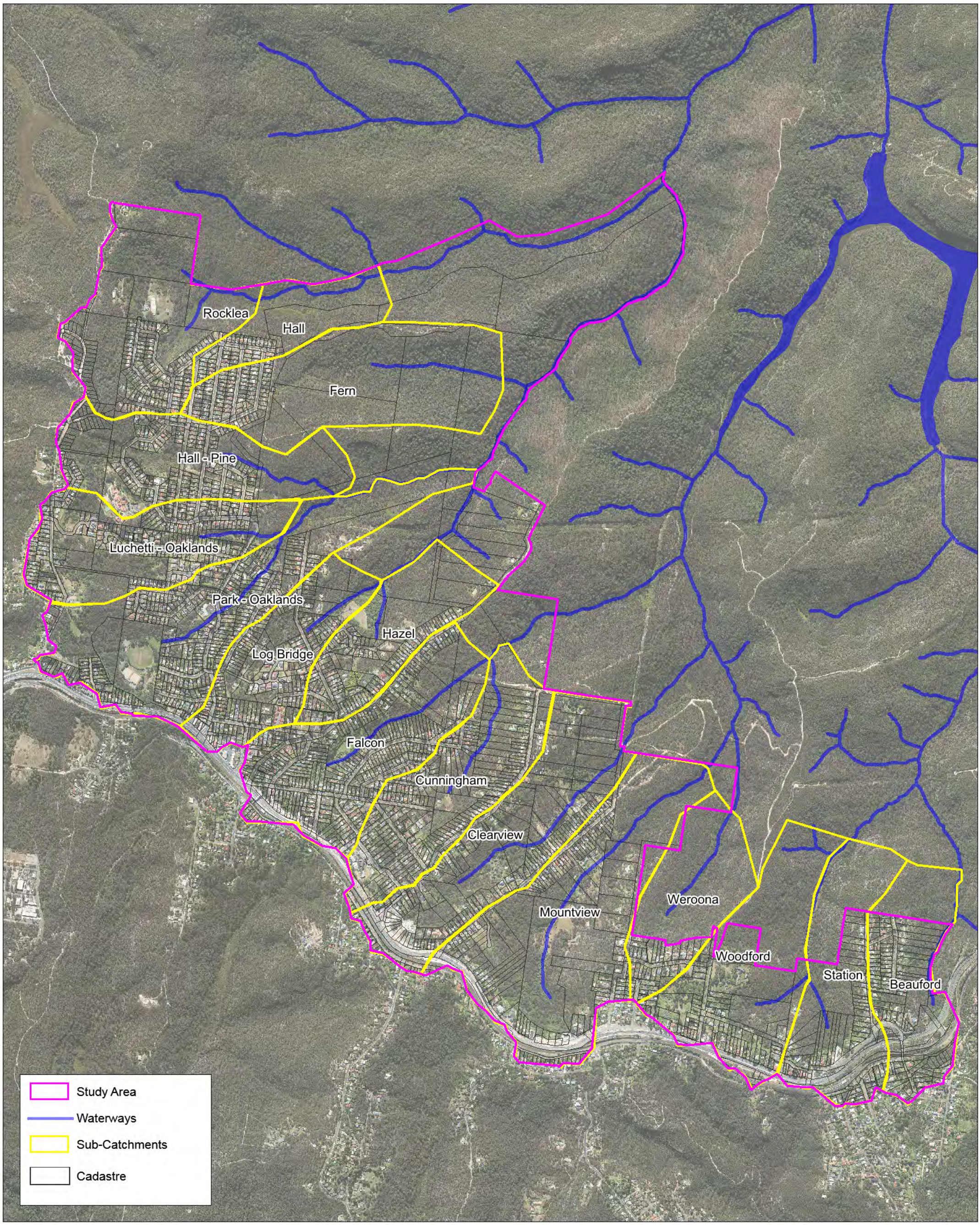
Coordinate System: GDA 1994 MGA Zone 56
Project: 59915031
Map: 59915031-GS-002-FloraFaunaHer.mxd 02



Scale 1:15,000 Scale at A3

Metres

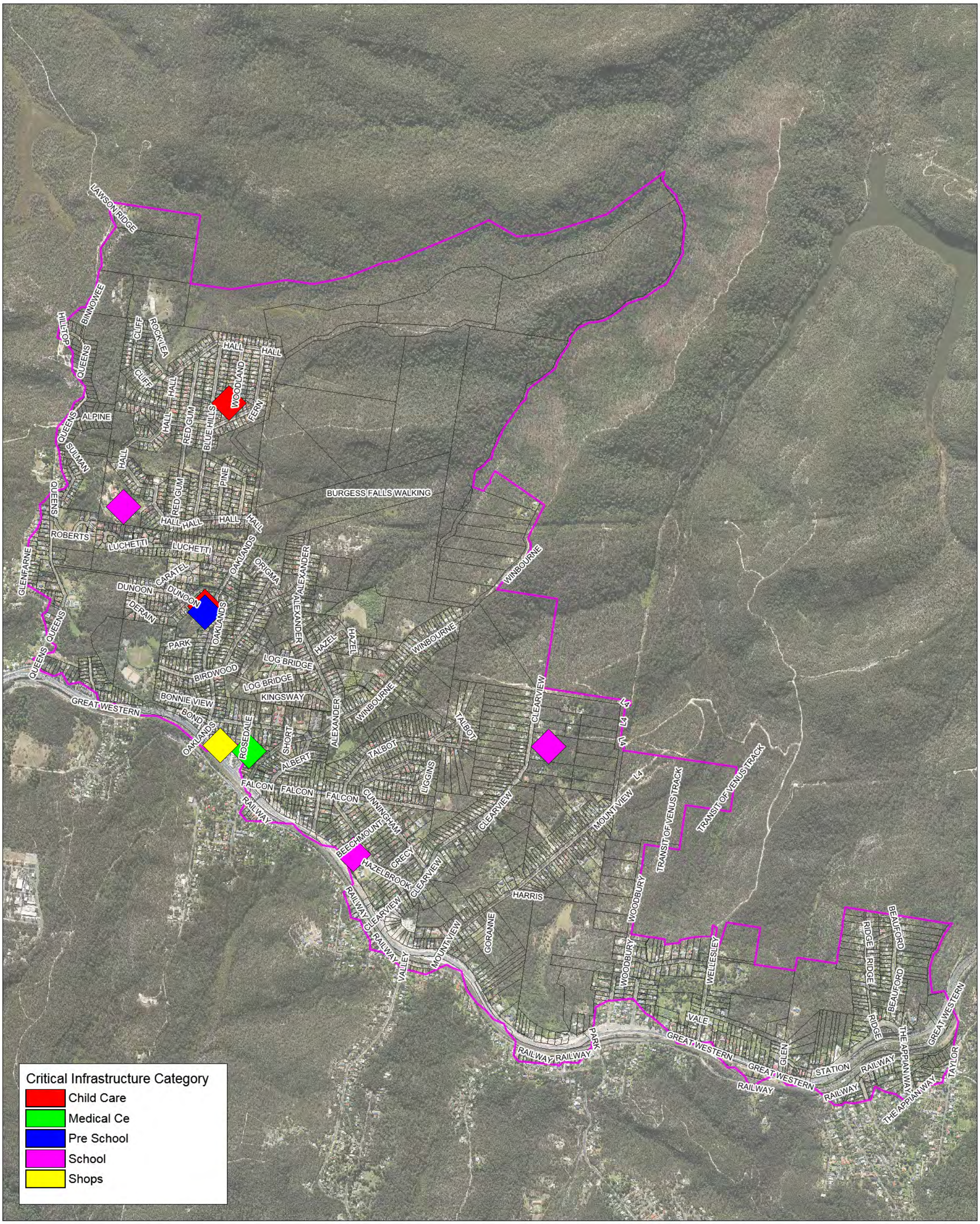
0 250 500

Sub Catchments

Figure 5-1

Cardno

Map Produced by Water & Environment
Date: 06/04/2016
Coordinate System: MGA56
Project:59915031



Critical Infrastructure

Figure 5-2

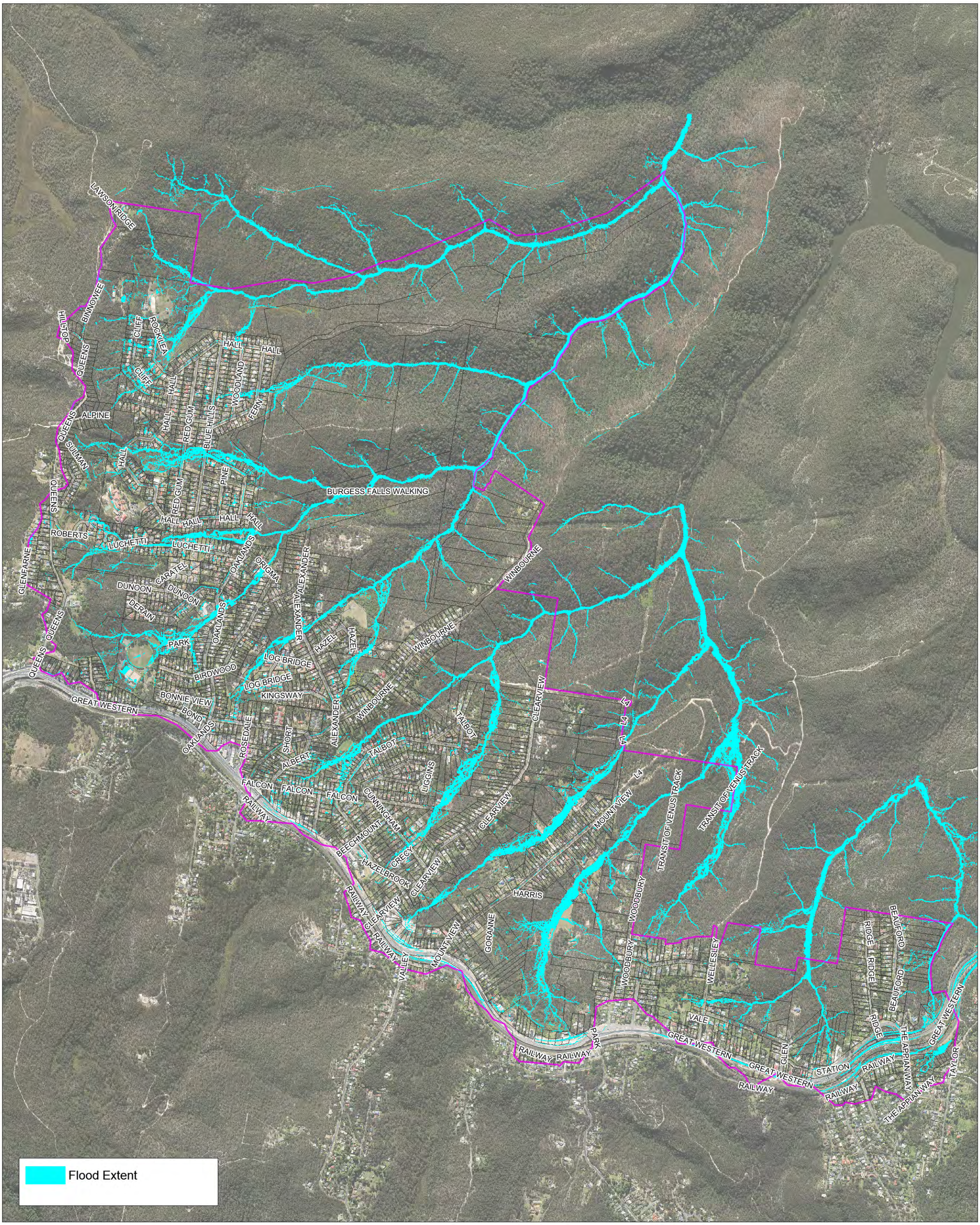
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: 06/04/2016
Coordinate System: MGA56
Project:59915031



Flood Extent - 20% AEP

Figure 5-3

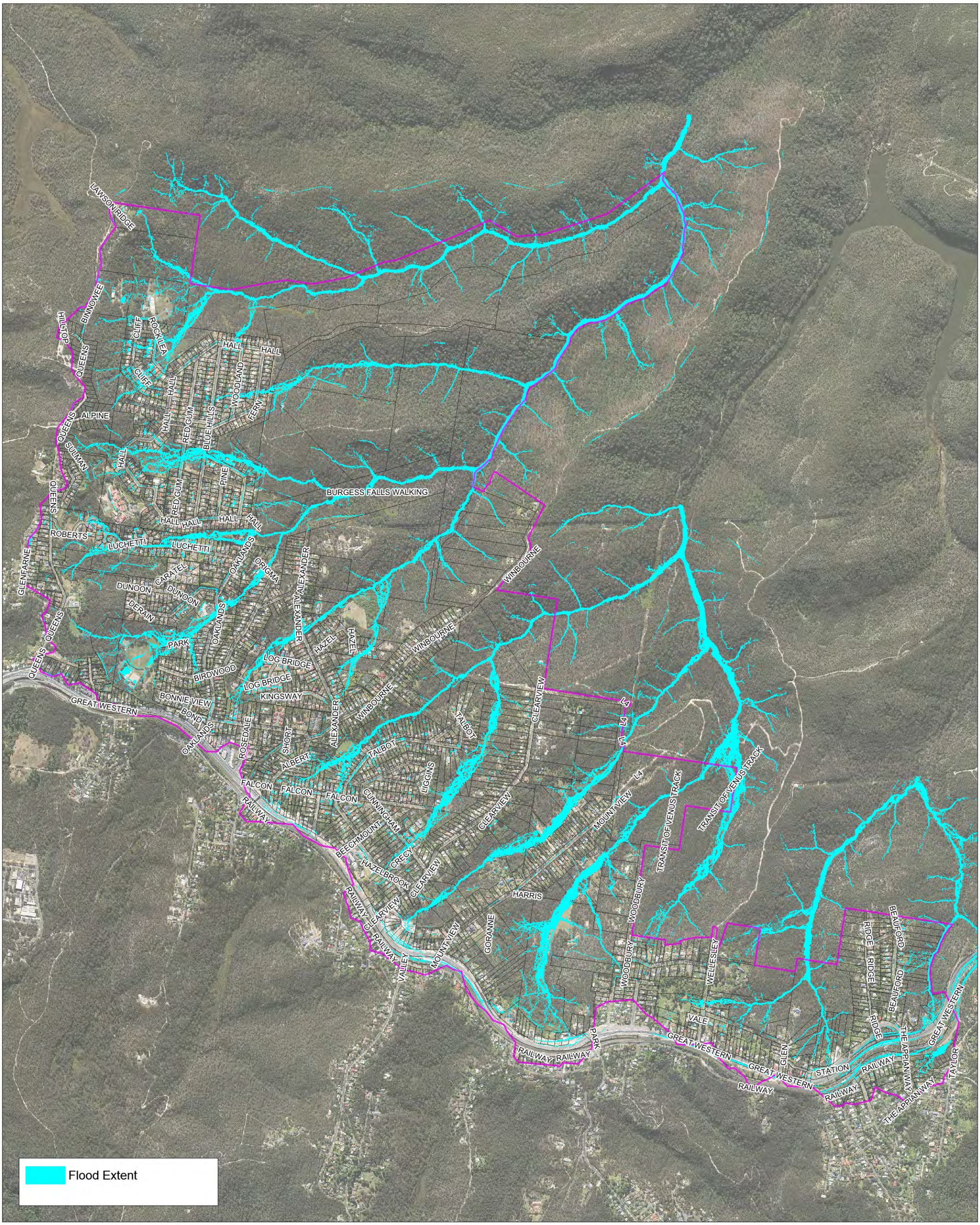
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Flood Extent - 10% AEP

Figure 5-4

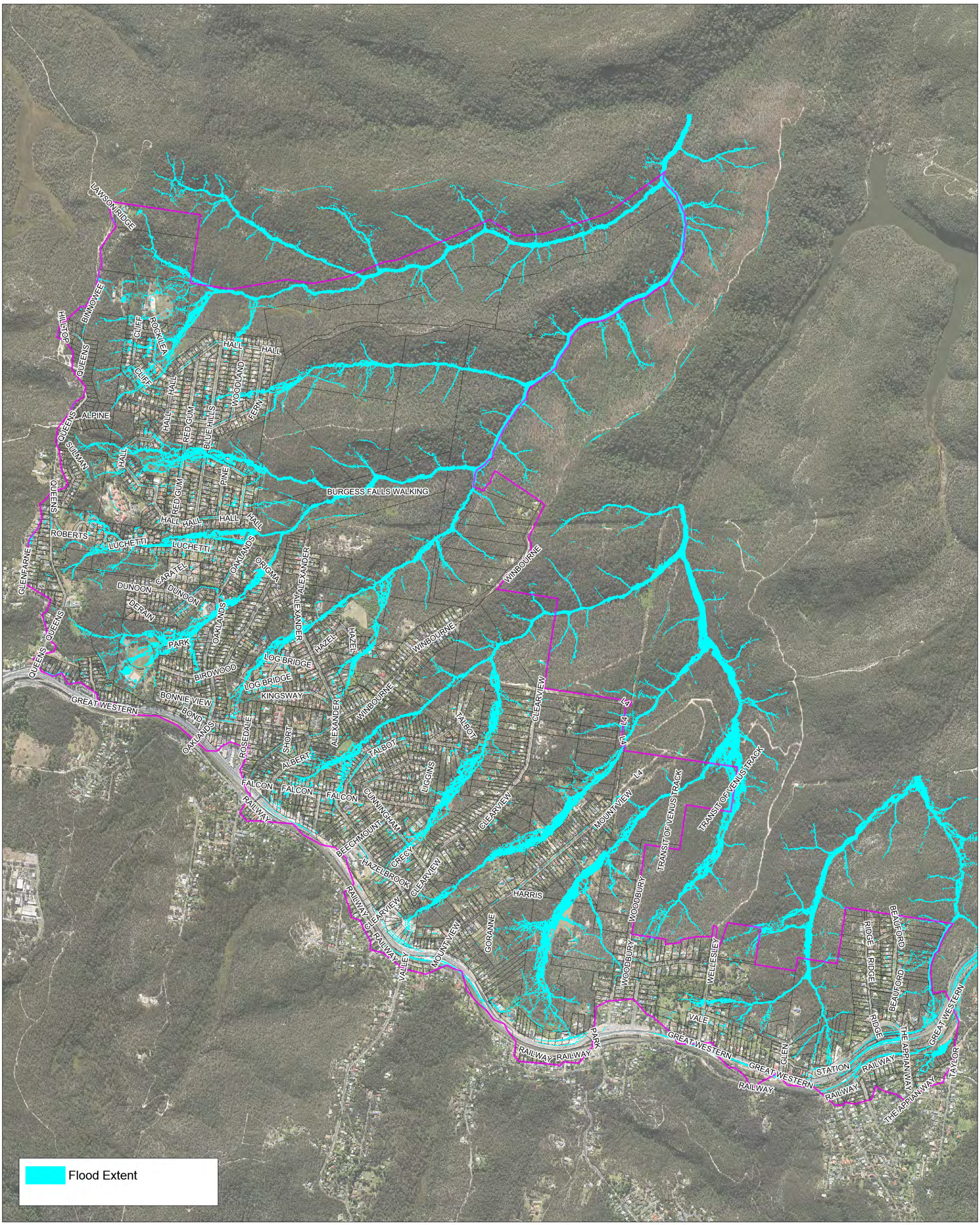
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Flood Extent - 2% AEP

Figure 5-5

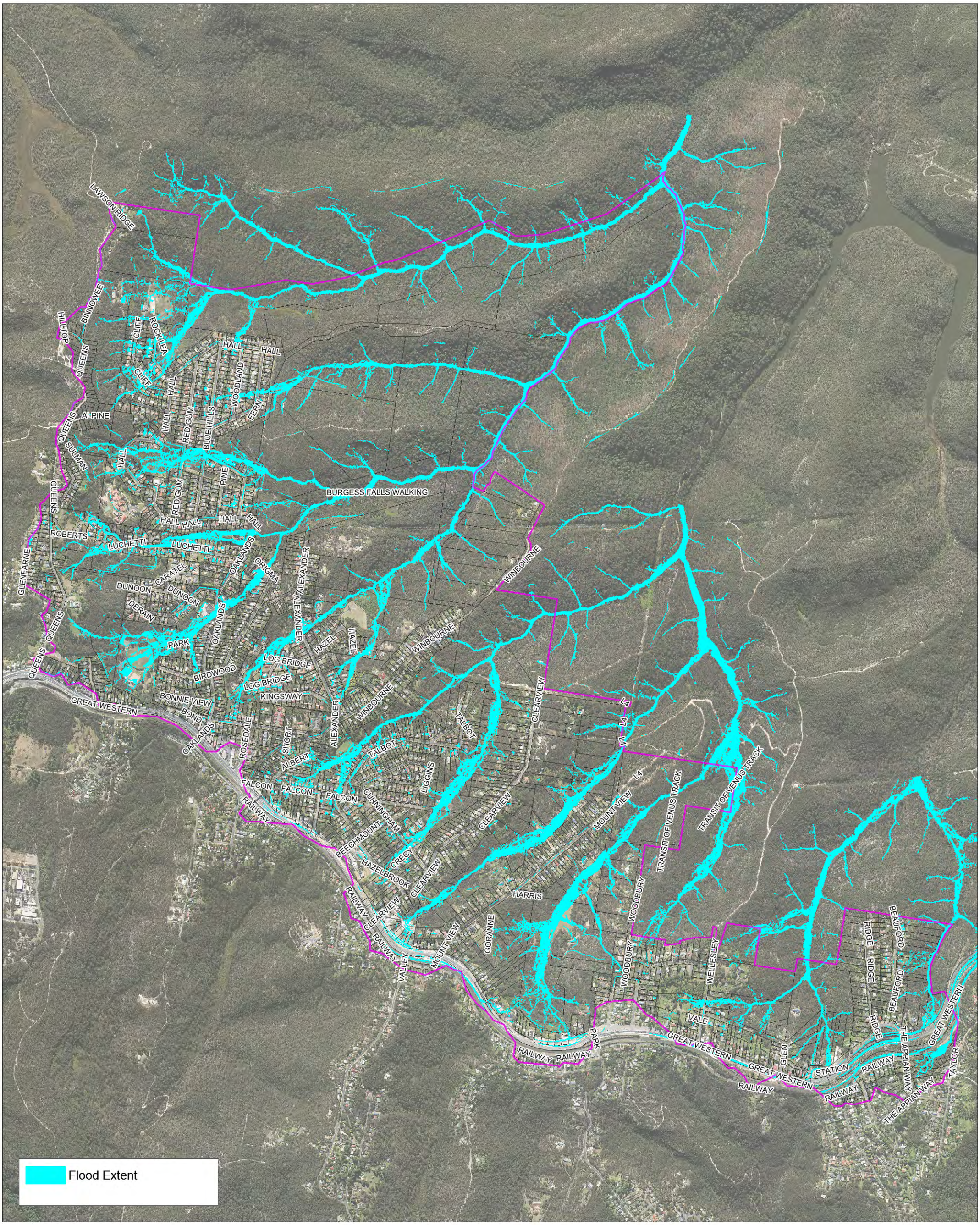
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Flood Extent - 1% AEP

Figure 5-6

Scale 1:15,000 Scale at A3

Metres

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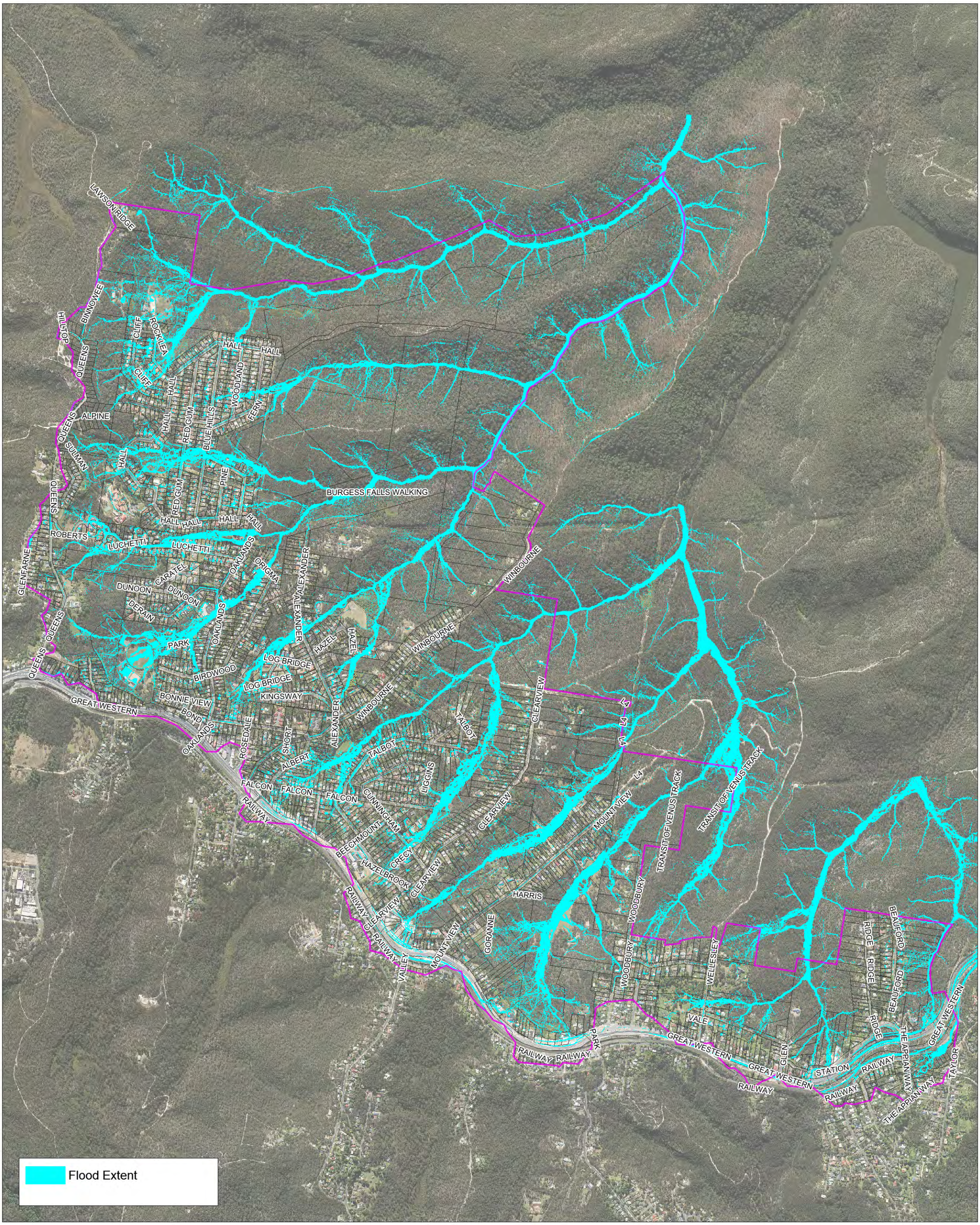
Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Flood Extent - 0.5% AEP

Figure 5-7

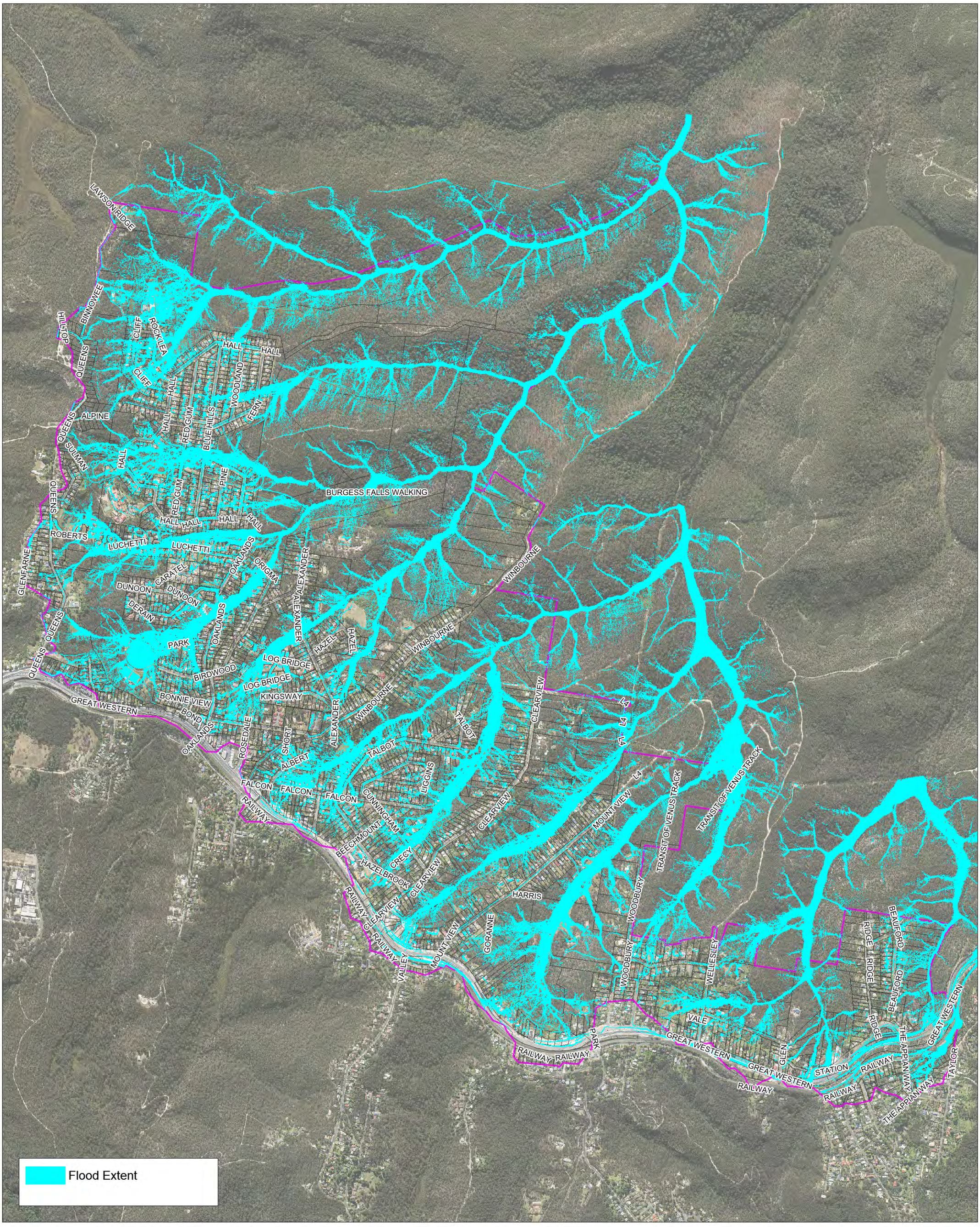
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Flood Extent - PMF

Figure 5-8

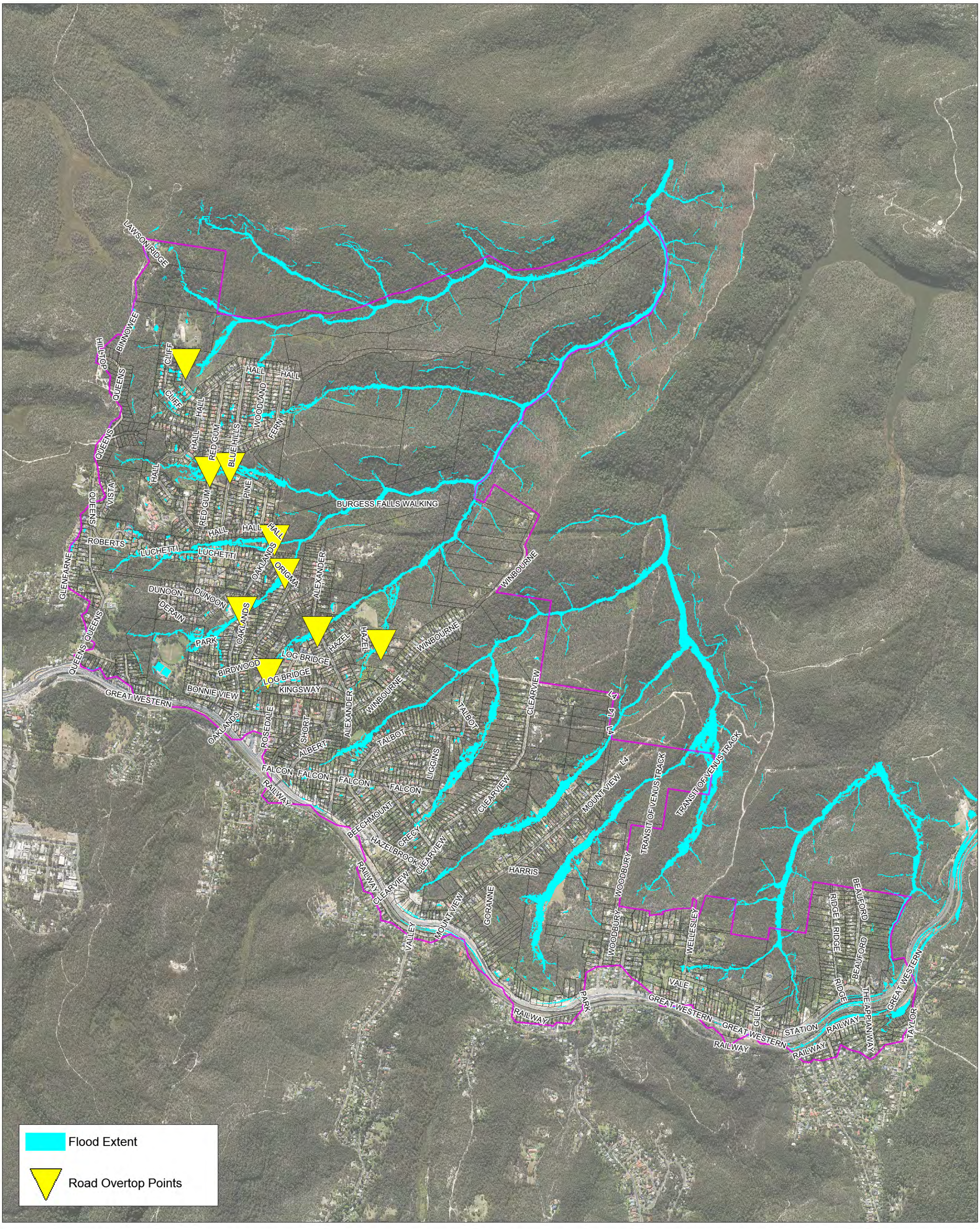
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Scale 1:15,000 Scale at A3

Metres

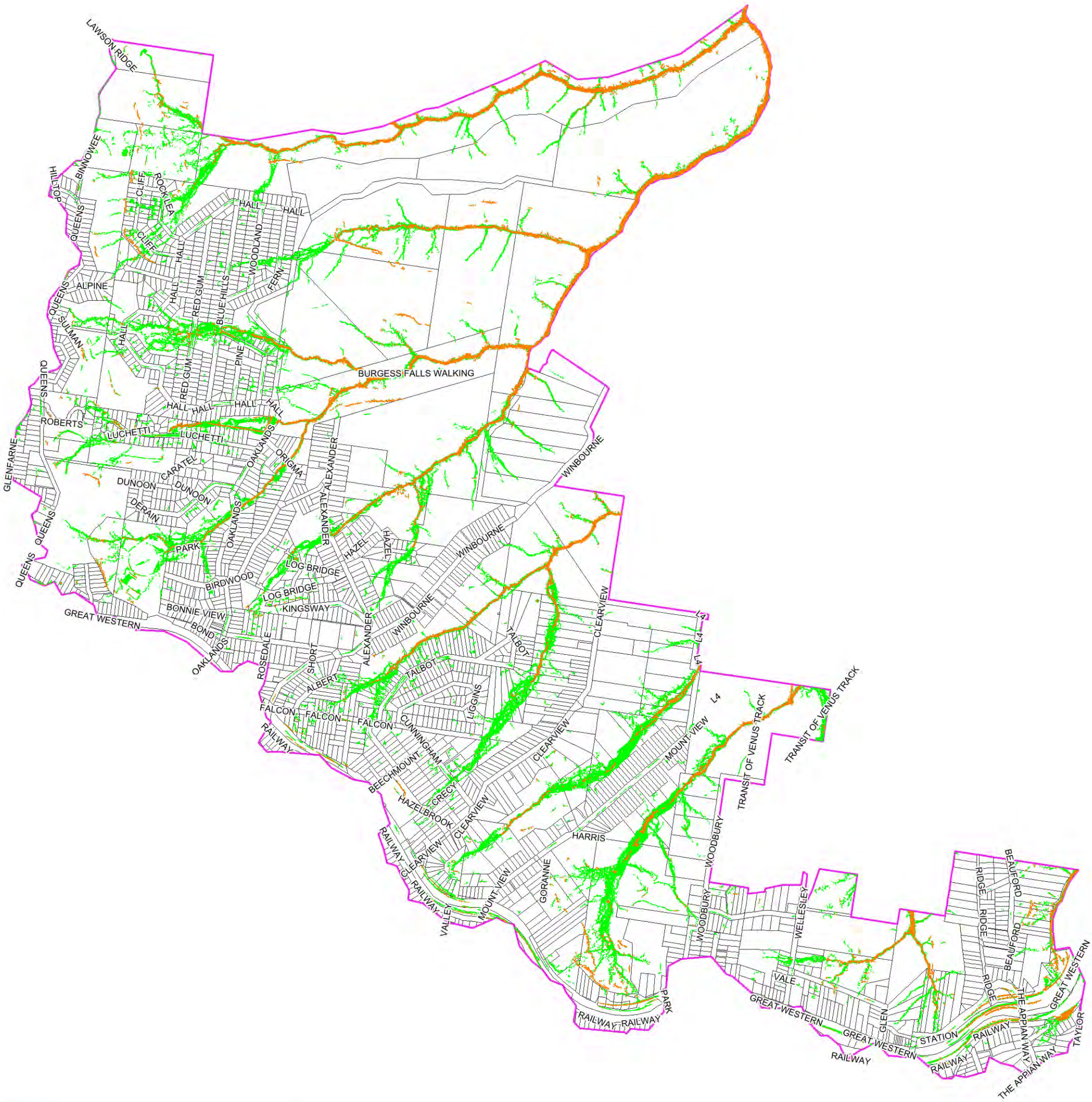
0 250 500

Roads Overtopped - 1% AEP

Figure 5-9

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



High Hazard - Depth and Velocity

Low Hazard - Depth and Velocity

True Hazard - 20% AEP

Figure 5-10

Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031

True Hazard - 10% AEP

Figure 5-11

Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031

True Hazard - 2% AEP

Figure 5-12

Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031

True Hazard - 1% AEP

Figure 5-13

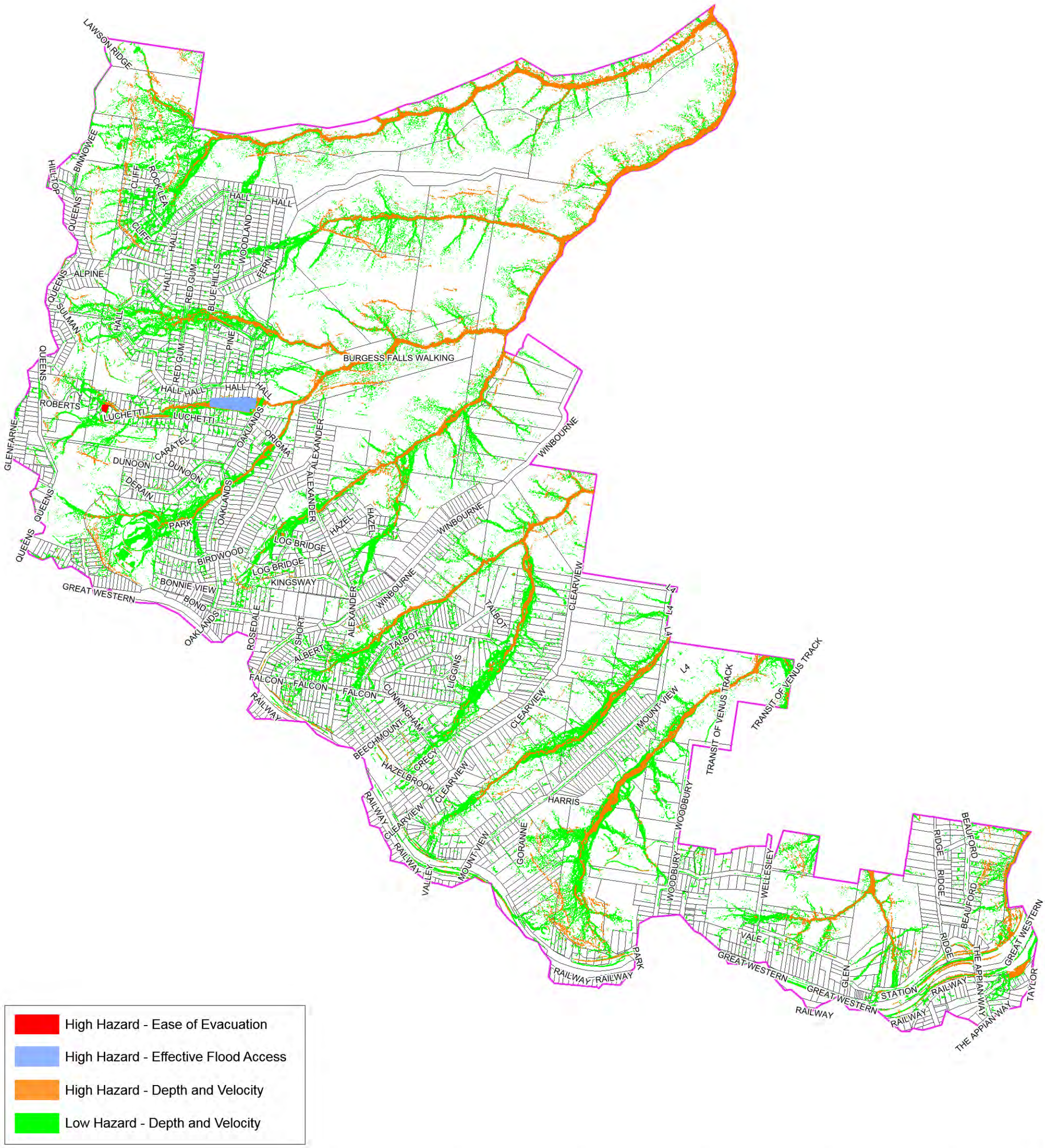
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



True Hazard - 0.5% AEP

Figure 5-14

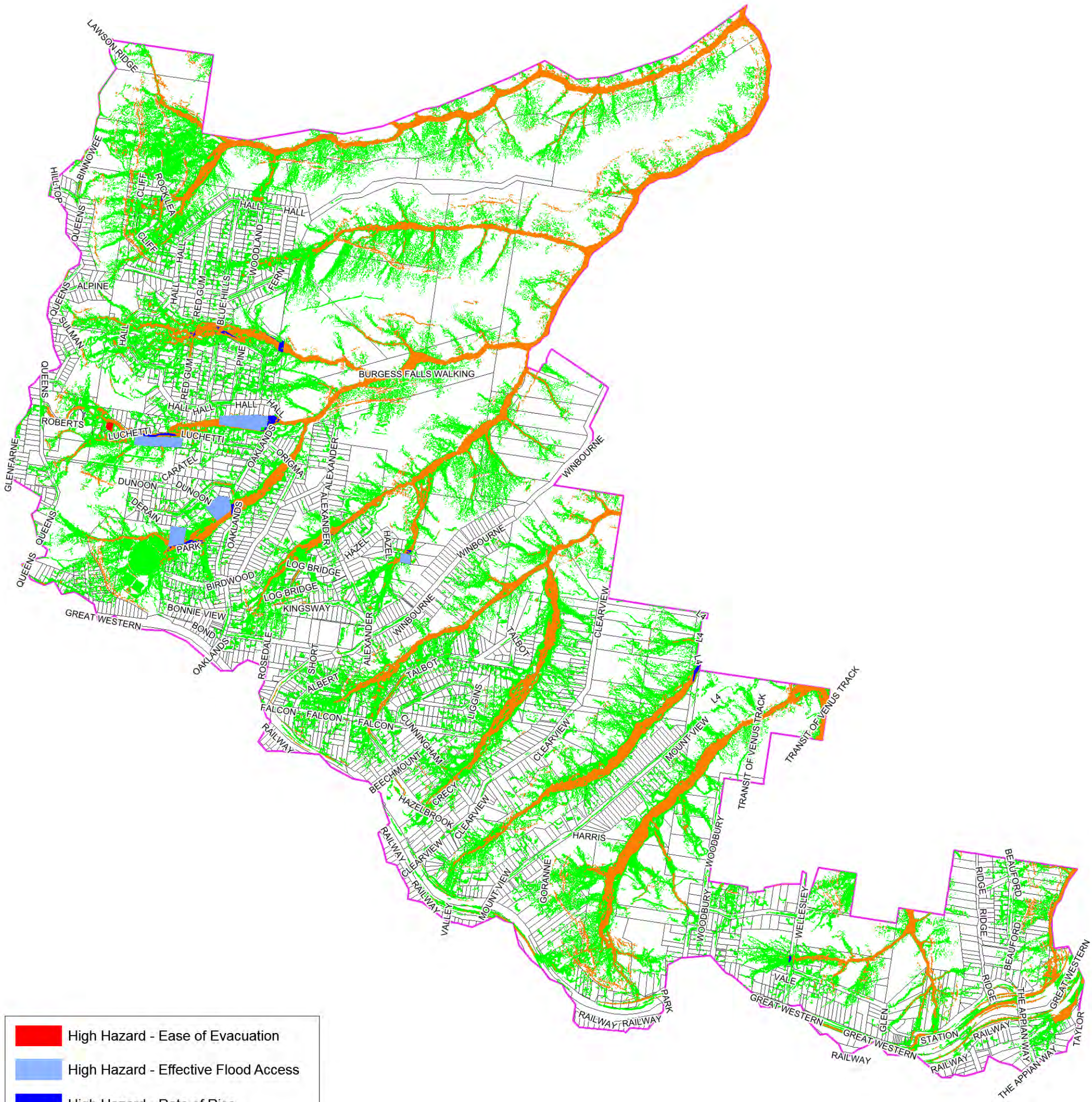
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



True Hazard - PMF

Figure 5-15

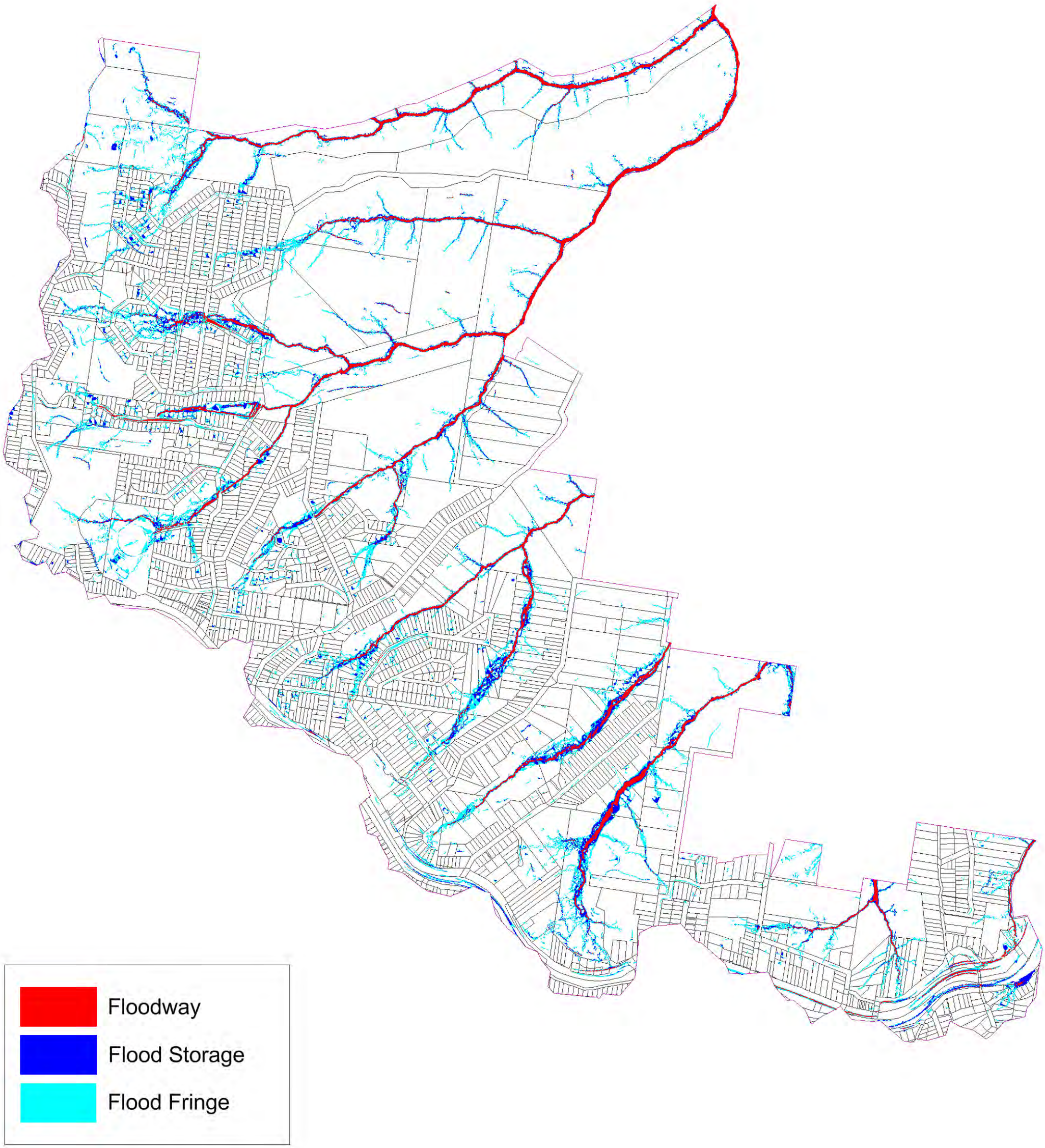
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories - 20% AEP

Scale 1:15,000 Scale at A3

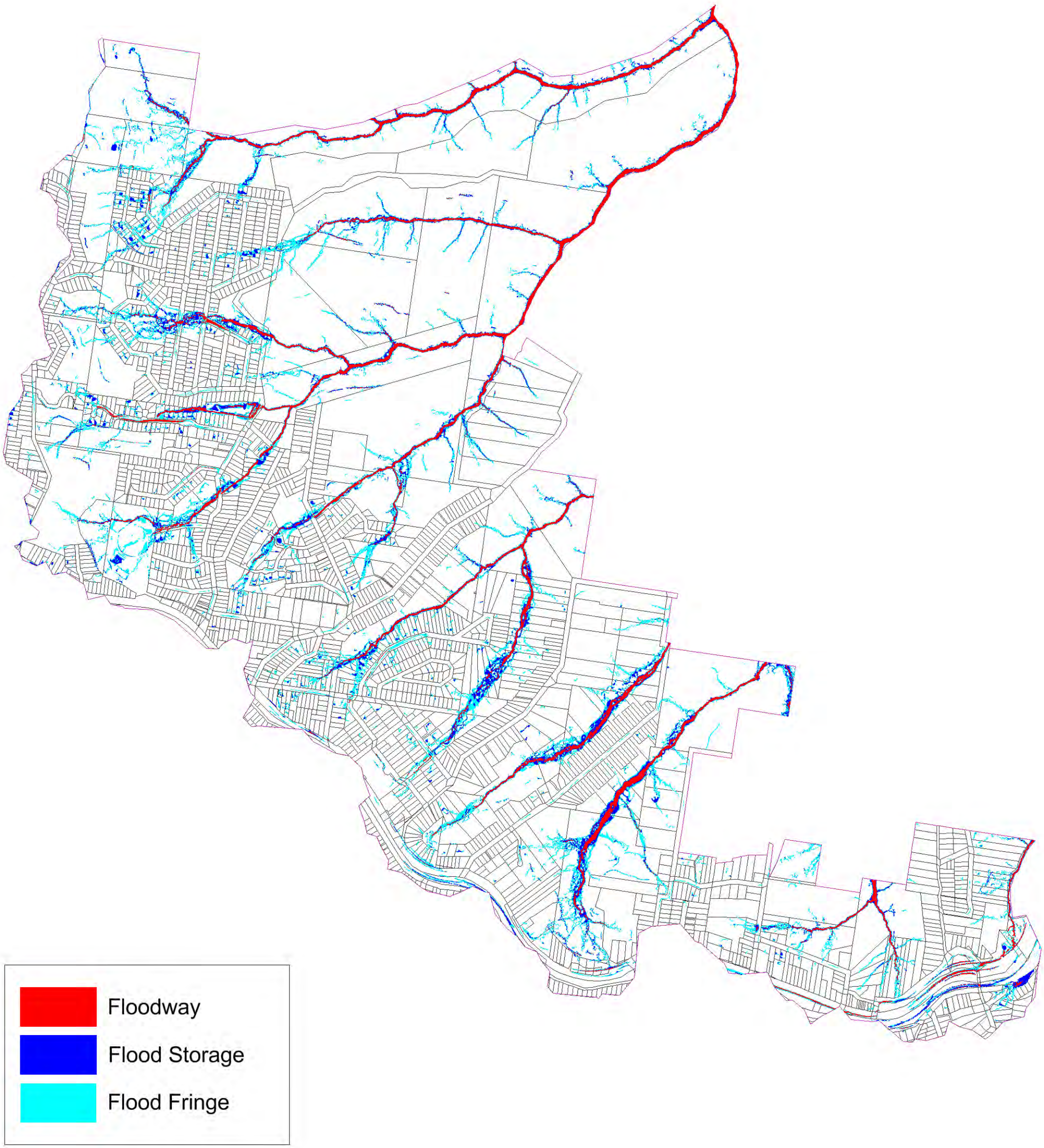
Metres

0 250 500

Figure 5-16

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories
10% AEP

Figure 5-17

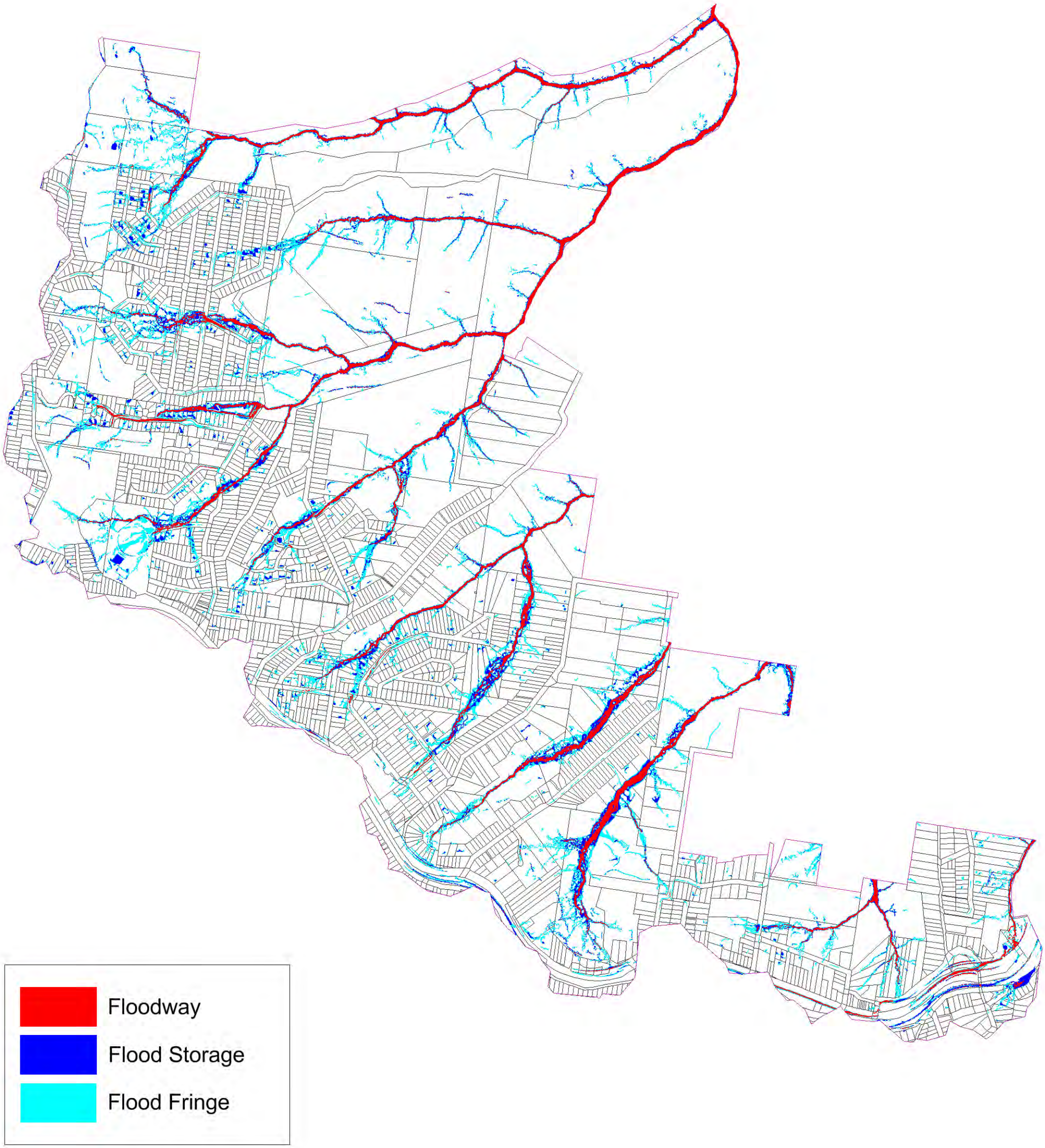
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories
2% AEP

Figure 5-18

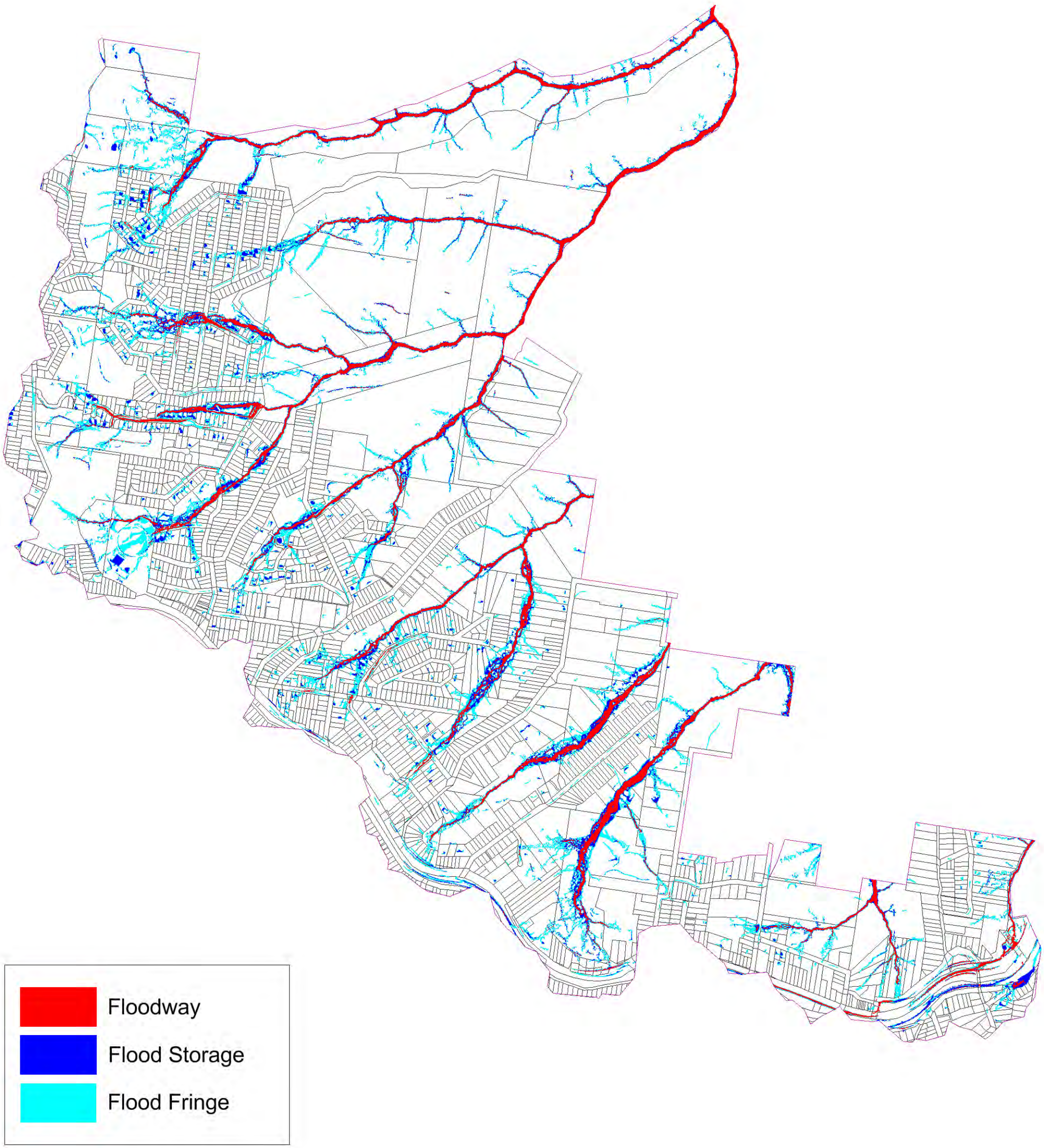
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories
1% AEP

Figure 5-19

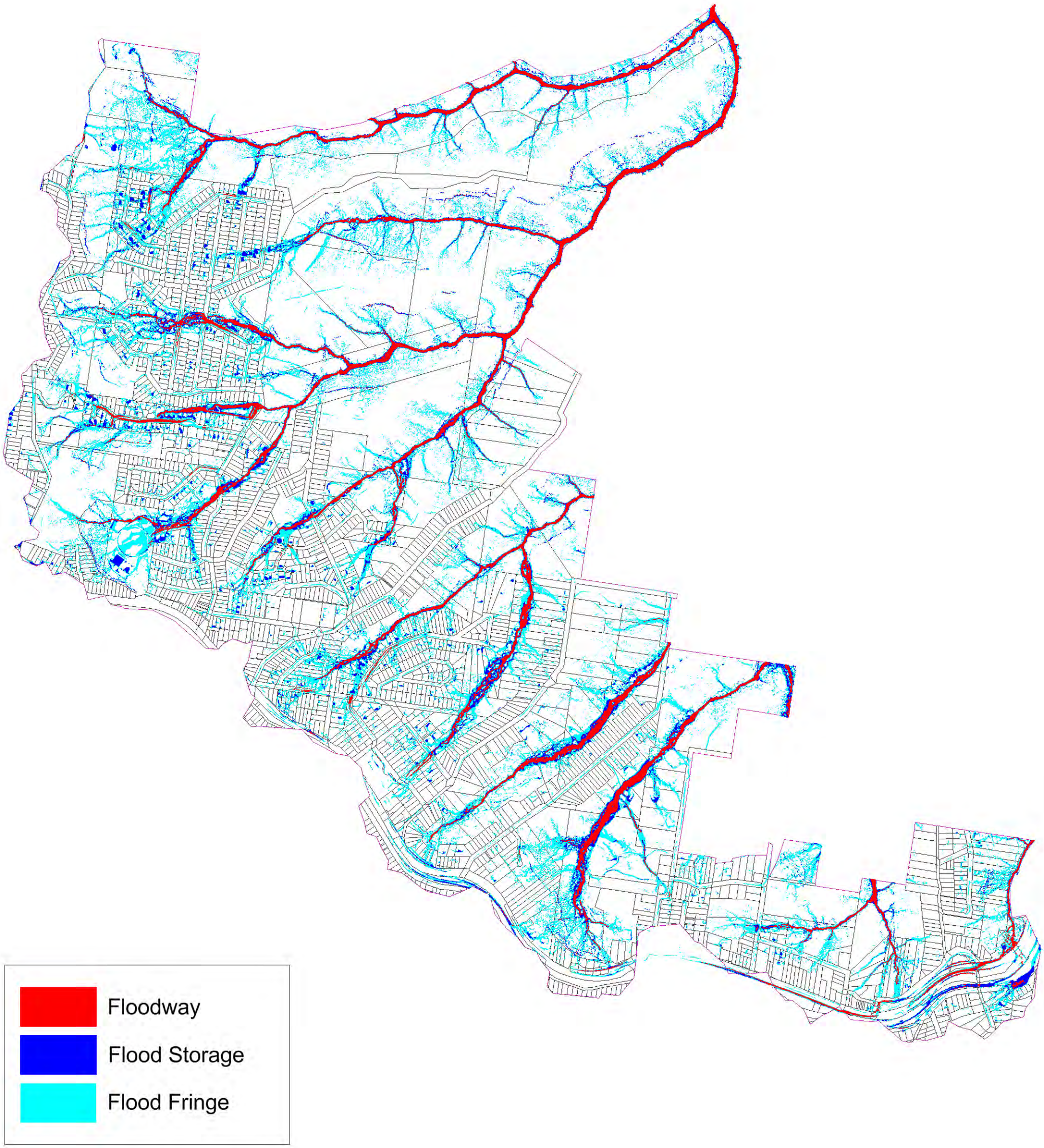
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories
0.5% AEP

Figure 5-20

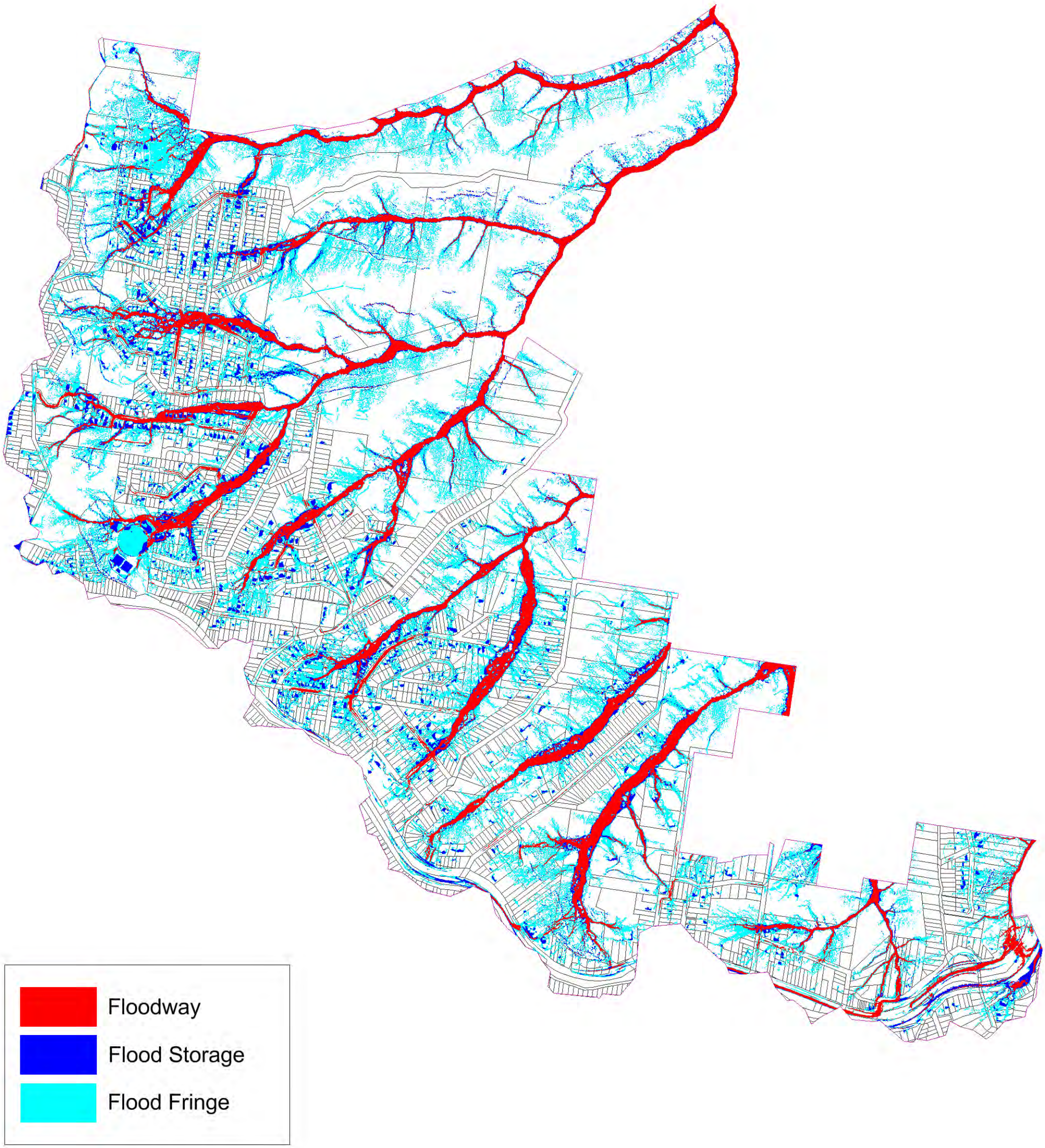
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Hydraulic Categories
PMF

Figure 5-21

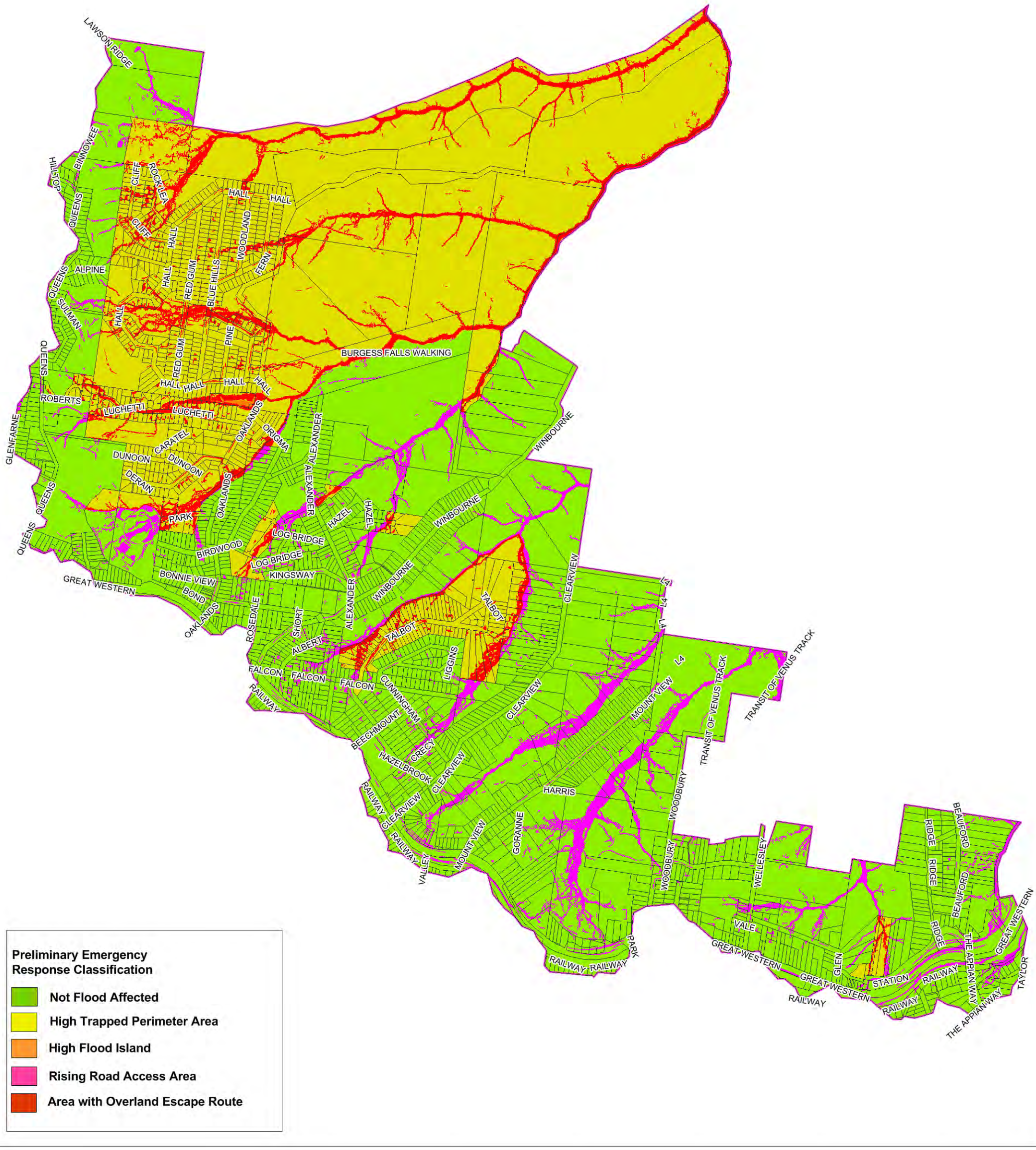
Scale 1:15,000 Scale at A3

Metres

0 250 500

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031



Emergency Response Classification

Scale 1:15,000 Scale at A3

Metres

0 250 500

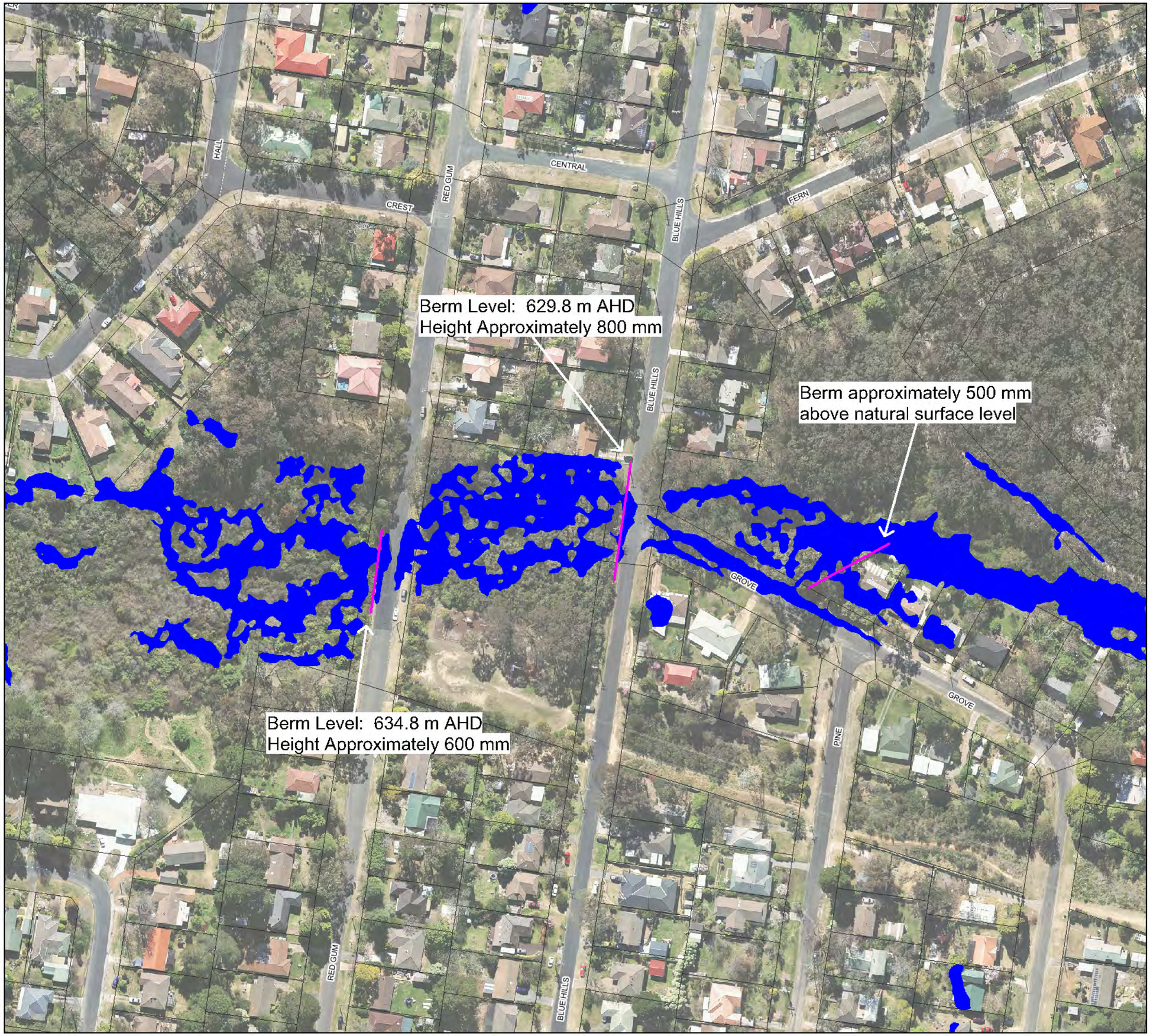
Figure 7-1

Cardno

Map Produced by Water & Environment
Date: April 2017
Coordinate System: MGA56
Project:59915031

FM1 - Red Gum Avenue and Blue Hills Road Berms

FIGURE 10-2



Legend

Berm Locations

Existing 20 Pct AEP Flood Extent

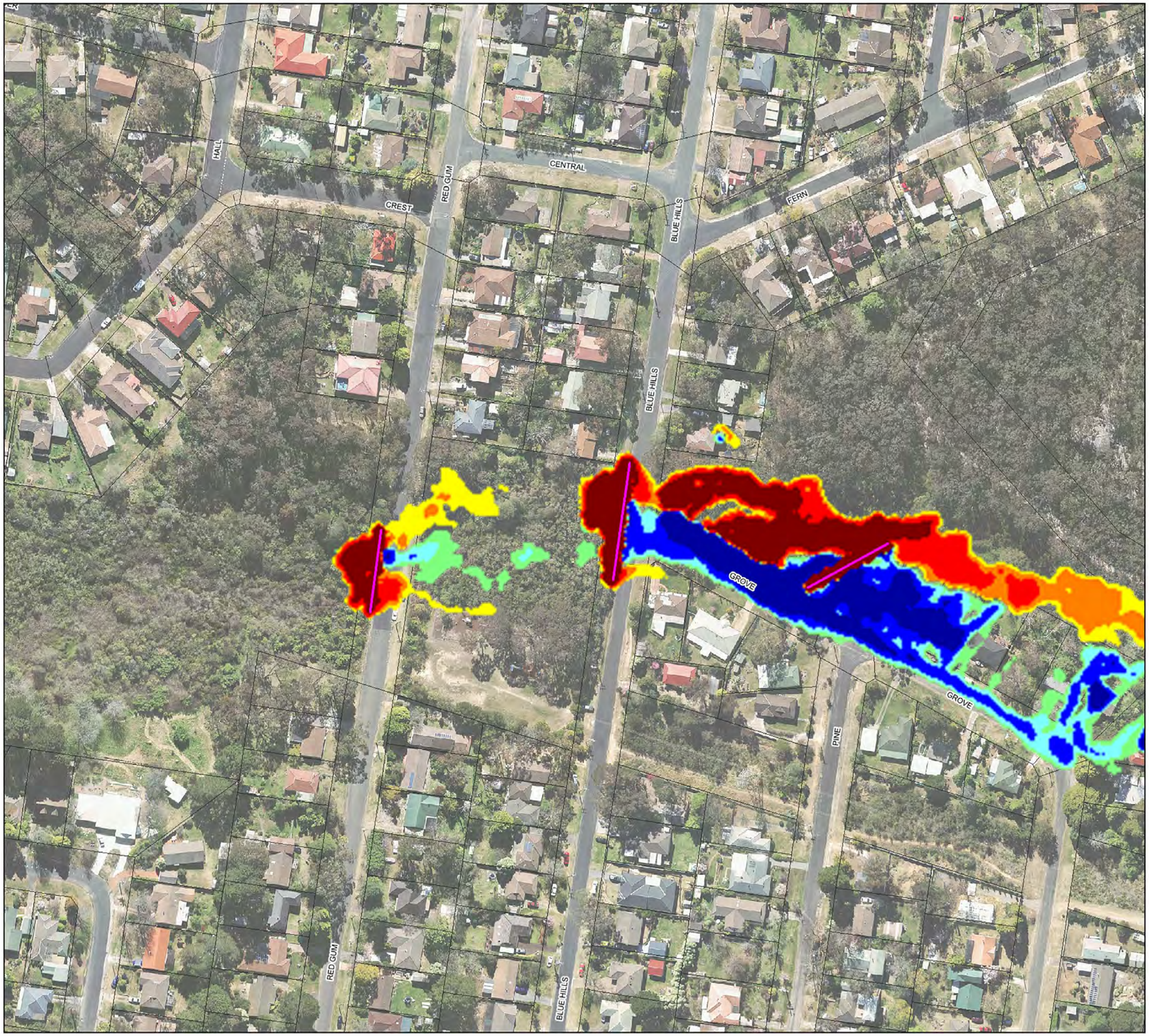
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM1 - Red Gum Avenue and Blue Hills Road Berms 20% AEP Water Level Difference

FIGURE 10-3

Legend

Berm Locations

Peak Water Level Difference millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

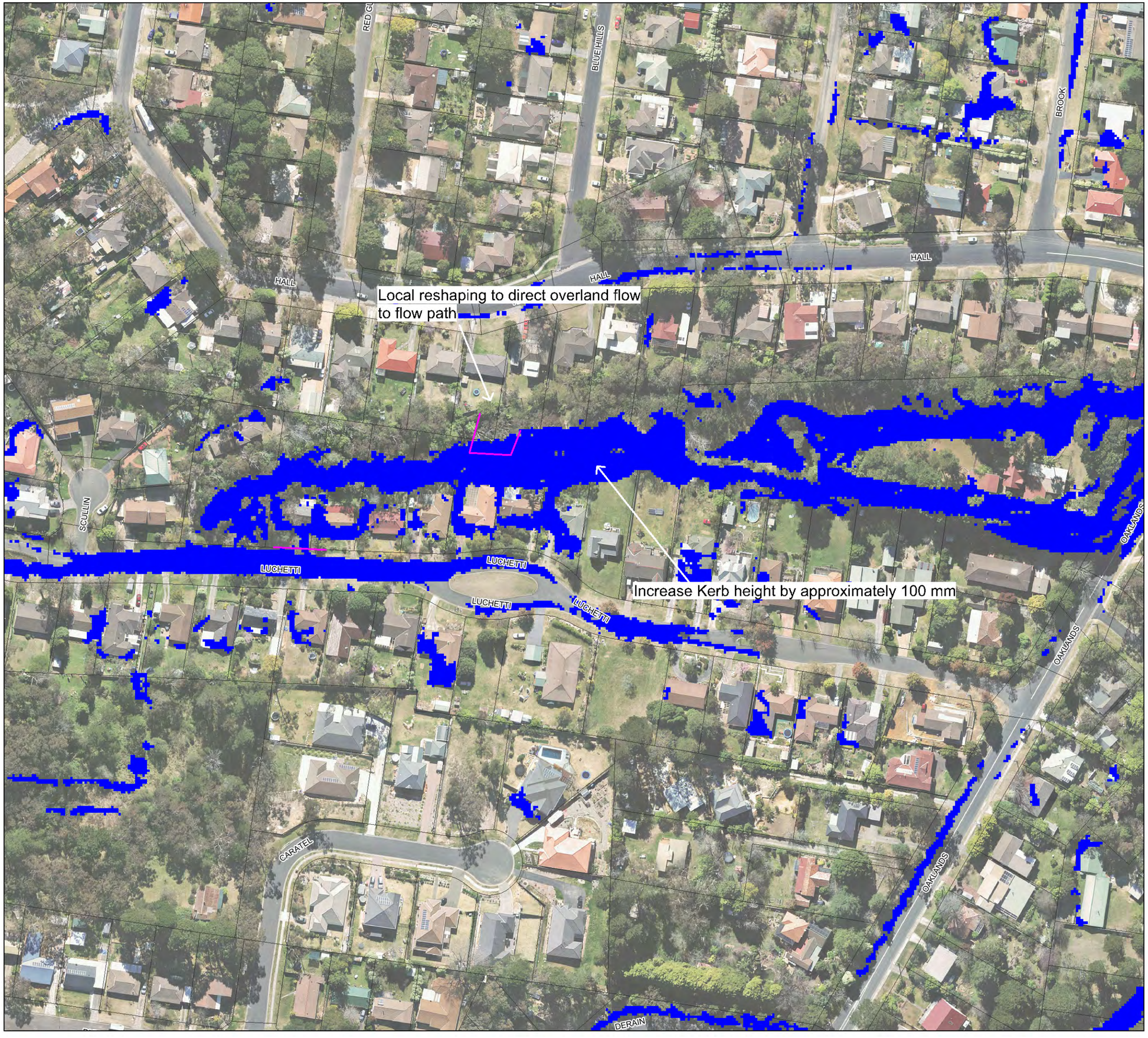
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM3 - Flow Path from Luchetti Avenue

FIGURE 10-4



Legend

- Level Change Locations
- Existing 20 Pct AEP Flood Extent

SCALE 1:1,500 Scale at A3

Metres

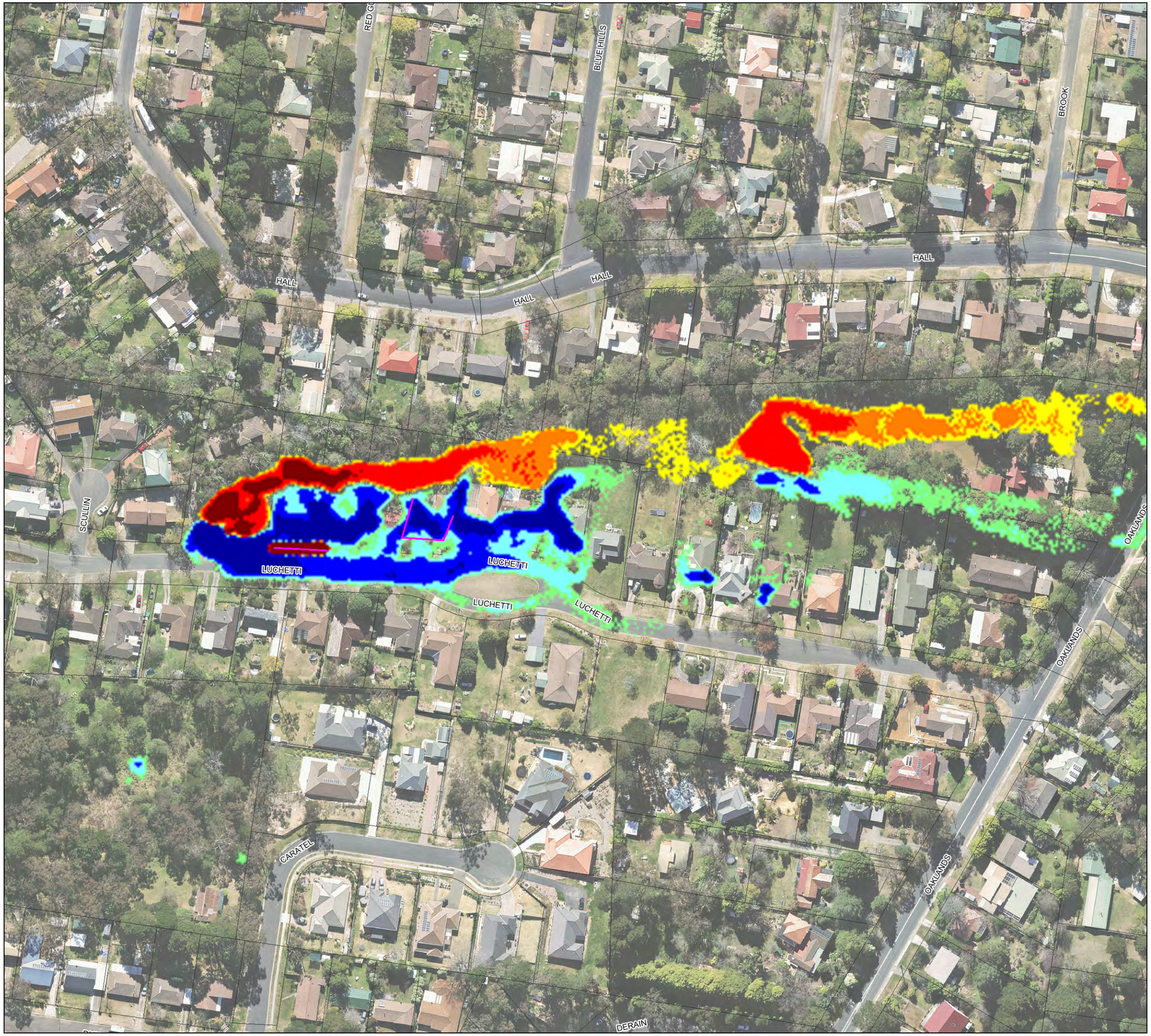
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM3 - Flow Path from Luchetti Avenue 20% AEP Water Level Difference

FIGURE 10-5



Legend

Level Change Locations

Peak Water Level Difference
millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

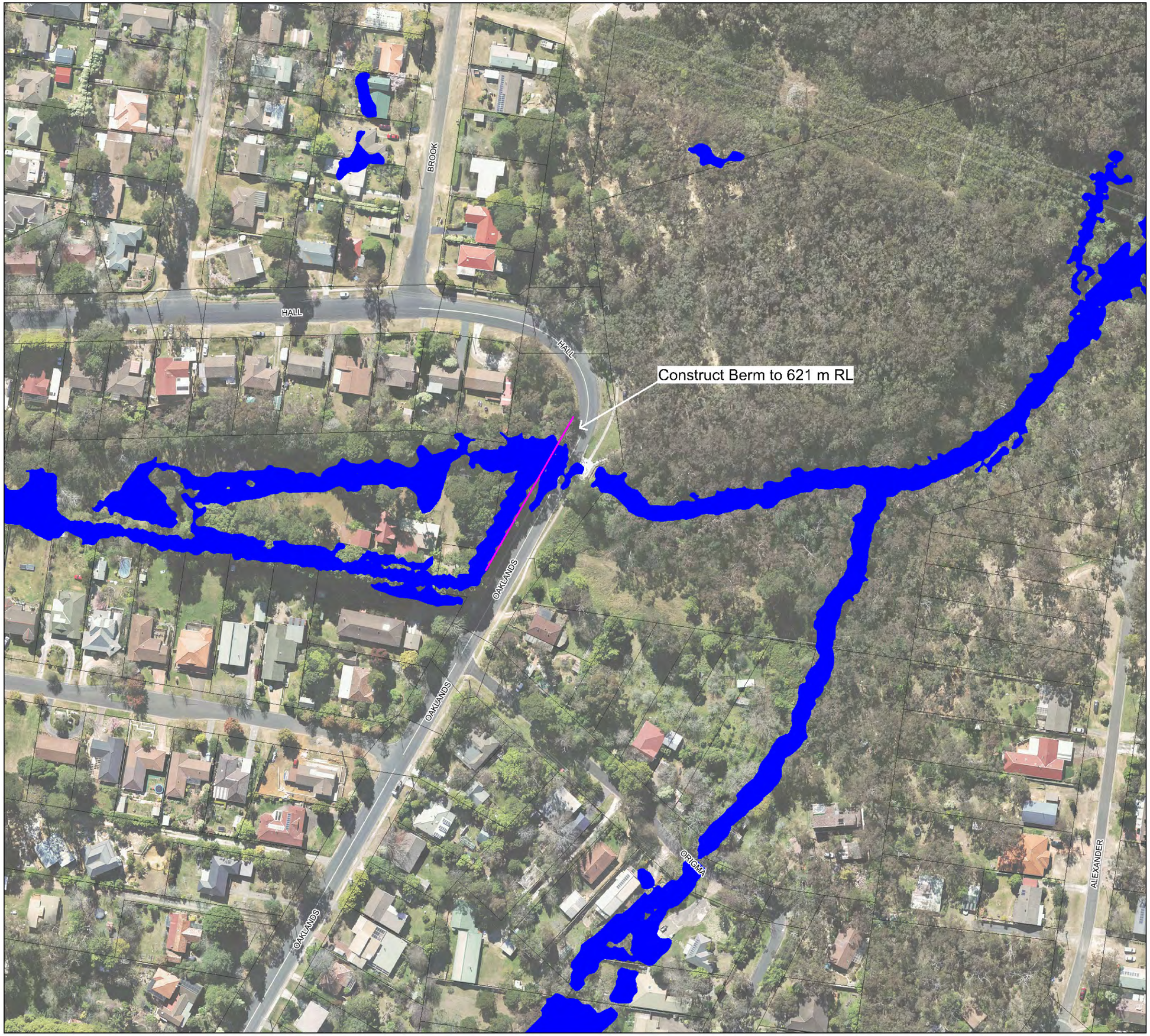
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM4 - Oaklands Road Berm (Luchetti-Oaklands)

FIGURE 10-6

Legend

- Berm Locations
- Existing 20 Pct AEP Flood Extent

SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM4 - Oaklands Road Berm (Luchetti-Oaklands) 20% AEP Water Level Difference

FIGURE 10-7

Legend

Berm Locations

Peak Water Level Difference millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

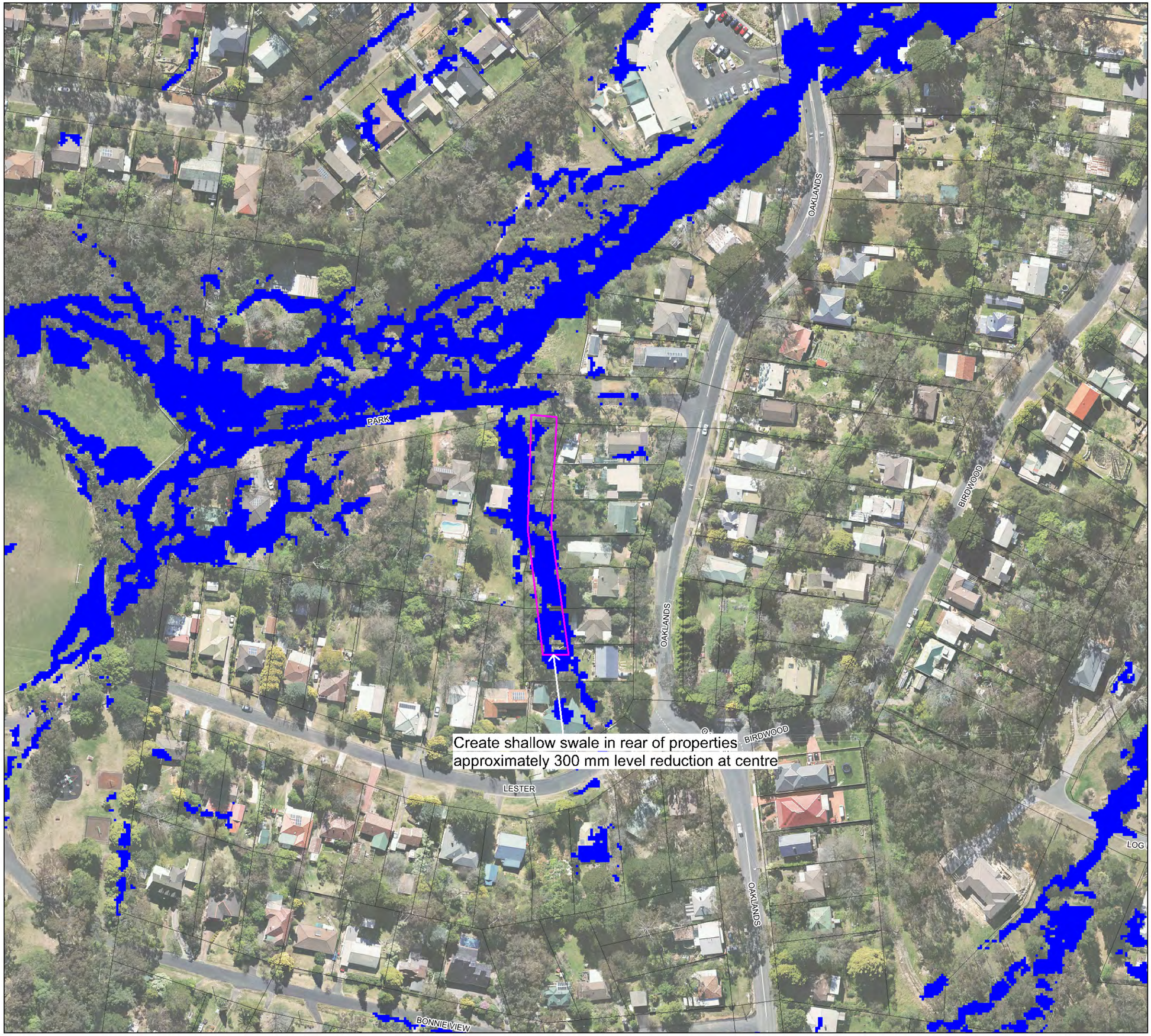
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM5 - Flow Path Park Road

FIGURE 10-8



Legend

Flow Path Extent

Existing 20 Pct AEP Flood Extent

SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM5 - Flow Path Park Road 20% AEP Water Level Difference

FIGURE 10-9

Legend

Flow Path Extent

Peak Water Level Difference millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

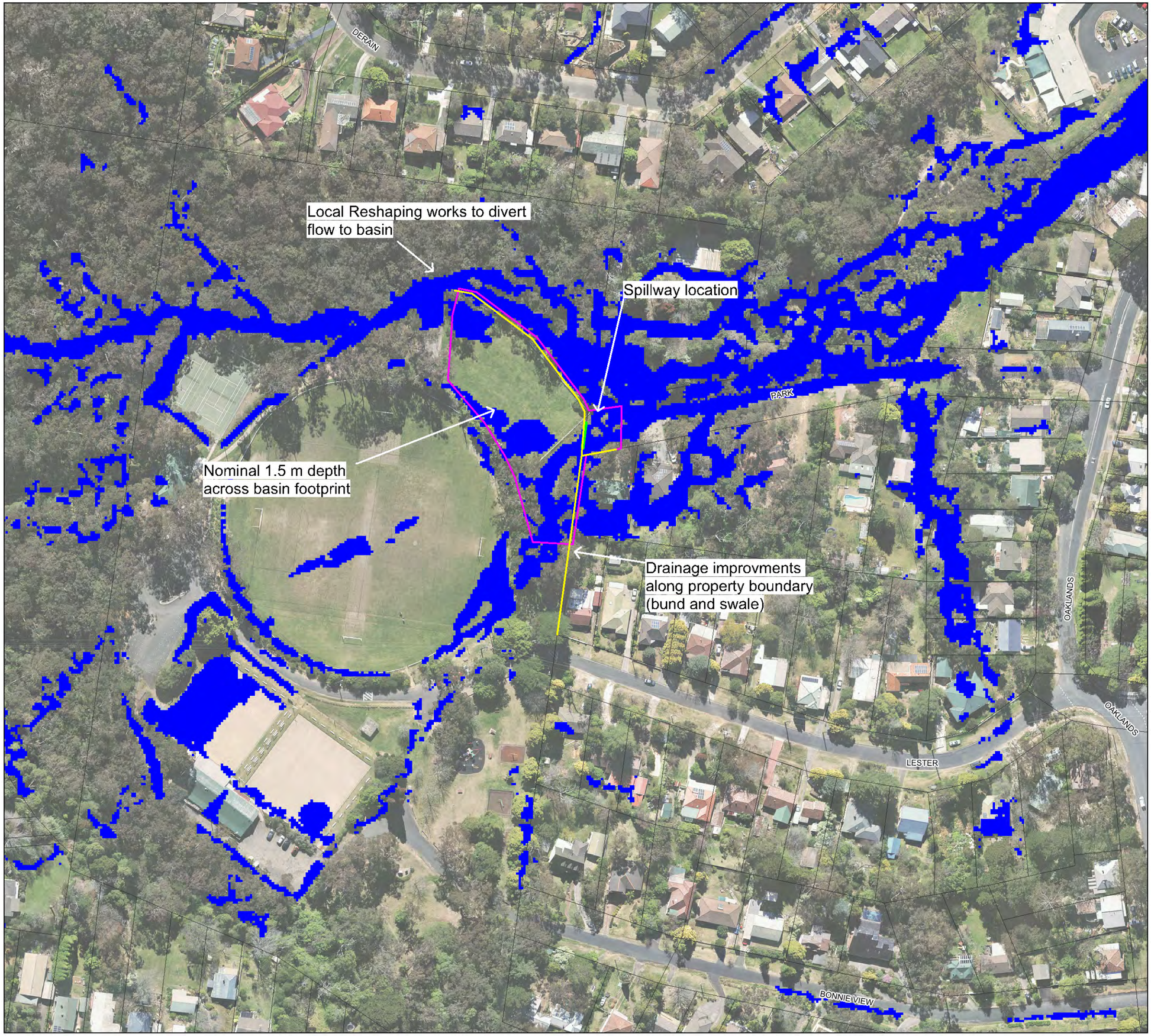
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM6 - Gloria Park Detention Basin and upstream flow path augmentation

FIGURE 10-10



Legend

- Basin Extent
- Existing 20 Pct AEP Flood Extent
- Basin Wall

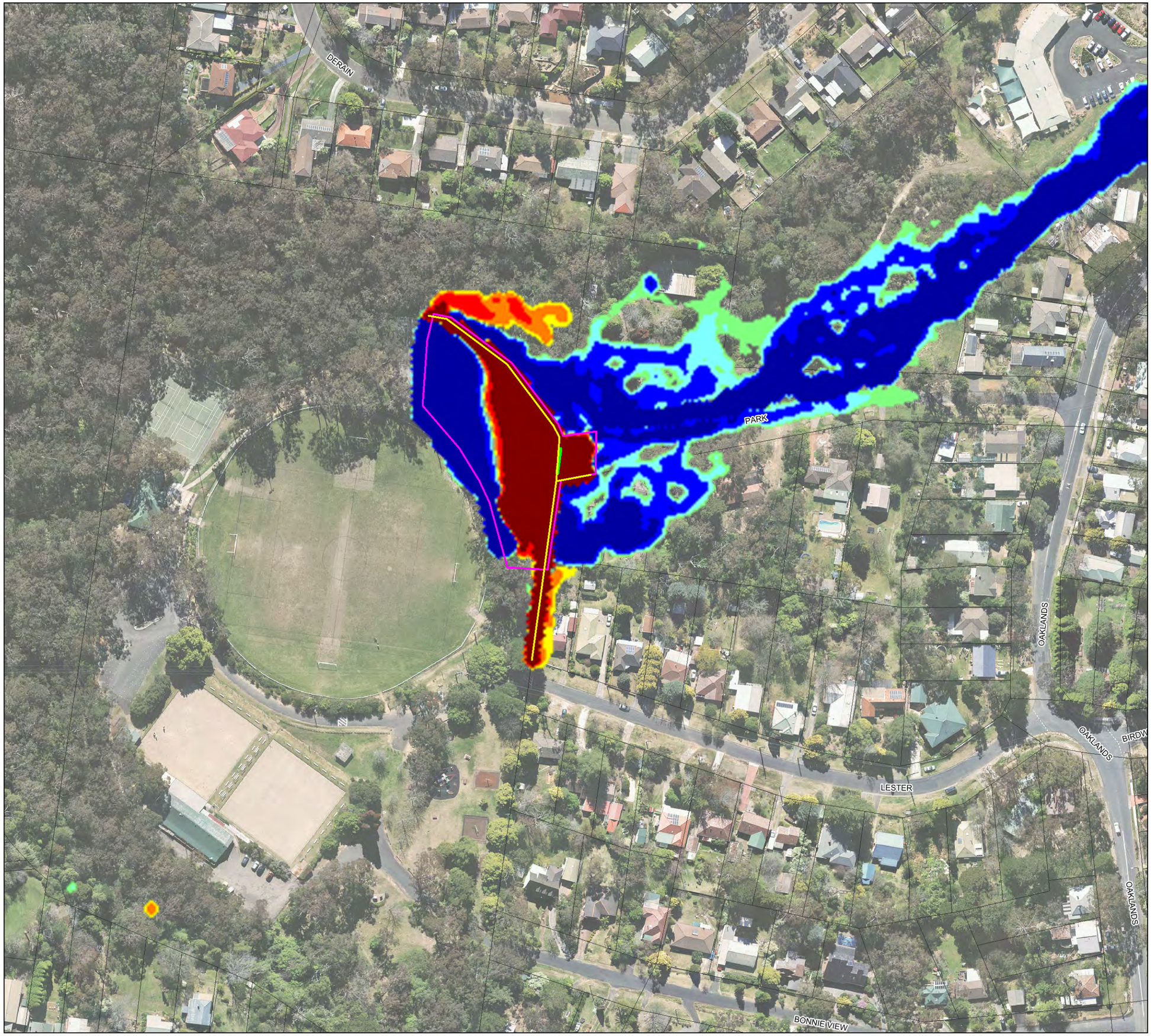
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM6 - Gloria Park Detention Basin and upstream flow path augmentation 20% AEP Water Level Difference

FIGURE 10-11

Legend

- Basin Extent
- Basin Wall

Peak Water Level Difference
millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

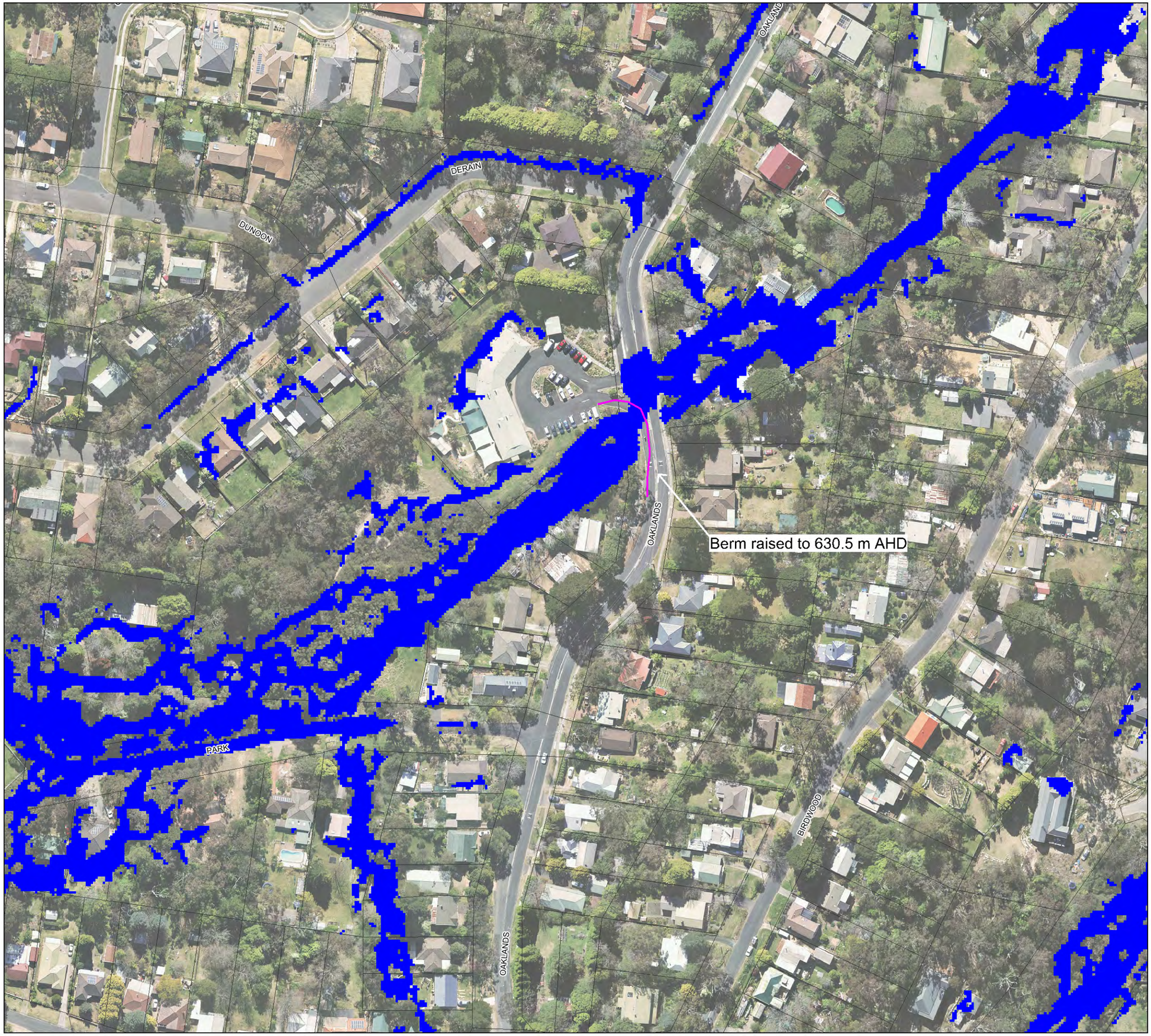
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM7 - Oaklands Road Berm (Park-Oaklands)

FIGURE 10-12



Legend

Berm Locations

Existing 20 Pct AEP Flood Extent

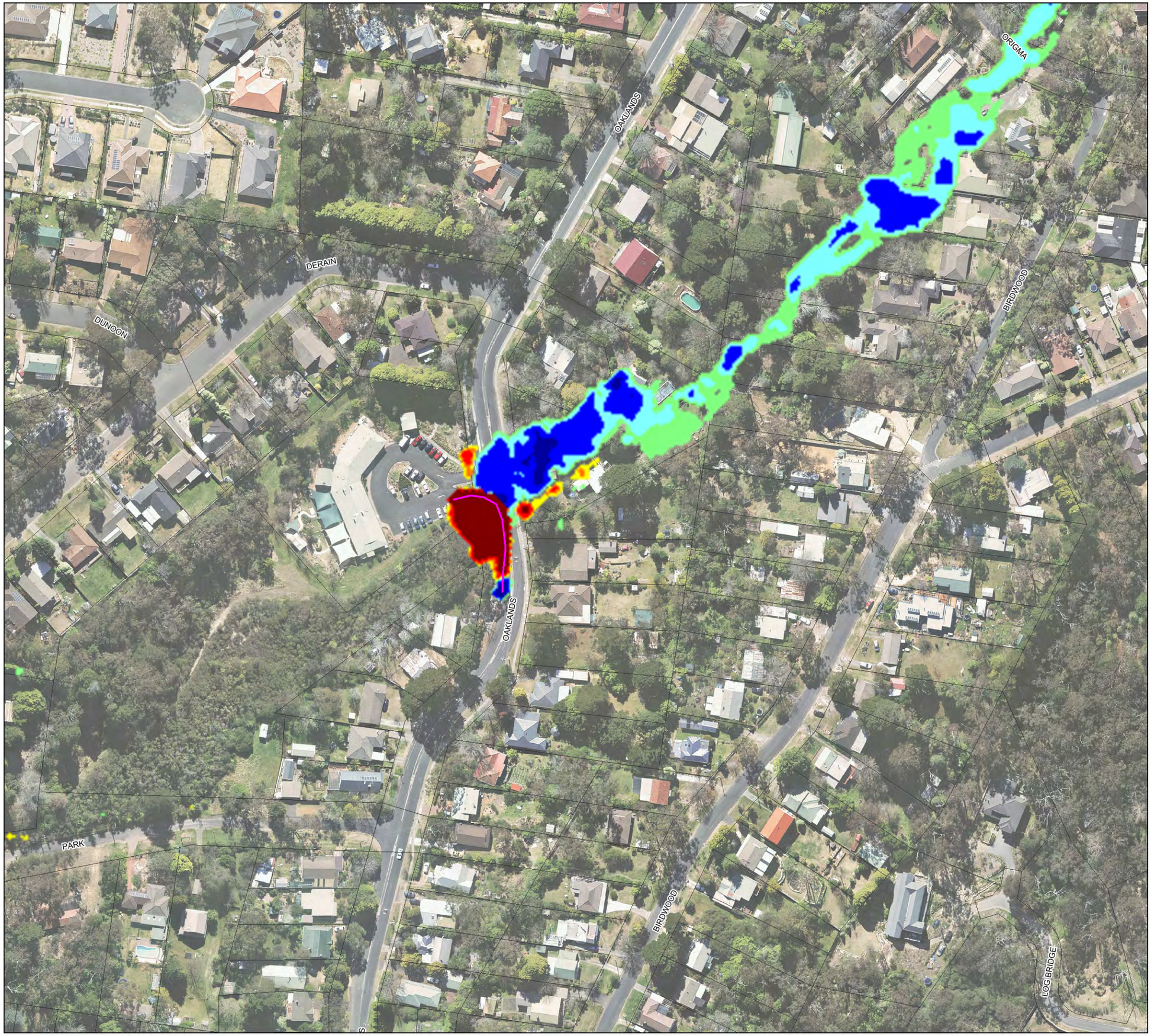
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM7 - Oaklands Road Berm (Park-Oaklands) 20% AEP Water Level Difference

FIGURE 10-13

Legend

Berm Locations

Peak Water Level Difference millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

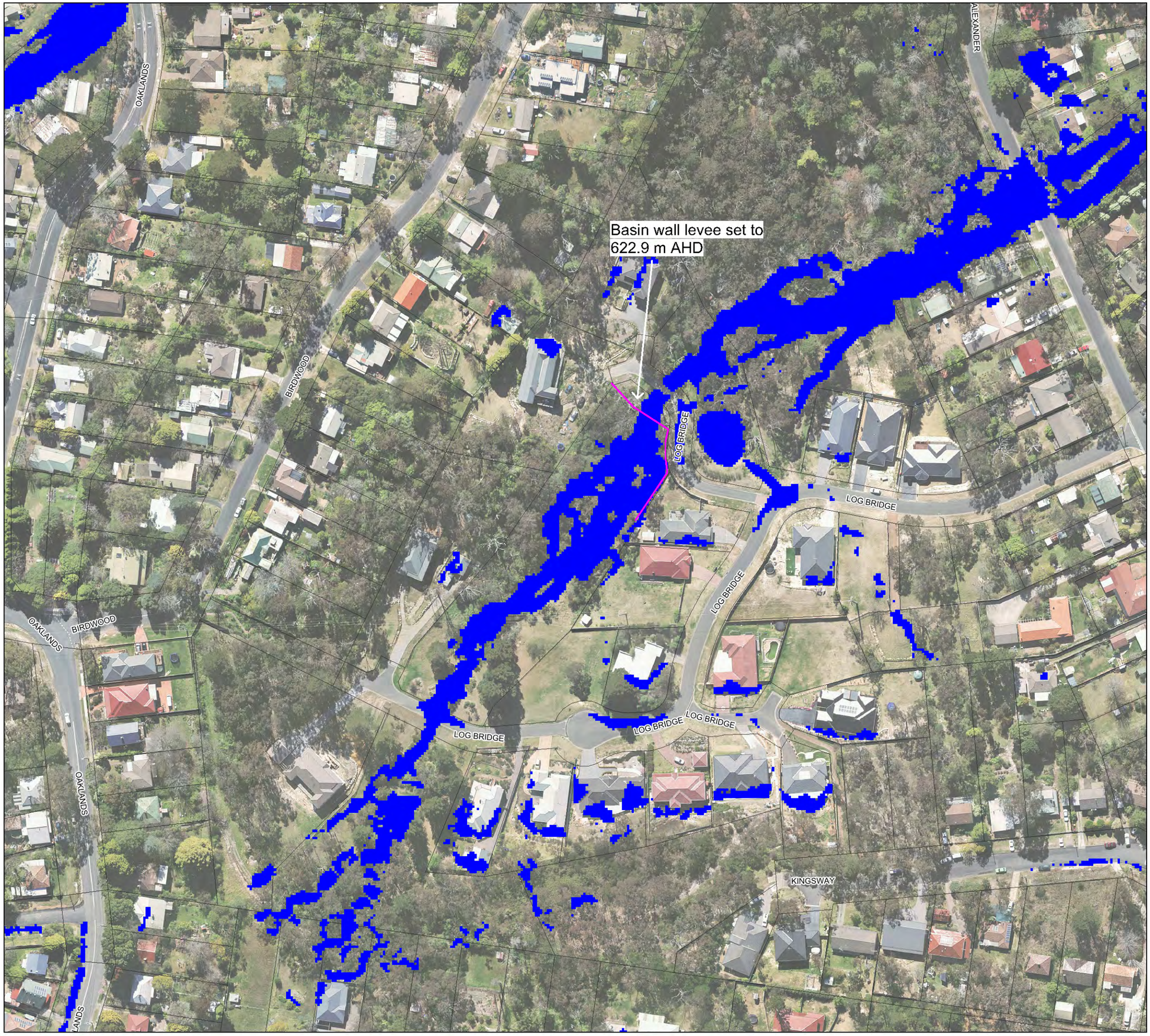
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM8 - Log Bridge Place Detention Basin

FIGURE 10-14



Legend

- Berm Locations
- Existing 20 Pct AEP Flood Extent

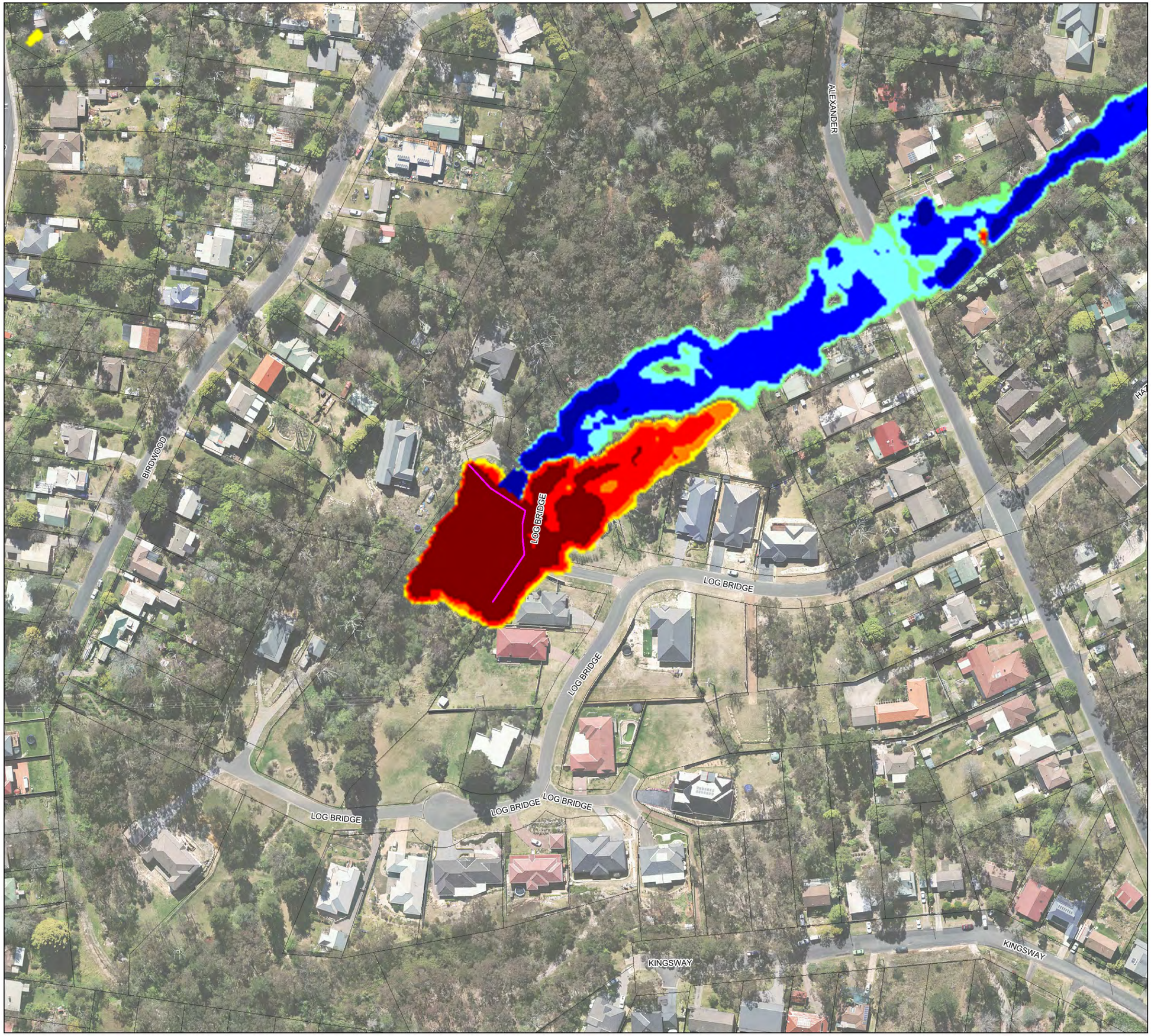
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM8 - Log Bridge Place Detention Basin 20% AEP Water Level Difference

FIGURE 10-15

Legend

Berm Locations

Peak Water Level Difference millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

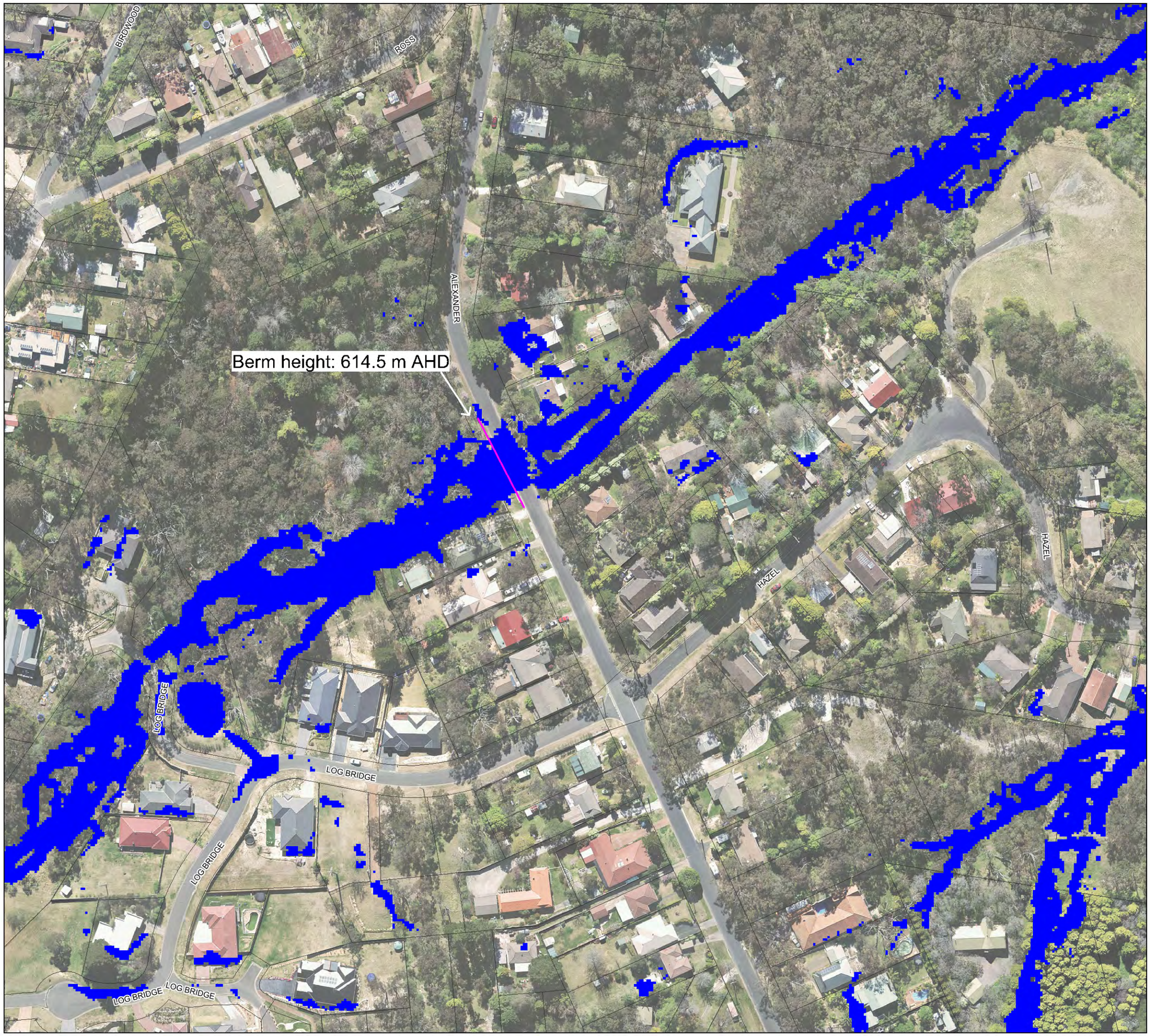
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM9 - Alexander Avenue Berm

FIGURE 10-16



Legend

Berm Locations

Existing 20 Pct AEP Flood Extent

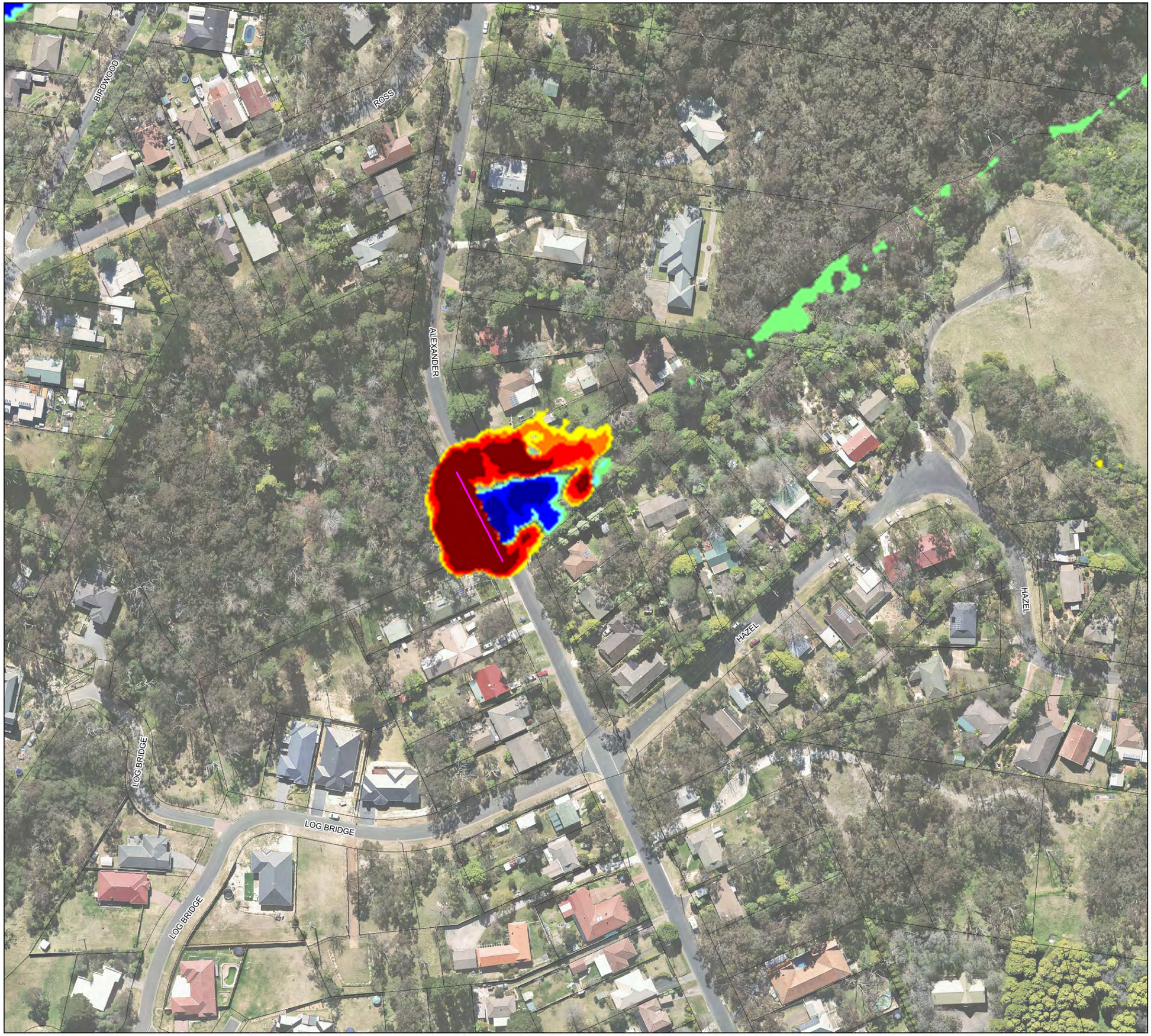
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM9 - Alexander Avenue Berm 20% AEP Water Level Difference

FIGURE 10-17

Legend

Berm Locations

Peak Water Level Difference
millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

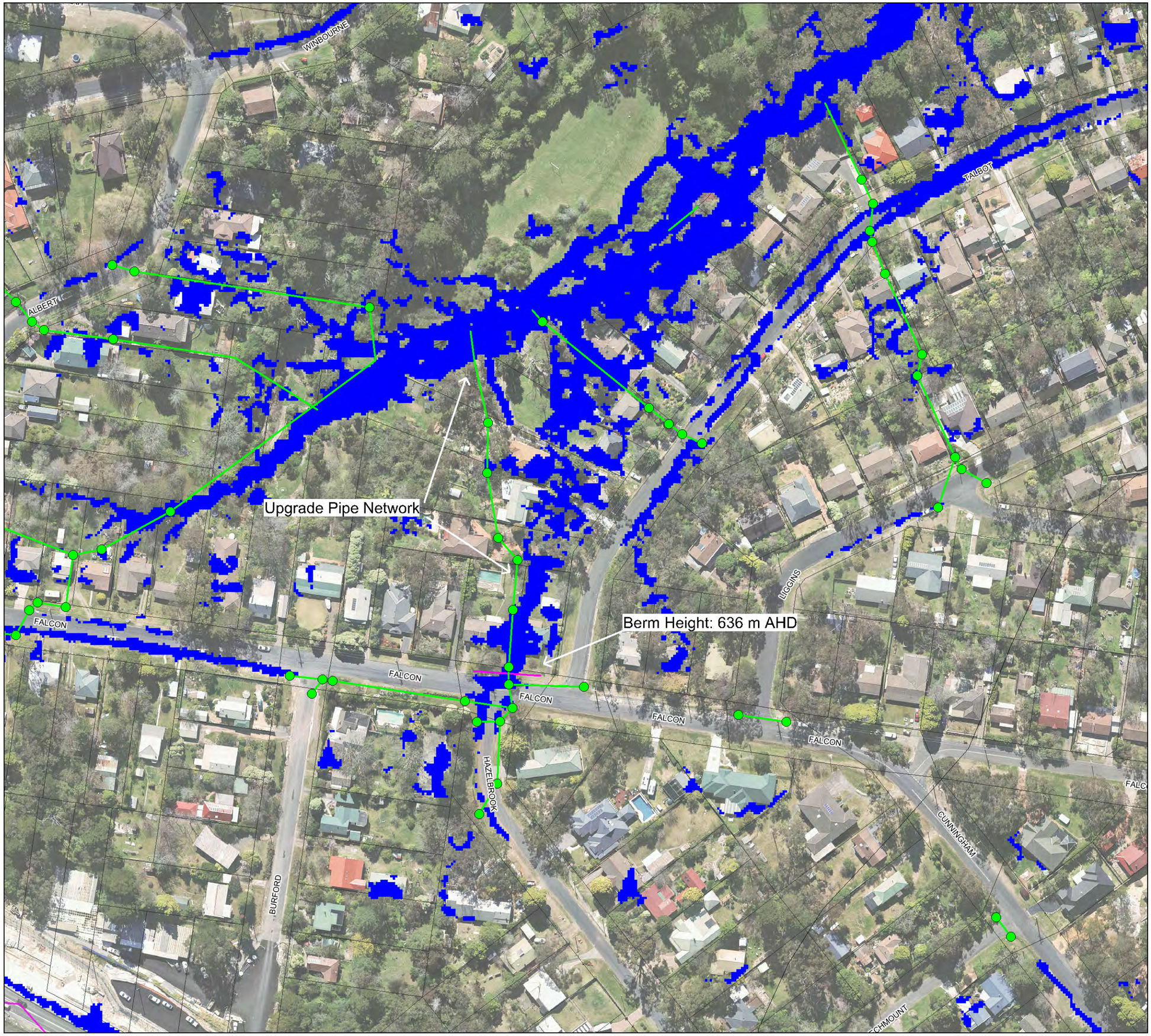
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM10 - Falcon Street Pipe Upgrade

FIGURE 10-18



Legend

- Berm Locations
- Existing 20 Pct AEP Flood Extent
- Pits
- Pipes

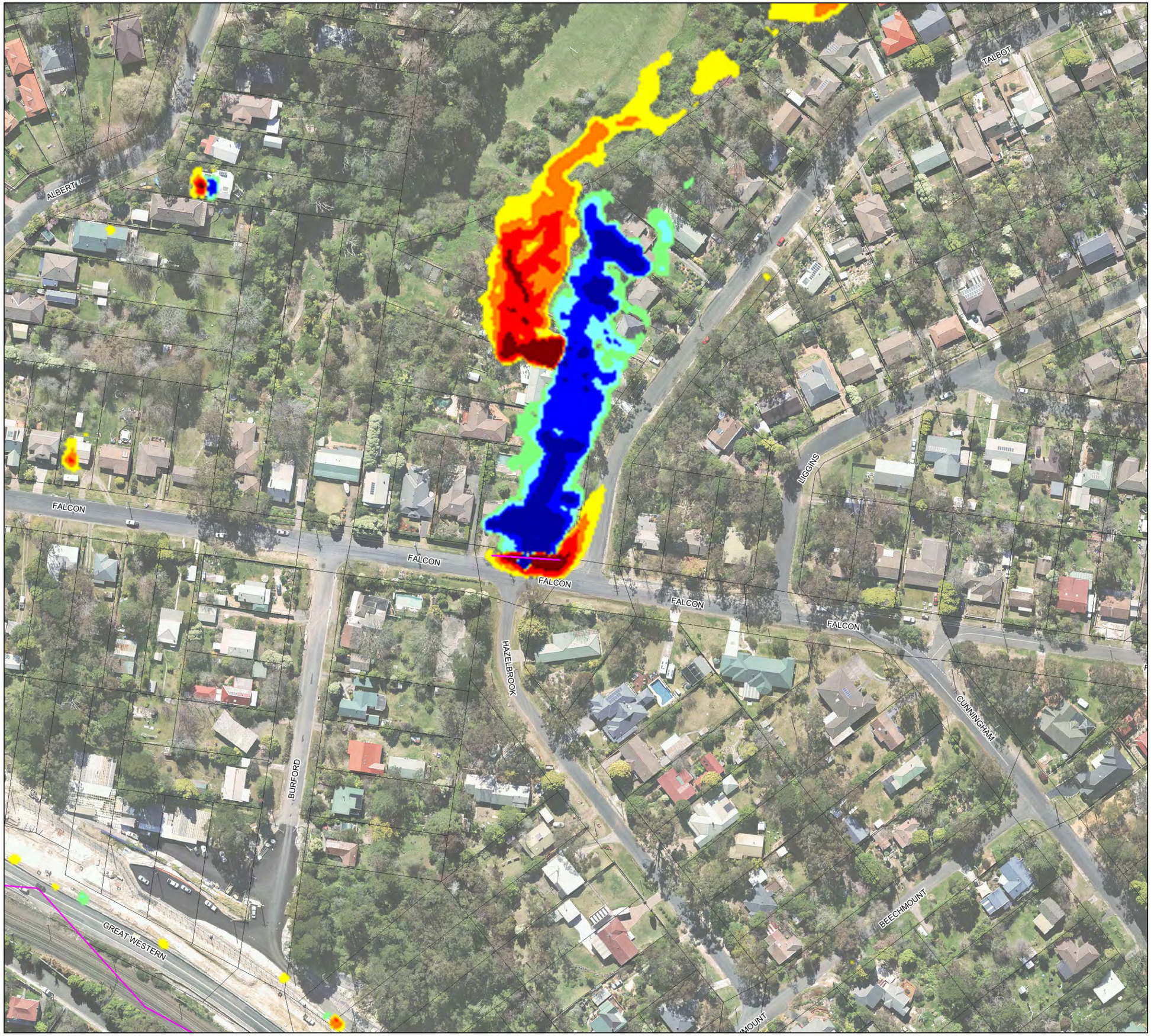
SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01



FM10 - Falcon Street Pipe Upgrade 20% AEP Water Level Difference

FIGURE 10-19

Legend

Berm Locations

Peak Water Level Difference
millimetres

- >50
- 20 to 50
- 10 to 20
- 5 to 10
- -5 to -10
- -10 to -20
- -20 to -50
- <-50

SCALE 1:1,500 Scale at A3

Metres

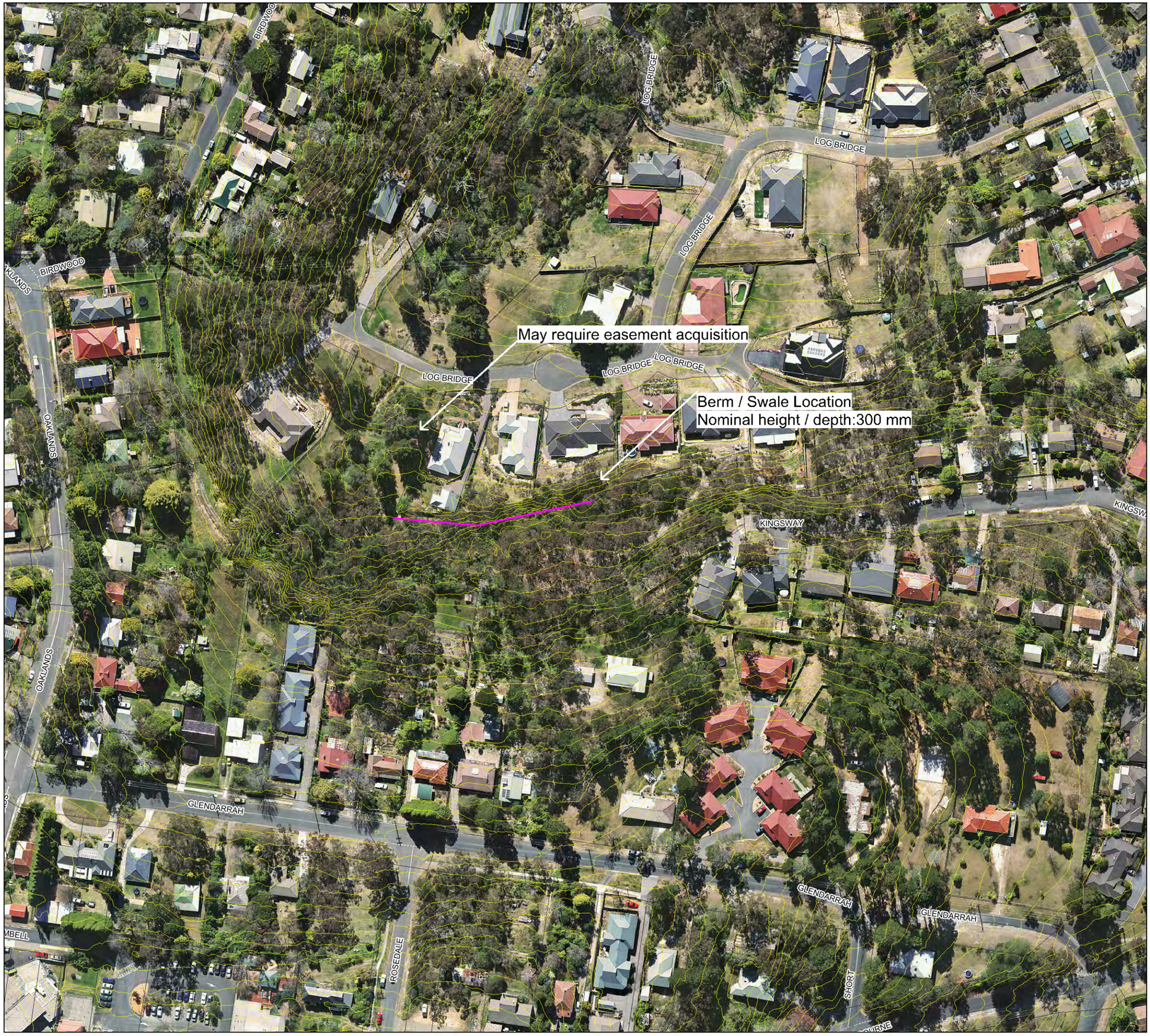
0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

FM12 - Glendarrah Road Swale / Berm

FIGURE 10-20



Legend

- Berm Locations
- 1 Meter Contour

SCALE 1:1,500 Scale at A3

Metres

0 25 50

Cardno

Map Produced by <Division> (<BU>)
Date: <Current Date>
Coordinate System: <Current Coordinate System>
Project:<Job Number>_<Phase>
Map:<map name>.wor 01

Hazelbrook and Woodford Creeks Floodplain Risk Management Study and Plan

APPENDIX

E

MULTI CRITERIA ASSESSMENT

Cardno
Shaping the Future

Option ID	Reference	Description	B/C	Estimated Capital Cost ($)	Estimated Maintenance Cost ($)	AAD	Economic					Social				Environment		Score	Overall Rank
							Benefit Cost Ratio	Capital Cost and Operating Cost	Reduction is Risk to Property	Feasibility	Protection of Vulnerable Facilities	Reduction in Risk to Life in 1% AEP Event	Reduction in Social Disruption	Community & Stakeholder Support	Compatibility with Council Policies & Plans	Compatibility with Water Quality Objectives[1]	Fauna/Flora Impact - Including Street Trees		
FM1	Red Gum Avenue and Blue Hills Road Berms	Storage at Blue Hills Road and Red Gum Road; and Raise driveways on Grove Street, created flow path from road to channel, clear vegetation.	4.74	$120,000	$1,000	$45,400	2.0	1.0	2.0	2.0	0.0	1.0	2.0	0	1.0	0	-1.0	1.90	**3**
FM3	Flow path from Luchetti Avenue	Divert flow from Luchetti Avenue from roadway to creek prior upstream of impacted properties. Possibly through nature strip	8.02	$44,000	$1,000	$33,200	2.0	2.0	2.0	2.0	0.0	1.0	1.0	1	2.0	0	0.0	2.85	**1**
FM4	Oaklands Road Berm (Luchetti-Oaklands)	Construct berm upstream of Oaklands Road and clear downstream watercourse. Berm/storage on upstream side of road and increase flow capacity across road	0.00	$65,000	$1,500	$0	-2.0	1.0	0.0	1.0	0.0	1.0	1.0	1	2.0	0	0.0	1.25	**12**
FM5	Flow Path Park Road	Drain flow from pipe outlet to Park Road and improve drainage across Park Road	0.32	$155,000	$1,000	$3,900	-1.0	1.0	1.0	0.0	0.0	0.0	0.0	0	1.0	0	0.0	0.45	**16**
FM6	Gloria Park detention basin and upstream flow path augmentation	New basin to detain flows including drainage augmentation upstream to divert flows to basin	0.10	$640,000	$10,000	$5,800	-2.0	-1.0	1.0	1.0	0.0	2.0	1.0	2	1.0	1	0.0	1.80	**5**
FM7	Oaklands Road Berm (Park-Oaklands)	Constructions of berms to create flood storage prior to spilling onto Oaklands Road. Channel improvements upstream and downstream	0.25	$75,000	$1,500	$1,700	-1.0	1.0	1.0	1.0	0.0	1.0	1.0	2	2.0	0	0.0	1.90	**3**
FM8	Log Bridge Place Detention Basin	Berm in channel and berm / flood deflector adjacent Log Bridge. Provide additional detention upstream of road to reduce flood peak downstream	0.08	$190,000	$5,000	$1,200	-2.0	1.0	1.0	1.0	0.0	0.0	1.0	1	1.0	1	0.0	1.45	**11**
FM9	Alexander Avenue Berm	Berm and clear upstream and downstream road crossing. Modification of driveway at 35 Alexander Avenue	-0.04	$40,000	$1,000	$0	-2.0	2.0	0.0	2.0	0.0	1.0	1.0	0	1.0	0	0.0	1.15	**13**
FM10	Falcon Street Pipe Upgrade	Diversion of flows from Hazelbrook Street and Talbot Road to Creek.	0.30	$238,000	$1,000	$5,600	-1.0	0.0	1.0	2.0	0.0	0.0	0.0	0	1.0	0	0.0	0.65	**15**
FM11	Vegetation management downstream of Origma Avenue	Clearing of flow path to reduce flood hazard at Origami Avenue	0.00	$67,000	$1,500	$0	-2.0	1.0	0.0	2.0	0.0	1.0	1.0	0	1.0	0	0.0	0.95	**14**
FM12	Glendarrah Road Swale / Berm	Reconstruction of swale at rear of properties on Glendarrah Road	0.00	$105,000	$1,500	$0	-2.0	1.0	0.0	2.0	0.0	0.0	0.0	0	1.0	0	0.0	0.45	**16**
Non-Structural Options																			
Option EM1	Shelter in Place Strategy	Development of a shelter in place strategy as a means of flood emergency response	0.00	$50,000	$1,000	$0	0.0	1.0	0.0	2.0	0.0	2.0	0.0	1	1.0	0.0	0.0	1.60	**7**
Option EM2	Public awareness and education	Program to ensure the public is aware and reamins aware of flood behaviour within the catchment	0.00	$10,000	$2,000	$0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	1	0.0	0.0	0.0	1.55	**8**
Option EM3	School Education Program	Education program to speficially targeted at children	0.00	$10,000	$2,000	$0	0.0	2.0	0.0	2.0	0.0	2.0	0.0	1	0.0	0.0	0.0	1.55	**8**
Option EM4	Flood warning signs at critical locations	Installation of flood warning signs at location where roads are likely to overtop.	0.00	$27,000	$5,400	$0	0.0	2.0	0.0	2.0	0.0	1.0	0.0	2	1.0	0.0	0.0	1.80	**5**
Option P3	Building and Development Controls	Changes to building and development controls to improve consistency and the managemetn of flood liable land	0.00	$10,000	$500	$0	0.0	2.0	0.0	2.0	0.0	1.0	0.0	1	1.0	1.0	0.0	2.05	**2**
Option P6	Flood Proofing Guidelines	Undertaking structural changes and other procedures in order to reduce the damage caused to the property by flooding	0.00	$15,000	$1,000	$0	0.0	2.0	0.0	2.0	0.0	1.0	0.0	1	1.0	0.0	0.0	1.55	**8**