Burradoo BU2 Catchment Floodplain Risk Management Study and Plan

W4962

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Wingecarribee Shire Council

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Shaping the Future

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Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9, The Forum, 203 Pacific Highway
St Leonards NSW 2065
PO Box 19 St Leonards NSW 1590

Telephone: 02 9496 7700
Facsimile: 02 9439 5170
International: +61 2 9496 7700

sydney@cardno.com.au
www.cardno.com

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Foreword

The NSW Government's 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 floodplain modification 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 flood management measures (flood modification, response modification and property modification), 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 Burradoo BU2 Catchment Floodplain Risk Management Study and Plan represents Steps 4 and 5 of the Floodplain Management Process. This Study and Plan was prepared by Cardno for Wingecarribee Shire Council. It was co-funded by Wingecarribee Shire Council, the Commonwealth and NSW Government under the 2012/13 Natural Disaster Resilience Program's Floodplain Risk Management Grants Scheme administered by the Ministry for Police and Emergency Services with assistance from the Office of Environment and Heritage.

The Flood Study (Step 3) was prepared by Cardno on behalf of Wingecarribee Shire Council in 2010 and is reported in the Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report.

Executive Summary

Cardno was commissioned by Wingecarribee Shire Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Burradoo BU2 Catchment. This FRMSP has been prepared to define the existing, future and continuing flood behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk.

Burradoo BU2 Catchment is a sub-catchment of Mittagong Creek which is a tributary of the Wingecarribee River. The total catchment area is approximately 244 hectares within the suburb of Burradoo with land use being predominantly rural-residential.

The Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report was prepared by Cardno in 2010. The Flood Study defined flood behaviour in the Catchment under existing and future climate change conditions for the 20% AEP, 5% AEP, 2% AEP, and 1% AEP events and the Probable Maximum Flood (PMF). A hydrologic model, XP-RAFTS, and hydraulic model, TUFLOW, were used to estimate the flood behaviour of flows, peak water levels, peak depths and peak velocities for a range of storm events. The provisional hazard and hydraulic categories were determined for mainstream flooding in the catchment.

A questionnaire was sent to all residents in the catchment seeking information on flood behaviour and potential floodplain risk management options for the Flood Study (Cardno, 2010). A total of 154 replies were received from the 440 questionnaire letters issued in August 2007. The responses indicated a relatively high level of awareness of potential flooding in the catchment. Sixty responses commented on the management options listed in the questionnaire. The most favoured measures were culvert / pipe enlarging and stormwater harvesting. Concerns were expressed at the location of existing and current development, and it was recommended that restrictions be placed on future developments within flood prone areas.

A knowledge of demographic character assists in the preparation and evaluation of floodplain risk management options which are appropriate for the local community. Burradoo has a significantly higher proportion of people over 60 years of age than is typical of the NSW population. The median property price is $650,000 compared with a median property price for houses in NSW of $437,000.

A review has been undertaken of environmental characteristics which are important to consider for the evaluation of floodplain risk management options. An endangered ecological community, Southern Highlands Shale Woodlands (SHSW), is located within the catchment. No listed Aboriginal heritage sites are located in the Burradoo BU2 catchment.

The hydrologic model (XP-RAFTS) and the hydraulic model (TUFLOW) were modified for new data obtained since the Flood Study was prepared in 2010. Modelled peak depths and peak velocities for the design AEP events from the revised model are mapped for this FRMSP. Maps of true hazard conditions are also presented. Modelling shows that two houses are inundated with floodwater over their floor level in a 1% AEP event. An average annual damage of about $60,000 is estimated for the catchment.

The short time interval available from the commencement of a storm event to elevated flood levels in the catchment restrict the availability of warnings to be disseminated and time for door-knocking or evacuations to be undertaken.

Landuse zoning in the catchment is predominantly residential (large lot). Flood risk precincts based on the Development Control Plan have been mapped. The Flood Planning Level (FPL) for Burradoo is recommended to be the 1% AEP plus 500mm freeboard. A 500mm freeboard is widely adopted in NSW.

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

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

Eight flood modification measures, including detention basin upgrades, culvert enlargement, and flowpath augmentation were reviewed. Notably, the majority of these measures did not result in significant improvements to flood inundation extents within the catchment.

Due to the nature of flood behaviour and residential development in the catchment, development and planning controls are more beneficial than programs such as house raising.

Flood education is recommended rather than application of flood warning systems, as flooding tends to be relatively quick to occur and dissipate (generally within an hour).

A multi-criteria assessment approach was adopted for the comparative assessment of all modification measures identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach allows comparisons to be made between alternatives using a common index for criteria based on economic, environmental and social criteria.

The following options were ranked high in the multi-criteria assessment and are recommended for detailed assessment and / or implementation:

Non-Structural Measures-

- P2 Building and Development Controls;
- P1 LEP Update;
- EM4 Public awareness and education;
- EM3 Flood warning system;
- EM1 Information transfer to SES;
- EM2 Preparation of Local Flood Plans and update of DISPLAN;
- EM5 Flood warning signs at critical locations;
- P5 Flood proofing.

Structural Measures-

- FM8 Construct two levees to protect properties from over-floor flooding.

The implementation strategy for recommended floodplain risk management measures is outlined in the Floodplain Risk Management Plan.

A draft of this Floodplain Risk Management Study and Plan was publicly exhibited inviting comments from the community and stakeholders for 60 days and ended on 11 November 2013. No submissions were received during the exhibition period.

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Glossary and Abbreviations

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large. The 1% AEP event is equivalent to the 1 in 100 year Average Recurrence Interval event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
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.
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.
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 in 1 year ARI 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	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. The concept of FPLs supersedes the “Standard flood event” of the first edition of the Manual. 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.
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 stage 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.
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.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	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 Annual Exceedance Probability.
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.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and 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 which defines the ground level of a chosen area.

1 Introduction

Cardno was commissioned by Wingecarribee Shire Council to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Burradoo BU2 Catchment. This FRMSP has been prepared to define the existing, future and continuing flood behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk. It has been prepared in accordance with the NSW Government Floodplain Development Manual (2005).

Burradoo BU2 Catchment is a sub-catchment of Mittagong Creek which is a tributary of the Wingecarribee River. The total catchment area is approximately 244 hectares within the suburb of Burradoo with land use being predominantly rural-residential. **Figure 1-1** shows the general location of the Catchment.

The Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report was prepared by Cardno in 2010. The Flood Study defined flood behaviour in the Catchment under existing and future climate change conditions for the 20% AEP, 5% AEP, 2% AEP, and 1% AEP events and the Probable Maximum Flood (PMF).

1.1 Study Objectives

The overall objective of this study was to assess flooding risk, investigate floodplain risk management options and develop a management plan that addresses the existing and future flood risk and minimises the continuing flood risk in the Burradoo BU2 Catchment. This was undertaken in accordance with the NSW Government's Flood Prone Land Policy as detailed in the Floodplain Development Manual (2005).

Objectives of the Burradoo BU2 Floodplain Risk Management Study and Plan were to:

- Ensure that the most up-to-date flood-related information is available within the study area to investigate existing, future and continuing flood behaviour including consideration of potential catchment and climate change conditions as well as hydraulic and true hazard categories and the continuing risk for the community.
- Review Council's existing environmental planning policies and instruments, including Council's long term planning strategies for the study 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. Innovative solutions to the management of the flood hazards within the study area were being sought, along with effective community consultation and participation throughout the Study.
- Evaluate the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future. It also considered the social, environmental and economic impact of these measures.
- Examine and recommend measures to improve community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.
- Undertake risk category mapping based on four zones (High, Medium, Fringe Low and Low) in line with Bowral Floodplain Risk Management Study and Plan (Bewsher Consulting, 2004).

1.2 Report Outline

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

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

2 Data Collation and Inputs to the Study

2.1 Previous Reports

The Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report was prepared by Cardno in 2010. The Flood Study defined flood behaviour in the Catchment under existing and future climate change conditions for the 20% AEP, 5% AEP, 2% AEP, and 1% AEP events and the Probable Maximum Flood (PMF).

A hydrologic model, XP-RAFTS, and hydraulic model, TUFLOW, were used to estimate the flood behaviour of flows, peak water levels, peak depths and peak velocities for a range of storm events. The provisional hazard and hydraulic categories were determined for mainstream flooding in the catchment.

The Flood Study (Cardno, 2010) provided the key information on flood behaviour for this Floodplain Risk Management Study and Plan.

2.2 Planning Documents

The Local Environmental Plan and Development Control Plan for the Burradoo BU2 catchment are reviewed in **Section 8**. The Local Flood Plan is reviewed in **Section 7**.

2.3 Available Data

The Flood Study (Cardno, 2010) was the basis for preparing this Floodplain Risk Management Study and Plan (FRMSP). Additional information to refine the flood models, including aerial laser scanning of ground elevations, was available for the FRMSP and is described in **Section 5**.

3 Community Consultation

3.1 Community Questionnaire

A questionnaire was sent to all residents in the catchment seeking information on flood behaviour and potential floodplain risk management options for the Flood Study (Cardno, 2010). A total of 154 replies were received from the 440 questionnaire letters issued in August 2007.

The responses indicated a relatively high level of awareness of potential flooding in the catchment. About 66% of respondents indicated an awareness or some knowledge of flooding, noting the storm event of June 2007 occurring just prior to the questionnaire distribution.

Sixty responses commented on the management options listed in the questionnaire. The most favoured measures were culvert / pipe enlarging and stormwater harvesting, as summarised in Table 3-1. Concerns were expressed at the location of existing and current development, and it was recommended that restrictions be placed on future developments within flood prone areas.

Comments emphasised that the community would like to stay informed regarding development of any of these solutions, and some comments expressed the wish that solutions which did not affect existing street landscapes and had no impacts to residents should be adopted.

Table 3-1 Responses to Floodplain Risk Management Options

Measure	Proportion of Supporting Comments Received
Retarding or detention basins	9%
Improved overland flow paths	12%
Culvert / Pipe Enlarging	26%
Channel widening or deepening	11%
Flood walls / Levee Banks	4%
Infiltration Basins and Trenches	5%
Stormwater Harvesting	24%
Planning Controls	10%

Further details of the questionnaire and responses are provided in the Flood Study (Cardno, 2010).

3.2 Public Exhibition

A draft of this Floodplain Risk Management Study and Plan was publicly exhibited inviting comments from the community and stakeholders for 60 days and ended on 11 November 2013. No submissions were received during the exhibition period.

4 Social and Environmental Characteristics

4.1 Social Characteristics

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

The demographic characteristics of the Burradoo BU2 catchment presented in this report are based on the suburb of Burradoo, where it was assumed that the catchment characteristics are generally consistent across the wider suburb. Population data for Burradoo was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census. The data was then aggregated to produce an overall summary for the region of interest.

In summary, the data revealed that:

- Burradoo has a significantly higher proportion of people over 60 years of age than is typical of the NSW population. In fact, almost 50 percent of the population of Burradoo is over 60 years of age. The region also had a lower proportion of people aged between 20 and 39 years of age (**Table 4-1**). This results in a community which may face issues with regards to any evacuation that might be considered during a flood event due to limited mobility, inability to drive or health issues associated with an aged community. In addition, the most able bodied portion of the community (aged 20 to 49 years), who might assist with emergency responses, comprise less than 20 percent of the population. This is a consideration for the development of the Local Flood Plan (**Section 7.1.2**).
- In Burradoo, 75.7% of people were born in Australia. The most common countries of birth outside of Australia were England 7.7%, New Zealand 2.2%, Scotland 1.0%, United States of America 1.0% and Netherlands 0.9%. Indigenous (Aboriginal and Torres Strait Islander) people comprised of 0.1% of the region's population.
- English was the only language spoken in approximately 89% of homes in Burradoo. The remainder of languages spoken at home included Italian, German, Dutch, Greek and Thai. However there was no specific other language contributing to greater than 1% of the total (**Table 4-2**).
- The average median weekly income for individuals in the region was $666, compared to the NSW average of $561. This trend of slightly above average income for the region compared to the NSW average was also evident for family and household incomes (**Table 4-3**). This may have implications for the economic damages incurred on property contents during a flood event (**Section 6**).
- The median property price is $650,000 (www.realestate.com.au, 2012), compared with a median property price for houses in NSW of $437,000 (APM, 2012). All dwellings comprised of single dwellings (detached, semi-detached and terraces) as listed in **Table 4-4**. This information has implications for the economic damages incurred during a flood event (**Section 6**).

Table 4-1 Age Structure of Burradoo (ABS, 2011)

Age Group (Years)	Persons in Burradoo	% of total persons in Burradoo	% of total persons in NSW
0-9 years	216	8.5	12.9
10-19 years	280	11	12.7
20-29 years	94	3.7	13.3
30-39 years	104	4.1	13.9
40-49 years	295	11.6	14
50-59 years	345	13.5	12.9
60-69 years	509	20	10
70+ years	711	27.9	10.3
TOTAL	2554	100	100

Table 4-2 Languages Spoken at Home in Burradoo (ABS, 2011)

Languages Spoken at Home	Homes in Burradoo	% of total homes in Burradoo	% of total homes in NSW
English Only	2,274	89	72.5
Italian	24	0.9	1.2
German	22	0.9	0.3
Dutch	15	0.6	0.1
Greek	11	0.4	1.3
Thai	8	0.3	0.2

Table 4-3 Average Median Income of Burradoo (ABS, 2011)

Income (For Population Aged 15 Years and Over)	Burradoo	New South Wales
Average Median Individual Income (weekly)	666	561
Average Median Family Income (weekly)	1,672	1,477
Average Median Household Income (weekly)	1,378	1,237

Table 4-4 Dwelling Structure in Burradoo (ABS, 2011)

Dwelling Structure (Occupied Private Dwellings)	Burradoo	% of Dwellings in Burradoo	% of Dwellings in NSW
Separate house	876	94.3	69.5
Semi-detached, row or terrace house, townhouse etc.	53	5.7	10.7
Flat, unit or apartment	0	0	18.8
Other dwelling	0	0	0.9

4.2 Environmental Characteristics

A review has been undertaken of environmental characteristics in the catchment. It is important to consider environmental characteristics in the evaluation of floodplain risk management options, particularly structural flood modification measures (**Section 9.2**).

4.2.1 Topography

The topography of the Burradoo BU2 Catchment comprises a ridgeline to the north, east and south of the floodplain. The catchment ridgeline to the east has a peak elevation of about 686m AHD, and rises to approximately 689m AHD in the south. The main floodplain is relatively flat with elevations ranging between approximately 677 and 657m AHD.

4.2.2 Geology and Soils

When developing floodplain management options it is important to understand the geology of the catchment to ensure appropriate locations for management options are selected and to assist with the planning of suitable foundations and other constructions.

The study area is located in the Moss Vale Highland (Mvh) within Sydney Basin Bioregion, which is typified by rolling hills and rounded peaks with deep channel incision on horizontal Triassic alternating quartz sandstone and shale, general elevation 0.70 to 0.85 m, local relief 80 m. Widespread yellow and grey texture-contrast soils, deep yellow earth on friable sandstone often with concretionary ironstone and accumulations of clan quartz sand in valleys (Mitchell, 2002).

The study area is comprised on Moss Vale Basalts (SB), which is characterised by flat top hills and small plateau standing above undulating shale hills of the Moss Vale Highlands landscape on Tertiary basalt flows, general elevation 800 to 850m, local relief 40m. Red and red-brown structured loam and clay loam with uniform or gradational profiles, good water holding capacity and high fertility (Mitchell, 2002).

The 1:1 500 000 surface geology maps provided by Geological Survey of NSW (2009) identified that the study area is comprised of Triassic sedimentary and volcanic rocks including Digby Formation and Napperby Formation (Massive quartzose sandstone, flaggy sandstone, siltstone and shale).

The 1:1 000 000 surface geology map provided by Geological Survey of NSW (Pogson, 1972) identified the study area is comprised of Triassic sedimentary and volcanic rocks known as Wianamatta Group (Shale and lithic sandstone). The shales have very low porosities and in their fresh state high strengths, but may contain swelling clay minerals, which swell and disintegrate rapidly on immersion in water and are generally not very durable (William & Airey, 1999).

The soil profiles have been classified as Kangaloon (kl) in the lower creek lines and overland flowpaths and Moss Vale (mv) in all other areas of the catchment.

The geological and soil constraints on floodplain management depend on the management options selected. However, no significant geological constraints have been identified which would significantly affect potential management options. Site-specific geotechnical assessment would need to be undertaken prior any detailed design and/or construction works.

4.2.3 Contaminated Land and Licensed Discharges

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

A search of the OEH Contaminated Land Record on 23 October 2012 showed four known contaminated sites within the Wingecarribee Shire Council LGA. However, none of these sites are within the Burradoo BU2 Catchment. The Contaminated Land Record is not an exhaustive index, and there may be unreported contamination present within the catchment. Given the predominance of residential and open space land-use in the catchment, there is no reason to suspect the presence of broad-scale contamination.

A search of the PoEO licensed premises public register on 23 October 2012 identified one licenced premise within the catchment. The Bowral Sewerage Treatment Plant is located on Burradoo Road in the western portion of the catchment at the downstream end of the floodplain. The fee-based activity licensed for this premise is 'sewage treatment processing by small plants'.

Flood modification works within this vicinity should both consider the protection of this facility from flooding and the compatibility of the flood works with the operations of the plant.

4.2.4 Flora and Fauna

The Burradoo BU2 Catchment is comprised of a combination of primarily residential and open space land-uses. There are several parkland areas which support native flora and fauna.

4.2.4.1 Flora

The study area is located in the Moss Vale Highland (Mvh) within Sydney Basin Bioregion, which is typified by woodland. Open forest is present in gullies at the head of rivers below the plateau on shale and poorly drained sites. Large areas of wet heath are also present within the region (Mitchell, 2002).

Mapping undertaken by Tozer et al (2006) identified Southern Highlands Shale Woodlands (SHSW) within the catchment. SHSW includes vegetation ranging from open-forest to woodland and scrub and is listed as an endangered ecological community under the Threatened Species Conservation Act 1995. Mapping of the SHSW provided by Council is shown in **Figure 4-1**.

DECC (2008) and DECCW (2011) mapping identified that the majority of the vegetation within the catchment is comprised of native woody vegetation, with some non-woody and woody non-natives.

A search of OEH's Atlas of NSW Wildlife on 23 October 2012 revealed two species listed as endangered, protected and/or vulnerable. **Table 4-5** provides the details of these species.

Although not endangered, there are also three koala primary feed-tree species which have been found in the area, namely:

- *Eucalyptus amplifolia* (Cabbage Gum);
- *Eucalyptus tereticornis* (Forest Red Gum); and
- *Eucalyptus viminalis (Ribbon Gum).*

These tree species are protected under State Environmental Planning Policy 44 – Koala Habitat Protection (SEPP 44).

Any flood management actions will need to recognise the presence of vegetation within the catchment and comply with flora legislative requirements.

Table 4-5 Vulnerable, Threatened and Endangered Flora Species (OEH, 2012)

Family Name	Scientific Name	Common Name	Legal Status
Myrtaceae	Eucalyptus macarthurii	Camden Woollybutt	Vulnerable (Threatened Species Conservation Act 1995) Endangered (Threatened Species Conservation Act 1995)
Orchidaceae	Diuris aequalis	Buttercup Doubletail	Protected (National Parks & Wildlife Act 1974) Endangered (Threatened Species Conservation Act 1995)

4.2.4.2 Fauna

A search of OEH's Atlas of Wildlife on 23 October 2012 revealed three species listed as endangered, protected and/or vulnerable. **Table 4-6** provides the details of these species.

Table 4-6 Vulnerable, Threatened and Endangered Fauna Species (OEH, 2012)

Family Name	Scientific Name	Common Name	Legal Status
Myobatrachidae	Limnodynastes dumerilii	Eastern Banjo Frog	Protected (National Parks & Wildlife Act 1974)
Cacatuidae	Callocephalon fimbriatum	Gang-gang Cockatoo	Vulnerable (Threatened Species Conservation Act 1995) Protected (National Parks & Wildlife Act 1974)
Phalangeridae	Trichosurus sp.	Brushtail Possum	Protected (National Parks & Wildlife Act 1974)

4.2.4.3 Fish

The Burradoo BU2 catchment is a sub-catchment of Mittagong Creek, which is a tributary of the Wingecarribee River. The primary flowpath is generally an informal drainage depression downstream of Foldgarth Way. Flow is also conveyed along the drainage depression between houses from the intersection of Osborne Road and Toongoon Rd. West of Moss Vale Road, flow is conveyed along drainage depressions within private property. Several driveways cross the flowpath and several ponds are also located within the drainage flowpath (Cardno Lawson Treloar, 2010). Due the ephemeral and disjointed nature of the flow path, it is unlikely to provide habitat or passage for fish species.

A desktop search of the Department of Primary Industries (Fishing and Aquaculture) database revealed that there are no known threatened species listed in this catchment or in Mittagong Creek or the Wingecarribee River (DPI, 2012).

4.2.5 Heritage

4.2.5.1 Aboriginal Heritage

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

A preliminary investigation of indigenous heritage was undertaken by searching the NPWS Aboriginal Heritage Information Management System (AHIMS) in October 2012 for known or potential indigenous archaeological or cultural heritage sites within or surrounding the Burradoo BU2 Catchment. The AHIMS search results are shown on **Figure 4-2** and relevant sites are presented in **Table 4-7**, with three listed Aboriginal sites near the catchment (only two can be seen on **Figure 4-2** as two of the sites are marked in the same location). Neither of these sites are located within the catchment and it is unlikely that any proposed flood modification measures would impact upon these sites.

Table 4-7 Items Identified Under the NPWS Aboriginal Heritage Information Management System for Burradoo BU2 Catchment

Site ID	Site Name	Site Type
52-4-0099	Site 1, Sutherland Park	Open Camp Site
52-4-0074	WR 10	Open Camp Site
52-4-0109	Site 1, Sutherland Park	Open Camp Site

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 23 October 2012 found one register of Native Title claim which encompasses the whole study area and no Land Use Agreements within the study area.

The Native Title Claim identified for the study area covers a total area of 18,675 km^2 and extends from the south of Katoomba to Goulburn. The claim was lodged in 1997 and the tribunal file number is NC97/7. 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.

4.2.5.2 Non-Aboriginal Heritage

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

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

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

A search of the Australian Heritage Database (DSEWPC, 2008) on 23 October 2012 identified four places within or in close proximity to the Burradoo BU2 Catchment (**Table 4-8**). The four places were all included on the Register of National Estate, which means these places may not be removed from the register.

Table 4-8 Australian Heritage Database Listings (DSEWPC, 2012)

Name	Address	Register
Anglewood	Yean Street, Burradoo, NSW, Australia	(Indicative Place) Register of the National Estate (Non-statutory archive)
Anglewood Garden	Yean Street, Burradoo, NSW, Australia	(Indicative Place) Register of the National Estate (Non-statutory archive)
Eridge Lodge and Surrounds	Eridge Park Road, Burradoo, NSW, Australia	(Registered) Register of the National Estate (Non-statutory archive)
San Michele Garden	Burradoo Road, Burradoo, NSW, Australia	(Registered) Register of the National Estate (Non-statutory archive)

The State Heritage Register (OEH, 2012) listed 20 places within or in close proximity to the Burradoo BU2 Catchment, as indicated in **Table 4-9**.

Table 4-9 State Heritage Register Listings (OEH, 2012)

Item name	Address	Information source
Yean Cottage, Anglewood Estate	Yean Street, Burradoo	Heritage Council (NSW Heritage Act)
Anglewood Garden: Anglewood Group	Yean Street, Burradoo	Local Government
Anglewood House: Anglewood Group	Yean Street, Burradoo	Local Government
Chevalier College	Moss Vale Road, Burradoo	Local Government
Chevalier College former Riversdale House (excl. modern additions)	Moss Vale Road, Burradoo	NSW Government Gazette (statutory listings prior to 1997)
Eridge Lodge	Eridge Park Road, Burradoo	NSW Government Gazette (statutory listings prior to 1997)
Eridge Park Lodge and Surrounds	Eridge Park Road, Burradoo	Local Government
Grey Leaves	Eridge Park Road, Burradoo	NSW Government Gazette (statutory listings prior to 1997)
Grey Leaves House	Eridge Park Road, Burradoo	Local Government
Hartzer Park Barn	Eridge Park Road, Burradoo	Local Government
Hartzer Park Convent	Eridge Park Road, Burradoo	Local Government
Hartzer Park Group	Eridge Park Road, Burradoo	Local Government
Hartzer Park including manager's residence (excl. modern additions)	Eridge Park Road, Burradoo	NSW Government Gazette (statutory listings prior to 1997)
Hartzer Park Noviate	Eridge Park Road, Burradoo	Local Government
San Michele	Burradoo Road, Burradoo	NSW Government Gazette (statutory listings prior to 1997)
San Michele Garden	Burradoo Road, Burradoo	Local Government
San Michele House	Burradoo Road, Burradoo	Local Government
Wintersloe	45 Links Road, Burradoo	Local Government
Yean Cottage: Anglewood Group	Yean Street, Burradoo	Local Government
Yokefleet Garden	Osborne Road, Burradoo	Local Government

5 Existing Flood Behaviour

5.1 Background

The Burradoo BU2 Catchment Assessment Study – Stage 1 Flood Study Report was prepared by Cardno in 2010. The Flood Study defined the flood behaviour in the study area, namely peak flood levels, depths, velocities, provisional hazard and hydraulic categories. Events considered were the 20% AEP, 5% AEP, 2% AEP, and 1% AEP events and the Probable Maximum Flood (PMF).

Two computer modelling tools were utilised to simulate comprehensive hydrological and hydraulic processes of this catchment in responding to rainfall. Firstly, an XP-RAFTS model was used to generate runoff hydrographs by combining rainfall information with the local catchment characteristics. Hydrographs at the relevant nodes generated by the XP-RAFTS model were input to the TUFLOW one-dimensional / two-dimensional hydraulic model. The fully-dynamic hydraulic modelling system, TUFLOW, was utilised to convert hydrographs into water levels, depths and velocities in the study area.

The XP-RAFTS and TUFLOW models were updated for this Floodplain Risk Management Study and Plan to incorporate additional information available since the Flood Study (Cardno, 2010) was completed.

5.2 Revision of Hydrologic and Hydraulic Models

The sub-catchment layout in the XP-RAFTS model was refined based on the elevation contours (0.5m resolution from aerial laser scanning [ALS]) received from Council. **Figure 5-1** shows the revised XP-RAFTS subcatchment layout.

The digital terrain model has been revised in the TUFLOW hydraulic model to incorporate refined details in the vicinity of Holly Road as recommended in the Flood Study and general improvement of levels based on the ALS data. The following figures show elements of the TUFLOW model:

- **Figure 5-2** shows elevations within the catchment;
- **Figure 5-3** shows the one-dimensional culverts modelled; and
- **Figure 5-4** shows the surface roughness modelled.

5.3 Modelled Flood Behaviour

The revised models were run for a series of events and modelled peak water levels are listed in **Table 5-1** for the reference locations shown in **Figure 5-5**.

The critical duration within the catchment is predominantly 2 hours for 1% AEP, 2% AEP, 5% AEP and 20% AEP events as determined in the Flood Study. Reference Point 15, the Pony Club Detention Basin, has a critical duration of 9 hours. For the PMF event, the critical duration is between 30 minutes in the upstream areas and 1 hour in the downstream areas. For the FRMSP, 2 hours and 9 hours storm durations were modelled for the 1% AEP, 2% AEP, 5% AEP and 20% AEP events. PMF events with durations of 30 minutes, 60 minutes, 90 minutes and 2 hours were analysed.

Peak modelled depths for the PMF, 1% AEP, 2% AEP, 5% AEP and 20% AEP events are shown in **Figures 5-6 to 5-10** respectively and the peak velocities for these design events are shown in **Figures 5-11 to 5-15** respectively.

Table 5-1 Peak Water Levels at Reference Locations

Point	Location	Ground Elevation	PMF	1% AEP	2% AEP	5% AEP	20% AEP
1	d/s Railway	657.54	658.84	658.14	658.10	658.07	658.03
2	u/s Railway	658.23	662.30	659.42	659.23	659.08	658.85
3	d/s Burradoo Road	658.50	662.29	660.10	660.04	659.96	659.88
4	u/s Burradoo Road	659.00	662.33	661.02	660.97	660.91	660.83
5	u/s Burradoo Road	660.66	662.40	661.02	660.97	660.91	660.83
6	d/s Ranelagh Road	662.12	663.56	662.79	662.76	662.73	662.69
7	u/s Ranelagh Road	663.00	664.45	663.33	663.28	663.25	663.18
8	d/s Holly Road	664.01	664.77	664.25	664.23	664.21	664.19
9	u/s Holly Road	665.50	665.77	665.58	665.58	665.58	665.57
10	d/s Holly Road	664.12	666.30	665.33	665.29	665.24	665.16
11	u/s Holly Road	665.50	666.71	665.75	665.70	665.63	665.50
12	d/s Moss Vale Road	667.23	667.79	667.60	667.59	667.57	667.53
13	u/s Moss Vale Road	668.00	671.54	670.22	670.09	669.92	669.58
14	d/s Moss Vale Road	667.00	668.35	667.42	667.37	667.34	667.31
15	u/s Moss Vale Road	668.15	670.67	670.39	670.22	669.98	669.58
16	u/s Moss Vale Road	670.50	671.54	670.72	670.68	670.66	670.60
17	d/s Osborne Rd	671.07	671.59	671.24	671.23	671.21	671.18
18	Foldgarth Way	672.50	673.11	672.66	672.62	672.59	672.50
19	d/s Stratford Way	673.00	673.85	673.40	673.36	673.33	673.24
20	u/s Stratford Way	674.00	675.40	674.96	674.93	674.90	674.81
21	u/s Stratford Way	674.50	675.79	675.19	675.11	675.04	674.94
22	u/s Stratford Way	675.96	676.77	676.40	676.36	676.33	676.28

5.4 Flood Hazard

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

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

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

5.4.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters as detailed in the Floodplain Development Manual (NSW Government, 2005). The hazard categories shown in **Figure 5-16** are defined as:

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

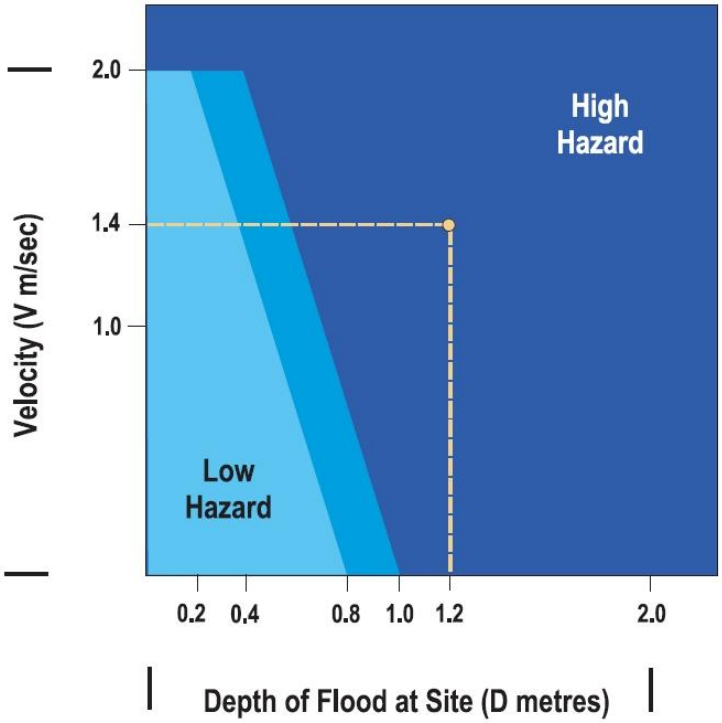

Figure 5-16 Provisional Hazard Classification (NSW Government)

Provisional flood hazard for the PMF, 1% AEP, 2% AEP, 5% AEP and 20% AEP events are shown in **Figures 5-17 to 5-21** respectively. The mapping shows the low and high provisional hazard, with flow conditions in the transition zone of **Figure 5-16** mapped as high hazard.

High provisional hazard for the 20% AEP event is shown in parts within the open channel near Stratford Way, in sections of the drainage depressions downstream of Moss Vale Road to Burradoo Road, and adjacent to the culvert opening under the railway. The Informal detention basin, Pony Club basin, and dams near Burradoo Road are also identified as high provisional hazard areas.

In a 1% AEP event, the extent of the high hazard areas shown in a 20% AEP have expanded. Roadways are generally low provisional hazard in this event. In a PMF event, high provisional hazard flow conditions occur along the length of the channel. Affected areas include Moss Vale Road, Burradoo Road, Holly Road and the railway line.

5.4.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described in **Section 5.4.1**, does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

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

In the Burradoo BU2 floodplain many of the above factors are not applicable in terms of affecting hazard definition. However, all of the above factors have been considered in this report to provide a thorough assessment process.

Size of Flood

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

Effective Warning Time

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

The Flood Study identified the critical duration within the catchment is 2 hours for 1% AEP, 2% AEP, 5% AEP and 20% AEP events in general. The Pony Club Detention Basin has a critical duration of 9 hours. For the PMF event, critical duration is between 30 minutes in the upstream areas and 1 hour in the downstream areas.

The flow peak can thus occur within an hour of the commencement of rainfall, therefore there is insufficient time to alert residents. The lack of warning time contributes to an increased flood risk to residents.

Flood Readiness

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

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. Responses from the community questionnaire (**Section 3.1**) indicated a relatively high awareness of flooding, noting that the last flood event occurred in June 2007 but was fairly minor (about a 1 year ARI event). As a result, no particular part of the catchment is likely to be any more prepared for a flood than another, thus flood readiness has not been considered in the preparation of hazard extents.

Rate of Rise of Floodwaters

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

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

A flood depth of 500 mm was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 0.5 m/hr.

Depth and Velocity of Floodwaters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping for the PMF, 1% AEP, 2% AEP, 5% AEP and 20% AEP events is presented in **Figures 5-17 to 5-21**. This provisional hazard mapping has been used as the base to determine true flood hazard.

Duration of Flooding

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple of hours, and as such this is not considered as a key issue for this Catchment.

Ease of Evacuation

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

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

A flood event in the catchment is likely to be a flash flood scenario, with limited warning time and period of exposure therefore evacuation may not be viable. It is noted that Burradoo has a significantly higher proportion of people over 60 years of age than is typical of the NSW population (refer to **Section 4.1**). No additional properties were identified as hazard with respect to ease of evacuation as no sites were identified in the catchment with particular criteria for this parameter.

Effective Flood Access

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

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

- Site is flooded and evacuation required through a high hazard flooded roadway;

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

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

In a 1% AEP event, no roads are shown as within high hazard. In a PMF event, Stratford Way, Moss Vale Road, and Burradoo Road / Yean Street have high hazard flow conditions (due to velocity and depth parameters).

Type of Development

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

True Hazard Mapping

Figures 5-22 to 5-24 show the true high hazard areas and low hazard areas mapped in the PMF, 1% AEP and 20% AEP events. The results indicate that the true high hazard mapping does not result in additional properties classified as true hazard in the PMF and 1% AEP events as the provisional hazard mapping already identifies properties as a high hazard risk. However, the true hazard mapping identifies additional four properties exposed to true hazard in 20% AEP event, which are not identified by the provisional hazard mapping. This is primarily due to consideration of the rate of rise of floodwaters.

6 Current Economic Impact of Flooding

6.1 Background

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

Table 6-1 Types of Flood Damages

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

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

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For this Study, generic spreadsheets have been used along with the damage curves provided by OEH.

6.2 Floor Level and Property Survey

The Burradoo BU2 catchment includes only residential properties, and does not include commercial or industrial land-uses. The floor levels for all properties within the PMF flood extent were surveyed for the Flood Study (Cardno, 2010).

6.3 Damage Analysis

A flood damage assessment for the existing catchment and floodplain conditions has been undertaken. The assessment is based on damage curves that relate the depth of flooding on a property to the potential damage within the property.

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and recourse is generally made to damage curves from other catchments. 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. However, correspondence at the outset of this project with OEH confirmed that the use of the OEH curves was appropriate.

6.3.1 Residential Damage Curves

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

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

All buildings were assumed to be single storey slab-on-ground in this study. The surveyed floor levels were used for all properties within the PMF flood extent.

Damages are generally incurred on a property prior to any over-floor flooding. The OEH curves allow for a damage of $10,701 (November 2012 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.3m below the floor level for slab on ground). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up). According to the damage curves this amount of damage remains constant from the base of the house to the floor level of the house.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- Based on interrogation of the aerial photos a value of 240m^2 was adopted as a conservative estimate of the floor area for residential dwellings for the floodplain. With a floor area of 240m^2, the default contents value is $60,000 (in November 2001 dollars before damage repair adjustment). The review of suburb demographics in **Section 4.1** indicated that Burradoo has a higher than average income and property valuation.
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).
- The Burradoo BU2 Catchment is a small part of the regional area and as such is not likely to cause any post-flood inflation. These inflation costs are generally experienced in remote areas, where re-construction resources are limited and large floods can cause a strain on these resources.

Average Weekly Earnings

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

While not specified, it has been assumed that the curves provided by OEH were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the OEH guidelines, and November 2012 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au) as shown in **Table 6-2**. Consequently, all ordinates on the damage curves were increased by 60%.

Table 6-2 AWE Statistics

Month	Year	AWE
November	2001	$676.40
November	2012	$1080.30
Change	60%	

6.3.2 Average Annual Damage

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

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

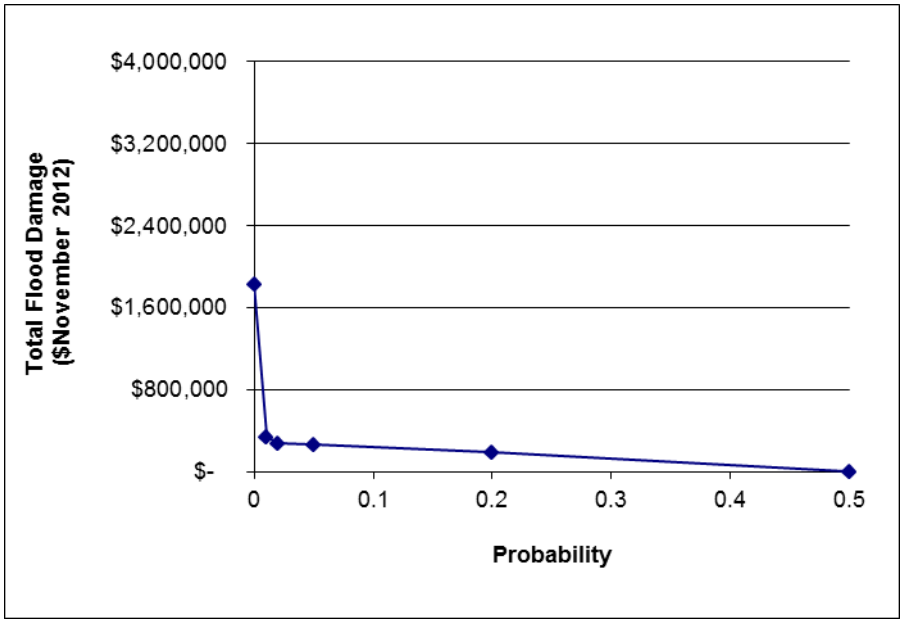

Figure 6-1 Annual Average Damage Curves for Burradoo BU2 Catchment

For this study, the damage resulting from a 50% AEP event (~2 year ARI) was assumed to be zero for the AAD analysis. The value is based on the assumption that flows for the 50% AEP event are contained generally within the channel and thus do not result in inundation with consequent damage to properties.

6.4 Results

Table 6-3 shows the results of the flood damage assessments for the modelled storm events. The average annual damage estimated for the floodplain under existing conditions is approximately $60,000.

Table 6-3 Flood Damage Assessment Summary

Event	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)
PMF	23	0.36	1.91	37	$1,824,000
1% AEP	2	0.08	0.12	16	$339,000
2% AEP	1	0.10	0.1	16	$273,000
5% AEP	1	0.08	0.08	15	$261,000
20% AEP	1	0.02	0.02	13	$183,000

The results identified two properties are exposed to over-floor flooding in a 1% AEP event, noting that one of these properties is inundated above floor level in a 20% AEP event. The locations of these two properties are shown in **Figure 6-2**.

Figure 6-2 shows a property exposed to over-floor flooding in a 1% AEP is affected by a major overland flowpath. Another property exposed to over-floor flooding in a 20% AEP is only affected by local ponding. It is noted that the DTM adopted in the current study may not fully represent the topography features around the property exposed to over-floor flooding in a 20% AEP. It is recommended undertaking a further detailed ground survey around this property to validate the model results for this property.

6.5 Qualifications

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

- The flood level for a property was estimated by the maximum flood level within the property boundary; and
- In the calculation of the Annual Average Damage, the damages in the 50% AEP design event are assumed to be zero with a linear increase in damage up to the 20% AEP design event. Assuming a different design event for zero damages can significantly change the AAD (Thomson et al., 2006). Flood modelling was not undertaken for events more frequent than the 20% AEP and a 50% AEP design event was considered to be a reasonable estimate of zero property damage in the catchment.

7 Flood Emergency Response Arrangements

Flood emergency measures are an effective means of managing the continuing risks to the area. Current flood emergency response arrangements for the management of flooding in the Burradoo BU2 Catchment are discussed below.

7.1 Flood Emergency Response Documentation

7.1.1 DISPLAN

The Wingecarribee Shire LGA is within the Illawarra South Coast Region of the Sydney South West Emergency Management District. Flood emergency management for the Wingecarribee Shire Council LGA is therefore organised under the South West Metropolitan Emergency Management District Disaster Plan (DISPLAN) (2012).

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

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

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

7.1.2 Local Flood Plan

A sub-plan to the district DISPLAN has been prepared by the SES in conjunction with Council. The Wingecarribee Shire Local Flood Plan was prepared in 2007 and covers the preparation, response and recovery of flooding emergencies for the Wingecarribee Shire Council area.

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

This Local Flood Plan encompasses the key components as follows:

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

The Local Flood Plan also notes key roads that can be flood affected and details evacuation centres for flood affected areas of the Wingecarribee LGA. It is recommended that the Flood Plan be updated to reflect the outcomes of this current study. Six years have passed since the Flood Plan has been updated thus this would be a suitable opportunity to update the Flood Plan for other studies that may have been completed within the LGA.

With respect to the Burradoo BU2 floodplain, the following amendments to the Flood Plan are recommended:

- Include a section in Annex B describing the effects of flooding in the Burradoo BU2 floodplain.
- The Burradoo railway station is potentially flood affected and should be considered for inclusion in Annex F.

- The following key access roads should be included in Annex G (further details of accessing road flooding is provided below in **Section 7.4.1**):
    - Burradoo Road (western end).
    - Holly Road (between Ranelagh Road and Moss Vale Road).
    - Moss Vale Road (between Osborne Road and Burradoo Road).
- Identify that any potential evacuation may require additional resources due to the proportion of aged residents in the catchment.

7.2 Emergency Service Operators

The Burradoo BU2 floodplain lies within the Wingecarribee Region of the State Emergency Service (SES). The SES is the legislated combat agency for floods and is responsible for the control of flood operations including the coordination of other agencies and organisations for flood management tasks. It has a Local Operations Centre at corner of Priestly Street and Etheridge Street, Mittagong. The SES is primarily a volunteer organisation and in times of emergency operates a paging service for on-call volunteers.

The key emergency services for the Burradoo BU2 floodplain are outlined in **Table 7-1**.

Table 7-1 Emergency Service Providers Locations

Emergency Service	Location
Bowral and District Hospital	Mona Road, Bowral
Bowral Police Station	53 Wingecarribee St, Bowral
Fire Station	10 Bowral Rd, Mittagong

7.3 Flood Warning Systems

There is no official flood warning system for the Burradoo BU2 catchment. However, sources of real-time flood intelligence during times of flooding are:

- Bureau of Meteorology (BoM):
    - Flood Watches: typically provide 24-48 hours notice that flooding is possible based upon current catchment conditions and future rainfall.
    - Severe Weather Warnings: provide warnings of possible flash flooding.
    - Severe Thunderstorm Warning: provide 0.5-2 hours notice of impending severe storms.
- Illawarra South Coast SES Region Headquarters provides information on flooding and its consequences including those in nearby council areas.
- Active reconnaissance. The SES Local Operations Controller coordinates the monitoring of known problem areas. However, none of these areas are located within the Burradoo BU2 catchment.

Warnings are provided as:

- BoM Flood Watches: If there are signs of impending floods, a Flood Watch may be incorporated in SES Flood Bulletins released to radio stations by the Illawarra South Coast SES Region Headquarters.
- BoM Severe Weather Warnings are issued when developing weather conditions indicate that flash flooding may occur. On receipt of such warnings, the SES Local Operations Controller will:
    - Advise the Wingecarribee Shire Council and the Wingecarribee Shire Local Emergency Operations Controller.
    - Provide the Illawarra South Coast SES Region Headquarters with information for inclusion in SES Flood Bulletins on the estimated impacts of flooding.
- Evacuation Warnings are disseminated as follows:
    - Using public address systems from emergency service vehicles.
    - By door-knocks by emergency service personnel.
    - By telephone.
    - By two-way radio.
    - By direct access to community radio.
    - In Illawarra South Coast SES Flood Bulletins.

- Standard Emergency Warning Signal (SEWS).

The short time interval available from the commencement of a storm event to elevated flood levels in the catchment restrict the availability of warnings to be disseminated and time for door-knocking or evacuations to be undertaken.

7.4 Access and Movement During Flood Events

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

Evacuation procedures would be difficult to enact for flooding in the Burradoo BU2 Catchment as inundation of properties is likely to occur within a short period after rainfall ('flash flooding') and only be for a relatively short duration (potentially less than an hour).

7.4.1 Access Road Flooding

A summary of road flooding in the Burradoo BU2 floodplain is listed in **Table 7-2**. Burradoo Road is significantly affected, even in the smaller flood events, making it unsafe for vehicles in most events. However, the flood affected section of Burradoo Road is unlikely to be used by other than the immediate community for access.

Holly Road would predominantly be used by local traffic only and dependent on debris, may be safe for vehicles in the smaller flood events.

Moss Vale Road is a major access road through the area. Appropriate detours and traffic signalling may be required to divert traffic onto Eridge Park Road in events larger than a 1% AEP event. Depth markers may be required to assist drivers in other events.

Table 7-2 Major Access Road Flooding

	Flood Depth (m)				
Road Name	**20% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**PMF**
Burradoo Road (western end)	0.2	0.3	0.4	0.4	1.7
Holly Road (between Ranelagh Road and Moss Vale Road)	-	0.1	0.2	0.2	1.1
Moss Vale Road (between Osborne Road and Burradoo Road)	-	<0.1	0.1	0.1	0.9

7.4.2 Evacuation Centres

The Local Flood Plan identifies Chevalier College on Moss Vale Road, Burradoo as one of the two appropriate evacuation centres for the Wingecarribee LGA. This location is in close proximity to the Burradoo BU2 floodplain and can be accessed easily by those in the southern portion of the floodplain and flood-free access is available via Eridge Park Road for those located in the northern portion of the floodplain.

7.5 Flood Emergency Response Planning Classifications

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

- **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:

  - High Flood Island - the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground.
  - Low Flood Island - the flood island does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by flood waters.
- **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through floodprone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:
  - High Trapped Perimeter - the area contains enough flood-free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground.
  - Low Trapped Perimeter - the area does not have enough flood-free land to cope with the number of people in the area or the island will eventually become inundated by flood waters.
- **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
  - Areas with Overland Escape Route - access roads to flood free land cross lower lying flood prone land.
  - Areas with Rising Road Access - access roads rise steadily uphill and away from the rising floodwaters.
- **Indirectly Affected Areas.** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood-damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.
- **Overland Refuge Areas.** These are locations that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

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

Table 7-3 outlines the response required for different flood emergency response planning classifications. Due to the size of the high trapped perimeter area and the relatively short duration flooding, resupply is unlikely to be required.

Table 7-3 Emergency Response Requirements

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

8 Current Development Zoning and Controls

8.1 Local Environmental Planning Instruments

At the time of writing, the New South Wales Planning Reforms required all local governments to prepare their planning instruments in accordance with a standard instrument LEP. The key features of these reforms were:

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

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

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

Flood planning is included Clause 7.9 of the LEP and generally outlines the objectives, areas of application and controls for floodplain management in the LGA. Clause 7.9 applies to areas within the Flood Planning Area Map, which does not include mapping of the Burradoo BU2 catchment. All land uses of the LEP are subject to the provisions of flood control if the land parcel, or a portion of it, is located within the floodplain. The following land use zones are specified in the catchment:

- R2 – Low Density Residential;
- R5 – Large Lot Residential;
- RE1 – Public Recreation;
- SP2 – Infrastructure; and
- E3 – Environmental Management.

The majority of the floodplain is within the ‘R5’ (large lot residential) land use zoning with some small pockets of ‘R2’ (low density residential) zoning. Areas of the floodplain designated for floodplain control, such as retarding basins, are only permissible in land zoned ‘RE1’. Flood modification works are permitted in rural land use zones, however these are not located in the Burradoo BU2 catchment.

The LEP states the historic character of the Burradoo area is to be retained and as such it is not expected that the density or type of development would change in future. Therefore future rural-residential development would be permissible having large lots and modest houses, which would not increase the demands on services and infrastructure or hinder the scenic aspects of the area. The specific objectives of the R5 zone listed in the LEP are:

- To provide residential housing in a rural setting while preserving, and minimising impacts on, environmentally sensitive locations and scenic quality.
- To ensure that large residential allotments do not hinder the proper and orderly development of urban areas in the future.
- To ensure that development in the area does not unreasonably increase the demand for public services or public facilities.
- To minimise conflict between land uses within the zone and land uses within adjoining zones.
- To provide a restricted range of opportunities for employment development and community facilities and services that do not unreasonably or significantly detract from:
    a) the primary residential function, character and amenity of the neighbourhood, and

b) the quality of the natural and built environments.

8.2 Bowral Town Plan Development Control Plan

The Bowral Town Plan Development Control Plan (DCP) provides specific guidance and controls for urban development. The area where the DCP applies includes the Burradoo BU2 catchment. It includes several sections relating to various characteristics of land development with Section 4 of Part A relating to flood liable land. The objective of Section 4 is to ensure existing and future development is aligned with the principles for floodplain risk management outlined in the NSW Government Floodplain Development Manual (2005).

The DCP objectives in relation to the management of flood prone land are:

- Increase public awareness of the hazard and extent of land affected by all potential floods, including floods greater than the 1% Annual Exceedance Probability (AEP) [ie 100 year Average Recurrence Interval (ARI)] flood and to ensure essential services and land uses are planned in recognition of all potential floods;
- Inform the community of Council's policy for the use and development of flood prone land;
- Manage the risk to human life and damage to property caused by flooding through controlling development on land affected by potential floods; and
- Provide detailed controls for the assessment of applications lodged in accordance with the Environmental Planning and Assessment Act 1979 on land affected by potential floods.

The development of this Study for the Burradoo BU2 catchment is required to take into consideration the objectives of DCP by mapping the flood planning precincts referenced in Section A4.3.2 (summarised below). Development proposals that meet the prescriptive controls schedule on DCP pages 35 and 36 will be considered to have met the requirements of the DCP.

8.2.1 High Flood Risk Precinct

This Precinct comprises land below the 1% AEP flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated or development would significantly and adversely affect flood behaviour. Most development should be restricted in this Precinct. There would be a significant risk of flood damages without compliance with flood-related building and planning controls.

8.2.2 Medium Flood Risk Precinct

This Precinct contains land below the 1% AEP flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this Precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

8.2.3 Fringe-Low Flood Risk Precinct

This Precinct contains land between the extents of the 1% AEP flood and the 1% AEP flood plus 0.5m in elevation (being a freeboard). In this Precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

8.2.4 Low Flood Risk Precinct

This Precinct contains land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

These Precincts are mapped for the modelled extent of Burradoo BU2 catchment in **Figure 8-2** and with respect to land use zoning in **Figure 8-3**. A majority of the floodplain is located in land zoned for residential uses. A small proportion of the floodplain classified as 'High Flood Risk Precinct' whereby residential development is not suitable. Therefore a range of development is permissible within the floodplain subject to the requirements of the flood prone land section of the DCP.

General requirements for flood prone land as listed in Section 4 of the DCP are summarised in **Table 8-1** with a comment relating to the Burradoo BU2 catchment.

Table 8-1 Review of Requirements Relating to General Controls

Control	Comments
Floor Level: • Habitable floor levels to be the 1% AEP [100 year ARI] plus 500mm freeboard. • Non-habitable floor levels to be the 1% AEP [100 year ARI] plus freeboard, where possible, or the 20% AEP [~5 year ARI] plus freeboard unless justified by specific assessment	• This control is recommended. • Freeboard = 500mm.
Building Components and Method: • All structures to have flood compatible components below the 1% AEP [100 year ARI] plus freeboard (500mm).	• This control is recommended.
Structural Soundness • The structure of the building should withstand the forces of floodwater up to and including the PMF	• This control is recommended.
Flood Effects: • The flood impact of the development should not adversely affect flood behaviour elsewhere having regard to loss of storage, changes in flood levels and velocity and cumulative impact of multiple developments in the vicinity.	• This control is recommended.
Carparking and Driveway Access: • Open space car parking is to be as high as practical and not below the 5 year ARI plus freeboard or the level of the crest of the road at the site access. • Driveways lower than 0.3m below the 1% AEP [100 year ARI] shall not exceed the flood depth at the road or the depth at the car space (see schedule 3). A lesser standard may be accepted for detached dwellings where risk to human life would not be compromised. • Restraints or vehicle barriers to be provided to prevent floating vehicles from a site during 100 year ARI flood.	• This control is recommended. • However Schedule 3 was not found in the DCP. • This control may be difficult to achieve and it is recommended that the driveway be located in an area where flood depths and velocity would not be sufficient to cause float
Evacuation: • Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level, or a minimum of 20% of the gross floor area of the dwelling above the PMF.	• This control is recommended, however the 20% of gross floor area requirement may be onerous for large dwellings. It may be more appropriate to specify a certain m^2 per occupant.
Management and Design: • If this application involved sub-division, Applicant to demonstrate that potential development as a consequence of the subdivision can be undertaken in accordance with this DCP	• Subdivision is not expected to be permissible considering the R5 zoning for most of the floodplain.

8.3 Review of the Flood Planning Level

The NSW Government Department of Planning and Department of Natural Resources advises Councils to adopt the 100 year flood (1% AEP) as the Flood Planning Level (FPL) for residential development (NSW DoP, 2007). The Floodplain Development Manual (2005) recommends an FPL of the 100 year ARI flood plus freeboard (generally 0.5m) for typical residential development. Properties within the Burradoo BU2 catchment comprise residential sites.

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

8.3.1 Likelihood of Flooding

As a guide, **Table 8-2** has been reproduced from the NSW Floodplain Development Manual (2005) to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life. Analysis of the data presented in **Table 8-2** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 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 8-2 Probability of Experiencing a Given Size Flood in an Average Lifetime (70 Years)

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

8.3.2 Current FPL

Based on the Bowral DCP, Council currently utilises the 1% AEP flood level plus a freeboard of 0.5m to define the Flood Planning Level for residential land use.

8.3.3 Incremental Height Difference between Events

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

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

Table 8-3 indicates a larger difference in the flood level of the PMF event compared to other events. The adoption of the 1% AEP event as the flood planning level is only marginally different from that of the 2% AEP (on average 0.05m higher). Therefore, the adoption of the 1% AEP event would provide an increased level of risk reduction over the 2% AEP event, without a significant difference in the flood planning level height.

Table 8-3 Relative Differences Between Design Flood Levels

Event	Diff to PMF (m)		Diff to 1% AEP (m)		Diff to 2% AEP (m)	
	Avg	SD	Avg	SD	Avg	SD
1% AEP	0.74	0.66	-	-	-	-
2% AEP	0.79	0.68	0.05	0.06	-	-
5% AEP	0.85	0.71	0.11	0.12	0.06	0.07

The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 1% AEP event (in the order of 0.74 metres) and may therefore potentially present an issue for the setting of flood planning levels in the catchment because the PMF represents an extreme event that may never occur.

Nevertheless, some properties may be protected in the PMF event even if the FPL is based on the 1% AEP level (with an appropriate freeboard). This is because the average difference between the PMF level and the 1% AEP level across the catchment is about 0.74m, with a maximum difference of about 1.4m. Therefore, adoption of the typical 0.3m – 0.5m freeboard on the 1% AEP level would result in the protection of some properties in the PMF event.

8.3.4 Consequence of Adopting the PMF as a Flood Planning Level

The difference in average flood levels between the 1% AEP and the PMF event (**Table 8-3**) indicate that the use of the PMF as the FPL would result in higher levels (0.74 metres on average), and as a result higher economic costs and inconvenience to the community. The use of the PMF level as the FPL may conflict with other development / building controls in the Councils DCP.

Given the risk of exposure outlined in **Table 8-3**, it is recommended that emergency response facilities be located outside of the floodplain and any other future planning ensure critical facilities be limited to areas outside of the floodplain. Modifications to any existing critical facilities within the floodplain are suggested to have a floor level at the PMF level.

8.3.5 Freeboard Selection

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

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

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

- Afflux (local increase in flood levels due to small local obstructions not accounted for in the modelling) (0.1m) (Gillespie, 2005);
- Local wave action (trucks and other vehicles) (allowances of ~0.1m are typical);
- Accuracy of ground / aerial survey (+/- 0.15m);

- Climate change impacts on rainfall intensity;
- Sensitivity of the model to roughness and culvert blockage = +/- 0.05m.

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

When applied to design events less than the PMF, the freeboard may still result in the FPL being higher than the PMF in certain cases. Council may wish to limit the FPL to the PMF in these cases.

8.3.6 Flood Planning Level Recommendations

The Flood Planning Level (FPL) for Burradoo is recommended to be the 1% AEP plus 500mm freeboard. A 500mm freeboard is standard practice in NSW. Mapping of the FPL is included in **Figure 8-4**.

The difference between the extent of the 1% AEP and the FPL does not sterilise land. That is, the difference between the two is accommodated within single lots for the most part and accommodation of the freeboard would be practical for residential properties built on flood prone land. The extent of the FPL also represents the outer edge of the Fringe-Low Flood Risk precinct and the DCP Prescriptive Controls for residential land uses are identical to the Medium Flood Risk precinct. Therefore the amount of freeboard has little bearing on the level of prescriptive controls for Burradoo BU2 catchment. It is noted that the extent of the PMF is generally greater than the extent of the FPL, indicating that the adopted freeboard does not extend beyond the extent of an extreme flood event that may occur rarely.

9 Floodplain Risk Management Options

9.1 Overview of Available Measures

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

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

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

Table 9-1 Flood Risk Management Alternatives

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

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

- Flood Modification Measures (to reduce existing and future risk);
- Property Modification Measures (to reduce existing and future risk); and
- Emergency Response Modification Measures (to reduce existing risk, minimise future risk and limit continuing risk).

9.2 Flood Modification Measures

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

Table 9-2 Summary of Flood Modification Measures

Measure	Description
FM1	Construct detention basin at either Osborne Road or Charlotte Street
FM2	Formalise informal detention basin upstream of Moss Vale Road
FM3	Augment railway culvert
FM4	Upgrade the open channel between Burradoo Road and Railway
FM5	Upgrade pipe capacity of channel crossings between Moss Vale Road and Burradoo Road
FM6	Construction of low-flow concrete lined base channel with vegetation clearing and maintenance of open waterway area between Holly Road and Burradoo Road
FM7	Upgrade the open channel by lowering the invert by 1.5m between Holly Road and Burradoo Road
FM8	Construction a flood protection wall/berm for two properties modelled as inundated by over-floor flooding

9.2.1 FM1 – Detention Basin at Osborne Road / Charlotte Street

This flood modification measure comprises a detention basin constructed at Osborne Rd or Charlotte St to the east of Moss Vale Road. A basin at this location would aim to reduce peak flows conveyed to the Pony Club detention basin. These locations are upstream of the hydraulic model extent.

Peak flow rates from the XP-RAFTS model were assessed to determine the potential effectiveness of this measure. In a 1% AEP 90 minute critical duration event, peak flowrates from Charlotte Street and Osborne Road are 3.0 m^3/s and 9.1 m^3/s respectively. The Pony Club Detention Basin limits flow downstream to 2.5 m^3/s which is small compared to the flow downstream of the Informal Detention Basin of 19.7 m^3/s.

Therefore FM1 is not considered viable for significant management of flood inundation for this Study.

9.2.2 FM2 – Formalise Informal Detention Basin

The informal detention basin acts to detain flow due to the restricted culvert capacity under Moss Vale Road. FM2 considers formalising this basin by constructing an earthen embankment to create additional storage in the vegetated area. An elevated basin embankment to RL 672m AHD results in an additional storage of about 6300 m^3 (which is approximately a 24% increase). **Figure 9-2** shows the location of FM2. The presence of a significant vegetation community, as described in **Section 4.2.4.1**, may affect the implementation of this measure due to potential construction and inundation considerations.

Figures 9-3 to 9-5 show the changes in peak water levels modelled for FM2 compared to existing for the 20% AEP, 1% AEP and PMF events respectively.

No changes to peak water levels occur for a 20% AEP event indicating that the existing basin outflow is not affected by the formalised basin. For a 1% AEP event, an increase in basin storage (by approximately 0.3m in water depth) results in a decrease of about 0.05m-0.15m along flowpath downstream of the Pony Club Detention Basin and increase of up to 0.03m downstream of the Informal Detention Basin. FM2 results in an increase in peak flood levels of about 0.7m and 0.08m at the Informal and Pony Club detention basins respectively in a PMF event. Downstream of Moss Vale Road peak water levels reduce by up to 0.1m in the PMF event.

9.2.3 FM3 – Augment Railway Culvert

The existing culvert under the railway is an opening 6.07m wide by 2.54m high. FM3 comprises expansion of the opening to twice the current width to assess potential benefits upstream by removing this potential flow constriction. **Figure 9-6** shows the location of this measure.

Figures 9-7 to 9-9 show the changes in peak water levels modelled for FM3 compared to existing for the 20% AEP, 1% AEP and PMF events respectively.

FM3 results in a minor reduction in flood impact for a 20% AEP event. This indicates that the existing railway culvert has sufficient capacity for a 20% AEP event. However, FM3 results in a decrease in water levels in the corner of Burradoo Road and the railway line by approximate 0.4m and 0.2m for 1% AEP and PMF event respectively.

The peak water depths of FM3 for 1% AEP event are shown in **Figure 9-10**. Though FM3 significantly decreases water levels in the corner of Burradoo Road and the railway line, this measure does not completely eliminate a flood risk in this area since the peak water depths still reach approximately 0.7m.

9.2.4 FM4 – Open Channel Between Burradoo Road and Railway

FM4 comprises formalising the open channel between Burradoo Road and the Railway Line. The location of this open channel is presented in **Figure 9-11**. This channel is approximately 130m long, 12m wide, and 1.5m deep. The changes of water levels of FM4 for 20% AEP, 1% AEP and PMF events are shown in **Figures 9-12 to 9-14** respectively.

FM4 results in reductions to the peak water levels around Burradoo Road and upstream of the railway line. Water levels are decreased by up to 0.35m, 0.50m and 0.25m in vicinity of the open channel for the 20% AEP, 1% AEP and PMF respectively. In a 1% AEP event, a minor increase of up to 0.02m occurs downstream of the railway line, however this changes to a 0.4m increase in a PMF event.

The peak water depths of FM4 in a 1% AEP event are shown in **Figure 9-15**. The results indicate that the peak depths reach up to 0.6m, indicating that FM4 does not remove the flood risk in vicinity for a 1% AEP event.

9.2.5 FM5 – Upgrade Capacity of Channel Crossings

From Moss Vale Road to Burradoo Road there are numerous driveway crossings of the main channel. Generally, these comprise several pipes to convey flow through otherwise solid embankments. FM5 upgrades the conveyance capacity, at least double existing, at several locations as shown in **Figure 9-16**. The modelled culvert arrangements are listed in **Table 9-3**, however these are representative of the capacity only and alternative configurations could be used.

Table 9-3 Culverts Upgraded in FM5

Location	Dimensions (m)	Number of Existing Culverts	Number of FM5 Culverts
Site1	0.75	1	3
Site2	0.6	4	8
Site3	0.75	3	6
Site4	0.6	5	10
Site5	0.6	4	8

Changes in peak water level levels of FM5 for the 20% AEP, 1% AEP and PMF events are shown in **Figures 9-17 to 9-19** respectively.

FM5 results in a localised decrease of up to 0.07m in peak water levels for the modelled 20% AEP and 1% AEP events. Thus, improvements to culvert capacity near these locations may be beneficial. Peak flood levels in a PMF event are unchanged by FM5 as flow conveyed in the watercourse is well in excess of the culvert capacity.

9.2.6 FM6 – Formalise Channel Between Moss Vale Road and Burradoo Road

FM6 comprises improving the conveyance along the existing watercourse from Moss Vale Road to Burradoo Road. Clearing of vegetation to create an open waterway area and a concrete-lined low flow base are the main items of this option. **Figure 9-20** shows the location and photographs of the watercourse. The assessment of significant flora in the catchment (**Section 4.2.4.1**) shows that the proposed works are not located within the endangered vegetation community.

The proposed measure has been modelled by reducing the roughness value along the open channel to 0.02 from the previous value of 0.045. **Figures 9-21 to 9-23** show the changes to peak water levels in a 20% AEP, 1% AEP and PMF event respectively.

Decreases in peak water levels of up to 0.05m are modelled along the channel from Ranelagh Road for the 20% AEP and 1% AEP events. In a PMF event some increases occur (up to 0.27m) due to the constriction of flow at some locations.

9.2.7 FM7 – Augment Channel Between Moss Vale Road and Burradoo Road

FM7 is similar to FM6, but increases the capacity of the open channel between Holly Road and Burradoo Road by excavating an additional 1.5m below the existing invert. The augmented channel has a length of 830m and width of about 10m.

A roughness value of 0.02 along this channel has been adopted in the flood model. **Figures 9-24 to 9-26** show the changes in peak water levels of FM7 for the 20% AEP, 1% AEP and PMF events respectively.

The additional channel capacity of FM7 compared to FM6 shows decreases of up to 0.3m to just downstream of Ranelagh Road in the 20% AEP, 1% AEP, and PMF events. This additional flowrate results in an increase of up to 0.04m upstream of Burradoo Road to the railway line in the 20% AEP and 1% AEP events.

Figure 9-27 shows FM7 reduces the extent of flood inundation in a 1% AEP event adjacent to properties along the open channel from Moss Road to approximately 150m downstream of Ranelagh Road for 1% AEP.

9.2.8 FM8 – Levee to Protect Properties from Flooding

FM8 comprises embankments constructed to exclude the over-floor flooding risk in a 1% AEP event for two properties affected in existing conditions. These levees may take the form of an earthen berm to divert flood runoff with locations shown in **Figure 9-28**. The elevation of the levees was assumed to be 0.5m higher than the water level of 1% AEP event. Thus, Levee1 has a length of 38m and an elevation of 665.8m AHD with Levee2 having a length of 69m and an elevation of 667.8m AHD.

Figures 9-29 to 9-31 show the changes in peak water levels of FM8 for the 20% AEP, 1% AEP and PMF events respectively. Modelling shows that FM8 results in some localised changes to peak water levels in the vicinity of the Levees. The peak water depths of 1% AEP event mapped in **Figure 9-32** show the two properties are excluded from inundation.

9.3 Property Modification Measures

A number of property modification measures were identified for consideration in the Burradoo BU2 floodplain. These are:

- LEP Update (P1)
- Building and Development Controls (P2)
- House Raising (P3)
- House Rebuilding (P4)
- Flood Proofing (P5)

These measures are discussed in detail below.

9.3.1 P1 – LEP Update

Update of the Wingecarribee LEP would involve changing of the land zoning to accommodate floodplain management options that require the development of land.

Flood planning is included as Clause 7.9 of the LEP and generally outlines the objectives, areas of application and controls for floodplain management in the LGA. Clause 7.9 applies to areas within the Flood Planning Area Map, which does not include mapping of the Burradoo BU2 catchment. This map should be updated to include Burradoo BU2.

All land uses of the LEP are subject to the provisions of flood control if the land parcel, or a portion of it, is located within the floodplain. The following land use zones are specified in the catchment:

- R2 – Low Density Residential;
- R5 – Large Lot Residential;
- RE1 – Public Recreation;
- SP2 – Infrastructure; and
- E3 – Environmental Management.

The majority of the floodplain is within the 'R5' (large lot residential) land use zoning with some small pockets of 'R2' (low density residential) zoning. Areas of the floodplain designated for floodplain control, such as retarding basins, are only permissible in land zoned 'RE1'. Flood modification works are permitted in rural land use zones, however these are not located in the Burradoo BU2 catchment.

Structural flood modification measures that require the development of land in order to reduce flood risk in the Burradoo catchment are FM1, FM2, FM4, FM6 and FM7. The zoning for the majority of the land where these structural measures are proposed is R5 and should be changed to RE1 in order for the flood management options to be permissible development. Alternatively, consideration could be given to permitting works for flood modification on any flood prone land in lieu of spot rezoning.

9.3.2 P2 – Building and Development Controls

Building and Development Controls should be included into a planning instrument, such as a DCP, for the Burradoo BU2 catchment. This would allow for the findings of the Floodplain Risk Management Study to be applied through improvements to existing development and consideration of flood planning controls for future development. Standard methods for administering the planning controls are with the use of a Flood Risk Precinct Map and associated Floodplain Development Matrix. This method was adopted for the Bowral DCP and it is recommended that a similar approach be extended to cover the Burradoo BU2 catchment. The Flood Risk Precinct map is shown in **Figure 8-3** and a review of the Bowral DCP, with recommended changes for the study area, is included in **Section 8.2**. It is suggested that Council shall either update the Bowral DCP to cover the Burradoo catchment or to prepare an independent DCP for Burradoo.

9.3.3 P3 – House Raising

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

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

- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area.

Section 6 describes the approximate Average Annual Damage (excluding overground only damage) for over-floor flooding commencing in different AEP events for individual residential properties. **Table 9-4** list the number of properties with over-floor flooding and Average Annual Damage per property, which was based on the damage calculations undertaken in **Section 6**.

Table 9-5 shows the reduction in AAD from different house raising scenarios.

Table 9-4 Estimate of AAD and NPV for Different Over-Flood Flood Scenarios

Event in which over-floor flooding commences	Number of properties with over-floor flooding*	AAD per Property	NPV (30 Years) per Property
20% AEP	1	$12,000	$149,000
5% AEP	1	$3,200	$40,000
2% AEP	1	$1,300	$16,000
1% AEP	2	$600	$8,000
PMF	23	$0	$0

Table 9-5 Reduction in AAD Resulting from Different House Raising Scenarios*

Option (change of AEP)	Number of properties	AAD Reduction (per property)	Overall Reduction in AAD	NPV (30 Years) of Reduction	Estimate Cost of Raising
20% to 5% AEP	1	$8,800	$8,800	$109,000	$80,000
5% to 2% AEP	1	$1,900	$1,900	$24,000	$80,000
2% to 1% AEP	1	$700	$700	$9,000	$80,000
1% AEP to PMF	21	$600	$12,600	$156,000	$1,680,000

Due to the limited number of properties with over-floor flooding in the more frequent events, Voluntary House Raising was identified as potentially appropriate at one property. However, the particular property is constructed as slab-on-ground therefore is not suitable for house raising.

9.3.4 P4 – House Rebuilding

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

The one property identified for voluntary house raising may also be suitable for House Rebuilding instead. Note that a number of other options may also be suitable, such as a levee or landscaping.

9.3.5 P5 – Flood Proofing

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

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

Examples of proofing measures include:

- All structural elements below the flood planning level shall be constructed from flood compatible materials;

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

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building. These measures are generally best applied to commercial properties which are not present in the Burradoo BU2 Catchment.

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

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

The SES Business Flash Flood Tool Kit (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures. It is noted that no businesses (commercial properties) are located in the catchment.

9.4 Emergency Response Modification Measures

A number of emergency response modification measures were considered within the Burradoo BU2 Catchment. These include:

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

These measures are discussed in detail below.

9.4.1 EM 1 – Information transfer to SES

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

9.4.2 EM 2 – Update of the Local Flood Plan

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

With respect to the Burradoo BU2 floodplain, the following amendments to the Flood Plan are recommended:

- Include a section in Annex B describing the effects of flooding in the Burradoo BU2 floodplain;
- The Burradoo railway station is potentially flood affected should be considered for inclusion in Annex F;
- The following key access roads should be included in Annex G (further details of accessing road flooding is provided below in **Section 7.4.1**):
    - Burradoo Road (western end);
    - Holly Road (between Ranelagh Road and Moss Vale Road); and
    - Moss Vale Road (between Osborne Road and Burradoo Road).

- Identify that any potential evacuation may require additional resources due to the proportion of aged residents in the catchment.

9.4.3 EM 3 – Flood Warning System

The short critical duration and response times for the Burradoo BU2 floodplain limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas.

9.4.4 EM 4 – Public Awareness and Education

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

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

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

It is recommended that the following awareness campaigns be considered for the floodplain. These should be prepared together with the SES, as they have a responsibility for community awareness under the DISPLAN. The demographics of Burradoo (described in **Section 4.1**) indicate a high proportion of English speakers suggesting a language focus for communication strategies. A more generic awareness campaign may be undertaken across the LGA as the Burradoo BU2 catchment is relatively small.

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

9.4.5 EM 5 – Flood Warning Signs at Critical Locations

Some public places in the catchment experience high hazard flooding in the 1% AEP event. It is therefore important that appropriate flood warning signs are posted at these locations. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths.

It is recommended that flood warning signs be installed nearby to Burradoo Railway Station and that depth gauges be installed at Burradoo Road (western end), which is subject to inundation in frequent events. Flood markers could also be installed at Moss Vale Road near Holly Road which is subject to inundation in storm events greater than 1% AEP.

9.5 Property Acquisition

Acquisition of flood affected properties is a last-resort option to remove genuine risk to life which cannot be mitigated by other means. Property acquisition is not a suitable or viable option in the Burradoo BU2 Catchment. There is no NSW Government subsidy for the purchase and redevelopment of floodprone land. Typical approaches for acquisition are discussed below.

9.5.1 Voluntary Purchase

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

However, this option should be considered after other, more practical options have been investigated and exhausted. It should be considered as a last resort when the continuing risk is unsustainable, particularly where there is a risk to life.

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

- Located in the high hazard zone for the 1% AEP flood event;
- Occurrence of above floor flooding in the 20% AEP flood event;
- Economic value of damages for a particular property is comparable to the property market value; and
- All other options have been exhausted.

There are no properties in the study area that meet these criteria. As such, voluntary purchase is not considered a viable option for the Burradoo BU2 floodplain.

9.5.2 Land Swap

An alternative to pure voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land in a non-flood prone area, such as an existing park, for the flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land rezoned to open space. This option should be considered as a last resort when the continuing risk is unsustainable, particularly where there is a risk to life.

No properties were identified for voluntary purchase and as such no properties fulfil the criteria for land swap either.

9.5.3 Council Redevelopment

In this option, Council would purchase the worst affected properties and redevelop these properties in a flood compatible manner. The properties would then be sold with a break-even objective.

No properties were identified for voluntary purchase and as such no properties fulfil the criteria for council redevelopment either.

10 Economic Assessment of Flood Modification Measures

10.1 Damage Estimation for Flood Modification Measures

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

The damage costs for each of the flood modification measures were estimated based on the peak flood levels for 1% AEP, 2% AEP, 5% AEP and 20% AEP events as detailed in **Section 6**. It is noted that the damage costs for the PMF event were based on the 60 minute duration storm.

Table 10-1 The Results of Damage Assessment for Flood Modification Measures

Scenario	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)	Reduction of Damage ($November 2012)
PMF						
Existing	21	0.36	1.91	37	$1,674,000	
FM2	22	0.35	1.87	37	$1,732,000	-$58,000
FM3	21	0.32	1.73	37	$1,649,000	$25,000
FM4	21	0.35	1.82	37	$1,665,000	$9,000
FM5	21	0.34	1.91	37	$1,659,000	$15,000
FM6	21	0.34	1.91	37	$1,659,000	$15,000
FM7	20	0.36	1.91	37	$1,614,000	$60,000
FM8	21	0.34	1.91	37	$1,659,000	$15,000
1% AEP						
Existing	2	0.08	0.12	16	$339,000	
FM2	1	0.13	0.13	15	$296,000	$43,000
FM3	2	0.09	0.13	16	$339,000	$0
FM4	2	0.09	0.13	16	$339,000	$0
FM5	2	0.07	0.13	16	$307,000	$32,000
FM6	2	0.08	0.13	16	$339,000	$0
FM7	1	0.13	0.13	14	$275,000	$64,000
FM8	0	-	-	15	$243,000	$96,000
2% AEP						
Existing	1	0.10	0.1	16	$273,000	
FM2	1	0.09	0.09	15	$261,000	$12,000
FM3	1	0.09	0.09	16	$272,000	$1,000
FM4	1	0.09	0.09	16	$272,000	$1,000
FM5	1	0.09	0.09	15	$261,000	$12,000
FM6	1	0.09	0.09	16	$272,000	$1,000
FM7	1	0.09	0.09	13	$230,000	$43,000
FM8	0	-	-	15	$209,000	$64,000

Scenario	Number of Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Number of Properties with overground flooding	Total Damage ($November 2012)	Reduction of Damage ($November 2012)
5% AEP						
Existing	1	0.08	0.08	15	$261,000	
FM2	1	0.08	0.08	15	$243,000	$18,000
FM3	1	0.08	0.08	15	$261,000	$0
FM4	1	0.08	0.08	15	$261,000	$0
FM5	1	0.08	0.08	15	$243,000	$18,000
FM6	1	0.08	0.08	15	$261,000	$0
FM7	1	0.08	0.08	13	$195,000	$66,000
FM8	0	-	-	13	$170,000	$91,000
20% AEP						
Existing	1	0.03	0.03	13	$184,000	
FM2	1	0.03	0.03	13	$184,000	$0
FM3	1	0.03	0.03	13	$184,000	$0
FM4	1	0.03	0.03	13	$184,000	$0
FM5	1	0.03	0.03	13	$184,000	$0
FM6	1	0.03	0.03	13	$184,000	$0
FM7	1	0.03	0.03	12	$173,000	$11,000
FM8	0	-	-	11	$112,000	$72,000

10.1.1 Results of FM2

FM2 results in a decrease in flood levels in a range 0.01-0.1m for five properties in a 1% AEP event, but over-floor flooding only occurs for one property. In a PMF event, FM2 results in an additional property exposed to a flooding risk since FM2 increases flood level by 0.69m (and thus damage costs) at this property due to the raised basin embankment.

10.1.2 Results of FM3, FM4, FM5 and FM6

FM3, FM4 and FM6 do not show a significant reduction to damage costs. FM5 results in a decrease to damage costs by approximately $32,000 in a 1% AEP event. A slight decrease in damage costs occurs in a PMF event for FM3 to FM6 is noted.

10.1.3 Results of FM7

Over-floor flooding only occurs at one property in FM7. The results indicate that FM7 is capable of eliminating the flood risk in a 20% AEP event at three properties in Holly Road. As a result, it decreases damage costs in a 20% AEP event by approximately $10,000. This measure also eliminates a flooding risk in a 1% AEP event at the three Holly Road properties resulting in a decrease of damage costs by approximately $64,000.

10.1.4 Results of FM8

FM8 is capable of protecting two properties from a potential over-floor flooding risk. The results indicate that no property within the study area has an over-floor flooding in a 1% AEP event. It results in a decrease of AAD by approximately 34%.

10.2 Cost Estimate of Flood Modification Measures

A preliminary cost estimate of the potential flood modification measures has been prepared to assist with the comparative assessment. The costs were prepared with reference to the Australian Construction Handbook (Rawlinsons, 2012).

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

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

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

Table 10-2 Costs of Quantitatively Assessed Measures

Measure	Capital Cost Estimate	Recurrent Cost Estimate	Measure Description
FM2	$885,000	$12,000	Formalise informal detention basin
FM3	$3,958,000	$5,000	Enlarge culvert under railway
FM4	$740,000	$1,000	Augment channel capacity from Burradoo Road to Railway
FM5	$389,000	$4,000	Upgrade pipe capacity of channel crossings.
FM6	$959,000	$4,500	Clear and formalise existing watercourse from Moss Vale Road to Burradoo Road.
FM7	$3,213,000	$4,500	Enlarge existing watercourse from Moss Vale Road to Burradoo Road.
FM8	$100,000	$300	Construct two levees to protect two properties from over-floor flooding

An example of recurrent cost is inspections and clearing of debris on an annual basis.

10.3 Average Annual Damage for Quantitatively Assessed Measures

The total damage costs for each modelled measure and an average annual damage (AAD) estimated as described in **Section 6**. **Table 10-3** lists the AAD for each measure and a comparison to the existing AAD of $59,000.

Table 10-3 Average Annual Damage for Quantitatively Assessed Measures

Option ID	Measure Description	AAD	Reduction in AAD due to Option
FM2	Formalise informal detention basin	$58,000	$1,000
FM3	Enlarge culvert under railway	$59,000	$0
FM4	Augment channel capacity from Burradoo Road to Railway	$59,000	$0
FM5	Upgrade pipe capacity of channel crossings.	$58,000	$1,000
FM6	Clear and formalise existing watercourse from Moss Vale Road to Burradoo Road.	$59,000	$0
FM7	Enlarge existing watercourse from Moss Vale Road to Burradoo Road.	$53,000	$6,000
FM8	Construct two levees to protect two properties from over-floor flooding	$39,000	$20,000

Generally, FM2 to FM7 only result in a marginal reduction in AAD, with the maximum reduction of $6,000 in AAD for FM7. FM8 results in a decrease in AAD by approximately 34%. The reduction in AAD for the flood modification measures needs to be considered with the capital and recurrent costs of the measure.

10.4 Benefit Cost Ratio of Measures

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

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled measures. Inputs for the assessment include the data reported in **Section 6** derived from a floor level and property survey along with the damage curves. The PMF, 1% AEP, 2% AEP, 5% AEP and 20% AEP events were considered for this evaluation. Preliminary costs of each measure were estimated in **Section 10.2** and a benefit-cost analysis of each measure was undertaken on a purely economic basis.

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

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

Table 10-4 Benefit-Cost Ratio of Flood Modification Measures

Measure ID	AAD	Reduction in AAD due to Measure	NPW of Benefit	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Measure	B/C Ratio	Rank
FM2	$58,000	$1,000	$12,400	$885,000	$12,000	$1,034,000	0.012	4
FM3	$59,000	$0	$0	$3,958,000	$5,000	$4,020,000	0.000	7
FM4	$59,000	$0	$0	$740,000	$1,000	$752,000	0.000	5
FM5	$58,000	$1,000	$12,400	$389,000	$4,000	$439,000	0.028	2
FM6	$59,000	$0	$0	$959,000	$4,500	$1,015,000	0.000	6
FM7	$53,000	$6,000	$74,500	$3,213,000	$4,500	$3,269,000	0.023	3
FM8	$39,000	$20,000	$248,000	$100,000	$300	$104,000	2.393	1

NPW – Net Present Worth is calculated using 7% interest over 30yrs.

The benefit-cost analysis shows that FM3, FM4 and FM6 do not have economic benefits. FM2, FM5 and FM7 have a benefit-cost ratio lower than 0.1. It suggests that these flood modification measures may not be suitable as these measures have a high cost compared with their potential economic benefit. FM8 generates a high benefit-cost ration of 2.4, indicating that FM8 can achieve a significant economic benefit.

10.5 Economic Assessment of Desktop Assessed Measures

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

11 Multi-Criteria Assessment of Measures

11.1 Overview

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

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

11.2 Scoring System

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

The criterion adopted includes:

Economic	Benefit Cost Ratio Capital and Operating Costs Reduction in Risk to Property
Social	Reduction in Social Disruption Reduction in Risk to Life Community Acceptance Council Support
Environmental	Meeting of River Flow and Water Quality Objectives Fauna/ Flora

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

Table 11-1 Details of Adopted Scoring System

Category	Category Weighting	Criteria	Criteria Weighting	Score				
				-2	-1	0	1	2
Economic	2	Benefit Cost Ratio	2	0 to 0.5	0.5 to 1	1	1 to 1.5	>1.5
		Capital and Operating Costs	1	Extreme >$2 million	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Very Low $10,000 - $50,000
		Reduction in Risk to Property*	1	Major increase in AAD	Slight increase in AAD	No Improvement	Slight decrease in AAD	Major decrease in AAD
Social	1	Reduction in Risk to Life	1	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
		Reduction in Social Disruption	1	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
		Council Attitude	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Community support	1	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
		Compatible with Policies and Plans	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Environment	1	Compatible with Water Quality and River Flow Objectives	1	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
		Fauna/Flora Impact	1	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit

*Values of likely AAD reduction assumed where actual assessment not undertaken

11.2.1 Economic Assessment Overview

The economic assessment involved an appreciation of:

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

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

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

11.2.2 Social Impact Assessment

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

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

In general, there is a reasonable level of flood awareness in the community, though may not be aware of the magnitude of potential flooding. The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption due to flooding (via the effects of property inundation, loss of access and traffic disruption) remains present. Similarly, while there is an understanding of the potential for flooding, the reduction in the risk to life is an important criterion to be taken into account. This criterion is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

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

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

11.2.3 Environmental Assessment

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

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

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

11.3 Multi-Criteria Matrix Assessment

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

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

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

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

12 Floodplain Risk Management Plan

12.1 Findings of Floodplain Risk Management Study

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

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

The plan consists of a mixture of:

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

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

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

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

12.2 Implementation Program

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

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

Steps in the floodplain management process are:

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

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

12.3 Key Stakeholders

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

- Sydney Water - particularly with regards to any impacts on their assets within the catchment.
- SES - particularly in regards to Option EM1, EM2, EM3, EM4 and EM5
- OEH - as it is likely that funding would be sourced from OEH for a number of the options, they should be consulted as a part of the design process.
- Transport NSW Trains – FM3 would require close liaison with the organisation to ensure an optimal design and minimal impact on the transport corridor.
- RMS - to be consulted regarding options that impact on any RMS roads in the study area.
- Private Residents – in particular, those residents to be affected by the proposed works.

Table 12-1 Floodplain Risk Management Options Recommended for Inclusion in the Burradoo BU2 Catchment Risk Management Plan

Option ID	Location	Description	Estimated Capital Cost	Estimated Recurring Cost	Funding Sources / Responsibility	Priority for Implementation
P2	Wingecarribee LGA	Building and Development Controls	$10,000	$1,500	Council	High
P1	Wingecarribee LGA	LEP Update	$3,000	$1,000	Council	High
EM4	Burradoo BU2 Floodplain	Public awareness and education	$10,000	$3,000	Council	High
EM3	Burradoo BU2 Floodplain	Flood Warning System	$5,000	$1,500	Council/ SES	High
EM1	Burradoo BU2 Floodplain	Information Transfer to SES	$2,500	$0	Council/ SES	High
EM2	Burradoo BU2 Floodplain	Preparation of Local Flood Plans and Update of DISPLAN	$10,000	$1,500	Council/ SES	High
EM5	Selected locations throughout the floodplain	Flood warning signs at critical locations	$5,000	$300	Council	Medium
P5	Selected locations throughout the floodplain	Flood Proofing	$50,000	$5,000	Council/ OEH	Medium
FM8	Two properties exposed to over-floor flooding in a 1% AEP	Construct levees to protect property from over-floor flooding	$100,000	$300	Council/ OEH	Medium
Estimated Cost of Implementing the Plan			**$195,500**	**$14,100**		

13 Conclusion

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

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

In order to assist Council and the relevant agencies in managing flood risk within the Burradoo BU2 Catchment, an assessment of potential floodplain risk management options has been undertaken. The outcome of the assessment identified a key role for planning related options to manage the existing flood risk. Several structural options were also identified as viable options for implementation.

The following options were ranked high in the multi-criteria assessment and are recommended for detailed assessment and / or implementation:

Non-Structural Measures-

- P2 Building and Development Controls;
- P1 LEP Update;
- EM4 Public awareness and education;
- EM3 Flood warning system;
- EM1 Information transfer to SES;
- EM2 Preparation of Local Flood Plans and update of DISPLAN;
- EM5 Flood warning signs at critical locations;
- P5 Flood proofing.

Structural Measures-

- FM8 Construct two levees to protect properties from over-floor flooding.

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

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Burradoo BU2 Catchment
Floodplain Risk Management Study
and Plan

APPENDIX A
FIGURES

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Shaping the Future

Figure 1-1 Catchment Locality

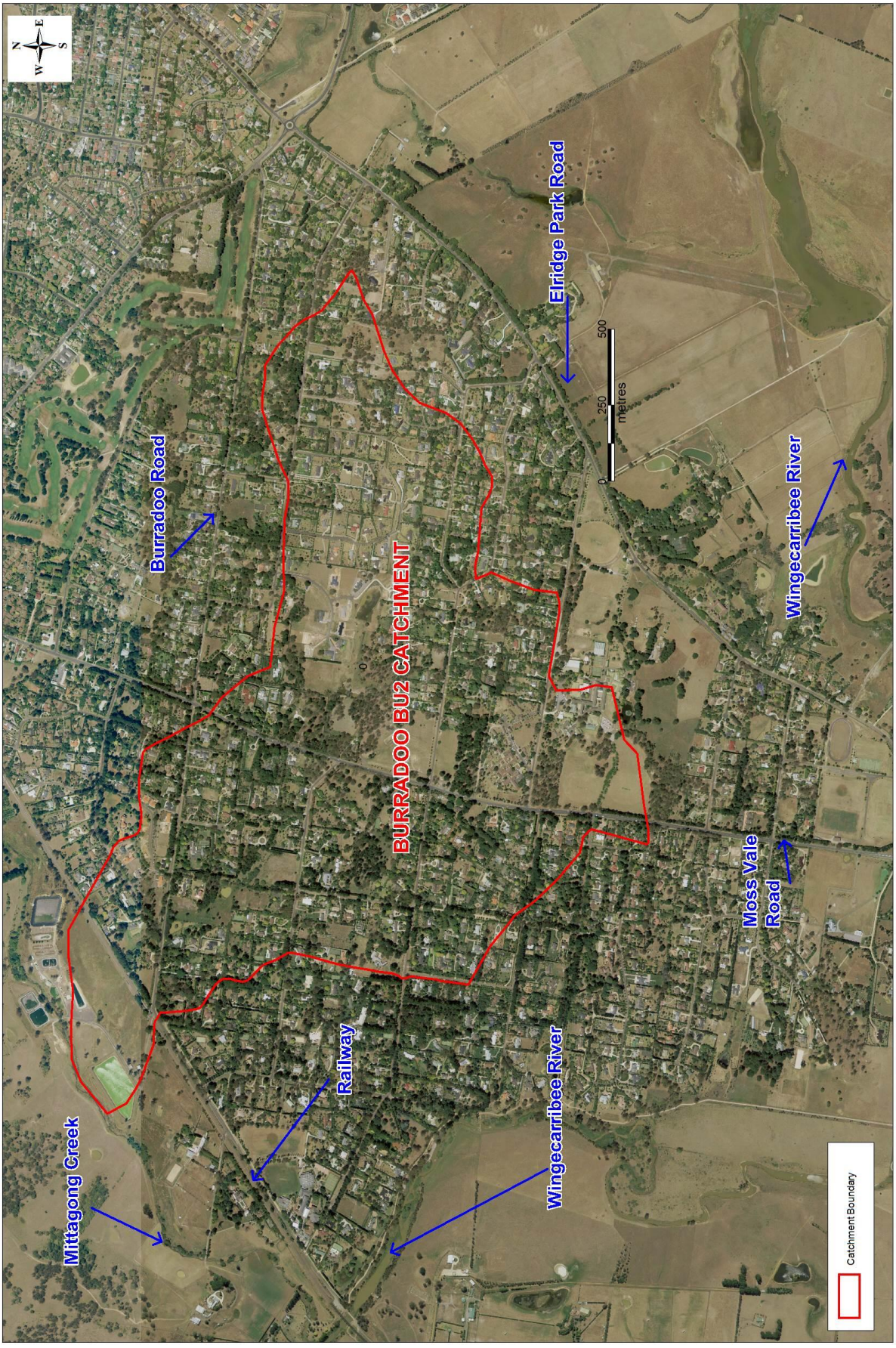


Figure 4-1 Endangered Flora Community

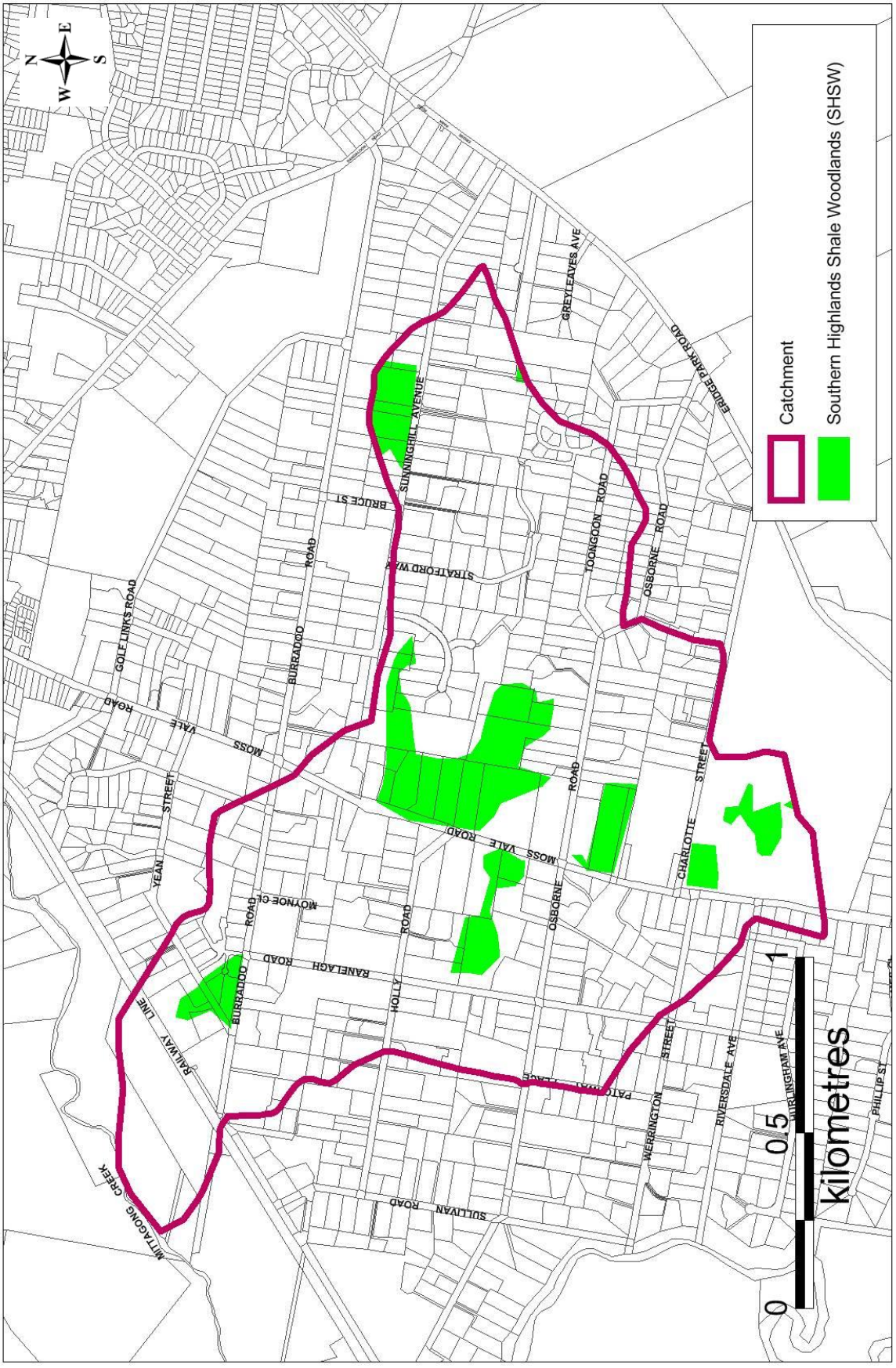


Figure 4-2 Aboriginal Heritage Sites

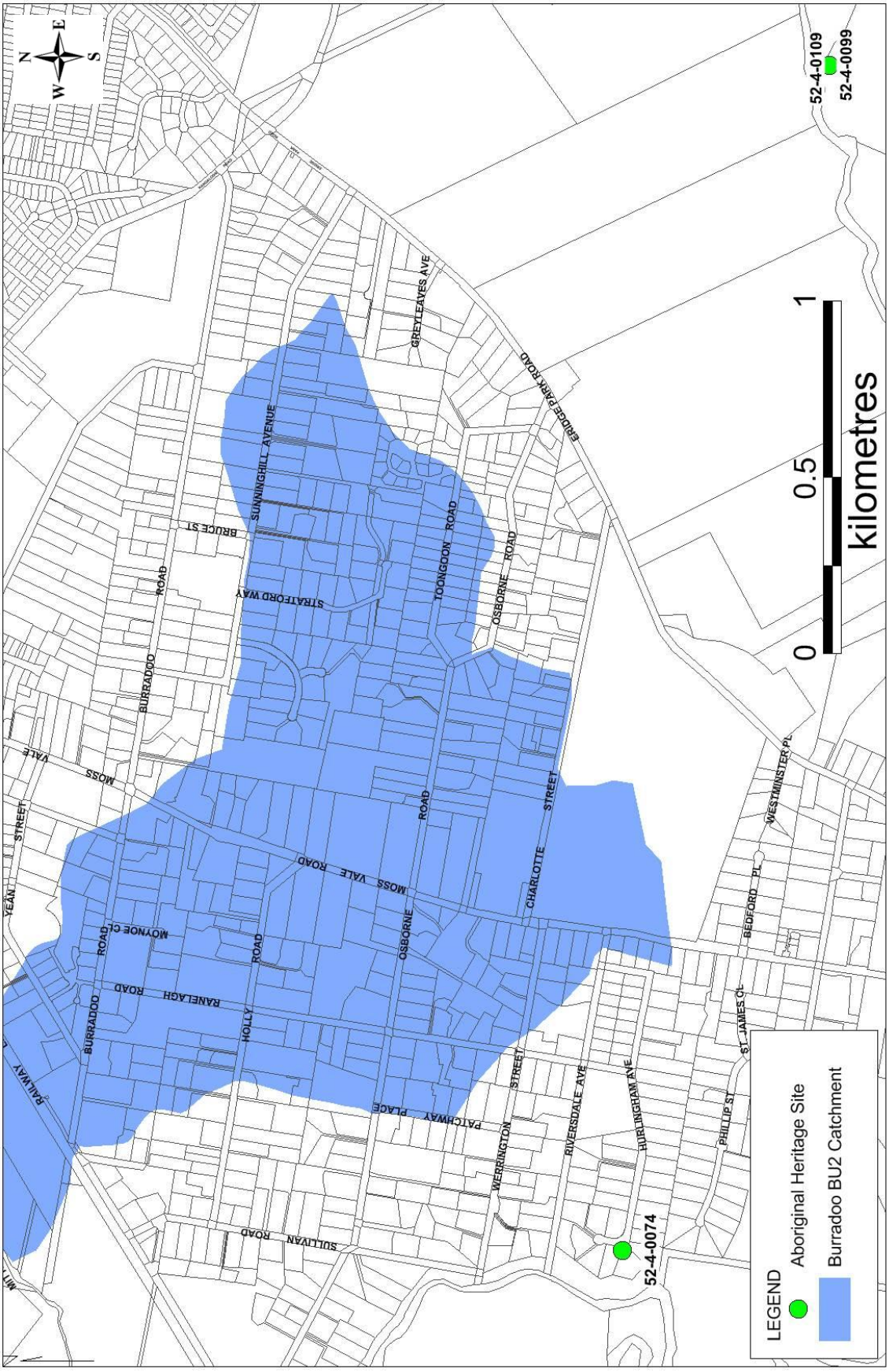


Figure 5-1 Revised RAFTS Sub Catchment Model Layout

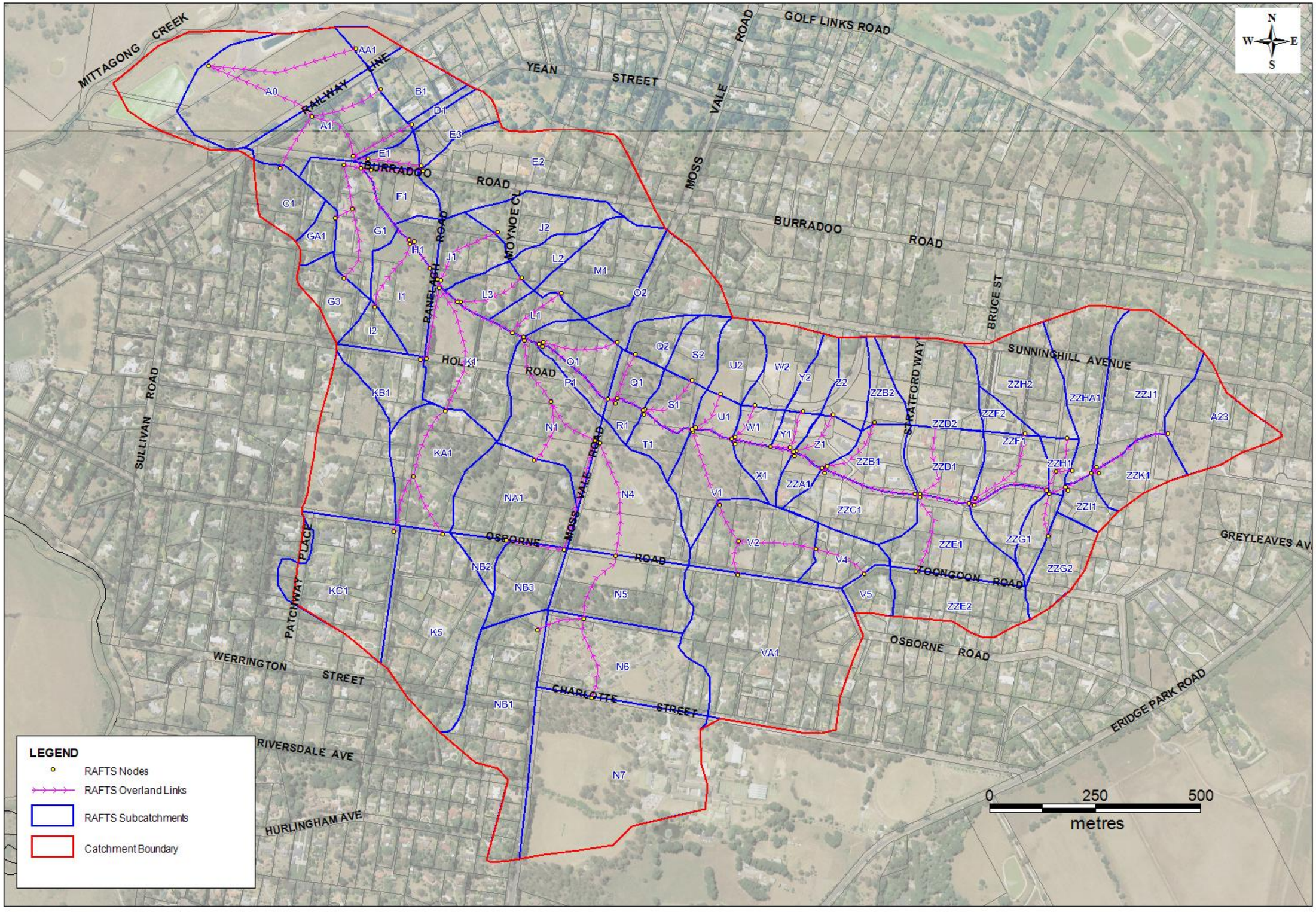


Figure 5-2 Elevation

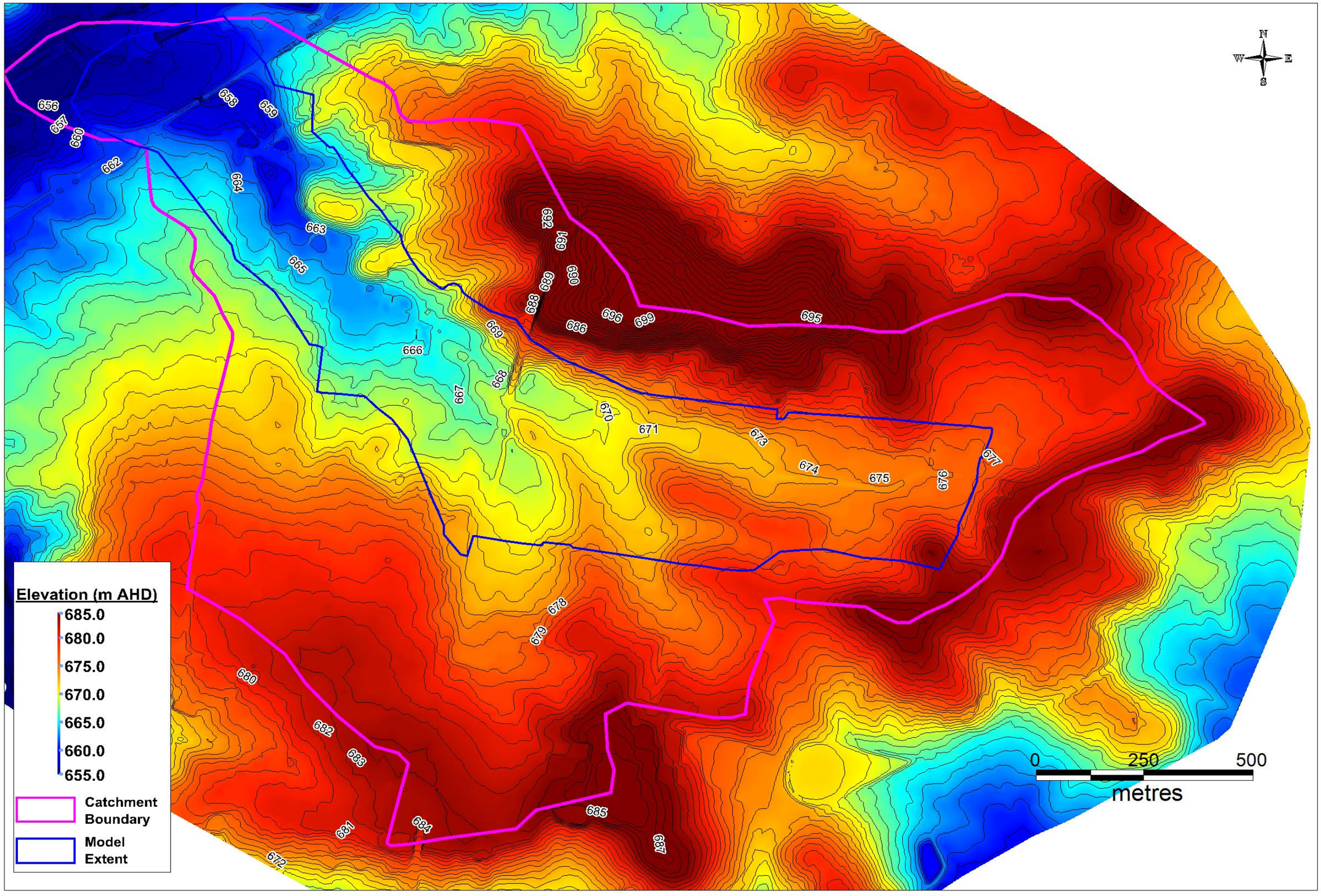


Figure 5-3 1D Culvert Reference Locations and Dimensions

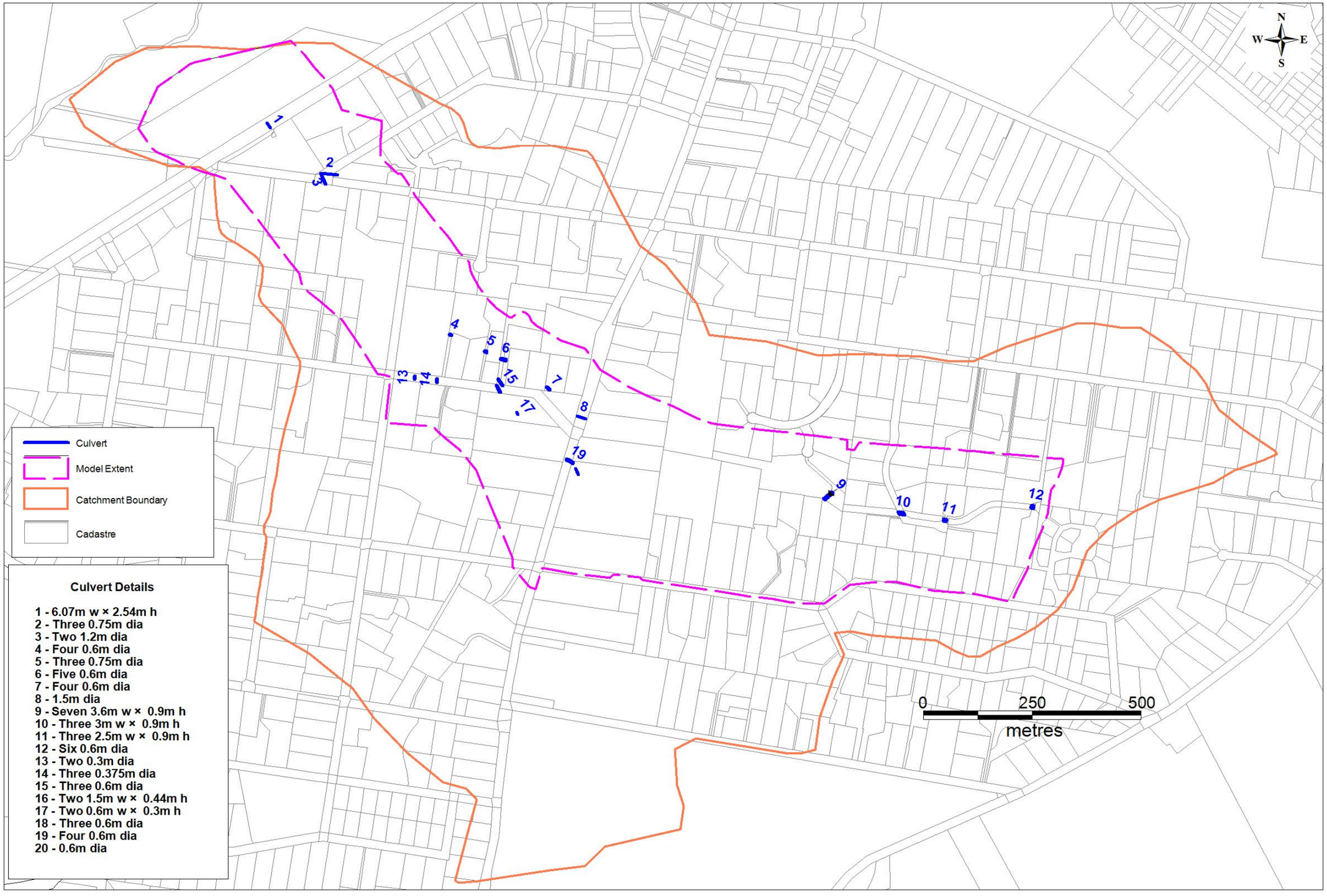


Figure 5-4 Roughness Model

Figure 5-5 Hydraulic Model Reference Points

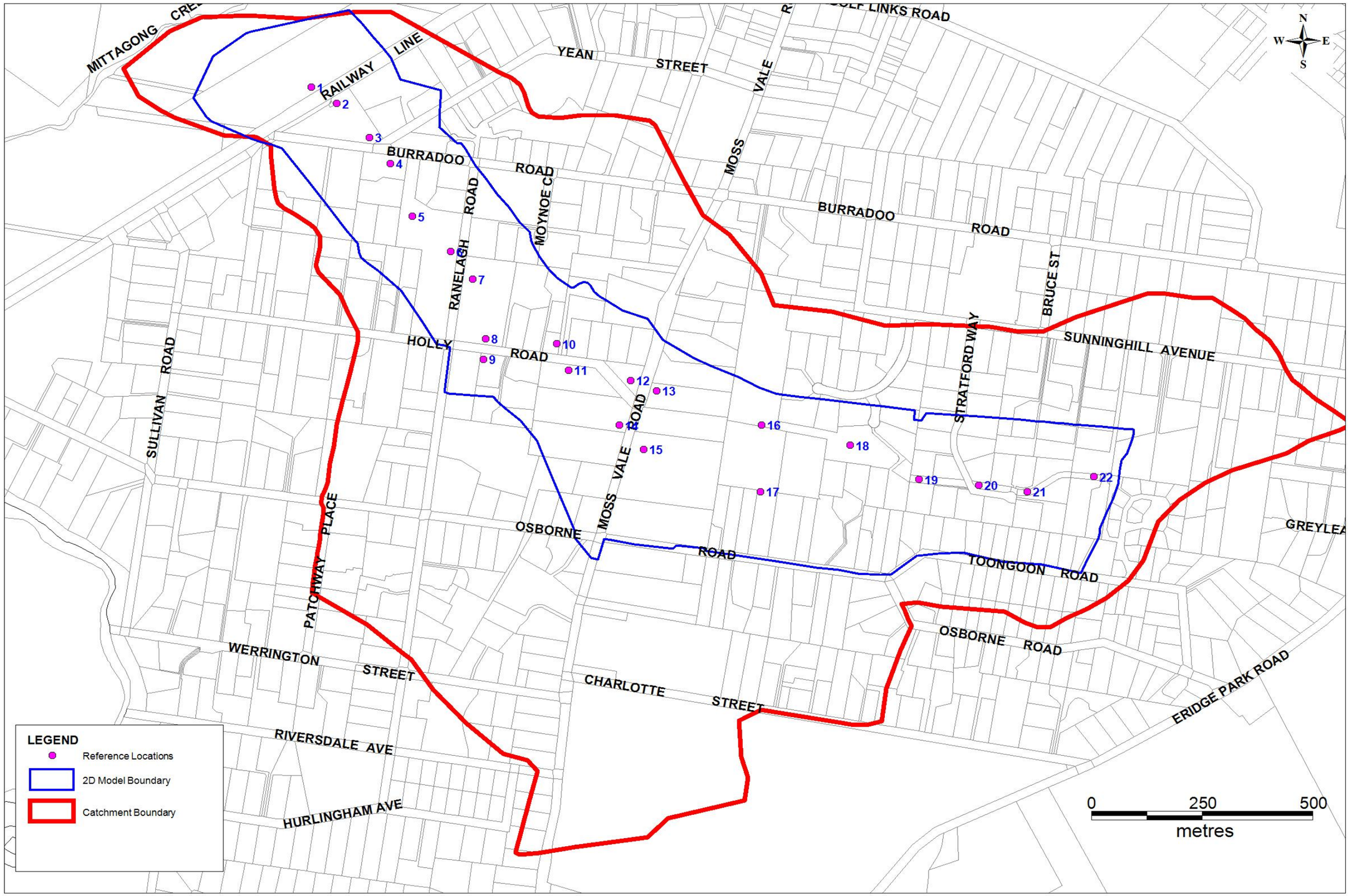


Figure 5-6 Peak Flood Depths – PMF

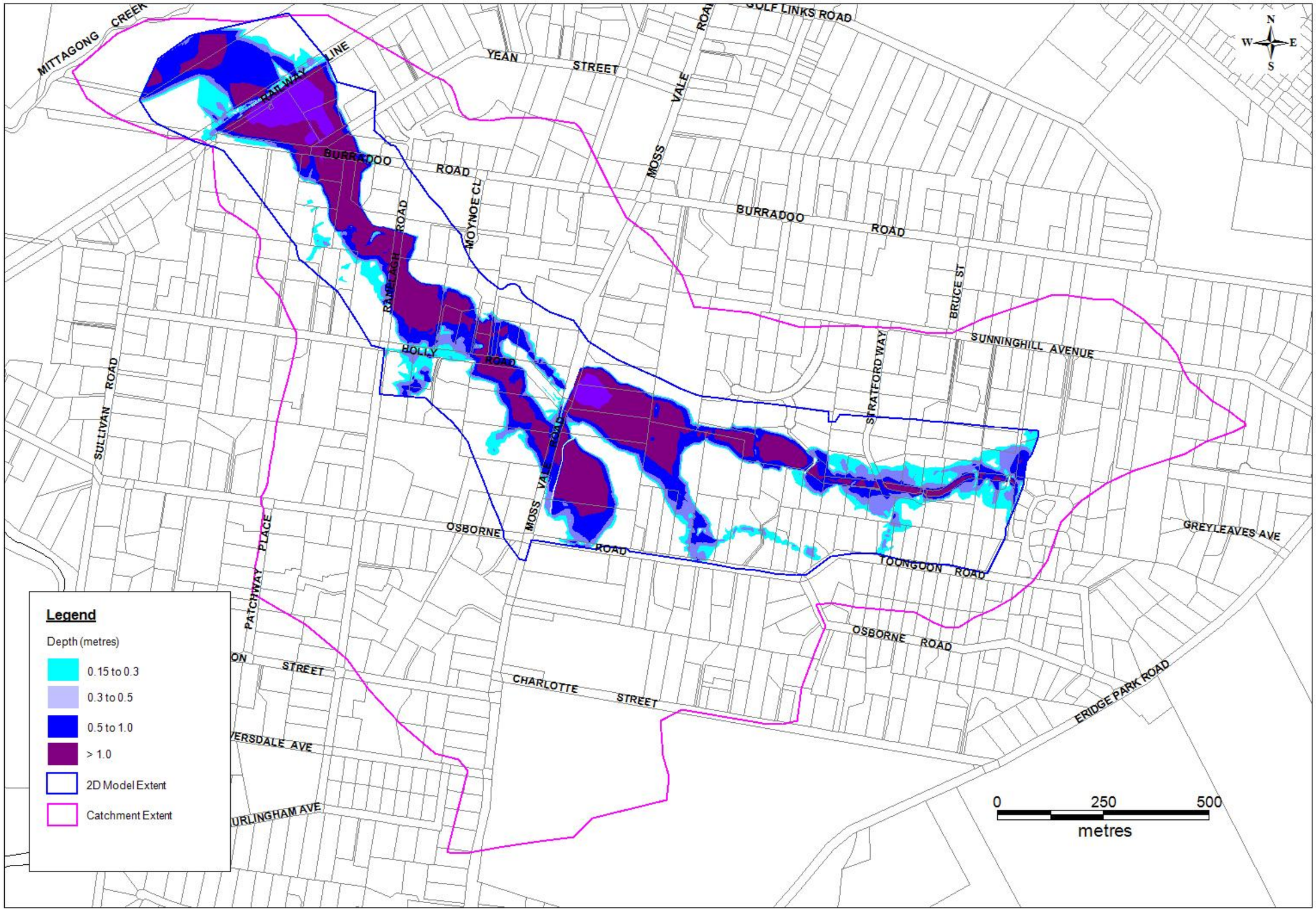


Figure 5-7 Peak Flood Depths – 1% AEP

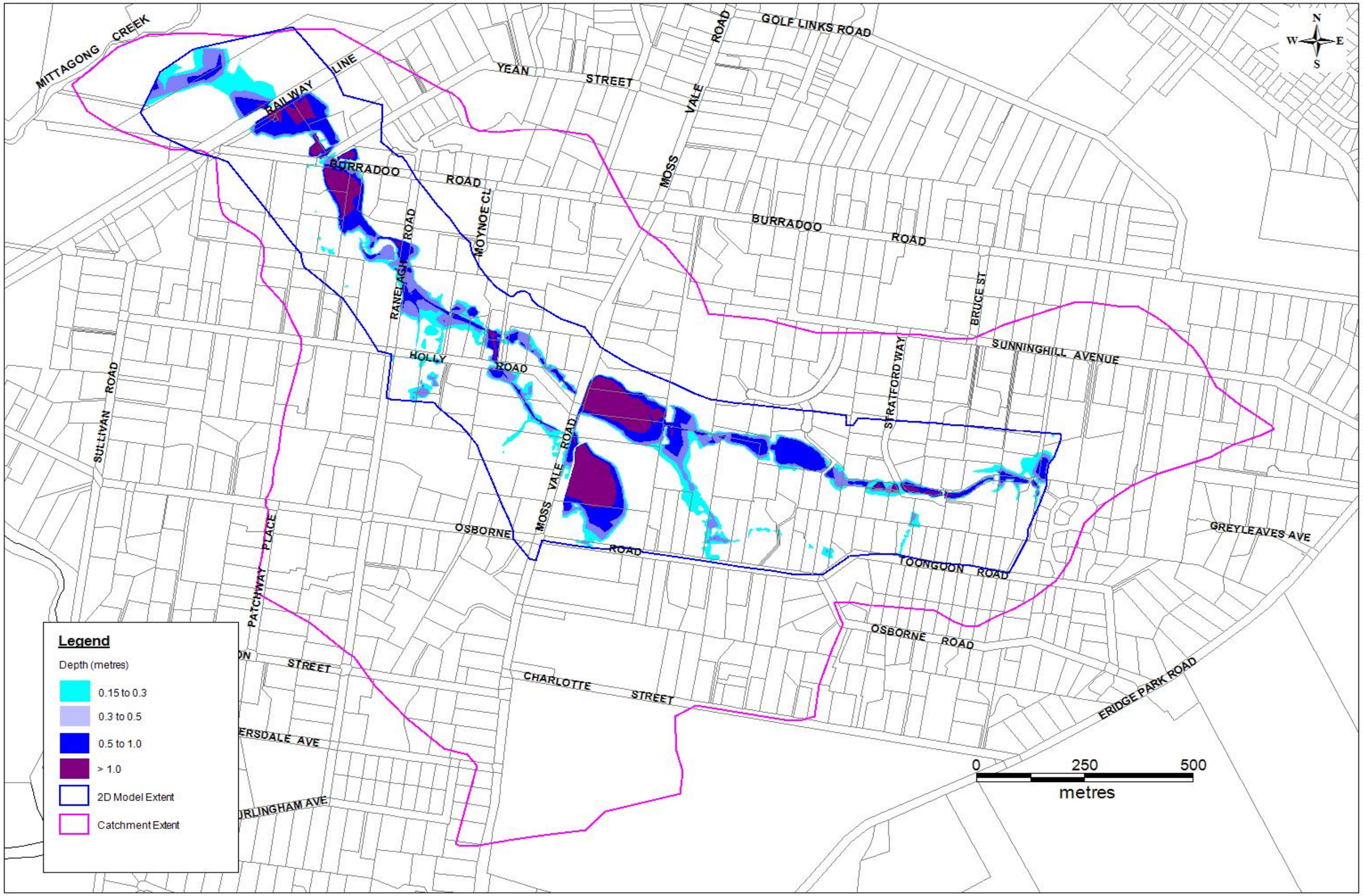


Figure 5-8 Peak Flood Depths – 2% AEP

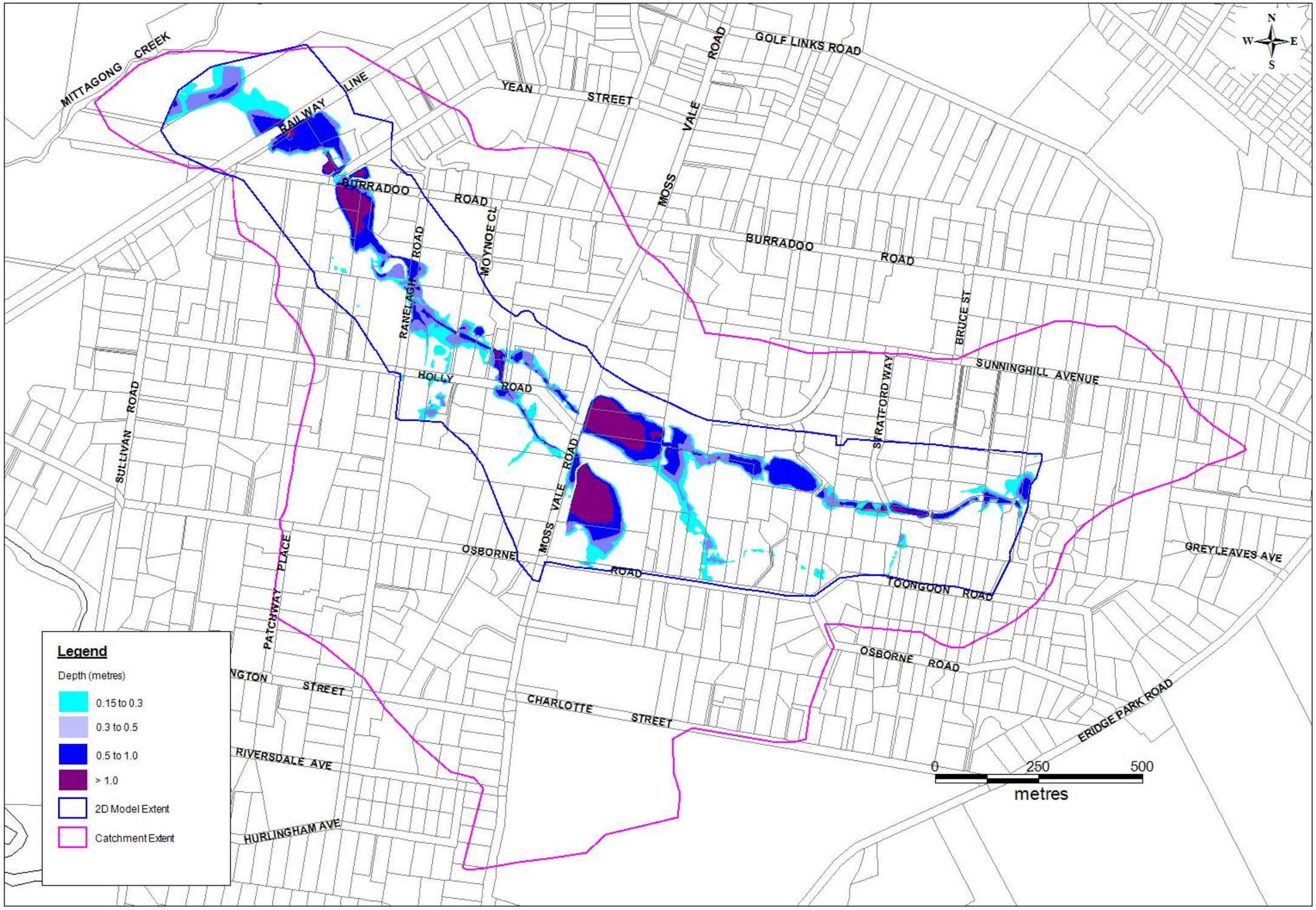


Figure 5-9 Peak Flood Depths – 5% AEP

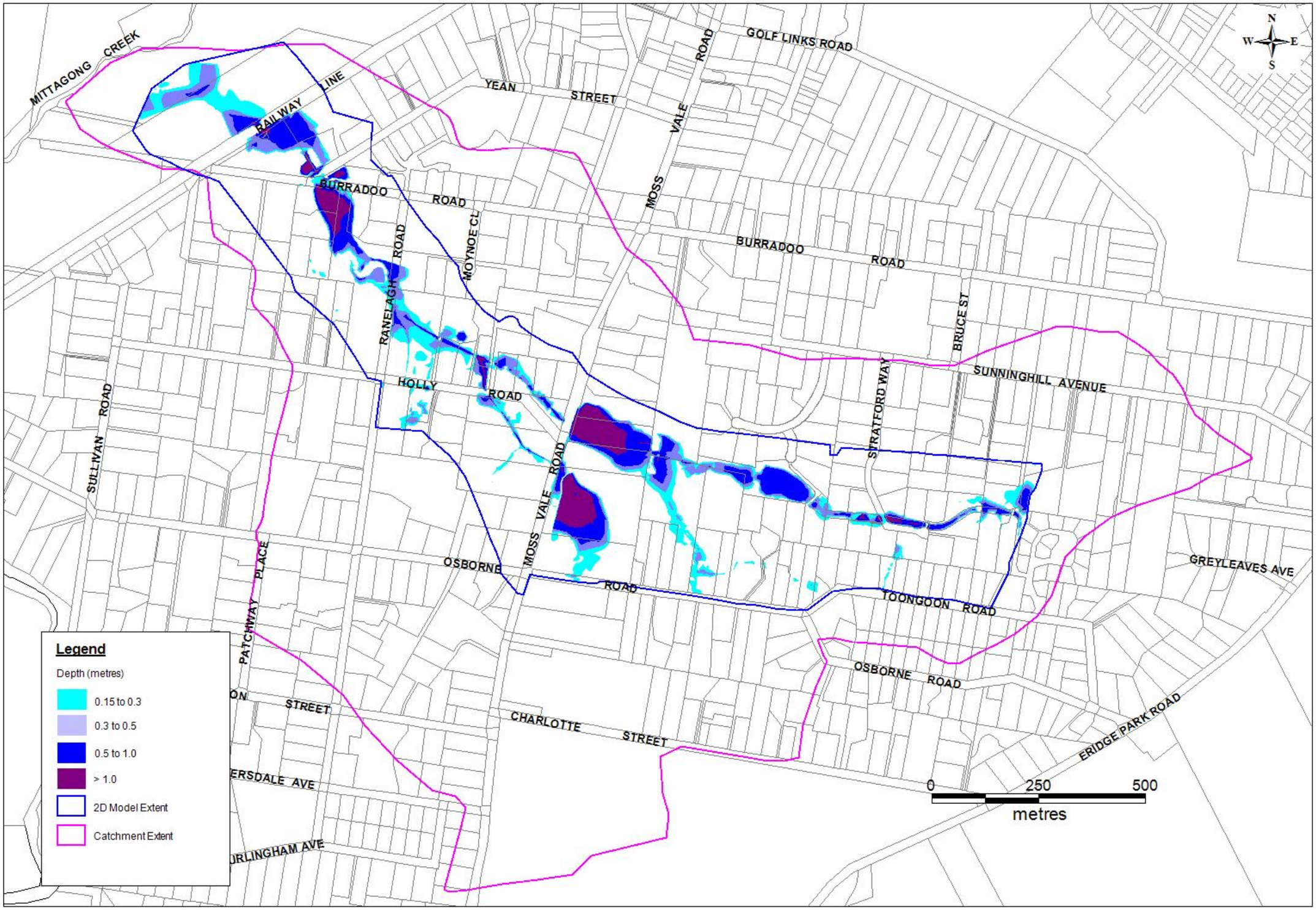


Figure 5-10 Peak Flood Depths – 20% AEP

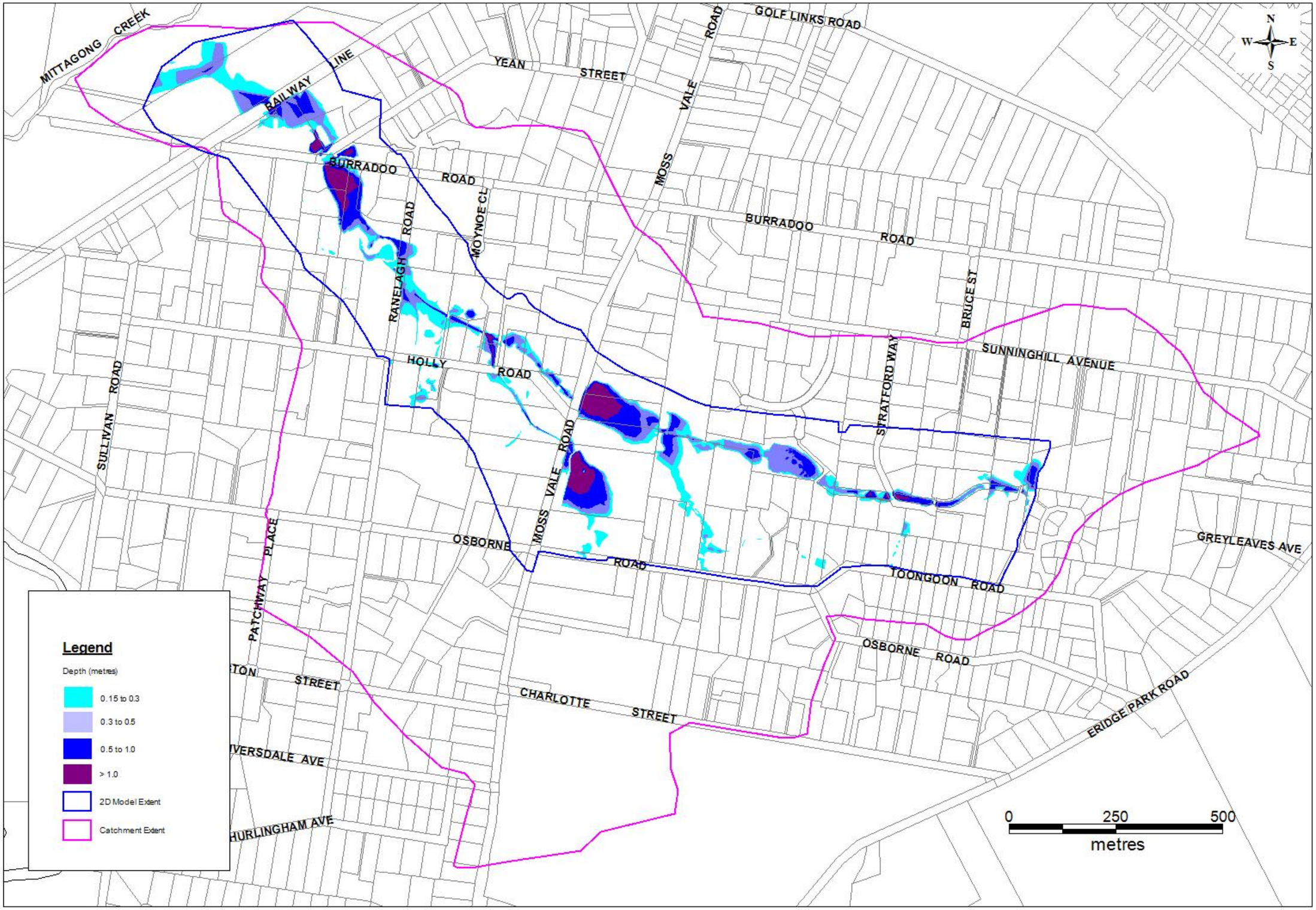


Figure 5-11 Peak Flood Velocities – PMF

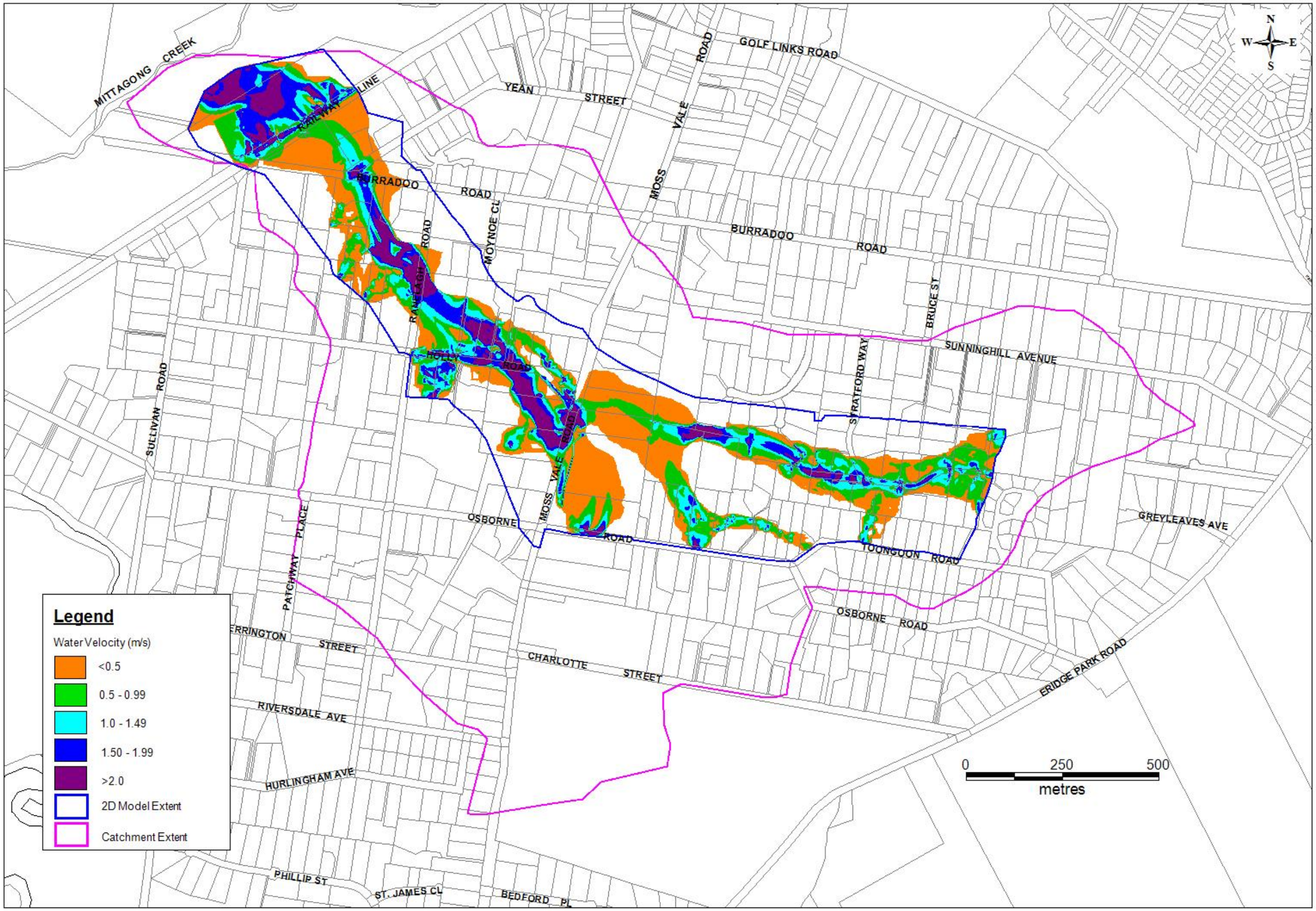


Figure 5-12 Peak Flood Velocities – 1% AEP

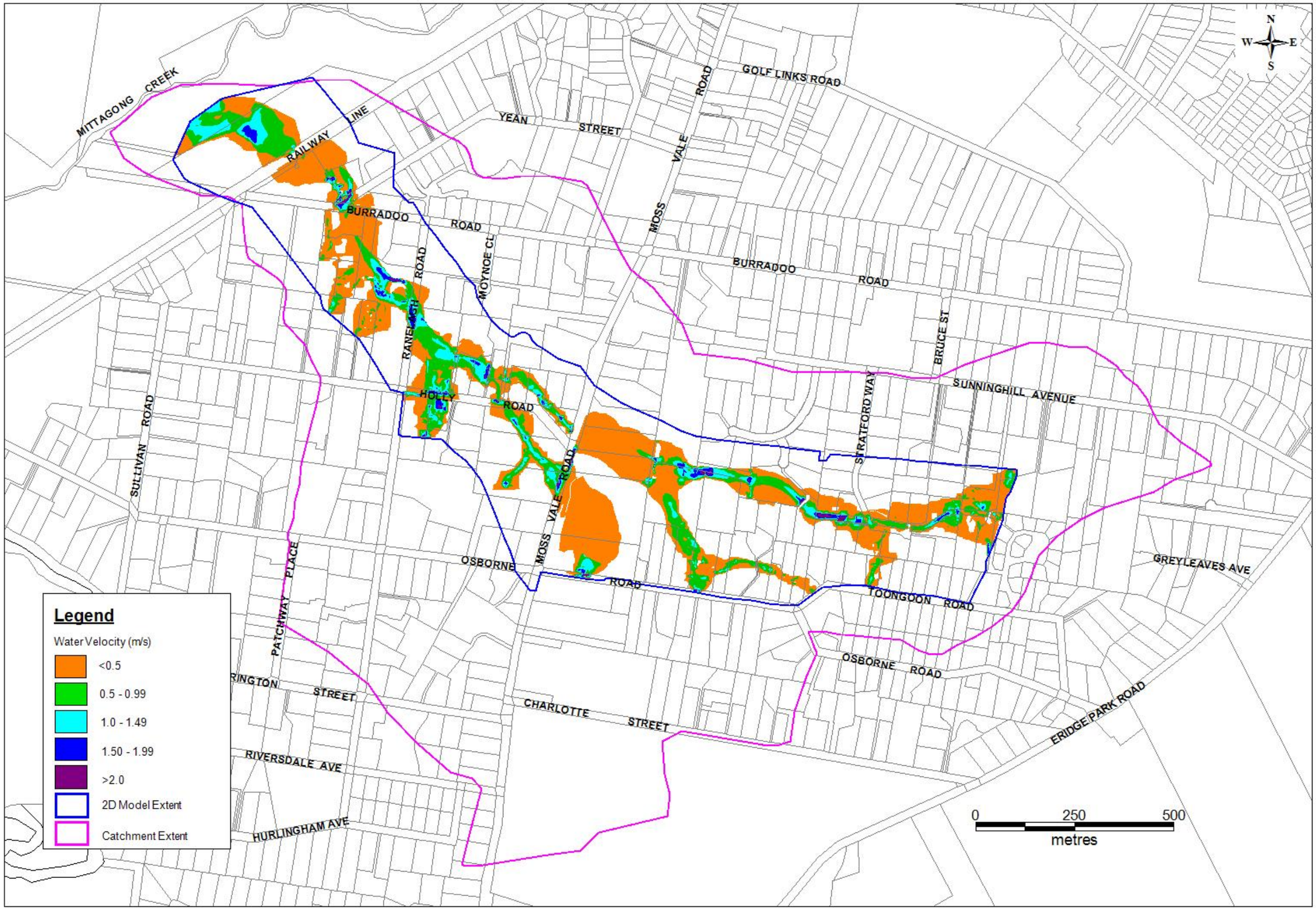


Figure 5-13 Peak Flood Velocities – 2% AEP

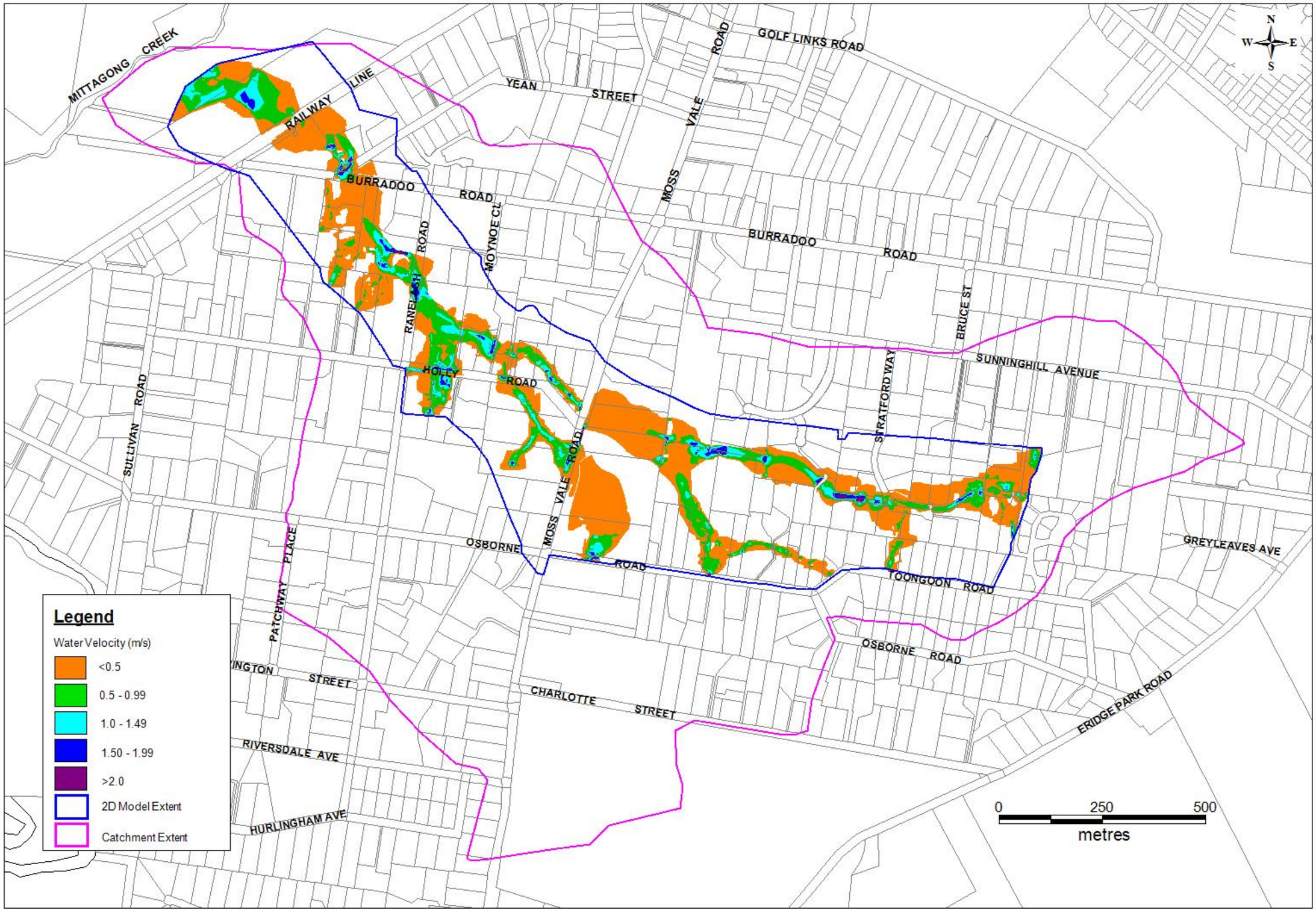


Figure 5-14 Peak Flood Velocities – 5% AEP

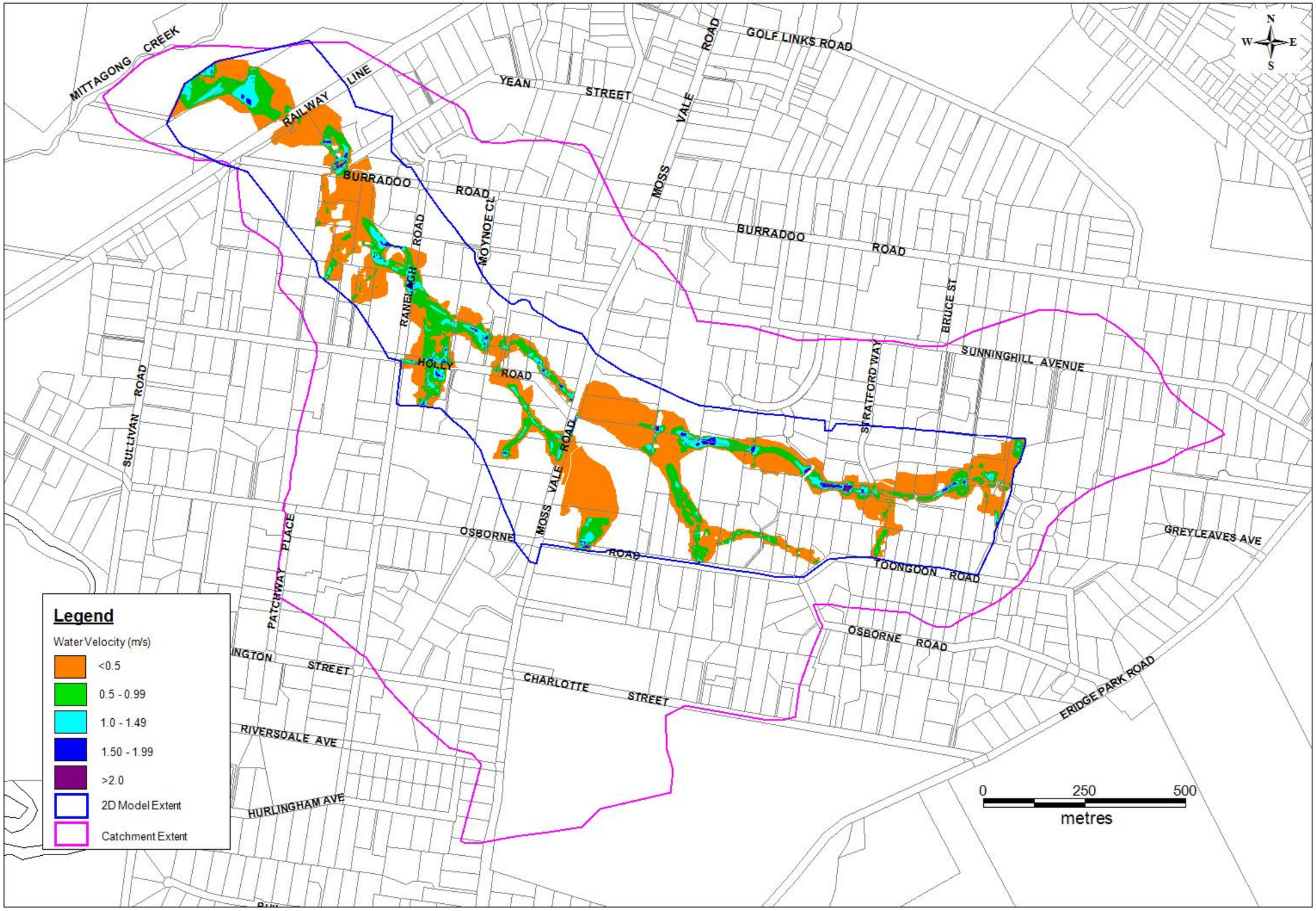


Figure 5-15 Peak Flood Velocities – 20% AEP

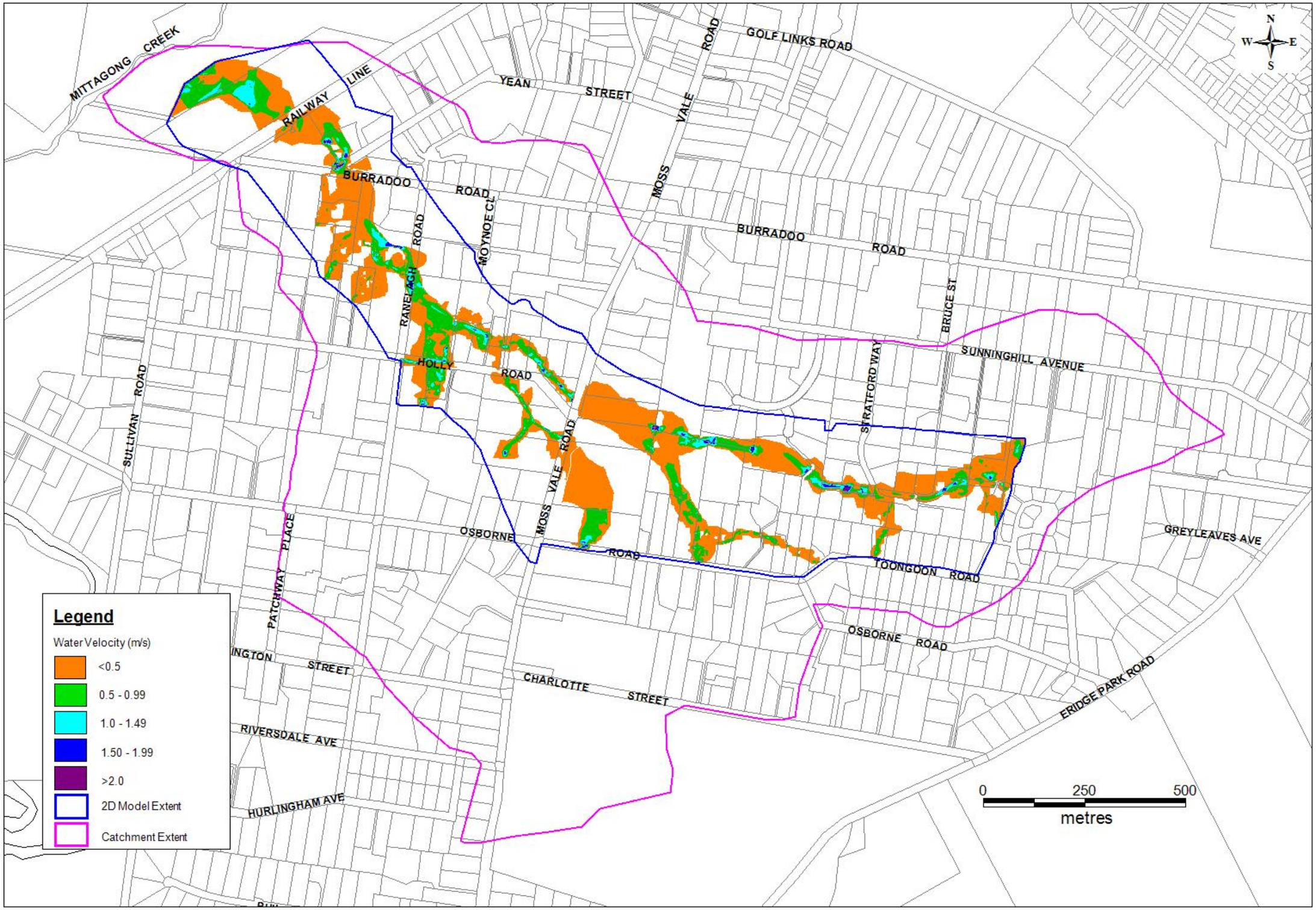


Figure 5-17 Provisional Hazard – PMF

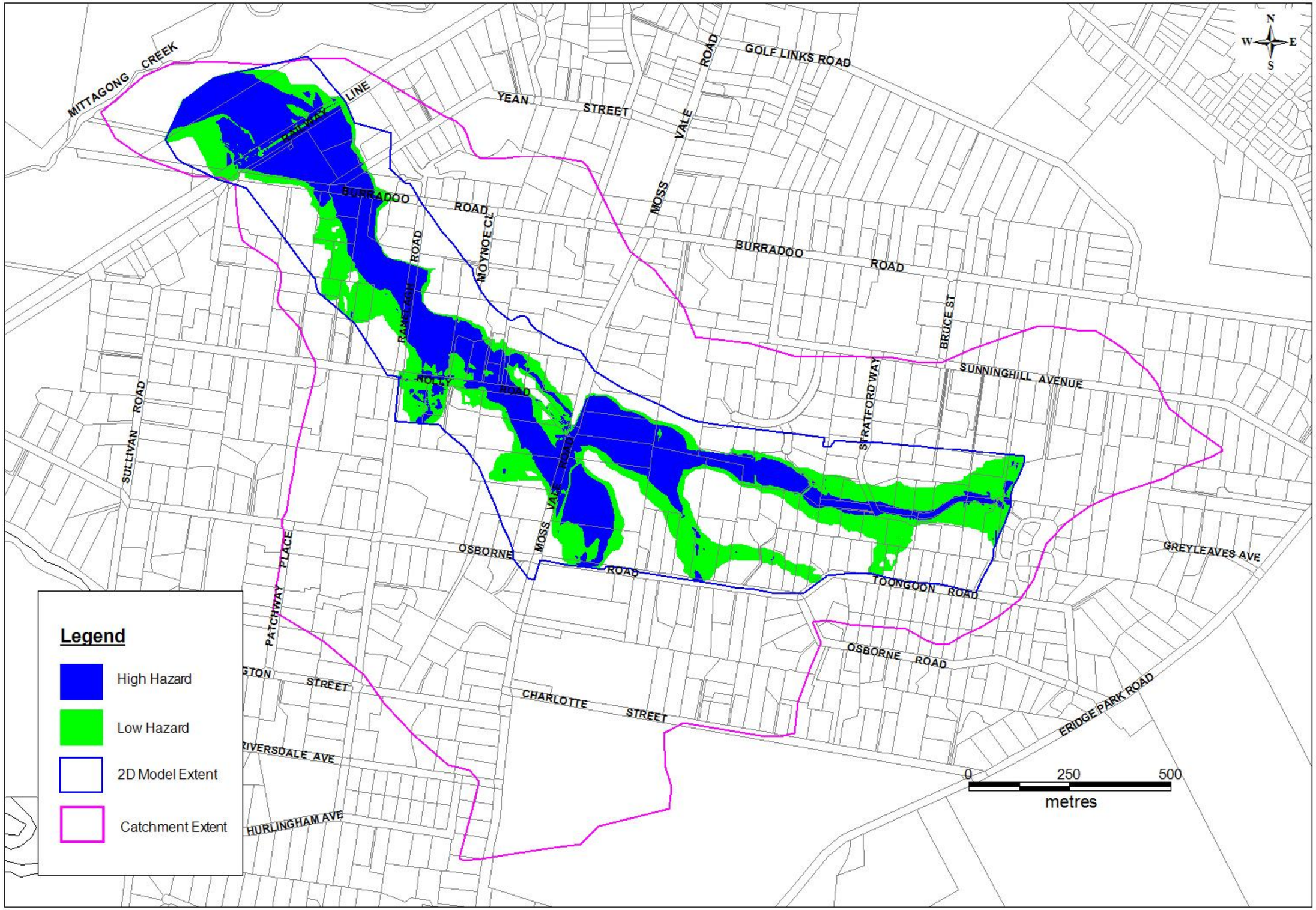


Figure 5-18 Provisional Hazard – 1% AEP

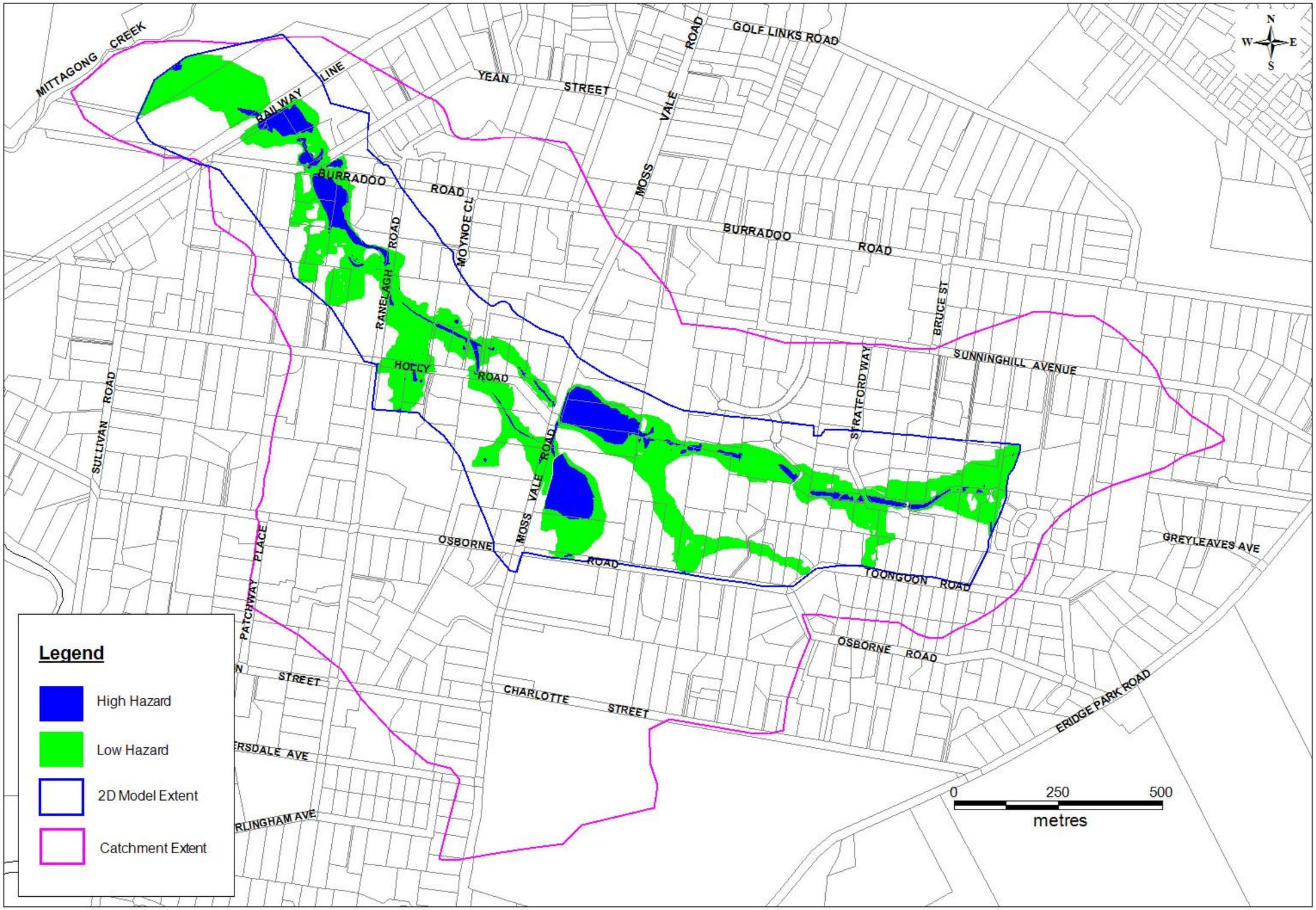


Figure 5-19 Provisional Hazard – 2% AEP

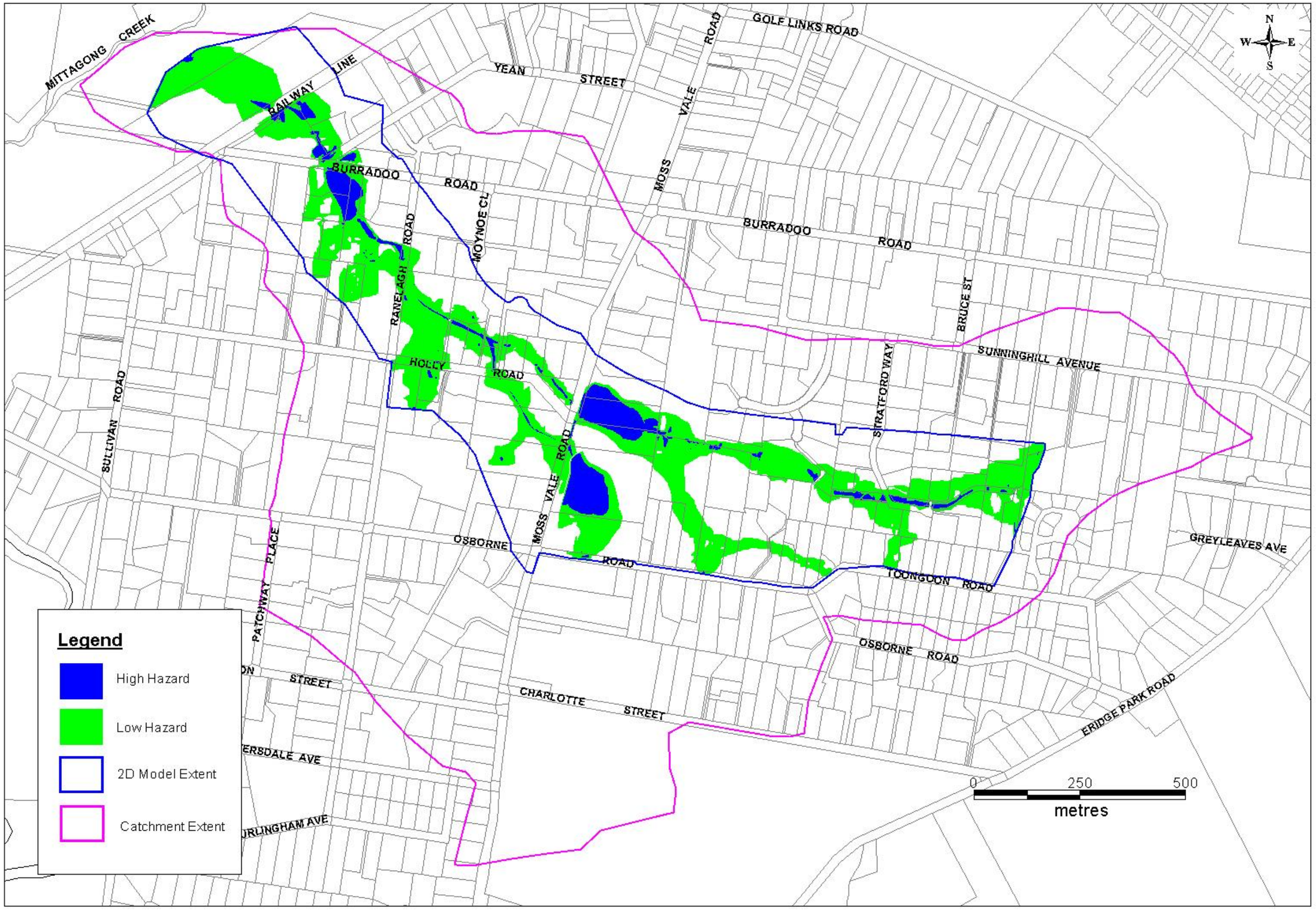


Figure 5-20 Provisional Hazard – 5% AEP

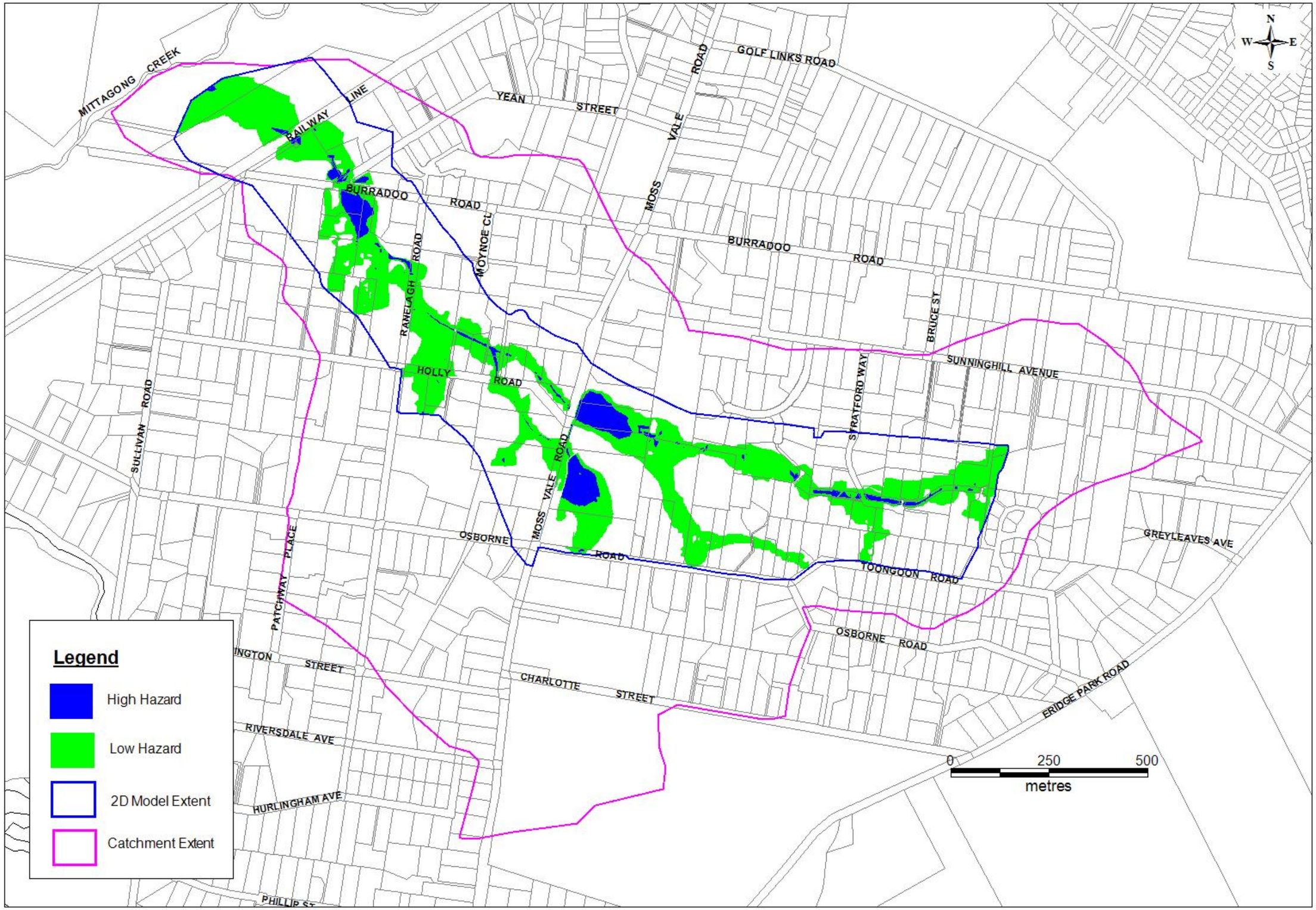


Figure 5-21 Provisional Hazard – 20% AEP

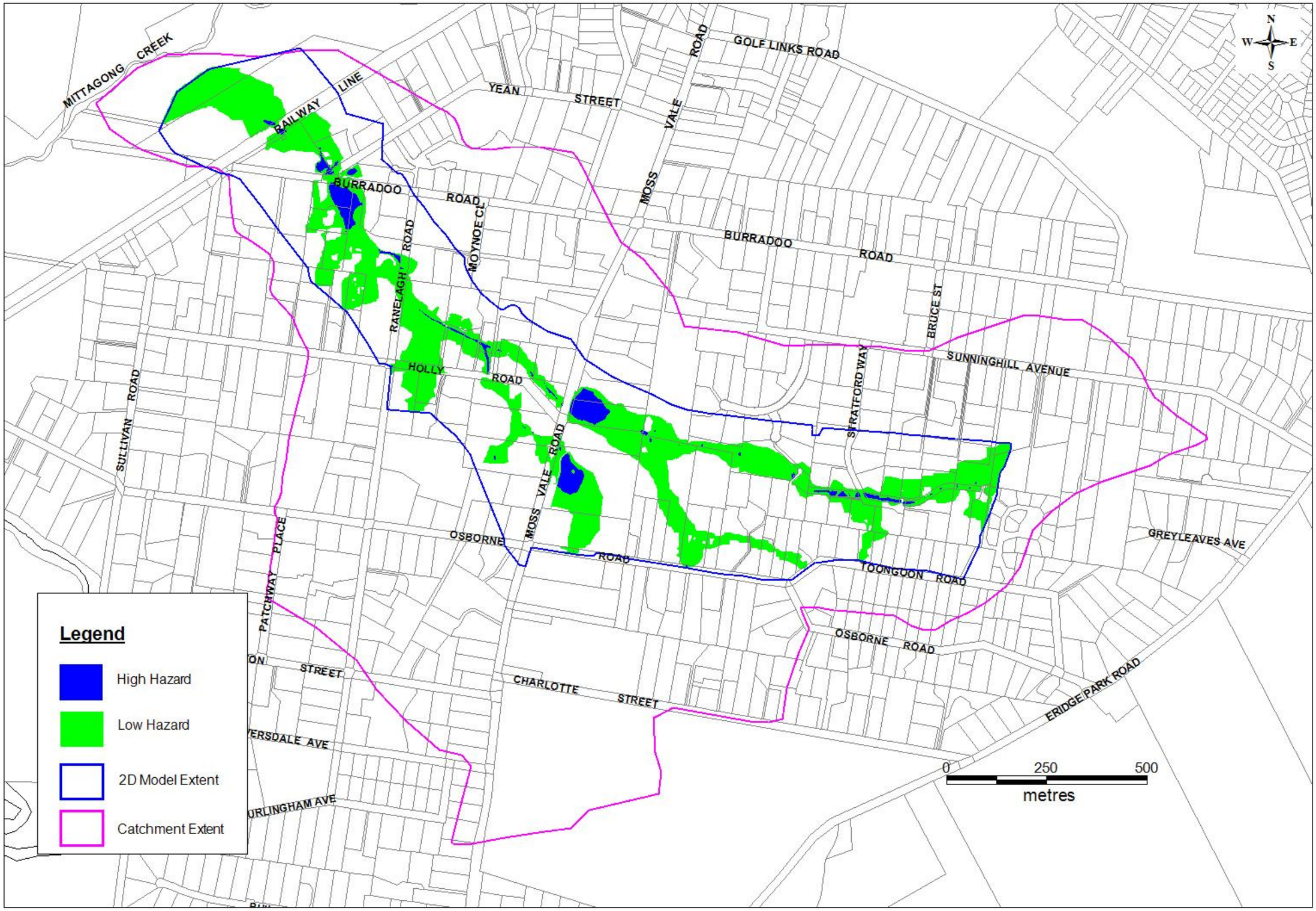


Figure 5-22 True Hazard – PMF

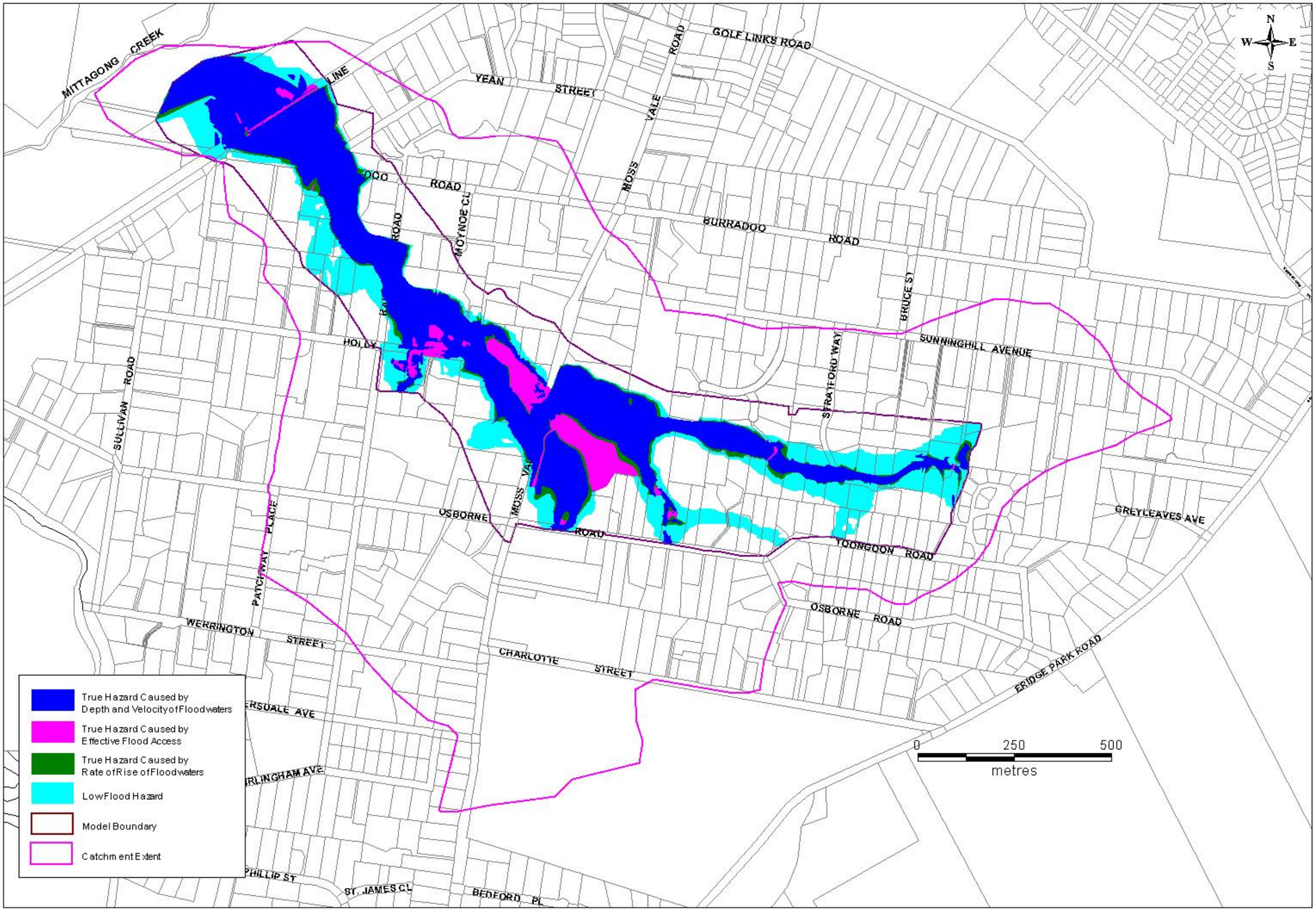


Figure 5-23 True Hazard – 1% AEP

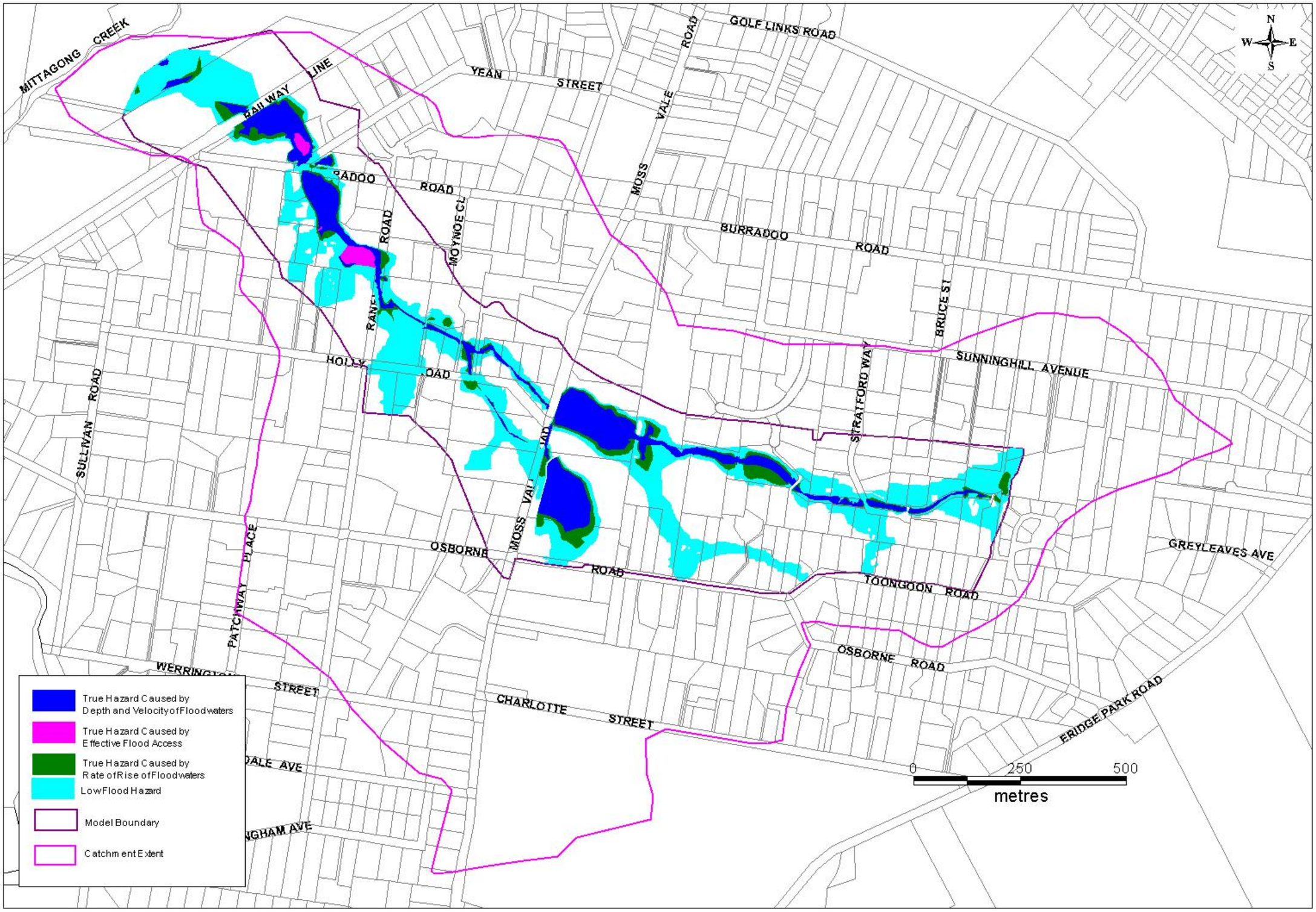


Figure 5-24 True Hazard – 20% AEP

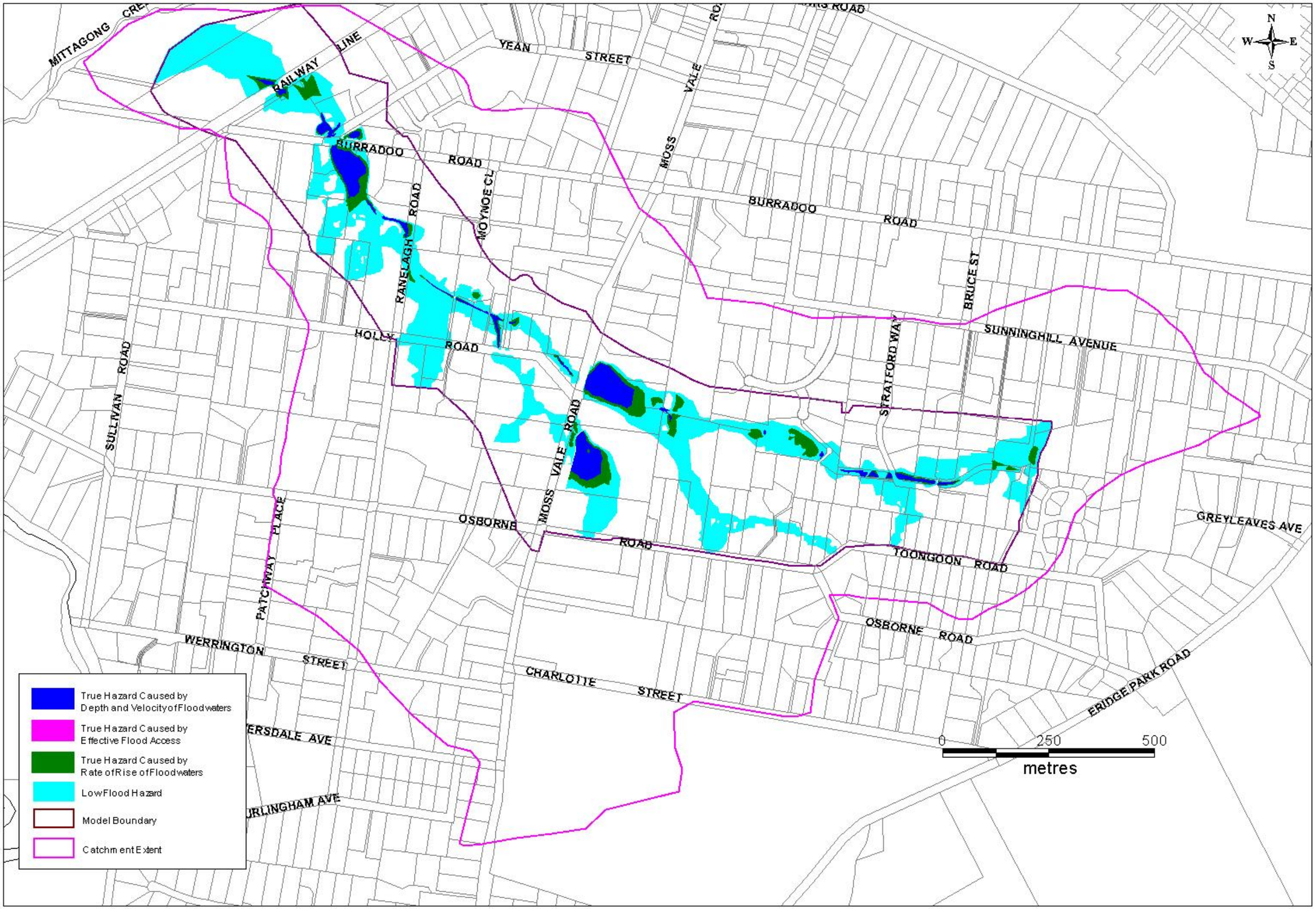


Figure 6-2 Properties Affected by Over-floor Flooding in a 1% AEP Event

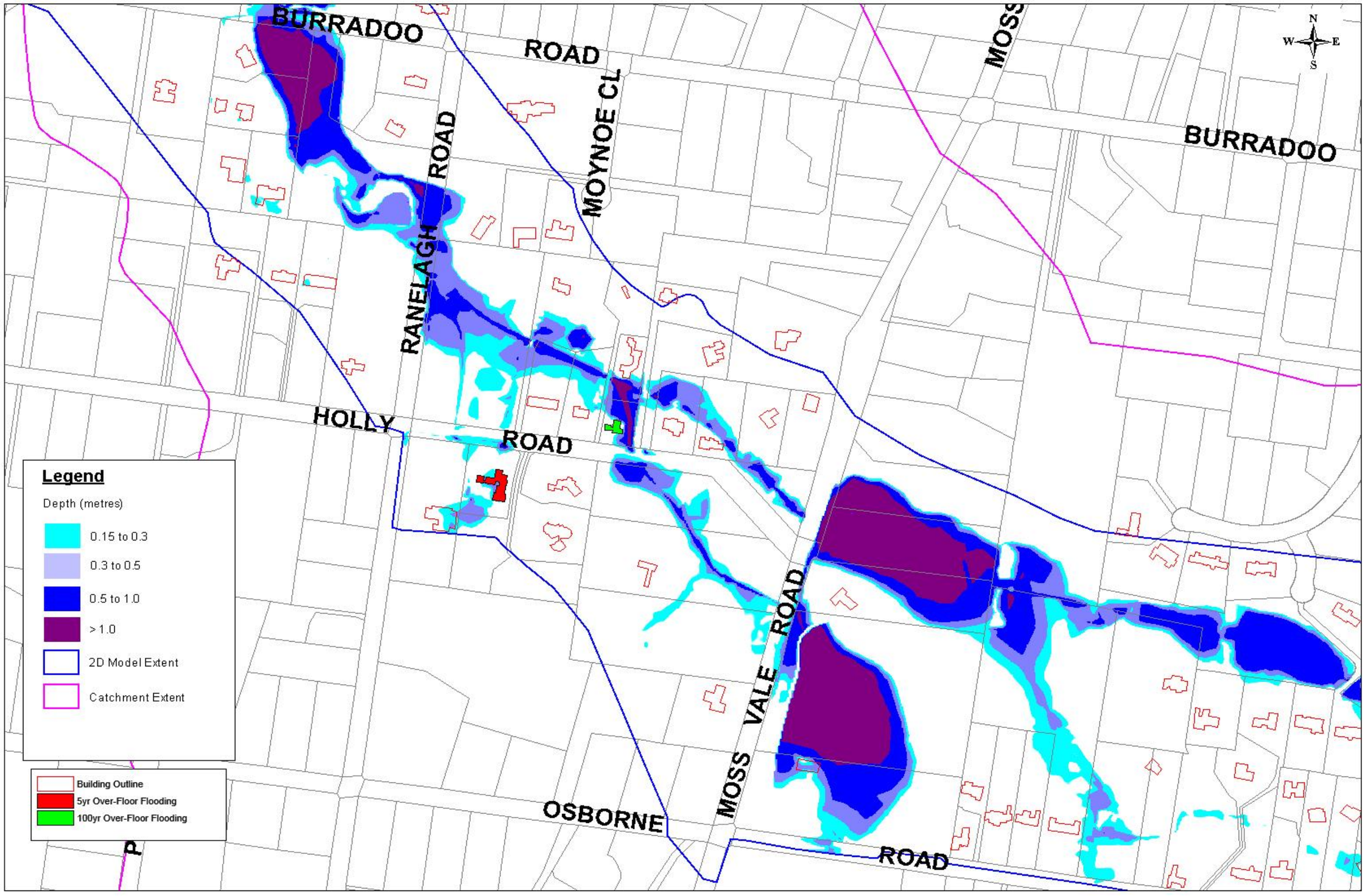


Figure 7-1 Flood Emergency Response Planning Classifications

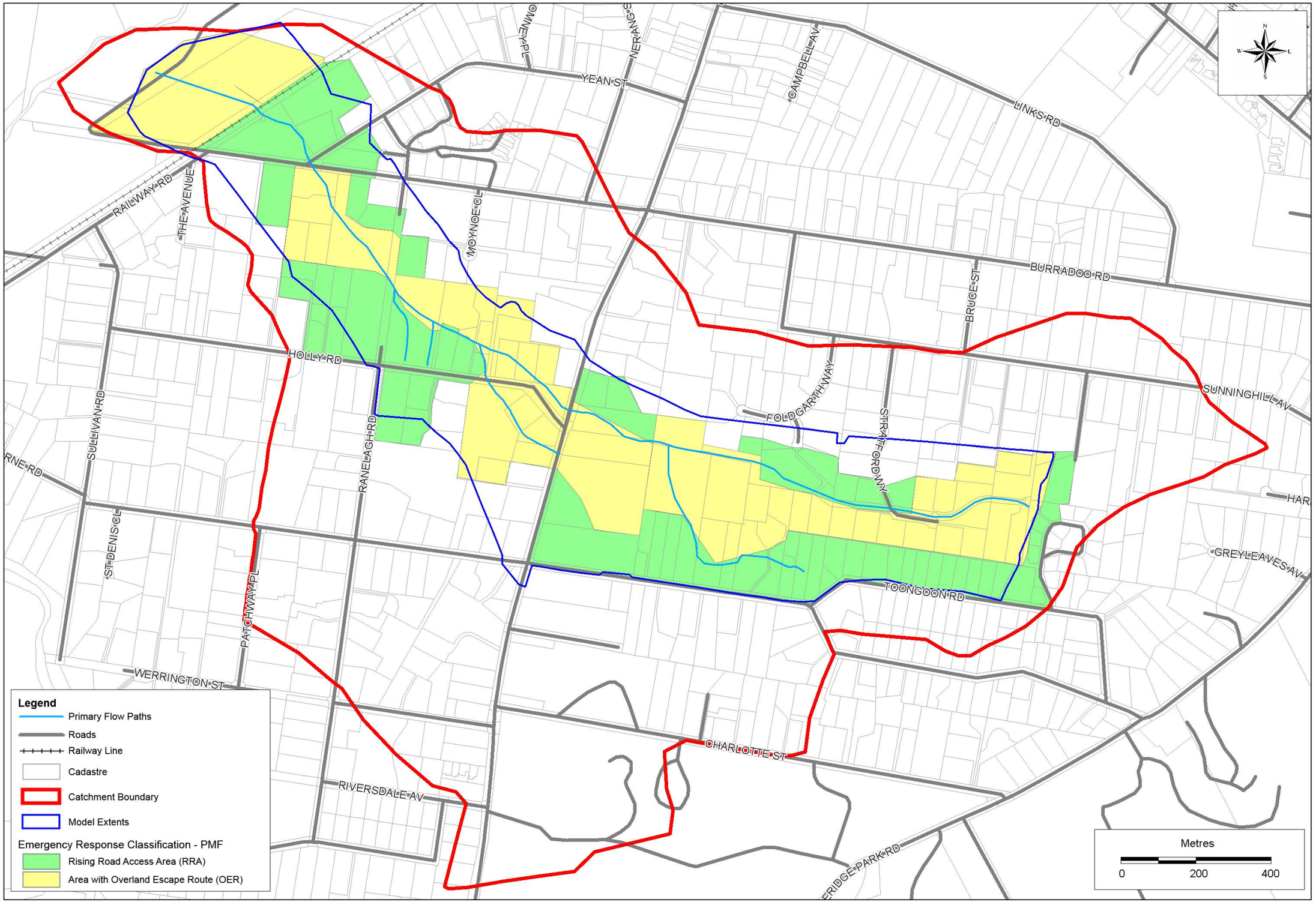


Figure 8-1 LEP Land-use Zones

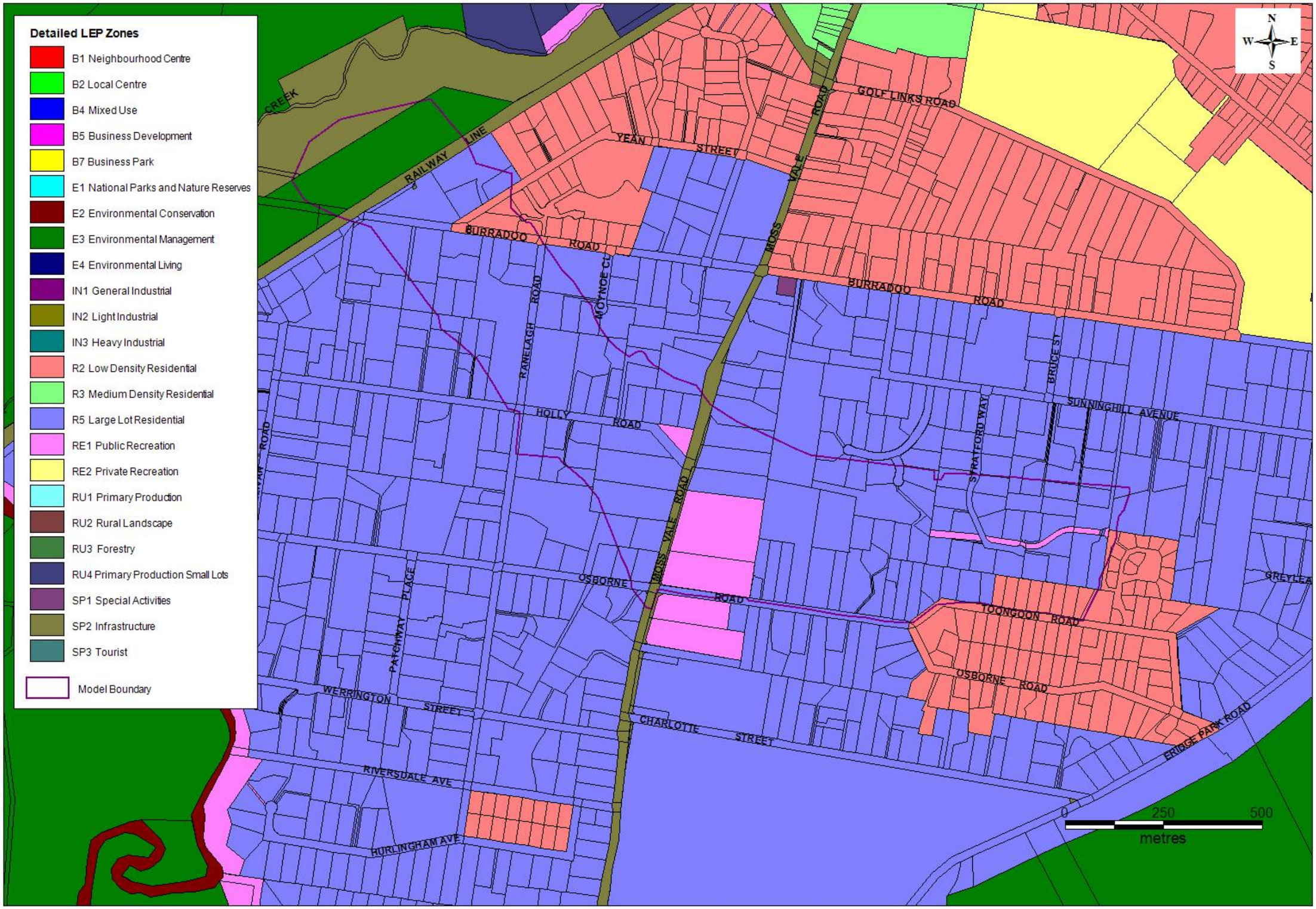


Figure 8-2 Flood Risk Precincts

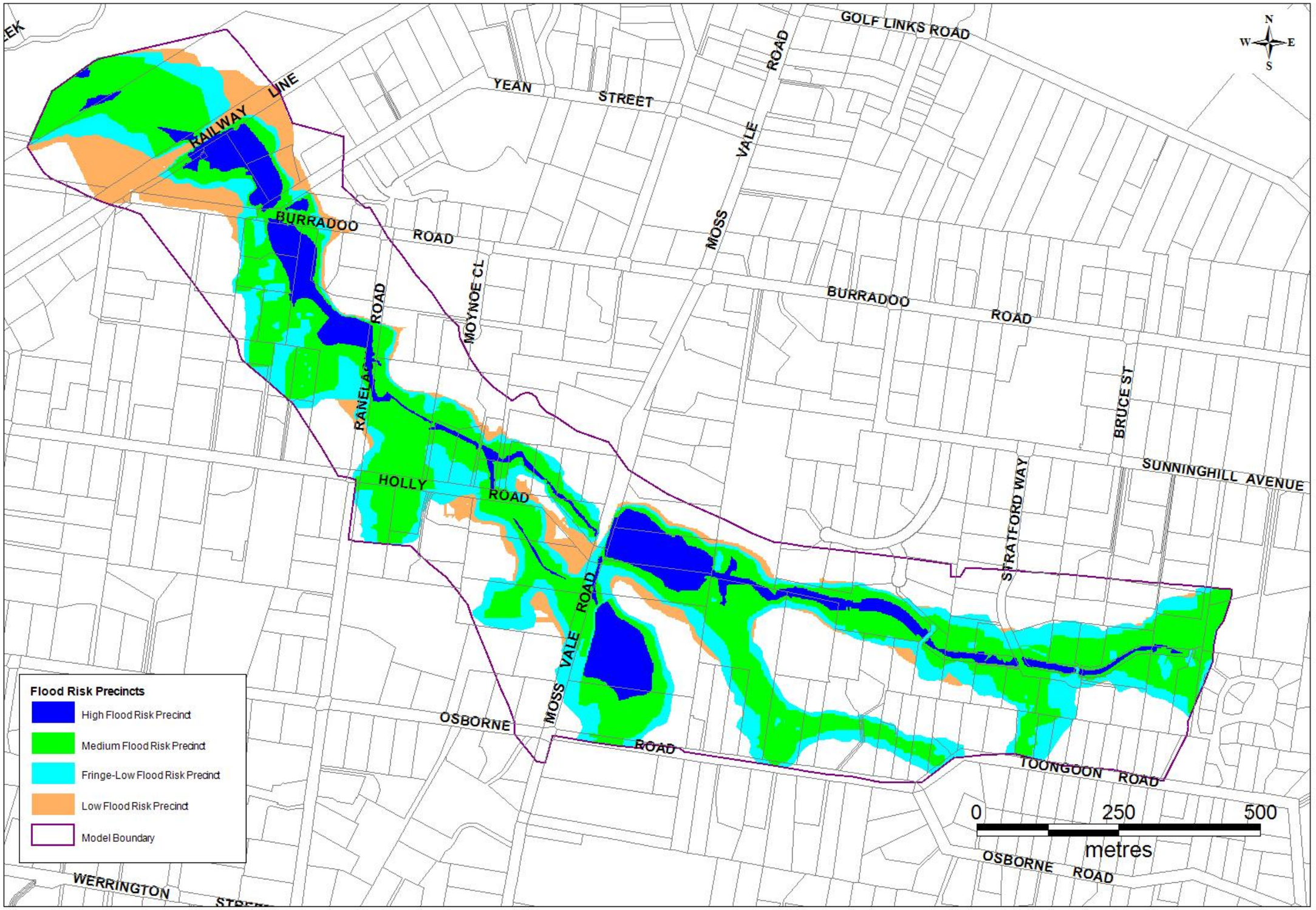


Figure 8-3 Flood Risk Precincts and Land-use Zones

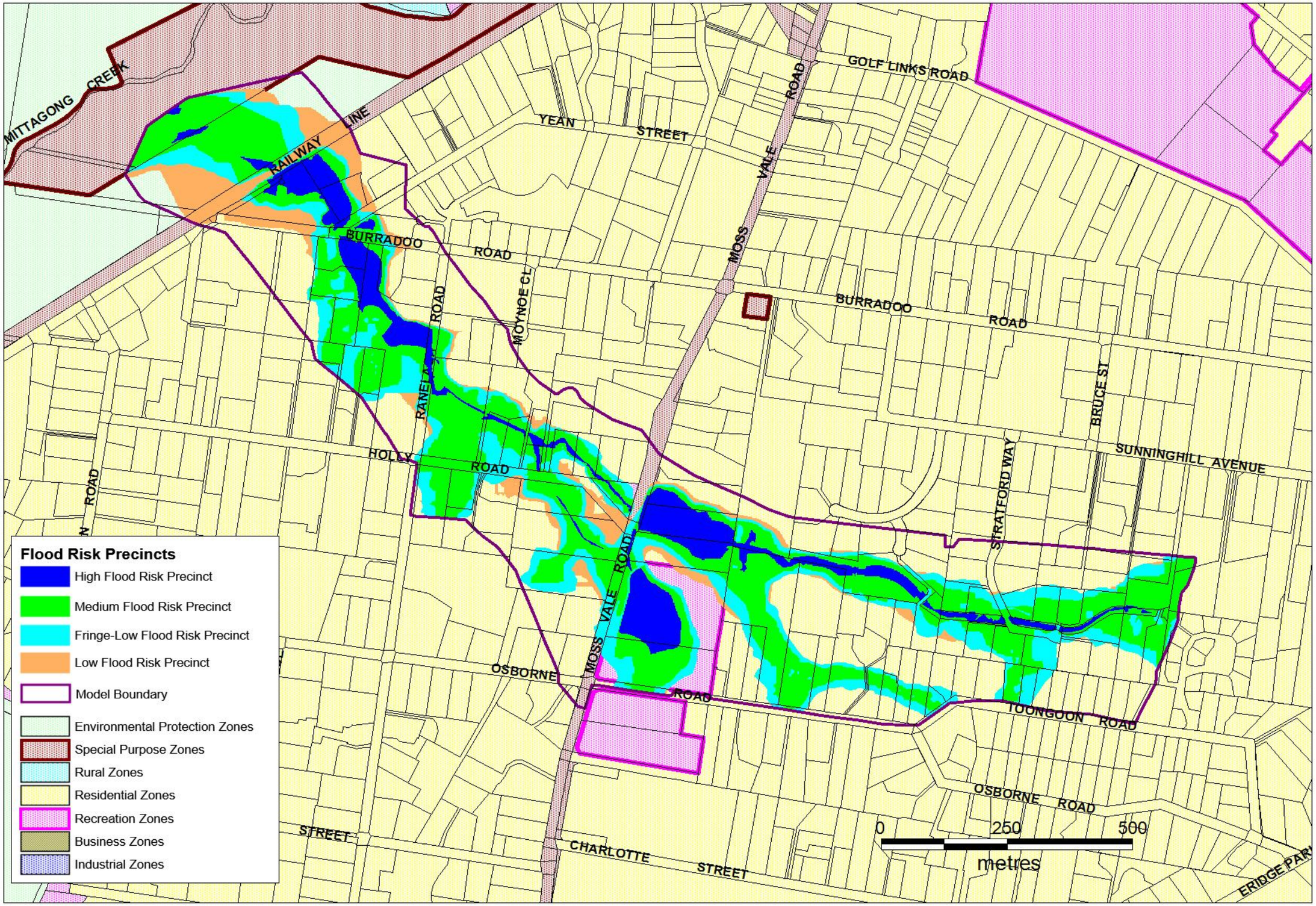


Figure 8-4 Flood Planning Level

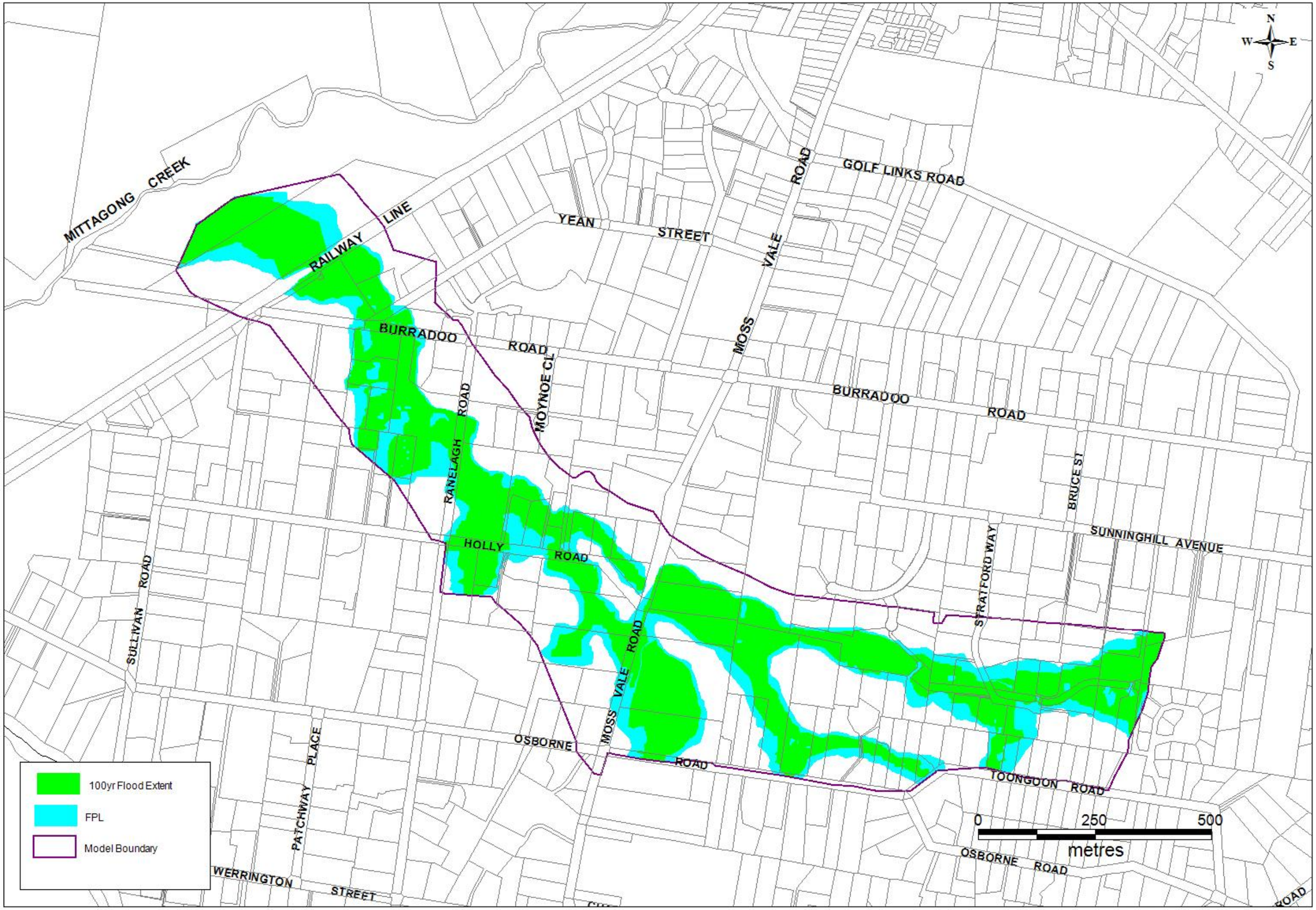


Figure 9-1 Design Layout of FM2 to FM8

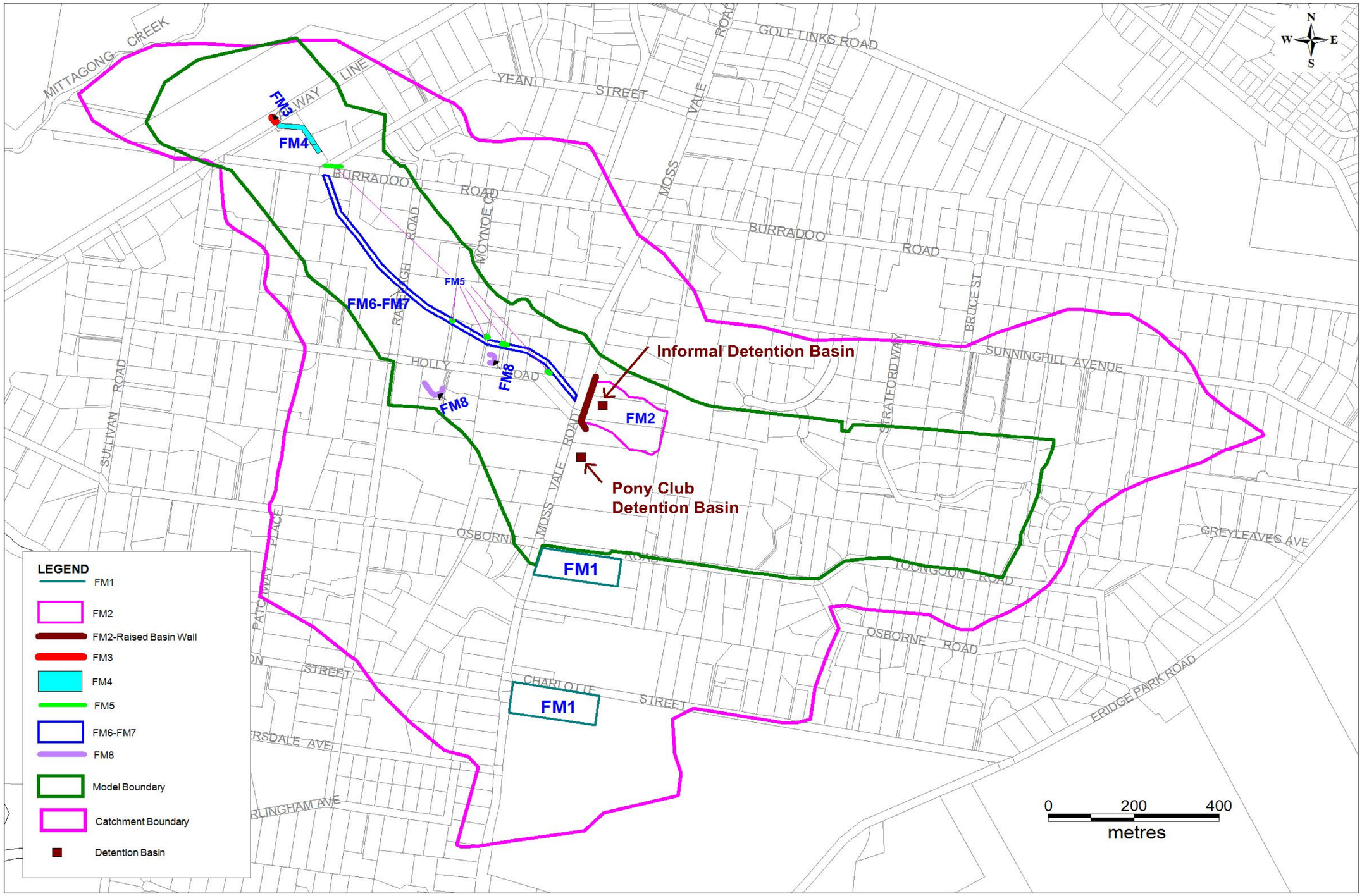


Figure 9-2 Design Layout of FM2

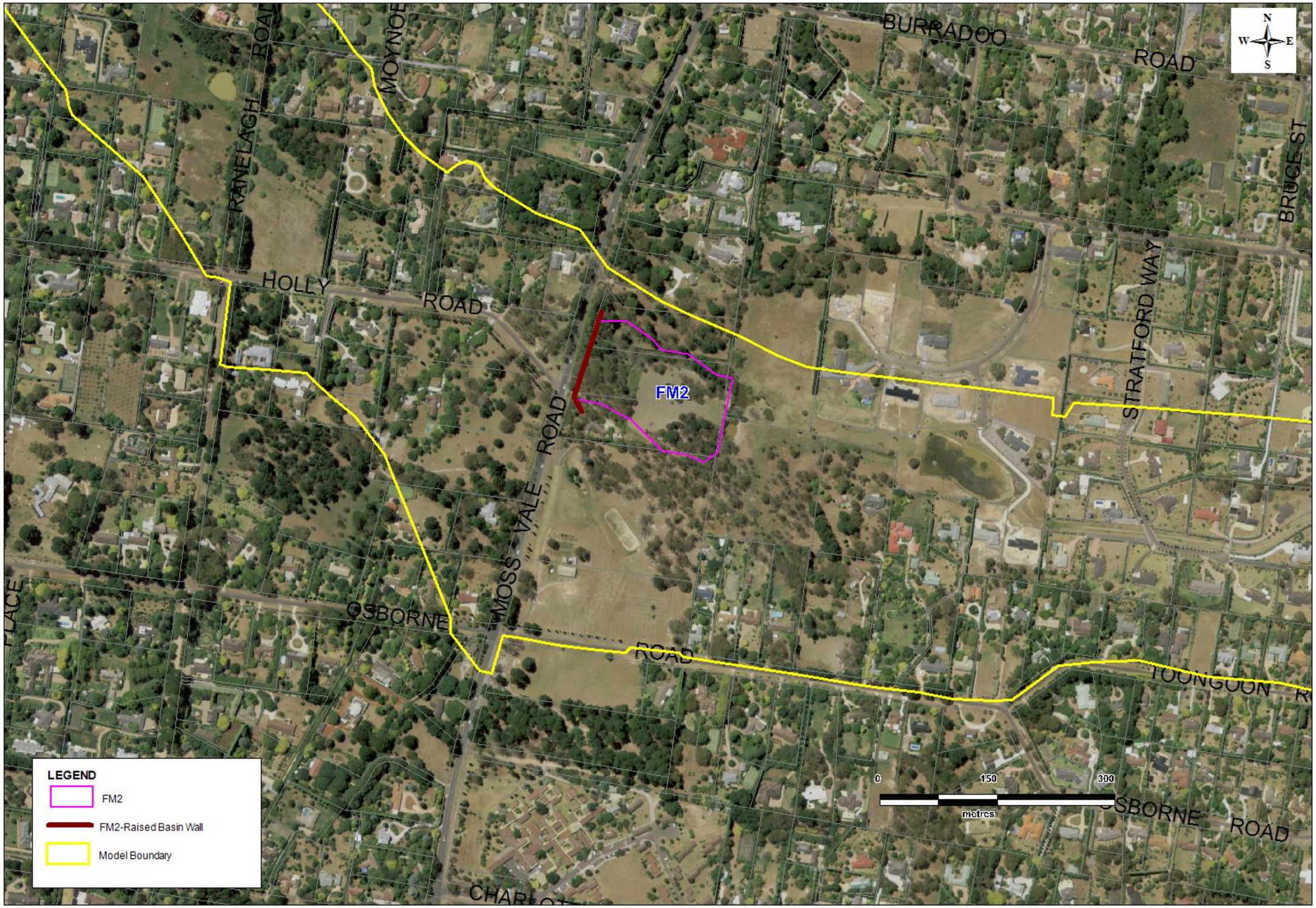


Figure 9-3 FM2 Water Level Impacts – 20% AEP

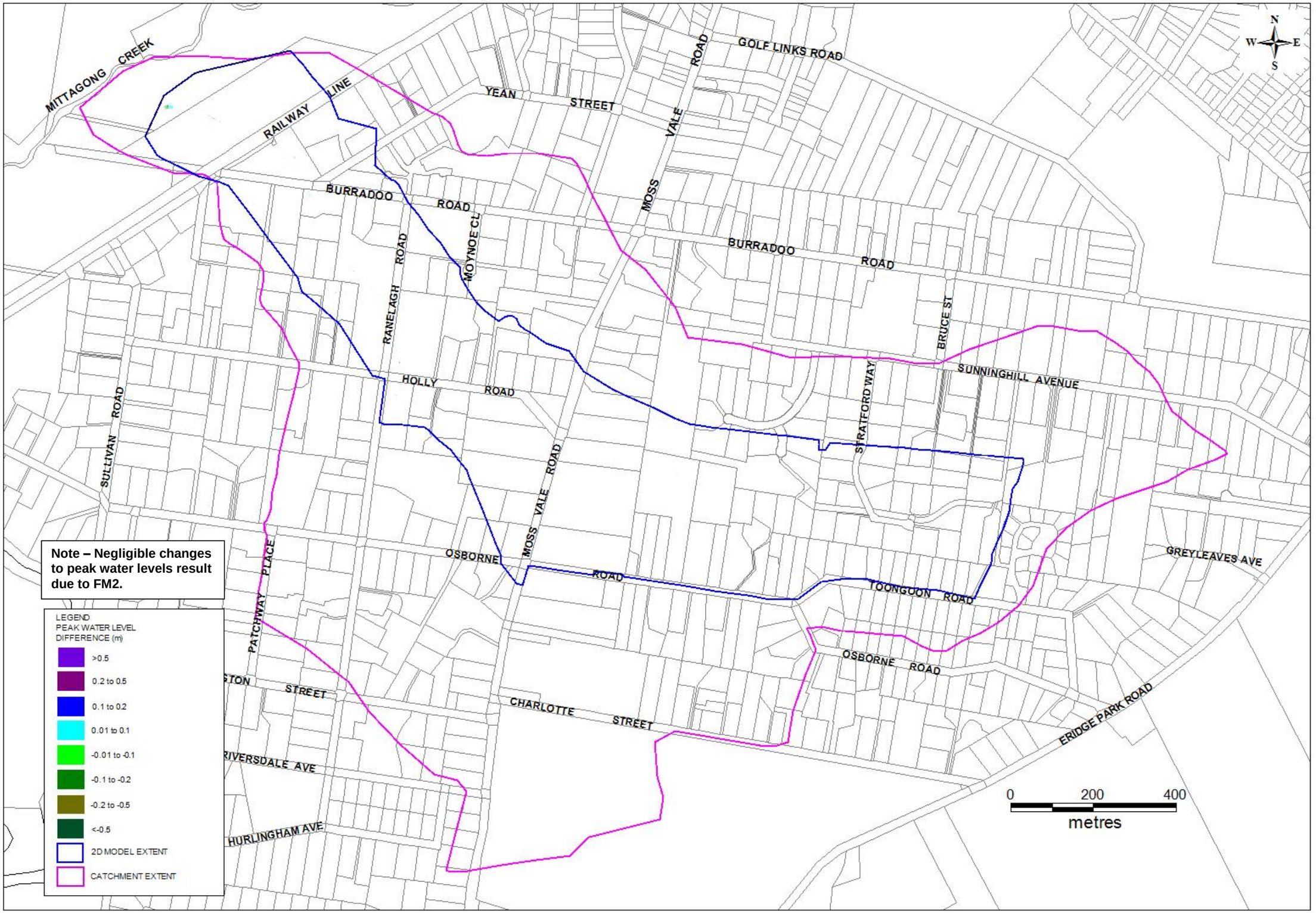


Figure 9-4 FM2 Water Level Impacts – 1% AEP

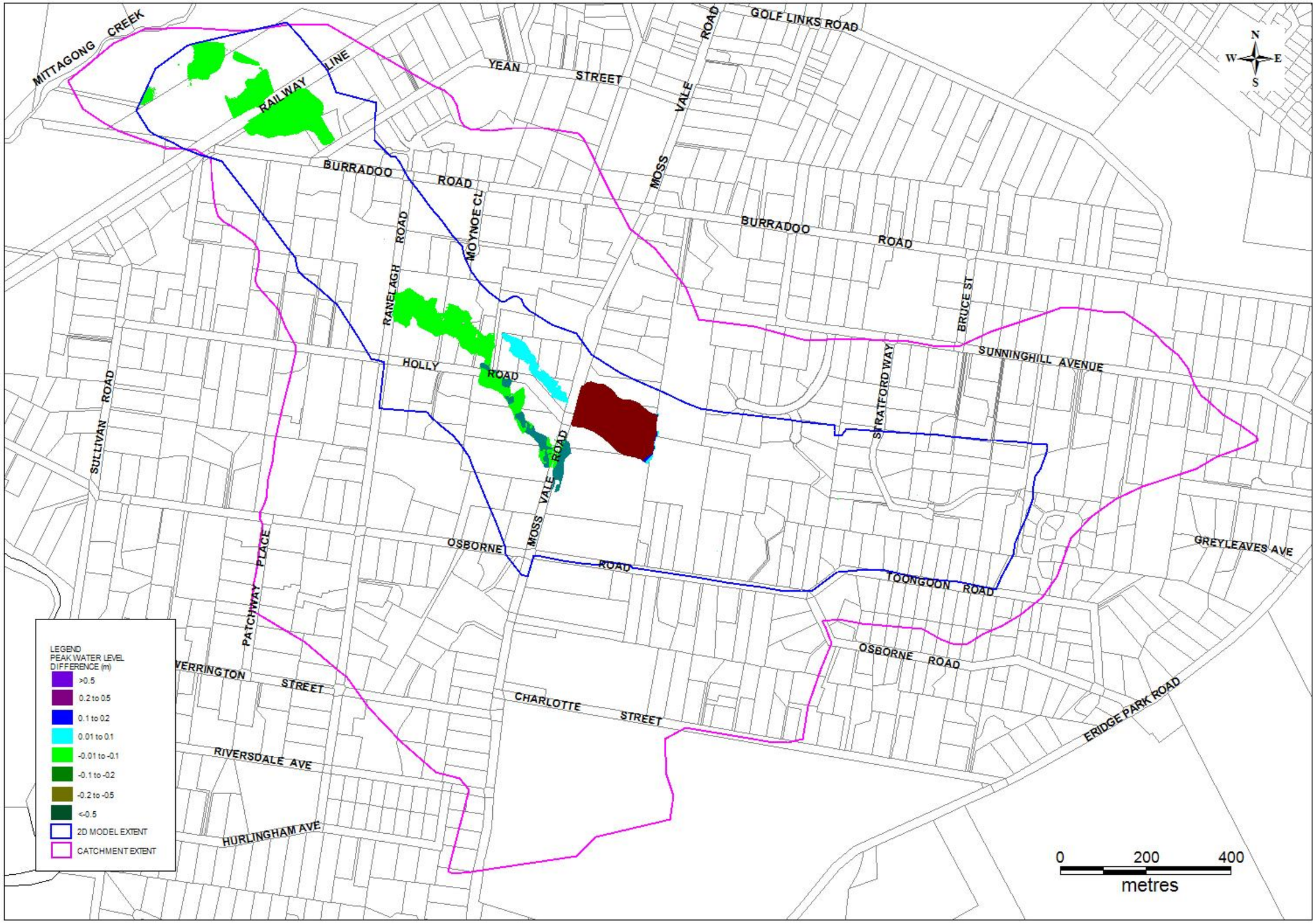


Figure 9-5 FM2 Water Level Impacts – PMF

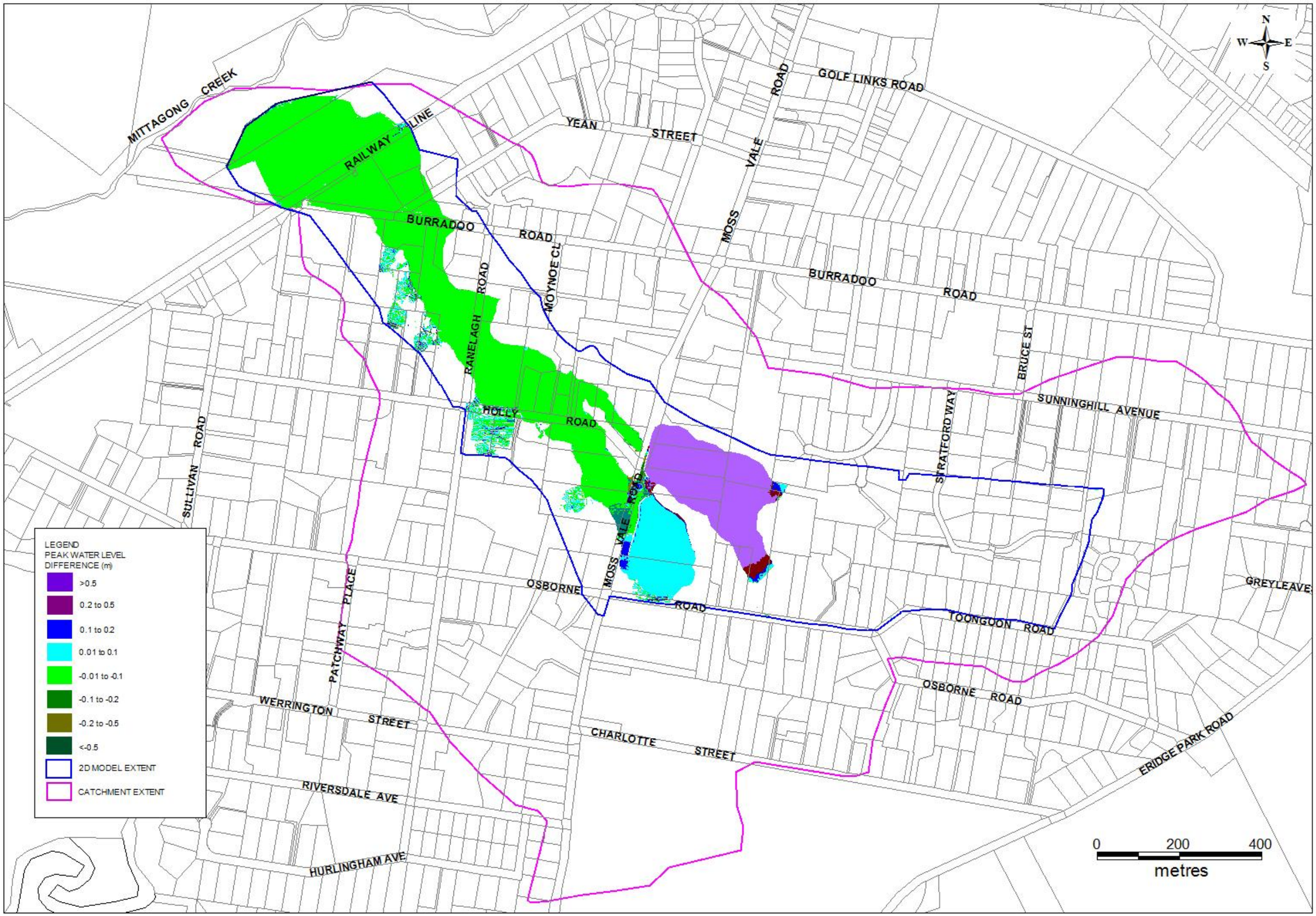


Figure 9-6 Design Layout of FM3

Figure 9-7 FM3 Water Level Impacts – 20% AEP

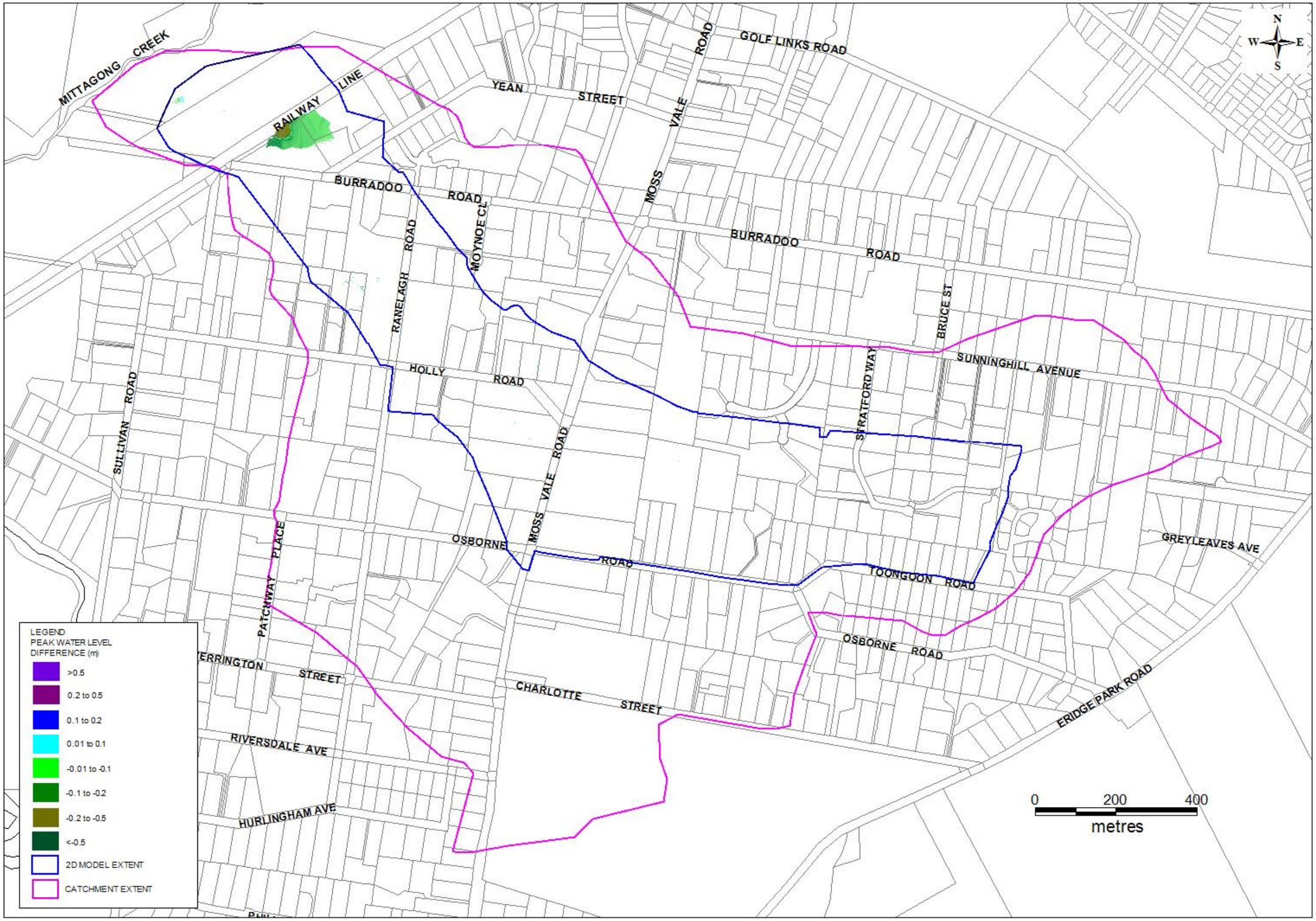


Figure 9-8 FM3 Water Level Impacts – 1% AEP

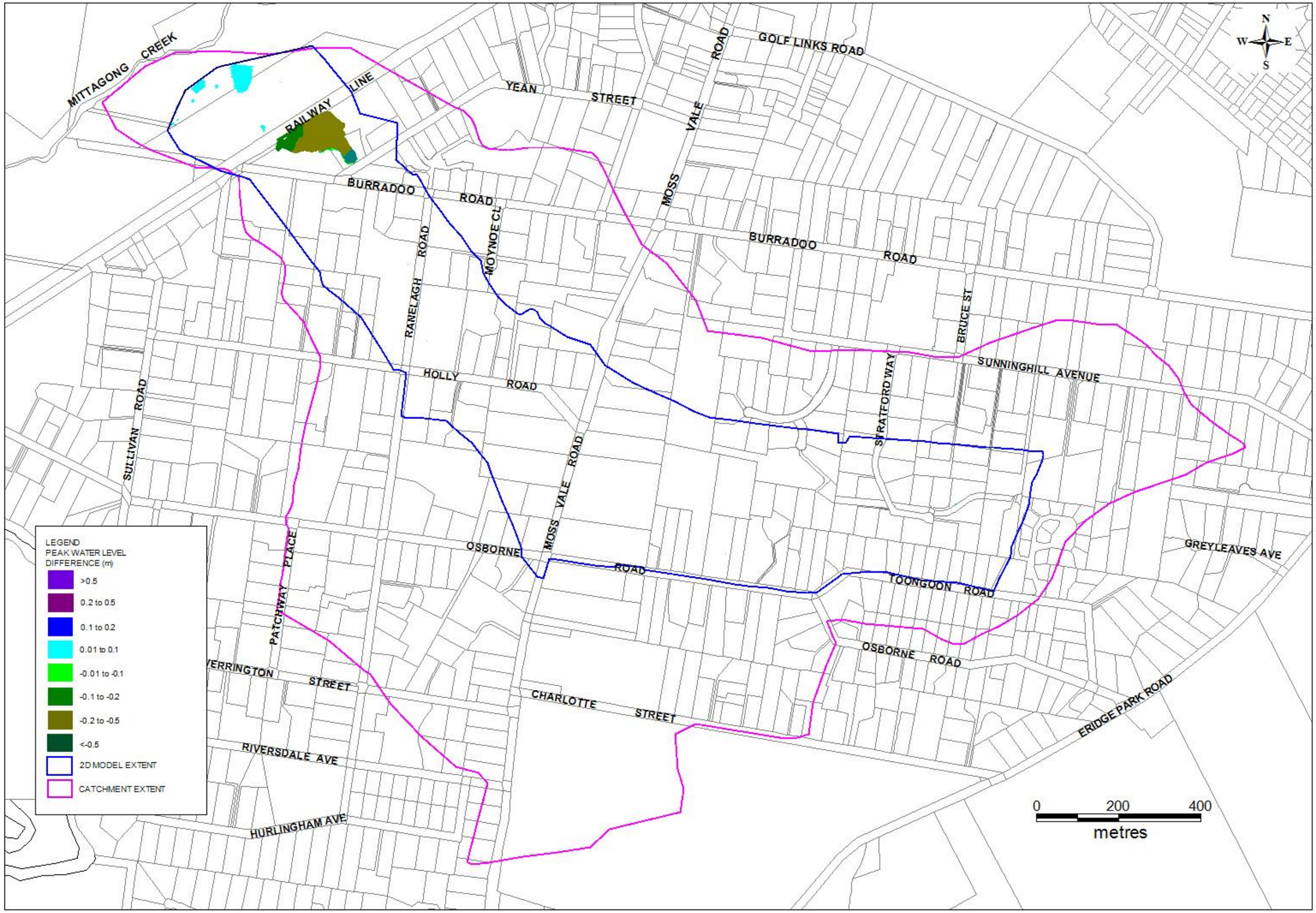


Figure 9-9 FM3 Water Level Impacts – PMF

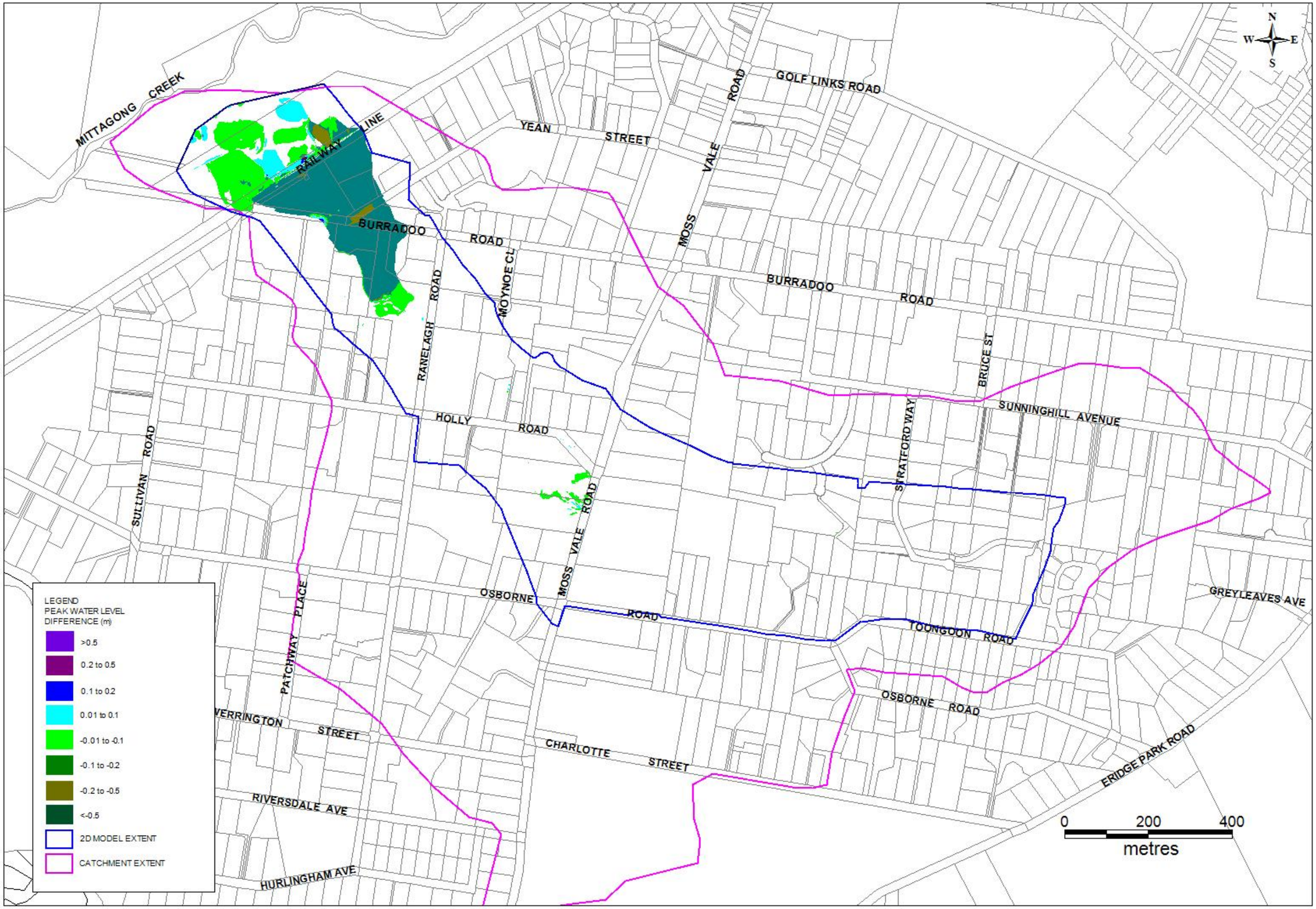


Figure 9-10 FM3 Peak Water Depths – 1% AEP

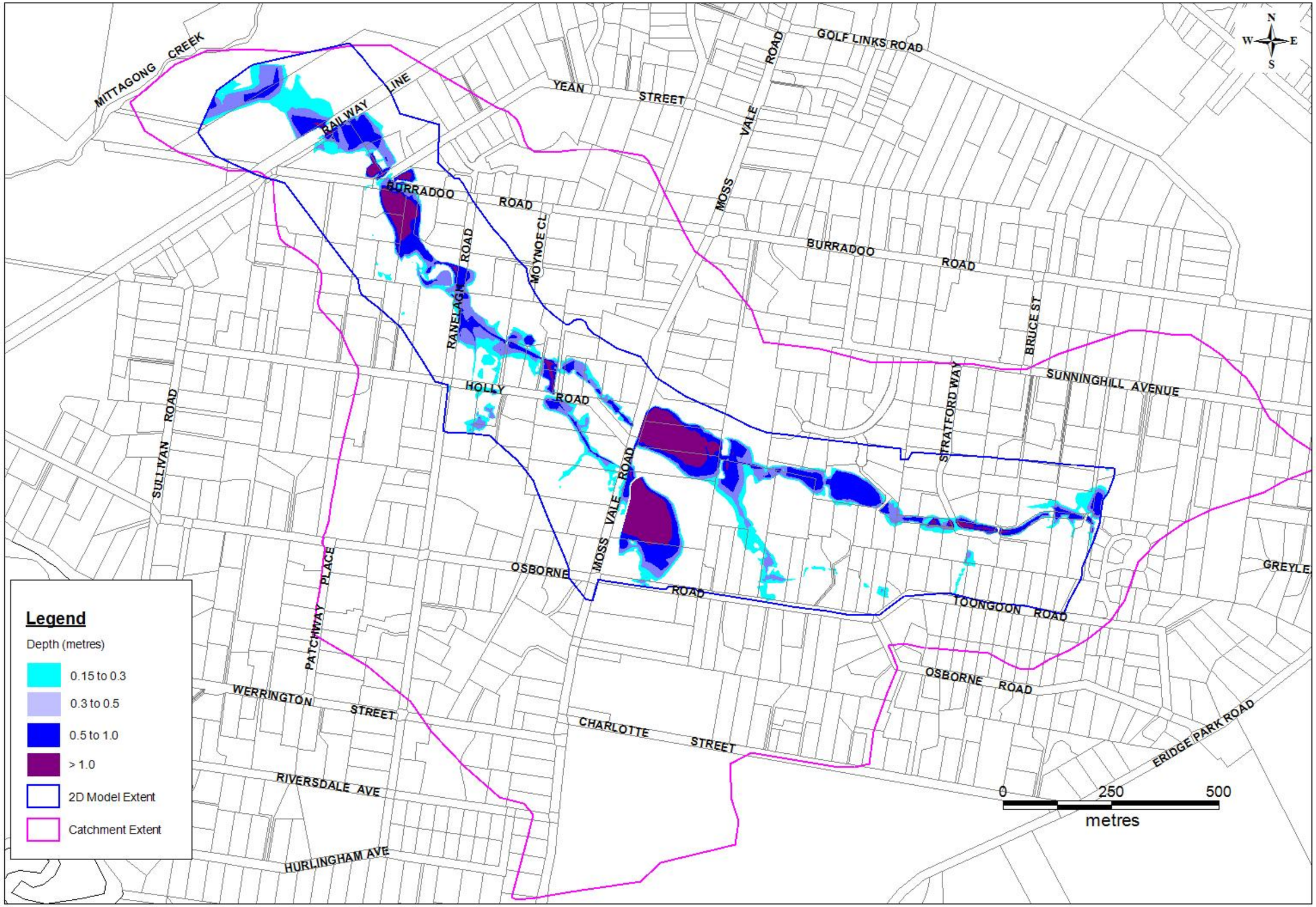


Figure 9-11 Design Layout of FM4

Figure 9-12 FM4 Water Level Impacts – 20% AEP

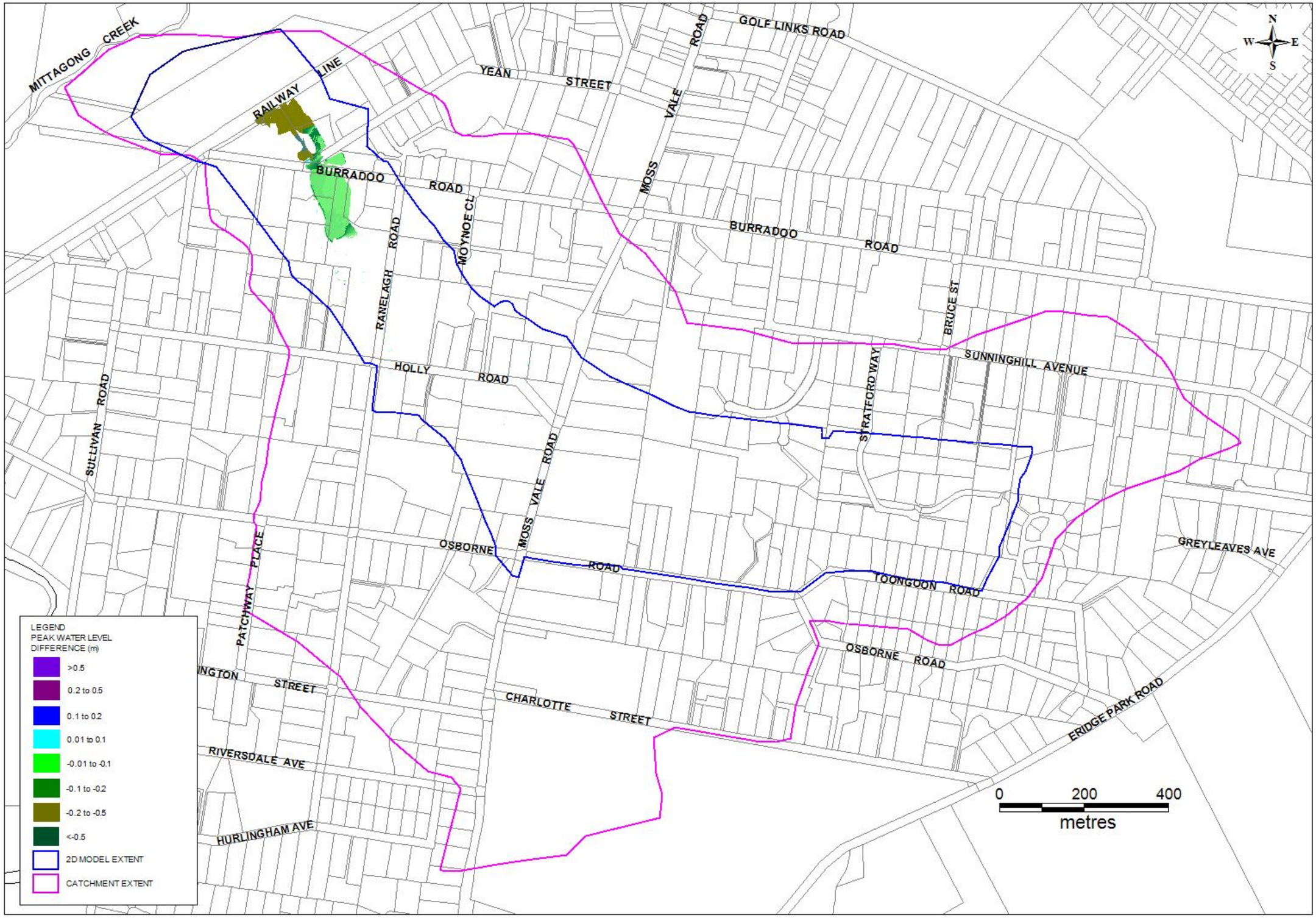


Figure 9-13 FM4 Water Level Impacts – 1% AEP

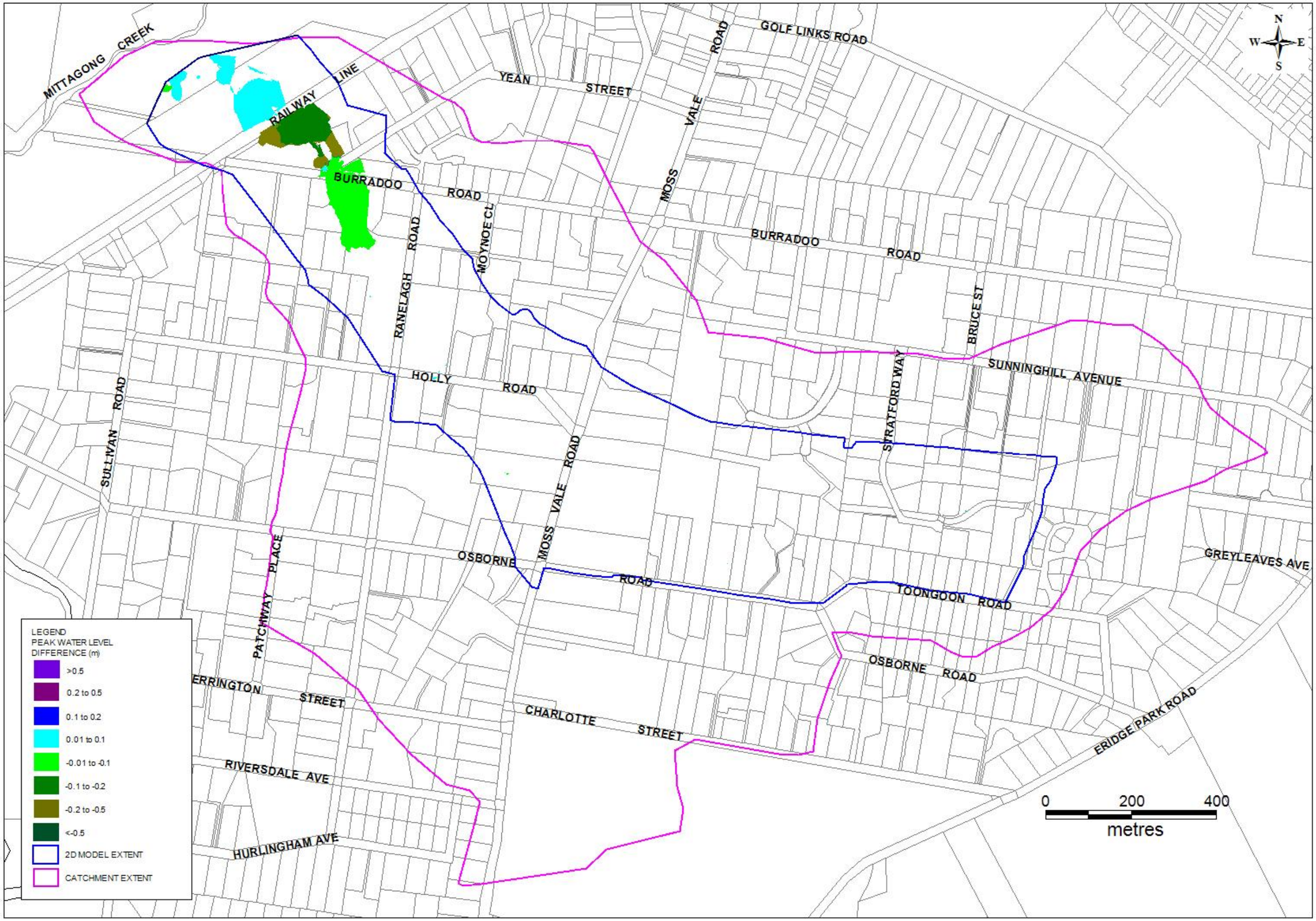


Figure 9-14 FM4 Water Level Impacts – PMF

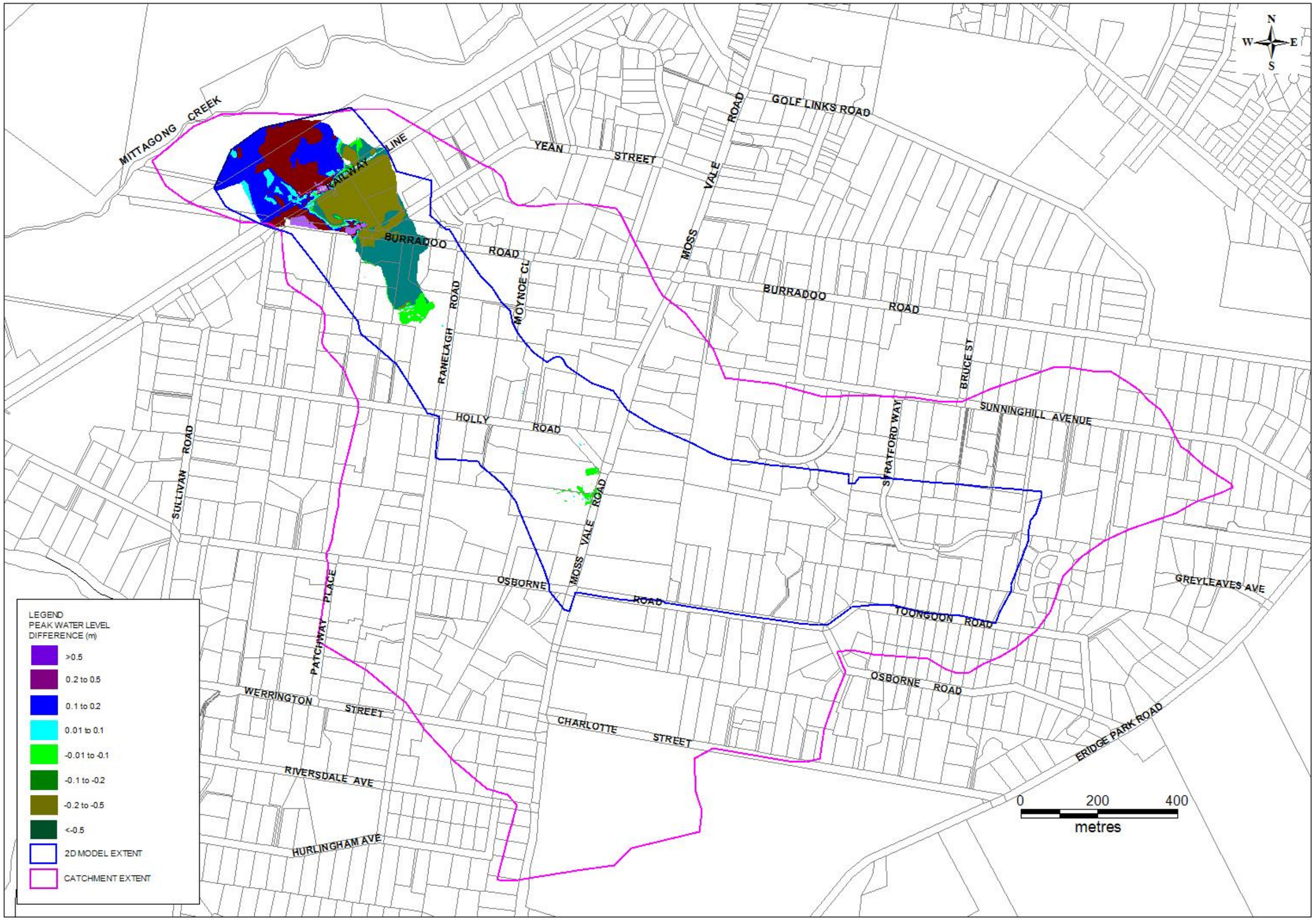


Figure 9-15 FM4 Peak Water Depths – 1% AEP

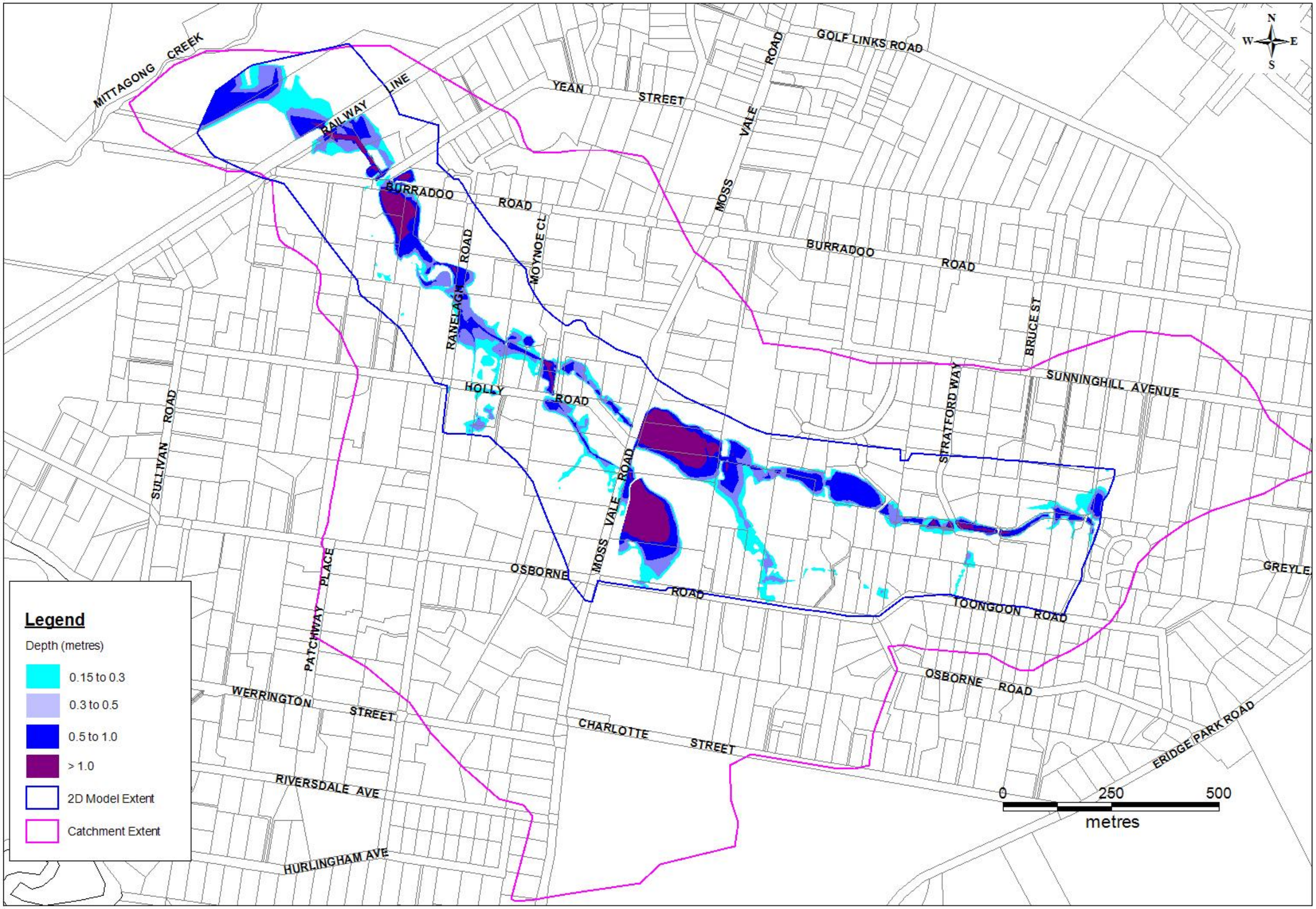


Figure 9-16 Design Layouts of FM5

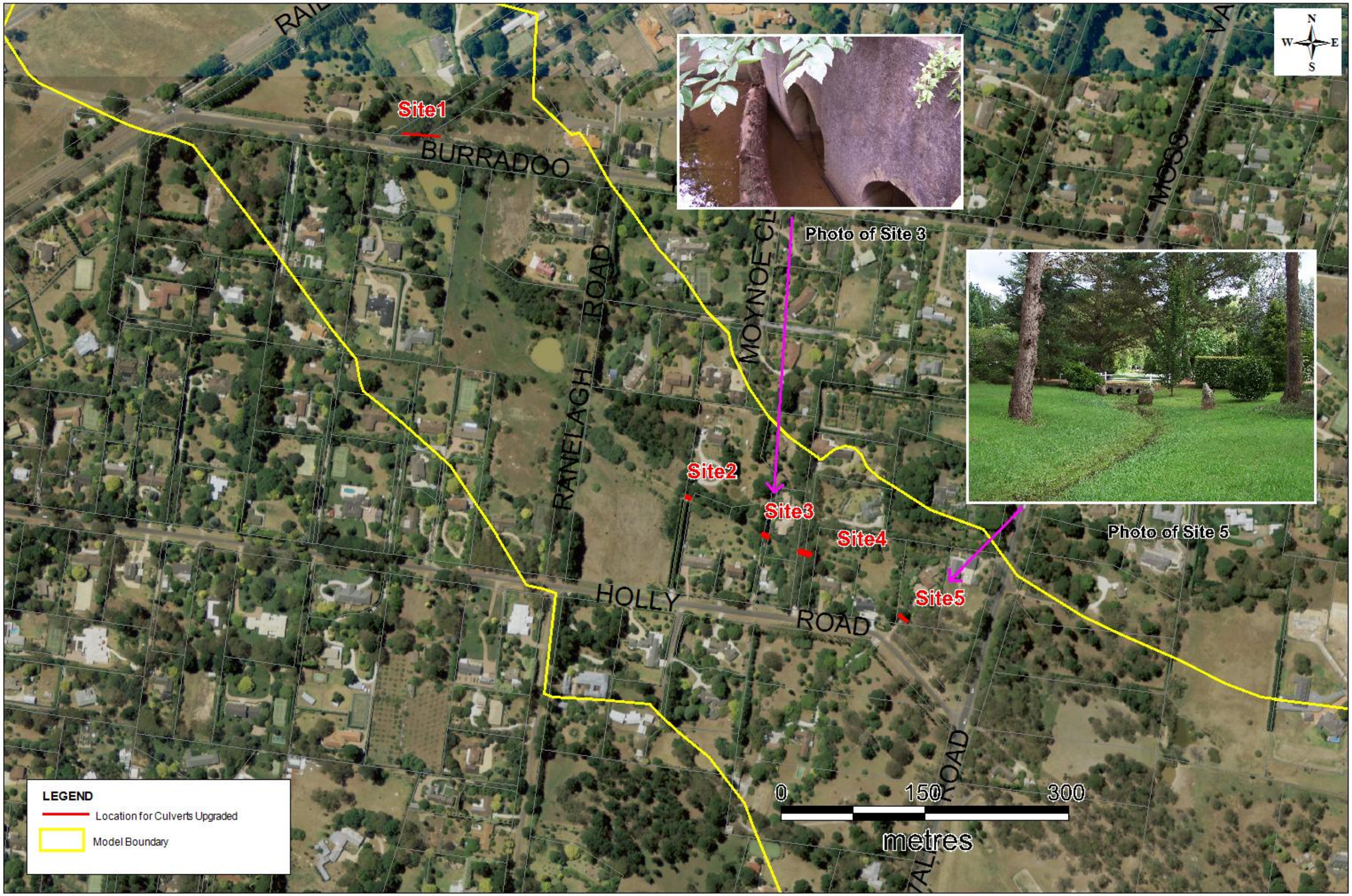


Figure 9-17 FM5 Water Level Impacts – 20% AEP

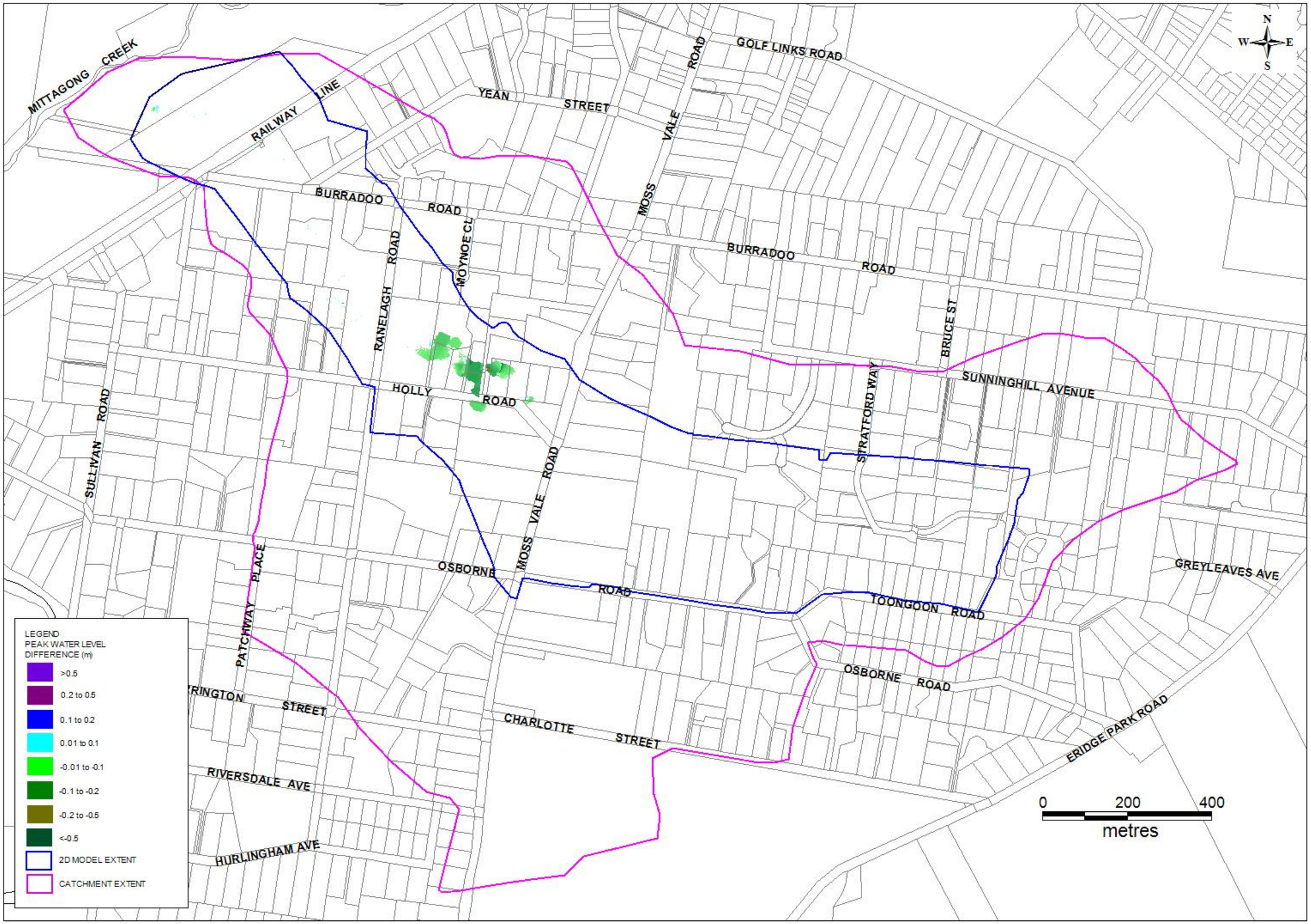


Figure 9-18 FM5 Water Level Impacts – 1% AEP

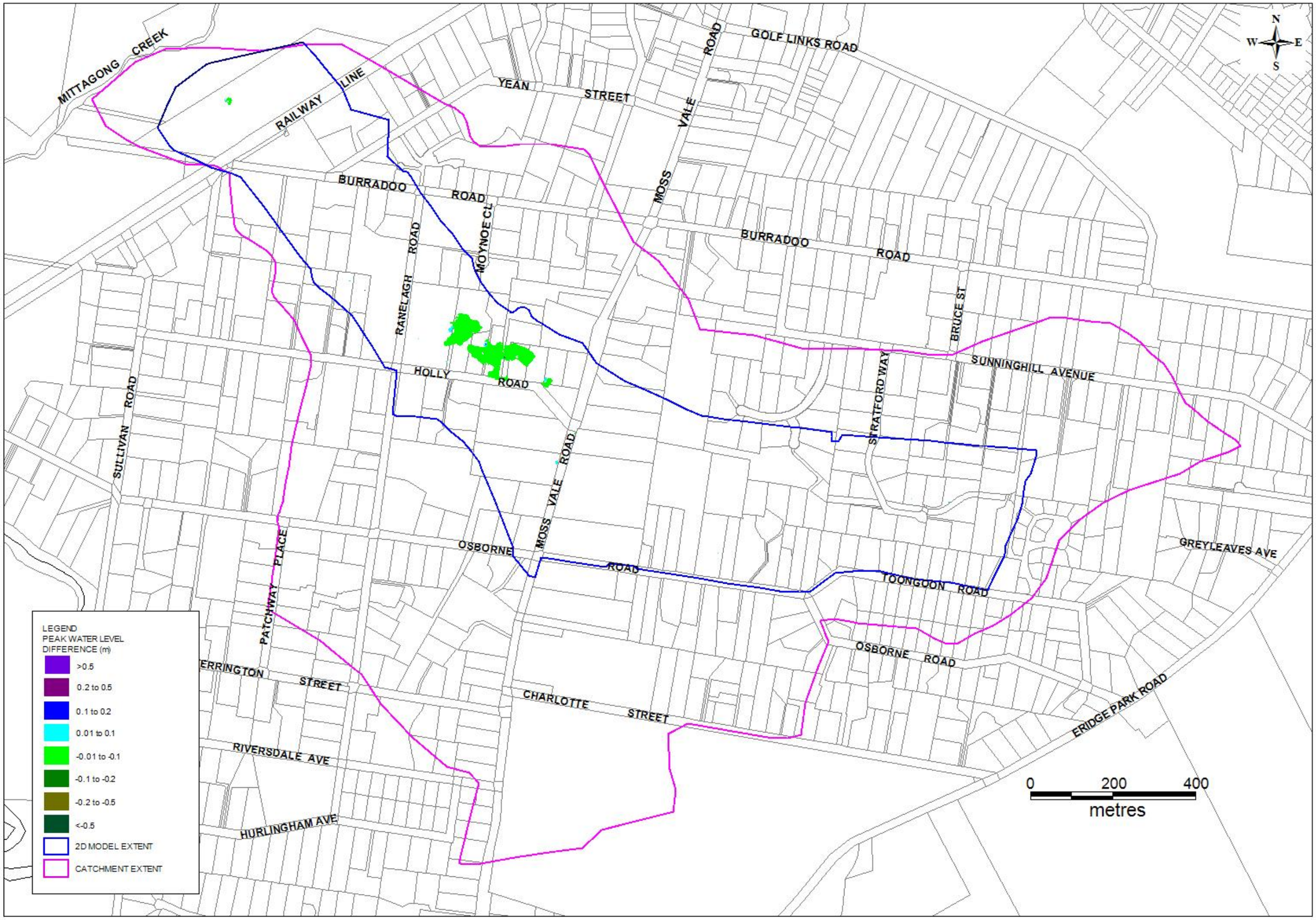


Figure 9-19 FM5 Water Level Impacts – PMF

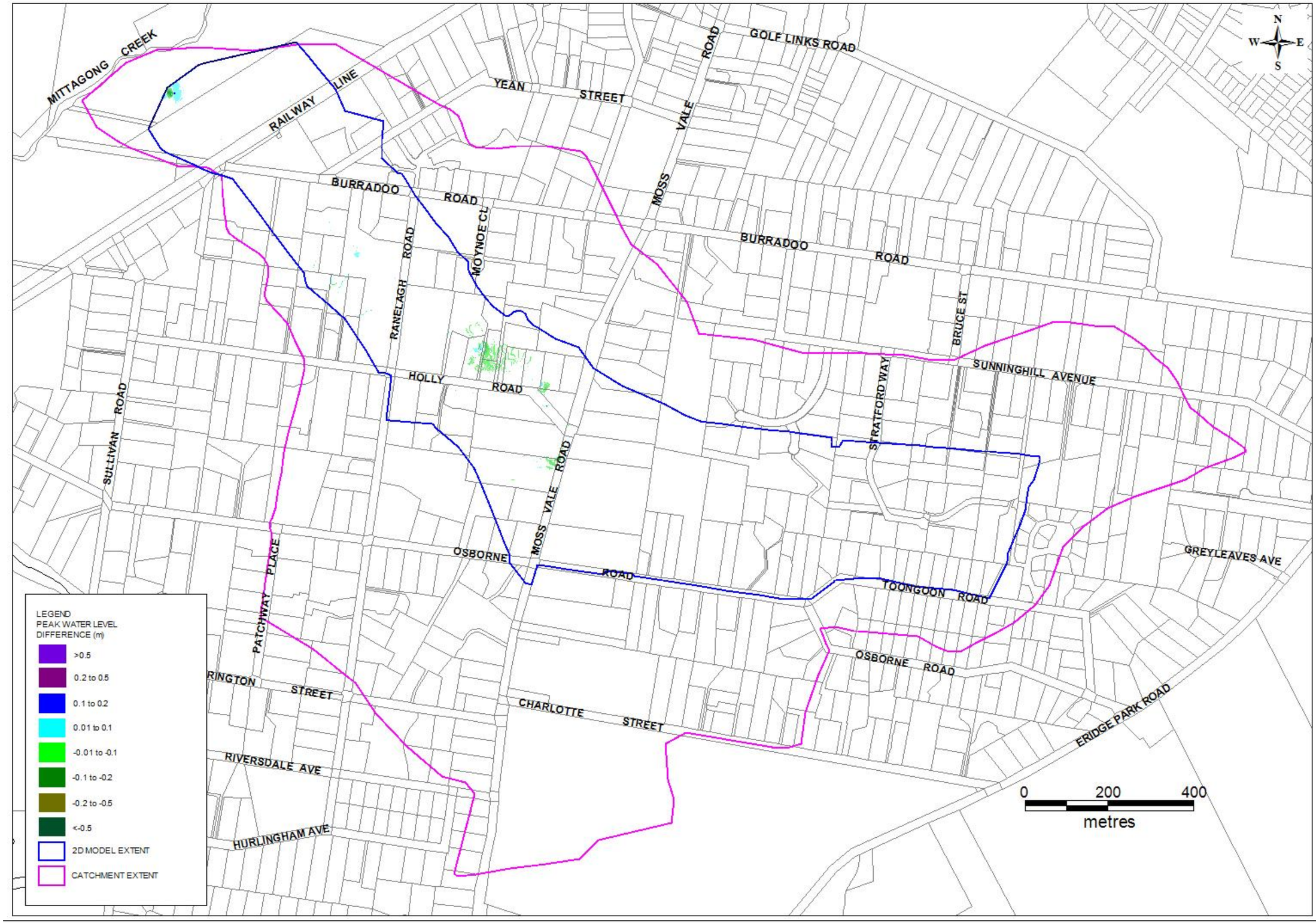


Figure 9-20 Design Layouts of FM6 & FM7

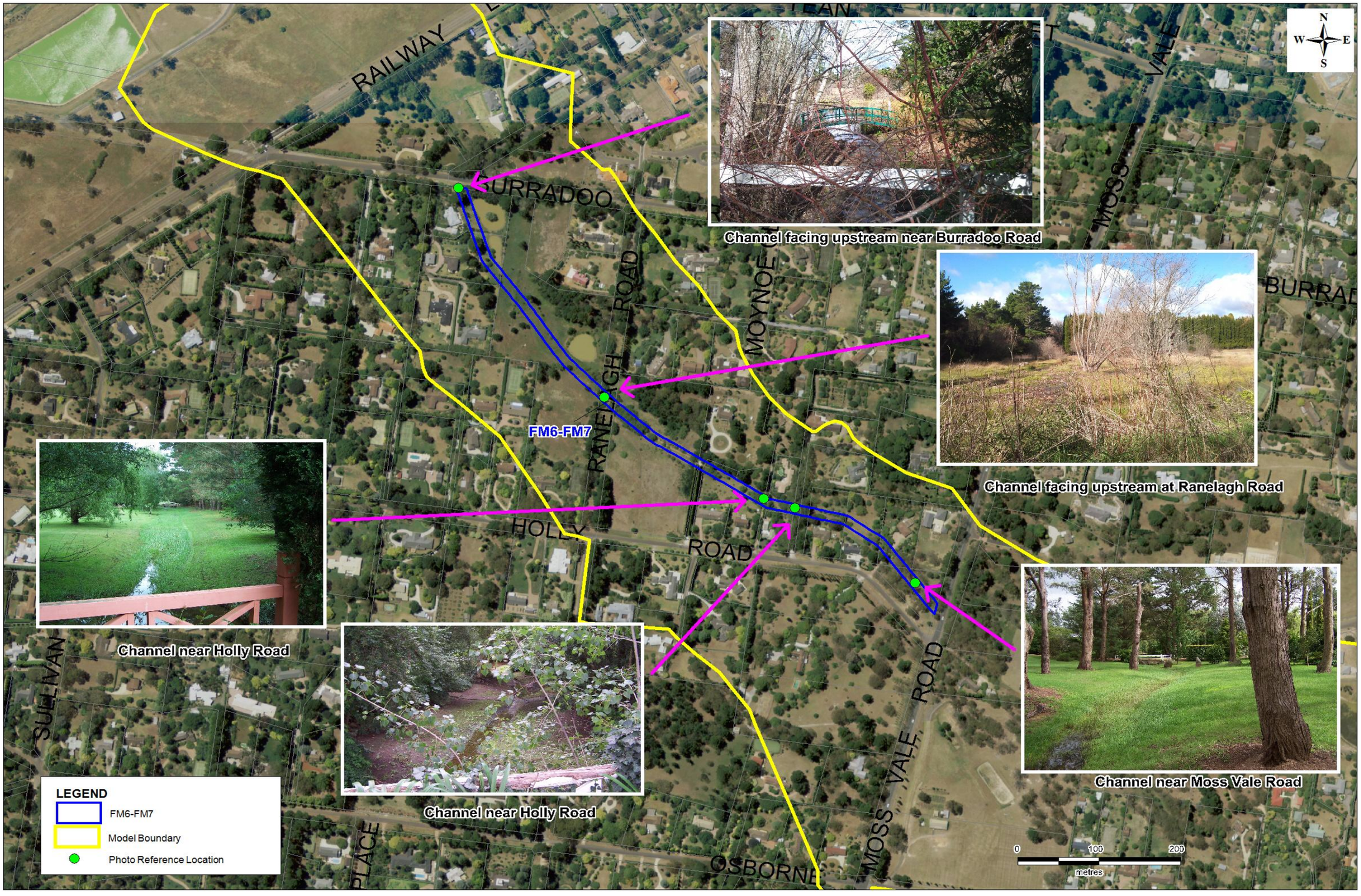


Figure 9-21 FM6 Water Level Impacts – 20% AEP

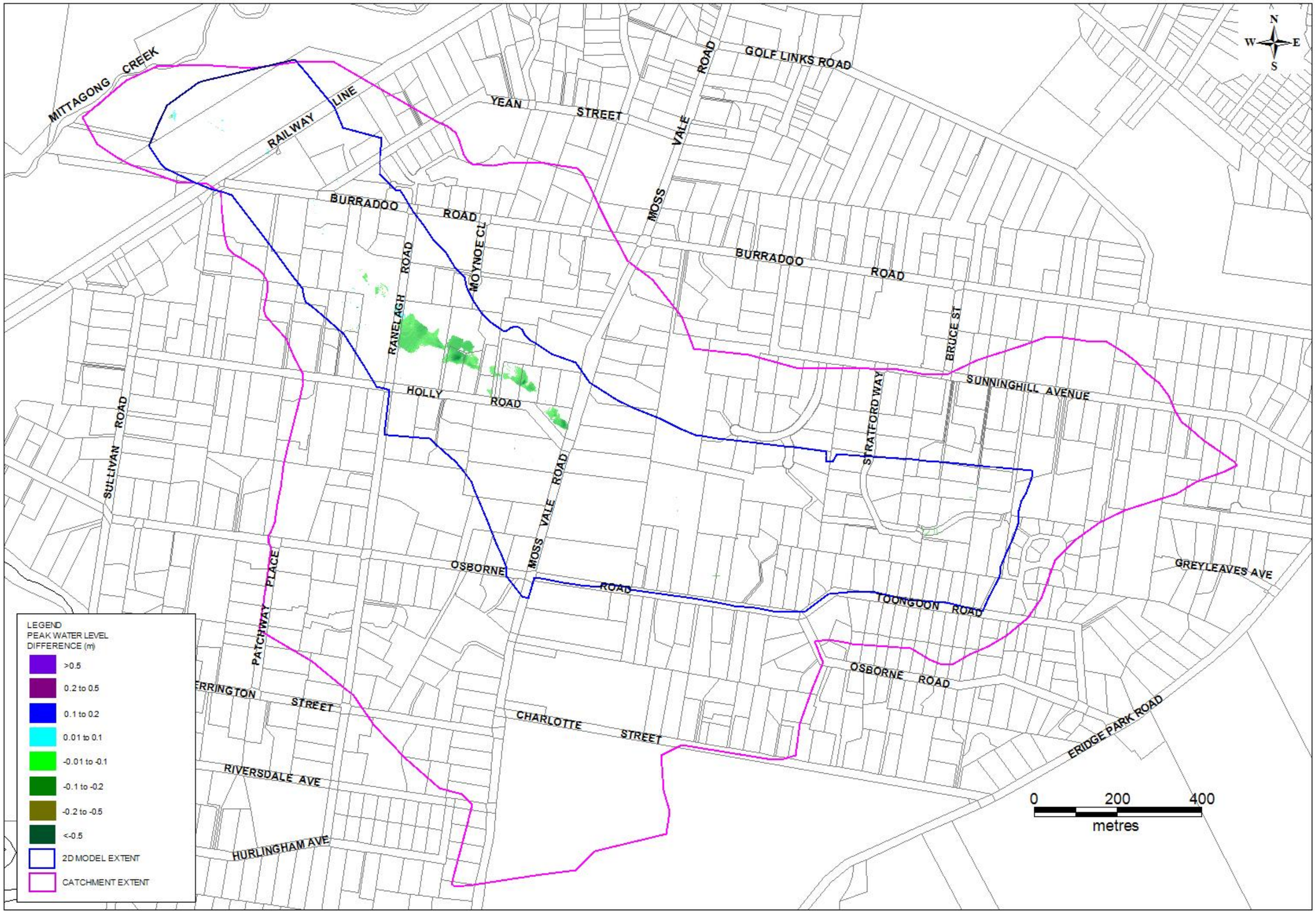


Figure 9-22 FM6 Water Level Impacts – 1% AEP

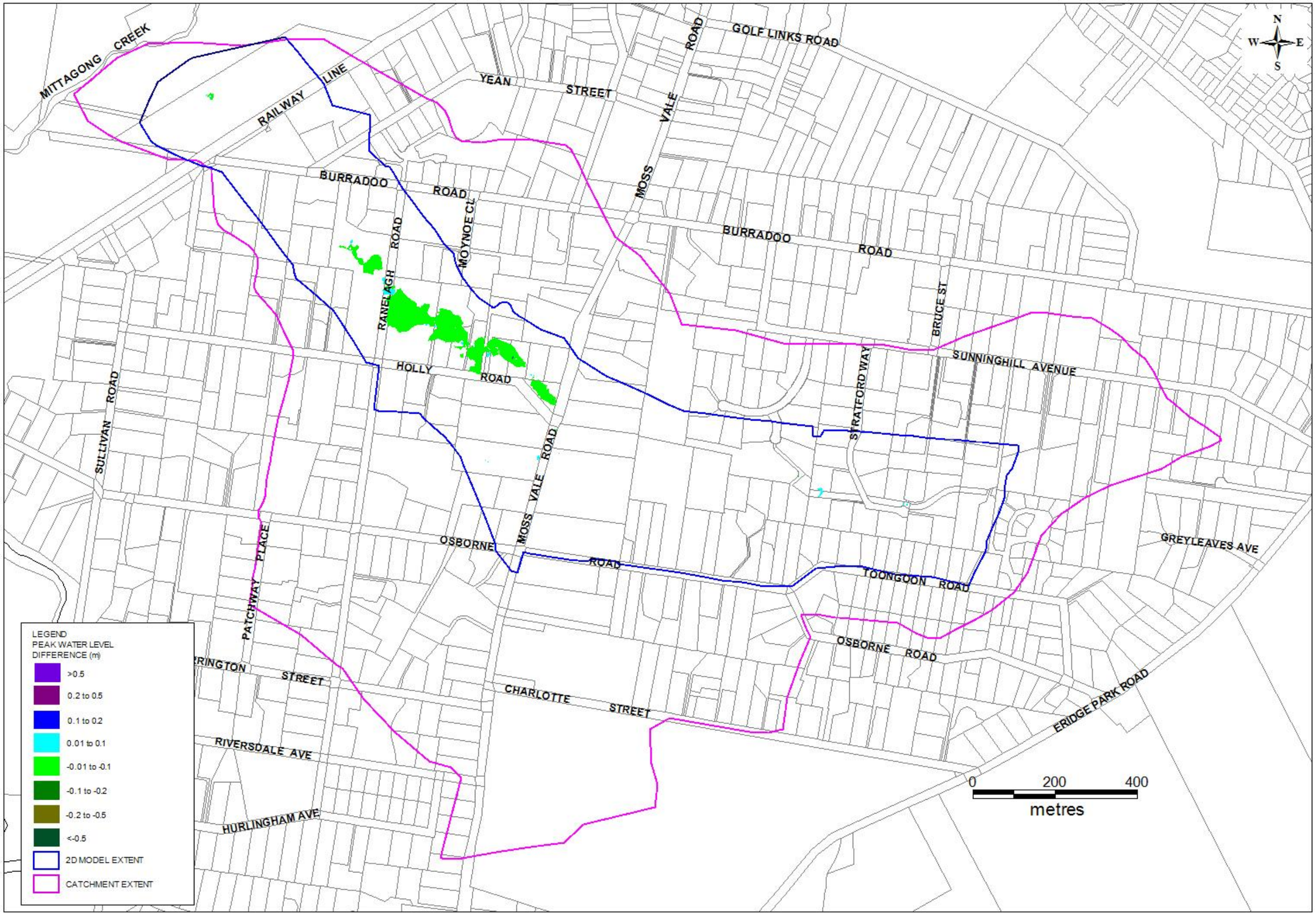


Figure 9-23 FM6 Water Level Impacts – PMF

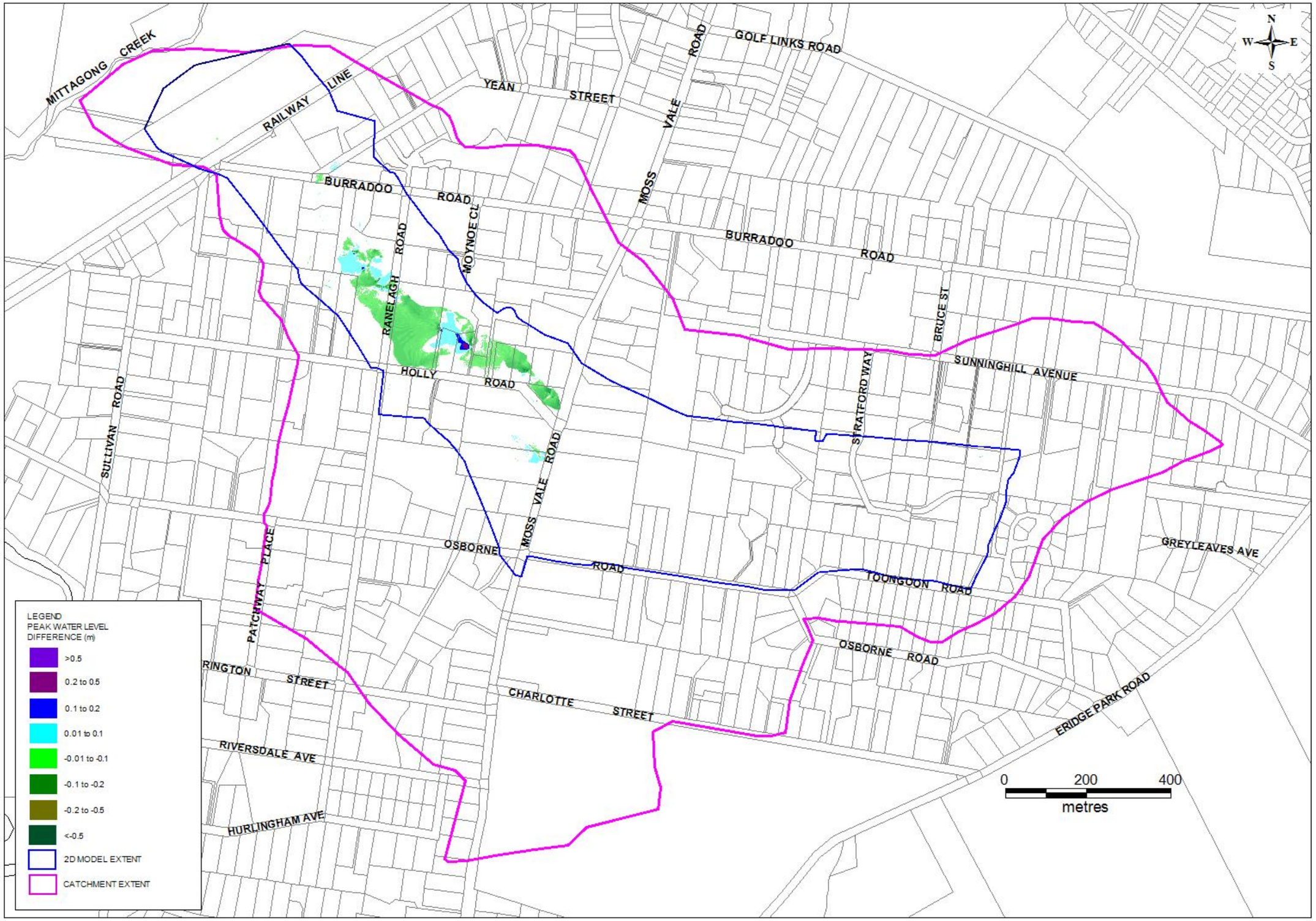


Figure 9-24 FM7 Water Level Impacts – 20% AEP

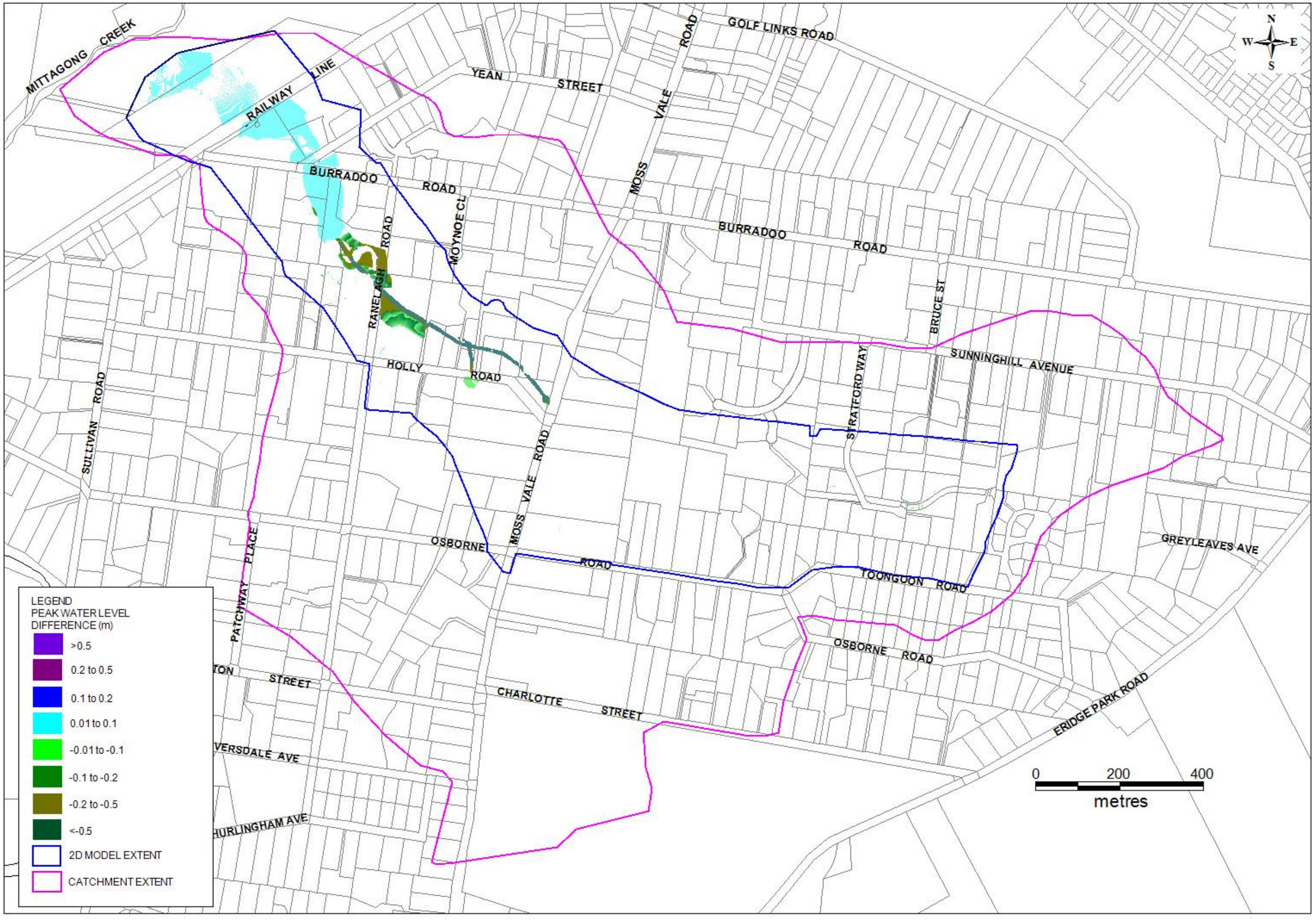


Figure 9-25 FM7 Water Level Impacts – 1% AEP

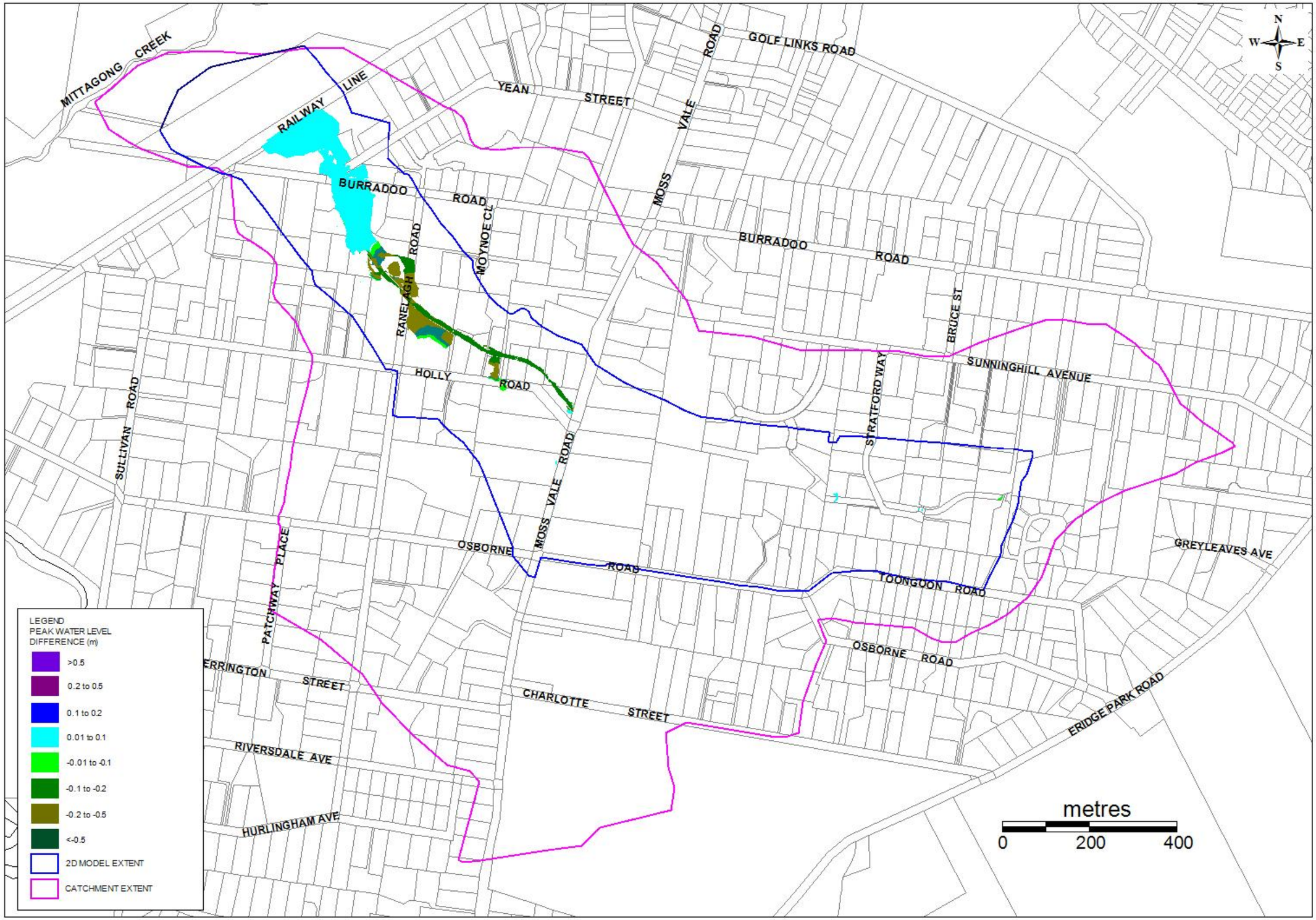


Figure 9-26 FM7 Water Level Impacts – PMF

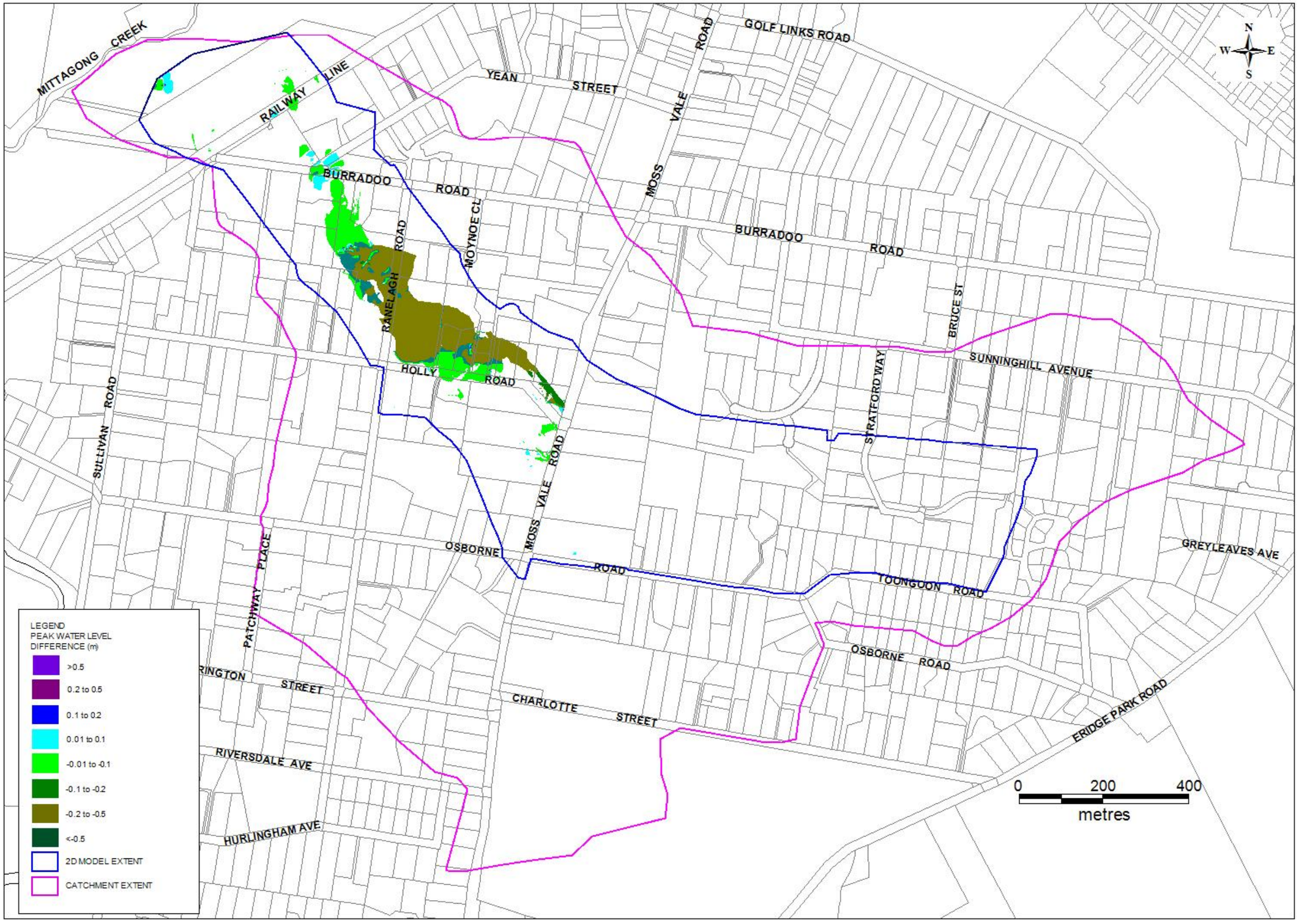


Figure 9-27 FM7 Peak Water Depths – 1% AEP

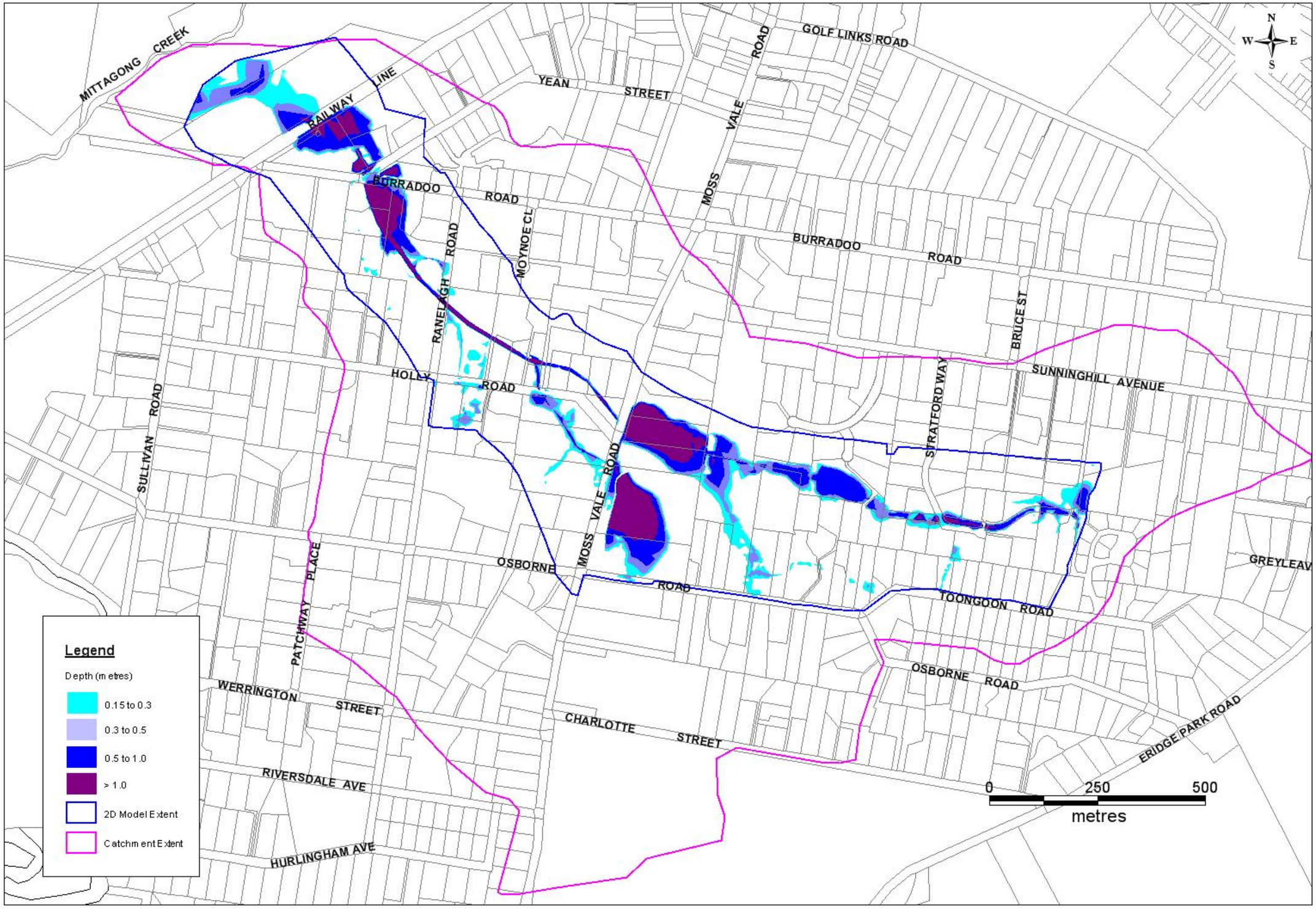


Figure 9-28 Design Layout of FM8

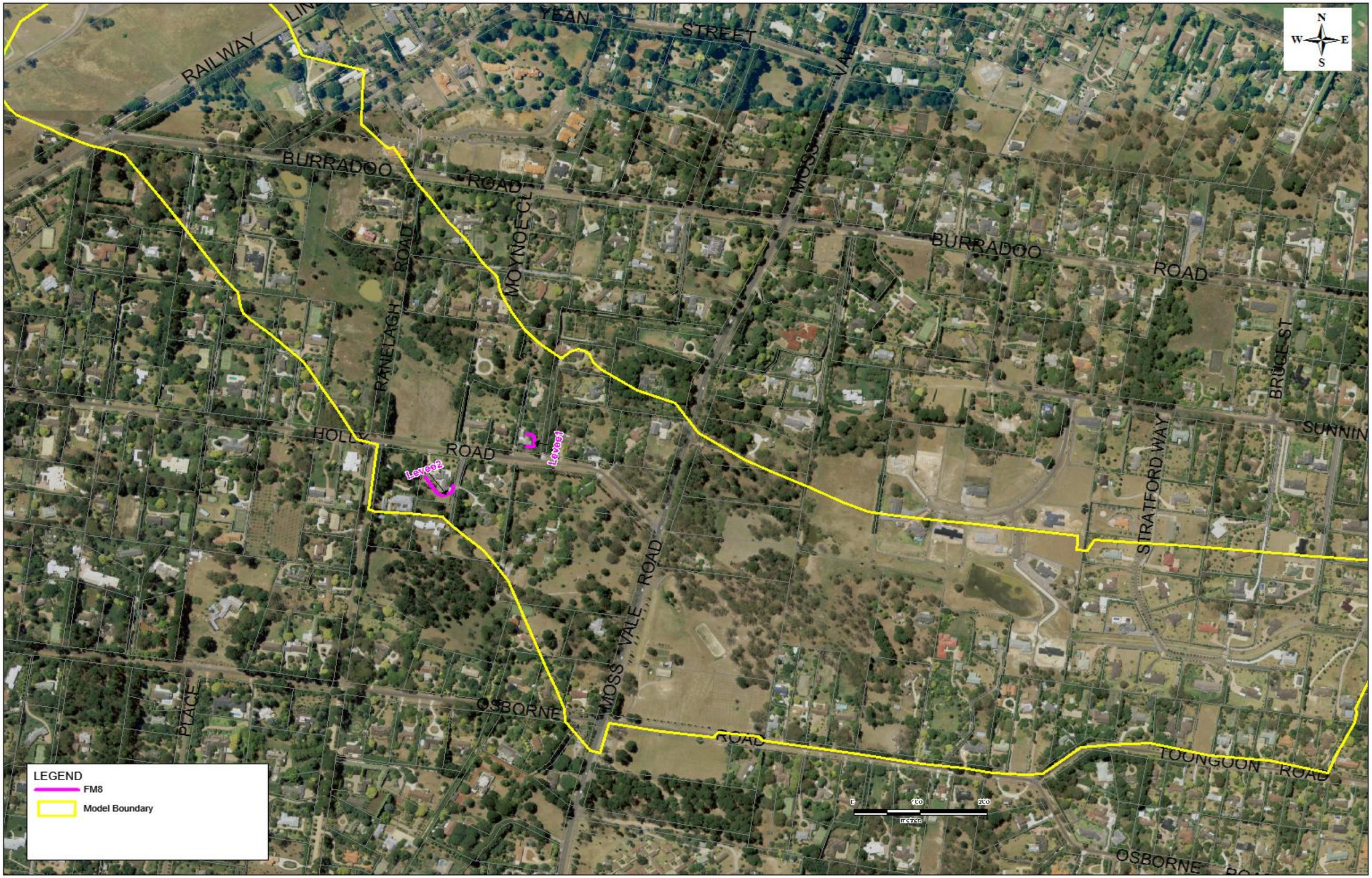


Figure 9-29 FM8 Water Level Impacts – 20% AEP

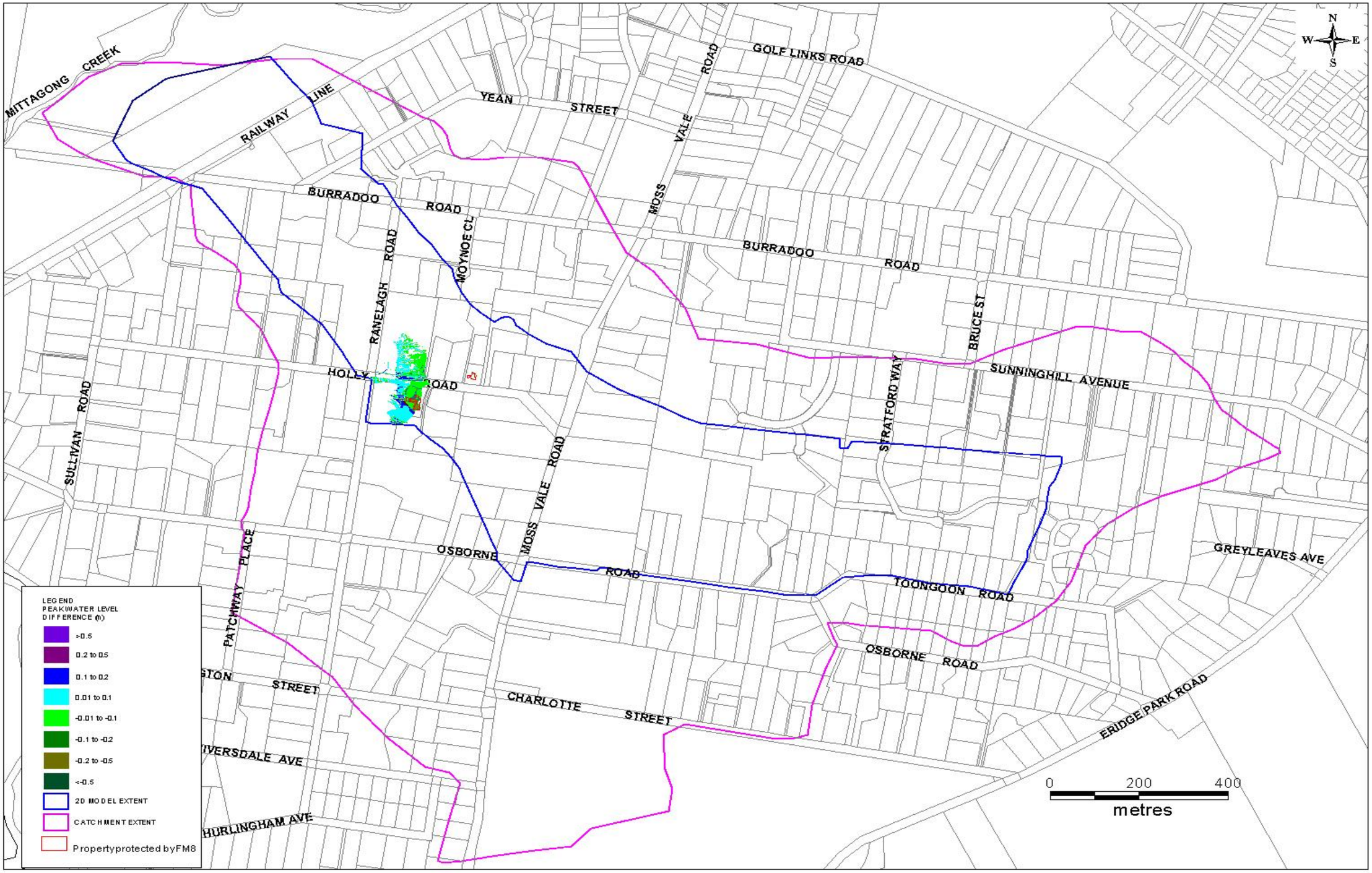


Figure 9-30 FM8 Water Level Impacts – 1% AEP

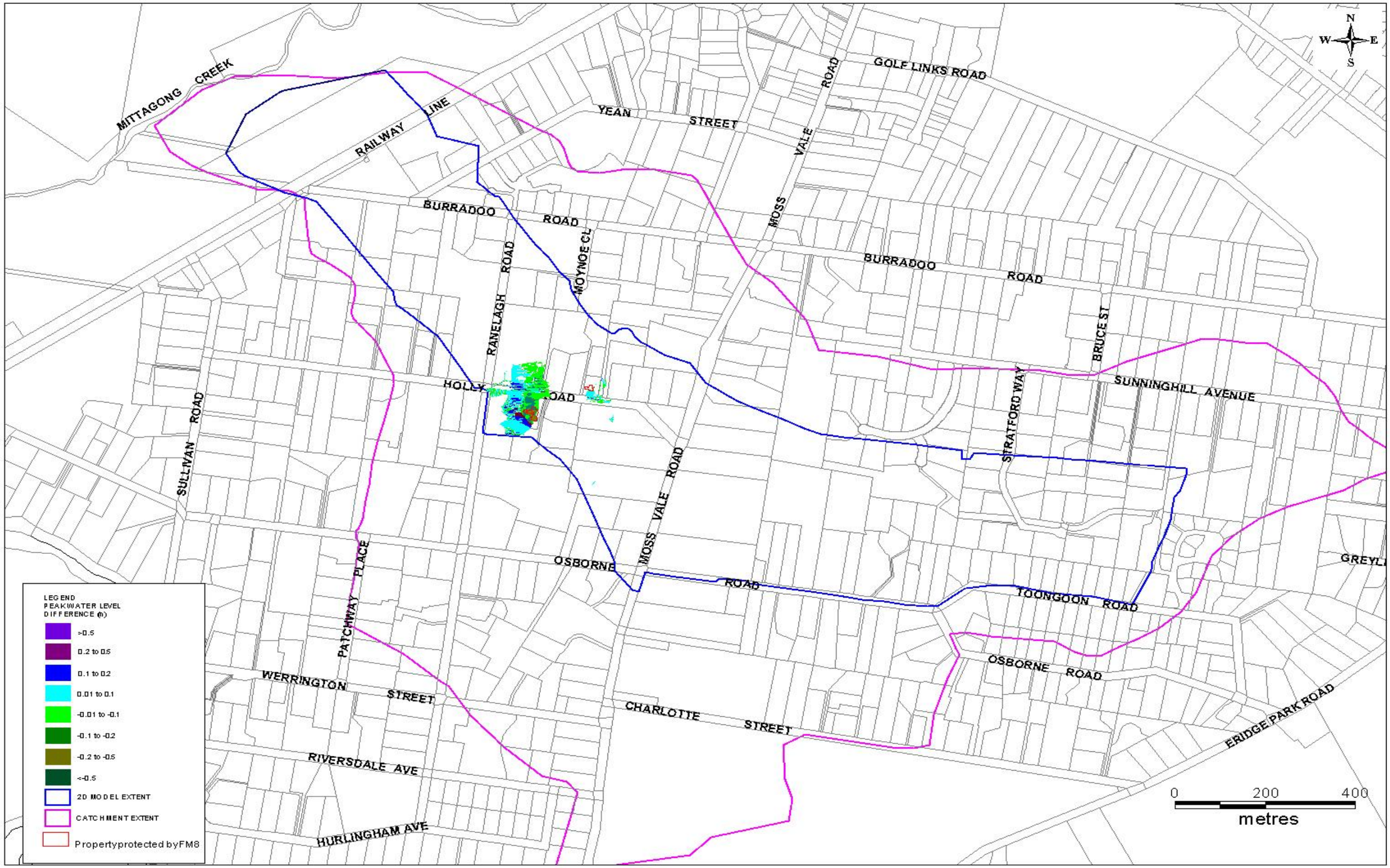


Figure 9-31 FM8 Water Level Impacts – PMF

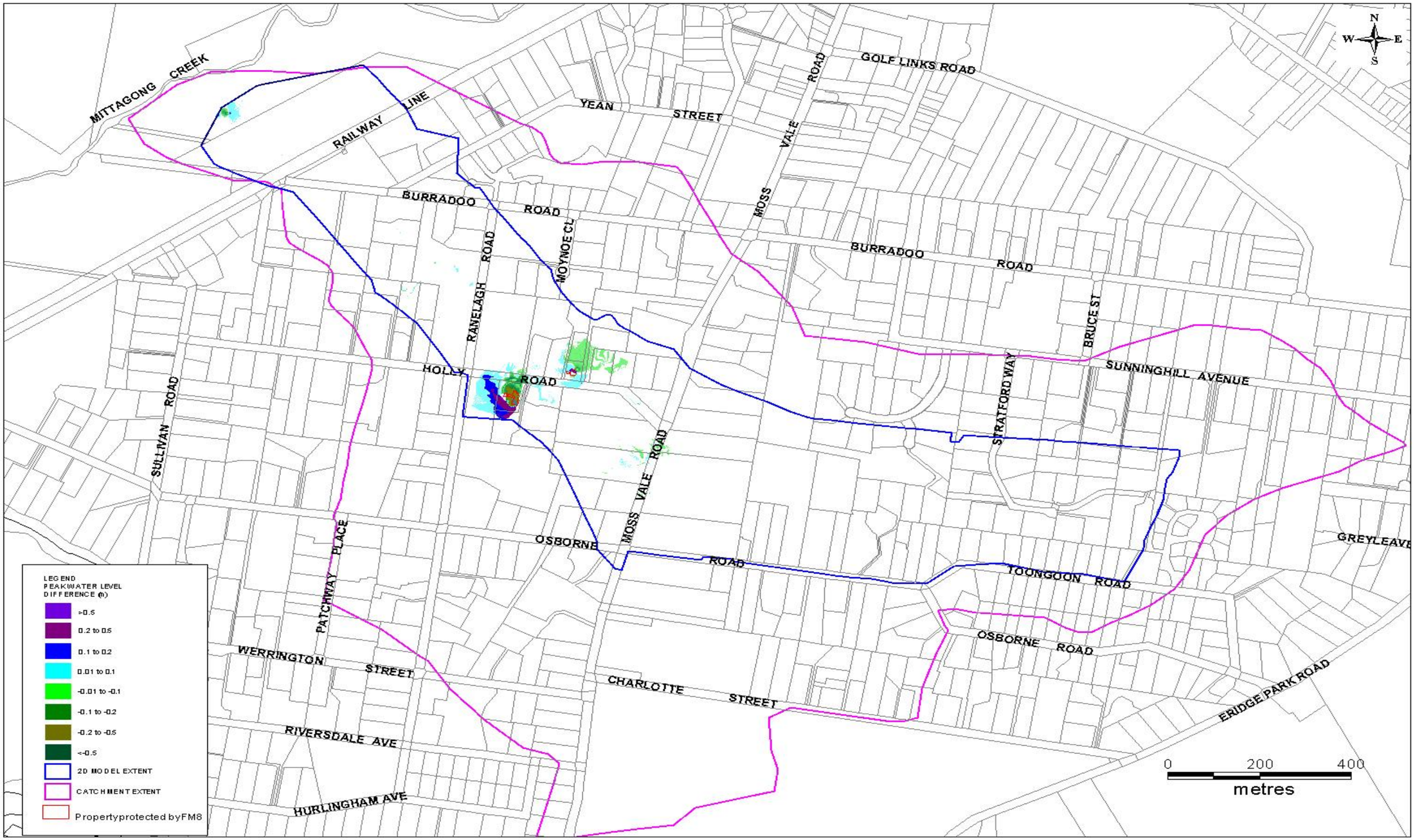
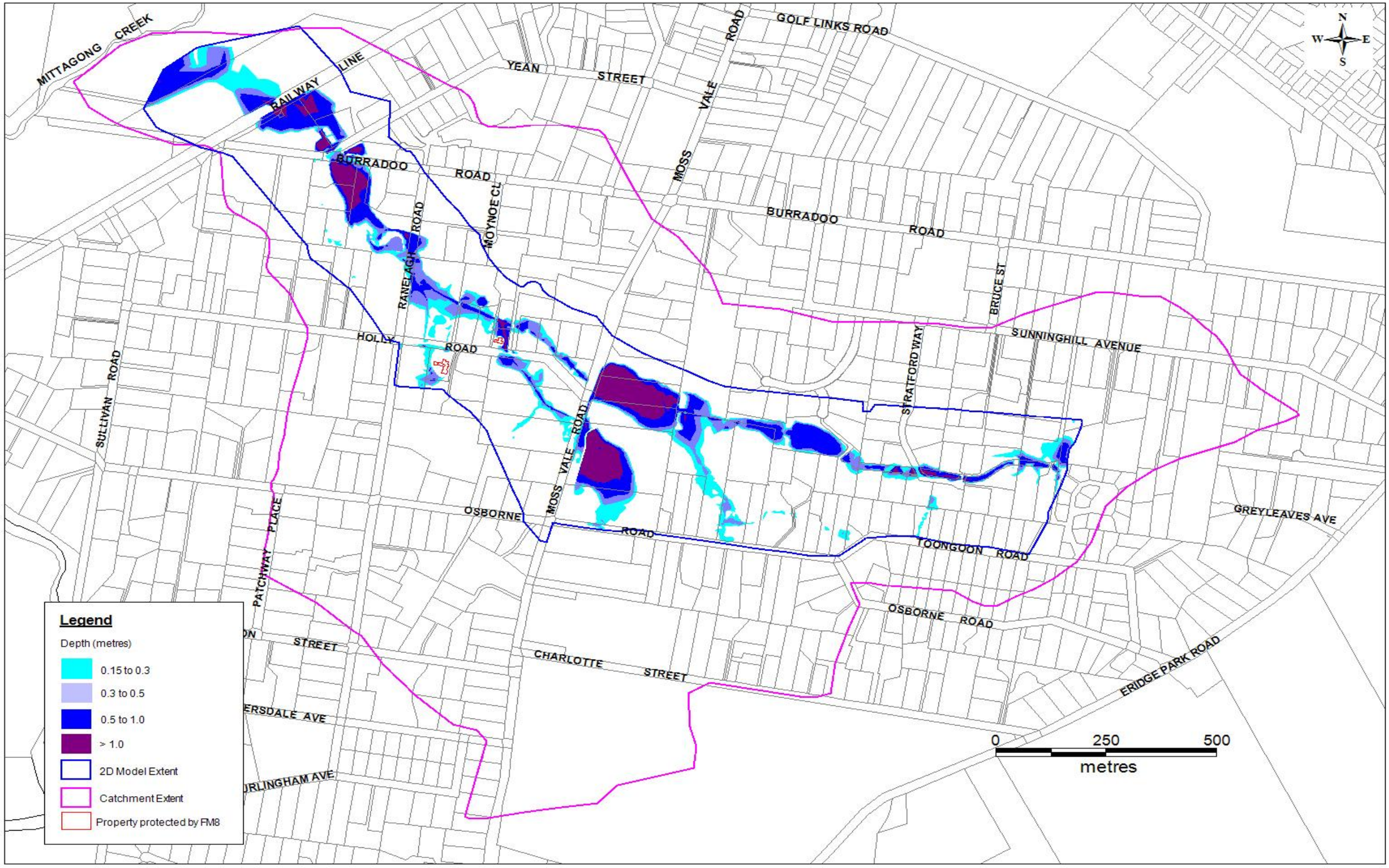


Figure 9-32 FM8 Peak Water Depth – 1% AEP



Burradoo BU2 Catchment
Floodplain Risk Management Study

APPENDIX B
FLOOD MODIFICATION MEASURES COST ESTIMATES

Cardno
Shaping the Future

W4962 - Burradoo

Cardno Shaping the Future

Cost Estimate
Opt: FM2
Formalise Detention Basin at Cnr of Holly & Moss Vale Road

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**70,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing and grubbing of wall area	3,375	sq. m	10	33,750
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	506.25	cu. m	25	12,656
2.3	Dispose of excess topsoil (nominal 10% allowance)	50.625	cu. m	60	3,038
	SUBTOTAL				**49,444**
3.0	**EARTHWORKS**				
3.1	Construction of earthern basin wall	3,510	cu.m	45	157,950
3.2	Disposal of excess cut (assuming 80% of total excavation)	2,808	item	60	168,480
	SUBTOTAL				**326,430**
4.0	**BASIN DRAINAGE**				
4.1	Construction of overflow path with erosion protection	200	sq.m	40	8,000
4.2	Construction of basin outlet structure	1	item	15000	15,000
	SUBTOTAL				**23,000**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	3,375	sq. m	20	67,500
	SUBTOTAL				**67,500**
	CONSTRUCTION SUB-TOTAL				**536,374**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**268,187**
	CONSTRUCTION TOTAL, excluding GST				**804,561**
	GST				**80,456**
	CONSTRUCTION TOTAL, including GST				**885,017**
	CONSTRUCTION TOTAL, rounded				**885,100**

DISCLAIMER:

1. This estimate of cost is provided in good faith using information available at this stage. This estimate of cost is not guaranteed. Cardno (NSW) will not accept liability in the event that actual costs exceed the estimate.

NOTES:

1. Estimate does not include Consultant's fees, including design or project management
2. Estimate / rates in 2012 dollars and does not allow for inflation

W4962 - Burradoo

Cardno
Shaping the Future

Cost Estimate
Opt: FM3
Railway Culvert Upgrade

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**312,900**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of works area	1,040	sq. m	10	10,400
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	156	cu. m	25	3,900
2.3	Dispose of excess topsoil (nominal 10% allowance)	15.6	cu. m	60	936
	SUBTOTAL				**15,236**
3.0	**DRAINAGE**				
4.1	Construct 6.07m x 2.54m culvert under railway line. Includes tunnelling, removal of ballast, erosion protection and any required stabilisation works	1	item	2000000	2,000,000
	SUBTOTAL				**2,000,000**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,040	sq. m	20	20,800
5.2	Reinstate park and oval infrastructure including stands, tracks, etc. (nominal allowance)	1	item	50000	50,000
	SUBTOTAL				**70,800**
	CONSTRUCTION SUB-TOTAL				**2,398,936**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**1,199,468**
	CONSTRUCTION TOTAL, excluding GST				**3,598,404**
	GST				**359,840**
	CONSTRUCTION TOTAL, including GST				**3,958,244**
	CONSTRUCTION TOTAL, rounded				**3,958,300**

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NOTES:

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2. Estimate / rates in 2012 dollars and does not allow for inflation

W4962 - Burradoo

Cardno Shaping the Future

Cost Estimate
Opt: FM4
Open Channel Between Burradoo Road and Railway Line

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**58,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of channel	1,620	sq. m	10	16,200
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	243	cu. m	25	6,075
2.3	Dispose of excess topsoil (nominal 10% allowance)	24.3	cu. m	60	1,458
	SUBTOTAL				**23,733**
3.0	**EARTHWORKS**				
3.1	Excavation of channel	3,510	cu.m	45	157,950
3.2	Disposal of excess cut (assuming 80% of total excavation)	2,808	item	60	168,480
	SUBTOTAL				**326,430**
4.0	**DRAINAGE**				
4.1	Erosion control at outlet of channel (nominal allowance)	1	item	7500	7,500
	SUBTOTAL				**7,500**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,620	sq. m	20	32,400
	SUBTOTAL				**32,400**
	CONSTRUCTION SUB-TOTAL				**448,563**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**224,282**
	CONSTRUCTION TOTAL, excluding GST				**672,845**
	GST				**67,284**
	CONSTRUCTION TOTAL, including GST				**740,129**
	CONSTRUCTION TOTAL, rounded				**740,200**

DISCLAIMER:

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NOTES:

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W4962 - Burradoo

Cardno Shaping the Future

Cost Estimate
Opt: FM5
Culvert Upgrades

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**30,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing of works area	80	sq. m	10	800
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	12	cu. m	25	300
2.3	Dispose of excess topsoil (nominal 10% allowance)	1.2	cu. m	60	72
2.4	Pull up and dispose existing road surface	340	sq.m	35	11,900
	SUBTOTAL				**13,072**
3.0	**DRAINAGE**				
3.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.6m dia. Pipe	35	lin.m	975	34,125
3.2	Supply, excavate, bed, lay, joint, backfill and provide connections for 0.75m dia. Pipe	40	lin.m	1075	43,000
3.3	Install new oulet structure, including erosion protection as required	5	each	4500	22,500
	SUBTOTAL				**99,625**
4.0	**PAVEMENTS**				
4.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	340	sq. m	120	40,800
	SUBTOTAL				**40,800**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	80	sq. m	20	1,600
5.2	Reinstate park and oval infrastructure including stands, tracks, etc. (nominal allowance)	1	item	50000	50,000
	SUBTOTAL				**51,600**
	CONSTRUCTION SUB-TOTAL				**235,897**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**117,949**
	CONSTRUCTION TOTAL, excluding GST				**353,846**
	GST				**35,385**
	CONSTRUCTION TOTAL, including GST				**389,230**
	CONSTRUCTION TOTAL, rounded				**389,300**

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W4962 - Burradoo

Cardno
Shaping the Future

Cost Estimate
Opt: FM 6
Formalisation of Open Channel

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**75,800**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing of channel width and 1m buffer	5,810	sq.m	10	58,100
	SUBTOTAL				**58,100**
3.0	**EARTHWORKS**				
3.1	Minor regrading (nominal allowance)	1	itme	20000	20,000
	SUBTOTAL				**20,000**
4.0	**CONCRETE CHANNEL**				
4.1	Construction of concrete channel incldung all required formwork, reinforcement, joints and foundations	4150	sq. m	75	311,250
	SUBTOTAL				**311,250**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	5,810	sq. m	20	116,200
	SUBTOTAL				**116,200**
	CONSTRUCTION SUB-TOTAL				**581,350**
8.0	**CONTINGENCIES**				
8.1	50% construction cost				**290,675**
	CONSTRUCTION TOTAL, excluding GST				**872,025**
	GST				**87,203**
	CONSTRUCTION TOTAL, including GST				**959,228**
	CONSTRUCTION TOTAL, rounded				**959,300**

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W4962 - Burradoo

Cardno Shaping the Future

Cost Estimate
Opt: FM 7
Upgrade of concrete open channel

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**254,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing of channel width and 1m buffer	9,960	sq.m	10	99,600
	SUBTOTAL				**99,600**
3.0	**EARTHWORKS**				
3.1	Excavation of channel	8,300	cu.m	45	373,500
3.2	Disposal of excess cut (assuming 80% of total excavation)	6,640	item	60	398,400
	SUBTOTAL				**771,900**
4.0	**CONCRETE CHANNEL**				
4.1	Construction of concrete channel incldung all required formwork, reinforcement, joints and foundations	8300	sq. m	75	622,500
	SUBTOTAL				**622,500**
7.0	**MINOR LANDSCAPING**				
7.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	9,960	sq. m	20	199,200
	SUBTOTAL				**199,200**
	CONSTRUCTION SUB-TOTAL				**1,947,200**
8.0	**CONTINGENCIES**				
8.1	50% construction cost				**973,600**
	CONSTRUCTION TOTAL, excluding GST				**2,920,800**
	GST				**292,080**
	CONSTRUCTION TOTAL, including GST				**3,212,880**
	CONSTRUCTION TOTAL, rounded				**3,212,900**

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W4962 - Burradoo

Cardno
Shaping the Future

Cost Estimate
Opt: FM8
Property Levees

v1

ITEM NO.	DESCRIPTION OF WORK	QUANTITY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item		
1.2	Provision of sediment & erosion control	1	item		
1.3	Construction setout & survey	1	item		
1.4	Work as executed survey & documentation	1	item		
1.5	Geotechnical supervision, testing & certification	1	item		
	SUBTOTAL (Assumed as 15% of works cost)				**7,900**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing of channel width and 1m buffer	1,100	sq.m	10	11,000
	SUBTOTAL				**11,000**
3.0	**EARTHWORKS**				
3.1	Construction of levee	440	cu.m	45	19,800
	SUBTOTAL				**19,800**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,100	sq. m	20	22,000
	SUBTOTAL				**22,000**
	CONSTRUCTION SUB-TOTAL				**60,700**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**30,350**
	CONSTRUCTION TOTAL, excluding GST				**91,050**
	GST				**9,105**
	CONSTRUCTION TOTAL, including GST				**100,155**
	CONSTRUCTION TOTAL, rounded				**100,200**

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Burradoo BU2 Catchment
Floodplain Risk Management Study

APPENDIX C
MULTI-CRITERIA ASSESSMENT MATRIX

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Multi-Criteria Matrix

ID	Category of Measure	Location	Description	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 30 years)	Reduction in AAD	% reduction in c.f. to base case	NPV of Reduction in AAD	Benefit - Cost Ratio	Score on Benefit Cost Ratio	Capital and Operating Costs	Reduction in Risk to Property	EconomicScore	Reduction in Risk to Life	Reduction in Social Disruption	Community Criteria	Council Support	Compatible with Policies and Plans	Social Score	Water Quality and Flow	Fauna & Flora	Environmental Score	TOTAL SCORE	RANK on TOTAL SCORE
P1	Property Modification	Wingecarribee LGA	LEP Update	$3,000	$1,000	$15,409	NC	N/A	N/A	N/A	2	2	2	**2.0**	2	1	1	2	2	**1.6**	0	0	**0.0**	**5.6**	**2**
P2	Property Modification	Wingecarribee LGA	Building and Development Co	$10,000	$1,500	$28,614	NC	N/A	N/A	N/A	2	2	2	**2.0**	2	1	2	2	2	**1.8**	0	0	**0.0**	**5.8**	**1**
P3	Property Modification	Selected locations throughout the floodplain	House Raising	**Not viable for this catchment**																					
P4	Property Modification	Selected locations throughout the floodplain	House Rebuilding	**Not viable for this catchment**																					
P5	Property Modification	Selected locations throughout the floodplain	Flood Proofing	$50,000	$5,000	$112,045	NC	N/A	N/A	N/A	2	1	1	**1.5**	2	1	0	2	2	**1.4**	0	0	**0.0**	**4.4**	**8**
EM1	Emergency Response Modification	Burradoo BU2 Floodplain	Information Transfer to SES	$2,500	$0	$2,500	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	2	0	2	2	**1.6**	0	0	**0.0**	**4.6**	**5**
EM2	Emergency Response Modification	Burradoo BU2 Floodplain	Preparation of Local Flood Plans and Update of DISPLAN	$10,000	$1,500	$28,614	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	2	0	2	2	**1.6**	0	0	**0.0**	**4.6**	**5**
EM3	Emergency Response Modification	Burradoo BU2 Floodplain	Flood Warning System	$5,000	$1,500	$23,614	NC	N/A	N/A	N/A	2	2	1	**1.8**	2	2	1	1	2	**1.6**	0	0	**0.0**	**5.1**	**4**
EM4	Emergency Response Modification	Burradoo BU2 Floodplain	Public awareness and education	$10,000	$3,000	$47,227	NC	N/A	N/A	N/A	2	2	1	**1.8**	2	2	1	2	2	**1.8**	0	0	**0.0**	**5.3**	**3**
EM5	Emergency Response Modification	Selected locations throughout the floodplain	Flood warning signs at critical locations	$5,000	$300	$8,723	NC	N/A	N/A	N/A	2	2	0	**1.5**	2	2	1	1	2	**1.6**	0	0	**0.0**	**4.6**	**5**
FM1	Flood Modification	Osborne Road / Charlotte Street	Construct detention basins on Osborne Road or Charlotte Street	**Not within modelled extent**																					
FM2	Flood Modification	Upstream of Moss Vale Road	Formalise informal detention basin	$885,000	$12,000	$1,033,908	$1,000	1.3%	$12,409	0.01	-1	-1	1	**-0.5**	0	1	-1	-1	-1	**-0.4**	0	-2	**-1.0**	**-2.4**	**14**
FM3	Flood Modification	Culvert at Railway	Enlarge culvert under railway	$3,958,000	$5,000	$4,020,045	$600	0.8%	$7,445	0.00	-2	-2	0	**-1.5**	0	1	1	-1	0	**0.2**	0	0	**0.0**	**-2.8**	**15**
FM4	Flood Modification	Burradoo Road to Railway	Augment channel capacity from Burradoo Road to Railway	$740,000	$1,000	$752,409	$300	0.4%	$3,723	0.00	-2	-1	0	**-1.3**	0	1	1	0	0	**0.4**	0	0	**0.0**	**-2.1**	**13**
FM5	Flood Modification	Moss Vale Road to Burradoo Road	Upgrade pipe capacity of channel crossings.	$389,000	$4,000	$438,636	$1,100	1.4%	$13,650	0.03	-2	0	1	**-0.8**	0	1	2	0	1	**0.8**	0	0	**0.0**	**-0.7**	**10**
FM6	Flood Modification	Moss Vale Road to Burradoo Road	Clear and formalise existing watercourse from Moss Vale Road to Burradoo Road.	$959,000	$4,500	$1,014,841	$300	0.4%	$3,723	0.00	-2	-1	0	**-1.3**	1	2	2	2	1	**1.6**	0	-1	**-0.5**	**-1.4**	**11**
FM7	Flood Modification	Moss Vale Road to Burradoo Road	Enlarge existing watercourse from Moss Vale Road to	$3,212,000	$5,000	$3,274,045	$6,600	8.4%	$81,900	0.03	-2	-2	1	**-1.3**	1	2	1	1	1	**1.2**	0	-1	**-0.5**	**-1.8**	**12**
FM8	Flood Modification	Two properties exposed to over-floor flooding in a 1% AEP	Construct levees to protect the properties from over-floor flooding	$100,000	$300	$103,723	$20,000	25.3%	$248,181	2.39	2	1	2	**1.8**	1	1	0	1	0	**0.6**	0	0	**0.0**	**4.1**	**9**

** Indicates hydraulic model and detailed economic assessment used*

NC - Not Costed