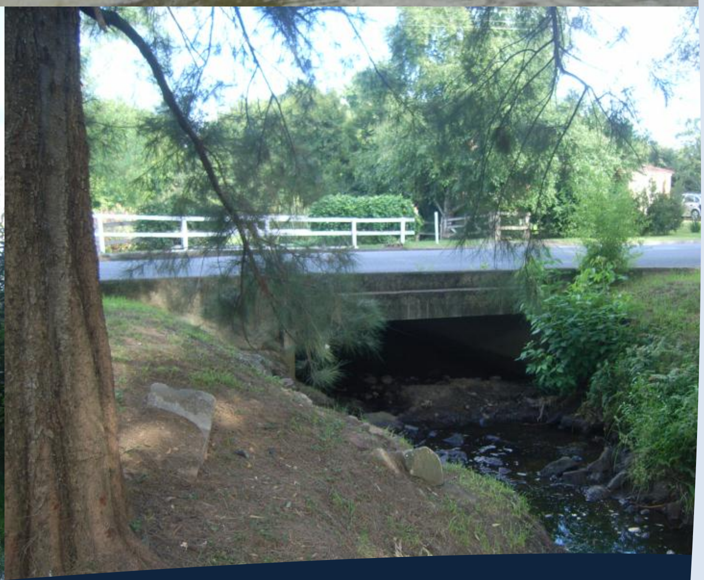

Broughton Creek Floodplain Risk Management Study

W4858

Prepared for Shoalhaven City Council

December 2012

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035
Level 9, The Forum
203 Pacific Highway
St Leonards NSW 2065
Australia
Telephone: 02 9496 7700
Facsimile: 02 9499 5170
International: +61 2 9496 7700
sydney@cardno.com.au
www.cardno.com.au

Report No:_____

Document Control

Version	Status	Date	Author		Reviewer	
1	Draft	3 February 2011	Luke Evans / Christina Chiu	LRE CC	Rhys Thomson	RST
2	Exhibition Draft	22 May 2012	Luke Evans/ Christina Chiu	LRE CC	Rhys Thomson	RST
3	Final Draft	7 December 2012	Luke Evans/ Christina Chiu	LRE CC	Rhys Thomson	RST
4	Final	14 December 2012	Luke Evans/ Christina Chiu	LRE CC	Rhys Thomson	RST

File Reference: W:_Current Projects\4858 Broughton Creek FPRMSP\Reports\6 Master Report\1 FRMSP Report\ 4858 Broughton Creek FPRMSP_v4.doc

Foreword

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

Under the Policy, the management of flood prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management 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 floodplain.
4. Floodplain Risk Management Study	Evaluates management options for the floodplain in respect of both existing and proposed development.
5. Floodplain Risk Management Plan	Involves formal adoption by Council of a management plan for the floodplain.
6. Implementation of the Plan	This may involve the construction of flood mitigation works (e.g. culvert amplification) to protect existing or future development. It may also involve the use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The process is iterative, and following the implementation of the plan, it is important that ongoing monitoring and evaluation is undertaken.

This Floodplain Risk Management Study (Stage 4) has been prepared for Shoalhaven City Council by Cardno.

Executive Summary

Cardno were commissioned by Shoalhaven City Council to undertake the Floodplain Risk Management Study and Plan for the Broughton Creek catchment.

Flooding in the Broughton Creek catchment can pose a hazard to some residents and properties near creeks and overland flowpaths. The purpose of this study is to identify and examine options for the management of flooding within the Broughton Creek catchment.

The Broughton Creek catchment area is approximately 518 km^2. Agricultural industry is the major land use within the catchment, with extensive areas utilised for dairy and beef cattle grazing in private pasture production. The township of Berry is the only urban area within the catchment.

The area downstream of Berry is flat and swampy and is generally below the level of the natural Broughton Creek levees. This floodplain has an elevation generally between 1mAHD and 2mAHD. Tidal influence extends approximately 12km upstream of the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge (SMEC, 2008).

The main tributaries to Broughton Creek, upstream of the Coolangatta Road bridge include Broughton Mill Creek, Bundewallah Creek, Connollys Creek and an unnamed watercourse locally know as Town Creek. Other tributaries include Anderson Lane Creek, Anderson Lane Tributary, Hitchcock's Lane Creek and Hitchcock's Lane Tributary.

The lower reaches of the Broughton Creek catchment, downstream of the Coolangatta Road bridge, forms part of the Shoalhaven River floodplain, and as such has previously been considered in the Lower Shoalhaven River Floodplain Risk Management Study and Plan (WMA, 2002) and subsequent Climate Change Review (WMAwater, 2011).

In the past, flooding in the catchment has caused property damage and posed a hazard to residents. Significant flood events occurred in 2011, 2005, 2002, 1988 and 1974. A flood study was previously prepared that identified the flood behaviour in the study area (SMEC, 2008). An update has subsequently been undertaken in this study to improve the definition of the flood behaviour in the Berry township, and in the areas immediately adjacent to the township. Details on the update of the study are provided in **Appendix B** and **Appendix C**.

The flooding behaviour of the catchment was found to fall into three distinct groups. The first is the flooding of the major creek systems. These larger creeks, including Broughton Creek, Broughton Mill Creek and Bundewallah Creek, convey the majority of flows in the catchment. They generally affect rural and agricultural land and impact access by affecting the Princes Highway and railway line. Major creek flooding is characterised by long duration flooding, with a critical duration of 6 – 9 hours.

The second type of flooding in the catchment is local creek flooding. This comprises Town Creek, the North Street flowpath, and the Hitchcocks Lane flowpath. These flowpaths cause significant property damage, as they affect the Berry Township. Local creek flooding is characterised by short duration flooding, with a critical duration of 2 hours.

The final flooding type in the catchment is flooding due to backwaters from the Shoalhaven River. This type of flooding is not significantly affected by local storm events, but from increases in water level of the Shoalhaven River. The impact extend to just south of the railway line, and affects primarily rural and agricultural land.

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

Table i: Flood affected properties and damages under existing conditions

Flood Event	Properties with Over-floor flooding	Properties with Over-ground flooding	Flood Damage
50% AEP	0	4	$26,200
20% AEP	0	7	$39,300
10% AEP	2	15	$310,300
5% AEP	2	31	$606,100
2% AEP	4	40	$1,305,300
1% AEP	9	59	$2,290,600
PMF	50	118	$6,237,500
Average Annual Damage			$139,500

This study investigates what can be done to reduce or manage the effects of flooding in the catchment, and recommends a mix of strategies to manage the risks of flooding.

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

These options included:

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

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

The assessment found, of the all the options investigated (including flood, property and emergency measures), the top three identified by the multi-criteria analysis were:

1.	P 2	Building and Development Control Plans
2.	P 1	LEP Update
3.	FM 1.2	Town Creek Vegetation Clearing

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1.	FM1.2	Town Creek Vegetation Clearing
2	FM 1.6	North St Diversion Swale
3.	FM 1.3	Railway Culvert Upgrade

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

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Glossary

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.
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
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.
Creek Rehabilitation	Rehabilitating the natural 'biophysical' (i.e. geomorphic and ecological) functions of the creek.
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 or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.

Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	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 fuller 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.

* Terminology in this Glossary have been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005, where available.

Abbreviations

AAD	Average Annual Damage
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AHIS	Aboriginal Heritage Information Services
ARI	Average Recurrence Intervals
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change & Water (now Office of Environment & Heritage)
DISPLAN	Local Disaster Plan
DHI	Danish Hydraulics Institute
EPI	Environmental Planning Instrument
EP&A	Environmental Planning and Assessment Act
ESD	Ecologically Sustainable Development
FPL	Flood Planning Levels
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
GSDM	Generalised Short Duration Method
ha	Hectare
HAT	Highest Astronomical Tide
IEAust	Institution of Engineers, Australia (now referred to as Engineers Australia)

IFD	Intensity Frequency Duration
km	Kilometres
km^2	Square kilometres
LAT	Lowest Astronomical Tide
LEP	Local Environment Plan
LGA	Local Government Area
LIC	Land Information Centre
m	Metre
m^2	Square metre
m^3	Cubic Metre
mAHD	Metres to Australian Height Datum
MHWL	Mean High Water Level
MHWN	Mean High Water Neaps
MHWS	Mean High Water Spring
MIKE11	MIKE11 Proprietary Software Package
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Spring
mm	Millimetre
m/s	Metres per second
MSL	Mean Sea Level
NPV	Net Present Value
NPWS	National Parks and Wildlife Service (within the Department of Environment and Conservation)

NSW	New South Wales
OEH	Office of Environment & Heritage
POEO	Protection of the Environment Operations Act
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
REP	Regional Environmental Plan
RMS	Roads and Maritime Services
RNE	Register of the National Estate
RL	Reduced Level
RTA	Roads and Traffic Authority (Now RMS)
SEPP	State Environmental Planning Policy
SES	State Emergency Service

1 Introduction

Cardno were commissioned by Shoalhaven City Council to undertake the Floodplain Risk Management Study and Plan for the Broughton Creek catchment. The catchment is approximately 518 km^2 in size and surrounds the township of Berry on the NSW south coast.

The study has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damage and risk. The tasks were undertaken alongside community consultations to ensure that community concerns were addressed.

In the past, flooding in the catchment has caused property damage and posed a hazard to residents. Significant flood events occurred in 2011, 2005, 2002, 1988 and 1974. A flood study was previously prepared that identified the flood behaviour in the study area (SMEC, 2008). An update has subsequently been undertaken in this study to improve the definition of the flood behaviour in the Berry Township, and in the areas immediately adjacent to the township. Details on the update and outcomes of the study are provided in **Appendix B** through **Appendix E**.

Flooding was assessed for the 50% AEP, 20% AEP, 10% AEP, 5% AEP, 2% AEP and 1% AEP events, as well as the Probable Maximum Flood (PMF). Flood levels, depths and velocities were determined, as well as provisional hazard categories, and hydraulic categories.

From the base case results, a number of flood mitigation options were examined to manage flooding within the Broughton Creek catchment. The identification and examination of these options was done in accordance with the NSW Government Floodplain Development Manual (NSW Government, 2005).

1.1 Study Context

The Floodplain Management process progresses through 6 stages, in an iterative process:

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

This report addresses Stage 4. A revision was also undertaken for Stages 2 and 3 which is attached in **Appendix B** through **Appendix E**.

1.2 Study Objectives

The overall objective of this study is to develop a Floodplain Risk Management Study where management issues are assessed, management options are investigated, and recommendations are made and a Floodplain Flood Risk Management Plan developed detailing how flood prone land within the study area is to be managed.

The specific objectives of this stage of the study, the Floodplain Risk Management Study, are:

- To undertake effective community consultation and participation throughout the project
- To identify and describe the various potential flood problems and specific future flooding issues in the study area
- To assess and document the implications for flooding of the most up to date predictions for climate change and sea level rise
- To assess whether the flood provisions in Council's existing environmental planning policies and instruments are consistent with each other, the Floodplain Development Manual and the findings of the flood analyses incorporating climate change impacts and sea level rise
- To identify and assess potential management measures for existing developed areas
- To assess the benefits and cost of the potential management measures and whether they might produce adverse effects in the floodplain
- To examine ways in which the creek and floodplain environment may be enhanced by preparing a strategy that will create a valuable corridor of vegetation without having a detrimental effect on flooding
- To identify modifications required to current policies in the light of investigations.
- To assess flood risks to or associated with existing infrastructure and opportunities to manage future infrastructure replacement so as to maximise flood tolerance and mitigation potential.

2 Catchment Description

Broughton Creek and its tributaries rise in the ranges to the north and west of the town of Berry, flowing through farming areas and forest to the Shoalhaven River downstream of Nowra.

The catchment and study area are shown in **Figure 2.1**.

The Broughton Creek catchment area is approximately 518 km^2. Agricultural industry is the major land use within the catchment, with extensive areas utilised for dairy and beef cattle grazing in private pasture production. The township of Berry is the only urban area within the catchment.

The area downstream of Berry is flat and swampy and is generally below the level of the natural Broughton Creek levees which form the banks of Broughton Mill Creek and Broughton Creek. This floodplain has an elevation generally between 1mAHD and 2mAHD. Tidal influence extends approximately 12km upstream of the Broughton Creek and Shoalhaven River confluence to the vicinity of the Coolangatta Road Bridge (SMEC, 2008).

The main tributaries to Broughton Creek, upstream of the Coolangatta Road Bridge, include Broughton Mill Creek, Bundewallah Creek, Connollys Creek and an unnamed watercourse locally know as Town Creek. Other tributaries include Anderson Lane Creek, Anderson Lane Tributary, Hitchcock's Lane Creek and Hitchcock's Lane Tributary.

The key features of the study area are shown in **Figure 2.2**.

The lower reaches of the Broughton Creek catchment, downstream of the Coolangatta Road bridge, forms part of the Shoalhaven River floodplain, and as such has previously been considered in the Lower Shoalhaven River Floodplain Risk Management Study and Plan (WMA, 2002) and subsequent Climate Change Review (WMAwater, 2011).

The significant recorded historical flood events for the Broughton Creek catchment were the August 1974, April 1988, February 2002 and June/July 2005 events, and were detailed in the Broughton Creek Flood Study (SMEC, 2008). Additionally, a more recent event occurred in March 2011. Of these, the 2005 event was the largest recorded.

3 Available Data

3.1 Previous Studies and Reports

A number of studies have been conducted concerning the Broughton Creek catchment and the wider Shoalhaven River catchment. These studies have been reviewed as part of this study and relevant information incorporated.

Previous studies are summarised in **Table 3.1**.

Table 3.1: Summary of Previous Studies and Reports

Study	Description
Lower Shoalhaven River Flood Study (Web McKeown & Associates, 1990)	The flood study for the region was undertaken in 1990 using the WBNM hydrological model, and the CELLS hydraulic model. The models were calibrated to yearly historical floods from 1974 – 1979, and the 1988 flood event. The study determined downstream conditions at Shoalhaven Heads for 20yr, 50yr, 100yr and PMF. Different levels were determined depending on if the heads were open or closed.
Shoalhaven City Local Flood Plan Draft (State Emergency Services, 2003)	The SES investigation covered the Shoalhaven City Council area. It was concerned with flood preparedness, response and recovery.
Lower Shoalhaven River Floodplain Risk Management Study (Webb McKeown & Associates, 2008)	The study was based on the initial 1990 study, further investigating key flooding issues and possible solutions. The model used had Shoalhaven Heads closed, but scouring out as the flood progressed. Key issues identified included blockage at Shoalhaven Heads, evacuation access, and urban development and expansion. It also stated that Broughton Creek and Bolong Rd Bridge had insufficient capacity to manage flood waters. An economic analysis was undertaken which estimated AAD at $1.8M, with 734 properties affected in the 100yr event. A variety of management measures were discussed including flood modifications (basins, levees), property modifications (raising, voluntary purchase) and response modifications (evacuation planning). Property and response initiatives were considered to be more applicable.

Lower Shoalhaven River Floodplain Risk Management Plan (Webb McKeown & Associates, 2008)	The study outlines which of the mitigation options put forward above are most likely to have benefits, and how council could implement these programs. An example of the mitigation measures proposed are: • Develop a post-flood evaluation and review program to further refine models • Implement stormwater management plan for local drainage flooding issues • Finalise and implement Council's Shoalhaven River Entrance Management Plan for Flood Mitigation (EMPFM) • Update flood polices such as FPL's property set-backs, and improve resident flood awareness
Broughton Creek Flood Study (SMEC Australia Pty Ltd, 2008)	The study determined the flood behaviour for the Broughton Creek catchment for a range of design events including PMF, 200yr, 100yr, 50yr, 20yr, 10yr and 5yr events. Hydrologic modelling was undertaken in RAFTS and hydraulic modelling in Mike-11. Downstream boundary conditions were taken from the CELLS model. Calibration was undertaken using historical events from 1974, 1988, 2002 and 2005. Historical flood levels were included in the report and utilised in the current investigations.
Berry Town Creek Flood Study (MacDonald International, 2009)	The study investigated the flooding of Town Creek in Berry between Queen Street and Prince Alfred Street. The investigation was undertaken using HEC-RAS and DRAINS for the 1%, 5%, 10%, 20% and 50% AEP events. The study recommended the upgrades of pipes and culverts at Princess Street, Victoria Street and Albany Street. The report included flood levels and extents which were utilised in the current investigations.
Lower Shoalhaven River Floodplain Management Study & Plan: Climate Change Assessment (WMAwater, 2011)	An amendment to the 2008 study to incorporate the predicted impacts of climate change. The study adopted NSW Government sea level rise estimates of 0.4m by 2050 and 0.9m by 2100, and increases in precipitation of 10%, 20% and 30% in line with DECC Guidelines. Based on these values, the findings of the previous study (Webb McKeown & Associates, 2008) were updated including planning levels, damages, flood mitigation options and evacuation procedures.

3.2 Survey Information

Council provided a substantial amount of the existing data of the study area. Additional survey was commissioned for the areas not covered by existing survey.

3.2.1 Existing survey

Survey information was obtained from a number of sources. The following summarises the information received:

- Airborne Laser Scanning (ALS) – Council provided aerial survey across the catchment. The survey was conducted in 2004 and is indicative of the catchment at this time. Generally, accuracy of ALS data is +/- 0.15m to one standard deviation on hard surfaces,
- Culvert Cross Sections – Culverts within Berry were surveyed by ESG group in 2002-2005,
- Creek Cross Sections – Cross sections for Andersons Lane Creek, Broughton Mill Creek, Bundewallah Creek, Bundewallah Tributary, Hitchcocks Lane Creek, Hitchcocks Lane Tributary and Town Creek were taken from the Mike11 model,
- Drainage Survey – survey of pits, pipes, culverts and bridges were supplied by Council,
- Historical levels – historical levels identified from the SMEC (2008) and Webb McKeown Associates (2008) flood studies for Broughton Creek and the Lower Shoalhaven River respectively.

3.2.2 Additional Survey

Additional survey was collected for parts of the study area where existing survey did not exist or did not provide sufficient information.

The following survey details were obtained:

- Retirement Village – Design plans of the access road detailing the culverts and bridge crossing, and the road crest level (Dwg Ref: 05001-C1B-01 to 09)

3.2.3 Floor Level Property Survey

A detailed floor level survey was carried out by Peter Smith Surveyors, and provided to Cardno on 14 February 2011. Floor levels and property descriptions of all the properties within the SMEC PMF extent (SMEC, 2008) were obtained. This information has been provided separately to Council for privacy reasons.

3.3 GIS Data

The following Geographic Information System (GIS) data was provided by Council as a part of the study:

- Cadastre,
- Drainage Layers: pits, pipes, easements,
- 2m contours,
- Aerial photography: undertaken by Council prior to the commencement of the current study. The imagery is centred on Berry, and extends for approximately 10km, reaching the Pacific Ocean in the East, and the Shoalhaven River in the South,
- Environmental and social characteristics: acid sulphate soils, vegetation zones, LEP zones, and areas of ecological sensitivity.

3.4 Site Inspection

A site inspection was conducted on 11 February 2011.

3.5 Historic Flood Information

The study area has experienced a number of large flood events, with the most recent being in 2002, 2005 and 2011. Previous studies include flood levels at certain locations for the 2002 and 2005 events, and Council has provided photographs taken during and after the 2005 and 2011 events.

3.6 Historical Rainfall Data

There are numerous rainfall stations around the study area. Not all of these however were operational during the identified storm events. Rainfall gauges identified in and around the study area are listed in **Table 3.2**. Isohyetal maps were produced for historic events as part of the SMEC study (SMEC, 2008).Daily totals for each historical storm event are summarised in **Table 3.3** and **Table 3.4.**

Table 3.2: Rain Gauges

Station No.	Station Name	Type	Source	Operation
068003	Berry Masonic Village	Daily	BOM	1886-current
068218	Wattamolla (Griffiths)	Daily	BOM	1982-current
68190	Wattamolla (Tamol)	Daily	BOM	1970-current
068197	Foxground Road	Daily	BOM	1972-current
068175	Toolijooa (Nyora)	Daily	BOM	1967-current
068247	Beaumont (The Cedars)	Daily	BOM	1993-current
068209	Jamberoo (Druewalla)	Daily	BOM	1963-2007
068035	Jamberoo (The Ridge)	Daily	BOM	1992-current

BOM = Bureau of Meteorology

Table 3.3: Rainfall Totals for July 2005 Flood Event

Station No.	Station Name	Total Daily Rainfall (mm to 9am)
		July 2005
068003	Berry Masonic Village	220.8
068218	Wattamolla (Griffiths)	198.6
68190	Wattamolla (Tamol)	163.2
068197	Foxground Road	170.0
068175	Toolijooa (Nyora)	74.4
068247	Beaumont (The Cedars)	83.6
068209	Jamberoo (Druewalla)	212.0
068035	Jamberoo (The Ridge)	137.0

The storm event occurred on 1st July 2005.

Table 3.4: Rainfall Totals for February 2002 Flood Event

Station No.	Station Name	Total Daily Rainfall (mm to 9am)
		February 2002
068003	Berry Masonic Village	170.2
068218	Wattamolla (Griffiths)	159
68190	Wattamolla (Tamol)	131.2
068197	Foxground Road	171.6
068175	Toolijooa (Nyora)	143.6
068247	Beaumont (The Cedars)	185.0
068209	Jamberoo (Druewalla)	122.0
068035	Jamberoo (The Ridge)	146.2

The storm event occurred on 5^{th} Feb 2002

4 Consultation

Community consultation was undertaken in three key phases over the course of the project:

- Resident Survey,
- Community Forum,
- Public Exhibition.

The resident survey was undertaken in December 2010.

Community forums were undertaken on the 29th November to discuss the results of the revised flood study. Community comments on the options presented have been incorporated into the study through the matrix assessment of the proposed mitigation options.

Public Exhibition took place during June and July 2012, closing on the 23 July 2012.

4.1 Resident Survey – Community Information Brochure/Questionnaire

Community consultation was undertaken in December 2010. An information brochure and questionnaire were distributed to those properties identified in the SMEC investigation (SMEC, 2008) as being within the PMF extent. The brochure and questionnaire are attached in **Appendix A**. The brochure provided an outline of the floodplain risk management process and the objectives of the study. The questionnaire sought information about historical flooding events and feedback on possible floodplain management options.

The brochure and questionnaire were delivered to approximately 550 property owners within the floodplain. These properties were selected as being in or near the PMF extent, and as such, they may have experienced or witnessed flooding in the catchment. A summary was also advertised in the local newspaper, the Berry Town Crier, informing residents of the study and advising that the survey was being undertaken.

From the distribution, 82 responses were received, representing a return of approximately 14% of direct distribution. An average response rate for these types of surveys is in the order of 10%, and so this represents a reasonable return rate.

A summary of the findings of the resident survey are presented below.

4.1.1 Years at Address

One of the questions in the survey related to the length of time that residents had resided at their current address. The majority of the responses were from owner occupiers (87%) with the remainder made up of tenants, businesses and farmland.

Of the 83 respondents, 52% had been at their property longer than 10yrs, and 65% were living in Berry at the time of the 2005 flood event. **Figure 4.1** provides an overview of the periods of residency.

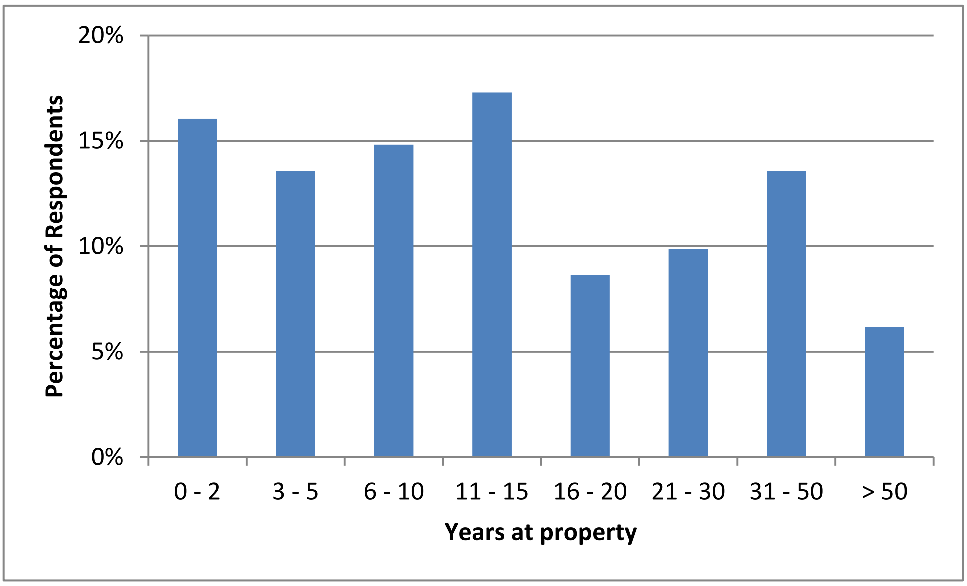

Figure 4.1: Years respondents have spent at current address

4.1.2 Flood Awareness & Information

Included in the questionnaire were a series of questions to determine resident's previous experiences of flooding. Of the 83 respondents, 39% state that flood waters entered their property, though only 2% experienced over-floor flooding. 45% of the respondents had not experienced flooding in Berry.

Approximately 30% of respondents had incurred some form of financial costs due to flooding. A further 20% reported being affected in other ways, such as restricted movement and forced relocation of livestock.

Residents were also asked to comment on how likely they thought future flood events would impact them. 81% believed that they would be unaffected or that flooding would only impact a small part of their yard. 17% believed that significant portions of their outdoor space would be flooded, whilst 5% believed that they would experience over-floor flooding.

It was also asked of residents if they had sought out information on flooding issues in the catchment. Nearly 30% had received information from relatives, friends, neighbours or the previous owner, and a further 12% had received information from the real estate agent when purchasing their property. Approximately 30% reported having sourced info from Council, either via customer service, or from the website.

It is important that when information is disseminated, that it be done in such a way that it reaches the population. Residents were asked to comment on which possible options of providing information they saw as the most effective. The responses have been ranked below in **Figure 4.2**.

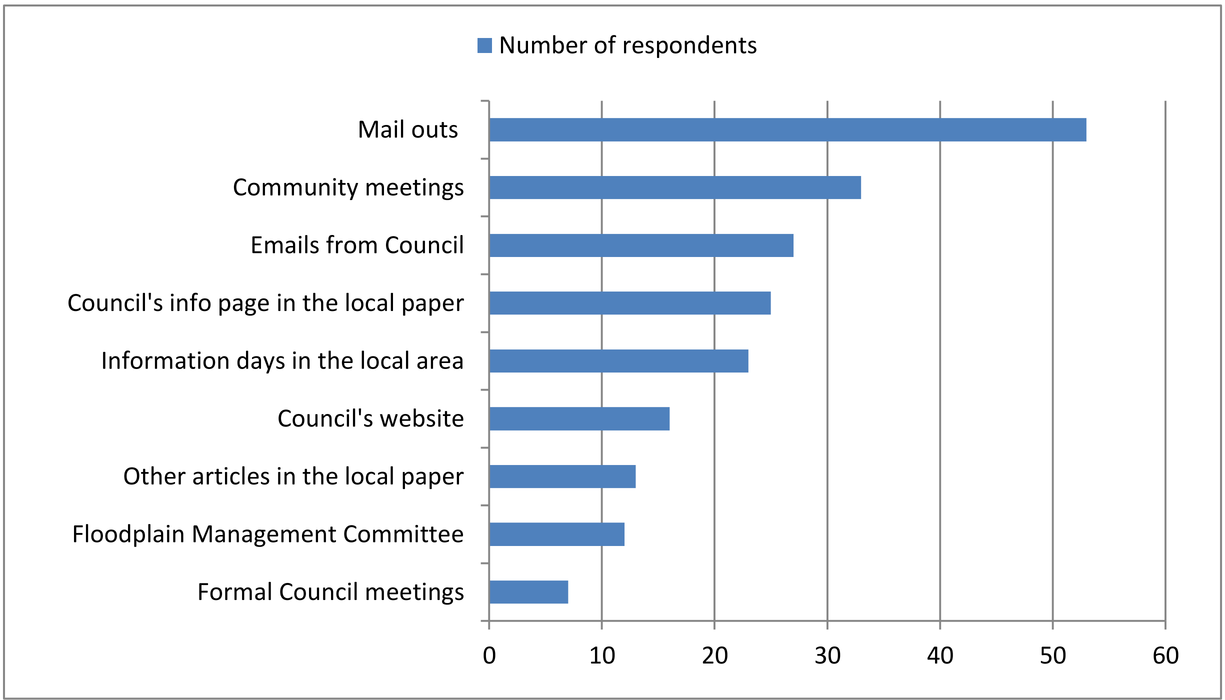

Figure 4.2: Preferred Channel for Information Distribution

4.1.3 Flood Management Options

A question in the questionnaire asked respondents to give a mark of 1 – 5 to a variety of potential management options, with 5 being the more preferred and 1 not preferred. By taking an average of the marks given to each option, it was possible to rank the options based on resident preference. The ranking is shown in **Figure 4.3**.

Improved flow paths and environmental channel improvements were the most preferred flood management options. It was noted by some residents that a number of waterways are clogged with weeds.

Planning and flood related development controls, flood forecasting, flood warning, evacuation planning and emergency response, education and stormwater harvesting were all ranked approximately equal.

Larger structural options such as detention basins, levees and diversions were least preferred.

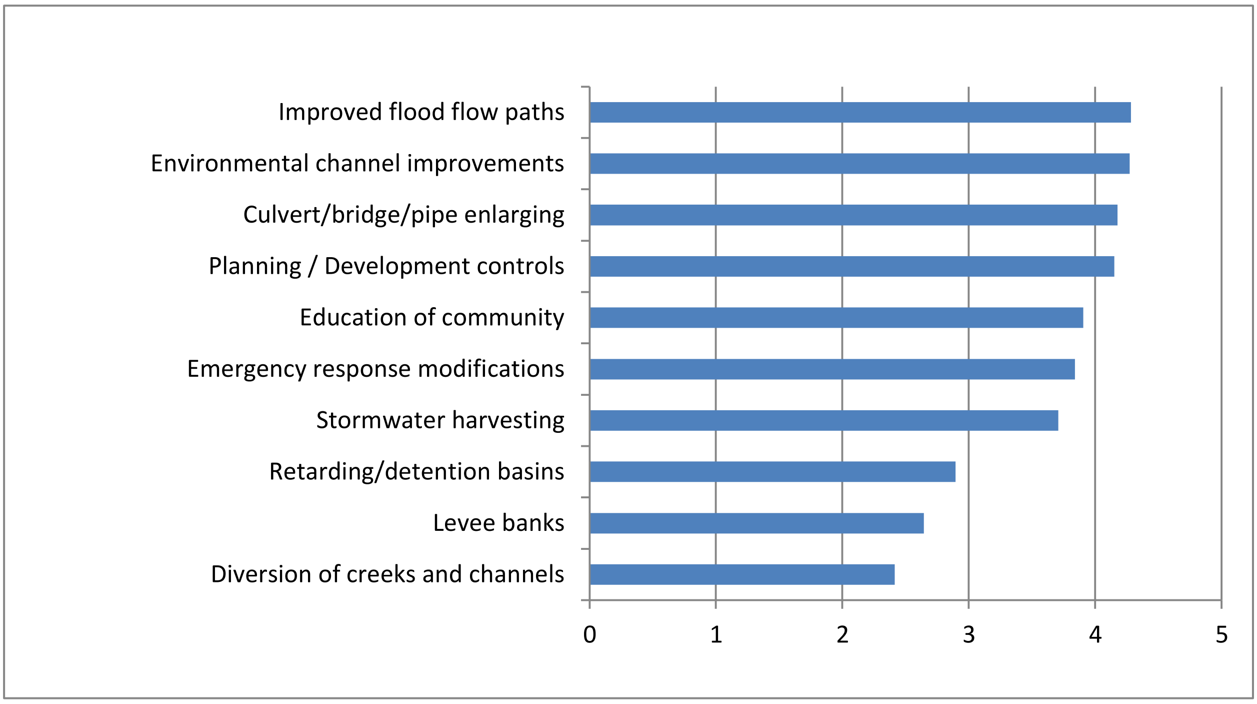

Figure 4.3: Resident Ranking of Possible Options

4.2 Community Forum

Community Forums were undertaken on the 29th November to discuss the results of the revised flood study as well as the identification of preliminary flood mitigation options.

Two separate meetings were held, one at 11am to 1pm and the other from 5:30pm to 7:30pm. The forums were well attended by the community, with a total of approximately 32 people attending. A copy of the PowerPoint presentation that was presented at the forums is provided in **Appendix A**.

Some of the key comments and feedback that was provided by the community during the meeting included:

- The vegetation and debris within the creeks in the study area results in reduced capacity of the channels and impacts on the community. The community would like to be able to organise clean-ups of the creek lines in conjunction with Council;
- Culverts along Town Creek have limited capacity and are prone to blockage. These culverts will need to be maintained and kept clean along with the creek;
- The need to ensure that options are environmentally responsible – in particular those that involve creek diversions or detentions;
- A community preference was expressed for vegetation management options, and minor drainage augmentations over more significant, large scale options.

Community comments on the options presented have been incorporated into the study both through identification of options and the assessment of the options.

4.3 Public Exhibition

The draft Floodplain Risk Management Study and Plan were placed on public exhibition during June and July 2012. A second community forum was held, with 16 people attending the two sessions.

Key points from the submissions and forums were:

- Expansion of recommended debris clearing to Broughton Mill and Bundewallah Creeks;
- The separation of the discussed Town Creek Care Group (**Section 11.2.4**) into a number of smaller groups each responsible for a portion of the creek;
- Development of a communication strategy to aid in discussions between Council and local residents and groups on flood-related issues; and,
- Create a dialog between Council and other agencies (Australian Rail Corporation, Southern Rivers Catchment Management Authority, RMS) to discuss the options put forth in the Floodplain Risk Management Study and Plan.

These comments have been incorporated into the Floodplain Risk Management Study and Plan.

In addition to comments, one submission also contained an additional flood mitigation option. This option involved the construction of a diversion culvert between Broughton Mill Creek and Broughton Creek to alleviate flooding along the eastern side of the Berry Township. This option was assessed as per the other options, and has been included in the options assessment. Further information on the investigations into this option are provided in **Appendix I**.

4.4 Ongoing Communication and Consultation

4.4.1 Community

It is recommended that the dialogue opened between Council and the Berry community as part of this study be maintained. Through this dialogue, it will be possible to engage the community in the further development and implementation of options discussed in the Floodplain Risk Management Study and Plan. This is particularly important for options identified that require an ongoing working relationship between residents and Council, such as creek vegetation management works (refer **Section 11**).

A method of communication may be the creation of an email / letter mailout list that residents and groups can sign up to, that will allow Council to disseminate information in relation to the implementation of the Plan.

General communication to the wider community could be undertaken through newspapers and community announcements.

4.4.2 External Agencies

Some of the flood management options discussed may benefit from collaboration / discussion with other agencies (refer **Section 11**), namely:

- **Australian Rail Corporation (ARC)** – As discussed in **Section 11.2** the railway culvert works delivered flood reductions and reduced the frequency of the railway line overtopping. However, the works require a large capital investment, and as such were not included in the Floodplain Risk Management Plan. It is recommended that the ARC be contacted and informed of the study and its findings, and an inquiry made as to whether they would consider partnering with Council in undertaking the works
- **Southern River Catchment Management Authority (SRCMA)** – The SRCMA is responsible for the river health of major water courses in southern NSW, including those in the Shoalhaven LGA. Options have been recommended as part of this study that include vegetation management and debris removal. It is recommended that the SRCMA be contacted and informed of this study and its findings, and an inquiry made as to whether they would consider entering into a partnership with Council and the community to manage the creeks within the Broughton Creek Catchment.
- **Roads and Maritime Services (RMS)** – Council is currently in discussion with RMS on incorporating mitigation options into the proposed Berry by-pass design. This relationship serves as an example of synergies that can be created in collaboration with other agencies.

5 Existing Flood Behaviour

As part of the study, the nature and extent of the existing flooding within the Broughton Creek catchment was defined.

Details and discussion on the existing flooding behaviour within the catchment are provided in **Appendix D**.

5.1 Properties with Overfloor Flooding

A detailed assessment of the flood damages and overfloor flooding is provided in **Section 6** of this report. The results are summarised below in **Table 5.1**. Single storey dwellings have been highlighted, as these properties have limited opportunity for vertical evacuation. It is noted that almost all flood affected residential properties are single storey.

Table 5.1: Properties with Overfloor Flooding

Flood Event (AEP)	Residential Properties		Commercial Properties	Industrial Properties
	Single Storey Dwellings	Total Residential		
PMF	41	43	4	3
1% AEP	6	6	2	1
2% AEP	2	2	2	0
5% AEP	1	1	1	0
10% AEP	1	1	1	0
20% AEP	0	0	0	0
50% AEP	0	0	0	0

5.2 Flood Hazard

5.2.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations (Appendix L; NSW Government, 2005). The Floodplain Development Manual (NSW Government, 2005) defines two categories for provisional hazard – high and low.

These hazard categories have been defined and are described in **Appendix D**.

5.2.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described above in **Section 5.2.1**, 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 the:

- Size of the flood,
- Effective warning time,
- Flood readiness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Ease of evacuation,
- Effective flood access.

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

While some properties may be classed as high hazard based on the following discussion, they have not been mapped for privacy reasons.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, flood hazard has been mapped for the PMF, the 1% AEP event and the 5% AEP event. These events were determined to be the appropriate events to categorise the "true" hazard for the Broughton Creek catchment.

Effective Warning Time

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

The critical duration storm for the study area is generally the 120 minute duration event for the 1% AEP event and the PMF. The larger creek systems have longer critical durations, but these do not have as much impact on properties as the shorter duration systems, such as Town Creek. In addition, as discussed in **Section 8**, the shorter duration, non-critical storms in the larger creeks still result in significant flooding. As such, the adoption of the 120 minute event to assess warning times was adopted across the whole catchment.

As such, the peak of the flow generally occurs at various locations within the catchment within 15 minutes to 2 hours from the start of the rainfall. Therefore, there is little to no warning time throughout the catchment.

However, it is noted that all areas within the catchment are exposed to similar flood response times, and therefore it can be considered that no area within the catchment is any more at risk than another.

The exception to this is overfloor flooding. Due to the critical durations within the catchment, if a property experiences overfloor flooding this will occur within a very short timeframe. This is considered to pose a hazard to these properties, and these should be included in the True Hazard Mapping. As per **Table 5.1**, there are 6 residential properties with overfloor flooding in the 1% AEP event and 2 commercial properties. Note that these have not been shown on the mapping for privacy reasons.

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. Significant flooding events have occurred in Berry in 2011, 2005, 2002, 1988 and 1974. Based on the responses from the resident survey (**Section 4**), which was conducted prior to the 2011 flood event, approximately 65% of respondents were living in Berry at the time of the 2005 flood event.

Given the recent nature of flooding issues within the catchment, and the strong level of flood awareness demonstrated in the returned questionnaires, the flood awareness within the catchment is taken to be relatively high.

As there is no reason to suggest that a particular part of the catchment is likely to be any more prepared for a flood than another, 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 0.2 m, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in defining areas affected by true high hazard.

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

In the study area, there are no properties with flow behaviour within these constraints for the 1% AEP event which are not already selected by the provisional high hazard criteria.

Depth and Velocity of Flood Waters

As outlined above, provisional hazard mapping is determined from a relationship between velocity and depth. The provisional hazard mapping for the PMF and 1% AEP events were undertaken and presented in **Appendix D** of this report. 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, even in the longer duration events. Those properties affected by longer periods of inundation are already selected by the provisional high hazard criteria.

As such, this is not considered a key issue for the Broughton Creek 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.

The duration of flooding in the catchment is short, as noted above. Therefore, evacuation issues for the majority of the catchment are not considered to be an issue. The exception to this is for properties that experience overfloor flooding in the 100 year ARI and PMF events that do not have a second floor. This allows for limited opportunities for residents to escape the inundation within their properties. There are a total of 6 of these residential properties in the 1% AEP event and 43 in the PMF event.

These have not been included on the figures at this stage due to privacy reasons.

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.

For the duration of the flooding experienced in the Broughton Creek catchment, evacuation is generally not recommended (refer **Section 8**). In this type of short duration flooding, residents are as likely to put themselves in harm's way by evacuating rather than staying indoors. As such, effective flood access is not considered in the True Hazard mapping.

5.3 Flood Categorisation

The flood categorisation of the catchment is defined in **Appendix D** for the PMF event, and the 1% and 5% AEP events.

6 Current Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are categorised as various types; these types are summarised in **Table 6.1**.

Table 6.1: Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural damage (building repair) 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) Inconvenience (general difficulties in post-flood stage)

The 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. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are 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 spread-sheets. For the purposes of this project, generic spread-sheets have been used based on a combination of OEH residential damage curves and FLDamage.

6.2 Floor Level and Property Survey

A floor level property survey was undertaken of properties within the flood extent (refer **Section 3.2**).

6.3 Damage Analysis

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely damage within the property. Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and as such, damage curves from other catchments, and available research in the area, is used as a substitute.

OEH has conducted research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties. The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW.

The following sections set out the methodology for the determination of damages within the Broughton Creek catchment.

6.3.1 Residential Damage Curves

The draft DNR (now OEH) Floodplain Management Guideline No. 4 *Residential Flood Damage Calculation*(NSW Government, 2005) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings, namely:

- Single story, slab on ground,
- Two story, slab on ground,
- Single story, high set.

Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for a damage of $10,023 (May 2011 dollars) to be incurred when the water level reaches the base of the house, with the base of the house assumed to be 0.3m below the floor level for slab on ground. We have assumed that this remains constant until overfloor flooding occurs. A nominal $3,000 has been allowed to represent damage to gardens where the ground level of the property is overtopped by more than 0.3m of depth but only up to 0.3m below the floor of the house. This may occur on steeper properties and larger properties where the garden and fences may be impacted, but the flood waters do not reach 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:

- A value of $150m^2$ was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain. With a floor area of $150m^2$, the default contents value is $56,516 (May 2011 dollars),
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents and hence reduce the potential damages of household contents,
- The Broughton Creek 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 regional 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 May 2011 dollars (as shown in **Table 6.2**). General recommendations by OEH are to adjust the 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 from the Australian Bureau of Statistics at the time of this study was for May 2011. Therefore, all ordinates in the residential flood damage curves were updated to May 2011 dollars. In addition, all damage curves include GST as per OEH recommendations.

The OEH guidelines were derived in November 2001, which allows us to use the November 2001 AWE statistics (issued quarterly) for comparison purposes. May 2011 AWE values were taken from the Australian Bureau of Statistics website (ABS, 2011).

Consequently, damages have been increased by 51% and GST has been included compared to 2001 values.

Table 6.2: Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$673.60
February	2011	$1,015.20

6.3.2 Commercial Damage Curves

Commercial damage curves were adopted from the FLDamage Manual (Water Studies Pty Ltd, 1992). FLDamage allows for three types of commercial properties:

- Low value commercial,
- Medium value commercial,
- High value commercial.

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual commercial properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to May 2011 dollars, using data from the Australian Bureau of Statistics (ABS, 2011). It was assumed that the FLDamage data was in June 1990 dollars. The CPI data is shown in **Table 6.3**.

Consequently, commercial damages have been increased by 73.8% and GST has been included compared to 1990 values.

Table 6.3: CPI Statistics for Commercial Damage Curves

Month	Year	AWE
June	1990	$102.50
May	2011	$178.30

6.3.3 Industrial Damage Curves

Cardno, as part of a previous floodplain management study (Cardno, 1998) conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. We therefore have used these damage curves for this study.

The curves were prepared for three categories:

- Low value industrial,
- Medium value industrial,
- High value industrial.

Within the catchment, there are no properties considered to be representative of high value industrial properties, and hence these curves were not used.

The floor areas for the industrial properties were estimated during the floor level survey. To normalise the damages for property size, the curves have been factored to account for floor area.

The survey conducted only accounts for structural and contents damage to the property. Clean-up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies Pty Ltd, 1992). Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the clean-up costs and indirect financial costs could be made. The values were adjusted to May 2011 dollars using the CPI statistics show in **Table 6.4**.

Consequently, damages have been increased by 47.4% and GST has been included compared to the 1998 values.

Table 6.4: CPI Statistics for Industrial Damage Curves

Month	Year	AWE
June	1998	$121.00
May	2011	$178.30

6.3.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6.1**. For purposes of illustration, the commercial and industrial damage curves are shown for a property with a floor area of $100m^2$, although the size will be individually determined for each commercial and industrial property when calculating catchment damages.

6.4 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event.

Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to 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.

The AAD value attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event. 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 (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve. Further information of the calculation of AAD can be found in Appendix M of the Floodplain Development Manual (NSW Government, 2005).

The probability curve for the Broughton Creek damages is shown in **Figure 6.2**.

For this study, the damage resulting from events more frequent that a 50% AEP were assumed to be zero for the AAD analysis.

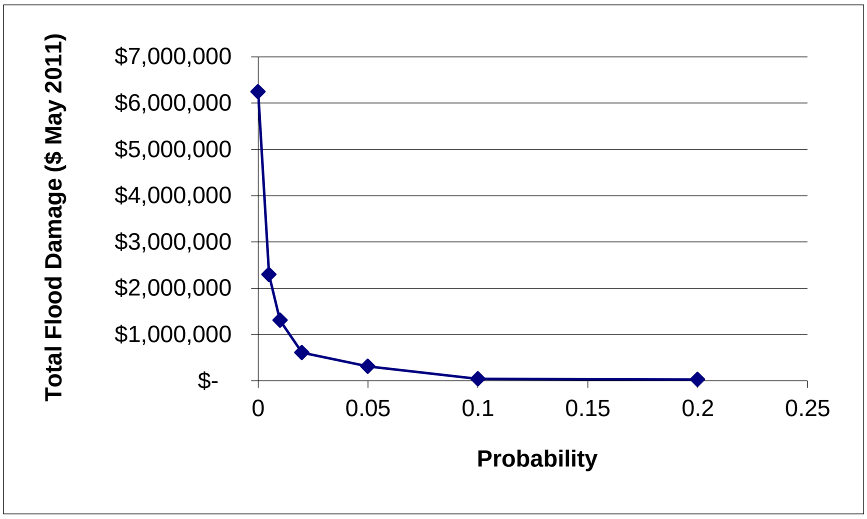

Figure 6.2: Broughton Creek Average Annual Damage Curve

6.5 Results

The results from the damage analysis are shown in **Table 6.5**. Based on the analysis described above, the average annual damage for the Broughton Creek floodplain under existing conditions is $139,500.

Table 6.5: Flood Damage Analysis Summary

Event / Property Type	Properties with overfloor flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with overground flooding	Total Damage ($ May 2011)
PMF					
Residential	43	0.63	2.67	109	$ 3,793,100
Commercial	4	1.74	2.55	8	$ 2,190,400
Industrial	3	1.22	3.03	1	$ 254,000
PMF Total	50			118	$ 6,237,500
1% AEP					
Residential	6	0.51	0.65	54	$ 937,000
Commercial	2	1.00	1.01	3	$ 1,192,900
Industrial	1	0.40	0.36	2	$ 160,700
100 Year ARI Total	9			59	$ 2,290,600
2% AEP					
Residential	2	0.13	0.54	36	$ 548,000
Commercial	2	0.47	0.79	3	$ 757,200
Industrial	0			1	$ -
50 Year ARI Total	4			40	$ 1,305,300
5% AEP					
Residential	1	0.45	0.45	27	$ 289,100
Commercial	1	0.51	0.51	3	$ 317,000
Industrial	0			1	$ -
20 Year ARI Total	2			31	$ 606,100
10% AEP					
Residential	1	0.38	0.38	13	$ 135,700
Commercial	1	0.25	0.25	2	$ 174,600
Industrial	0			0	$ -
10 Year ARI Total	2			15	$ 310,300
20% AEP					
Residential	0			6	$ 39,300
Commercial	0			1	$ -
Industrial	0			0	$ -
5 Year ARI Total	0			7	$ 39,300
50%AEP					
Residential	0			4	$ 26,200
Commercial	0			0	$ -
Industrial	0			0	$ -
2 Year ARI Total	0			4	$ 26,200

7 Environmental and Social Characteristics

Environmental and social characteristics of the study area will impact the type and extent of flood mitigation options. Environmental characteristics, such habitats housing threatened species, topography and geology are constraints of structural flood mitigation sites.

Social characteristics will also impact the type of flood mitigation options. Community consultation will give light to the preferred flood mitigation options in the study area.

7.1 Geology, Soils and Geomorphology

7.1.1 Study Area Topography and Drainage

The northern border of the catchment (**Figure 2.1**) is surrounded by foothills of escarpment slopes and tributary valleys to Broughton Creek floodplain (**Appendix Figure B.1**). Broughton Creek extends from the escarpment slopes from the north and northeast to the south and southeast of the catchment (**Figure 2.2**). The highest elevation of the catchment lies in the north west corner of the study area, at over 100m elevation. The lowest is Broughton Creek, south east of the study are at 0m elevation (**Appendix Figure B.1**). Broughton Creek flows across a broad floodplain in a southerly direction, flowing into the Shoalhaven River about 5km west of Shoalhaven Heads (Maunsell, 2007). The confluence of Broughton Creek and the Shoalhaven River is at Coolangatta Road bridge. The lower reaches of Broughton Creek catchment, downstream of Coolangatta Road bridge forms part of Shoalhaven River floodplain (SMEC, 2008).

7.1.2 Geology and Soils

The geology of the study area can be mainly categorised under the Shoalhaven group of rocks found in the older south eastern sections of the Sydney basin (**Figure 7.1**). The hilly areas associated with the lower escarpment slopes, located to the north and west of Berry are underlain by Budgong Sandstone, Blow Hole Latite and the Berry Formation (Hazelton, 1992). The soils in this area are prone to erosion. The soil landscapes are characterised by low bearing strength of topsoils and localised mass movement hazards resulting in the likelihood in landslides (Hazelton, 1992). The rest of the study area is underlain by alluvium derived mainly from sandstone and shale and are described as active floodplains (Hazelton, 1992). The floodplain has a permanently high water table, resulting in a tendency for increased drainage times of floodwaters.

7.1.3 Acid Sulfate Soils

According to the Acid Sulfate Soil Risk Maps published by the Department of Land and Water Conservation (DLWC), some sections of the study area are noted as being affected by Acid Sulfate Soils (ASS). These areas are typically in the south and east of the study area as shown in **Figure 7.1**. The majority of the ASS identified in the study area has a low probability of occurrence except for a strip in the south east corner with a high probably of occurrence. For any flood mitigation works where ASS has been identified, further environmental assessment must be taken. Disturbance of ASS may result in the release of acid and/or the mobilisation of heavy metals. This can affect water quality, flora and fauna and have other environmental consequences within and downstream of the study area.

7.1.4 Contaminated Soils

A search of the EPA Contaminated Land Register conducted in July 2011 identified two contaminated notices in Nowra, southwest of the study area.

It is important to note that the EPA Contaminated Land Record is not an exhaustive database, and there may be previously unreported contamination affecting study area. The potential for contamination should be considered for any flood mitigation works.

7.2 Land Use and Flooding

Different land use zoning will affect the type, extent and location of flood mitigation options. Land use is also a major factor in the level of risk to assets and human life during a flood event. The Shoalhaven Draft Local Environment Plan (LEP) 2009 is used in this analysis. The impacts of flooding on the land use zones are further outlined in **Section 9.2**.

7.3 Demographic Characteristics

Demographic characteristics for the township of Berry were derived from the Australian Bureau of Statistics (ABS) 2006 Census:

- 1,932 people were residents of Berry, with 0.7% of the population identify as Indigenous persons ;
- English is the primary language in Berry, with 94.2% of the population speaking only English at home. Other languages spoken in homes are German, Croatian, Mandarin, Italian and Dutch.

It is unclear if non-English languages are solely spoken in the home or if spoken additionally to English. Emergency response plans need to be effectively communicated to the community, and may need to consider non-English speakers.

Table 7.1: Demographic Characteristics of Berry

Demographic Characteristics of Berry	Number of population	Percentage of total population
Total population	1932	100%
Indigenous population	14	1%
Infants and children 0 to 14 years	312	16%
Adults 15 to 64 years	1128	58%
Mature adults 65 years and over	494	26%

Table 7.2 shows a high proportion of the population is more than 65 years old, more than one quarter of the total population. This is reflective of a high number of retirees in the area. There are also a number of aged care facilities including the Masonic Retirement Village and Bupa Care Services in the south and west Berry respectively. Two independent living retirement homes are also west of the study area: the Arbour and The Grange at Berry. Consideration of flooding and access needs to consider these facilities. Additionally, 16% of the population are infants and children. Berry Public School is located in the west in the study area.

7.4 Resident Survey

The resident survey was a phase of the community consultation process (**Section 4**). While the ABS statistics gives a broad overview of demographics, the community survey specifically targets those within the study area's PMF flood extent. The aim is to obtain demographic statistics which are in context to the flood prone areas and to give insight into community's past flooding experiences. The detail of the resident survey and community consultation is outlined in **Section 4**.

From the resident survey 80.5% of respondent properties were owner occupied. A total of 346 people lived on the properties of those who responded. A total of 43% of residents identified themselves as being in the age bracket, a higher proportion than 26% from the ABS 2006 census. The average number of years respondents have occupied their properties is 17.8 years. The large majority of respondents who own and occupy their properties and relatively long duration of average residency indicate the respondents are invested in the Berry area. The respondents will likely have had valuable past experiences and observations during a flood event. Approximately two thirds of the respondents have experienced a flood event.

For those who have experienced a flood event, 15% experienced isolation and 13% had friends or family who experienced isolation, indicating evacuation risk during past floods events. Any experience of isolation needs to be addressed in flood mitigation options.

All 83 respondents spoke only English at home. No other languages were specified. Unsurprisingly, respondents were likely to be English speakers as the resident surveys were solely printed in English. The 2006 Census results, detailed in **Section 7**, indicate 5.8% of the population speak languages other than English at home. Further investigation needs to be taken to determine if non-English speakers are in the study area in order to effectively communicate the flood mitigation options and emergency response plans.

7.5 Water Quality

Sources of pollutants impacting upon water quality in the study area include:

- "Point" Sources and
- "Non-Point" Sources.

Point sources of pollutants, for example, can be discharged from premises licensed by the NSW EPA within the catchment under the *Protection of the Environment Operations Act* (1997). A search of the register of licensed premises maintained by the EPA found one licence has been issued within the catchment to the Berry Sewage Treatment Plant off Wharf Road, Berry. The license is held by Shoalhaven City Council. Treated discharges from this facility enter Broughton Creek, south east and downstream of the study area.

In rural areas point sources can also include septic tanks, especially those which are poorly maintained, older or no longer in use. Contaminated lands can also act as point sources of pollutant (see **Section 7.1.4)**. Where pesticides or fertilisers are used for agricultural purposes, these may also act as a point source of pollution

Non-point sources are diffuse sources of pollutants, such as the build-up of pollutants on roads, nutrients from smaller scale use of fertilisers, pesticides or cleaning products by residents. In the event of rainfall these pollutants and other debris will be entrained in stormwater flows and make their way into creeks and thereafter into the Shoalhaven River. A major contributor of non-point source pollution in the catchment will be animal droppings due to the extensive use of land for dairy and beef cattle grazing. Access by livestock to the banks of creeks has also caused erosion in some locations, which can contribute to local water quality issues and increase turbidity (Maunsell, 2007). Generally, these diffuse sources of pollutants are harder to manage and identify.

Water quality in the greater Shoalhaven River Catchment has improved in the last decade. As Shoalhaven River is downstream of Broughton Creek, this may indicate water quality from Broughton Creek Catchment has also improved. The Shoalhaven River Catchment has a good aesthetic quality due to low turbidity levels in the majority of the catchment area. Heavy metal and nutrients levels have decreased significantly (SCA, 2009; EPA 1997).

7.6 Flora and Fauna

A search on the *Environmental Protection and Biodiversity Conservation* (EPBC) Act database and Office of Environment and Heritage (OEH) Wildlife Atlas was undertaken to identify the potential for occurrence of any threatened or endangered flora or fauna in or near the study area, adopting a 1km buffer and a 5km buffer respectively. The presence of flora and fauna in the study area has the potential to constrain the type or design of any proposed flood mitigation works. In addition, threatened flora and fauna species are protected under the EPBC Act, *Fisheries Management Act* 1995 and *Threatened Species Conservation* (TSC) Act 1995.

The study area is mostly surrounded by cleared paddocks with no or little native vegetation. However, older established trees in these paddocks may house native wildlife, such as hollows for native birds (Maunsell, 2007). In Berry's west, there are three pockets of vegetation which can be described as Currambene-Batemans Lowlands Forest, a eucalypt forest (Maunsell, 2007). Northeast of the study area is a strip of Illawarra Gully Wet Forest, a tall eucalypt forest (Maunsell, 2007). The forests most likely houses native fauna species, however, numbers may be limited in potential due to their small areas.

Broughton Creek catchment is home to varying quality of fish habitats. North of Berry in Bundewallah Creek and Connellys Creek, there is minor fish habitat, characterised by intermittent water flows and semi-permanent pools. North east of Berry, Broughton Mill Creek is home to major fish habitats, with a permanently flowing waterway that may potentially be home to threatened fish species. Broughton Creek itself is also considered a major fish habitat (Maunsell, 2007).

The Wildlife Atlas search did not identify any threatened flora species records for the study area, however, the EPBC database revealed six threatened flora species (**Table 7.2**). EPBC database and Wildlife Atlas Data lists a combined 19 threatened fauna and 2 fish species shown (**Table 7.3**). The Wildlife Atlas Search also revealed three Critically Ecological Endangered Communities and forty-five Ecological Endangered Communities within a 5km radius of the centre of the study area.

Table 7.2: Threatened Flora Species

Common Name	Scientific Name	Legal status EPBC Act	Legal status TSC Act
Leafless Tongue-orchid [1]	*Cryptostylis hunteriana*	V	V
White-flowered Wax Plant[1]	*Cynanchum elegans*	E	E
Tree[1]	*Daphnandra johnsonii*	E	-
Biconvex Paperbark [1]	*Melaleuca biconvexa*	V	V
Illawarra Greenhood, Rufa Greenhood, Pouched Greenhood [1]	*Pterostylis gibbosa*	E	E
Austral Toadflax, Toadflax[1]	*Thesium australe*	V	V

V = Vulnerable
E = Endangered
[1]EPBC Act Database results, not Wildlife Atlas
- = no status under Act

Table 7.3: Threatened Fauna Species

Common Name	Scientific Name	Legal status EPBC Act	Legal status TSC Act
Birds			
Regent Honeyeater[1]	*Anthochaera phrygia*	E	CE
Australasian Bittern[1]	*Botaurus poiciloptilus*	E	E
Swift Parrot[1]	*Lathamus discolor*	E	E
Orange-bellied Parrot[1]	*Neophema chrysogaster*	CE	CE
Australian Painted Snipe[1]	*Rostratula australis*	V	-
Fairy Tern[1]	*Sternula nereis nereis*	V	-
Gang-gang Cockatoo*[2]	*Callocephalon fimbriatum*	-	V

Black Bittern[2]	*Ixobrychus flavicollis*	-	V
Frogs			
Giant Burrowing Frog[1]	*Heleioporus australiacus*	V	V
Green and Golden Bell[12]	*Litoria aurea*	V	E
Littlejohn's Tree Frog, Heath Frog[1]	*Litoria littlejohni*	V	V
Mammals			
Large-eared Pied Bat, Large Pied Bat[12]	*Chalinolobus dwyeri*	V	V
Spot-tailed Quoll, Spotted-tail Quoll, Tiger Quoll[12]	*Dasyurus maculates (SE mainland population)*	E	E
Southern Brown Bandicoot[1]	*Isoodon obesulus*	E	E
Brush-tailed Rock-wallaby[1]	*Petrogale penicillata*	V	E
Long-nosed Potoroo[12] (SE mainland)	*Potorous tridactylus*	V	V
New Holland Mouse	*Pseudomys novaehollandiae*	V	-
Grey-headed Flying-fox[12]	*Pteropus poliocephalus*	V	V
Myotis macropus*[2]	*Southern Myotis*	-	V
Fish			
Macquarie Perch[^1]	*Macquaria australasica[1]*	E	-
Australian Grayling[1]	*Prototroctes maraena*	V	-

V=Vulnerable
E=Endangered
CE=Critically Endangered
- = no status under Act
[1]EPBC Act Database results
[2]Wildlife Atlas results
*sited in the last 10 years
[^]listed as Endangered under the *Fisheries Management Act 1994*

7.7 Aboriginal and European Cultural Heritage

7.7.1 Indigenous Cultural Heritage

The study area is thought to fall within the tribal area of the Wodi Wodi people. The Wodi Wodi people occupied the area from approximately Stanwell Park, north of the study area, to the northern bank of the Shoalhaven River, south of the study area.

Shoalhaven River is perceived as a boundary between the Wodi Wodi and the Wandandian people to the south of the river (Tindale, 1974; cited by Maunsell, 2007).

A search of the Aboriginal Heritage Information Services (AHIMS) database revealed six Aboriginal sites recorded in or near the study area. These included a potential archaeological deposit, grinding groove and artefacts. Flood mitigation management options need to consider the potential impact of any flood mitigation options on these sites, either to ensure the preservation of these sites or to remove artefacts from site to prevent further damage from flood events. Consultation with the local Aboriginal community may be required during implementation of any proposed flood mitigation works.

A search was undertaken for the National Native Title Tribunal for active Native Title claims in the study area to establish if there could be constraints on the implementation of flood mitigation controls. There are no active Native Title claims in the study area.

7.7.2 Non-Indigenous Heritage Items

Searches of the following databases were conducted in October 2011 to establish whether there were any non-Indigenous heritage items within the study area:

- **Australian Heritage Database** (***National and Commonwealth Heritage Lists,*** *EPBC Act, UNESCO World Heritage List)*
- **NSW State Heritage Branch** (NSW Heritage Act)
- ***EPBC*** **database** (*EPBC Act*)

12 sites were found to be Register of National Estate (RNE) sites, listed under the EPBC Act, 5 sites were listed under the NSW Heritage Act and 36 items are listed by State and Local governments.

Berry Post Office, Berry Local History Museum, Berry Courthouse, National Bank Building, Berry Soldiers Memorial & Memorial Avenue and the Berry district itself are all within the study area and listed under EPBC Act as RNE sites. David Berry Hospital and Berry Railway, also in the study area, are listed under the NSW Heritage Act 1977. Any flood mitigation works must not impact the integrity of these listed sites.

7.8 Visual Amenity

Much of the land was cleared in the early nineteenth century for forestry and as agriculture developed in Berry and its surrounds. There has been an increase of residential housing to the south of Kangaroo Valley Road in the north west of Berry in recent years (Maunsell, 2007).

Berry has well established gardens, vegetation and trees. Cambewarra range is a dramatic north east backdrop of Berry. Berry can be described as picturesque and is frequented by day trippers.

7.9 Impacts of Environmental and Social Characteristics on Flood Mitigation Options

The social and environmental characteristics described constrain the type, sites and extent of flood mitigation options. The topography and geology will affect the flow and drainage times of flood waters while acid sulfate soils will affect the location of some flood mitigation options. Disturbance of these soils may affect water quality, flora and fauna in the study area. Threatened flora and fauna species, and endangered ecological communities will be considered, complying with the *Environmental Protection and Biodiversity Conservation* (EPBC) *Act*, *Threatened Species Conservation (TSC) Act* and *Fisheries Management Act*. Land use in the study area will also determine flood mitigation options depending on population density, the type of assets and isolation risks. The aim is to decrease the risk to assets and human life. The resident survey, a phase of the community consultation process, also needs to be considered. Survey results can indicate the attitude towards the risk of flood events and can assist in the development of the emergency response plan and how it can be effectively communicated.

8 Emergency Response Arrangements

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

8.1 Emergency Response Documentation

8.1.1 DISPLAN

Flood emergency management for the Shoalhaven LGA is organised under the Shoalhaven City Local Disaster Plan (DISPLAN) (2008) and has been issued under the authority of the *State Emergency and Rescue Management Act, 1989* (as amended). The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- Roles and responsibilities in emergencies,
- Preparedness measures,
- Conduct of response operations,
- Co-ordination of immediate recovery measures.

The DISPLAN outlines the key responsibilities of the different organisations involved in emergency management. It is generally the responsibility of the SES, as the ”combat” agency, to respond to and coordinate the flood emergency response. It is the responsibility of Council and OEH to manage flood prevention / mitigation through development controls, the floodplain management process and mitigation schemes.

The Shoalhaven DISPLAN identifies flood hazard to be a high probability with high consequences. It should be noted that this categorisation is a general one for the whole LGA.

8.1.2 Shoalhaven Local Flood Plan

A sub-plan to the local DISPLAN has been prepared by the SES, in conjunction with Council. The *Shoalhaven City Local Flood Plan* was prepared in 2004 and covers the preparation, response and recovery of flooding emergencies for the Shoalhaven City Council Area(SES, 2004).

The Flood Plan focuses exclusively on flooding emergencies, and more explicitly defines the roles and responsibilities of parties in a flood event. It also makes note of which key roads can be flood affected, and details evacuation centres for flood affected areas of the Shoalhaven catchment.

The Flood Plan notes that Berry is a flood prone region of the catchment, and identifies the Princes Highway, Beach Road, Coolangatta Road, and the railway as having access cut during large flood events.

The Flood Plan lists flood evacuation points for flood affected regions. For Berry, these locations are:

- Berry School of Arts, Alexander Street,
- Showgrounds, Alexandra Street,
- Sporting Complex, North Street.

It is recommended that the Flood Plan be updated to reflect the outcomes of this current study. As it has been 8 years since the update of the Flood Plan, this would be a good opportunity to update the Flood Plan for other recent studies within the LGA.

With respect to the upper reaches of Broughton Creek, the following alterations to the Flood Plan are recommended, based on the results of the Floodplain Risk Management Study:

- Expand the discussion on flooding within Berry to include the flooding caused by Town Creek and Hitchcocks Lane Tributary in restricting access through the Township
- Include the newly installed river gauge on Broughton Mill Creek, downstream of Berry, in "Annex C" of the Plan which lists the gauges monitored by the SES to provide flood warning
- Provide alternative evacuation locations, as discussed in detail below
- Update "Map 5" which depicts Berry to include recent development such as the retirement village and developments along Kangaroo Valley Road

Note also that this document should be updated following the construction of the Princes Highway upgrade as this will alter the flooding behaviour and access for a number of areas, including the Berry Township and its surrounds.

8.2 Emergency Service Operators

The Broughton Creek floodplain lies within the Illawarra / South Coast region of the State Emergency Service (SES). The SES maintains a Local Operations Headquarters at 92 Albatross Rd, Nowra. The Illawarra / South Coast region office is located at 6-8 Regent St, Wollongong.

The access road from the Local Operations Centre to Berry is the Princes Highway, which may be flood affected during large storm events.

The SES is listed as the "Combat Agency" for flooding and storm damage control in the DISPLAN, as well as the primary coordinator for evacuation and the initial welfare of affected communities.

The SES is primarily a volunteer organisation. In times of emergency, the SES operates a paging service for on-call volunteers. However, more experienced crew know when to mobilise based on their understanding of the local area.

The role of the SES in flash flood areas such as Town Creek is generally at the clean-up stage. However, for longer duration flooding, such as Broughton Creek, the SES can assist in evacuation and protection of properties.

The locations of key emergency services for Broughton Creek are outlined in **Table 8.1**.

Table 8.1: Emergency Service Providers Locations

Emergency Service	Location
Shoalhaven Hospital	2 Shoalhaven Street, Nowra
Berry Police Station	56 Victoria Street, Berry
Berry Fire Station	26 Prince Alfred Street, Berry

It is important to note that David Berry Hospital is not an emergency response facility, and as such has not been included in the above table.

8.3 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 be evacuation of residents from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

8.3.1 Access Road Flooding

Summarised in **Table 8.2** below are the key access routes out of, and through, the Berry Township. The crossings are shown in **Figure 8.1**. The table shows the time it takes for them to overtop by greater than 0.2m in the 1% AEP, for the 9hr duration, and how long they are overtopped for.

The table shows that most roads remain open for a significant period of time, and only remain overtopped for relatively short periods of time during long duration storm events.

In short duration events, the roads both overtop and reopen quickly, due to the short, intense nature of the rainfall and flooding.

Table 8.2: Flooding time of key access roads

Location	ID	Time to Loss of Access (hours)	Time of Lost Access (hours)
Corner of Princes Highway and Woodhill Mountain Road	A	5	3
Princes Hwy, near Hitchcocks Lane	B	*Remains Open*	*Remains Open*
Kangaroo Valley Road	C	5	1
Queen Street, near Town Creek crossing	D	2	1
Corner Edward and Princess Streets, Town Creek crossing	E	2	1
Corner Albany and Princess Streets, Town Creek crossing	F	2	1.5
Victoria Street, Town Creek crossing	G	2.5	1
Prince Alfred St, near Town Creek Crossing	H	3	5.5

Berry Evacuation Locations

It is recommended that alternative evacuation locations be selected for Berry. The flood study review (refer **Appendix B**) showed that both the Berry School of Arts property, and its access, is affected in major flood events. A similar situation exists for the sporting complex on North Street.

Whilst access is not restricted for significant periods of time, it is still recommended that alternative evacuation points be used. As Town Creek restricts access across town, it is recommended that an evacuation point be provided both north and south of Town Creek. Suggested alternatives are:

- Anglican Church, North Street
- Berry Primary School, Victoria Street

8.3.2 Driving Condition Analysis

Movement during a storm event is likely to be undertaken by car, or similar vehicle. The safety of operating such a vehicle needs to be determined if movement options are to be recommended.

During an extreme rainfall event, the intensity of rainfall as well as other factors (such as wind and debris), would make driving either difficult or potentially more dangerous than sheltering in place. These factors would not be unique to a floodplain, and would be equally as dangerous if an extreme event were to occur in any location. It would be expected that the risk to life of driving in these conditions would increase with lower frequency rainfall events.

A review was therefore undertaken on driver safety related to rainfall events.

A study into rainfall effects on single-vehicle crash severities based on an analysis of crash and traffic data for the Wisconsin, USA area for the period 2004-2006 found that rainfall events with a mean rainfall intensity of 3.16 mm/hr resulted in an increased likelihood of crashes ranging in severity from fatal to possible injury (Jung, Qin, & Noyce, 2009).

An analysis of data for the cities of Calgary and Edmonton, Canada during 1979-1983 concluded that the overall accident risk during rainfall conditions was found to be 70% higher than normal (Andrey, 1993).

Andreescu and Frost (1998) in an analysis of data for Montreal, Canada 1990-1992, found that a best fit line of data found a linear increase in number of accidents in relation to increased daily rainfall intensity (mm/day). This is reproduced in **Figure 8.2**. It is noted that there is significant scatter in the source data and that the correlation is relatively low. However, the data does demonstrate a link between daily rainfall and accidents.

The NSW Governments Roads and Traffic Authority (RTA) *Road User's Handbook* (2010) states that "Driving during extreme weather events or conditions should be undertaken with care and caution. Driving should be avoided in extreme conditions."

The rainfall intensity temporal distribution for the 1% AEP 9 hour event is shown in **Figure 8.3**. It is noted that these are exclusive of climate change impacts on rainfall intensities.

The figure shows that rainfall intensities are generally greater than 10mm/hr, with peaks of 20mm/hr, 33mm/hr and 55mm/hr at 1 hour, 3 hours and 5 hours into the storm respectively.

The literature evaluated does not give a definitive threshold of rainfall intensity for which unsafe driving can be expected (with the exception of Jung (2009) which has a very low intensity of only 3 mm/hr, which can be expected in relatively frequent events).

However, average rainfall intensities for the 1% AEP 9 hour event are well in excess of the values identified in the literature as beginning to have an effect on driving risk.

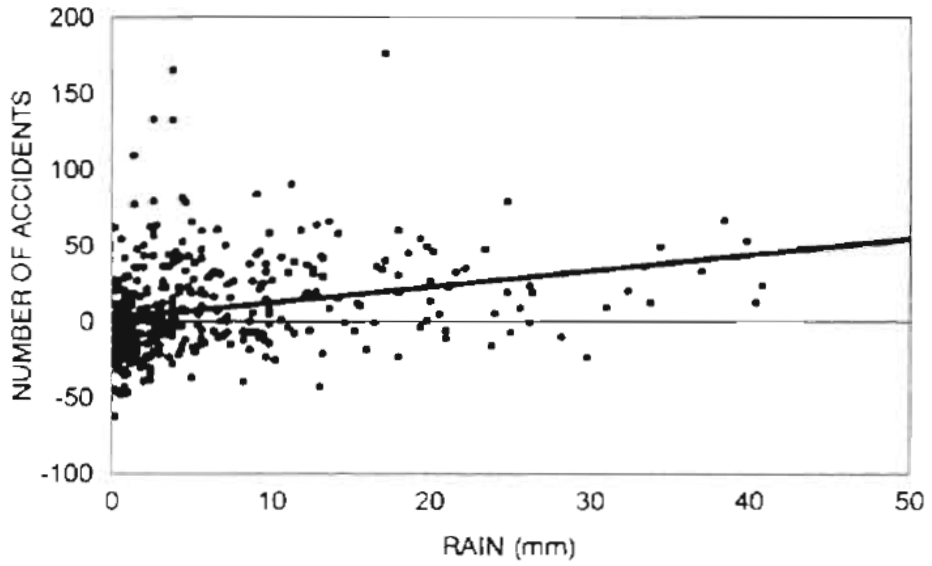

Fig. 4. Montreal, 1990–1992, number of accidents per day vs rainfall amount on days with rain, including the best fit linear regression line, r = 0.27

Figure 8.2 Number of accidents vs daily rainfall (Andreescu & Frost, 1998)

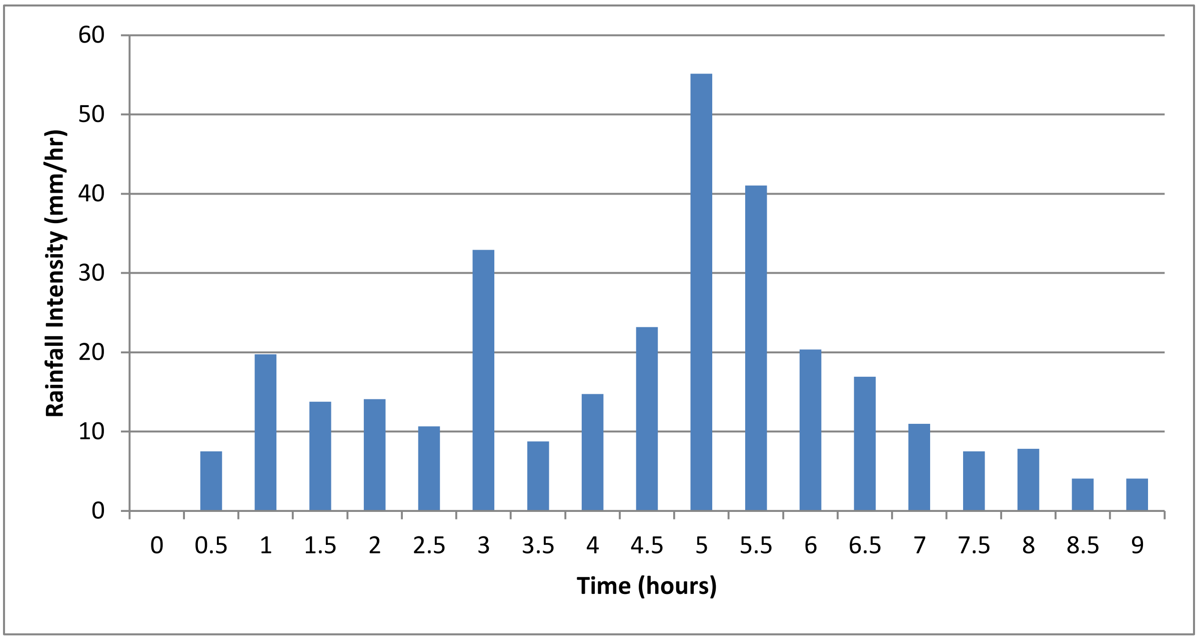

Figure 8.3: Broughton Creek 1% AEP 9hr Temporal Rainfall Distribution

From the above, it is not recommended that people attempt to drive during a significant rain event. As the most intense rainfall will be associated with short duration storms, the safer option is to wait for the rain to lessen before attempting to drive. During longer duration events, where flood warning may be possible, the rainfall intensity will be reduced, and may allow evacuation whilst the rain is falling. However, in general, it is recommended that driving not be undertaken during intense rainfall periods.

8.4 Flood Emergency Response

The flooding behaviour in and around Berry may be broadly characterised into three modes:

- Local Creek and overland flooding,
- Major Creek flooding,
- Shoalhaven River backwater.

Each of these modes, and the emergency responses which may be applied to them, are discussed below.

8.4.1 Local Creek and Overland Flooding

The local creeks and overland flowpaths within the study area are responsible for the majority of flood damages. These waterways are:

- Town Creek,
- North Street Flowpath,
- Hitchcocks Lane Flowpath.

The critical duration of these flowpaths is 2 hours, with the peak of the flood reached approximately 1 hour after the start of the storm.

Shown below in **Table 8.3**, are the numbers of properties affected by over-floor flooding from local creeks, in each AEP event. The table also notes how many of these affected properties have second stories which can offer flood refuge.

It can be seen that relatively few properties are affected until larger events (1% AEP and greater) are experienced. However, most properties lack a second storey to take refuge in, which increases the hazard level of these properties in flood events.

Table 8.3: Properties affected by over-floor flooding from local creeks

AEP	Total properties with over-floor flooding	Single floor properties with over-floor flooding	Double story properties with over-floor flooding
50%	0	0	0
20%	0	0	0
10%	0	0	0
5%	0	0	0
2%	1	1	0
1%	4	3	1
PMF	25	21	4

Flood Warning

Due to the short interval between the start of the storm, and the peak of the flood, there is little in the way of warning that can be provided. The best warning will be provided by weather and storm forecasts provided by the Bureau of Meteorology (BOM).

The BOM issues “severe weather” and “severe thunderstorm” warnings, based on predictions of severe rainfall, primarily taken from rainfall radar systems.

These weather based warnings are generally faxed to media outlets and the SES, as well as being shown on the BOM website (www.bom.gov.au). Flood Watches (from the Hydrology Section of the Bureau) are only sent to the SES who then disseminates the information to media outlets.

Flood Response

The short critical duration does not allow sufficient time to evacuate residents from their properties. In this case, evacuation is generally not recommended as the response during a flooding event as it is likely to be hurried and uncoordinated, which can expose residents to a hazardous situation. This hazard would be increased by attempting to drive during intense rainfall (refer **Section 8.3.2**).

As such, the preferred approach is to remain within the property, preferably within the upper levels if available. Properties where a second storey is not available are noted as being a higher hazard than others. It is important to note that evacuation for most single storey properties is possible on foot as a last resort, as in general the land slopes away from the creeks.

It is important that residents are aware of signs that will signal an approaching flood, and are aware of the correct response such that the small time period before the flood arrives may be used as effectively as possible to move people and belongings to a safe location within the residence.

8.4.2 Major Creek Flooding

The major creeks of the study area include:

- Broughton Creek
- Broughton Mill Creek
- Bundewallah Creek

These systems are characterised by long critical durations, generally 6 – 9hrs, and large flow volumes. For Broughton Creek and Bundewallah Creek, the critical duration is 9 hours, with the peak of the flood occurring approximately 6.5 hours after the start of the storm. For Broughton Mill Creek, the critical duration is 6 hours, with the peak of the flood occurring approximately 3 hours after the start of the storm.

Within the study area, these creek systems cause flooding issues for the Berry Bowling Club, properties along Prince Alfred Street, Queen Street, Albert Street and

North Street, and affect access along the Princess Highway, Woodhill Mountain Road and Tannery Road.

While longer duration storms result in the peak flooding within these creek systems, it is also important to also consider the severity of short duration events. Peak water levels for a range of durations are shown for key locations in **Table 8.4**.

The results show that whilst the 6hr event is critical in these locations, shorter duration events are still capable of resulting in significant peak water levels, and associated smaller warning and evacuation times. As such, it's important to make provisions for short duration responses in these regions as well.

Shown below in **Table 8.5**, are the numbers of properties affected by over-floor flooding from major creeks, in each AEP event. The table also notes how many of these affected properties have second stories which can offer flood refuge.

Similar to the local creek flooding, relatively few properties are affected until larger events (1% AEP and greater) are experienced. However, nearly all properties lack a second storey to take refuge in, which increases the hazard level of these properties in flood events.

Table 8.4: Severity of storm durations for the 1% AEP event

Location	Peak Water Level (mAHD) (Depth (m))				Time to loss of access (hours)			
	2hr Storm	6hr Storm	9hr Storm	12hr Storm	2hr Storm	6hr Storm	9hr Storm	12hr Storm
Corner Princes Hwy & Woodhill Mountain Rd	9.52 (0.3)	9.73 (0.5)	9.54 (0.3)	9.46 (<0.2)	1.3	2.2	5	*Not lost*
Prince Alfred St	6.96 (0.6)	6.99 (0.6)	6.98 (0.6)	*Not flooded*	1	1.9	3	*Not lost*
Rail Line	7.03 (0.2)	7.05 (0.3)	7.02 (0.2)	*Not flooded*	1.2	2.5	4	*Not lost*

Table 8.5: Properties affected by over-floor flooding from major creeks

AEP	Total properties with over-floor flooding	Single floor properties with over-floor flooding	Double story properties with over-floor flooding
50%	0	0	0
20%	0	0	0
10%	1	1	0
5%	1	1	0
2%	1	1	0
1%	2	2	0
PMF	18	17	1

Flood Warning

Longer duration flooding allows the implementation of additional flood warning and flood emergency response measures, as there is a greater available response time. However, as noted above, the creeks are still influenced by shorter duration flooding.

There are existing river gauges along Broughton Mill Creek, and pluvio-stations in the ranges at the upstream end of Broughton Creek, though none within the Broughton Creek catchment.

It may be possible to tie manual or automatic alerts to the data gathered by these instruments. Alerts to SES may be generated at trigger levels, or automatic SMS alerts to residents and businesses that could be impacted. It is noted that this would likely only provide adequate warning for lower intensity, longer duration events. During short duration events, the response and warning time would be similar to the local creeks.

Gauges located in the upper reaches of the Broughton Creek catchment could provide warnings times of approximately 4 – 5 hours, depending on the trigger levels used to issues warnings. The warning time would reduce for stations located closer to the township.

Flood Response

The longer duration flooding that occurs in Broughton Mill Creek and Broughton Creek allows for the possibility of pre-flood responses.

These responses include:

- Sand bagging,
- Elevation of property contents,
- Lashing down potential flood hazards,
- Moving vehicles to high ground,
- Evacuation.

Flood warning systems would utilise rainfall / stream gauges to provide advance warning of approaching flood waters.

These warnings could be via alerts issued by the SES, Council, or the monitoring authority of the gauge. Alternatively, the alerts may be automatically generated by a certain gauge trigger level, and distributed via SMS to high risk locations, and others who have requested the alerts.

This warning would allow residents to install temporary flood proofing (sand bags), relocate items / property to higher ground, and secure items which may come loose during the flood event.

Advance warning would also allow high risk properties the opportunity to evacuate.

In the case of evacuation, it is important to assess the benefits, and to determine who is likely to be able to take advantage of this option. It must also be determined if they would be any safer doing so, than staying within their property.

Two key concerns with evacuation are:

- The depth and duration of floodwaters over key access roads,
- Driving conditions occurring during the evacuation period (noting that evacuation to higher ground or evacuation centres will primarily be via private vehicle).

An area of particular concern is the Berry Bowling Club. As a club and social venue, it is common for a number of people to be at the site at a given time and access can be quickly lost when the Princes Highway overtops.

As such, it needs to be ensured that a suitable short duration response be developed. This could be constructing a second storey flood shelter on top of the existing building, or building a specially designed flood shelter elsewhere on site (which could double as additional function space). Alternatively, the possibility of relocating the club to a less flood prone area could also be investigated.

It is suggested that the flood response should focus on a 'remain in place' policy, and that the community be educated as to the appropriate actions to take in a flood event. As discussed in **Section 8.3.2**, movement during storm events can be dangerous due to blocked access, and intense rainfall.

8.4.3 Shoalhaven Backwater Flooding

The third form of flooding behaviour in the Broughton Creek catchment is backwater flooding from the Shoalhaven River system. This flooding occurs as a result of prolonged periods of rainfall throughout the Shoalhaven River catchment area, which cause significant backwater affects in the downstream reaches of the river system.

The warning times for this type of flooding behaviour is relatively large, and the volume of water required to cause the flooding means that low volume, short duration storms do not cause significant flooding.

As such, warning systems are well suited to this type of flooding behaviour.

As previously discussed, the system would be linked to existing and future rainfall and river gauges, and would provide alerts to authorities or to registered residents via SMS when trigger levels on the gauge were reached. This option was proposed as part of the Lower Shoalhaven River FRM Study and Plan (Webb McKeown & Associates, 2008), and it is recommended that it be extended to include the upper reaches of the Broughton Creek catchment

The area affected by Shoalhaven backwater flooding is generally rural and agricultural properties. Buildings on these properties are, for the most part, built above 1% AEP flood levels, but they still experience significant flooding problems with regards to loss of access, and risk to livestock.

A warning system would be well suited to these properties, as it would allow for the transfer of stock and machinery to high ground, whilst access is still open. Additionally, it may be possible to construct stock mounds (refer **Section 11.2**) within the property to provide a flood-free refuge for stock during storm events.

8.4.4 High Flood Risk Locations

Aged Care Facilities and Schools

Generally speaking, the most vulnerable people during a flood event are the elderly and children. A number of aged care facilities, retirement villages and a school are located within the study area (refer **Figure 9.2**). The Masonic Retirement Village is inundated during both the 1% AEP flood event and the PMF. The only access to the Masonic Retirement village during the flood events will be the residential land adjacently west, as Albany Road north of this facility would also be inundated during a flood. The facility will experience long duration flood during a flood event.

The Berry Public School is predominantly free of inundation for the 1% AEP and PMF events as is the surrounding residential land.

The flooding of the Princes Highway and Albany Road would also hinder access to two independent living retirement villages, The Arbour and The Grange, whose access routes are inundated during both the 1% AEP event and the PMF event.

Another aged care facility, Bupa Care Services is situated on the border of both the PMF and 1% AEP flood extent. Although Bupa Care Services may not be inundated, the facility is currently isolated due to the flooding of the Princess Highway, west of the facility. The Arbour, The Grange and Bupa Care services will experience short duration flooding.

Berry Bowling Club

A property of particular interest that is affected by major creek flood is the Berry Bowling Club, located immediately downstream of the Broughton Mill Creek Princes Highway crossing. The Bowling Club is located on low lying land adjacent to Broughton Mill Creek.

The Berry Bowling Club is of particular concern during flood events. This is due to:

- The frequency with which it experiences overground and overfloor flooding;
- The possibility of a number of people being concentrated at the property during a flood event;
- The likelihood that patrons will include a significant portion of elderly patrons;
- A restricted ability to evacuate to high ground, as people are required to cross a large portion of the floodplain before the terrain rises; and,
- A lack of vertical evacuation and shelter in place options.

Protection options for the site were investigated (refer **Section 11**) but they did not prove feasible as the options resulted in flood level increases on adjacent properties.

To manage the residual risk of the property, it is recommended that a Flood Response Plan be prepared for the property, and that an employee at the Bowling Club be designated as a Response Manager. The Response Manager would be briefed on the flooding risks and appropriate responses, and serve as a contact person between the Bowling Club and SES / Council. It is envisaged that when the SES or Council are alerted to a possible flood event, they would contact the Bowling Club Response Manager, who would proceed to implement the building Flood Response Plan.

8.5 Recovery

In a major flood event, structural damage to flood-affected properties may occur and residents may need to be accommodated temporarily during the recovery operation. The Department of Community Services is responsible for the long term welfare of the affected community. However, the immediate action is likely to be undertaken by the SES Local Controller.

8.6 Development of a Flood Response Plan

Building on the above investigation into the flood risks and management options, a Flood Response Plan has been developed as part of the project, and provided as a supplementary document.

The Flood Response Plan has been developed for use during a flood event. The Emergency Response Plan includes details on:

- Available access along key roads in flood events,
- Trigger levels for rainfall / creek levels which would initiate an evacuation response,
- Detailed, property specific, flood summaries to inform property owners of expected flood levels for given storms, and appropriate responses.

9 Policies and Planning

9.1 Planning Instruments / Policy

The Broughton Creek catchment is located in the Shoalhaven LGA where development is controlled through the Shoalhaven Local Environment Plan (LEP) and Development Control Plans (DCP). The LEP is a planning instrument which designates land uses and development in the LGA, while DCPs regulates development with specific guidelines and parameters.

Due to the *Environmental Planning and Assessment Amendment Act 2008* and *Environmental Planning and Assessment Amendment Regulation 2009*, the standardisation of all NSW Local Authority LEPs is in process. Due to significant changes within the LGA and the NSW Planning Reforms implemented by the NSW Government, the LEP is in the process of being updated. Shoalhaven Council has prepared the Draft Shoalhaven LEP 2009. The Draft Shoalhaven LEP 2009 was released for public viewing and comment. The public draft exhibition period ended on the 14th October 2011 and is currently undergoing final reviews prior to adoption.

The discussion following is in reference to the Draft LEP document. Significant changes have been made to the 1985 LEP document regarding Flood Controls as part of the revision process, so a discussion on this document was not undertaken. Instead, comment was made on the draft LEP.

This section reviews flood controls covered by the LEP and relevant DCPs.

9.1.1 Flood Controls within the LEP

The current draft update of the LEP incorporates a section on flood affected land. The objectives of *Section 7.8: Flood Planning Land [Local]* are:

- To maintain the existing flood regime and flow conveyance capacity,
- To enable safe occupation and evacuation of land subject to flooding,
- To avoid significant adverse impacts on flood behaviour,
- To avoid significant effects on the environment that would cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses,
- To limit uses to those compatible with flow conveyance function and flood hazard.

The land to which this clause applies is the 1% AEP flood extent, plus a 0.5m freeboard.

9.2 Current Land Use and Zoning

The Broughton Creek catchment is comprised predominately of rural or undeveloped land, with isolated centres of urban development, such as the Berry township.

The land use within the Broughton Creek catchment is controlled by the Shoalhaven Local Environment Plan (LEP). The zoning of the study area (as in the current draft) is shown in **Figure 9.1**, and these zones are described in **Table 9.1** as per the Standard LEP Instrument (NSW Government, 2011).

Table 9.1: Broughton Creek Catchment Land Uses

Zone	Land Use	Description
Rural	RU1 Primary Production	• Rural land used for primary industry production. For example, extensive agriculture, horticulture, intensive livestock agriculture, mining, forestry, and extractive industries. • Aimed at maintaining and enhancing the natural resource base.
	RU2 Rural Landscape	• Rural land with general landscape values or that has reduced agricultural capability but which is suitable for grazing and other forms of extensive agriculture.
Residential	R1 General Residential	• To provide for a variety of residential housing types and densities, including dwelling houses, multi-dwelling housing, residential flat buildings, boarding houses and seniors housing • Also to provide facilities or services to residents, including neighbourhood shops and child care centres
	R2 Low Density Residential	• Land where primarily low density housing are to be established or already exist. • Also to encourage the provision of facilities or services that meet the day-to-day needs of residents
	R3 Medium Density Residential	• Land where a variety of medium density accommodation exists or can be considered. • Also to provide additional uses to provide facilities or services to residents, including neighbourhood shops and child care centres

Zone	Land Use	Description
	R5 Large Lot Residential	• Residential housing in a rural or semi-rural setting
Business	B2 Local Centre	• Intended for centres that provide a range of commercial, civic, cultural and residential uses that typically service a wider catchment than a neighbourhood centre. • To provide a mix of uses such as businesses, educational facilities, function centres; will increase walking, cycling and public transport options for more people by making more activities available in one location.
Industrial	IN1 General Industrial	• Generally intended to accommodate a wide range of industrial and warehouse uses including industrial training facilities, high technology industries and depots. • Suitable to have a range of industrial land uses and other compatible land uses generally catered for in an industrial zone.
Special Purpose	SP1 Special Activities	• Generally intended for land uses or sites with special characteristics that cannot be accommodated in other zones. For example, large complexes such as a major scientific research facility, communications establishment, or an international sporting facility.
	SP2 Infrastructure	• Infrastructure land that is highly unlikely to be used for a different purpose in the future, for example cemeteries and major sewage treatment plants • Also appropriate for major state infrastructure or strategic sites such as major hospitals and large campus universities/TAFEs.
	SP3 Tourist	• To be used where tourism is considered the focus of the particular location, for example, where there is a natural or built site or location which attracts visitors
Recreation	RE1 Public Recreation	• Generally intended for a wide range of public recreational areas and activities including local and regional parks and open space. For example, recreation facilities

Zone	Land Use	Description
	RE2 Private Recreation	• Generally intended to cover a wide range of recreation areas and facilities on land that is privately owned or managed or on land leased from councils or State authorities. • The use of facilities developed on this land may be open to the general public or restricted e.g. to registered members only. For example, racecourses, golf clubs, bowling clubs, rifle ranges, speedways, tennis complexes and other sporting facilities.
Environmental Protection	E3 Environmental Management	• Generally intended to be applied to land that has special ecological, scientific, cultural or aesthetic attributes, or land highly constrained by geotechnical or other hazards. • This zone can also be suitable as a transition between areas of high conservation value and other more intensive land uses such as rural or residential.

A number of land uses are affected by flooding in the 1% AEP event, as shown in **Figure 9.2**.

A spatial analysis of the land use within the extent of both the 1% AEP and the PMF was conducted (**Figure 9.1** and **Figure 9.2** respectively).

Zones within the 1% AEP event flood affected area are mainly RU1 Primary Production and R2 Low Density Residential. There is a pocket of R3 Medium Density Residential south of North Street which shows inundation during a 1% AEP flood event. The majority of residential and B2 local centre land that is impacted by the 1% AEP is within the Town Creek and North Street overland flowpaths. These areas are characterised by short duration flooding, as discussed in **Section 6**. In these areas evacuation will not be recommended.

9.3 Development Control Plans

A number of DCPs cover either the entire Shoalhaven LGA, or the Berry region specifically. They have all been reviewed for their relevance to this study. Those that have some concern / association with flooding are discussed below. Development controls concerning flooding are embedded within separate DCPs with additional controls in the DCP No.106, Development on Flood Prone Land (Amendment No.1). Council have consolidated all flood control policies into DCP 106 (Amendment No. 1) for ease as well as to avoid inconsistencies.

DCP No. 49 – Berry (Co-ordinate Future Development of Berry CBD Area)

The DCP deals primarily with retaining the character of the CBD. The DCP states that developments which include roof or paved areas greater than $30m^2$ require on site detention and detailed stormwater drainage plans.

Is recommended that an additional control be added to the Environmental Management section of the DCP and its addendums that a flood study be undertaken for buildings constructed within the 1% AEP flood extent to ensure no off site impacts.

DCP No.62 – Residential Development in Foreshore Areas

The DCP aims to manage residential development that is adjacent to the water front such as Town Creek and Broughton Creek.

Currently, there are no specific building controls in relation to floods. The only requirement is if the site is on flood prone land, a submission is required detailing extent of flooding on the site and source of the flood. Additionally, flood free road access and proposed management of the flooding on the site needs to be detailed. It is recommended that this DCP explicitly refers to DCP No. 91 Minimal Building Requirements regarding flood prone lands and/or adding a Section 2.9 detailing building controls for flood planning under Section 2 Design Elements.

DCP No. 70 – Berry (Graham Park Area)

The DCP aims to manage the development of the site bordered by the Princes Highway, Schofields Lane and Kangaroo Valley Road.

During the 1% AEP event, a flow path passes through the centre of this site.

It is recommended that a reference to flooding be included in the DCP by including DCP No. 106 (Amendment 1) in the list of codes / policies covering the region under Section 1.4.4. Additionally, under Section 2.7, a need to undertake a flood assessment of proposed buildings on flood affected property.

DCP No.71 – Medium Density Housing

The aim of the DCP is to manage the development of medium density housing.

During the 1% AEP event, the flow path passes through the R3 Medium Density Housing north of the study area.

It is recommended that the DCP be amended to include building controls under this section to minimise damage from flooding under Section 3.4 Design Element – Stormwater and Utilities. Building controls should include floor planning levels and flood free road access as a minimum.

DCP No.72 – Subdivision for Rural Lifestyle Development

The DCP controls the use of rural land for small holdings within the Shoalhaven LGA. The DCP states that it should be ensured buildings are not constructed in broad stream valleys, or within the floodplain.

DCP No.91 – Minimum Building Requirements

As part of the DCP, the following performance criteria are set out for the construction of buildings on flood prone land:

- Dwellings and ancillary structures do not adversely impede the flow of floodwaters on flood liable land,
- The floor level of habitable rooms in a dwelling are above the relevant flood criteria including a suitable free board (i.e. flood planning levels),
- The design of all buildings and construction elements must resist the impacts of flood waters,
- Access is provided to the dwelling during time of localised flooding to assist evacuation,
- Site works and building structures meet the standards of Councils Flood Policy, and relevant NSW Floodplain Development Manual guidelines. Applicants should also refer to DCP 106.

DCP No.100 – Subdivision Code

The DCP covers subdivisions with the Shoalhaven LGA.

The DCP states that flood planning levels of subdivisions are to be 0.5m above the 1% AEP flood level for residential developments in the floodway and 0.3m above the 1% AEP flood level in flood storage and flood fringe areas.

The DCP also states that flood assessment should be undertaken for properties within the floodplain. It is also recommended reference to the NSW Floodplain

Development Manual 2001 be updated to the current NSW Floodplain Development Manual 2005.

DCP No.106 (Amendment 1) – Development on Flood Prone Land

This DCP supersedes the Interim Flood Policy which previously defined development guidelines in regard to flood management. The DCP offers a consolidated document for the relevant flood planning controls, outlined in the prior descriptions of DCPs, and applicable flood policies in the Shoalhaven LGA. The DCP provides context of all flood planning requirements in the Shoalhaven LGA. An overview of the flood planning controls and policies applicable to the LGA is included, as well as the requirements of management of flood prone land, technical reporting requirements and flood proofing guidelines.

Additionally, this DCP includes site specific locations for which a Floodplain Risk Management Plan has been prepared. At the time of writing, the DCP lists four such areas:

- Terara Village,
- Riverview Road Area,
- St George's Basin, and
- Lower Shoalhaven River.

The DCP states that development of flood-prone land in other areas of the Shoalhaven LGA area is governed by this DCP. Site specific Management Plans override any generic planning controls dictated in this DCP. Additionally, this DCP overrides any conflicting flood planning controls in other DCPs.

It is recommended that this DCP be updated to include the Broughton Creek catchment, following the completion of the Floodplain Risk Management Plan.

9.4 Summary of Existing Flood Controls

Table 9.2 summarises the Flood Management Issues (FMI) addressed by relevant DCPs. Most DCPs and Policies need to address flood water detention on properties. Additionally, DCPs need to reference the relevant policies to ensure the ease and the adoption of relevant development controls to mitigate flood risk to properties.

Table 9.2 DCP and Policies addressing Flood Management Issues

	Flood Management Issue								
Policy	**FPL**	**EM**	**FA**	**ENV**	**DET**	**DRA**	**OE**	**ODC**	**Comments**
Draft LEP 2009									LEP does not address drainage or detention of floodwaters
DCP No. 49									Should reference DCP 106 (Amendment 1)
DCP No.62									DCP needs to additionally specify FPLs, emergency plans and offsite effects.
DCP No. 70									DCP needs to reference DCP 106 (Amendment 1) to address most FMIs.
DCP No.71									DCP needs to reference DCP 106 (Amendment 1) and should require a flood assessment
DCP No.72									Although DCP does not address most FMIs, construction is not permitted in the floodplain
DCP No.91									DCP sepcifies construction should resist impact of floodwaters.
DCP No.100									DCP also addresses site regrading.
DCP No.106 (Amendment 1)									DCP also addresses fill and excavation
NSW Flood Policy					-	-			References Department of Infrastucture Planning and Natural Resources (DIPNR) as lead manager.
									Also specifies building materials and construction methods.

References NSW Flood Policy
References DCP 100 - Subdivision Code

EM = Emergency
FA = Flood Assessment
ENV = Environmental Factors e.g. Riparian vegetation
DET= Water Detention
DRA=Drainage
OE=Offsite Effect e.g. impeding flows
ODC=Other Development controls

9.5 Recommended Controls for Broughton Creek

As a result of the investigation into planning controls, a number of recommendations are proposed to increase the effectiveness of the planning controls. Changes to existing controls are summarised in **Table 9.4**. The existing controls are Schedule 7 – Flood Related Development Controls – Generic found in DCP 106 (Amendment 1) which applies to all areas in the Shoalhaven LGA without an implemented Flood Management Plan.

Additional recommended controls are summarised in **Table 9.4**.

Table 9.4: Review of Existing Flood Planning Controls in Berry

Existing Control	Comments
Floor planning levels For the majority of developments, generic floor planning levels are set at 1% AEP flood level + 0.5m freeboard. Variations on this overarching control are for minor developments where the above generic floor planning level is preferred, however, if this cannot be achieved the existing habitable floor level or higher is acceptable. Additionally, carparks in High Hazard Flood Storage or Flood Fringe areas, need to be high enough to ensure a velocity – depth of less than 0.3 m^2/s for a 1% AEP. Critical infrastructure which lie in Low Hazard Floodway / Flood Storage / Flood Fringe areas only have to set floor levels up to 5% AEP flood levels.	Refer to **Section 10** for recommendations for freeboard and minimum floor levels.
Flood Proofing The DCP dictates that that any part of a building which extends below the flood planning level be constructed from flood proof materials. Additionally, the all electrical installations are above the FPL.	Refer to **Section 10** for recommendations
Filling and Excavation Within those areas affected by flooding, filling is not to be undertaken unless Development approval has been obtained from Council. Filling and excavation operations must not restrict the flow of floodwaters, not unduly increase the level or flow of floodwaters or stormwater runoff on land in the vicinity including adjoining land, not exacerbate	It is recommended that these development controls be adopted. However, for areas upstream of the rail line, an additional control should be added to undertake a hydraulic analysis to demonstrate no adverse impact on flooding.

Existing Control	Comments
erosion siltation and destruction of vegetation by floodwaters, and does not create new habitable rooms, non-habitable storage areas or carparks below with floor levels below existing ground level. The DCP dictates that earthworks are not suitable in a High Hazard Floodway.	
Floodways **High Hazard Floodways** The general principle is to keep floodways free for flood flow and, in this regard, development (residential, commercial/industrial, subdivisions) is not encouraged. However, for existing lots in floodways, each application for new residential buildings will be considered on its merits. **Low Hazard Floodways** Development needs to meet 1% AEP + 0.5m freeboard and PMF FPL, minimum building component and flood proofing requirements, and access requirements.	Any changes to existing buildings may be permissible if footprint does not change. It is recommended that developments proposed on both high hazard and low hazard floodways need to submit a flood study of the proposed development in order to ensure no adverse impacts upstream and downstream of the property. Developments on the floodway have the risk of increasing the severity of economic loss and risk to human life on surrounding areas.
New Residential Construction Schedule 7 of the DCP also states that new residential construction in a High Hazard Floodway is not suitable for development, unless there are already existing rights. Any portion of the building which lie below a 1% AEP flood level 0.5m freeboard (Low Hazard), and a PMF	Any new developments should be compliant with Flood Planning Levels outlined in **Section 10**.

Existing Control	Comments
(High Hazard Flood Storage or Flood Fringe) needs to satisfy flood proofing requirements as previously mentioned. New construction also needs to satisfy structural soundness requirements; the structure will not become floating debris during a 1% AEP flooding scenario in a Low Hazard area and High Hazard area. In a High Hazard Flood area, the building will need to withstand forces up to a 0.2% AEP scenario. New construction in a High Hazards area also needs to satisfy hydraulic impact requirements; either to include a report to prove no increase in flood hazard or flood damage to other properties or adversely affect flood behaviour for a 5% up to the PMF scenario or to allow free flood flow for a 1% AEP flood event.	
Minor Development For proposed dwelling extensions where it is impractical to raise the floor level, applications for extensions of the building at the existing level will be treated on their individual merits up to a maximum cumulative total increase in habitable floor area of: • $50m^2$ for residential and rural residential dwellings. • $100m^2$ for dwellings associated with bona fide large area rural enterprises such as dairying.	It is recommended that this be allowed where it does not have an adverse impact on flooding.

Table 9.5: Proposed Additional Policy Controls

Additional Control	Comments
No adverse impact on flooding It should be demonstrated that development will not adversely affect flood behaviour for all flood events (up to and including the Probable Maximum Flood). • No increase in peak water level at any point upstream or downstream of the proposed development • No increase in the extent of flood high hazard on any property • No restriction on the capacity of any floodway, unless related to flood detention on the property only. • No loss of storage (i.e cut to fill volumes to be neutral or positive cut). In order to demonstrate no adverse affect on flood behaviour, a site specific flood study is required unless a replacement of the exact footprint is proposed. Developments are not to increase the likelihood of flood damage to any other property.	There is a potential to incorporate some allowance for loss of storage where this is in a flood storage area. A threshold could be set based on the storage within the overall floodplain
Carparks above ground Entrance to carparks should be no lower than 100 year ARI flood level plus 0.5 metres All above ground car parks should be designed taking into account vehicle stability up to the PMF event. Vehicle stability can be assessed in accordance with the NSW Floodplain Development Manual (2005). Three options are available: • The floor planning level of the car park is sufficient to prevent the instability of vehicles due to flooding, • The car park is flood proofed to prevent the instability of vehicles due to flooding, • Bollards are provided to prevent cars being swept away.	Ensuring the stability of cars in any flood event will prevent cars from becoming debris, preventing further damage downstream in a flood event.

Evacuation Evacuation plans to be prepared for properties that experience long duration flooding. Any changes to increase of density within R (Residential) zones need to be justified.	Refer to **Section 8**.
Town Creek and North Street Overland Flowpaths Shelter point should be established with floor levels above the PMF event. Increases in density in this area should not be a significant issue as long as: • There is no adverse impact on flooding, • Flood levels are above the 1% AEP plus 0.5m, • There is a place to shelter within the development that is above the 1% AEP plus 0.5m, or PMF, whichever is greater.	The land experiences short duration flooding, evacuation would not be recommended (refer **Section 8**). The key challenge, therefore, is to provide a shelter point above the PMF event in a large flood.

10 Flood Planning Level Review

10.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 – 0.5m for residential properties, and can vary for industrial and commercial properties.

A variety of factors are worthy of consideration in determining an appropriate FPL. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of an FPL.

The Floodplain Development Manual (NSW Government, 2005) identifies the following issues to be considered:

- Risk to life,
- Long term strategic plan for land use near and on the floodplain,
- Existing and potential land use,
- Current flood level used for planning purposes,
- Land availability and its needs,
- FPL for flood modification measures (levee banks etc),
- Changes in potential flood damages caused by selecting a particular flood planning level,
- Consequences of floods larger than the flood planning level,
- Environmental issues along the flood corridor,
- Flood warning, emergency response and evacuation issues,
- Flood readiness of the community (both present and future),
- Possibility of creating a false sense of security within the community,
- Land values and social equity,
- Potential impact of future development on flooding,
- Duty of care.

These issues are dealt with collectively in the following sections.

10.2 Likelihood of Flooding

As a guide, **Table 10.1** 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 10.1** 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 10.1: Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70yrs)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10%	99.9	99.3
5%	97	86
2%	75	41
1%	50	16
0.5%	30	5

10.3 Current FPL

Based on DCP 106 Amendment 1 (**Section 9**), Council currently utilises the following flood planning levels:

- For residential development, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m
- For industrial and commercial development, based on the 1% AEP flood level, floor levels have a minimum freeboard of 0.5m
- Council strongly recommends that any part of a building which extends below the minimum floor level be flood proofed in accordance with Appendix F NSW Floodplain Development Manual 2001, now superseded by Appendix J NSW Floodplain Manual 2005

10.4 Land Use and Planning

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

A potential impact on flooding can arise through the intensity of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. DCP 106 Amendment 1 restricts building within the floodway, and recommends against filling in flood storage areas. In general, DCP 106 Amendment 1 limits development in flood prone regions. Given this, and other controls within the DCPs (**Section 9.3**), this is not considered to be a significant issue within the catchment.

In addition to the above, it would be recommended to control development such that any increase in impervious area is countered by appropriate use of on-site detention. There is no discussion on on-site detention in DCP 106 Amendment 1. It is recommended that it be included in this over-arching document on flood controls, rather than in individual DCP's or other documents.

10.5 Damage Cost Differential between Events

Based on flood damages for a property of $50,000, the incremental difference in Annual Average Damage (AAD) for different recurrence intervals is shown in **Table 10.2**. The table shows the AAD of a given property that experiences overfloor flooding in each design event, and the net present value (NPV) of those damages over 50 years at 7%.

Table 10.2 indicates that the largest incremental differences between AAD per property occurs between the more frequent events. The greatest difference between damages occurs between the 50% and 20% AEP events. It can be seen that the differences between the 2% and 1% AEP event, and the 1% AEP event and the PMF are relatively small, suggesting that increasing the FPL beyond the 2% AEP level does not significantly alter the savings achieved from a reduction in damages.

Table 10.2: Damage Differential Costs

Event	AAD	Change in AAD	NPV of AAD	Change in NPV
50% AEP	$25,000	-	$345,000	-
20% AEP	$10,000	$15,000	$138,000	$207,000
10% AEP	$5,000	$5,000	$69,000	$69,000
5% AEP	$2,500	$2,500	$34,500	$34,500
2% AEP	$1,000	$1,500	$13,800	$20,700
1% AEP	$500	$500	$6,900	$6,900
PMF	$0	$500	$0	$6,900

10.6 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 10.3** for selected events. These are determined based on the flood levels determined at each of the properties within the catchment as part of the flood damages analysis. Note that differences are only calculated where flood levels are reported in the 5% AEP event.

Table 10.3: 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	0.61	0.56	-	-	-	-
2% AEP	0.7	0.62	0.09	0.06	-	-
5% AEP	0.81	0.69	0.20	0.13	0.11	0.07

Avg = Average; SD = Standard Deviation of Differences

Table 10.3 indicates a larger difference in 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% event (on average 0.09m 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 flood planning level.

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 0.61 metres) and may therefore potentially present an issue for the setting of flood planning levels in the catchment.

With regards to an appropriate freeboard, the maximum difference between the PMF and the 1% AEP is 2.4m, but the average is 0.61m, indicating that basing the FPL on the 1% AEP level, with an appropriate freeboard would result in the protection of some buildings in the PMF event.

10.7 Consequence of Adopting the PMF as a Flood Planning Level

Analysis of the flood damages (**Section 10.5)** indicates that the choice of the PMF event over the 1% AEP event as the FPL would result in limited economic benefits (in annualised terms) to the community.

The difference in average flood levels between the 1% AEP and the PMF event (**Section 10.6**) indicate that the use of the PMF as the FPL would result in higher levels (0.61 metres on average), and as a result higher economic costs and inconvenience to the community. In addition, the incremental AAD per building from the 1% AEP to the PMF is relatively low (approximately $256).

Given this, the economic costs may in fact outweigh the benefits of using the PMF event as the FPL. The use of the PMF level as the FPL may also conflict with other development/building controls in Councils DCPs.

Given the risk of exposure outlined in **Table 10.1**, it is recommended that emergency response facilities be located outside of the floodplain and any other likely critical facilities be limited to areas outside of the floodplain. Other critical facilities, such as schools and day care centres are suggested to have a floor level at the PMF level.

10.8 Environmental and Social Issues

The FPL can result in housing being placed higher than it would otherwise be. This can lead to a reduction in visual amenity for surrounding property owners, and may lead to encroachment on neighbouring property rights. This may also cause conflict with other development controls already present within the Council's development assessment process.

10.9 Climate Change – Sea Level Rise

A climate change assessment was recently completed for the Lower Shoalhaven River, which the Broughton Creek catchment drains into (WMAwater, 2011). The report concluded that sea level rise impacts should be included in development planning, but that increased rainfall should not be. Flood behaviour changes due to increased rainfall volumes was not used as:

- It has not been officially adopted by the BOM
- It's exclusion is representative of current climate change schemes adopted by other councils in NSW

In order to treat all areas of the LGA equitably, the same conditions were adopted for assessing the flood planning level in the Broughton Creek catchment; that is, only impacts due to sea level rise were considered. A complete investigation into climate change impacts due to both sea level rise and rainfall intensity increase was undertaken to provide Council with this information, and is included in **Appendix F**.

Sea level rise impacts on the Broughton Creek catchment are minimal, as shown in **Table 10.4**. The levels and changes shown are at the downstream boundary of the Tuflow model, south of the railway line.

The change in water level due to sea level rise was determined from the recently undertaken in Lower Shoalhaven River FRMSP: Climate Change Assessment (WMAwater, 2011).

Upstream of the railway line, the increases are even less, with increases of <0.01m in 2050, and <0.02m in 2100 for the 1% AEP event. The increase in water levels extends approximately 100m north of the railway line. The change does not reach as far upstream as Town Creek, and does not impact any properties.

Consequently, climate change impacts are very minimal within the Broughton Creek catchment, and do not affect the selection of flood planning levels.

Table 10.4: Sea level rise impacts on downstream boundary

Scenario	Downstream Water Level (1% AEP event) (mAHD)	Downstream Water Level Change (m)
Existing	5.59	-
2050 (0.4m sea level rise)	5.61	0.02
2100 (0.9m sea level rise)	5.64	0.05

10.10 Risk

The selection of an appropriate FPL also depends on the potential risk of different development types. For example, consideration should be given for different FPLs for industrial, commercial and residential properties, which have different implications should overfloor flooding occur.

Critical infrastructure, such as hospitals, fire stations, electricity sub-stations and other critical infrastructure, has wider spread implications should inundation occur. As such, FPLs are typically selected for these types of structures higher than for residential, commercial or industrial properties.

10.11 Culvert Blockage

Culvert blockage has come to prominence with flooding in Wollongong in the late 1990s (Wollongong City Council, 2002) and other similar catchments where reasonably large culverts were blocked by debris, resulting in significantly greater flooding than projected. In the lower parts of catchments, this debris is likely to be a mixture from anthropomorphic and natural sources. Blockages have the potential to increase flood water levels in the upstream area.

Culvert blockages were assessed using Council's culvert blockage policies (**Appendix E**), namely:

- 50% blockage of all culverts and structures
- 100% blockage of all culverts and structures

The results showed that for the 50% blocked scenarios, 5% of properties experienced an increase in flood levels due to blocked culverts, with 90% of the increases being less than 0.03m. In the 100% blocked scenario, 15% of properties experienced an increase in flood levels, with 90% of the increases being less than 0.22m.

The maximum water level change at a property was 0.16m with culverts 50% blocked and 1.12m with culverts 100% blocked.

The analysis shows that overall culvert blockages have little effect on flood levels for properties. However, some properties do experience increased flood levels as a result of blockages, and for the 100% blockage rate, these can be significant.

It is recommended that the effects of culvert blockages continue to be assessed when undertaking flooding investigations as they can significantly impact some properties. However, with respect to freeboard, blockage rates have minimal flood level impacts on the majority of properties within the catchment, and do not affect the selection of flood planning levels.

10.12 Freeboard Selection

As outlined in **Section 10.1**, a freeboard ranging from 0.3 - 0.5 m is commonly adopted in determining the FPL. It should be realised that 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. This consideration may result in the adopted FPL being higher than the PMF in certain cases. However, given the inherent purpose of freeboard, the FPL should still be used in such cases.

The freeboard may account for factors such as:

- Changes in the catchment,
- Changes in the creek/channel vegetation,
- Accuracy of model inputs (e.g. accuracy of ground survey, accuracy of design rainfall inputs for the area),

Model sensitivity:

- Local flood behaviour (e.g. due to local obstructions etc),
- Wave action (e.g. such wind-induced waves or wash from vehicles or boats),
- Culvert blockage,
- Climate change (affecting ocean water levels).

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

- Afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m) (Gillespie, 2005),
- Local wave action (allowances of ~0.1 m are typical) (truck wash etc),
- Accuracy of ground/ aerial survey ~ +/-0.15m,
- Climate change – Sea Level Rise – there is minimal impact on the properties in this catchment.
- Sensitivity of the model ~ +/-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 Broughton Creek Catchment.

10.13 Planning Level Scenarios

A selected number of FPL scenarios have been assessed, to test the implications on the floodplain, in regards to the number of existing buildings which are below this level as well as the flood protection provided in various design events.

Table 10.5 summarises potential benefits for the setting of a 1% AEP and PMF FPL options with freeboards. The analysis does not differentiate between residential, industrial and commercial buildings.

Analysis shows a 0.3m freeboard to the 1% AEP flood planning level benefits 9 properties during the larger PMF event, approximately 8% of total properties. Raising the freeboard to 0.5m above the 1% AEP benefits 14 properties (an additional 5), approximately 12% of total properties.

The analysis shows that both the 0.3m and 0.5m freeboard scenarios do assist in reducing the number of properties at risk during events larger than the 1% AEP event.

10.14 Flood Planning level Recommendations

Based on the previous assessments, it is recommended that Council adopts a FPL of 1% AEP and a 0.5m freeboard for Residential Development.

Commercial and/or Industrial properties have adopted higher frequency flood events such as the 5% AEP planning level based on the perception of risk. These occupiers can make informed commercial decisions on their ability to bear the burden of economic loss through flood damage, while residential lots don't generally provide an income to offset losses. Additionally, inventory, machinery and other assets can be stored above flood levels to lessen economic loss during a flood event.

As there is a relatively low number of commercial and industrial sites affected by floods and a less than 0.1m difference between the 1% AEP and 5% AEP flood water levels, the adoption of the 1% AEP +0.5m as the FPL is recommended for commercial and industrial properties, as well as residential properties.

Additionally, underground car park entrances in addition to vents and openings are also to be set at the FPL, or PMF, whichever is the higher. These locations are a particularly high risk to life.

It is also recommended that flood planning levels also be adjusted to individual lots. For critical infrastructure, such as hospitals, police stations, ages care and schools, the PMF should be adopted as the FPL. It is important that these facilities, which are either difficult to evacuate or are essential during an emergency, remain flood free.

A summary of the proposed flood planning levels for development are shown below in **Table 10.6.**

Table 10.5: Selected Flood Planning Level Scenarios & Impact on Properties

	FPL Scenario			
Description	**Current**	**1% AEP + 0.3m**	**1% AEP + 0.5m**	**PMF**
Total number of properties evaluated (Non-Vacant Lots)	117	117	117	117
Number of properties requiring raised floor level (above current elevation)	-	32	42	50
Percentage of Properties	-	27%	36%	43%
PMF				
Properties flooded above floor level	50	41	36	0
Maximum depth of above floor flooding (m)	3.03	2.37	2.17	0
Average depth of above floor flooding (m)	0.92	0.96	0.89	0
1% AEP				
Properties flooded above floor level	9	0	0	0
Maximum depth of above floor flooding (m)	1.01	0	0	0
Average depth of above floor flooding (m)	0.37	0	0	0

Table 10.6: Recommended FPL Level Summary

Property Type	Recommended FPL
Residential	1% AEP peak level +0.5m
Commercial	1% AEP peak level +0.5m
Industrial	1% AEP peak level +0.5m
Critical Infrastructure	PMF peak flood level

11 Floodplain Risk Management Options

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

- **Existing Flood Risk** – existing buildings and developments on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding
- **Future Flood Risk** – buildings and developments that may be built on flood prone land. Such buildings and developments would be exposed to a flood risk when they are built
- **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it will be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outline in **Table 11.1**.

Table 11.1: Flood Risk Management Alternatives (SCARM, 2000)

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

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories of management;

- **Flood modification measures** – Flood modification measures are structural options aimed at preventing / avoiding or reducing the likelihood of flood risks
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks

11.1 Base Case

In order to assess the various mitigation options, it is necessary to define a base case. This base case provides a reference against which the effectiveness of various options can be assessed.

In this case, the base case is the existing (2011) Broughton Creek catchment, as defined in the Flood Study Review (see **Appendix D**)

11.2 Flood Modification Measures

Based on the flood model results, historical information, community feedback and engineering judgement, possible flood modification options (i.e. structural options) for the study area were identified. These options are outlined in **Table 11.2** and shown in **Figure 11.1**.

A number of these options were further assessed with the hydraulic model (as marked with an asterisk (*)). These options were chosen for further assessment based on:

- Expected effectiveness
- Viability
- Liaison with the community
- Liaison with Council
- Liaison with other stakeholders

11.2.1 Proposed Princes Highway Upgrade – Berry By-Pass

In addition to general floodplain management measures for the general catchment, there exists for Berry an opportunity for flood mitigation through the proposed Princes Highway upgrade.

The Roads and Maritime Services (RMS) is currently in the process of planning and design of an upgrade to the Princes Highway between Gerringong and Bombaderry. As part of this upgrade, the RMS are proposing to construct a Highway by-pass around the Berry Township which, at the time of the assessment carried out for this study, considered an alignment either north or south of Berry.

A northern by-pass will cross the major flowpaths of the Broughton Creek catchment and presents an opportunity to use the construction to aid in mitigating the flooding issues within Berry.

The southern option would take the by-pass below Berry to the south of the railway line. As the southern options passes downstream of the township, it does not offer significant opportunities to mitigate flooding.

The current flood mitigation option under discussion to be included with the northern by-pass is the diversion of some or all of the water from Town Creek upstream of North Street, to Bundewallah Creek. The design is currently in progress, and the amount of water to be diverted will be dependent on the final design.

The construction of the northern by-pass, and the resulting changes to flood behaviour, will affect the operation of a number of proposed flood mitigation measures, particularly those along Town Creek. For instance, vegetation clearing or culvert amplification works along Town Creek will be less effective when used in conjunction with the by-pass, as the quantity of water flowing in Town Creek will be reduced.

It is important to note that even with the northern by-pass in place, flooding may still be an issue for sections of Town Creek. The diversion proposed acts only on the upper 27% of the catchment. There is still a reasonable portion of catchment downstream of the by-pass, most of which is urban land-use, which may continue to create a flood risk.

Current details of the by-pass, and relevant project contact details may be found on the Roads and Maritime website at:

- http://www.rta.nsw.gov.au/roadprojects/projects/princes_hway/index.html

Included in **Table 11.2** below is a column providing a qualitative indication of how affected each mitigation option may be by the construction of the by-pass. Options which are significantly affected may be best postponed until further details of the by-pass design are finalised, to determine their feasibility. Note that in the assessment following, each option has been assessed against the existing case, which does not include the by-pass.

Table 11.2: Flood Mitigation Options

Option ID	Option	Location	Option Outline	Projected Area of Improvement	Affected by By-Pass
Drainage Augmentation / Upgrade These options primarily focus on increasing capacity and efficiency of various pipes, culverts and channels throughout the study area. It is noted that for modelling purposes, it was generally assumed that the existing pipe would be duplicated, or doubled in capacity. This could be optimised during the detailed design process.					
FM 1.1 *	Town Creek Culvert Upgrade	Town Creek	Increase culvert sizes along Town Creek to improve efficiency of the channel	Localised flooding surrounding Town Creek, particularly in areas adjacent to culvert crossings	High
FM 1.2 *	Town Creek Vegetation Management	Town Creek	Remove foreign weed species and dense vegetation from the channel and vegetate with native species. Also remove debris blocking the channel such as tree branches and litter. Clean culverts to remove sedimentation build up.	Localised flooding surrounding Town Creek	High
FM 1.3 *	Railway Culvert Upgrade	Railway at Town Creek and Broughton Mill Creek	Increase culvert capacity to convey a greater flow volume to reduce water building up upstream of the railway line	Reduced levels within the ponding regions upstream of the railway line. May reduce levels further up Broughton Mill Creek and Town Creek due to lower tailwater levels. Reduction in overtopping of rail line	Low
FM 1.4 *	Railway Bridge Upgrade	Railway bridge at Broughton Creek and Broughton Mill Creek	Increase bridge capacity to convey a greater flow volume to reduce water building up upstream of the railway line	Reduced levels within the ponding regions upstream of the railway line. May reduce levels further up Broughton Mill Creek and Town Creek due to lower tailwater levels	Low
FM 1.5 *	Woodhill Mountain Rd, Bundewallah Creek Bridge Upgrade	Woodhill Mountain Rd crossing of Bundewallah Creek	Increase the bridge capacity to convey a greater flow volume to reduce water overtopping the upstream banks and short-circuiting to Broughton Mill Creek through the Berry Township	Reduced levels upstream of the bridge, and a reduction in overland flow volumes overtopping the creek banks and passing through the north east of Berry	Medium
FM 1.6 *	North St Diversion Swale	Northern side of North Street	Construction of a swale along the northern side of North Street to intercept the North Street flowpath and direct it to Bundewallah Creek.	Properties on North St, Alexandra St and Albert St affected by the North Street flowpath	High
FM1.7*	Town Creek Diversion	Town Creek, north of North Street	Construction of a diversion channel to divert Town Creek flows north of North Street to Bundewallah Creek. Channel will be sized to convey 1% AEP flows.	Localised flooding surrounding Town Creek	*Potentially Included in By-Pass Option (for northern option)*

Option ID	Option	Location	Option Outline	Projected Area of Improvement	Affected by By-Pass
FM1.8*	Broughton Mill Creek Diversion	Broughton Mill Creek, immediately south of Bundewallah Creek confluence	Construction of a diversion culvert between Broughton Mill Creek and Broughton Creek. Culvert sized to carry the 20% AEP flow.	Overbank flooding from Broughton Mill Creek into eastern Berry.	Low
FM1.9*	Broughton Mill Creek Diversion with levee	Broughton Mill Creek, immediately south of Bundewallah Creek confluence	As per FM 1.8, but with a levee constructed between Woodhill Mountain Road and the diversion culvert at the 20% AEP level to direct flows to the culvert and increase its capacity.	Overbank flooding from Broughton Mill Creek into eastern Berry.	Low
FM1.10	Broughton Mill Creek Diversion – best case	Broughton Mill Creek, immediately south of Bundewallah Creek confluence	Based on FM 1.8, this option assumed that the option is sufficiently optimised to result in all properties within its area of influence being flood free in events up to the 1% AEP event. This assumes that the diversion removes sufficient water from Broughton Mill Creek to lower flood levels downstream to such an extent that adjacent properties no longer experience either over floor or over ground flooding.	Overbank flooding from Broughton Mill Creek into eastern Berry.	Low
Levee Banks These options are focused on the construction of levee banks or flood walls to create barriers to flood waters.					
FM 2.1 *	Berry RSL / Prince Alfred Street Levee 5% AEP level	Berry Bowling Club and surrounds, extending along Prince Alfred Street to Victoria Street	Construction of a levee bank along the boundary of the Bowling Club site, as well as a section along the Princes Highway and behind properties on Prince Alfred Street.	To reduce flooding impacts on the Bowling Club and smash repairs shop, as well as adjacent residential properties along the Princes Highway and Prince Alfred Street up to the 5% AEP event	Low
FM 2.2 *	Berry RSL / Prince Alfred Street Levee 1% AEP level	Berry Bowling Club and surrounds, extending along Prince Alfred Street to Victoria Street	Construction of a levee bank along the boundary of the Bowling Club site, as well as a section along the Princes Highway and behind properties on Prince Alfred Street.	To reduce flooding impacts on the Bowling Club and smash repairs shop, as well as adjacent residential properties along the Prince Highway and Prince Alfred Street up to the 1% AEP event	Low
FM 2.3	Town Creek Flood Walls 5% AEP level	Town Creek	Construction of flood walls / levee banks to prevent the overflow of Town Creek in events up to the 5% AEP event	Localised flooding surrounding Town Creek	High
FM 2.4	Town Creek Flood Wall 1% AEP level	Town Creek	Construction of flood walls / levee banks to prevent the overflow of Town Creek in events up to the 1% AEP event	Localised flooding surrounding Town Creek	High

Option ID	Option	Location	Option Outline	Projected Area of Improvement	Affected by By-Pass
Detention Basins These options propose to create upstream detention basins upstream of flooding issues to detain flood waters and release them in a controlled manner					
FM 3.1 *	Town Creek upstream detention	Town Creek flowpath prior to George Street crossing	Construction of a detention basin upstream of North Street on the North Street flowpath to detain upstream flows up to the 1% AEP event, and reduce outflow to the 20% AEP volumes	Localised flooding surrounding Town Creek	High
Rural Property Options Options developed for rural properties					
FM 4.1	Stock Mounds	Various locations within farmland north and south of Berry	Creation of raised mounds that would provide a dry / shallow depth region for the storage of stock and machinery during flood events	Provision of places of refuge of sufficient size for stock to shelter on during flood events up to the PMF event	Very Low

*** Indicates options that were assessed with the hydraulic model**

11.2.2 Preliminary Option Assessment

To test the feasibility of each of the hydraulically assessed structural options, they were first run for the 10% AEP and 1% AEP events to ensure they worked as expected and did not result in adverse flooding behaviour. The results of this analysis are summarised below in **Table 11.3**. The table summarises the outcome of the 10% and 1% AEP runs, and whether the option should be considered for further analysis. Impact plots for the 1% AEP have been prepared for each option, and the figure numbers are shown in the table.

Table 11.3: Results of Preliminary Options Assessment

ID	Assessment Outcome	Suitable for further testing?	1% AEP Impact Figure Number
1.1	Unsuccessful – option increased flood levels on private properties downstream of culverts.	No	11.2
1.2	Successful – option reduced flooding along and surrounding Town Creek.	Yes	11.3
1.3	Successful – reduction in levels upstream of railway, extending into Town Creek	Yes	11.4
1.4	Successful – reduction in levels upstream of railway, extending into Town Creek	Yes	11.5
1.5	Unsuccessful – in larger events, increased capacity resulted in increased water levels at the railway, with increases extending into Town Creek	No	11.6
1.6	Successful – option reduced water levels along the North Street flowpath	Yes	11.7
1.7	Generally Successful – option significantly reduced peak levels along Town Creek. Increases of 0.01 – 0.03cm were observed in Bundewallah Creek. These increases did not extend beyond Woodhill Mountain Road, and did not increase the flood extent. However, the 0.01 – 0.03m increases occurred on private land adjacent to the creek. Only pasture land was impacted, and was some distance from properties. The option has continued to be assessed due to the significant benefits to the Berry Township. Negotiation will be required with property owners adjacent to Bundewallah Creek if the option is to proceed.	Yes	11.8

ID	Assessment Outcome	Suitable for further testing?	1% AEP Impact Figure Number
1.8	Generally Successful – diversion resulted in reductions along Broughton Mill Creek, reducing flood levels along Prince Alfred Street. However, it resulted in flood increases within Broughton Creek. The land was generally open space and pastures, and it may be that this increase can be accepted. Assessment of the option was progressed assuming that this acceptance was forthcoming.	Yes	11.9
1.9	Generally Successful – the inclusion of the levee further reduced levels along Broughton Mill Creek, at the expense of further increasing levels along Broughton Creek. As above, the analysis of the option was progressed assuming this increase was either acceptable or able to be mitigated.	Yes	11.10
1.10	Generally Successful – this option was not modelled, but it is expected to perform in a similar fashion to FM1.8 and FM1.9.	Yes	-
2.1	Unsuccessful – levee caused flood level increases upstream of bowling club on private and Council land	No	11.11
2.2	Unsuccessful – levee caused flood level increases upstream of bowling club, and ponding along Prince Alfred Street on private and Council land	No	11.12
2.3	Unsuccessful – requires significant and costly construction on private property. Unlikely to be approved by property owners.	No	-
2.4	Unsuccessful – requires significant and costly construction on private property. Unlikely to be approved by property owners.	No	-
3.2	Successful – option reduced levels along Town Creek	Yes	11.14

11.2.3 Environmental Considerations

According to State Environmental Planning Policy (SEPP) (Infrastructure) 2007, flood mitigation works "may be carried out by or on behalf of a public authority without consent on any land". These works include construction, routine maintenance and environmental management works which applies to most of the flood mitigation options in **Table 11.2**.

Although consent is not required, most flood mitigation works will require further environmental assessment.

The determining authority, in this case Shoalhaven Council, is required to "examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment by reason of that activity" complying with Section 111 of the EP&A Act, most likely in the form of a Review of Environmental Factors (REF).

When carrying out flood mitigation works, Council will be required to take out further permits, licenses and approvals such as:

- Flood mitigation works which emit into a water body will need an Environment Protection Licence complying with the Protection of the Environment Operations Act (POEO) 1997,
- Any removal of vegetation and debris in the water body may need a Threat Abatement Plan complying with the Fisheries Management Act 1999,
- A licence to harm threatened species, population or ecological community or damage habitat under the Fisheries Management Act 1999.

Additionally, all flood mitigation works should not impact Berry as an RNE site.

11.2.4 Town Creek Care Group

As part of mitigation option FM 1.2 – Town Creek Vegetation Management, it is proposed to form a Creek Care Group, who will assume responsibility for the management of Town Creek, and be provided with the required permissions to undertake works on both Council and private land within the confines of the creek system.

It is recommended that this group be provided with the required training and / or supervision to ensure that creek works are undertaken both an environmentally and safety conscious way.

It is also recommended that works be undertaken only during scheduled working days, and that a Council representative is present when creek works are being undertaken.

The group would operate on a volunteer basis, but some small amount of ongoing financial support is recommended for the purchase of required maintenance equipment, safety equipment and provision of planting stock if required.

It may be desirable to create a number of small groups, each responsible for a reach of creek. The organisational structure of this group should be determined in consultation with participants.

11.3 Property Modification Options

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

- LEP update P 1
- Building and Development controls P 2
- House Raising P 3
- House Rebuilding P 4
- Voluntary Purchase P 5
- Land Swap P 6
- Council Redevelopment P 7
- Flood Proofing P 8

These options are discussed in detailed below.

P 1 – LEP Update

Local environment plans are prepared by councils to guide planning decisions for local government areas. Through zoning and development controls, they allow councils to supervise the ways in which land is used.

The Shoalhaven LEP is discussed in **Section 9**. Suggested changes are generally minor and can be undertaken as part of a larger update to the LEP, and as such, this option is considered to be relatively minor.

P 2 – Building and Development Controls

The key document for flood related controls in the Shoalhaven LGA is DCP106 Amendment 1, and recommended updates to this document are discussed in **Section 9.3**.

P 3 – House Raising

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

- Difficulties in raising some houses, such as slab on ground buildings. In some slab on ground situations it may be possible to install a false floor, although this is limited by the ceiling heights.
- The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages, etc

- Unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists – i.e. there will still be a residual risk
- Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounds a property
- The need to ensure the new footings or piers can withstand flood-related forces.
- Potential conflict with height restrictions imposed for a specific zone or locality within the local government area

For a single storey slab on ground property, the flooding damage that occurs for over-floor flooding of around 0 to 0.5m of depth is around $50,000. **Table 11.4** provides the approximate Annual Average Damage (excluding overground only damage) for over-floor flooding commencing in different AEP events for individual residential properties. It assumes that over-floor flooding damage is constant at $50,000 for each over-floor event. This effectively provides a typical AAD for an individual property, and can be used as a guide.

Table 11.4 also demonstrates that properties with over-floor flooding in less frequent events are not exposed to flood damages as frequently, and hence the annualised damage for that property is not as significant. Properties that are exposed to over-floor flooding commencing in the 10% AEP event experience annualised damages of approximately $5,000 with a NPV (over 30 years) of approximately $68,800.

Table 11.5 shows the reduction in AAD from different house raising scenarios. In order for the scheme to be equitable, the house raising should only occur by raising floor levels up to the next AEP flood level. If it were to occur for a higher level, then it is arguable that the properties experiencing over-floor flooding in the next AEP event would be disadvantaged. In order to overcome this equity issue, it may be possible to apply a sliding scale subsidy which applies to all properties which are affected by over-floor flooding in events more frequent than the 1% AEP event.

As there are no properties which experience over-floor flooding in the frequent events, and minimal numbers of properties in the mid-range AEP events, the cost of raising is significantly greater than the benefit achieved. Consequently, house raising is not considered a viable option for the Broughton Creek area.

Table 11.4: Estimates of AAD and NPV for Difference Over-Floor Flooding Scenarios

Event in which over-floor flooding commences	Number of properties with over-floor flooding*	AAD per Property	NPV (30yrs) per Property
100% AEP	0	$50,000	$688,200
50% AEP	0	$25,000	$344,100
20% AEP	0	$10,000	$137,600
10% AEP	1	$5,000	$68,800
5% AEP	2	$2,500	$34,400
2% AEP	8	$1,000	$13,800
1% AEP	11	$500	$6,900
PMF	50	$0	$0

Table 11.5: Reduction in AAD Resulting From Different House Raising Scenarios *

Option (change of AEP)	Number of Properties	Reduction in AAD (per property)	Overall Reduction in AAD	NPV of Reduction	Estimated Cost of Raising
50% to 20%	0	0	0	0	0
20% to 10%	0	0	0	0	0
10% to 5%	1	$2,500	$2,500	$34,400	$80,000
5% to 2%	2	$1,500	$3,000	$41,300	$160,000
2% to 1%	8	$500	$4,000	$55,000	$640,000
1% to PMF	11	$500	$5,500	$75,000	$880,000

*** Estimated based on a "typical" property with overfloor flooding damage of $50,000**

P 4 – House Rebuilding

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

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

Similar to the house raising option, the fact that no properties experience overfloor flooding in frequent events, make this option unviable in the Broughton Creek catchment.

P 5 – Voluntary Purchase

An alternative to the construction of flood modification options and for properties where house raising is not possible is the use of 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 need to be rezoned to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

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

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

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

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

P 6 – 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 may be suitable for managing the flood risk at the bowling club. However, an alternative site would need to be found that was Council owned, of sufficient size, currently un-used, and which is not flood affected. The site should also be located within the township, as the existing bowling club is.

No sites fitting the above criteria were found, and as such, this option is not considered viable.

P 7 – Council Redevelopment

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

As no properties were identified as suitable for voluntary purchase, this option is not considered viable for the Broughton Creek area.

P 8 – 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
- 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. It is noted that there are 3 commercial / industrial properties that experience flooding in the 5% AEP event or greater.

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
- 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 recommended that this tool kit is distributed to the flood affected businesses within the Broughton Creek floodplain.

11.4 Emergency Response Modification Options

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

• Information transfer to the SES	EM 1
• Preparation of Local Flood Plans and Update of DISPLAN	EM 2
• Flood warning system	EM 3
• Public awareness and education	EM 4
• Flood warning signs at critical locations	EM 5

These options are discussed in detail below.

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. Information of this transfer will be detailed in the Flood Emergency Plan, to be prepared as part of the next stage of the study.

EM 2 – Update of the Local Flood Plan and DISPLAN

This option would implement the updates and alterations to the Local Flood Plan and the DISPLAN, as discussed in **Section 8.1**.

EM 3 – Flood Warning System

The critical duration and response times for flooding north of the railway line in the Broughton Creek catchment limit the implementation of a flood warning system. As discussed in **Section 8.4** 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.

South of the railway line, where flooding is primarily governed by backwater effects from the Shoalhaven River, and for long duration flooding in the major creek systems, the implementation of a flood warning system may be suitable. The implementation of such a system is discussed in **Section 8.4**.

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. The more recent and frequent the flooding, the greater the level of community awareness. The community consultation, as discussed in **Section 4**, identified a high level of flood awareness within the community.

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

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

- Preparation of a FloodSafe brochure. Such a brochure with a fridge magnet may prove to be a more effective means of ensuring people retain information

- 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 meeting of local Community groups could be used to arrange flood awareness programs on regular intervals.

Information dissemination is recommended to be included in Council rates notices for all affected properties on a regular basis.

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.

EM 5 – Flood Warning Signs at Critical Locations

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

It is recommended that depth gauges be installed at road crossings which are subject to inundation in frequent events, such as those along Town Creek, which experience overtopping in the 10% AEP event.

In addition, it is recommended that flood warning signs, similar to that currently on the Princes Highway crossing on Broughton Mill Creek, be installed on the approaches to the Woodhill Mountain Road bridge over Bundewallah Creek.

11.5 Data Collection Strategies

This would involve the preparation of a flood data collection form and the use of this form following a flood event. This would allow for more information to be gathered concerning the nature of flooding within the catchment, building on the knowledge from the Flood Study.

12 Economic Assessment of Options

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated.

This calculation is described below.

12.1 Preliminary Costing of Options

Cost estimates were prepared for those options which allow for an economic assessment. A summary of these estimated capital costs are provided in **Table 12.1**. Details of these costings are provided in **Appendix G**.

For other options, broad estimates were made for the purpose of comparison in the multi-criteria assessment. These are detailed in **Section 13**.

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

Table 12.1: Costs of Quantitatively Assessed Options

Option ID	Option	Capital Cost	Ongoing Costs
FM 1.2	Town Creek Vegetation Management	$372,000	$500
FM 1.3	Railway Culvert Upgrade	$1,330,000	$1,500
FM 1.4	Railway Bridge Upgrade	$4,096,000	$1,500
FM 1.6	North St Diversion Swale	$847,000	$2,500
FM 1.7	Town Creek Diversion	$1,400,000 *	$2,500
FM 1.8	Broughton Mill Creek Diversion	$10,318,100	$10,000
FM 1.9	Broughton Mill Creek Diversion with levee	$12,097,000	$10,000
FM 1.10	Broughton Mill Creek Diversion – best case	$41,272,400 #	$20,000
FM 3.2	Town Creek upstream detention	$773,000	$1,000

* Cost estimate provided by RMS

Capital cost estimated to be 4x greater than FM1.8 as the culvert would need to be 4x greater to carry the required flow.

12.2 Average Annual Damage for Quantitatively Assessed Options

The total damage costs were evaluated for each of the options assessed by hydraulic modelling (quantitative assessment). The average annual damage (AAD) for each of the options is shown comparatively against the existing case ($139,504) in **Table 12.2**.

Table 12.2: Average Annual Damage for Quantitatively Assessed Options

Option ID	Option	AAD	Reduction in AAD due to Option
FM 1.2	Town Creek Vegetation Management	$133,006	$6,498
FM 1.3	Railway Culvert Upgrade	$138,595	$909
FM 1.4	Railway Bridge Upgrade	$133,433	$6,071
FM 1.6	North St Diversion Swale	$134,082	$5,422
FM 1.7	Town Creek Diversion	$119,001	$20,503
FM 1.8	Broughton Mill Creek Diversion	$107,508	$31,996
FM 1.9	Broughton Mill Creek Diversion with levee	$106,341	$33,163
FM 1.10	Broughton Mill Creek Diversion – best case	$52,144	$87,360
FM 3.2	Town Creek upstream detention	$138,048	$1,456

The results in **Table 12.2** show that the Broughton Mill Creek diversions resulted in the greatest reduction in AAD. The next largest reduction was due to the Town Creek vegetation management, with the railway bridge upgrade and North Street diversion swale providing similarly large reductions.

The railway culvert upgrade resulted in the least improvement, which is likely due to the reductions not reaching far enough upstream to provide flood level reductions for properties.

Whilst the AAD is reduced to various degrees for different options, this reduction needs to be offset against the capital and recurrent costs of the option. This is investigated below.

12.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option.

The existing condition (or the 'do nothing' option) was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data reported in **Section 6** derived from a floor level and property survey along with damage curves derived for other, similar areas. The PMF, 1% AEP, 2% AEP 5%AEP, 10% AEP, 20% AEP and 50% AEP events were considered for this evaluation. Preliminary costs of each option were prepared and a benefit-cost analysis of each option was undertaken on a purely economic basis.

Table 12.3 summarises the overall economics for each option that was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

The B/C ratio provides an insight into how the damage savings from an option, relate to its cost of construction and maintenance:

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

Table 12.3: Summary of Economic Assessment of Management Options

Option ID	AAD	Reduction in AAD due to Option	NPW of Benefit	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Option *	B/C Ratio	Rank
FM 1.2	$133,006	$6,498	$89,677	$371,700	$500	$371,700	0.24	1
FM 1.3	$138,595	$909	$12,545	$1,329,800	$1,500	$1,350,500	0.01	9
FM 1.4	$133,433	$6,071	$83,784	$4,095,960	$1,500	$4,113,700	0.02	8
FM 1.6	$134,082	$5,422	$74,828	$846,800	$2,500	$881,300	0.08	3
FM 1.7	$119,001	$20,503	$282,957	$1,400,000	$2,500	$1,434,500	0.2	2
FM 1.8	$107,508	$31,996	$441,569	$10,318,100	$10,000	$10,456,107	0.04	4
FM 1.9	$106,341	$33,163	$457,674	$12,097,000	$10,000	$12,235,007	0.04	4
FM 1.10	$52,144	$87,360	$1,205,633	$41,272,400	$20,000	$41,548,415	0.03	6
FM 3.2	$138,048	$1,456	$20,094	$772,500	$1,000	$772,500	0.03	6

***** NPW – Net Present Worth is calculated using 7% interest over 50yrs.

It is noted that none of the proposed options have a benefit-cost ratio greater than 1. The primary reason for this is that the frequency of inundation for most properties which experience overfloor flooding is quite low – generally only in events larger than the 2% AEP. As a result, the annualised damage savings of these events are relatively small. For instance, a saving of $100,000 in 1% AEP damages is reduced to a difference of $1,000 once the damages have been annualised.

Also, whilst the options are successful in reducing flood levels, these reductions do not result in significant numbers of properties moving from having over-floor flooding, to no over-floor flooding. This is demonstrated in **Table 12.4** which shows the number of properties experiencing overfloor flooding in each AEP event for the various options.

Table 12.4: Number of Properties with Overfloor Flooding under different options

Option ID	PMF	1% AEP	2% AEP	5% AEP	10% AEP	20% AEP
FM 1.1	48	7	4	2	2	0
FM 1.2	46	7	4	2	2	0
FM 1.3	50	8	4	2	2	0
FM 1.4	49	8	4	2	2	0
FM 1.6	50	9	4	2	2	0
FM 1.7	38	7	4	2	2	0
FM 1.8	50	8	2	2	1	0
FM 1.9	50	8	2	2	1	0
FM 1.10	50	4	2	1	1	0
FM 3.2	50	7	4	2	2	0

12.4 Economic Assessment of Desktop Assessed Options

Where a desktop assessment was utilised for options (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. Instead, a judgement on the economic benefits of the options was made. This is described in **Section 13**.

13 Multi-Criteria Matrix Assessment

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

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion as shown in **Table 13.1**.

13.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as the community preferences. 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 flow and water quality objectives
	Fauna / Flora

The scoring system is shown in **Table 13.1** for the above criteria.

Table 13.1: 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 0.2	0.2 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 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

13.1.1 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 options were quantitatively assessed for the hydraulically modelled options, 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.

13.1.2 Social Impact Assessment

The social impact assessment involved an appreciation of:

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

In general, there is a high level of flood awareness in the community. 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 well as the community meetings, as discussed in **Section 4** report into a numerical score. This will be updated following exhibition of the draft report, and feedback from the community

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

13.1.3 Environmental Assessment

The environmental impact assessment involved an appreciation of both:

- Compatibility of the option with Water Quality and 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.

13.2 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix H**. 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 13.1**. The overall score for the option is then calculated by the weights for each of the categories.

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

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

Of the options investigated, the top three identified by the multi-criteria analysis were:

1. P 2 Building and Development Control Plans
2. P 1 LEP Update
3. FM 1.2 Town Creek Vegetation Clearing

Of the structural options assessed, the top three identified by the multi-criteria analysis were:

1.	FM1.2	Town Creek Vegetation Management
2.	FM 1.7	Town Creek Diversion
2	FM 1.6	North St Diversion Swale

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 H** is not "absolute" and the proposed scoring and weighting should be reviewed at regular intervals to ensure they are still representative.

14 Floodplain Risk Management Plan

The results of the Floodplain Risk Management Study were used to form the Broughton Creek Floodplain Risk Management Plan (Cardno, 2012), which has been prepared as a supplementary document to this, the Floodplain Risk Management Study.

15 Qualifications

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

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

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

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

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

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Figures

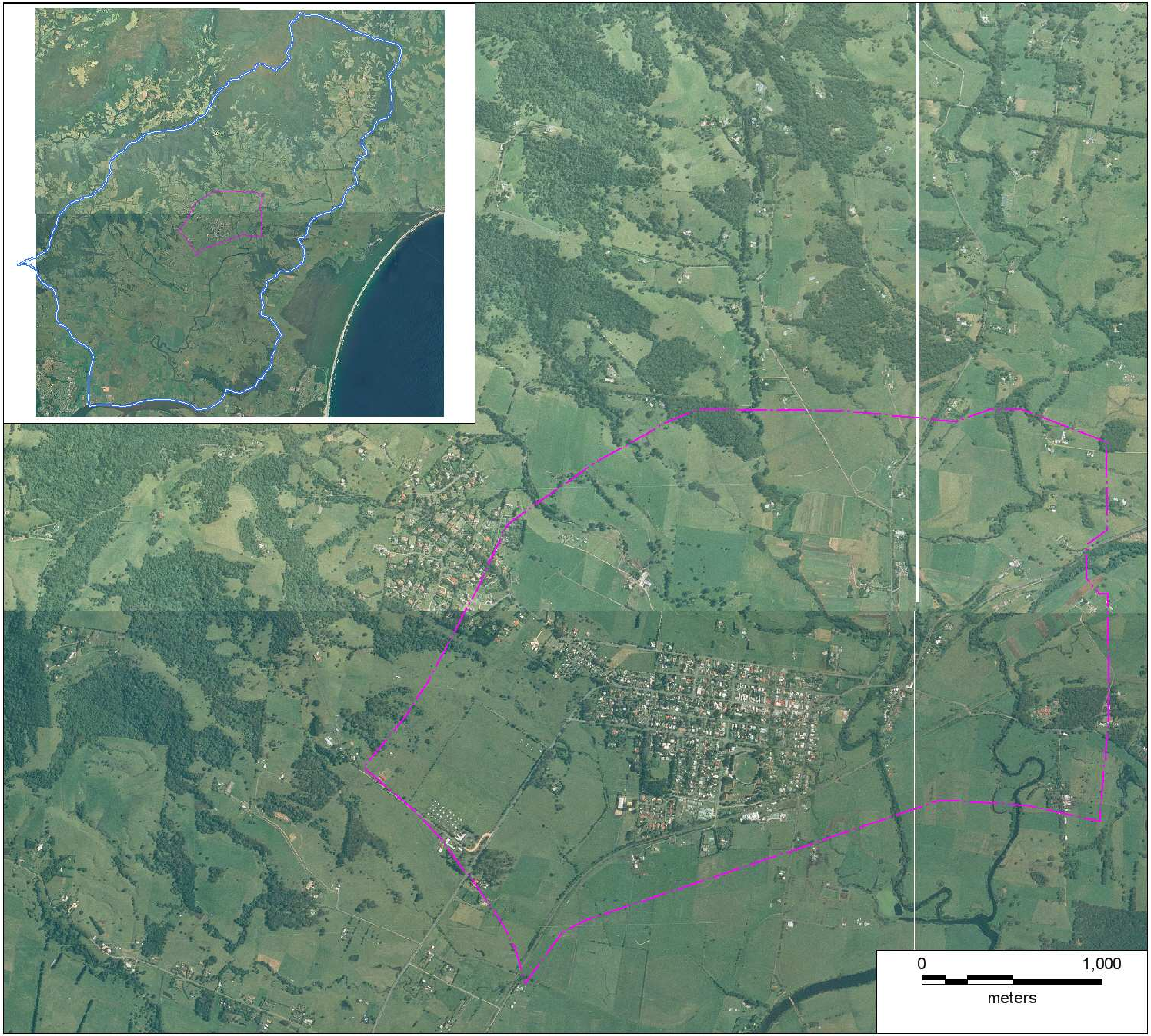


FIGURE 2.1

CATCHMENT AND STUDY AREA

Berry FRMSP

Model Extent

Broughton Creek Catchment Area

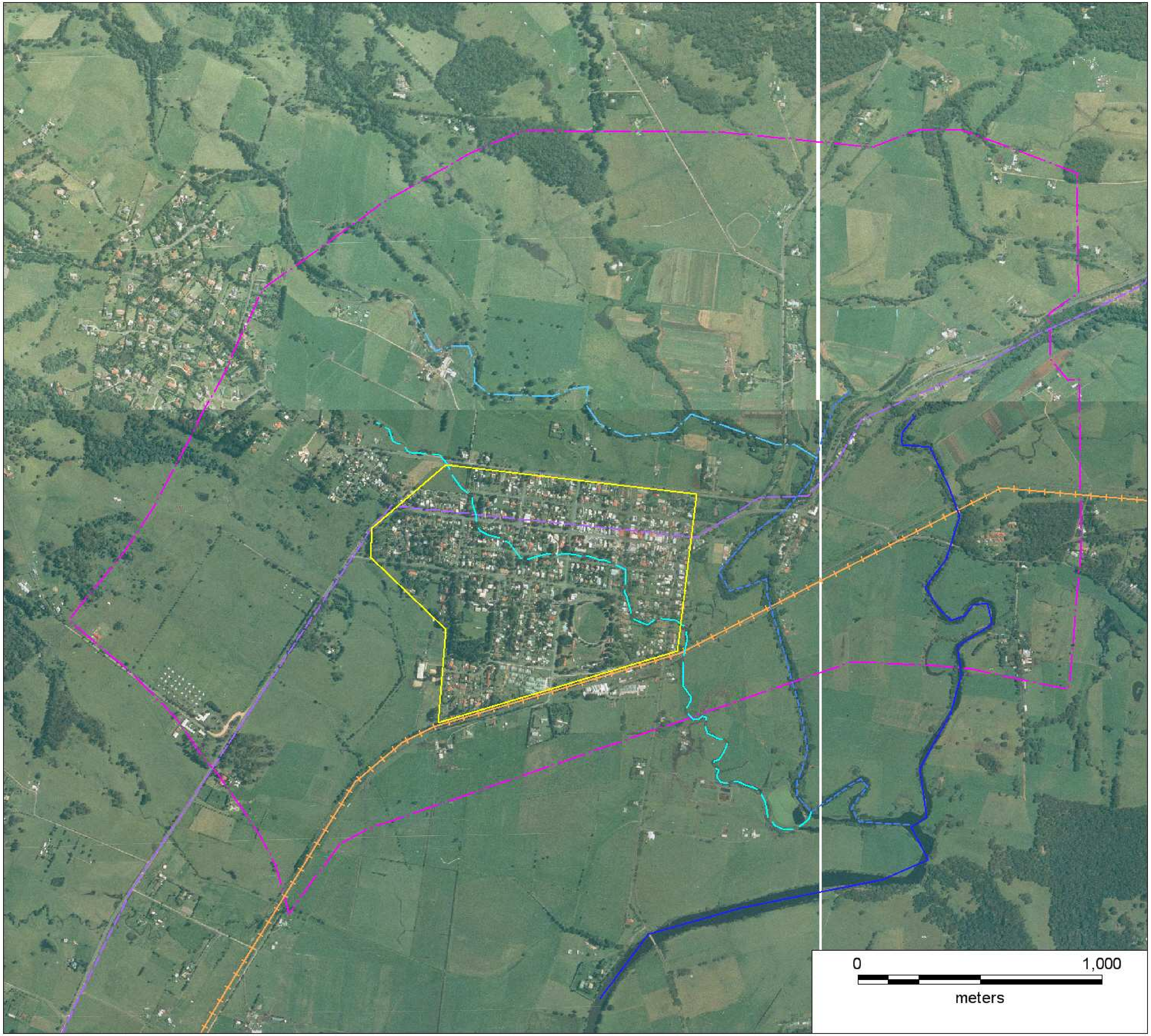
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 23 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_2-1_Catchment_Area.mxd 02

FIGURE 2.2

STUDY AREA FEATURES

Berry FRMSP



Model Extent
Berry Township
Princes Highway
Railway Line
Broughton Creek
Broughton Mill Cree
Bundewallah Creek
Town Creek

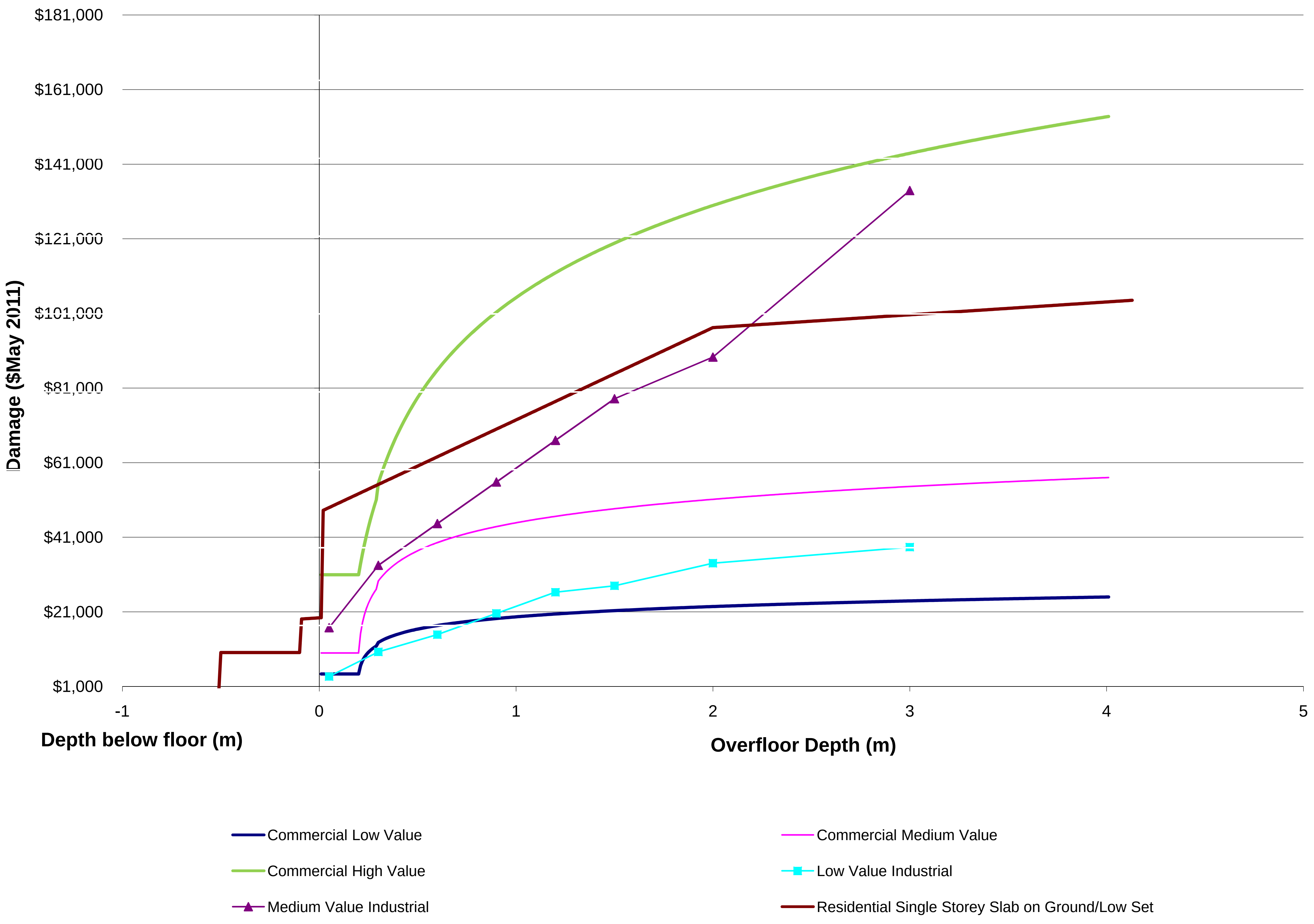
Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 23 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_2-2_Study_Area_Features.mxd 02

FIGURE 6.1

DAMAGE CURVES

Berry FRMSP



Note: Data for Commercials and Industrials is shown for a 100m2 floor area, for demonstration only. Garden damage ($3000) for residentials is not shown in these curves.

Cardno

Figure Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011

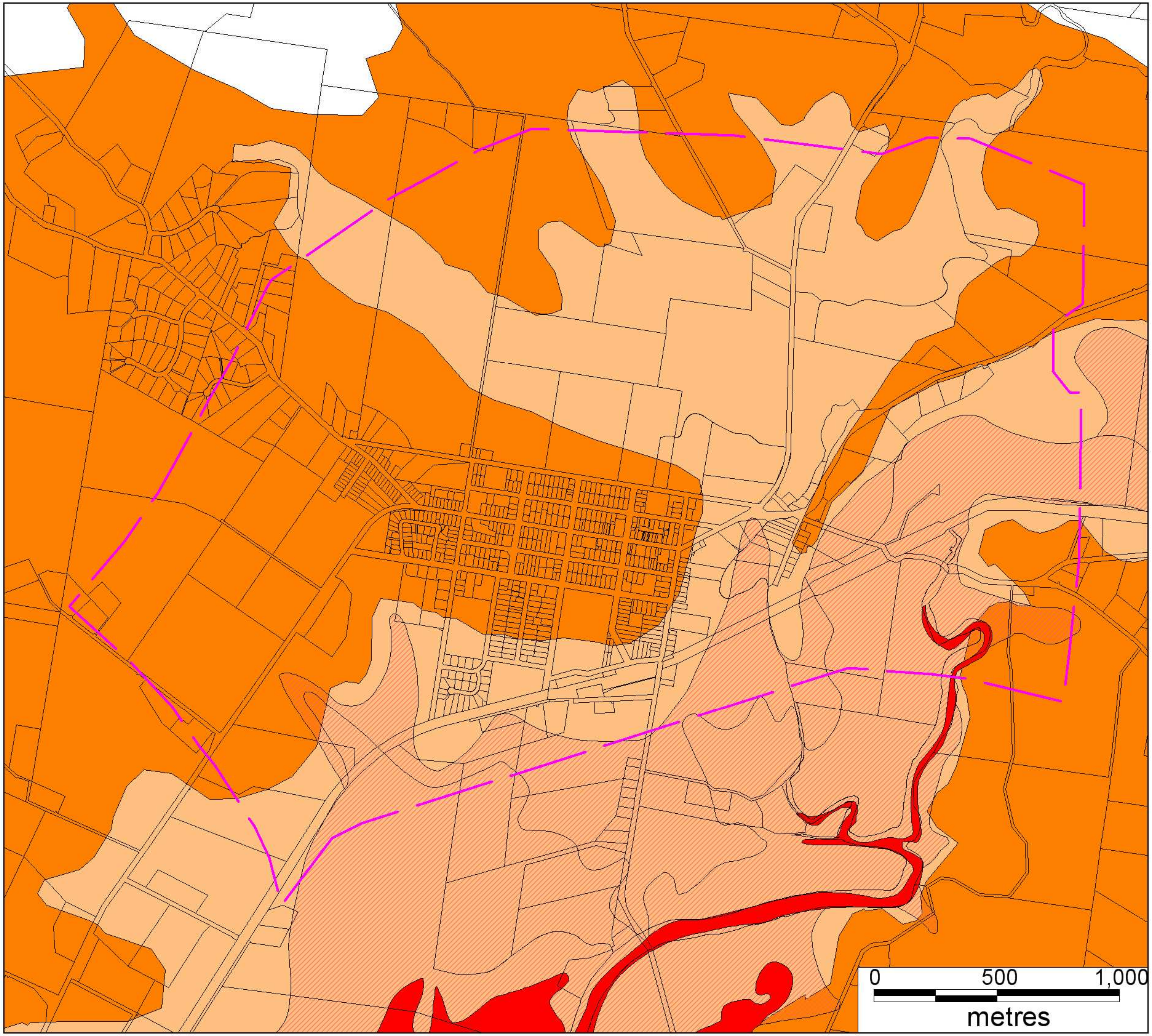


FIGURE 7.1

GEOLOGY AND ACID SULFATE SOILS

BERRY FRMSP

Model Extent

Geology

Alluvium

Shoalhaven Group

Acid Sulfate Soils

High probability of occurrence

Low probability of occurrence

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 02 August 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
<Job Number>_<commission>_<map name>.mxd 01

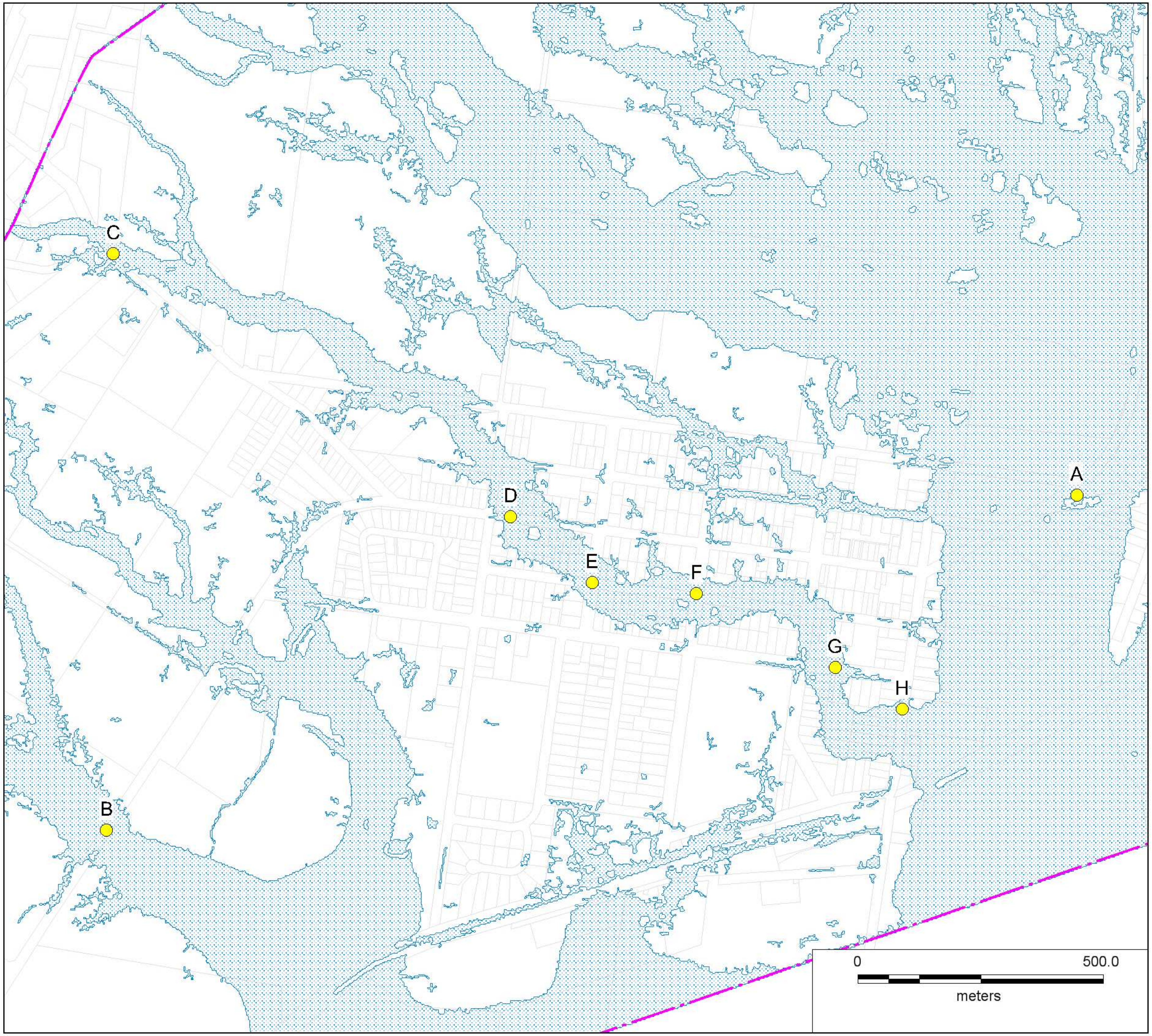


FIGURE 8.1

KEY ACCESS OVERTOPPING LOCATIONS

Berry FRMSP

Model Extent

Cadastre

1% AEP Flood Extent

Access Location ID

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-1_Access_Overtopping.mxd 02

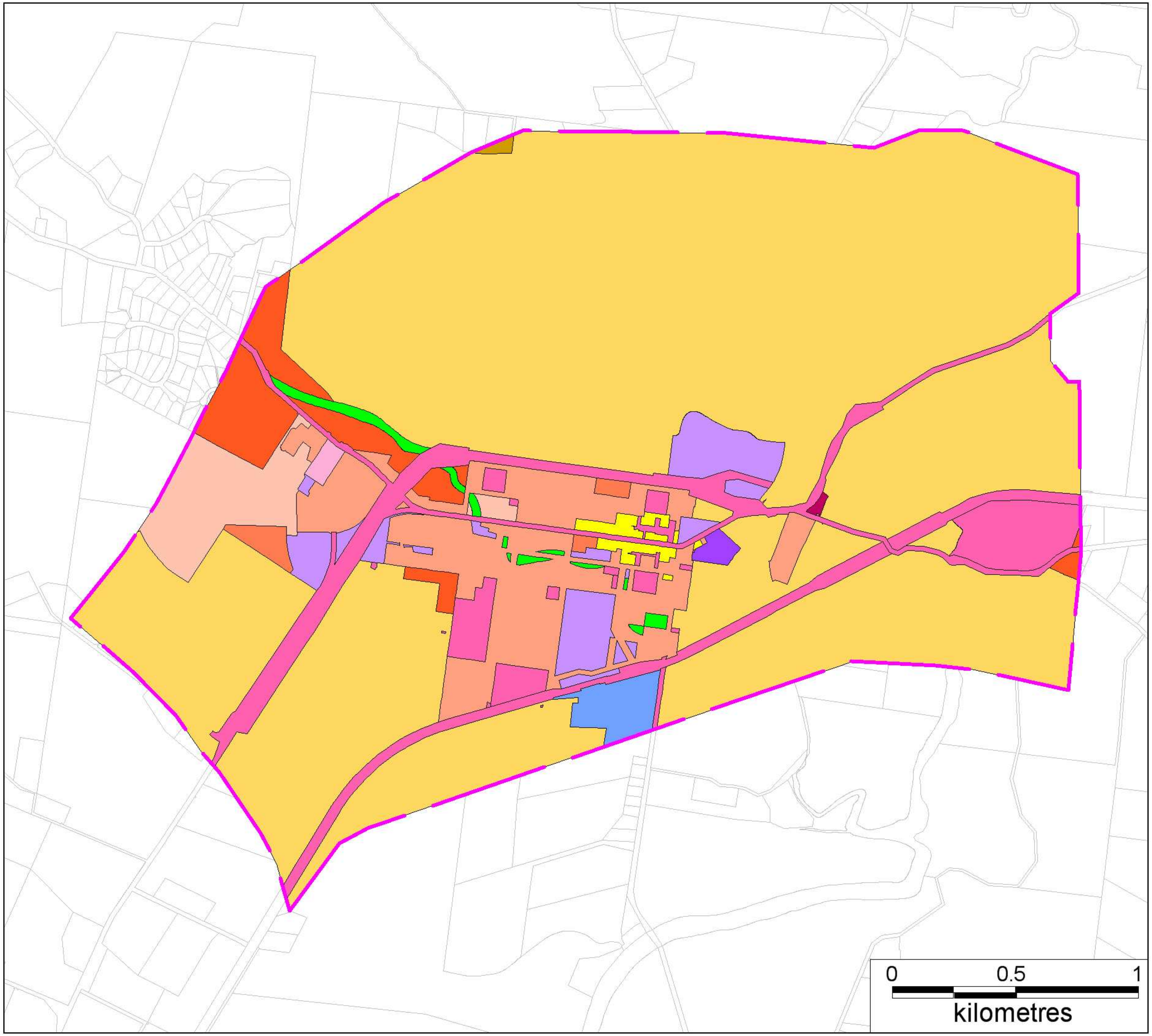


FIGURE 9.1

DRAFT LEP 2009

BERRY FRMSP

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 02 August 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
w4858_Figure10.1_DraftLEP2009.mxd 01

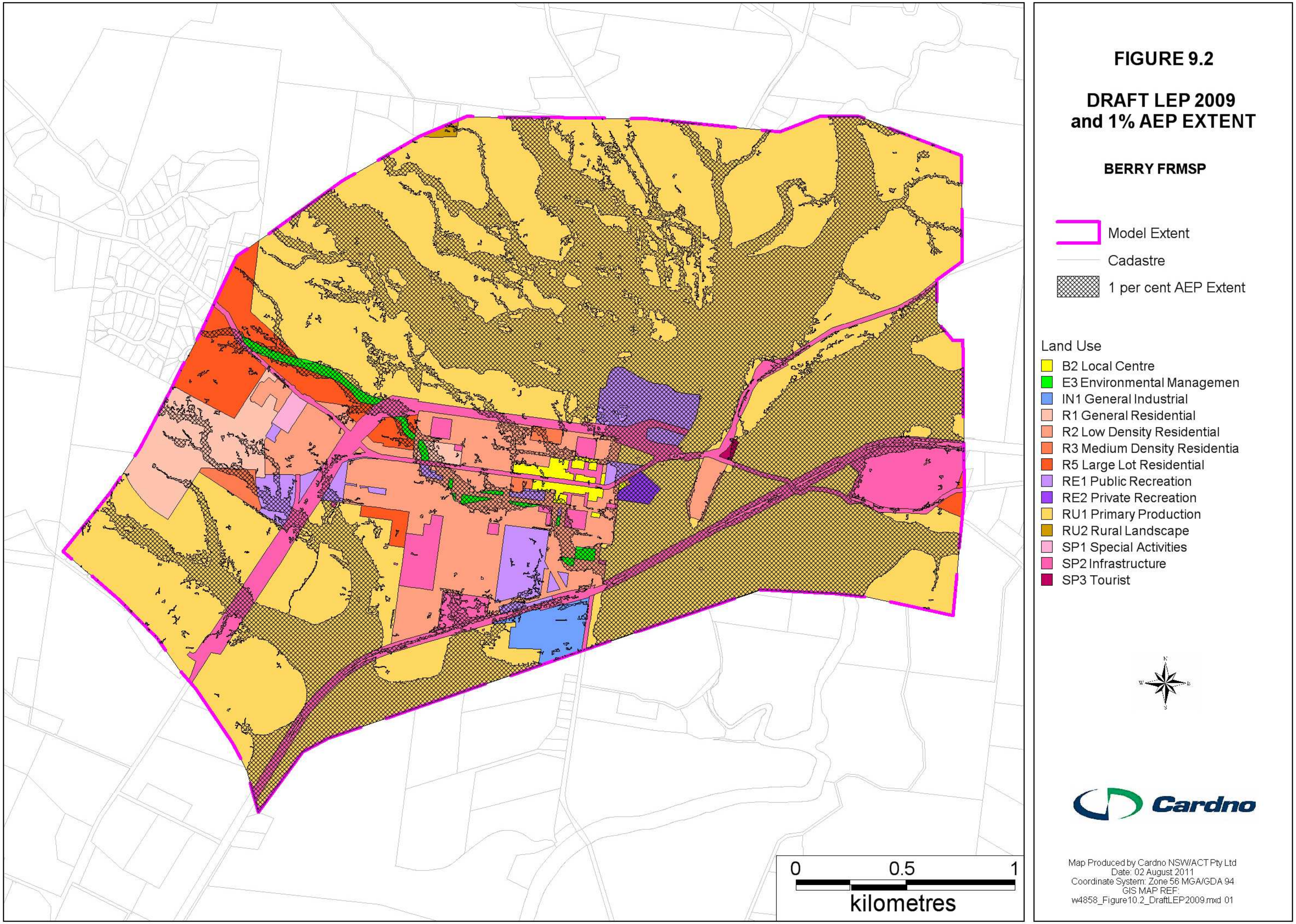


FIGURE 9.2
DRAFT LEP 2009
and 1% AEP EXTENT
BERRY FRMSP
Model Extent
Cadastre
1 per cent AEP Extent
Land Use
B2 Local Centre
E3 Environmental Managemen
IN1 General Industrial
R1 General Residential
R2 Low Density Residential
R3 Medium Density Residentia
R5 Large Lot Residential
RE1 Public Recreation
RE2 Private Recreation
RU1 Primary Production
RU2 Rural Landscape
SP1 Special Activities
SP2 Infrastructure
SP3 Tourist
0
0.5
1
kilometres
Cardno
Map Produced by Cardno NSW/ACT Pty Ltd
Date: 02 August 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
w4858_Figure10.2_DraftLEP2009.mxd 01

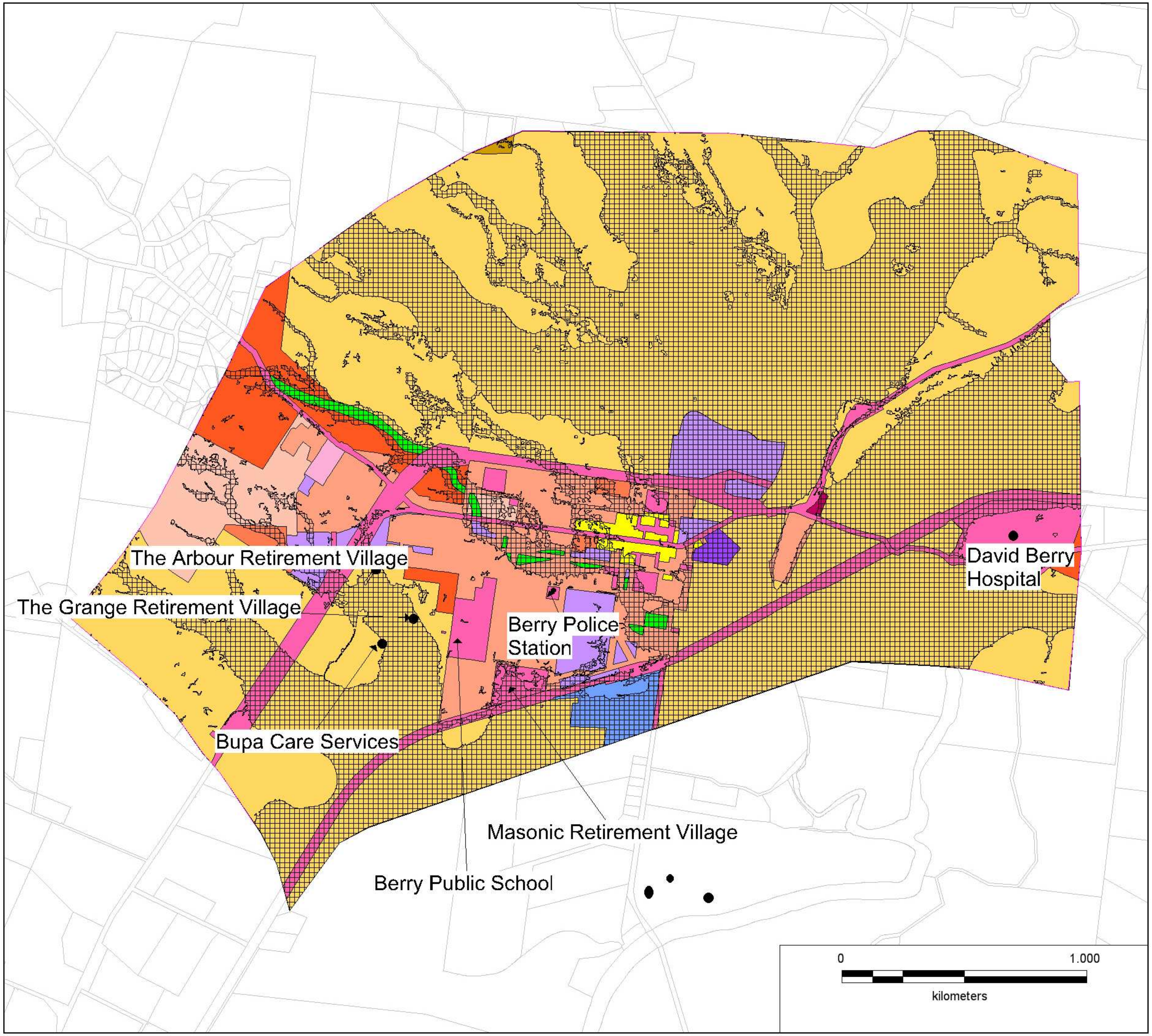


FIGURE 9.3

DRAFT LEP 2009 and PMF EXTENT

BERRY FRMSP

Model Extent
Cadastre
PMF extent

Land Use
- B2 Local Centre
- E3 Environmental Managemen
- IN1 General Industrial
- R1 General Residential
- R2 Low Density Residential
- R3 Medium Density Residentia
- R5 Large Lot Residential
- RE1 Public Recreation
- RE2 Private Recreation
- RU1 Primary Production
- RU2 Rural Landscape
- SP1 Special Activities
- SP2 Infrastructure
- SP3 Tourist

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 02 August 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
w4858_Figure10.3_DraftLEP2009_PMF.mxd 01

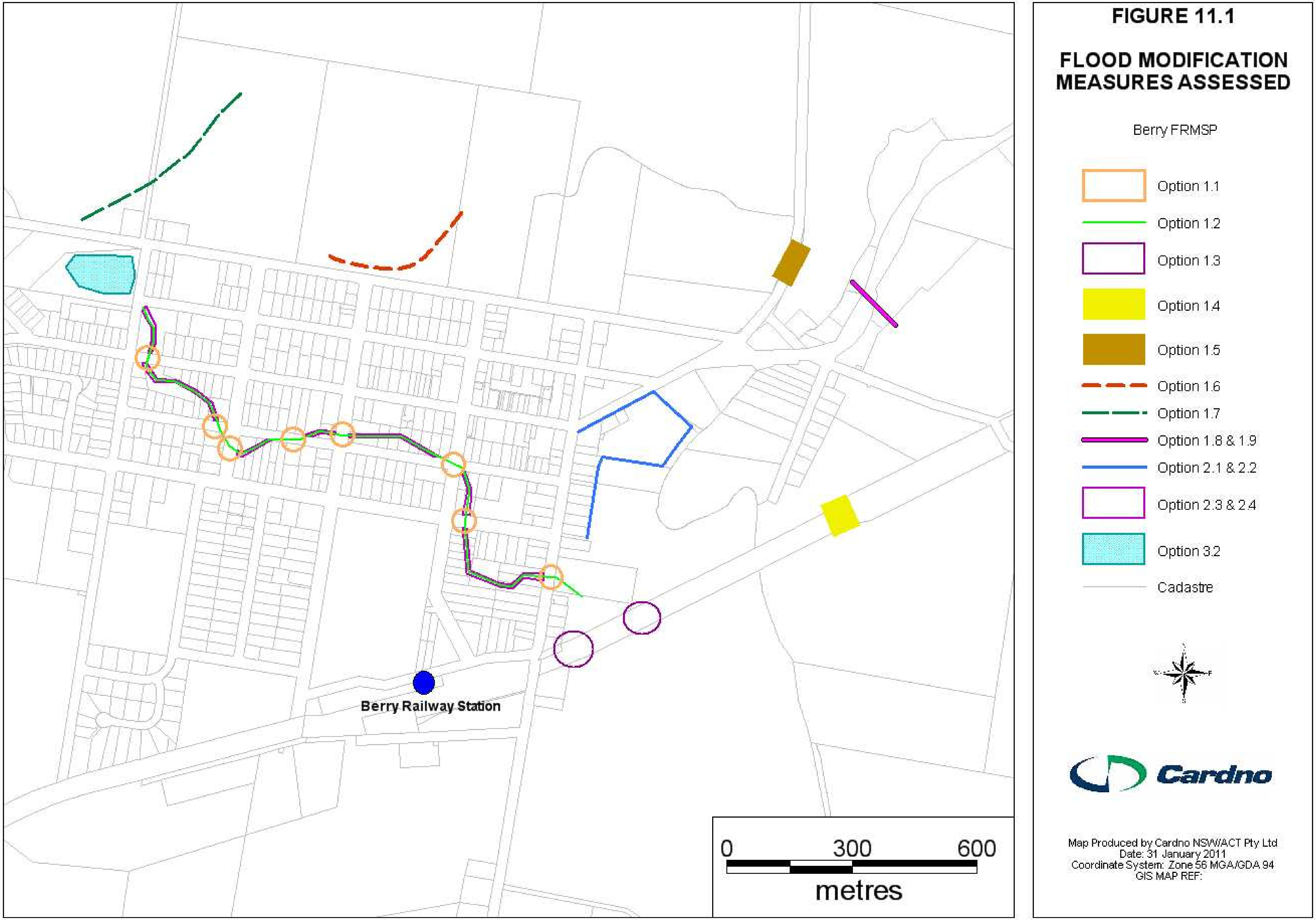


FIGURE 11.1
FLOOD MODIFICATION MEASURES ASSESSED
Berry FRMSP
Option 1.1
Option 1.2
Option 1.3
Option 1.4
Option 1.5
Option 1.6
Option 1.7
Option 1.8 & 1.9
Option 2.1 & 2.2
Option 2.3 & 2.4
Option 3.2
Cadastre
Berry Railway Station
0
300
600
metres
Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:

FIGURE 11.2

OPTION FM 1.1

TOWN CREEK CUVLERT UPGRADE

DIFFERENCES 1% AEP

Cadastre

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE 11.3

OPTION FM 1.2

TOWN CREEK VEGETATION CLEARING

DIFFERENCES 1% AEP

Cadastre

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE 11.4

OPTION FM 1.3

RAIL CULVERT UPGRADE

DIFFERENCES
1% AEP

Cadastre

Model Boundary

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE 11.5

OPTION FM 1.4

RAIL BRIDGE UPGRADE

DIFFERENCES
1% AEP

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

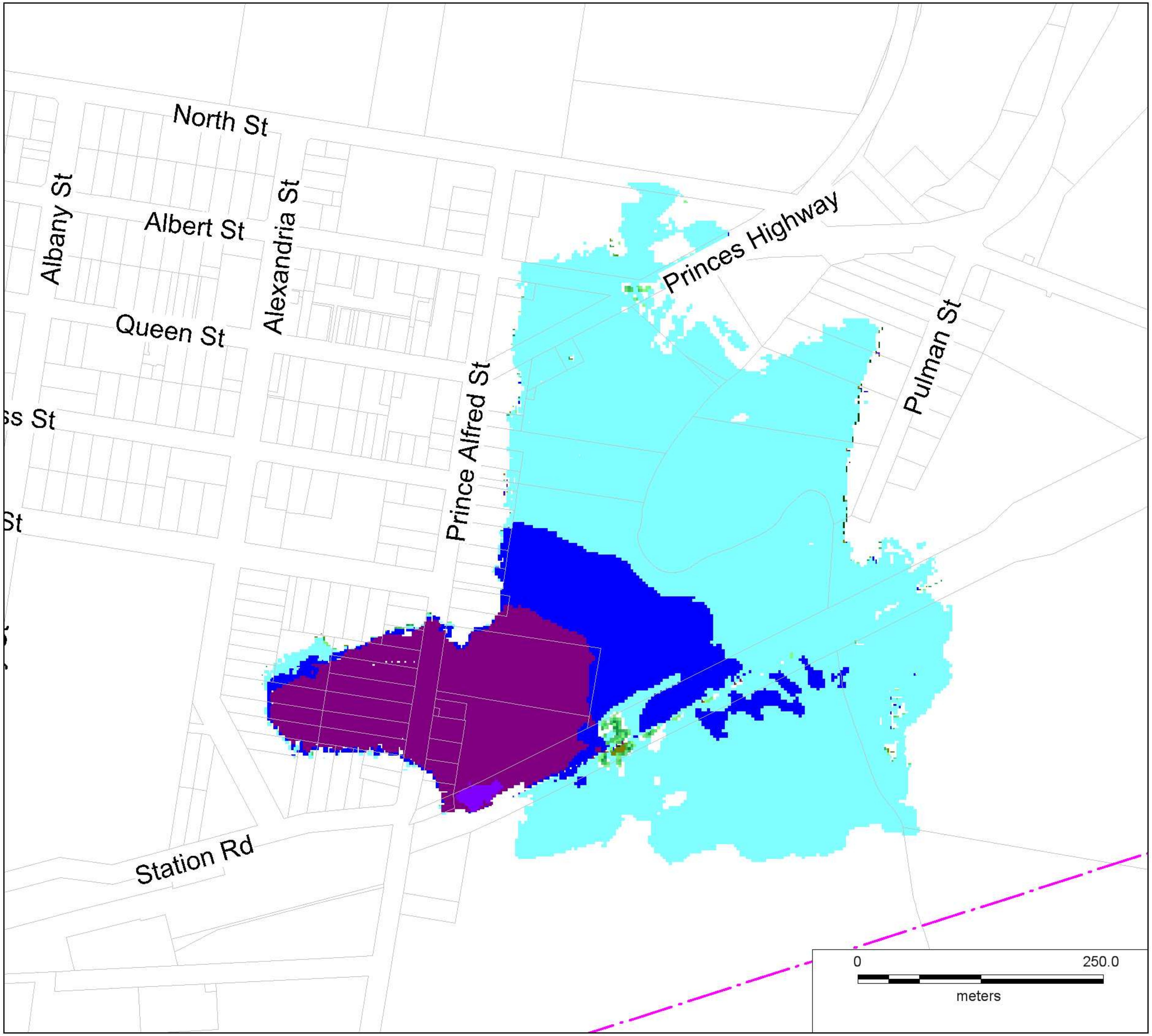


FIGURE 11.6

OPTION FM 1.5

BUNDEWALLAH BRIDGE UPGRADE

DIFFERENCES 1% AEP

Model Extent

Cadastre

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

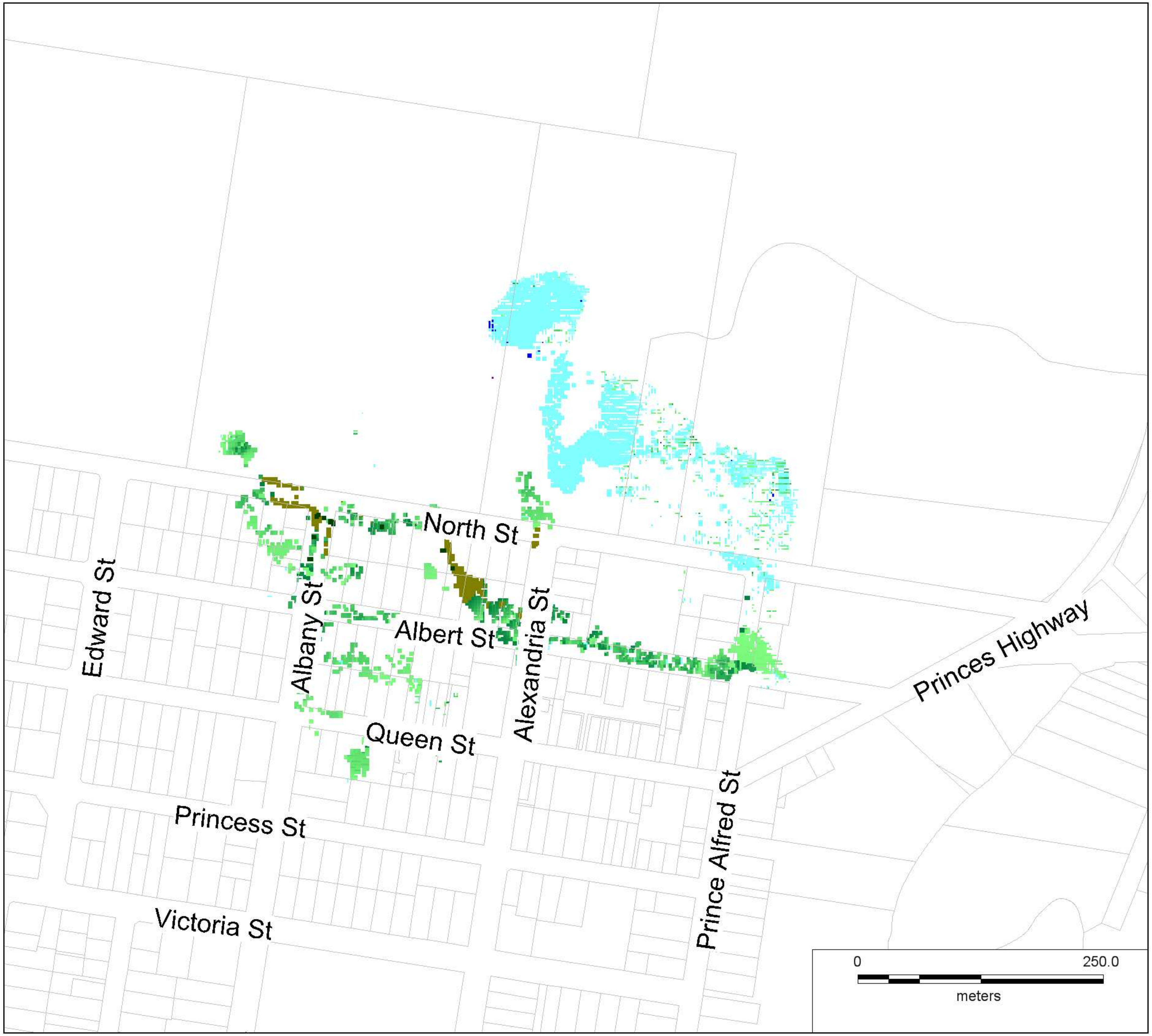
Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE 11.7

OPTOIN FM 1.6

NORTH STREET DIVERSION SWALE

DIFFERENCES 1% AEP



Cadastre

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

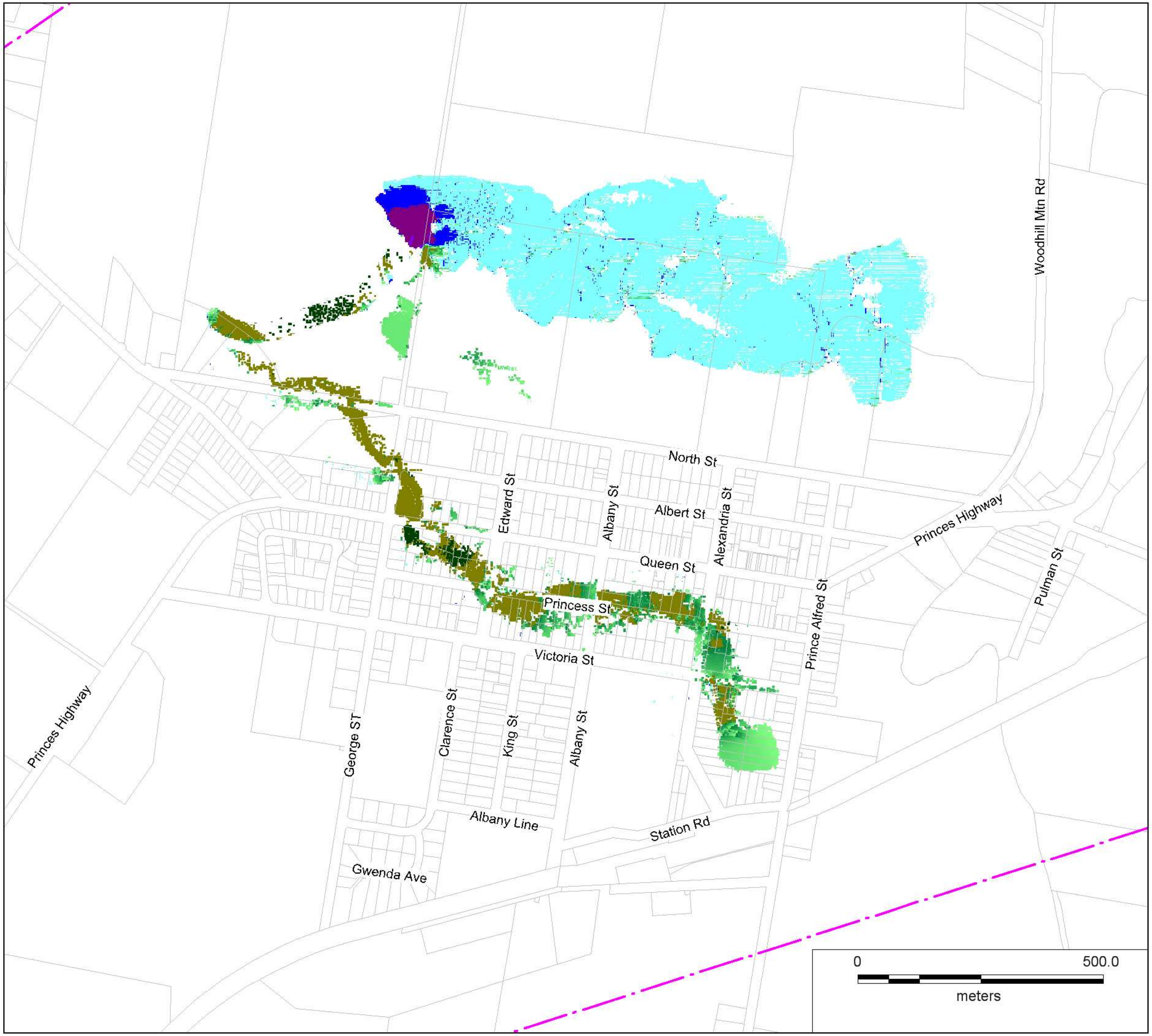


FIGURE 11.8

OPTION FM 1.7

TOWN CREEK DETENTION

DIFFERENCES
1% AEP

Cadastre

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 31 January 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

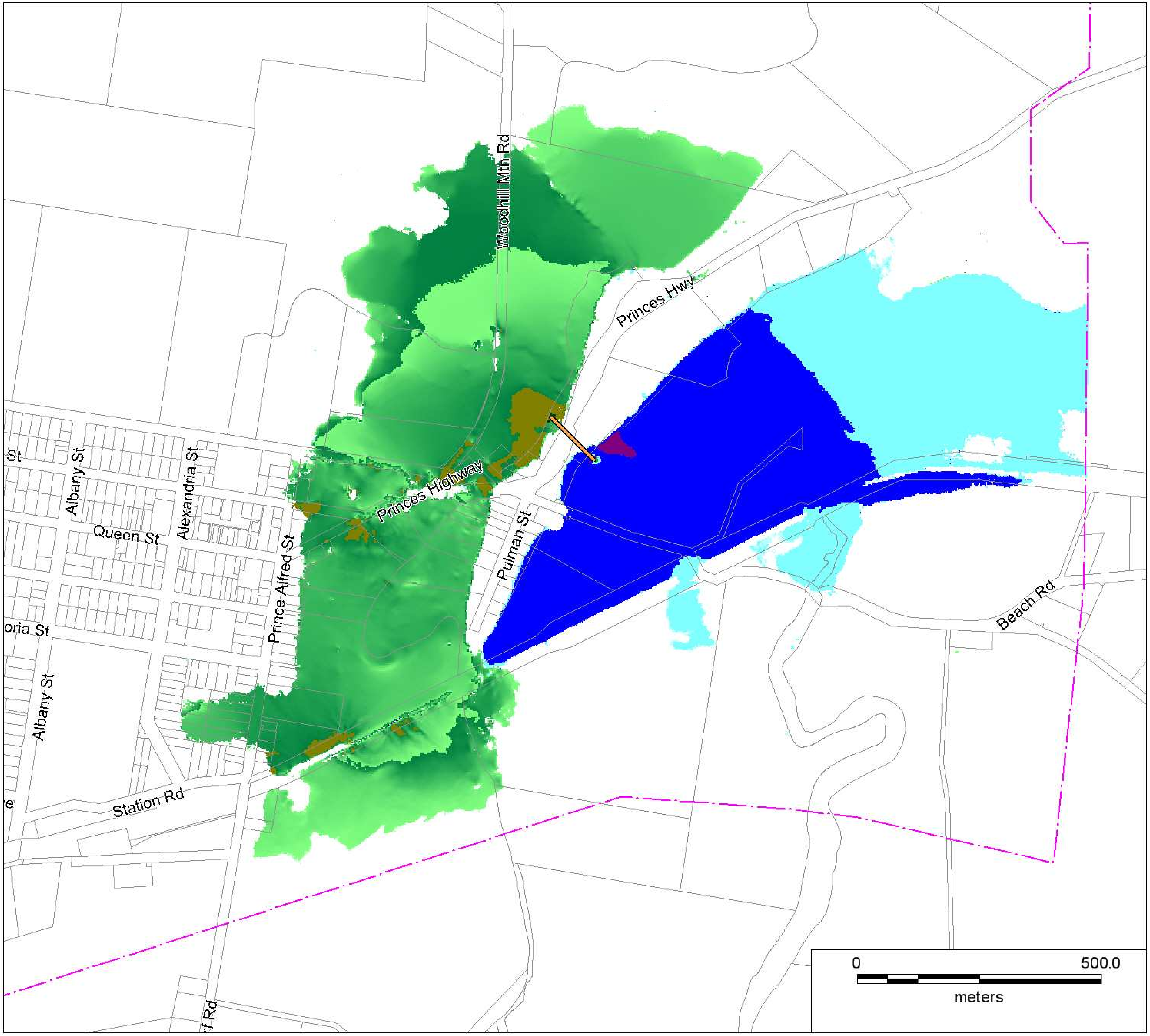


FIGURE 11.9

OPTION FM 1.8

BROUGHTON MILL CREEK DIVERSION CULVERT

DIFFERENCES 1% AEP

Cadastre
Model Extent
Diversion Culvert

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 25 September 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

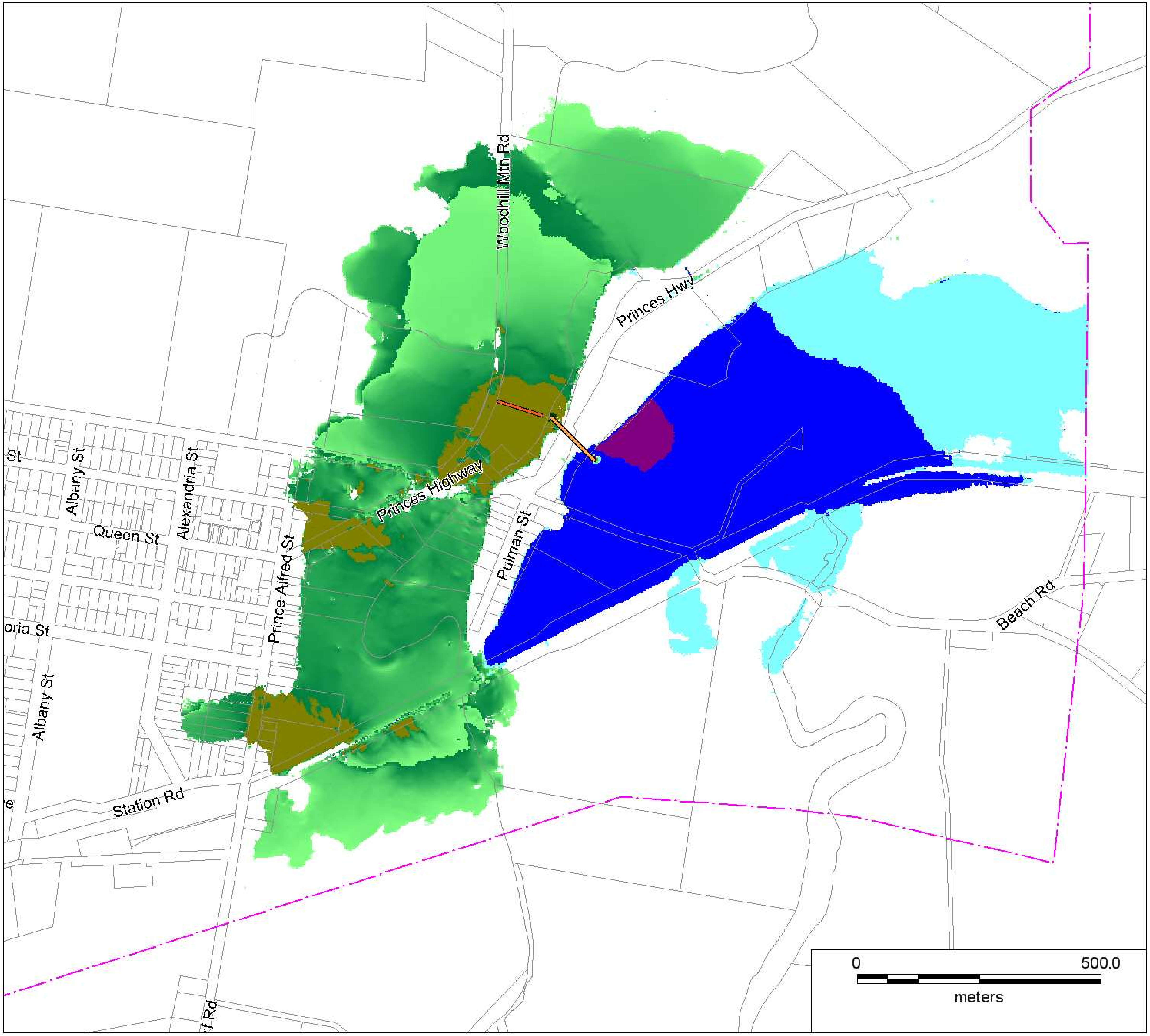


FIGURE 11.10

OPTION FM 1.9

BROUGHTON MILL CREEK DIVERSION CULVERT

DIFFERENCES 1% AEP

Cadastre
Model Extent
Diversion Culvert
Diversion Levee

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 25 September 2012
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

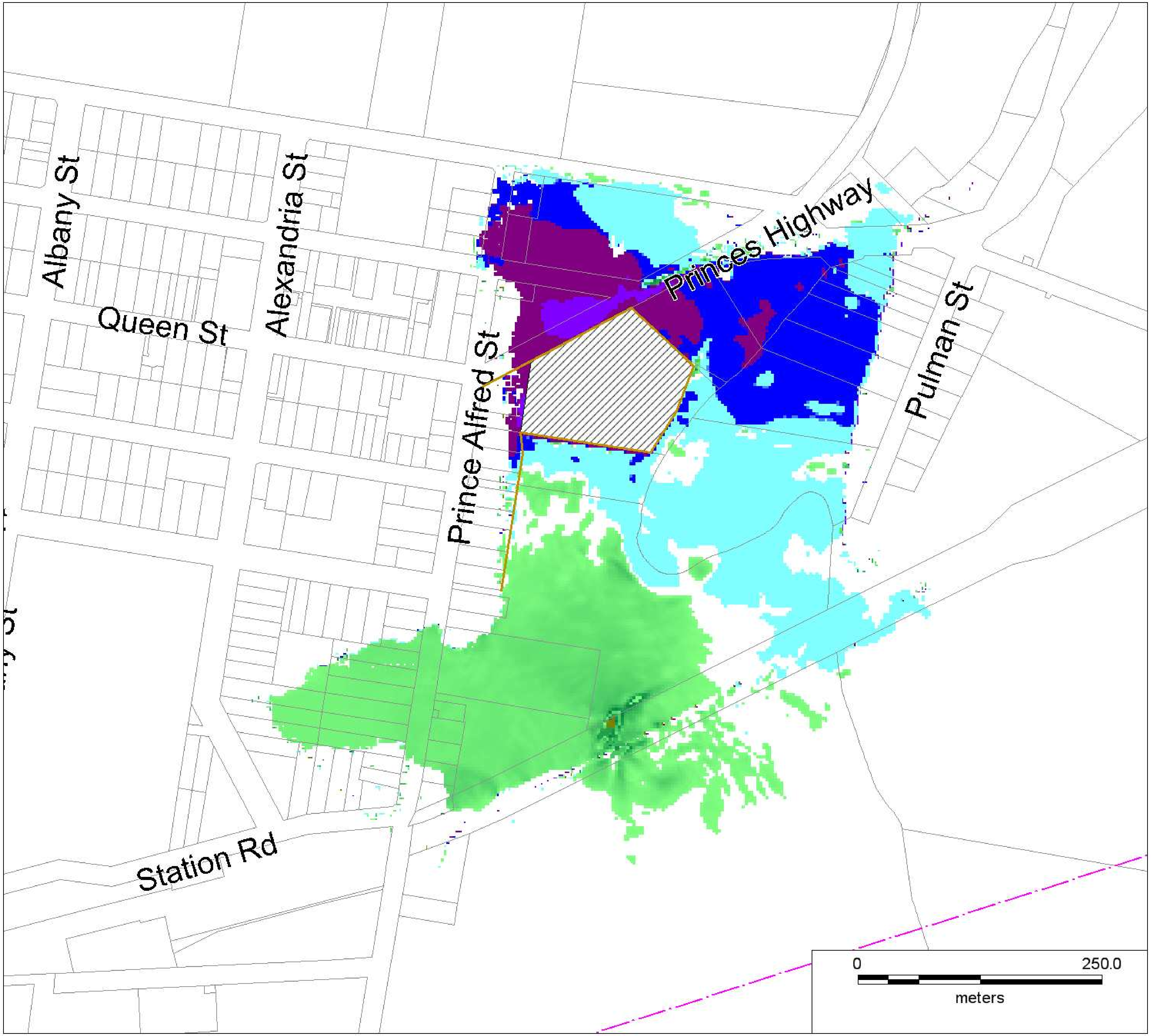


FIGURE 11.11

OPTION FM 2.1

BOWLING CLUB LEVEE
5% AEP LEVEL
DIFFERENCES
1% AEP

Model Extent
Cadastre
Levee
Area protected by levee

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 25 September 2012
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

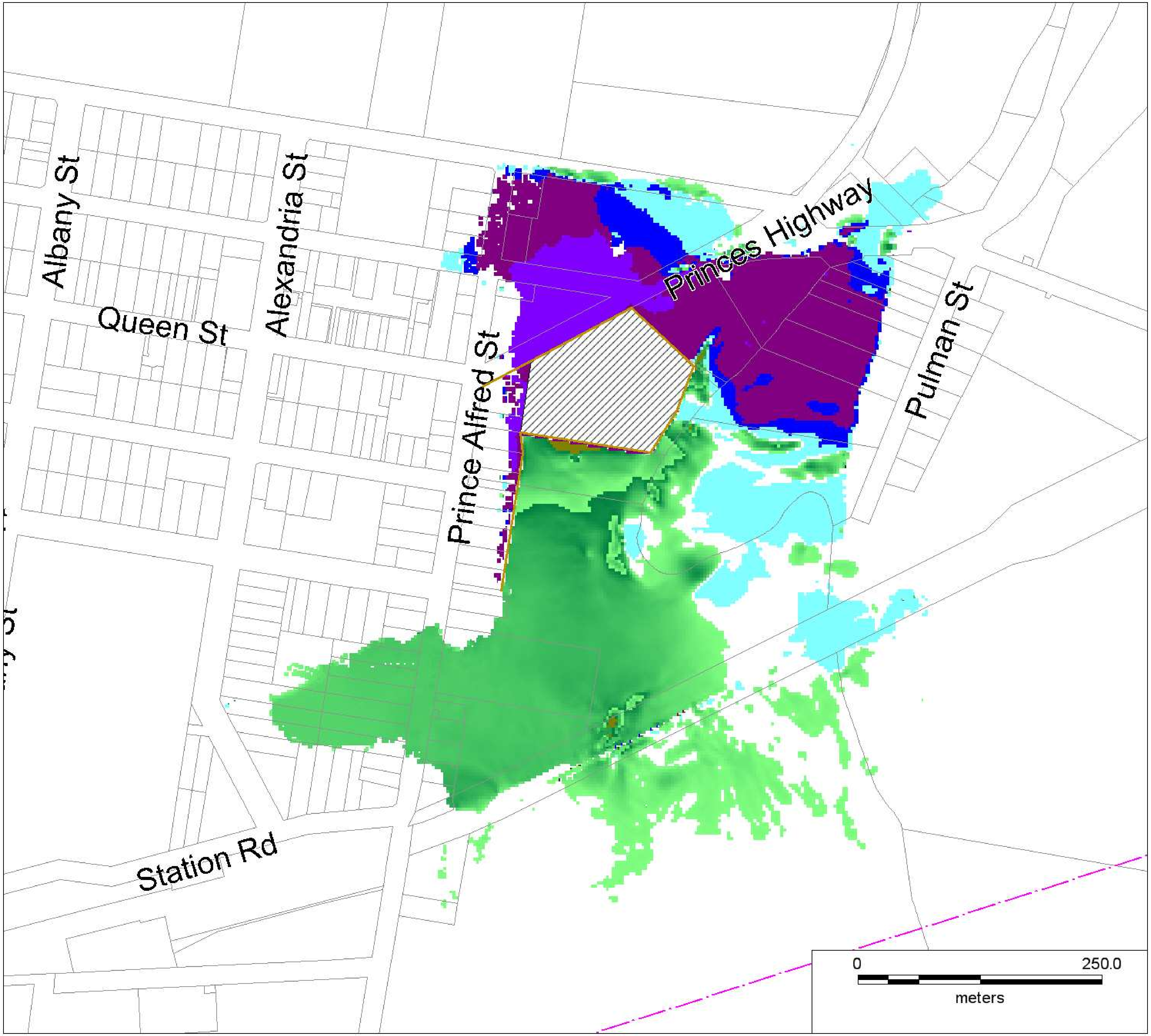


FIGURE 11.12

OPTION FM 2.2

BOWLING CLUB LEVEE
1% AEP LEVEL

DIFFERENCES
1% AEP

Model Extent
Cadastre
Levee
Area protected by levee

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 25 September 2012
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE 11.13

OPTION FM 3.2

TOWN CREEK DETENTION

DIFFERENCES 1% AEP

Cadastre

Town Creek Detention Basin

Peak Water Level Difference metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 25 September 2012
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

Appendices

Broughton Creek

Floodplain Risk Management Study

List of Appendices

List of Tables

List of Figures

Appendix A
Community Consultation
Brochure & Questionnaire

Floodplain Risk Management Options

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

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

Consultation

During the Floodplain Risk Management Study and Plan process, consultation will be undertaken with the community in order to establish a comprehensive list of management options.

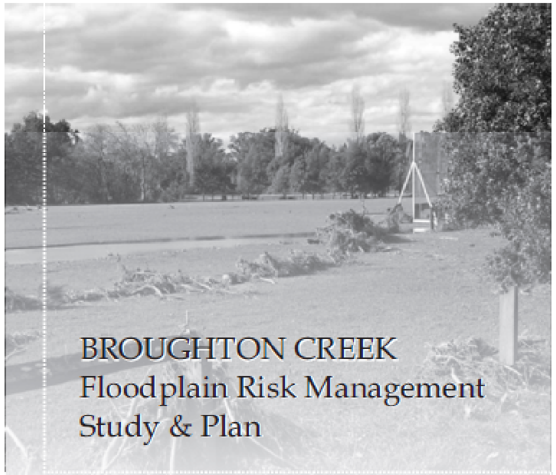
In addition to the accompanying Questionnaire, which can also be found on Council's website, you will have further opportunities to comment on the direction of the project during the public exhibition periods of the Draft Risk Management Study and Plan. Any comments received during these periods will be taken into account before finalisation.

For further information regarding this project please see Council's website www.shoalhaven.nsw.gov.au, or contact either Shoalhaven City Council or Cardno via the details below.

Contact Us

Matthew Apolo
Shoalhaven City Council
36 Bridge Road, Nowra
P: (02) 4429 3145
F: (02) 4422 1816
E: apolom@shoalhaven.nsw.gov.au

Rhys Thomson
Cardno
910 Pacific Highway
Gordon NSW 2072
P: (02) 9496 7700
F: (02) 9499 3902
E: ryhs.thomson@cardno.com.au



BROUGHTON CREEK Floodplain Risk Management Study & Plan

Information Brochure

Shoalhaven City Council has engaged Cardno to assist with the preparation of the Broughton Creek Floodplain Risk Management Study and Plan.

The Risk Management Study and Plan follows from the Flood Study, completed in 2007, which identified the existing flooding behaviour in the Broughton Creek catchment. The purpose of this Risk Management Study and Plan is to identify and recommend appropriate actions to manage flood risks in the Broughton Creek catchment.

This brochure provides an introduction to the Risk Management Study and Plan and informs you of the its objectives.

Your feedback on the accompanying questionnaire will play an important role in the project.

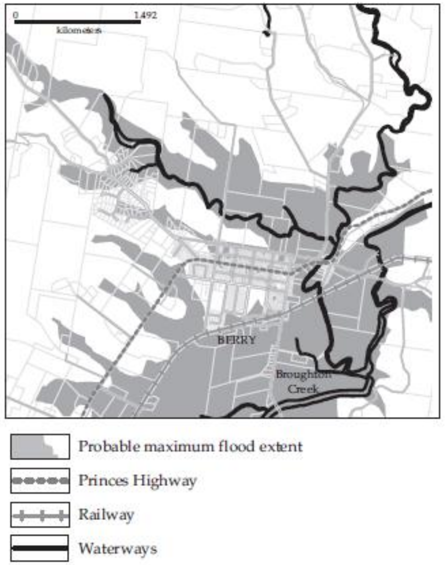
prepared for Shoalhaven City Council | prepared by Cardno

Existing Flooding Issues

As identified within the Flood Study (SMEC, 2007), Broughton Mill, Connollys, Bundewallah and Town Creeks are the main sources of flooding in Berry. Other locations affected by flooding include rural areas surrounding Berry and the Princes Highway.

Access to David Berry hospital and the rail line can also be affected during flood events.

The probable maximum flood extent (extreme flood) for the Broughton Creek catchment is shown below. During this event, properties in Berry are affected by flooding primarily from Town Creek.



Study Area

The study area comprises the Broughton Creek catchment incorporating Berry and surrounding farmlands. Broughton Creek and its tributaries rise in the ranges to the north and west of the town of Berry, flowing through farmlands and forest to the Shoalhaven River downstream of Nowra. The catchment area of Broughton Creek covers approximately 104 square kilometres (see below).

Floodplain Management Process

Council's Shoalhaven River Natural Resource and Floodplain Risk Management Committee (the Committee) oversees the Floodplain Management process. The Committee meets regularly and includes representatives from Council, Department of Environment, Climate Change and Water (DECCW), State Emergency Service (SES), Industry and Investment NSW, and representatives of the local community.

Floodplain Risk Management Study and Plan Objectives

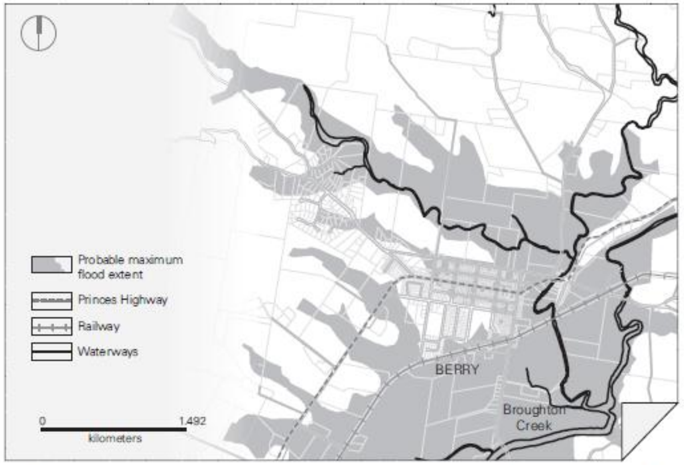
The objectives of the study and plan are:

Floodplain Risk Management Study

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

Floodplain Risk Management Plan:

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



If you have any further comments that relate to the Broughton Creek Floodplain Risk Management Study and Plan, please express them in the space below. Please feel free to attach additional pages if necessary.

....

....

....

Thank you for providing the above information. Please remember to put the pages back in the reply paid envelope by Friday 10 December 2010. A representative from Cardno may contact you in the near future to discuss your response.

YOUR PERSONAL INFORMATION WILL REMAIN CONFIDENTIAL

If you have any queries, please contact:

Matthew Apolo
Shoalhaven City Council
P: (02) 4429 3145
F: (02) 4422 1816
E: apolom@shoalhaven.nsw.gov.au

Rhys Thomson
Cardno
P: (02) 9496 7700
F: (02) 9499 3902
E: rhys.thomson@cardno.com.au

*Note: information supplied will remain completely confidential.

Q1. Could you please provide us with the following details? We may wish to contact you to discuss some of the information you have provided us.	Name: .... Address: .... Daytime Ph: .... Email:		
Q2. Is your property (please tick)?	☐ Owner occupied	☐ Occupied by a tenant	
	☐ A business	☐ Farmland	
Q3. How long have you lived, worked and/or owned your property?	.... Months	.... Years	
Q4. How long have you lived in Berry?	.... Months	.... Years	
Q5. How many people occupy your property?	....		
Q 6. Please indicate the number of permanent residents at this address aged:	☐ 0 - 4 years	☐ 5 - 24 years	
	☐ 25 - 64 years	☐ 65+ years	

prepared for Shoalhaven City Council

prepared by Cardno Shaping the Future

Our team appreciates the diverse effects of flooding – from its dynamic shaping of the environment through to its potential negative social and economic impact. With this knowledge we analyse and develop comprehensive plans.

Q 7. Have you ever experienced flooding since living/working/ owning your property? (please tick relevant boxes)

- ☐ Yes, floodwaters entered my house/business
- ☐ Yes, floodwaters entered my yard/surrounding property
- ☐ Yes, the road was flooded and I couldn't drive my car
- ☐ Yes, the creek broke its banks
- ☐ Yes, other parts of my neighbourhood were flooded
- ☐ No, I haven't experienced a flood (go to Q.9)
- ☐ Other (specify) ....

Q 8. If you have experienced a flood, how did the flooding affect you and your family/business? (please tick relevant boxes)

- ☐ Parts of my house/business building were damaged
- ☐ The contents of my house/business were damaged
- ☐ My garden, yard, and/or surrounding property were damaged
- ☐ My car(s) were damaged
- ☐ Other property was damaged (specify) ....
- ☐ I couldn't leave the house/business
- ☐ Family members/work mates couldn't leave/return to the house/business
- ☐ My family had to evacuate the house/business
- ☐ I had to move livestock/my livestock were threatened by flooding
- ☐ The flood disrupted my daily routine
- ☐ The flood affected me in other ways (specify) ....
- ☐ The flood didn't affect me

Q 9. Do you think your property would be flooded sometime in the future? (please tick relevant boxes)

- ☐ No
- ☐ Yes, but only a small part of my yard
- ☐ Yes, most of my yard/outdoor areas of business could be flooded
- ☐ Yes, my house/office/business could flood over the floor

Q10. Have you looked for information about flooding on your property? (please tick relevant boxes)

- ☐ Council's customer service centre
- ☐ Other information from Council (specify) ....
- ☐ Viewed a Property Planning (Section 149) Certificate
- ☐ Information from a real estate agent
- ☐ Information from relatives, friends, neighbours, or the previous owner
- ☐ Other information (specify) ....
- ☐ No information has been sought
- ☐ I do not believe my property is affected by flooding
- ☐ Council's website

If you answered yes to having looked for information on Council's website:

- ☐ What information have you looked for? (Please specify) ....
- ☐ Where were you able to find information? (Please specify) ....

Q11. What do you think are the best ways to get input and feedback from the local community about the options being considered to manage flooding and the results for this project? (please tick relevant boxes)

- ☐ Council's website
- ☐ Emails from Council
- ☐ Council's Floodplain Management Committee
- ☐ Formal Council meetings
- ☐ Council's information page in the local paper
- ☐ Other articles in the local paper
- ☐ Information days in the local area
- ☐ Community meetings
- ☐ Mail outs to all residents/business owners in the study area
- ☐ Other (specify) ....

Q12. What is the main language spoken at home?

- ☐ English
- ☐ Other (specify) ....

Q13. As a local resident who may have witnessed flooding/drainage problems, you may have your own ideas on how to reduce flood risks. Which of the following management options would you prefer for the Broughton Creek catchment (1=least preferred, 5=most preferred)? Please also provide comments as to the location where you think the option might be suitable.

Proposed Option	Preference (please circle)	Location/Other Comments?
Retarding or detention basins; these temporarily hold water and reduce peak flood flows	1 2 3 4 5	
Stormwater harvesting, such as rainwater tanks	1 2 3 4 5	
Improved flood flow paths	1 2 3 4 5	
Culvert/ bridge/pipe enlarging	1 2 3 4 5	
Levee banks	1 2 3 4 5	
Diversion of creeks and channels	1 2 3 4 5	
Environmental channel improvements, including removal of weeds & bank stabilisation	1 2 3 4 5	
Planning and flood-related development controls	1 2 3 4 5	
Education of community, providing greater awareness of potential hazards	1 2 3 4 5	
Flood forecasting, flood warning, evacuation planning and emergency response	1 2 3 4 5	
Other (please specify any options you believe are suitable). Please attach extra pages for other suggestions	1 2 3 4 5	

Broughton Creek Floodplain Risk Management Study and Plan

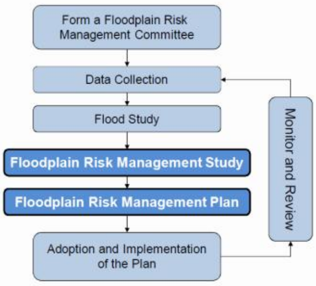
Community Information Session – 29 November 2011

Overview

- Study Objectives
- Study Area
- Study Approach
- Existing Flood Behaviour
- Summary of Community Feedback
- Flood Management Options
- Forthcoming Activities

Study Objectives

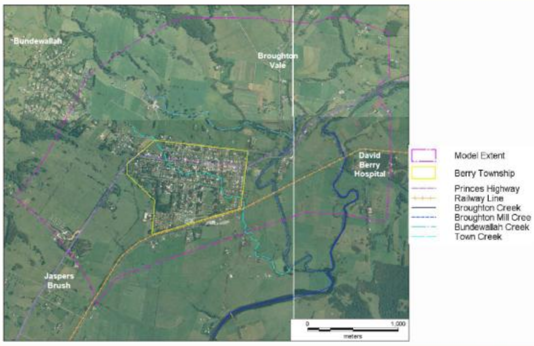
NSW Floodplain Management Process



Study Objectives

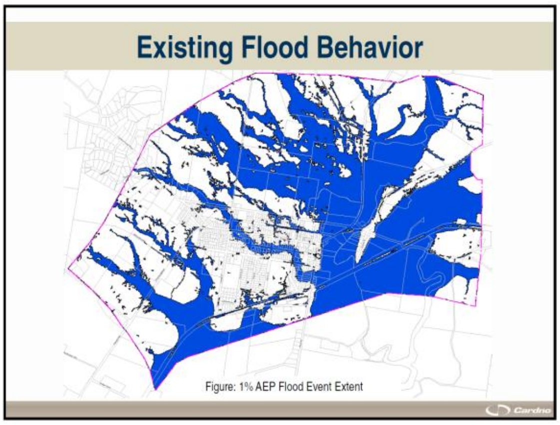
- Review the flood study.
- Update flood modelling to improve understanding of flood behaviour.
- Consider the available flood management options.
- Compare the management options and identify preferred options.

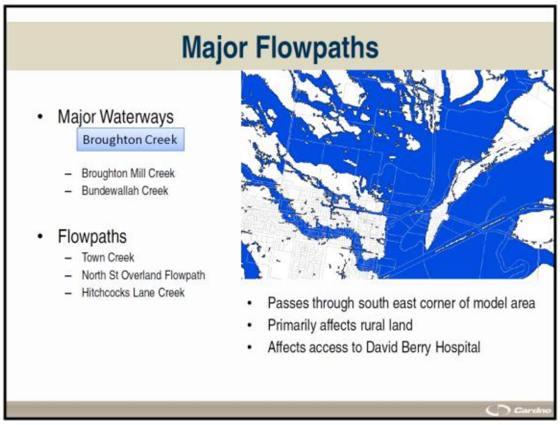
Study Area

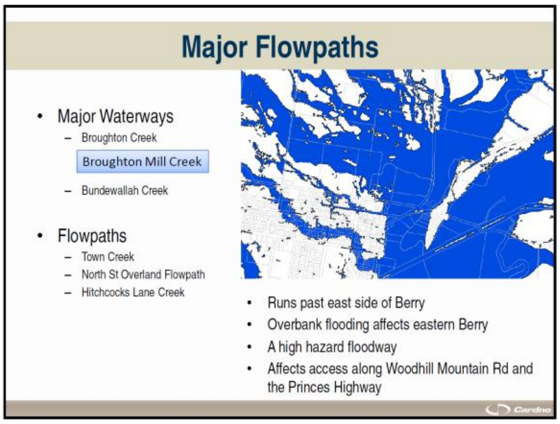


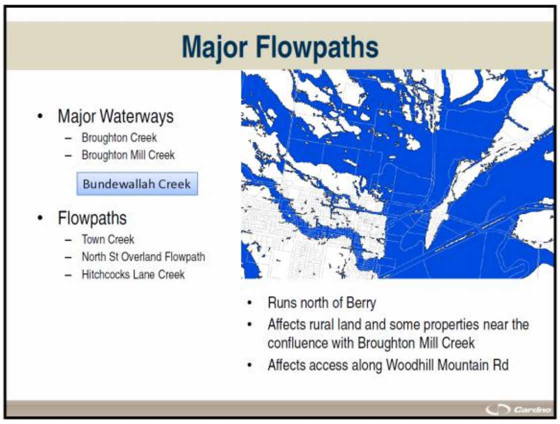
Study Approach

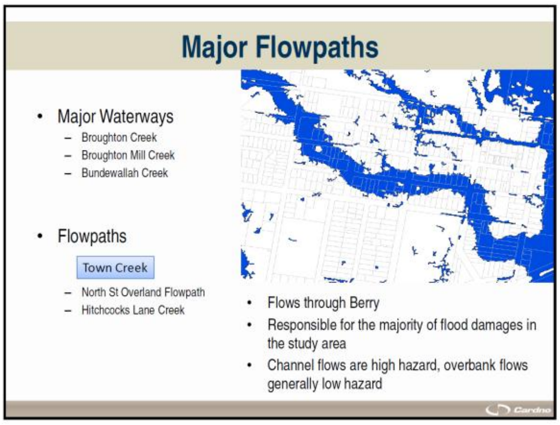
- Update flood modelling
- Stakeholder consultation
  - Council, SES, RTA, Utilities.
- Community consultation
  - Survey, information evening, forthcoming activities
- Develop & assess management options
- Identify preferred management options
- Develop Floodplain Risk Management Plan

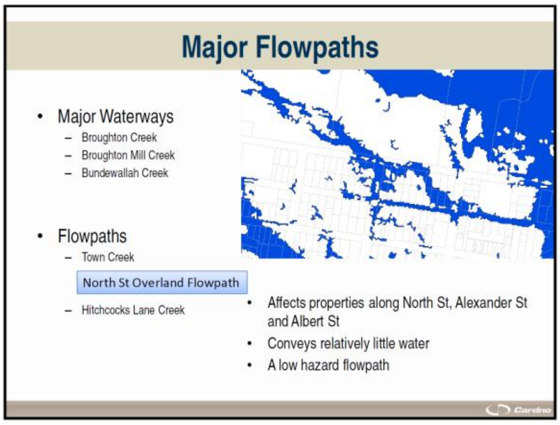

Existing Flood Behavior
Figure: 1% AEP Flood Event Extent

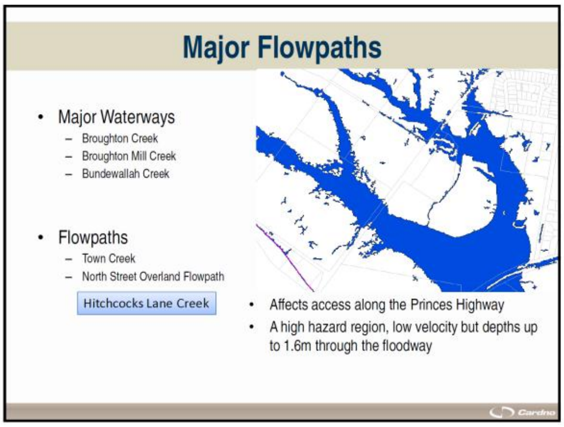

Major Flowpaths
Major Waterways
Broughton Creek
Broughton Mill Creek
Bundewallah Creek
Flowpaths
Town Creek
North St Overland Flowpath
Hitchcocks Lane Creek
Passes through south east corner of model area
Primarily affects rural land
Affects access to David Berry Hospital

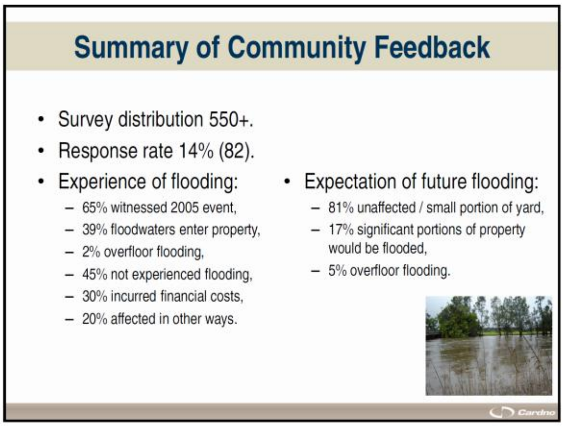

Major Flowpaths
Major Waterways
Broughton Creek
Broughton Mill Creek
Bundewallah Creek
Flowpaths
Town Creek
North St Overland Flowpath
Hitchcocks Lane Creek
Runs past east side of Berry
Overbank flooding affects eastern Berry
A high hazard floodway
Affects access along Woodhill Mountain Rd and the Princes Highway

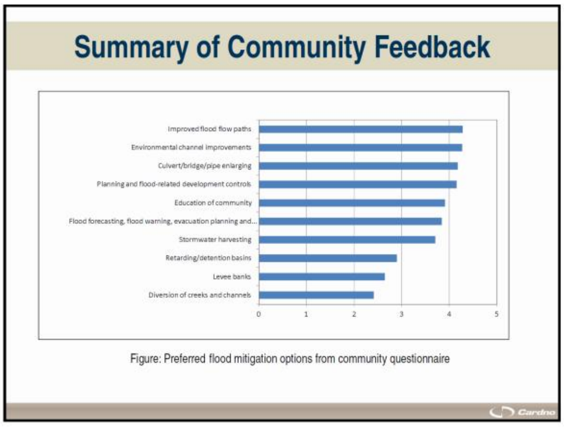

Major Flowpaths
Major Waterways
Broughton Creek
Broughton Mill Creek
Bundewallah Creek
Flowpaths
Town Creek
North St Overland Flowpath
Hitchcocks Lane Creek
Runs north of Berry
Affects rural land and some properties near the confluence with Broughton Mill Creek
Affects access along Woodhill Mountain Rd

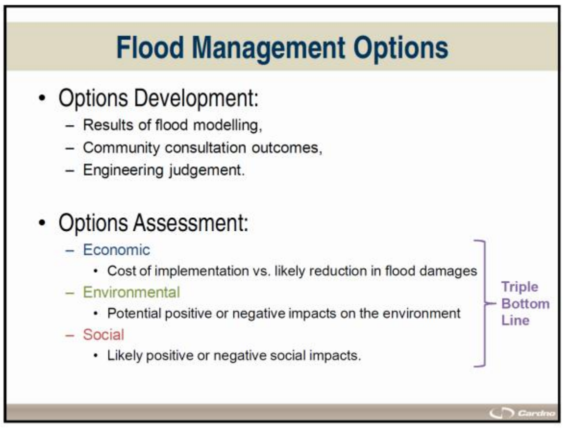

Major Flowpaths
Major Waterways
Broughton Creek
Broughton Mill Creek
Bundewallah Creek
Flowpaths
Town Creek
North St Overland Flowpath
Hitchcocks Lane Creek
Flows through Berry
Responsible for the majority of flood damages in the study area
Channel flows are high hazard, overbank flows generally low hazard

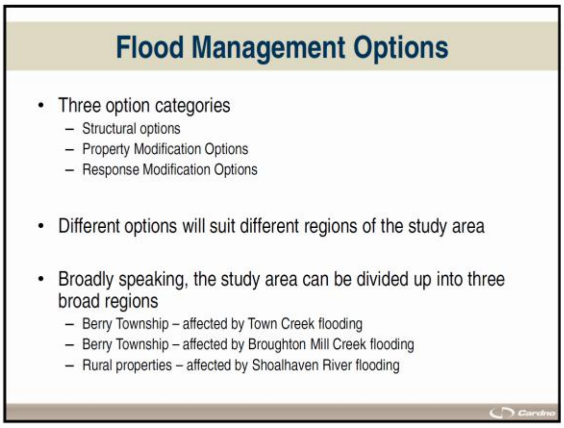

Major Flowpaths
Major Waterways
Broughton Creek
Broughton Mill Creek
Bundewallah Creek
Flowpaths
Town Creek
North St Overland Flowpath
Hitchcocks Lane Creek
Affects properties along North St, Alexander St and Albert St
Conveys relatively little water
A low hazard flowpath

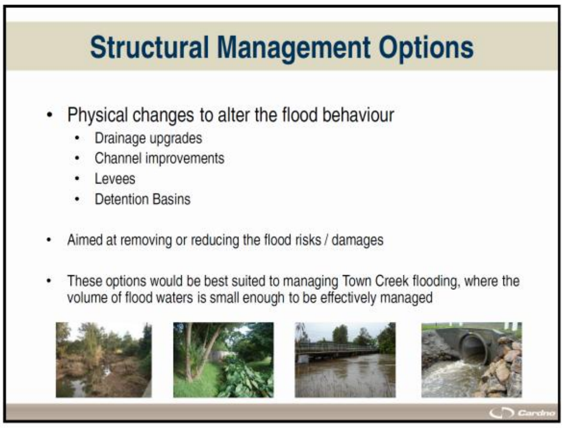

Major Flowpaths
• Major Waterways
– Broughton Creek
– Broughton Mill Creek
– Bundewallah Creek
• Flowpaths
– Town Creek
– North Street Overland Flowpath
Hitchcocks Lane Creek
• Affects access along the Princes Highway
• A high hazard region, low velocity but depths up to 1.6m through the floodway


Summary of Community Feedback
• Survey distribution 550+.
• Response rate 14% (82).
• Experience of flooding:
– 65% witnessed 2005 event,
– 39% floodwaters enter property,
– 2% overfloor flooding,
– 45% not experienced flooding,
– 30% incurred financial costs,
– 20% affected in other ways.
• Expectation of future flooding:
– 81% unaffected / small portion of yard,
– 17% significant portions of property would be flooded,
– 5% overfloor flooding.


Summary of Community Feedback
Improved flood flow paths
Environmental channel improvements
Culvert/bridge/pipe enlarging
Planning and flood-related development controls
Education of community
Flood forecasting, flood warning, evacuation planning and...
Stormwater harvesting
Retarding/detention basins
Levee banks
Diversion of creeks and channels
0 1 2 3 4 5
Figure: Preferred flood mitigation options from community questionnaire


Flood Management Options
• Options Development:
– Results of flood modelling,
– Community consultation outcomes,
– Engineering judgement.
• Options Assessment:
– Economic
• Cost of implementation vs. likely reduction in flood damages
– Environmental
• Potential positive or negative impacts on the environment
– Social
• Likely positive or negative social impacts.
Triple Bottom Line


Flood Management Options
• Three option categories
– Structural options
– Property Modification Options
– Response Modification Options
• Different options will suit different regions of the study area
• Broadly speaking, the study area can be divided up into three broad regions
– Berry Township – affected by Town Creek flooding
– Berry Township – affected by Broughton Mill Creek flooding
– Rural properties – affected by Shoalhaven River flooding


Structural Management Options
• Physical changes to alter the flood behaviour
• Drainage upgrades
• Channel improvements
• Levees
• Detention Basins
• Aimed at removing or reducing the flood risks / damages
• These options would be best suited to managing Town Creek flooding, where the volume of flood waters is small enough to be effectively managed

Property Modification Options

- Changes to structures to make them more flood compatible
  - Planning controls
  - Flood proofing
  - House raising
  - Voluntary purchase
  - Stock mounds
- Aimed at making structures better able to cope with flooding, and thus reducing the flood damage
- These options would be best suited to managing Broughton Mill Creek flooding, and rural flood affected properties where it is not possible to alter the course of the flood

Emergency Response Modification Options

- Changes to how emergency services, Council and residents respond to flood events
  - Preparation of a local flood plan
  - Flood warning systems
  - Public awareness campaigns
  - Flood warning signs
- Aimed at improving the response to flood events to reduce the risk to life and property
- These options are generally good practice in a flood prone area, regardless of the risks and damages of flooding.
- They would be suitable to be applied across the study area

The Princes Highway Upgrade

- The RTA is proposing to upgrade the Princess Highway which incorporates a by-pass around Berry
- There are opportunities to use this to help alleviate flooding
  - Inclusion of storage north of the highway to reduce downstream flooding
  - The diversion of Town Creek
  - The use of excess cut to create stock mounds to provide flood safe regions for animals

Next Steps

- Assessment of options in reducing flood impacts using the hydraulic model
  - Benefit – Cost analysis of successful options
  - Multi-criteria analysis to inform option priorities
- Planning review
- Climate change assessment

Questions?

Appendix B

Flood Study Revision: Model Set Up

B Flood Study Modelling

The TUFLOW 1D/2D hydraulic model was used to define the flood behaviour in the Broughton Creek study area. The hydrological model XP-RAFTS was used to generate inflow hydrographs while the Direct Rainfall method was adopted for areas within the 2D model domain.

The intention of the TUFLOW model is to provide a better definition of the flood behaviour from the previous MIKE11 model that was adopted. The 2D component of the model allows for a better definition of the overbank and floodplain flows. This is particularly important in the areas near the township, where there are both complicated local flows along Town Creek as well as cross catchment flows which occur near Broughton Mill Creek.

For areas downstream of the railway line, the flood levels are primarily influenced by the backwater from the Shoalhaven River. These areas tend to be outside of the main focus of this study. As such, the TUFLOW model boundary was set a few hundred metres downstream of the railway line. For areas downstream of this, the MIKE11 model should still be adopted to define the flood behaviour.

B.1 Model Area

A 3m grid was developed to cover the township of berry and its immediate surrounds. The size of the model area is approximately 8.95 km^2, represented by approximately 995,000 grids cells.

B.2 Topography (2D)

A terrain grid was generated to represent surface elevations from ALS data supplied by Shoalhaven City Council. **Figure B.1** shows the elevations of the Broughton Creek model area.

B.3 1D Network

Pipes drainage systems and selected open channels were modelled in TUFLOW as distinct 1D elements connected to the 2D terrain grid via pits.

The location and size of pipes and culverts were determined from Shoalhaven City Council database information, and additional survey. The majority of the catchment had detailed information on the piped drainage network. Where invert data did not exist, a standard cover depth was assumed and surface levels were estimated from the ALS data. Where no pipe sizes were found, pipe size was assumed to be equal to the largest pipe connected to the upstream pit.

Town Creek was modelled as a distinct 1D element, while other creeks were represented in the 2D domain. This was because the width of Town Creek was generally too small to be accurately represented by the 3m 2D grid. Town creek cross sections were taken from the previous MIKE11 model, and additional survey.

Figure B.2 shows the 1D elements in the model. The lengths of the drainage system components for the model are:

- Pipes 6.5km,
- Box Culverts 0.1km,
- 1D Open Channels 1.1km.

B.4 Roughness

B.4.1 2D Roughness

Each of the 2D grid cells has a roughness value applied to model the influence of flow behaviour of the particular land use. The adopted roughness layout, shown in **Figure B.3,** was based on aerial photographs, site inspections and Council's land-use zonings. The roughness value for each land-use is listed in **Table B.1**.

Table B.1: 2D Roughness Values

Land Use	Roughness Parameter
Roads	0.015
Medium Residential	0.11
Low Residential	0.09
Medium – High Density Vegetation (bush)	0.1
Low Density Vegetation (open space, pasture)	0.06
Waterways	0.05

B.4.2 1D Roughness

Each 1D element in the model – pipes, culverts, open channels – was also given a roughness parameter. Where possible, roughness values were taken from the previous SMEC MIKE11 model. Where elements did not form a part of the previous model, roughness values were determined from photographs and site inspections. The roughness values for 1D elements are listed in **Table B.2**.

Table B.2: 1D Roughness Values

1D Element	Roughness Parameter
Concrete Pipes	0.015
Concrete Box Culverts	0.015
Town Creek – Max	0.16
Town Creek – Min	0.07
Town Creek - Average	0.14

B.5 Hydrology

There were two hydrological methods used in this model – one for upstream flows, and one for the 2D domain. The hydrological model XP-RAFTS was used to generate the inflow hydrographs to the study area. A XP-RAFTS model was constructed as part of the previous SMEC (2008) study. The model required minor adjustments to catchment areas due to the new 2D domain, but all other parameters remained unchanged. These changes are shown in **Figure B.4**, and the area changes summarised in **Table B.3**.

Table B.3: RAFTS Model Changes

RAFTS Catchment ID	Previous Area (ha)	Updated Area (ha)
BC_HL1	71.5	39.1
BC_CP1	64.5	10.3
BC_BW3	5.4	4.9
BC_CN1	597.3	508.9
BC_BM4	461.6	302.1
BC_BC7	231.4	201.7
BC_BCTrib1	455.2	128.8

For the 2D domain, the Direct Rainfall Methodology was adopted. In this procedure, rainfall is applied directly to the 2D grid, and the resultant flows routed through model. As such, no separate hydrological model was required for the study area. A schematisation of the hydrological set up is shown in **Figure B.5**.

The design Intensity-Frequency-Duration (IFD) parameters were taken from the previous RAFTS model, and confirmed with data from the Bureau of Meteorology. Due to the large size of the total catchment area (approximately 184km^2) the areal distribution of rainfall is variable. The IFD parameters for the regions covering the Broughton Creek catchment, adopted in the SMEC (2008) study, are shown in **Table B.6** Boundary Conditions

The downstream boundary was modelled as a constant water level. The downstream boundary conditions were taken from the MIKE11 model .

The boundary conditions for the SMEC (2008) study were based on a previous study of the Shoalhaven River and Shoalhaven Heads .

The downstream level accounts for the combined effects of flooding in the Shoalhaven River and ocean tide levels.

The downstream boundary of the TUFLOW model is approximately 2.6km upstream of the MIKE11 boundary, and therefore the boundary levels adopted in this study differ to those adopted in the SMEC study . Downstream levels for the TUFLOW model were taken from the MIKE11 model at the point where the TUFLOW model ends.

The downstream boundary water level for each event is shown in **Table B.6.** The values shown are the downstream value from the MIKE11 model, and the water level 2.6km upstream, which was adopted as the downstream value in the TUFLOW model.

The loss rates applied to the rainfall based on the soil conditions of the catchment are listed in **Table B.5**.

Table B.4: Design IFD Parameters

Parameter	Berry	Berry East	Berry North	Berry North East
50% AEP 1-hour Intensity	47	50	50	52
50% AEP 12-hour Intensity	10.5	11	11.5	12.5
50% AEP 72-hour Intensity	3.5	3.5	4	4.5
2% AEP 1-hour Intensity	105	110	115	120
2% AEP 12-hour Intensity	25	27.5	29	32
2% AEP 72-hour Intensity	9	9	10.5	12
Skew	0	0	0	0
F2	4.274	4.274	4.274	4.274
F50	15.78	15.78	15.78	15.78
Temporal Pattern Zone	1	1	1	1

Table B.5: Rainfall Loss Parameters

Land Use	Initial Loss (mm)	Continuing Loss (mm/hr)
Roads	1	0
Medium Residential	10	2
Low Residential	12	3
Medium – High Density Vegetation (bush)	15	5
Low Density Vegetation (open space, pasture)	15	5
Waterways	0	0

B.6 Boundary Conditions

The downstream boundary was modelled as a constant water level. The downstream boundary conditions were taken from the MIKE11 model (SMEC, 2008).

The boundary conditions for the SMEC (2008) study were based on a previous study of the Shoalhaven River and Shoalhaven Heads (Webb McKeown & Associates, 2002).

The downstream level accounts for the combined effects of flooding in the Shoalhaven River and ocean tide levels.

The downstream boundary of the TUFLOW model is approximately 2.6km upstream of the MIKE11 boundary, and therefore the boundary levels adopted in this study differ to those adopted in the SMEC study (SMEC, 2008). Downstream levels for the TUFLOW model were taken from the MIKE11 model at the point where the TUFLOW model ends.

The downstream boundary water level for each event is shown in **Table B.6**. The values shown are the downstream value from the MIKE11 model, and the water level 2.6km upstream, which was adopted as the downstream value in the TUFLOW model.

Table B.6: Downstream Boundary Conditions

Event	MIKE11 Downstream Boundary Water Level (mAHD)	TUFLOW Downstream Boundary Water Level (mAHD)
2002 Historical Event	3.9	5.23
2005 Historical Event	3.9	5.23
50% AEP	2.9	4.44
20% AEP	3.3	4.65
10% AEP	3.6	4.8
5% AEP	3.9	4.97
2% AEP	4.5	5.2
1% AEP	5.0	5.59
PMF	7.0	7.6

Appendix C
Flood Study Revision: Model Calibration and Verification

C Model Calibration and Verification

The TUFLOW model was calibrated against the 2005 and 2002 historical flood events and verified against the MIKE11 model for the 100yr design flood event.

C.1 Calibration Results

A comparison of the model peak water levels and the historic flood levels for the 2002 and 2005 events are summarised in **Table C.1** and **Table C.2** respectively. The location of these points is shown in **Figure C.1** and **Figure C.2** respectively.

A comparison of the model peak water levels and the MIKE11 model results for the 1% AEP event is summarised in **Table C.3.** The location of these points is shown in **Figure C.3**.

Table C.1: Comparison of Tuflow and Historic 2002 Flood Levels

Location	Tuflow Peak Level (mAHD)	Historic Peak Level (mAHD)	Difference (m)*
Town Creek 1	6.13	5.95	0.18
Town Creek 2	12.07	12.05	0.02
Town Creek 3	17.31	17.27	0.04
Town Creek 4	17.22	17.22	0.00
Town Creek 5	17.63	17.43	0.20
Bundewallah Creek 1	7.30	7.23	0.07
Bundewallah Creek 2	7.52	7.44	0.08

***Positive numbers represent a higher level for the numerical model, compared to the historic levels**

Table C.2: Comparison of Tuflow and Historic 2005 Flood Levels

Location	Tuflow Peak Level (mAHD)	Historic Peak Level (mAHD)	Difference (m)*
Broughton Mill Creek 1	7.01	6.91	-0.10
Broughton Mill Creek 2	6.04	5.93	-0.11
Broughton Mill Creek 3	9.19	9.13	-0.06
Town Creek 1	6.61	6.92	0.31
Town Creek 2	9.21	9.21	0.00
Town Creek 3	9.27	9.34	0.07
Town Creek 4	9.74	9.73	-0.01
Town Creek 5	9.52	9.39	-0.13
Town Creek 6	9.46	9.46	0.00
Town Creek 7	9.82	9.66	-0.16
Town Creek 8	9.64	9.54	-0.10
Town Creek 9	9.68	9.59	-0.09
Town Creek 10	15.82	15.52	-0.30
Town Creek 11	17.81	17.64	-0.18
Town Creek 12	17.45	17.66	0.21
Town Creek 13	17.82	17.66	-0.17
Town Creek 14	17.96	17.90	-0.06

***Positive numbers represent a higher level for the numerical model, compared to the historic levels**

Table C.3: Comparison of Tuflow and 1% AEP Mike11 Flood Levels

Location	Tuflow Peak Level (mAHD)	Mike11 Peak Level (mAHD)	Difference (m)*
BC_TRIB_1	6.4	6.21	-0.19
BMC_1	5.8	5.69	-0.11
BMC_2	7.79	7.73	-0.06
BMC_3	10.14	10.08	-0.06
BMC_4	11.42	11.26	-0.16
BMC_5	15.21	15.2	-0.01
BW_1	12.95	12.82	-0.13
BW_2	16.05	15.89	-0.16
BW_3	25.36	25.27	-0.09
Nth_Rd_1	11.76	11.97	0.21
STH_1	5.03	5.01	-0.02
STH_2	5.21	5.41	0.2
STH_3	9.05	9.11	0.06
STH_TRIB_1	5.21	5.42	0.21
STH_TRIB_2	10.31	10.35	0.04
TC_1	5.8	5.72	-0.08
TC_2	6.75	6.58	-0.17
TC_3	12.81	12.58	-0.23
TC_4	16.52	16.6	0.08
TC_5	20.2	20.43	0.23
TC_6	29.98	30.09	0.11

***Positive numbers represent a higher level for the numerical model, compared to the Mike11 levels**

For the 2002 historical event, the TUFLOW model reports values within +/-0.2m of the recorded historical values, with the majority within +/-0.1m.

For the 2005 historical event, the TUFLOW model reports values within +/-0.3m of the recorded historical values, with the majority within +/-0.1m

This is considered sufficiently accurate given the sources of the historical data which were generally flood marks, or resident observations, which were surveyed after the flood had past.

Most of the historical marks were focused on Town Creek and Broughton Mill Creek. In order to verify the accuracy of the wider model, locations were taken from across the study area from the 1% AEP Mike11 model, and compared to the TUFLOW results.

For the 1% AEP design event, TUFLOW predicted flood levels that were generally within +/-0.2m of the Mike11, with the majority within +/-0.1m.

Appendix D
Flood Model Revision: Results

D Existing Case Results

D.1 Exist flood behaviour

Flood modelling of design storms was undertaken for the 50%, 20%, 10%, 5%, 2% and 1% AEP events and the PMF event. Each AEP was run for a series of durations; 1hr, 1.5hr, 2hr, 3hr, 6hr and 9hr storms. An envelope of different durations were taken to determine the peak extent, depth and water level in the study area.

Rainfall was applied directly to the 2D domain, using the Direct Rainfall approach. This approach effectively results in every 2D cell being inundated with some flood depth. In order to create model extents and provide reasonable results, a filter was applied to separate what is catchment runoff and what is flooding.

In this study, flood extents were drawn for depths greater than 0.15m. Isolated wet or dry regions smaller than 9 grid cells were also removed.

Flood extents with peak water level contours for the design storms are shown in **Figure D.1** to **Figure D.7**.

The peak flood depths for the design storms are shown in **Figure D.8** to **Figure D.14**.

D.2 Flood Hazard and Hydraulic Categories

Combined flood hazard and hydraulic category maps have been prepared for the 20% AEP and 1% AEP events, and the PMF event, and are shown in **Figure D.15** to **Figure D.17** respectively.

A description of the hazard and hydraulic categories are provided below.

Flood Hazard

Flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations (Appendix L; NSW Government, 2005), as well as an assessment of the true hazard (refer **Section 5.2.2** of the Floodplain Risk Management Study). The Floodplain Development Manual (NSW Government, 2005) defines two categories for provisional hazard – high and low.

The model results were processed using an in-house developed program, which utilises the model results of flood level and velocity to determine hazard. Provisional hazard was prepared for three design events, namely the PMF, 1% AEP and 5% AEP events. The provisional hazard is based on the envelope of the hazard at each location for each AEP.

Hazard is calculated for each grid cell at each time step based on velocity, depth and velocity x depth, with the highest value giving the hazard rating for the cell.

The produced hazard maps were then manually updated based on the true hazard assessment (refer **Section 5.2.2** of the Floodplain Risk Management Study).

Hydraulic Categories

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

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

Floodways were determined for the 1% AEP event of Scenario 3 by considering those model branches that conveyed a significant portion of the total flow. These branches, if blocked or removed, would cause a significant redistribution of the flow. The criteria used to define the floodways are described below (based on Howells et al, 2003).

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

- Velocity x Depth product must be greater than 0.25 m2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

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

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10% of the conveyance is lost, the criteria for flood storage would be satisfied To determine the limits of 10% conveyance in a cross-section, the depth was determined at which 10% of the flow was conveyed. This depth, averaged over several cross-sections, was found to be 0.2 m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

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

All areas that were not categorised as Floodway or Flood Storage, but still fell within the flood extent, where the depth is greater than 0.1 m, are represented as Flood Fringe.

D.3 Discussion of Existing Flooding

Major Waterways

Broughton Creek

The major creek of the catchment is Broughton Creek. It passes through the south east corner of the model area. The majority of the flooding along this creek affects rural land, and generally does not impact on a significant number of houses or buildings. It does affect emergency access to David Berry Hospital, although it is noted that this hospital is not affected and is also not an emergency hospital.

Broughton Mill Creek

Broughton Mill Creek is a major tributary of Broughton Creek. It runs north to south past the east side of Berry, and crosses both the Princes Highway and the railway. Its overbank flooding affects the eastern side of Berry. Much of the floodplain is classed as high hazard in the 1% AEP, generally due to depth. Depths in this area are generally in excess of 1m along the rear of properties on Prince Alfred St and adjacent to Woodhill Mountain Road in the 1% AEP event. The flooding affects some of the commercial properties to the east of the main Berry Township and also the Bowling Club. This watercourse also affects the railway, and can cause overtopping of the railway embankment in events larger than the 5% AEP event.

Bundewallah Creek

Bundewallah Creek flows west – east through pastureland to the north Berry. It joins Broughton Mill Creek immediately upstream of the Princes Highway crossing. This waterway is responsible for some minor property flooding near its confluence with Broughton Mill Creek, as well as inundation of some rural properties upstream, but generally does not significantly affect the Berry township.

Flowpaths

Town Creek

The major flowpath through the township of Berry is along the central watercourse, known locally as Town Creek. This flowpath originates in the north-west, and flows overland through pastureland before crossing North Road and entering a channel which winds through the centre of Berry. Town Creek passes under Prince Alfred Street near Victoria Street, and then flows south along side Prince Alfred Street before passing under the railway, and joining with Broughton Mill Creek downstream of the study area.

The Town Creek flowpath is responsible for the majority of flood damages in the study area.

It is generally slow moving, with velocities below 0.75m/s for the most part, but they can reach up to 1.5m/s along some sections of the channel where the channel has been rock lined. Flood depths adjacent to the main channel are generally 0.5 – 0.8m in the 1% AEP. Increased flood depths of up to 1.2m occur at some locations.

Town Creek flooding also causes the overtopping of roadways within Berry, which can affect access during a flood event. Peak water depths at key intersections along Town Creek are shown in **Table D.1** for the 5% and 1% AEP events, and the PMF event.

Table D.1: Peak Depths at Berry Intersections (*)

Intersection	5% AEP Peak Depth (m)	1% AEP Peak Depth (m)	PMF Peak Depth (m)
Albert Street & George Street	0.21	0.39	0.59
Princess Street & Edward Street	-	0.20	0.35
Princess Street & Albany Street	-	0.23	0.39
Princess Street & Alexandria Street	0.29	0.41	0.61

*** note that depths are indicative and may vary across the road.**

North Street Overland Flowpath

A small flowpath conveys water along North Street and Albert Street in the north of Berry. The flowpath originates as an overland flowpath in pastureland adjacent to North Street. Shortly after Albany Street, the flowpath crosses North Street, and progresses through residential properties to emerge on the corner of Alexander and Albert Streets. Water is then conveyed down Albert Street to Broughton Mill Creek.

This flowpath conveys relatively little water. It causes flooding to some properties with depths of up to 0.5m, but velocities are low, and the flowpath is categorised as low hazard.

Hitchcocks Lane Creek

Two flowpaths cross the Princes Highway in the south-west. They are unnamed, but were referred to as Hitchcocks Lane Creek and Hitchcocks Lane Tributary in previous studies (SMEC, 2008). They combine immediately downstream of the retirement village, just prior to passing under the railway line.

Much of the flow between the Princes Highway and railway line is classified as high hazard, due to depths of up to 1.6m along the floodway, and up to 2.2m of ponding at the railway line in the 1% AEP.

Most of the affected area is pastureland with occasional residences, although the new retirement village has been built between these flowpaths. The properties within the retirement village have been raised above the 100yr level, and the access road is flood-free up to, and including, the 1% AEP event.

Critical Duration

Each AEP was run for a series of durations (see **Appendix D**). Generally, storm durations of 1 – 2 hours were critical throughout much of the catchment, including minor watercourses such as Town Creek, Bundewallah Creek and Broughton Mill Creek. Longer durations of 6 – 9 hours were found to be critical for Broughton Creek, where flooding is primarily driven by peak flood volumes rather than peak rainfall intensity.

Major Access Road/ Railway Overtopping

There are a number of major access routes within the Broughton Creek catchment. The most significant of these are:

- Princes Highway – Primary access to and from Berry in both directions
- Tannery Road – Access road to David Berry Hospital
- Railroad – Part of the Illawarra and Southern Highlands railroad track

Each of these locations are subject to flooding during storm events of sufficient magnitude, and the loss of access along these routes has consequences for emergency evacuation and access to medical treatment.

Approaching Berry from the north, the Princes Highway crosses Broughton Mill Creek shortly before entering Berry. There is a low point on this length of road at the corner out Albert Street, which experiences flooding from Broughton Mill Creek.

To the south of Berry, the Princes Highway crossed Hitchcocks Lane Creek, and a low point exists at this location which is also susceptible to flooding.

Tannery Road provides access to David Berry Hospital, and this access road crosses under the railway shortly before climbing up to the hospital located on a ridge. This underpass can be significantly flood affected.

The railway has a low point as it drops from the ridge near to Broughton Creek to the flatter plain near Berry. This low point is close to Broughton Mill Creek, and can be affected by flooding of this watercourse.

The peak depths at these critical locations are shown in **Table D.2** for the 5% AEP, 1% AEP and the PMF design events.

Table D.2: Major Access Road Flood Depths (*)

Location	5% AEP Peak Flooding Depth (m)	1% AEP Peak Flooding Depth (m)	PMF Peak Flooding Depth (m)
Princes Highway, corner of Albert St	0.31	0.74	2.31
Princes Highway, Hitchcock's Lane crossing	0.16	0.22	1.71
Tannery Road, railway underpass	1.87	2.59	4.52
1.1.1 Railway, Broughton Mill Creek crossing	-	0.21	1.87

*** note that depths are indicative and may vary across the road.**

Appendix E

Flood Study Revision: Sensitivity Analysis

E Sensitivity Analysis

E.1 Model Parameters

A sensitivity analysis was undertaken on the TUFLOW model for the 100 year ARI. The analysis was undertaken by:

- Varying 1D and 2D roughness values by +/- 20%,
- Varying the inflows and rainfall by +/- 20%,
- Varying the downstream boundary by +/- 20%.

A large majority of the changes in flood levels occurred within creek systems and on farmland or parkland. To undertake a meaningful analysis of the sensitivity of the model, the differences of peak water levels were extracted within residential properties based on the floor level survey locations for each of the sensitivity analyses. Properties with a water level change of less than 5mm where classified as no change.

The sensitivity results are summarised in **Table E.1**.

Table E.1: Model Sensitivity Results Summary

	Roughness WL change		Inflow & Rainfall WL change		Boundary WL change	
	+20%	-20%	+20%	-20%	+20%	-20%
% of Properties with Increase	23%	2%	40%	0%	5%	1%
% of Properties with Decrease	1%	25%	0%	53%	0%	1%
Max Increase (m)	0.14	0.01	0.11	0.01	1.16	0.01
Max Decrease (m)	-0.01	-0.24	-0.01	-0.45	-0.02	-1.01
25th Percentile Increase (m)	0.00	0.00	0.00	0.00	0.00	0.00
90th Percentile Increase (m)	0.01	0.01	0.02	0.01	0.00	0.00
25th Percentile Decrease (m)	0.00	0.00	0.00	0.00	0.00	0.00
90th Percentile Decrease (m)	-0.01	-0.01	0.00	-0.11	0.00	0.00

E.2 Blockages

Stormwater pits can potentially block through a number of factors. A number of Councils in NSW adopt a “blockage policy” in undertaking design flood analysis. Shoalhaven City Council, as part of DCP106 Amendment 1, requires flood investigations to assess culvert blockages of 50% and 100%.

The culverts and bridges within the study area are primarily located along Town Creek and under the railway line. Blockages of these structures can occur by the accumulation of debris from upstream. Historical observations in other similar catchments have shown this debris to be diverse, and can include vegetation, tress, garbage bins and cars.

In the model, the blockages adopted were based on the SMEC investigation (SMEC, 2008), which had a blockage rate of 50% for culverts along Town Creek, while blockages throughout the rest of the catchment were kept unblocked, ie, a blockage of 0%.

An analysis was undertaken in the model to asses on the effects of Council’s blockage policy. Two scenarios were tested in line with Council’s blockage policy, namely;

- All culverts 50% blocked
- All culverts 100% blocked

The results of the blockage analysis are summarised in **Table E.2**.

The results show that the 50% blockage rates had little impact on property flooding. Water level increases were observed at 5% of properties. The maximum increase was 0.16m, with 90% of increases being less than 0.03. An additional 1 property was flooded as a result of the 50% blockage.

The impacts of 100% blockage were more pronounced. 15% of properties experienced increased water levels. The maximum increase was 1.12m; however 90% of increases were less than 0.22. An additional 5 properties were flooded as a results of the 50% blockage.

In both cases, the median water level increase was zero.

The large maximum water level change in the 100% blocked scenario is to be expected, as this scenario results in all the railway culverts and bridges been completed blocked, and as such, flow builds up behind the railway before overtopping it. The fact that few additional properties were flooded, and the median increase was zero, suggests that the impact of this ponding is relatively localised, and does not impact the wider catchment.

Table E.2: Blockage Sensitivity Results Summary

	Blockage Sensitivity WL change - 50% blockage Rate (m)	Blockage Sensitivity WL change - 100% blockage Rate (m)
% of Properties with Increase	5%	15%
% of Properties with Decrease	9%	10%
No. of Additional Properties with Overfloor Flooding	1	5
Max Increase (m)	0.16	1.12
Max Decrease (m)	-0.23	-0.39
Median Increase (m)	0	0
25th Percentile Increase (m)	0	0
90th Percentile Increase (m)	0.03	0.22
25th Percentile Decrease (m)	-0.01	0
90th Percentile Decrease (m)	-0.04	-0.05

Appendix F

Climate Change Assessment

F Climate Change Assessment

F.1 Introduction

Within the Floodplain Risk Management Study, climate change impacts were only considered as a result of sea level rise. Previous climate change investigations in for the Lower Shoalhaven River (WMAwater, 2011) concluded that only sea level rise should be considered in assessing climate change impacts on flooding as the likely rainfall increases were not clearly defined or understood at the present time.

As such, to ensure that each area of the Shoalhaven LGA is treated equally, only sea level rise impacts were considered in the Broughton Creek Floodplain Risk Management Study.

However, to provide Council with a fuller picture of climate change impacts on the Broughton Creek Catchment, this appendix has been prepared to investigate the impact of increased rainfall in conjunction with increased mean sea levels.

F.1.1 Climate Change Impacts

The Broughton Creek Climate Change Assessment was undertaken using the same climate change criteria as the Lower Shoalhaven River climate change assessment (WMAwater, 2011).

Climate change impacts were assessed for the 1% AEP flood event.

The Lower Shoalhaven River climate change assessment adopted the following climate change impacts:

- Ocean level rise
  - by 2050 0.4m
  - by 2100 0.9m
- Increase in peak rainfall and storm volume
  - Low level 10%
  - Medium Level 20%
  - High Level 30%

Sea level rises were adopted from the *NSW Policy Statement on Sea Level Rise* and rainfall intensity increases were taken from *Practical Considerations of Climate Change*.

In order to assess the above impacts, eight scenarios were assessed:

- Ocean rise of 0.4m, 0% rainfall increase
- Ocean rise of 0.4m, 10% rainfall increase
- Ocean rise of 0.4m, 20% rainfall increase
- Ocean rise of 0.4m, 30% rainfall increase
- Ocean rise of 0.9m, 0% rainfall increase
- Ocean rise of 0.9m, 10% rainfall increase
- Ocean rise of 0.9m, 20% rainfall increase
- Ocean rise of 0.9m, 30% rainfall increase

The above scenarios provide a comprehensive overview of the potential climate change impacts on the Broughton Creek catchment.

From the results of the scenarios, it was possible to define the impact on flood behaviour and on potential flood mitigation options.

F.2 Climate Change Assessment Methodology

F.2.1 Modelling Approach

F2.1.1 Sea Level Increase

The sea level rise was applied at the Shoalhaven Heads, approximately 22km downstream from the Broughton Creek Tuflow model boundary.

The CELLS model used in the Lower Shoalhaven River Climate Change Assessment extends up Broughton Creek, with the extent of the CELLS model located approximately 2km from the Tuflow model boundary (Webb Mckeown & Associates, 1990).

The water level rise in Broughton Creek due to sea level rise was determined at the extent of the CELLS model by extracting the existing peak level, and the 2050 and 2100 sea level rise peak levels. These levels are shown in **Table F.1**.

Table F.1: Water Levels in Broughton Creek at upstream extent of CELLS model

Existing Level	2050 Sea Level Rise Level	2050 Sea Level Rise Impact	2100 Sea Level Rise Level	2100 Sea Level Rise Impact
5 mAHD	5.02 mAHD	0.02 m	5.05 mAHD	0.05 m

As noted above, this location is approximately 2km from the Tuflow boundary. It was assumed that the water level increase was constant from the CELLS boundary to the TUFLOW boundary.

This is a conservative assumption, as the sea level rise impact will continue to reduce the further it progresses upstream. Using this assumption, the downstream boundary levels for the Tuflow model was increased by 0.02m in the 2050 scenario and 0.05m in the 2100 scenario. The levels are summarised in **Table F.2**.

Table F.2: Water Levels in Broughton Creek at upstream extent of CELLS model

Existing Tuflow Downstream Boundary	2050 Tuflow Downstream Boundary	2100 Tuflow Downstream Boundary
5.59mAHD	5.61mAHD	5.64mAHD

F2.1.2 Rainfall Increase

Rainfall increases were applied to both the RAFTS hydrological model, and to the rainfall within the Tuflow model.

RAFTS Rainfall Increase

The RAFTS hydrological model was used to generate upstream inflows for the Tuflow model area (Cardno, 2012). Rainfall intensities were increased by 10, 20 and 30% and new inflow hydrographs were generated as a result of these increases.

Shown in **Table F.3** below are the peak inflows from RAFTS for the existing and climate change scenarios. It should be noted that the percentage increases were applied to rainfall intensities, which does not translate precisely to the same increases in run-off volume.

Tuflow Rainfall Increase

The Tuflow model has rainfall applied directly to the 2D terrain in the model. This rainfall intensity was also increased by 10, 20 and 30%.

Table F.3: Peak Inflow Volume from Upstream Catchments Under Climate Change Scenarios (cumecs)

Location	Existing	10% Intensity Increase	20% Intensity Increase	30% Intensity Increase
Hitchcocks Lane Creek Tributary	16.5	19.2	21.7	24.0
Hitchcocks Lane Creek	12.0	13.8	15.4	17.1
Town Creek	8.6	10.0	11.3	12.7
Bundewallah Creek	268.6	308.0	351.2	395.4
Bundewallah Creek Tributary	156.9	179.1	201.2	223.3
Broughton Mill Creek	608.9	699.7	788.7	879.1
Broughton Creek	755.9	861.0	971.3	1083.7
Broughton Creek Tributary – North of Railway Line	58.8	68.4	78.1	88.0
Broughton Creek Tributary – South of Railway Line	35.3	40.2	45.1	50.2

F.3 Climate Change Impacts

F.3.1 Property Impacts

In order to assess the impacts on flood behaviour, the 1% AEP event was run for each of the eight climate change scenarios. The results of these scenarios on property flooding are summarised below in **Table F.4**.

Flood impact plots for each scenario are shown in **Figure F.1** to **Figure F.8**.

Table F.4: Change in Property Flooding due to Climate Change

Sea Level	2050				2100			
Rainfall Increase	0%	10%	20%	30%	0%	10%	20%	30%
% of Properties with Increase	10%	22%	24%	25%	10%	22%	24%	25%
Additional properties with overground flooding	1	4	8	10	1	4	8	10
Additional properties with overfloor flooding	0	0	10	16	0	0	10	16

Table F.5 below analyses the properties that experience flooding increases due to climate change.

Table F.5: Analysis of Properties Impacted by Climate Change

Sea Level	2050				2100			
Rainfall Increase	**0%**	**10%**	**20%**	**30%**	**0%**	**10%**	**20%**	**30%**
Max Increase (m)	0.02	0.18	0.34	0.50	0.06	0.18	0.34	0.50
Average Increase for affected properties(m)	0.00	0.05	0.09	0.14	0.01	0.05	0.09	0.14
25th Percentile Increase for affected properties (m)	0.00	0.02	0.03	0.05	0.00	0.02	0.03	0.05
75th Percentile Increase for affected properties (m)	0.00	0.07	0.11	0.16	0.02	0.07	0.11	0.16

The results show that sea level rise plays an insignificant role in flood behaviour changes due to climate change, due to the small magnitude of the change this distance from the ocean.

Increased rainfall intensity affects a greater proportion of properties; approximately 20% - 25% of properties experienced flood level increases as a result of increased rainfall. An additional 10 properties experienced overfloor flooding under the 30% rainfall increase scenario.

The larger increases occur alongside the major waterways, such as Broughton Mill Creek and Broughton Creek, affecting properties along Prince Alfred Street. Increases along Town Creek are in the order of 0.1 – 0.2m in the 30% rainfall increase scenario.

The analysis of the flood level increases shown in **Table F.5** shows that although some properties experience large increases, the vast majority of increases are relatively small. For instance, in the 30% rainfall intensity increase, the largest increase was 0.5m, however, the average was 0.14m, and the 75% of increases were less than 0.16m.

Shown in **Figure F.9** is a flood extent comparison between the existing 100yr ARI flood, and the 2100 30% rainfall increase flood. The figure shows that there is little change in the flood extent, and no areas where the climate change flood extent has significantly extended into areas that were previously unaffected by flooding.

F.3.2 Access and Evacuation Impacts

Climate change impacts on access and evacuation have been assessed using the 30% rainfall increase with 2100 sea level rise scenario, as this represents the worst case climate change scenario.

Summarised below in **Table F.6** are the peak road overtopping levels at key access locations, and the time to loss of access at these locations.

The results show that peak overtopping depths along key access roads increase 0.1m to 0.4m. The time to loss of access is very similar to the existing case.

This suggests that while peak levels are greater, the timing is not significantly affected. As such, climate change is likely to only impact on the frequency of inundation of roads, not on the planning of evacuation.

Table F.6: Climate Change Impacts on Access Road Flooding

Location	Existing Peak Level (mAHD)	Existing Time to Loss of Access (hrs)	Climate Change Peak Level (mAHD)	Climate Change Time to Loss of Access (hrs)
Corner of Princess Highway & Woodhill Mountain Road	9.52	1.3	9.88	1.1
Prince Alfred Street at Town Creek	6.96	1.0	7.31	1.0
Corner Princess Street & Alexandra Street	9.91	0.9	9.97	0.8
Corner Princess Street & Edward Street	14.90	0.9	15.00	0.8

F.3.3 Impacts on Proposed Flood Mitigation Options

Climate change is not expected to significantly affect the non-structural options. It will have no effect on the planning, policy or emergency response options discussed in the Floodplain Risk Management Study and Plan.

Climate change has potential impacts on the structural management options, as it results in increased discharges, which will affect the sizing of culverts and diversion swales.

Increases in flow volumes in the 2100, 30% rainfall increase scenario which affect structural options are summarised below in **Table F.7**.

The results in **Table F.7** show that flows through the proposed structural mitigation options increase by generally 40 – 50% over existing levels.

This suggests that the structural options may require amplification to cope with flow increases due to climate change. For the 10%, 20% and 30% increases in rainfall intensity, this amplification is in the order of 15%, 30% and 45% respectively.

Table F.7: Flow Increase Through Structural Mitigation Options in Climate Change Scenarios

Option	Increase in Peak Discharge over Existing Discharge through Option (%)		
Rainfall Increase	10%	20%	30%
Town Creek Vegetation Management	16%	31%	48%
Railway Culvert Upgrade	14%	28%	42%
Railway Bridge Upgrade	14%	28%	42%
North St Diversion Swale	12%	24%	38%
Town Creek Diversion	14%	28%	43%
Town Creek Upstream Detention	14%	28%	43%

F.4 Conclusions

The Broughton Creek catchment is relatively unaffected by climate change. It is sufficiently far upstream that sea level rise does not impact the flood behaviour.

Increased rainfall does result in flood level increases, but these are predominantly confined to existing flooding regions, and do not result in large additional areas of the catchment becoming flood effected.

A small number of properties experience significant flood level increases, particularly in the 30% rainfall increase scenarios. However, the majority of properties do not experience any change in flood levels even with a 30% increase in rainfall intensity. Of those that do, the majority of increases are relatively low, in the order of 0.1m – 0.15m.

Climate change is not expected to impact on flood emergency response or flood accessibility. The majority of options proposed in the Floodplain Risk Management Study are still suitable under a climate change scenario. The structural options may require some degree of amplification to cope with increased flow volumes.

F.5 References

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Appendix G

Flood Mitigation Options Costing Details

G Flood Mitigation Options Costing Details

The following tables detail the costing for each mitigation option. Please note that the follow conditions apply to all costings:

- Estimate does not include consultants fees
- No allowance has been made for detection and exposure of existing services
- It has been assumed that existing buildings will not obstruct excavations
- Estimates in 2011 dollars and does not allow for inflation
- Estimates are provided in good faith using available information. The estimate is not guaranteed, and Cardno will not accept liability in the event actual costs exceed the estimate.

Town Creek Vegetation Clearing					
ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	5000	5,000
1.2	Provision of sediment & erosion control	1	item	4000	4,000
1.3	Construction setout & survey	1	item	5000	5,000
1.4	Work as executed survey & documentation	1	item	5000	5,000
1.5	Geotechnical supervision, testing & certification	1	item	3000	3,000
	SUBTOTAL				**22,000**
2.0	**CLEARING AND WEEDING**				
2.1	Minor weeding of creek sections with good existing natvie vegetation.	325	lin.m	5	1,625
2.2	Weeding / clearing of creek sections with mix of native and introduced vegetation, accumulated debris, or large trees / shrubs.	970	lin.m	15	14,550
2.3	Weeding / clearing of creek sections with significant introduced vegetation, or large, established trees / shrubs.	860	cu. m	40	34,400
	SUBTOTAL				**50,575**
3.0	**PLANTING**				
3.1	Plant species as listed by ecologist, at stocking densities as defined by landscape architect to stabilise banks and channel - GENERAL AREAS	1,295	lin.m	50	64,750
3.2	Plant species as listed by ecologist, at stocking densities as defined by landscape architect to stabilise banks and channel - CLEARED AREAS	860	lin.m	175	150,500
	SUBTOTAL				**150,500**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed bank areas in accordance with landscape architects requirements (nominal allowance)	215	sq. m	10	2,150
	SUBTOTAL				**2,150**
	CONSTRUCTION SUB-TOTAL				**225,225**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**112,613**
	CONSTRUCTION TOTAL, excluding GST				**337,838**
	GST				**33,784**
	CONSTRUCTION TOTAL, including GST				**371,621**
	CONSTRUCTION TOTAL, rounded				**371,700**

Town Creek Detention

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	3000	3,000
1.2	Provision of sediment & erosion control	1	item	2000	2,000
1.3	Construction setout & survey	1	item	3500	3,500
1.4	Work as executed survey & documentation	1	item	3500	3,500
1.5	Geotechnical supervision, testing & certification	1	item	2500	2,500
	SUBTOTAL				**14,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	8,300	sq. m	10	83,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	1245	cu. m	20	24,900
2.3	Dispose of excess topsoil (nominal 10% allowance)	124.5	cu. m	50	6,225
	SUBTOTAL				**114,125**
3.0	**EARTHWORKS**				
3.1	Excavate basin - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	4980	cu. m	50	249,000
	SUBTOTAL				**249,000**
4.0	**DETENTION BASIN DRAIANGE**				
3.1	Instal entry and exit weirs, construct drainage and conect to existing network (nominal cost)	1	item	7500	7,500
	SUBTOTAL				**7,500**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	8,300	sq. m	10	83,000
	SUBTOTAL				**83,000**
	CONSTRUCTION SUB-TOTAL				**468,125**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**234,063**
	CONSTRUCTION TOTAL, excluding GST				**702,188**
	GST				**70,219**
	CONSTRUCTION TOTAL, including GST				**772,406**
	CONSTRUCTION TOTAL, rounded				**772,500**

Town Creek Culvert Upgrade					
ITEM NO.	**DESCRIPTION OF WORK**	**QTY**	**UNIT**	**RATE**	**COST**
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	8500	8,500
1.2	Provision of sediment & erosion control	1	item	7500	7,500
1.3	Construction setout & survey	1	item	6000	6,000
1.4	Work as executed survey & documentation	1	item	7500	7,500
1.5	Geotechnical supervision, testing & certification	1	item	5000	5,000
	SUBTOTAL				**34,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	200	sq. m	10	2,000
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	30	cu. m	20	600
2.3	Dispose of excess topsoil (nominal 10% allowance)	3	cu. m	50	150
2.4	Pull up and dispose existing road surface	450	sq.m	35	15,750
	SUBTOTAL				**18,500**
3.0	**EARTHWORKS**				
3.1	Excavation of cuvlert trenches, and additional minor earthworks as requried - regrade to suit new design levels, including disposal / provision of cut / fill	1270	cu. m	50	63,500
	SUBTOTAL				**63,500**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.8m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	50	lin.m	2500	125,000
4.2	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.5m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	45	lin.m	2100	94,500
4.3	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.2m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	90	lin.m	1800	162,000
4.4	Supply, excavate, bed, lay, joint, backfill and provide connections for Ø1.0m RCP including demolition and disposal of existing pipe, and installation of headwalls and erosion protection as required	105	lin.m	1600	168,000
	SUBTOTAL				**549,500**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	450	sq. m	50	22,500
	SUBTOTAL				**22,500**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	200	sq. m	10	2,000
6.2	Undertake creek rehabilitation of distirubed creek areas (nominal allowance)	1	item	10000	10,000
	SUBTOTAL				**12,000**
	CONSTRUCTION SUB-TOTAL				**700,500**
7.0	**CONTINGENCIES**				
7.1	50% construction cost				**350,250**
	CONSTRUCTION TOTAL, excluding GST				**1,050,750**
	GST				**105,075**
	CONSTRUCTION TOTAL, including GST				**1,155,825**
	CONSTRUCTION TOTAL, rounded				**1,155,900**

Rail Culvert Upgrade

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	10000	10,000
1.2	Provision of sediment & erosion control	1	item	10000	10,000
1.3	Construction setout & survey	1	item	5000	5,000
1.4	Work as executed survey & documentation	1	item	6000	6,000
1.5	Geotechnical supervision, testing & certification	1	item	4000	4,000
	SUBTOTAL				**35,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	250	sq. m	10	2,500
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	37.5	cu. m	20	750
2.3	Dispose of excess topsoil (nominal 10% allowance)	3.75	cu. m	50	188
2.4	Pull up existing rail line over proposed culvert	25	lin.m	750	18,750
	SUBTOTAL				**22,188**
3.0	**EARTHWORKS**				
3.1	Minor Earthworks - regrade to suit new design levels, including disposal / provision of cut / fill	1125	cu. m	50	56,250
	SUBTOTAL				**56,250**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 2.75m x 2.75m RCBC including installation of headwalls and erosion protection as required	120	item	4500	540,000
4.2	Re-lay removed rail track including connections, ballast, batters as required	25	lin.m	6000	150,000
	SUBTOTAL				**690,000**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	250	sq. m	10	2,500
	SUBTOTAL				**2,500**
	CONSTRUCTION SUB-TOTAL				**805,938**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**402,969**
	CONSTRUCTION TOTAL, excluding GST				**1,208,906**
	GST				**120,891**
	CONSTRUCTION TOTAL, including GST				**1,329,797**
	CONSTRUCTION TOTAL, rounded				**1,329,800**

Rail Bridge Upgrade

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	8500	8,500
1.2	Provision of sediment & erosion control	1	item	15000	15,000
1.3	Construction setout & survey	1	item	6000	6,000
1.4	Work as executed survey & documentation	1	item	7500	7,500
1.5	Geotechnical supervision, testing & certification	1	item	5000	5,000
	SUBTOTAL				**42,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	1,680	sq. m	10	16,800
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	252	cu. m	20	5,040
2.3	Dispose of excess topsoil (nominal 10% allowance)	25.2	cu. m	50	1,260
2.4	Pull up and dispose existing bridge	30	lin.m	350	10,500
	SUBTOTAL				**33,600**
3.0	**EARTHWORKS**				
3.1	Minor Earthworks - regrade to suit new design levels, including disposal / provision of cut / fill	600	cu. m	50	30,000
	SUBTOTAL				**30,000**
4.0	**BRIDGE CONSTRUCTION**				
4.1	Construct 40m span, dual carriage rail bridge with 1 central pier. Includes transitions to existing track, ballast, bridge abutments, erosion protection	1	item	2000000	2,000,000
4.2	Rehabilitate disturbed areas of creek and bank	1200	sq.m	300	360,000
	SUBTOTAL				**2,360,000**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,680	sq. m	10	16,800
	SUBTOTAL				**16,800**
	CONSTRUCTION SUB-TOTAL				**2,482,400**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**1,241,200**
	CONSTRUCTION TOTAL, excluding GST				**3,723,600**
	GST				**372,360**
	CONSTRUCTION TOTAL, including GST				**4,095,960**
	CONSTRUCTION TOTAL, rounded				**4,096,000**

North Road Flowpath

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	4000	4,000
1.2	Provision of sediment & erosion control	1	item	2500	2,500
1.3	Construction setout & survey	1	item	4000	4,000
1.4	Work as executed survey & documentation	1	item	4000	4,000
1.5	Geotechnical supervision, testing & certification	1	item	3000	3,000
	SUBTOTAL				**17,500**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	8,840	sq. m	10	88,400
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	1326	cu. m	20	26,520
2.3	Dispose of excess topsoil (nominal 10% allowance)	132.6	cu. m	50	6,630
	SUBTOTAL				**121,550**
3.0	**EARTHWORKS**				
3.1	Earthworks - cut / fill & regrade to suit new design levels, including disposal / provision of cut / fill	5715	cu. m	50	285,750
	SUBTOTAL				**285,750**
4.0	**MINOR LANDSCAPING**				
4.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	8,840	sq. m	10	88,400
	SUBTOTAL				**88,400**
	CONSTRUCTION SUB-TOTAL				**513,200**
5.0	**CONTINGENCIES**				
5.1	50% construction cost				**256,600**
	CONSTRUCTION TOTAL, excluding GST				**769,800**
	GST				**76,980**
	CONSTRUCTION TOTAL, including GST				**846,780**
	CONSTRUCTION TOTAL, rounded				**846,800**

Bundewallah Bridge Upgrade

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	8500	8,500
1.2	Provision of sediment & erosion control	1	item	15000	15,000
1.3	Construction setout & survey	1	item	6000	6,000
1.4	Work as executed survey & documentation	1	item	7500	7,500
1.5	Geotechnical supervision, testing & certification	1	item	5000	5,000
	SUBTOTAL				**42,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	1,680	sq. m	10	16,800
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	252	cu. m	20	5,040
2.3	Dispose of excess topsoil (nominal 10% allowance)	25.2	cu. m	50	1,260
2.4	Pull up and dispose existing bridge and road	30	lin.m	2500	75,000
	SUBTOTAL				**98,100**
3.0	**EARTHWORKS**				
3.1	Minor Earthworks - regrade to suit new design levels, including disposal / provision of cut / fill	1200	cu. m	50	60,000
	SUBTOTAL				**60,000**
4.0	**BRIDGE CONSTRUCTION**				
4.1	Construct 40m span, dual carriage bridge. Includes transitions to existing road, pedestrian footpath, railings, bridge abutments, erosion protection	40	lin.m	12000	480,000
4.2	Rehabilitate disturbed areas of creek and bank	1200	sq.m	150	180,000
	SUBTOTAL				**660,000**
5.0	**MINOR LANDSCAPING**				
5.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	1,680	sq. m	10	16,800
	SUBTOTAL				**16,800**
	CONSTRUCTION SUB-TOTAL				**876,900**
6.0	**CONTINGENCIES**				
6.1	50% construction cost				**438,450**
	CONSTRUCTION TOTAL, excluding GST				**1,315,350**
	GST				**131,535**
	CONSTRUCTION TOTAL, including GST				**1,446,885**
	CONSTRUCTION TOTAL, rounded				**1,446,900**

Broughton Mill Creek Diversion

ITEM NO.	DESCRIPTION OF WORK	QTY	UNIT	RATE	COST
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	60000	60,000
1.2	Provision of sediment & erosion control	1	item	7500	20,000
1.3	Construction setout & survey	1	item	6000	15,000
1.4	Work as executed survey & documentation	1	item	7500	20,000
1.5	Geotechnical supervision, testing & certification	1	item	5000	50,000
	SUBTOTAL				**165,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	3,525	sq. m	10	35,250
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	528.75	cu. m	20	10,575
2.3	Dispose of excess topsoil (nominal 10% allowance)	52.875	cu. m	50	2,644
2.4	Pull up and dispose existing road surface	750	sq.m	100	75,000
	SUBTOTAL				**123,469**
3.0	**EARTHWORKS**				
3.1	Excavation of cuvlert trench in soil (sand or clay), and additional minor earthworks as requried - regrade to suit new design levels, including disposal / provision of cut / fill	4100	cu. m	50	205,000
3.1	Excavation of cuvlert trench in rock (hard rock), and additional minor earthworks as requried - regrade to suit new design levels, including disposal / provision of cut / fill	8200	cu. m	300	2,460,000
	SUBTOTAL				**2,665,000**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 16m x 2.4m RCBC	121	lin.m	30000	3,630,000
4.2	Install headwalls at inlet and outlet including erosion protection	2	each	30000	60,000
	SUBTOTAL				**3,690,000**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement,	750	sq. m	200	150,000
	SUBTOTAL				**150,000**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	3,525	sq. m	10	35,250
6.2	Undertake creek rehabilitation of distirubed creek areas (nominal allowance)	1	item	50000	50,000
	SUBTOTAL				**85,250**
	CONSTRUCTION SUB-TOTAL				**6,878,719**
7.0	**CONTINGENCIES**				
7.1	50% construction cost				**3,439,359**
	CONSTRUCTION TOTAL, excluding GST				**10,318,078**
	GST				**1,031,808**
	CONSTRUCTION TOTAL, including GST				**11,349,886**
	CONSTRUCTION TOTAL, rounded				**11,349,900**

Broughton Mill Creek Diversion with Levee					
ITEM NO.	**DESCRIPTION OF WORK**	**QTY**	**UNIT**	**RATE**	**COST**
1.0	**GENERAL AND PRELIMINARIES**				
1.1	Site establishment, security fencing, facilities & disestablishment	1	item	60000	60,000
1.2	Provision of sediment & erosion control	1	item	7500	20,000
1.3	Construction setout & survey	1	item	6000	15,000
1.4	Work as executed survey & documentation	1	item	7500	20,000
1.5	Geotechnical supervision, testing & certification	1	item	5000	50,000
	SUBTOTAL				**165,000**
2.0	**DEMOLITION, CLEARING AND GRUBBING**				
2.1	Clearing & grubbing	6,825	sq. m	10	68,250
2.2	Strip topsoil & stockpile for re-use (assuming 150mm depth)	1023.75	cu. m	20	20,475
2.3	Dispose of excess topsoil (nominal 10% allowance)	102.375	cu. m	50	5,119
2.4	Pull up and dispose existing road surface	750	sq.m	100	75,000
	SUBTOTAL				**168,844**
3.0	**EARTHWORKS**				
3.1	Excavation of cuvlert trench in soil (sand or clay), and additional minor earthworks as requried - regrade to suit new design levels, including disposal / provision of cut / fill	4500	cu. m	50	225,000
3.2	Excavation of cuvlert trench in rock (hard rock), and additional minor earthworks as requried - regrade to suit new design levels, including disposal / provision of cut / fill	9000	cu. m	300	2,700,000
3.3	Construct levee bank between Woodhill Mountain Rd and westen Broughton Mill Creek bank, immediately downstream of Bundewallah Creek confluence, at 20% AEP level	2860	cu. m	40	114,400
	SUBTOTAL				**3,039,400**
4.0	**DRAINAGE**				
4.1	Supply, excavate, bed, lay, joint, backfill and provide connections for 16m x 2.4m RCBC	121	lin.m	30000	3,630,000
4.2	Install headwalls at inlet and outlet including erosion protection	2	each	30000	60,000
	SUBTOTAL				**3,690,000**
5.0	**PAVEMENTS**				
5.1	Reinstate disturbed road pavement, including demolition and disposal of additional material to provide good jointing	750	sq. m	200	150,000
	SUBTOTAL				**150,000**
6.0	**MINOR LANDSCAPING**				
6.1	Repair disturbed areas in accordance with landscape architects requirements (nominal allowance)	6,825	sq. m	10	68,250
6.2	Undertake creek rehabilitation of distirubed creek areas (nominal allowance)	1	item	50000	50,000
	SUBTOTAL				**118,250**
	CONSTRUCTION SUB-TOTAL				**7,331,494**
7.0	**CONTINGENCIES**				
7.1	50% construction cost				**3,665,747**
	CONSTRUCTION TOTAL, excluding GST				**10,997,241**
	GST				**1,099,724**
	CONSTRUCTION TOTAL, including GST				**12,096,965**
	CONSTRUCTION TOTAL, rounded				**12,097,000**

Appendix H

Multi-Criteria Matrix

No.	ID	Category of Measure	Description	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 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	EconomicS core
1	FM 1.1 *	Flood Modification	Town Creek Culvert Upgrade	Not viable, refer report										
2	FM 1.2 *	Flood Modification	Town Creek Vegetation Clearing	$371,700	$500	$378,600	$6,498	4.7%	$89,677	0.24	-1	0	2	**0.0**
3	FM 1.3 *	Flood Modification	Railway Culvert Upgrade	$1,329,800	$1,500	$1,350,501	$909	0.7%	$12,545	0.01	-2	-1	1	**-1.0**
4	FM 1.4 *	Flood Modification	Railway Bridge Upgrade	$4,095,960	$1,500	$4,116,661	$6,071	4.4%	$83,784	0.02	-2	-2	2	**-1.0**
6	FM 1.6 *	Flood Modification	North St Diversion Swale	$846,800	$2,500	$881,302	$5,422	3.9%	$74,828	0.08	-2	-1	2	**-0.8**
6	FM 1.7 *	Flood Modification	Town Creek Diversion	$1,400,000	$2,500	$1,434,502	$20,503	14.7%	$282,957	0.20	-2	-1	2	**-0.8**
31	FM 1.8	Flood Modification	Broughton Mill Creek Diversion	$10,318,100	$10,000	$10,456,107	$31,996	22.9%	$441,569	0.04	-2	-2	2	**-1.0**
32	FM 1.9	Flood Modification	Broughton Mill Creek Diversion +levee	$12,097,000	$10,000	$12,235,007	$33,163	23.8%	$457,674	0.04	-2	-2	2	**-1.0**
33	FM 1.9	Flood Modification	Broughton Mill Creek Diversion best case damage reduction	$41,272,400	$20,000	$41,548,415	$87,360	62.6%	$1,205,633	0.03	-2	-2	2	**-1.0**
7	FM 2.1 *	Flood Modification	Berry RSL / Prince Alfred St Levee - 5% AEP level	Not viable, refer report										
8	FM 2.2 *	Flood Modification	Berry RSL / Prince Alfred St Levee - 1% AEP level	Not viable, refer report										
9	FM 2.3	Flood Modification	Town Creek Flood Walls - 5% AEP level	Not viable, refer report										
10	FM 2.4	Flood Modification	Town Creek Flood Wall - 1% AEP level	Not viable, refer report										
14	FM 3.1 *	Flood Modification	Town Creek upstream detention	$772,500	$1,000	$786,301	$1,456	1.0%	$20,094	0.03	-2	-1	1	**-1.0**
15	FM 4.1	Flood Modification	Stock Mounds	$2,500	$0	$2,500	NC	N/A	N/A	N/A	1	2	2	**1.5**
16	FM 5.1 *	Flood Modification	Princes Highway Berry By-Pass	To be assessed following finalisation of by-pass design										
17	P1	Property Modification	LEP Update	$5,000	$1,000	$18,801	NC	N/A	N/A	N/A	1	2	2	**1.5**
18	P2	Property Modification	Building and Development Controls	$15,000	$1,000	$28,801	NC	N/A	N/A	N/A	1	2	2	**1.5**
19	P3	Property Modification	House Raising	Not viable, refer report										
20	P4	Property Modification	House Rebuilding	Not viable, refer report										
21	P5	Property Modification	Voluntary Purchase	Not viable, refer report										
22	P6	Property Modification	Land Swap	Not viable, refer report										
23	P7	Property Modification	Council Redevelopment	Not viable, refer report										
24	P8	Property Modification	Flood Proofing Guidelines	$15,000	$1,000	$28,801	$3,185	2.3%	$43,955	1.53	1	2	1	**1.3**
25	EM1	Emergency Response Modification	Infomation transfer to the SES	$3,000	$0	$3,000	NC	N/A	N/A	N/A	0	2	0	**0.5**
26	EM2	Emergency Response Modification	Preparation of Local Flood Plans and update of DISPLAN	$30,000	$2,000	$57,601	NC	N/A	N/A	N/A	0	1	0	**0.3**
27	EM3	Emergency Response Modification	Flood warning system	$10,000	$1,500	$30,701	NC	N/A	N/A	N/A	0	2	1	**0.8**
28	EM4	Emergency Response Modification	Public awareness and education	$20,000	$2	$20,028	NC	N/A	N/A	N/A	0	2	1	**0.8**
29	EM5	Emergency Response Modification	Flood warning signs	$5,000	$200	$7,760	NC	N/A	N/A	N/A	0	2	0	**0.5**
30	DC1	Data Collection Strategy	Data collection following a flood event	$5,000	$3,000	$46,402	NC	N/A	N/A	N/A	0	2	0	**0.5**

No.	ID	Category of Measure	Description	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
1	FM 1.1 *	Flood Modification	Town Creek Culvert Upgrade	Not viable, refer report										
2	FM 1.2 *	Flood Modification	Town Creek Vegetation Clearing	2	2	2	2	2	**2.0**	2	2	**2.0**	**4.0**	**3**
3	FM 1.3 *	Flood Modification	Railway Culvert Upgrade	0	0	2	1	1	**0.8**	0	0	**0.0**	**-1.2**	**14**
4	FM 1.4 *	Flood Modification	Railway Bridge Upgrade	0	0	2	1	1	**0.8**	0	0	**0.0**	**-1.2**	**14**
6	FM 1.6 *	Flood Modification	North St Diversion Swale	1	2	-1	1	1	**0.8**	0	0	**0.0**	**-0.7**	**13**
6	FM 1.7 *	Flood Modification	Town Creek Diversion	5	2	0	1	1	**1.8**	0	0	**0.0**	**0.3**	**12**
31	FM 1.8	Flood Modification	Broughton Mill Creek Diversion	1	1	0	1	1	**0.8**	-0.5	0	**-0.3**	**-1.5**	**17**
32	FM 1.9	Flood Modification	Broughton Mill Creek Diversion +levee	1	1	0	1	1	**0.8**	-0.5	0	**-0.3**	**-1.5**	**17**
33	FM 1.9	Flood Modification	Broughton Mill Creek Diversion best case damage reduction	2	2	0	1	1	**1.2**	-1	0	**-0.5**	**-1.3**	**16**
7	FM 2.1 *	Flood Modification	Berry RSL / Prince Alfred St Levee - 5% AEP level	Not viable, refer report										
8	FM 2.2 *	Flood Modification	Berry RSL / Prince Alfred St Levee - 1% AEP level	Not viable, refer report										
9	FM 2.3	Flood Modification	Town Creek Flood Walls - 5% AEP level	Not viable, refer report										
10	FM 2.4	Flood Modification	Town Creek Flood Wall - 1% AEP level	Not viable, refer report										
14	FM 3.1 *	Flood Modification	Town Creek upstream detention	1	1	0	1	2	**1.0**	0	-1	**-0.5**	**-1.5**	**19**
15	FM 4.1	Flood Modification	Stock Mounds	0	0	1	2	1	**0.8**	-1	0	**-0.5**	**3.3**	**5**
16	FM 5.1 *	Flood Modification	Princes Highway Berry By-Pass	To be assessed following finalisation of by-pass design										
17	P1	Property Modification	LEP Update	1	1	1	1	2	**1.2**	0	0	**0.0**	**4.2**	**2**
18	P2	Property Modification	Building and Development Controls	2	1	1	1	2	**1.4**	0	0	**0.0**	**4.4**	**1**
19	P3	Property Modification	House Raising	Not viable, refer report										
20	P4	Property Modification	House Rebuilding	Not viable, refer report										
21	P5	Property Modification	Voluntary Purchase	Not viable, refer report										
22	P6	Property Modification	Land Swap	Not viable, refer report										
23	P7	Property Modification	Council Redevelopment	Not viable, refer report										
24	P8	Property Modification	Flood Proofing Guidelines	1	0	1	1	2	**1.0**	0	0	**0.0**	**3.5**	**4**
25	EM1	Emergency Response Modification	Infomation transfer to the SES	2	0	0	1	2	**1.0**	0	0	**0.0**	**2.0**	**9**
26	EM2	Emergency Response Modification	Preparation of Local Flood Plans and update of DISPLAN	2	0	1	1	2	**1.2**	0	0	**0.0**	**1.7**	**11**
27	EM3	Emergency Response Modification	Flood warning system	1	1	1	1	2	**1.2**	0	0	**0.0**	**2.7**	**7**
28	EM4	Emergency Response Modification	Public awareness and education	2	1	1	1	2	**1.4**	0	0	**0.0**	**2.9**	**6**
29	EM5	Emergency Response Modification	Flood warning signs	1	0	0	1	2	**0.8**	0	0	**0.0**	**1.8**	**10**
30	DC1	Data Collection Strategy	Data collection following a flood event	0	0	2	2	2	**1.2**	0	0	**0.0**	**2.2**	**8**

Appendix I

Broughton Mill Creek Diversion Assessment

I Broughton Mill Creek Diversion Assessment

I.1 Introduction

A Floodplain Risk Management Study and Plan is currently being finalised for the Broughton Creek catchment.

The draft plan has been placed on exhibition, and during this period, a submission was made detailing an alternative structural flood mitigation option.

This summary report details the investigation into this option, and incorporates the option into the existing multi-criteria ranking alongside the previously investigated flood management options.

This assessment has been undertaken at the concept level only.

I.1.1 Option Overview

The option proposes to divert flows from Broughton Mill Creek to Broughton Creek in order to alleviate flooding alongside Broughton Mill Creek within the Berry Township. The diversion is proposed to be located immediately downstream of the Bundewallah Creek confluence with Broughton Mill Creek

In order to convey flows from Broughton Mill Creek to Broughton Creek, a culvert is proposed. The culvert would run under the existing Princes Highway, and discharges into the Broughton Creek floodplain, approximately 280m upstream of the railway line.

The aim of the option is to reduce flood levels along Broughton Mill Creek. This will improve flooding behaviour for properties along Prince Alfred Street and the Princes Highway.

It also has the benefit of improving the flooding of the Bowling Club by improving the ability to evacuate this area and hence reduce the risk to life.

I.2 Option details

Provided below are the details of the diversion option.

I.2.1 Location

The location of the concept diversion culvert is shown in **Figure I.1**.

The diversion was located immediately downstream of the confluence of Bundewallah Creek so that the diversion of these flows was also possible. This provides the opportunity to divert a portion of both the Bundewallah and Broughton Mill Creek flows.

A ridge line separates Broughton Mill Creek and Broughton Creek, as shown in **Figure I.1**. The concept culvert crosses this ridge at a point which should minimise the overall earthworks required as much as possible.

The invert levels of the culvert were placed such that:

- The upstream invert was 1m above the creek invert to allow low flows to bypass the diversion. This resulted in the invert being approximately 2m below the western creek bank. This could be optimised through more detailed analysis.
- The downstream invert was placed 0.05m above the existing 5yr flood level on the Broughton Creek floodplain, to prevent frequent backwatering of the pipe.
- The above inverts resulted in a grade of 1.2%.

I.2.2 Culvert Sizing

At a concept level, the culvert was sized to convey the 20% AEP flows. From the existing scenario, the peak flow immediately downstream of the Bundewallah Creek confluence was 360 cumecs.

Based on the pipe grade of 1.2%, the culvert size was sized preliminarily based on a manning's calculation. The culvert size adopted was 16m x 2.4m. It is noted that this is likely to consist of a number of box culvert sections.

I.2.3 Key Challenges with Option

The option presents a number of challenges with its construction that will need to be addressed if the option is to be implemented.

I.2.3.1 Culvert Size and Excavation

The concept culvert is a significant size. This has impacts on the construction cost to supply and install the culvert, and also on the excavation volume required in order to lay the culvert.

Shown in **Figure I.2** is a longsection along the concept culvert length, showing the ground elevations along the culvert reach. The figure shows that excavation depths of up to 6m are required. This depth, coupled with the resulting batters and benches to excavate to this depth, result in a significant excavation volume and footprint.

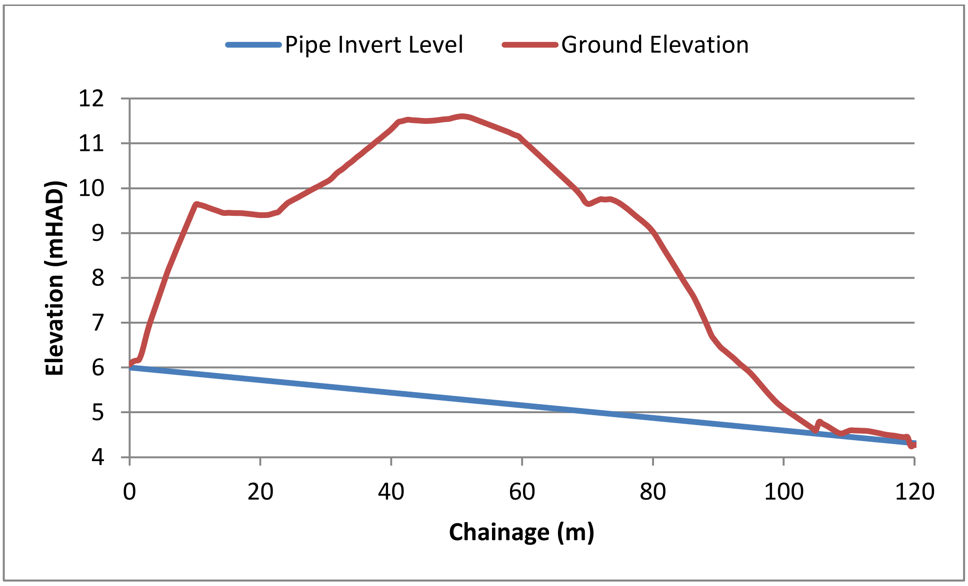

Figure I.2: Concept Culvert Longsection

I.2.3.2 Property Impacts

The concept culvert (and concept levee) involve construction on private property. Whilst is may be possible to negotiate temporary access and post construction rehabilitation for some portions, other aspects will require permanent structures, notably the culvert headwalls and the levee bank. This may necessitate the acquisition of the private property on which these elements are located.

I.2.3.3 Environmental Impacts

The option involves the transfer of significant volumes of water from Broughton Mill Creek to Broughton Creek. This has the potential to impact on the flora and fauna within both these creeks. It is important that an appropriate flow regime be maintained in both Broughton Mill Creek and Broughton Creek to support the existing ecosystems.

I.3 Modelling Results

As per the assessment procedure for the other modelled options, the diversion scenario was modelled for the 10% AEP and 1% AEP events to determine its effect on flood behaviour. The 10% AEP and 1% AEP peak flood level differences are shown in **Figure I.3** and **Figure I.4** respectively.

The peak flow through the culvert was 145 cumecs, 40% of the calculated capacity. This flow volume is likely due to inefficient entry into the culvert due to it being at an angle to the direction of flow.

The results show that the diversion culvert reduced levels downstream within Broughton Mill Creek by up to 0.25m in the 10% AEP event, and up to 0.2m in the 1% AEP event. In both events, the reductions extended both upstream and downstream on Broughton Mill Creek.

However, it resulted in increases within Broughton Creek of 0.13m and 0.17m in the 10% and the 1% AEP events respectively. These increases did not impact any buildings; the affected land being generally open pastures or parklands. The level increases at the Broughton Creek rail bridges was 0.08m in the 10% AEP event, and 0.09m in the 1% AEP event.

It may be possible to mitigate this impact by increasing the capacity of the railway bridges on Broughton Creek. However, this is likely to very expensive, and may only succeed in moving the impact further downstream.

I.3.1 Design Alternative

To attempt to pass more flow through the culvert, and to potentially provide further reductions, modifications were made to the option. These modifications were:

- Lowering the upstream invert by 0.5m. This allows the culvert to be engaged sooner during a flood event; and
- The provision of a levee bank, with a crest at the 20% AEP level, between Woodhill Mountain Road and Broughton Mill Creek to direct water into the culvert. The location of the levee is shown in **Figure I.5**.

The results of the design alternative are shown for the 10% AEP event and the 1% AEP event in **Figure I.6** and **Figure I.7** respectively.

Flow through the culvert was marginally increased to 160 cumecs. In the 1% AEP event, this translated to an additional 0.02m reduction within Broughton Mill Creek, and a corresponding 0.02m increase within Broughton Creek.

In the 10% AEP, the floodwaters were more affected by the levee, resulting in additional reductions downstream of up to 0.1m compared to the original design. However, water levels increased compared to the existing case upstream of the levee by 0.05m, although this increase did not impact any residential properties. Levels in Broughton Creek increased by an additional 0.1m as a result of the levee and lower culvert invert. Again, these increases did not impact buildings.

I.4 Economic Assessment of Options

I.4.1 Preliminary Costing

Cost estimates were prepared for both option scenarios, and are shown in **Table I.1**.

Table I.1: Costs of Quantitatively Assessed Options

Option ID	Option	Capital Cost	Ongoing Costs
FM 1.8	Broughton Mill Creek Diversion	$10,318,100	$10,000
FM 1.9	Broughton Mill Creek Diversion with Levee	$12,097,000	$10,000

I.4.2 Average Annual Damage

A damage assessment was undertaken on both the option scenarios. Flood levels in other AEP events were determined on the follow assumptions:

- The water level differences observed in the 10% AEP event were assumed to be the same in 20% and 50% AEP events;
- The water level difference observed in the 1% AEP event were assumed to be the same in the 2% AEP event; and
- The option did not result in changes to the PMF flood level.

Property flood levels in each AEP event were then determined, and a damage calculation undertaken according to the methodology in the Floodplain Risk Management Study (Cardno, 2012).

The average annual damage (AAD) for each of the options is shown comparatively against the existing case ($139,504) in **Table I.2**.

Table I.2: Average Annual Damage for Options

Option ID	Option	AAD	Reduction in AAD due to Option
FM 1.8	Broughton Mill Creek Diversion	$107,508	$31,996
FM 1.9	Broughton Mill Creek Diversion with Levee	$106,341	$33,163

I.4.3 Best Case Damage Reduction

There are a number of alternatives that could be considered for the capacity of the diversion.

To assess the best possible damage reduction that alternatives could provide, an additional damage assessment was undertaken with the assumption that all properties within the extent of the options influence experienced no damages in events up to the 1% AEP event. This assumes that the diversion removes sufficient water from Broughton Mill Creek to lower flood levels downstream to such an extent that adjacent properties no longer experience either over floor or over ground flooding.

The AAD for the best case damage reduction is shown in **Table I.3**.

Table I.3: Average Annual Damage for Best Case Reduction

Option ID	Option	AAD	Reduction in AAD due to Option
FM 1.10	Broughton Mill Creek Diversion	$52,144	$87,360

The assessment shows that if an option could provide complete flood protection for properties within its area of influence, then significantly greater AAD reductions could be achieved.

From the existing scenario, the peak flow in Broughton Mill Creek at the culvert location in the 1% AEP event 960 cumecs. In order to achieve the best case damage reduction, this flow volume needs to be reduced to the 20% AEP volume. Based on the flow through the option culvert, this would require an increase in culvert size of 400%, to a size of approximately 32m x 4.8m.

I.4.4 Benefit Cost Ratio

The economic evaluation of each modelled option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of implementing the option.

The B/C ratio provides an insight into how the damage savings from an option, relate to its cost of construction and maintenance:

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

Table I.4 summarises the overall economics for each option.

Note that the capital cost of the best case damage scenario has been increased by 400% compared to the diversion option. This is to allow for the additional works required to divert a much larger flow of water (refer **Section 4.3**).

Table I.4: Summary of Economic Assessment of Options

ID	Option	AAD	Reduction in AAD due to Option	NPW of Benefit *	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Costs *	B/C Ratio
1.8	Broughton Mill Creek Diversion	$107,508	$31,996	$441,569	$10,318,100	$10,000	$10,456,107	0.04
1.9	Broughton Mill Creek Diversion with Levee	$106,341	$33,163	$457,674	$12,097,000	$10,000	$12,235,007	0.04
1.10	Best Case Damage Reduction	$52,144	$87,360	$1,205,633	$41,272,400	$20,000	$41,548,415	0.03

***** NPW – Net Present Worth is calculated using 7% discount rate over 50yrs.

The benefit-cost ratio for the scenarios shows that whilst the options result in flood damage reductions, their cost of implementation is significantly higher than the savings obtained.

I.4.4.1 Shared Costs with RMS

It was suggested as part of the option submission that cost savings could be realised by undertaking the construction during the Berry by-pass construction, as it may then be possible to utilise RMS machinery to undertake the bulk earthworks.

The feasibility of such an option will require consultation with RMS. However, on the assumption that it would be possible, the benefit-cost analysis has been updated to reflect this scenario.

It has been assumed that RMS will undertake the clearing and grubbing of the site, and the excavation and the backfilling of the culvert trench at no charge. Council will still be required to pay for site establishment, culvert installation and remediation works. This reduces the capital cost of the options by $2,833,844.

Table I.5 shows the benefit-cost analysis incorporating this reduction.

Table I.5: Summary of Economic Assessment of Options, incorporating RMS savings

ID	Option	AAD	Reduction in AAD due to Option	NPW of Benefit *	Capital Cost Estimate	Recurrent Cost Estimate	NPW of Option *	B/C Ratio
1.8	Broughton Mill Creek Diversion	$107,508	$31,996	$441,569	$7,484,256	$10,000	$7,622,263	0.06
1.9	Broughton Mill Creek Diversion with Levee	$106,341	$33,163	$457,674	$9,263,156	$10,000	$9,401,163	0.05
1.10	Best Case Damage Reduction	$52,144	$87,360	$1,205,633	$29,937,024	$20,000	$30,213,039	0.04

***** NPW – Net Present Worth is calculated using 7% discount rate over 50yrs.

The cost for the best case damage option was kept at four times the diversion option

It was found that this savings reduction has little influence on the final benefit-cost ratio.

I.5 Multi-Criteria Assessment

Following the assessment procedure undertaken in the Floodplain Risk Management Study (Cardno, 2012), both option scenarios were assessed using the multi-criteria matrix to provide a ranking of the options compared to the other flood management options assessed. The multi-criteria matrix assesses options based on economic, environmental and social factors. The matrix is detailed in the Floodplain Risk Management Study (Cardno, 2012).

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

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

The multi-criteria matrix scores of the scenarios discussed above are shown in **Table I.6**. Note that the RMS savings scenario is not included as the cost savings did not alter the economic rating, and it performs identically to the base option on environmental and social factors.

Table I.6: Multi-criteria Assessment Scores

Option	Matrix Score
Broughton Mill Creek Diversion	-1.5
Broughton Mill Creek Diversion with Levee	-1.5
Best Case Damage Reduction	-1.3

The best case damage option has additional environmental and social issues associated with its implementation. However, it also provides improvements to risk to life and social disruption, resulting in its slightly higher matrix score.

The ranking of the options, compared with other flood management options assessed in the Floodplain Risk Management Study, is shown in **Table I.7**.

The table shows that the option ranks towards the bottom of the options assessed. Given the ranking, the significant capital investment required, and it's negative matrix score, the option would not be recommended for inclusion in the Floodplain Risk Management Plan.

Table I.7: Multi-criteria Assessment Ranking

Option	Matrix Score	Ranking
Building and Development Controls	4.4	1
LEP Update	4.2	2
Town Creek Vegetation Clearing	4.0	3
Flood Proofing Guidelines	3.5	4
Stock Mounds	3.3	5
Public awareness and education	2.9	6
Flood warning system	2.7	7
Data collection following a flood event	2.2	8
Information transfer to the SES	2.0	9
Flood warning signs	1.8	10
Preparation of Local Flood Plans and update of DISPLAN	1.7	11
Town Creek Diversion	0.3	12
North St Diversion Swale	-0.7	13
Railway Culvert Upgrade	-1.2	14
Railway Bridge Upgrade	-1.2	14
Broughton Mill Creek Diversion best case damage reduction	-0.8	16
Broughton Mill Creek Diversion	-0.8	17
Broughton Mill Creek Diversion +levee	-0.8	17
Town Creek upstream detention	-1.5	19

The Broughton Mill Creek diversion falls into a similar category to the railway culvert upgrades. That is, able to offer flood level reductions, but at a significant cost. Similar to the railway option, should an opportunity arise to share costs with another agency (the RMS in this instance) the rankings may change if large cost savings for Council are able to be achieved. However, the initial assessment into possible cost savings suggests that even then, the option is not cost effective.

I.6 Conclusion

The diversion of Broughton Mill Creek into Broughton Creek was assessed using the methodology outline in the Floodplain Risk Management Study (Cardno, 2012).

The assessment found that the option was able to improve flood levels for properties affected by flooding from Broughton Mill Creek. However, the significant cost associated with the option resulted in a poor benefit-cost ratio. Similarly, the multi-criteria assessment ranked the option poorly.

To further explore the possibilities of the option, alternative scenarios were assessed including:

- A flood levee to direct flows to the culvert;
- An assumption that the option could remove flooding on all properties within its area of influence; and,
- An assumption that RMS could contribute to the construction of the option, resulting in cost savings for Council.

It was found that none of these alternatives were able to improve the benefit-cost ratio of the option.

Based on the results of the multi-criteria assessment, the option has not been recommended for inclusion in the Floodplain Risk Management Plan.

Appendix Figures

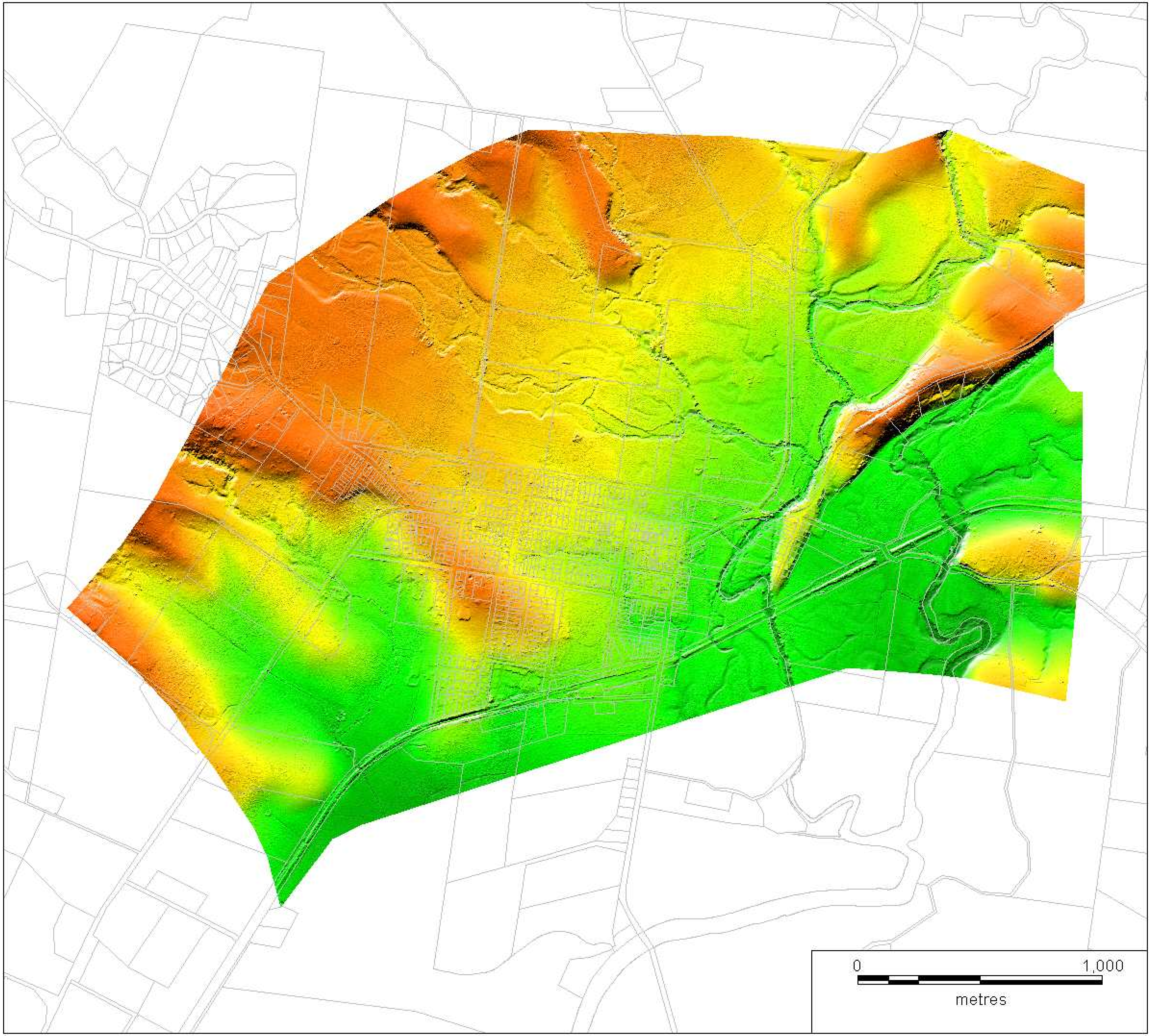

FIGURE B.1

MODEL TOPOGRAPHY

Berry FRMSP

Cadastre

LEGEND - ELEVATION (m)

- 0.0m
- 1.5m
- 3.0m
- 4.5m
- 6.0m
- 10.0m
- 20.0m
- 30.0m
- 50.0m
- 100.0m

Cardno

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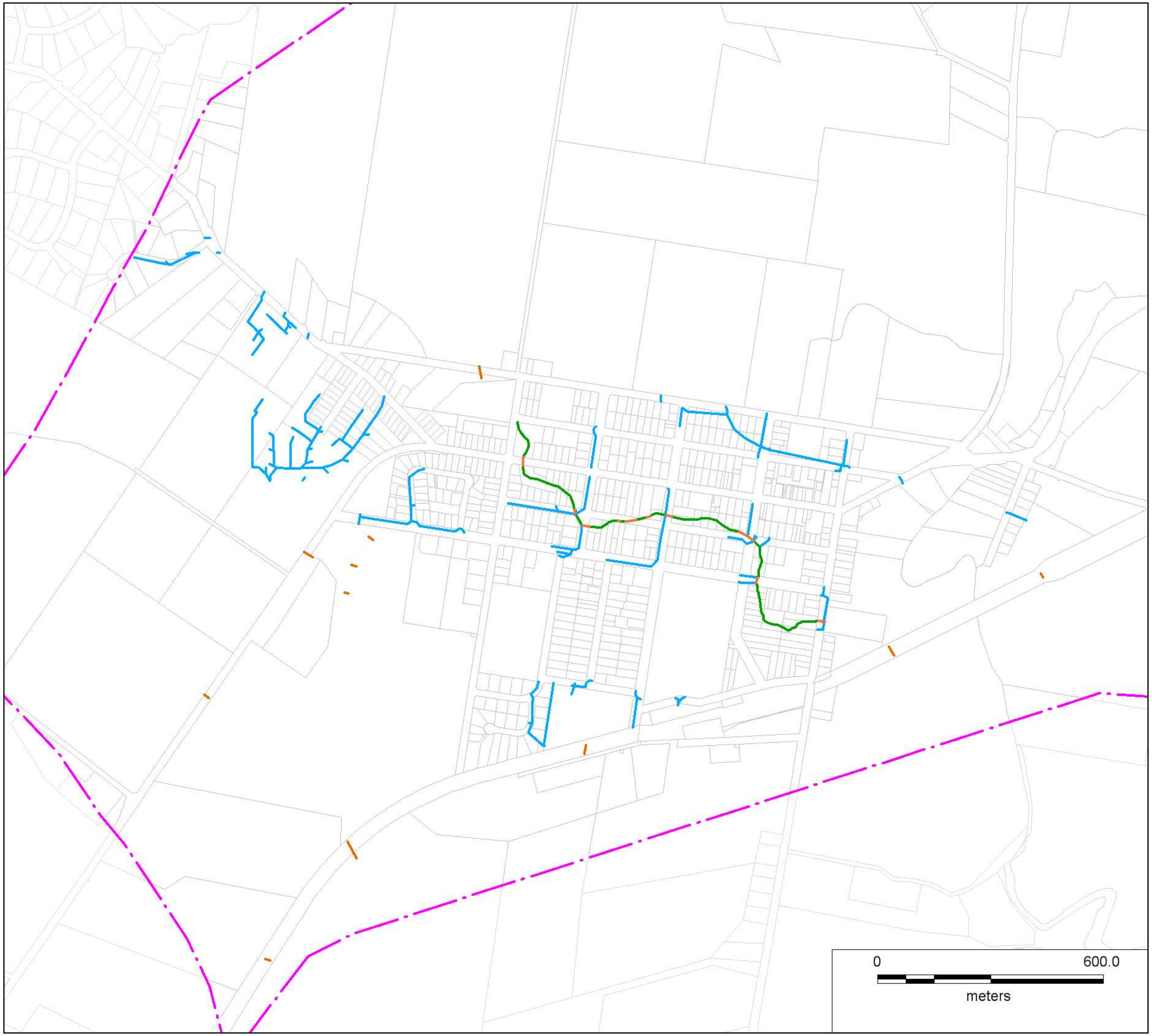

FIGURE B.2

1D LAYOUT

Berry FRMSP

Cadastre
Open Channel
Culvert
Pipe
Model Boundary

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 13 February 2012
Coordinate System: Zone 56/1 ISG

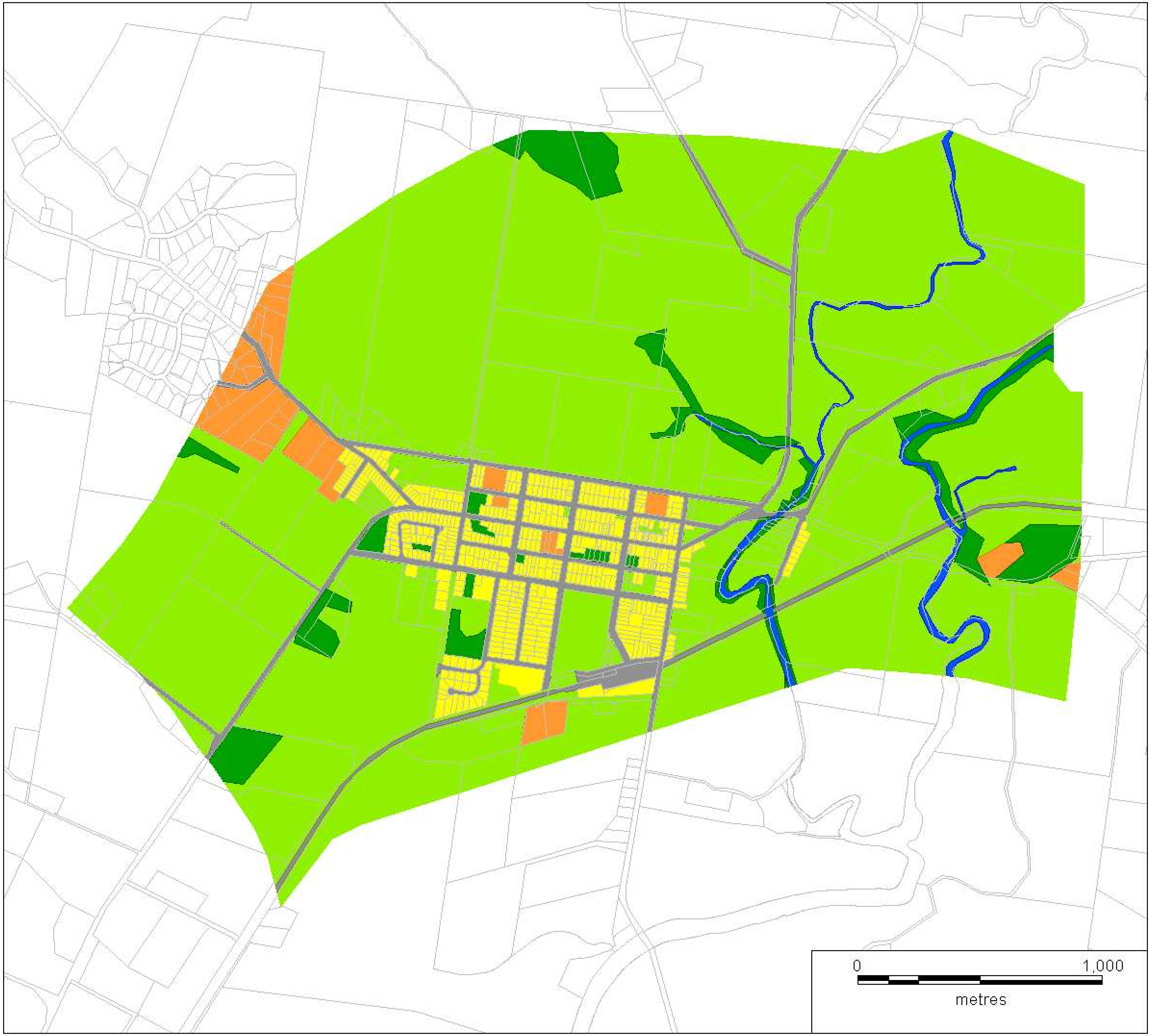

FIGURE B.3

ROUGHNESS ZONES

Berry FRMSP

Cadastre

Roughness Zones

- Road
- Low Residential
- Medium Residential / Commercial
- Low Density Vegetation
- High Density Vegetation
- Waterways

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 22 August 2011
Coordinate System: Zone 56/1 ISG
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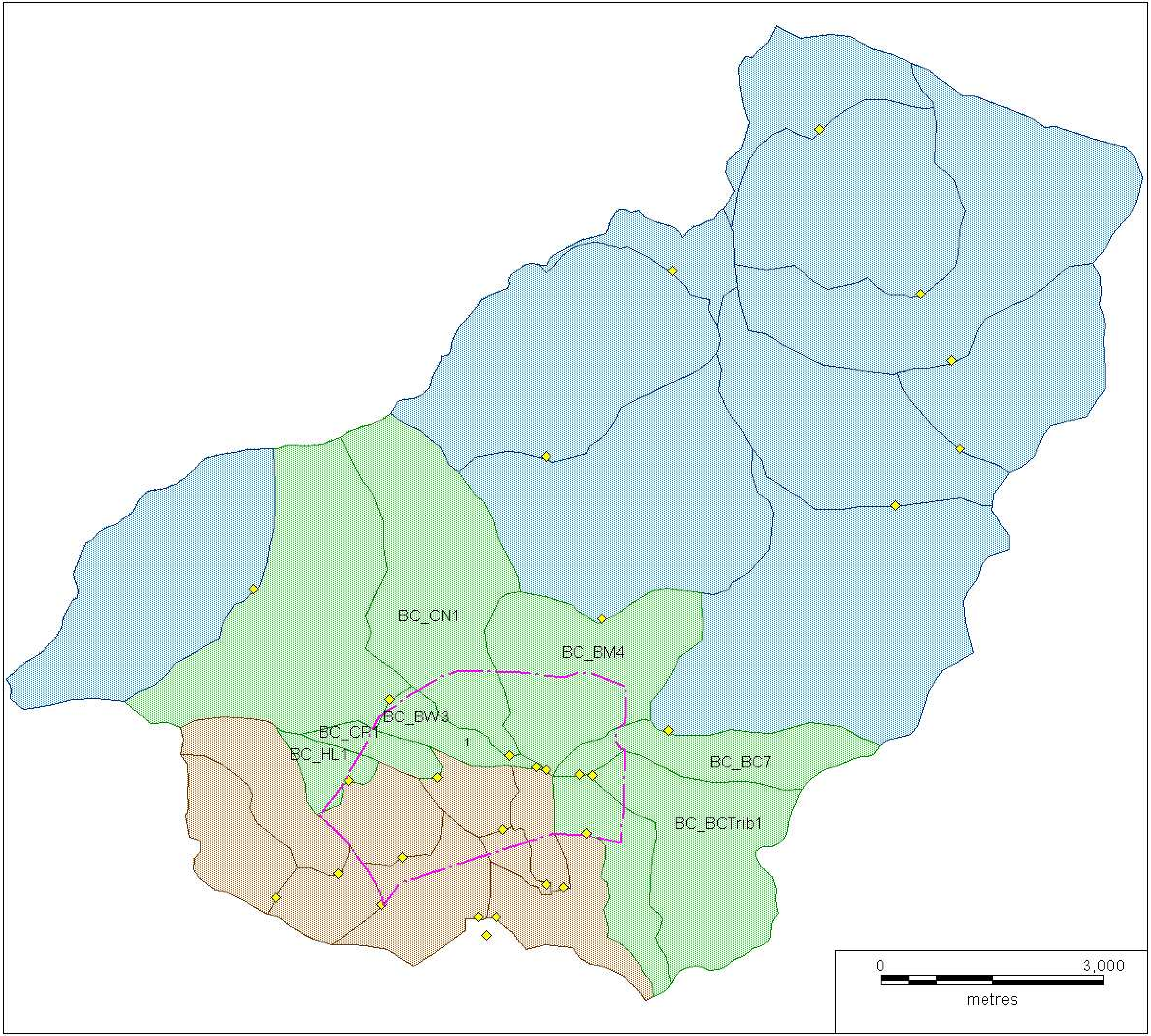

FIGURE B.4

CHANGES TO RAFTS MODEL

Berry FRMSP

Model Boundary

Downstream Boundary

RAFTS Node

RAFTS Link

RAFTS Catchment - No Change

RAFTS Catchment - 2D Area removed from catchment

RAFTS Catchment - Not used, catchments downstream / within study area

Cardno

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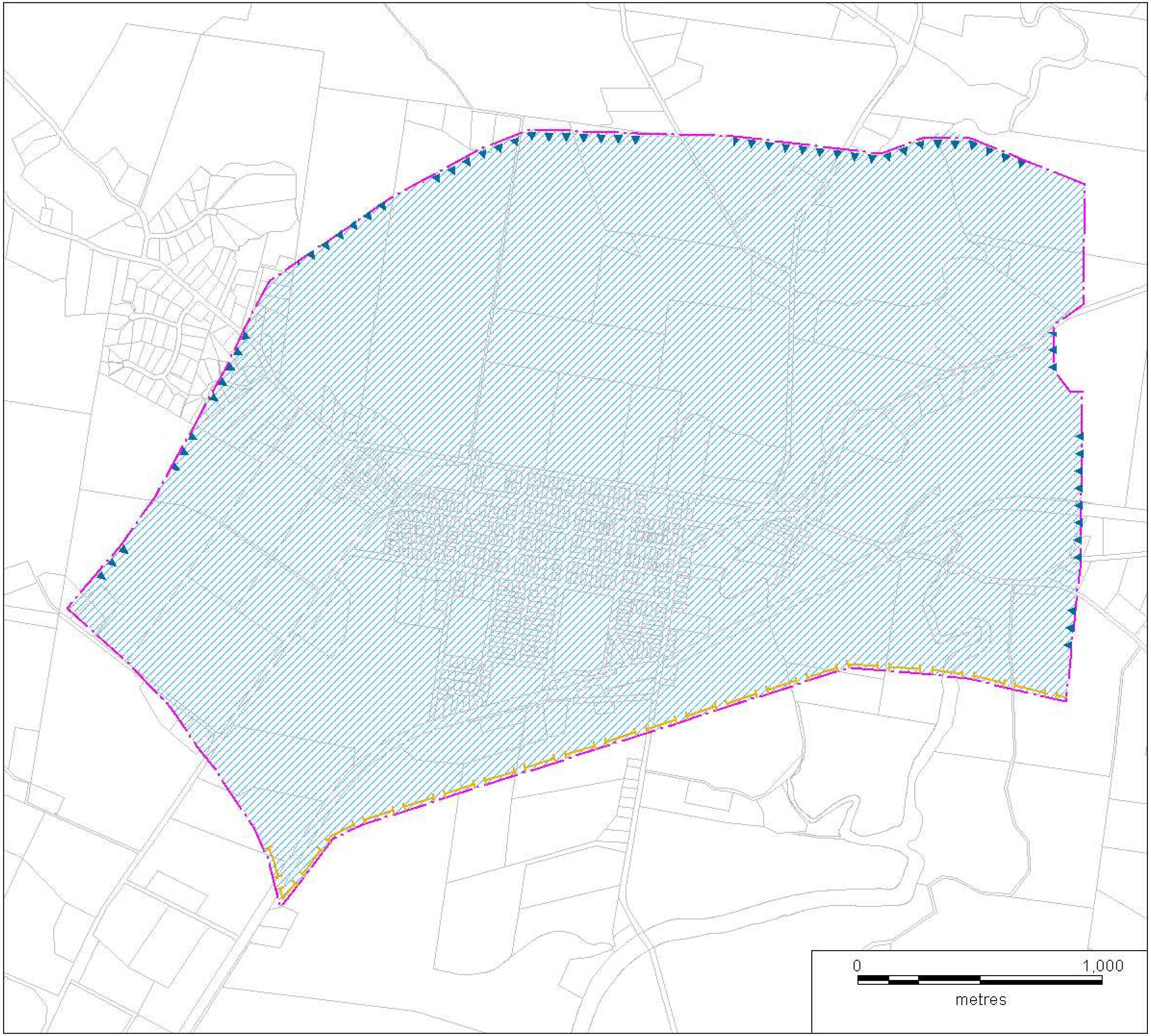

FIGURE B.5

HYDROLOGY SCHEMATISATION

Berry FRMSP

Cadastre
Model Boundary
RAFTS Inflows
Rainfall on Grid
Downstream Boundary

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GIS MAP REF:
W4858_01_Figure_B-5_Hydrology.mxd 02

FIGURE C.1

2002 CALIBRATION LOCATIONS

Berry FRMSP

Cadastre

Calibration Location

Town Creek

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_C-1_2002_Calibration.mxd 02

FIGURE C.2

2005 CALIBRATION LOCATIONS

Berry FRMSP

Cadastre

Calibration Location

Cardno

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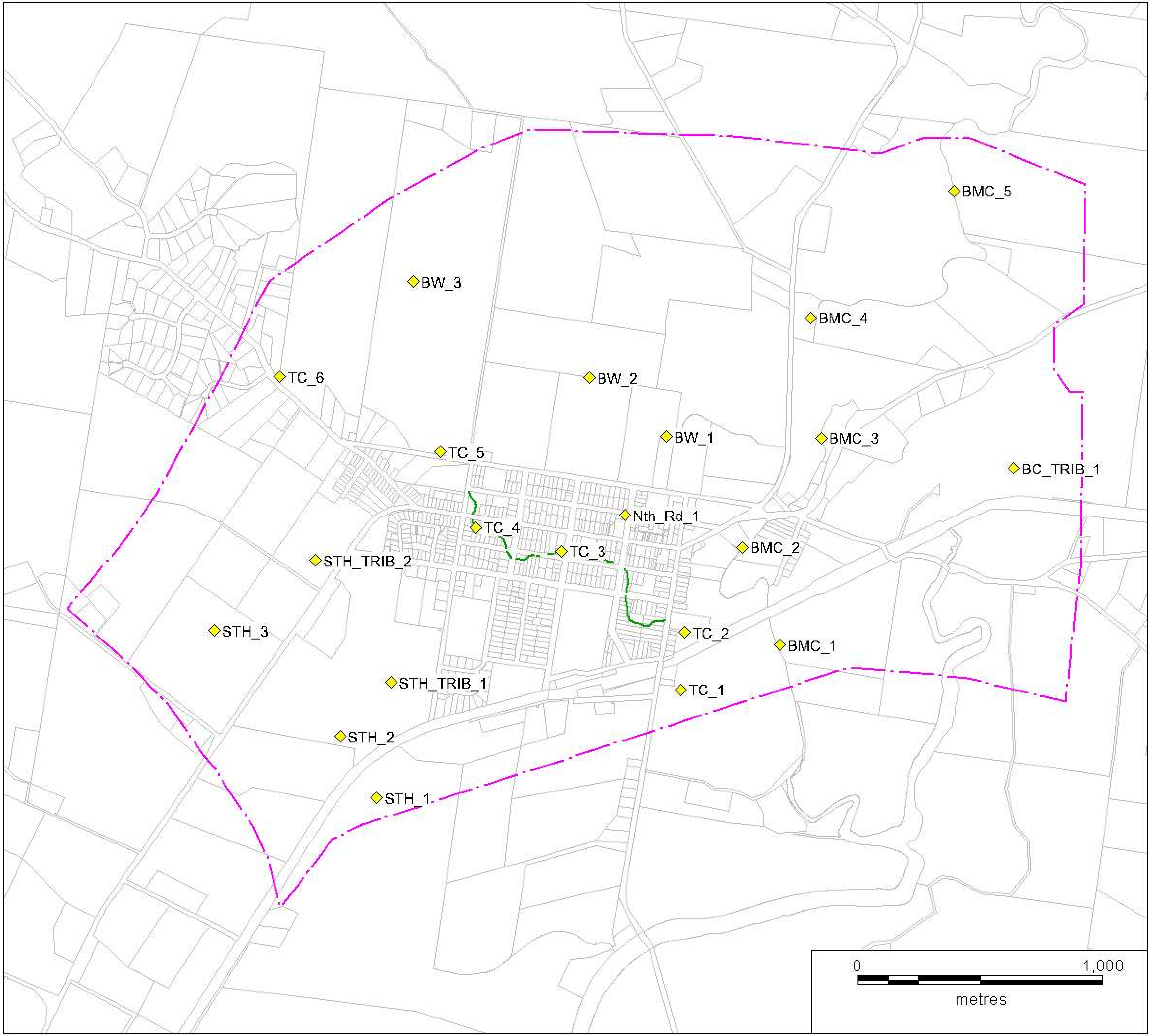

FIGURE C.3

1% AEP CALIBRATION LOCATIONS

Berry FRMSP

Model Extent

Calibration Location

Town Creek

Cadastre

Cardno

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GIS MAP REF:
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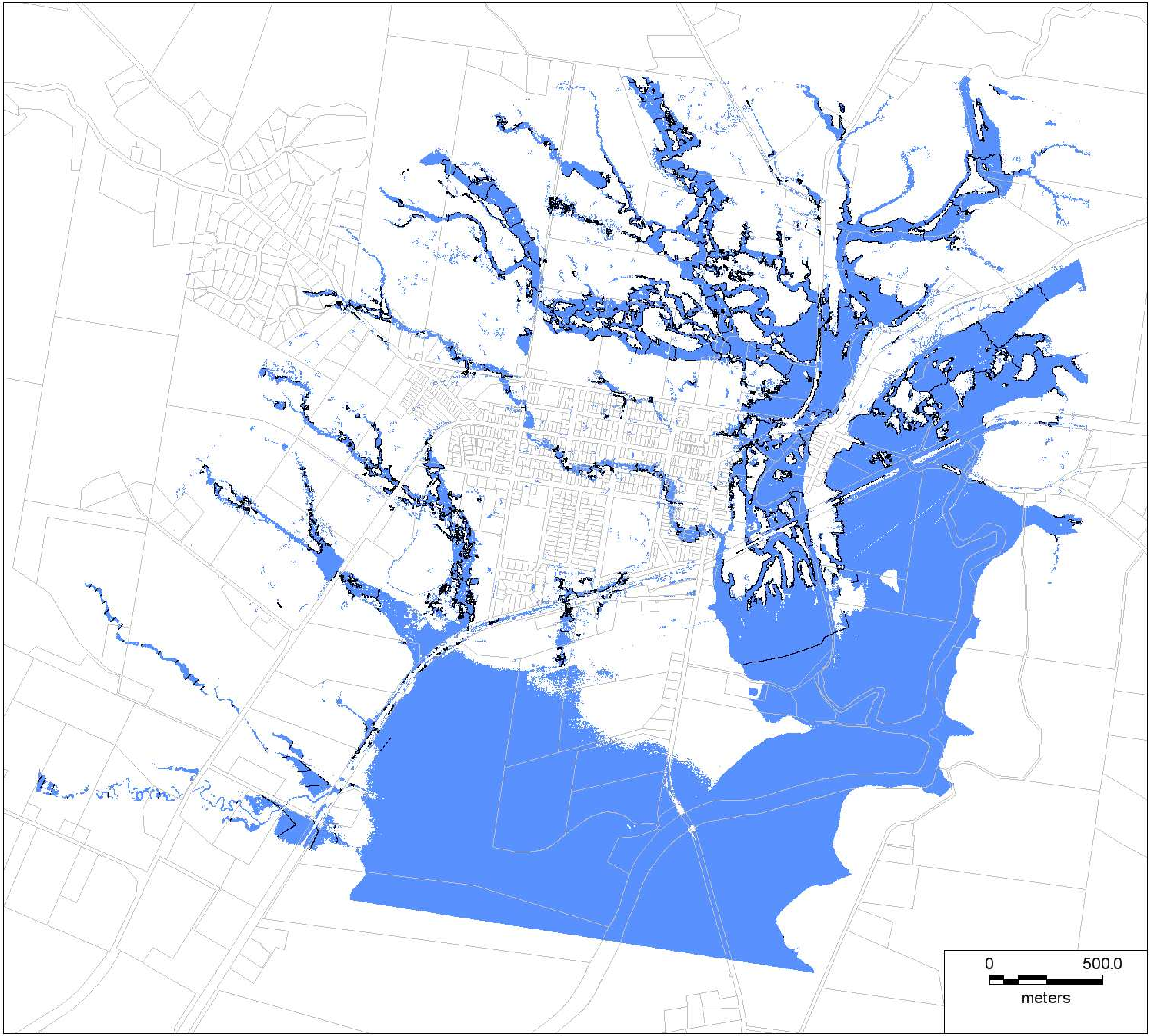

FIGURE D.1

50% AEP FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Flood Level Contours 1m Increments

Flood Extent

Cardno

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Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE D.2

20% AEP FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Flood Level Contours 1m Increments

Flood Extent

Cardno

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GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE D.3

10% AEP FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Flood Level Contours 1m Increments

Flood Extent

Cardno

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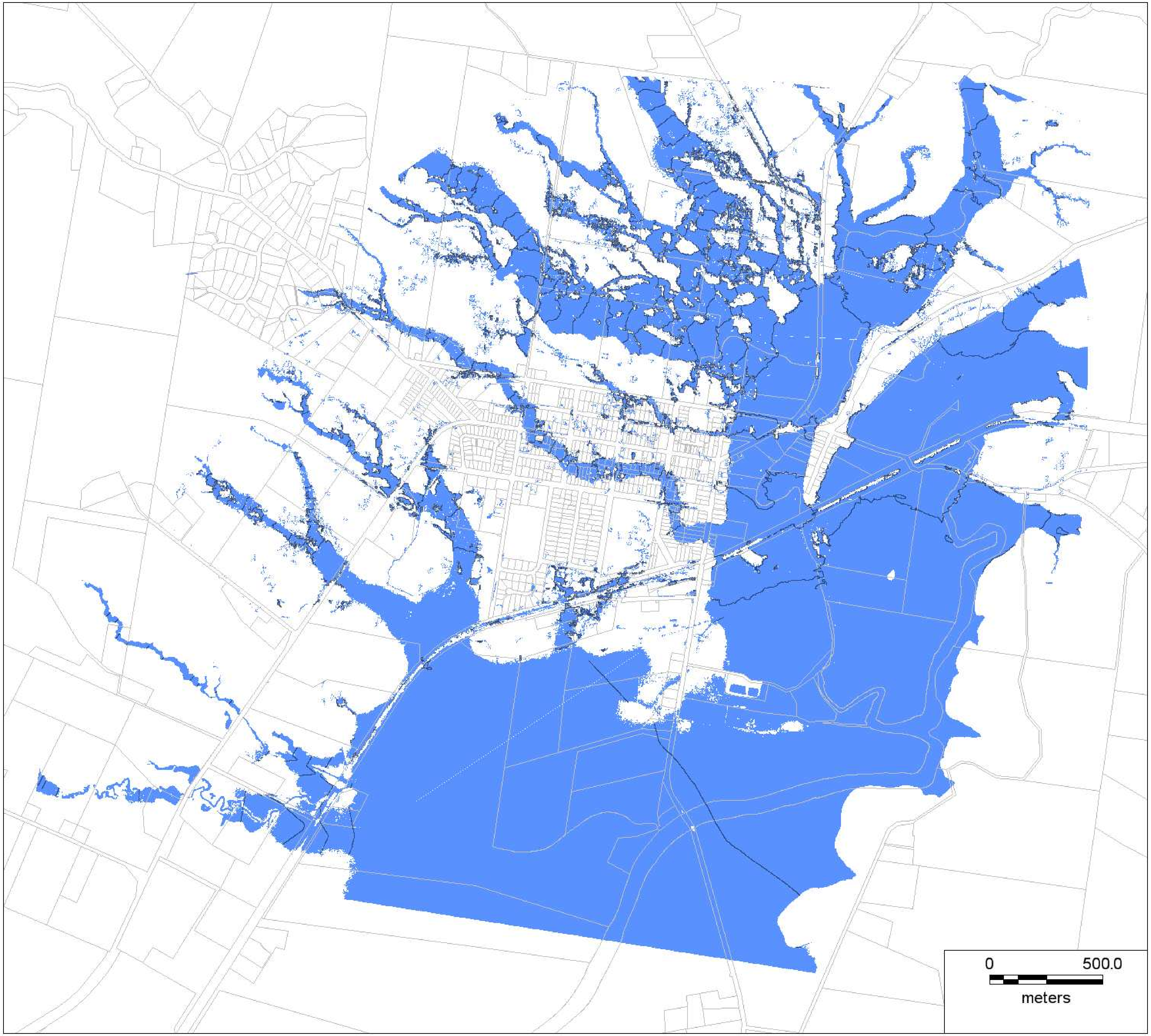

FIGURE D.4

5% AEP FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Flood Level Contours 1m Increments

Flood Extent

Cardno

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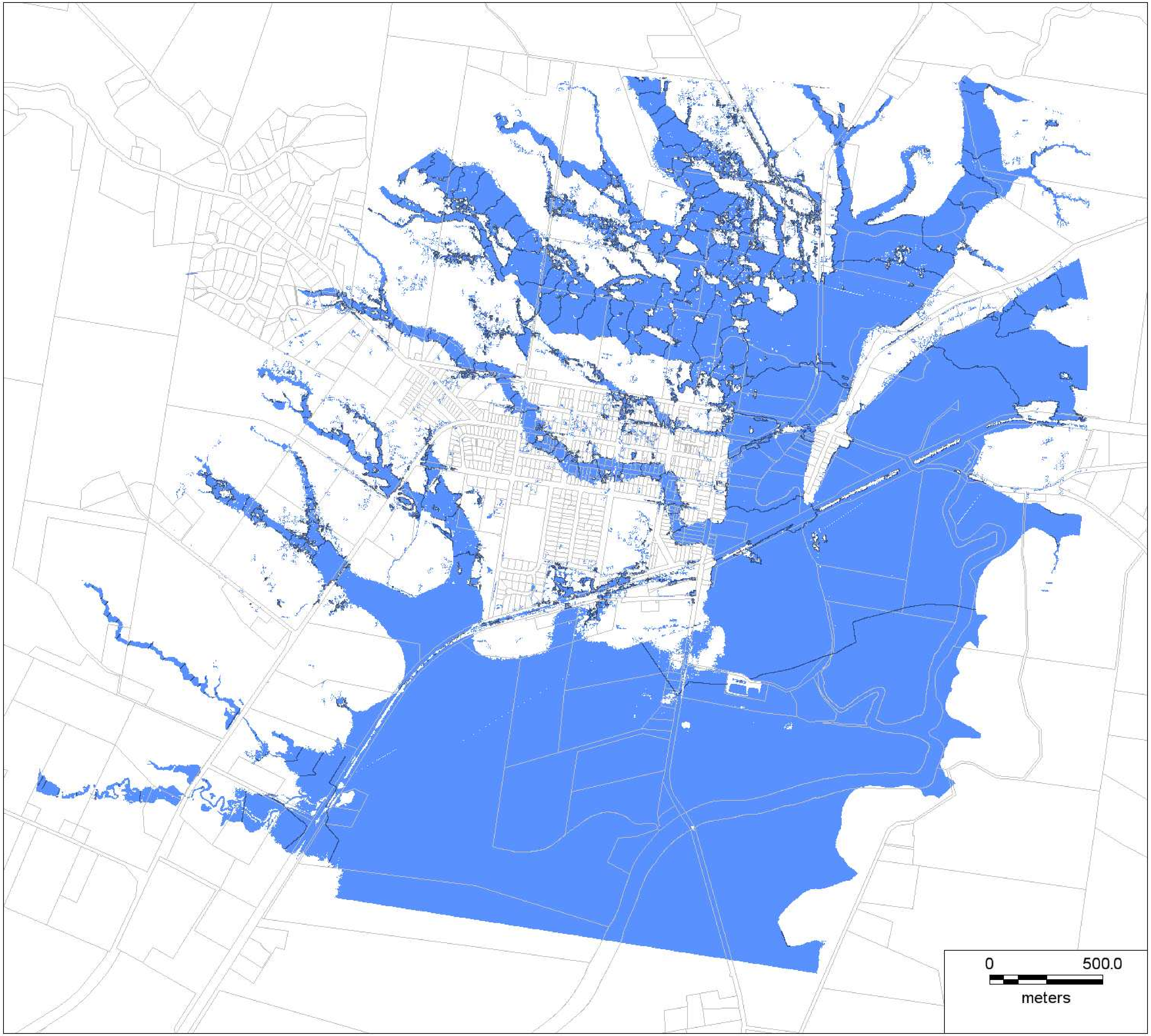

FIGURE D.5

2% AEP FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Flood Level Contours 1m Increments

Flood Extent

Cardno

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Coordinate System: Zone 56/1 ISG
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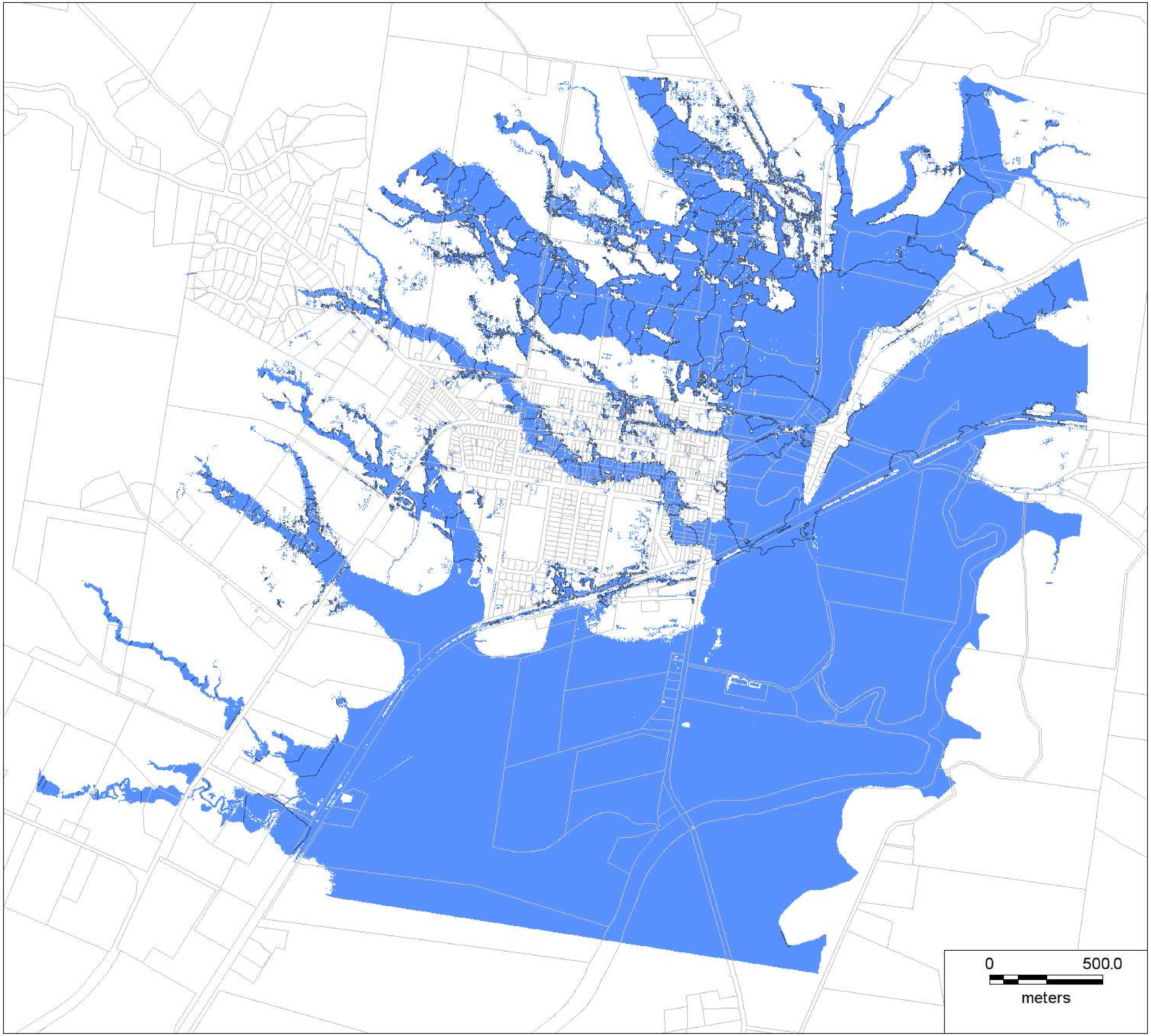

FIGURE D.6

1% AEP FLOOD EXTENT

Berry FRMSP

Cadastre
Peak Flood Level Contour 1m Increment
Flood Extent

Cardno

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Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE D.7

PMF
FLOOD EXTENT

Berry FRMSP

Cadastre

Peak Water Level Contours 1m Increments

Flood Extent

Cardno

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Coordinate System: Zone 56/1 ISG
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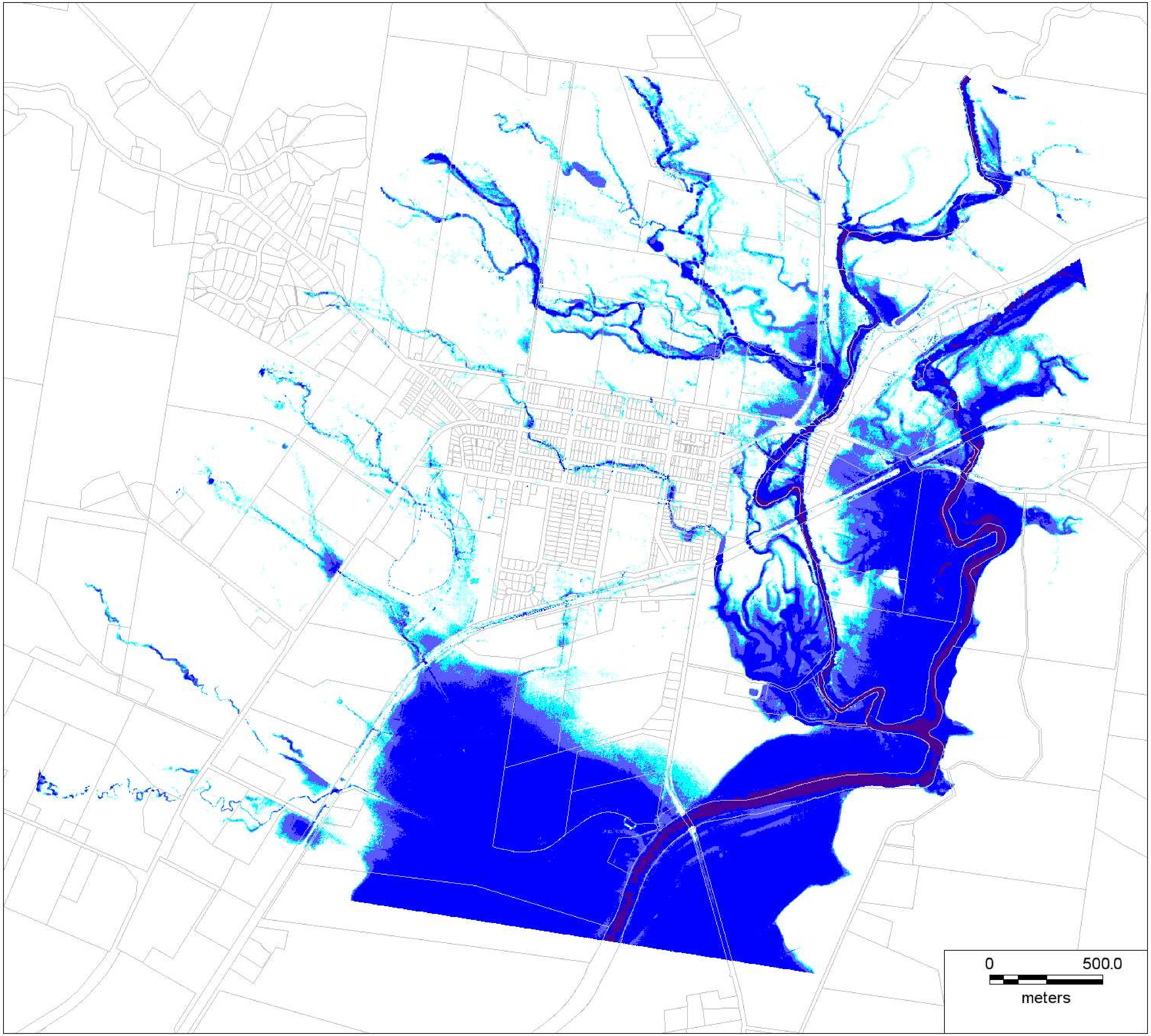

FIGURE D.8

50% AEP PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
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Coordinate System: Zone 56/1 ISG
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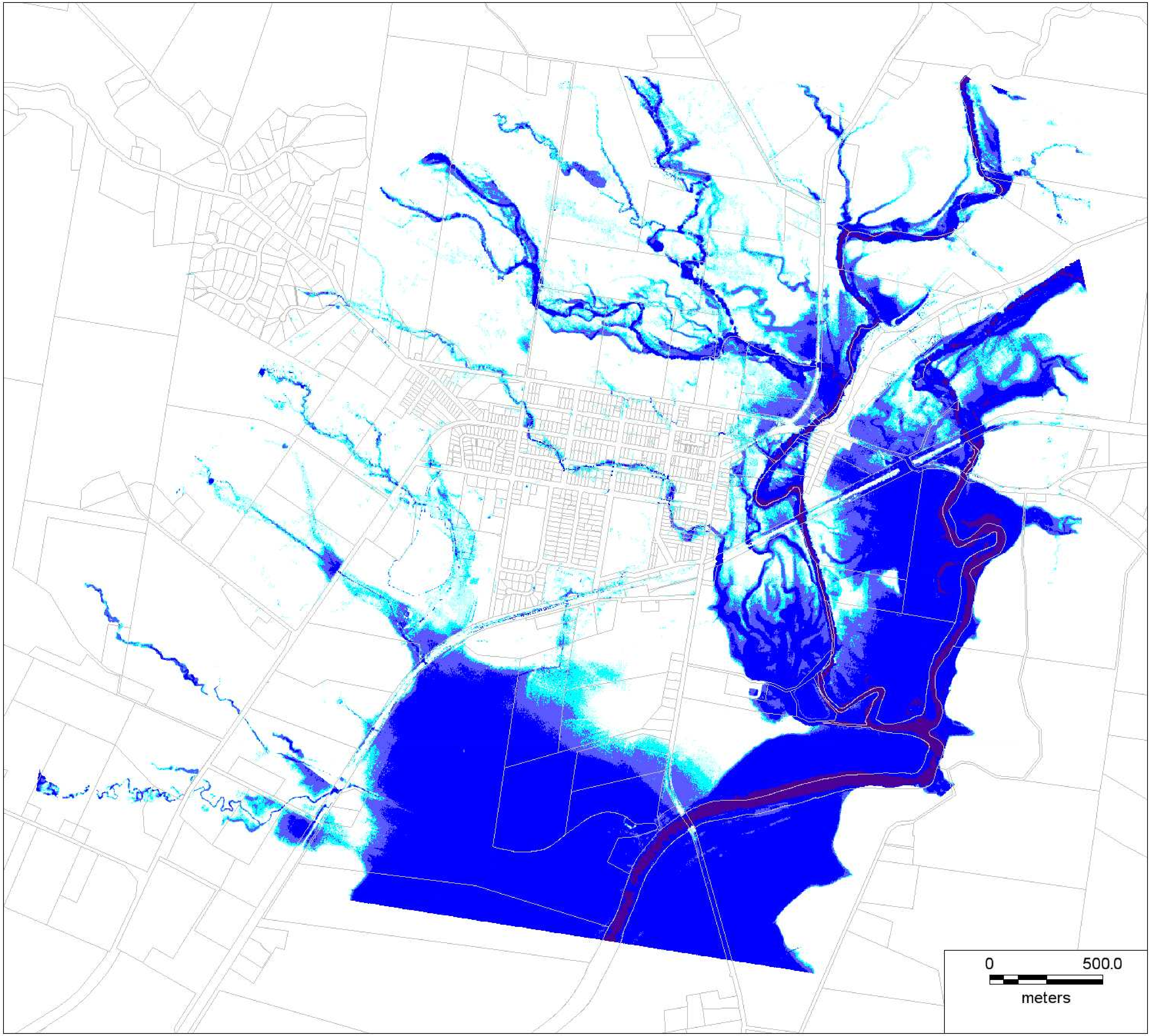


FIGURE D.9

20% AEP
PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

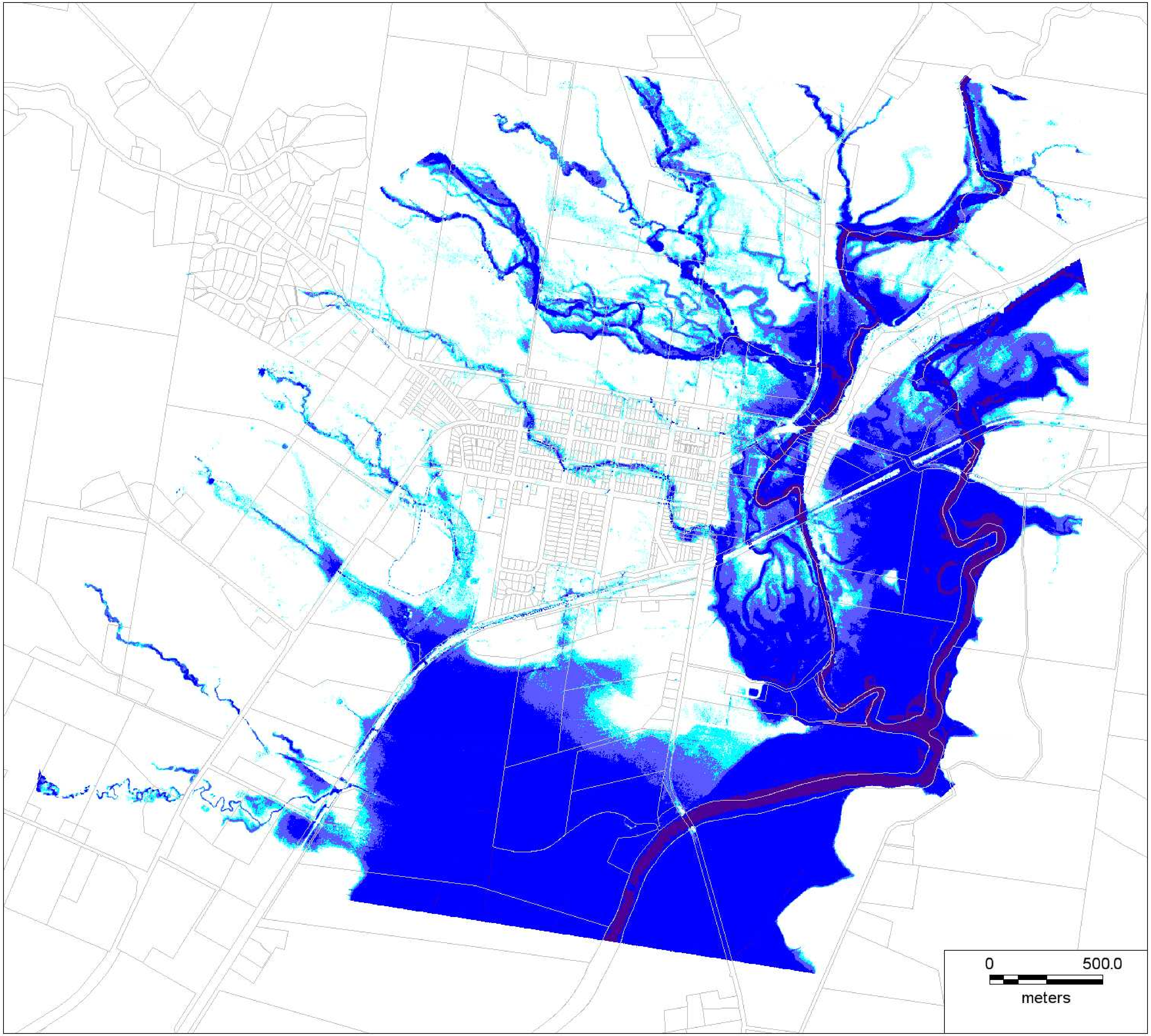


FIGURE D.10

10% AEP PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

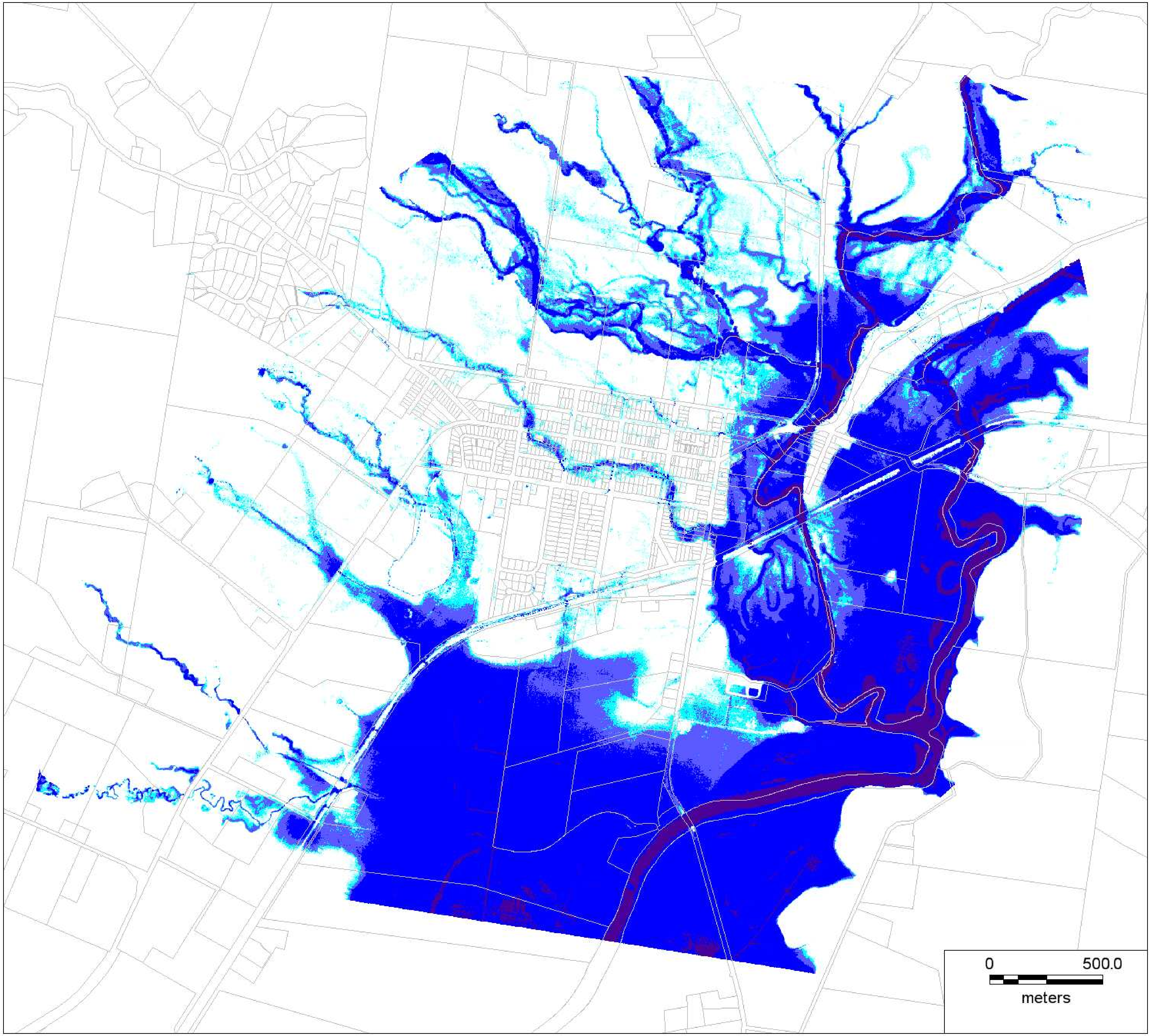


FIGURE D.11

5% AEP PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

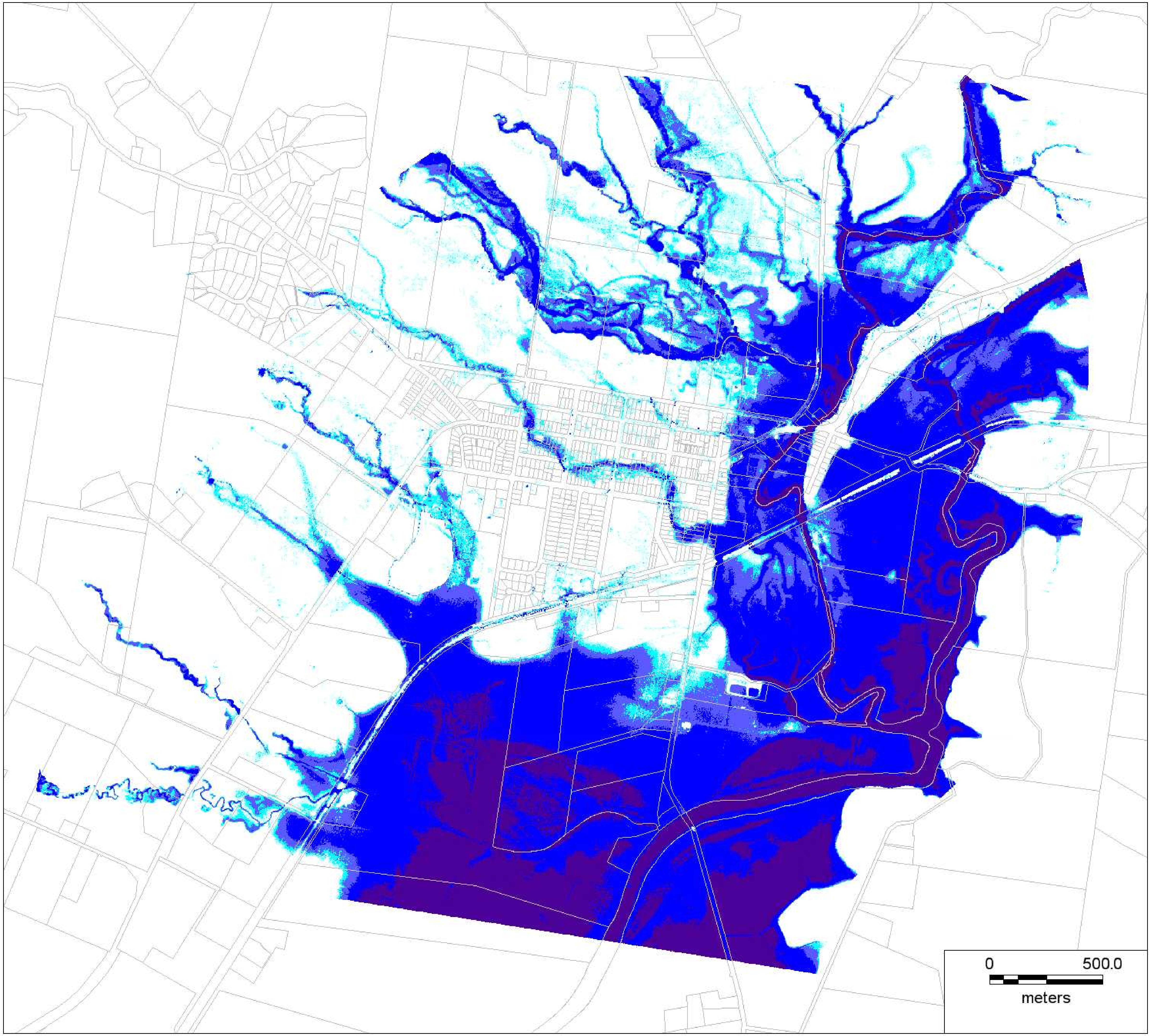


FIGURE D.12

2% AEP PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

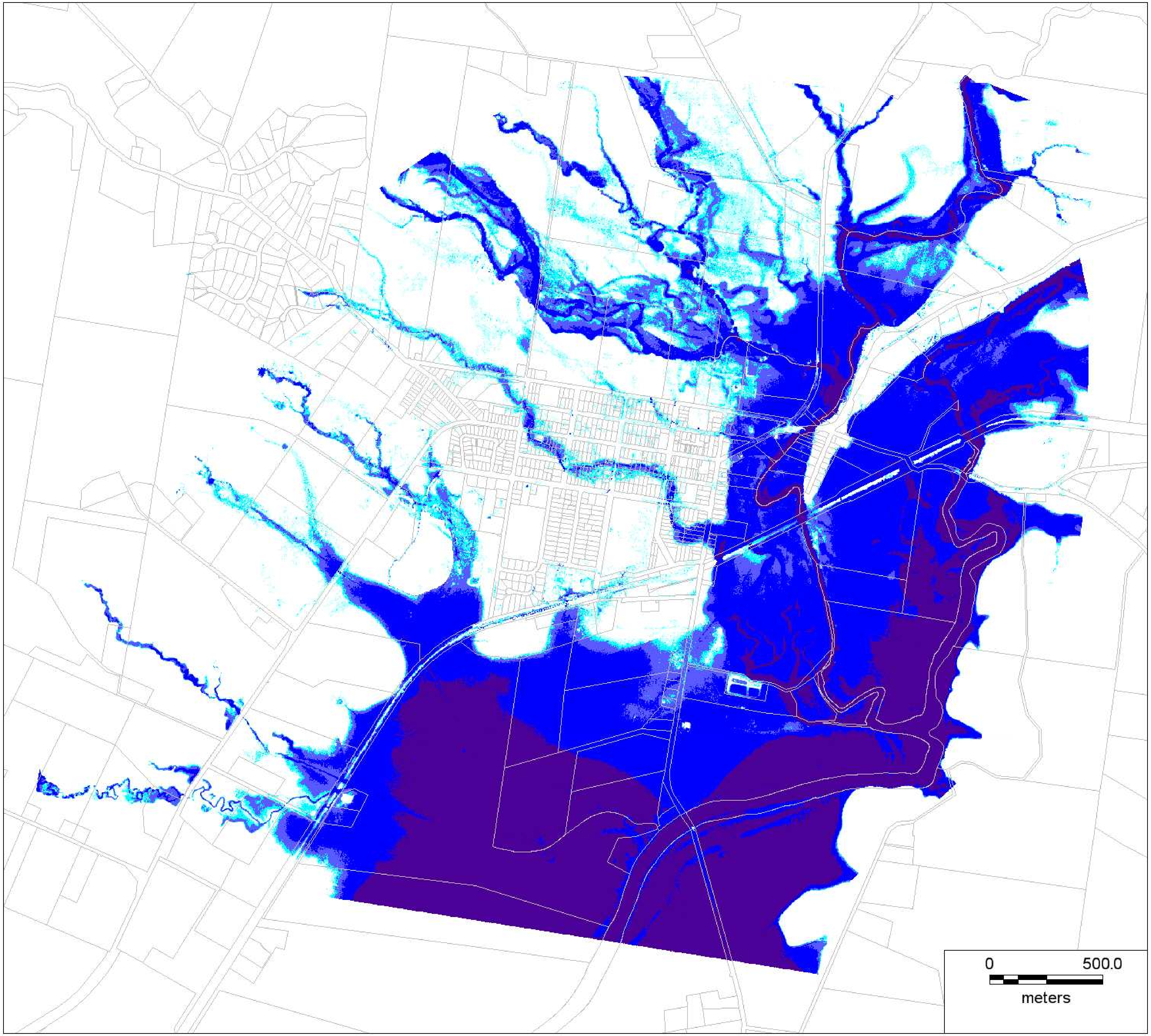


FIGURE D.13

1% AEP
PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

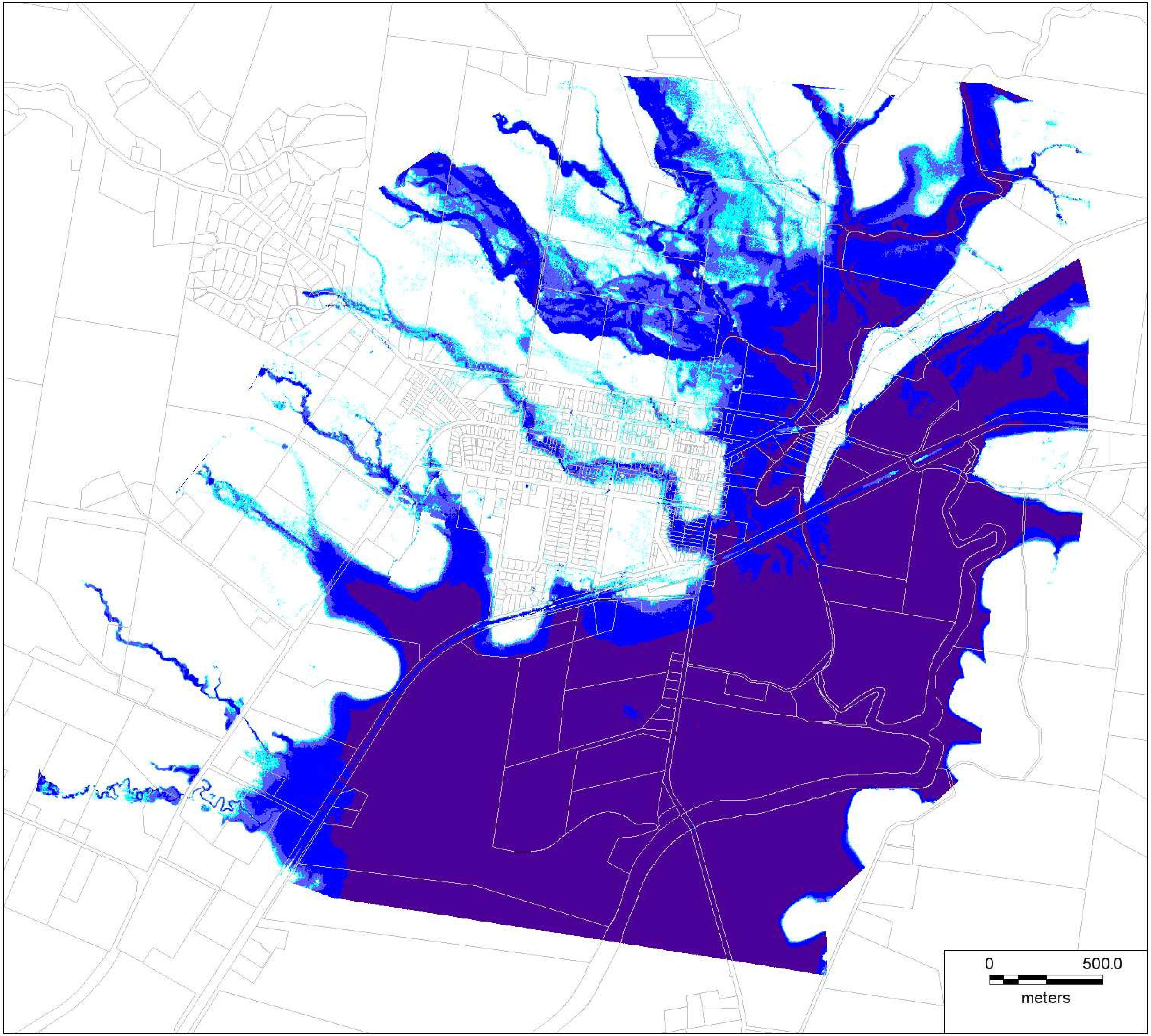


FIGURE D.14

PMF
PEAK FLOOD DEPTH

Berry FRMSP

Depth (metres)

- 0.15 - 0.30
- 0.30 - 0.50
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

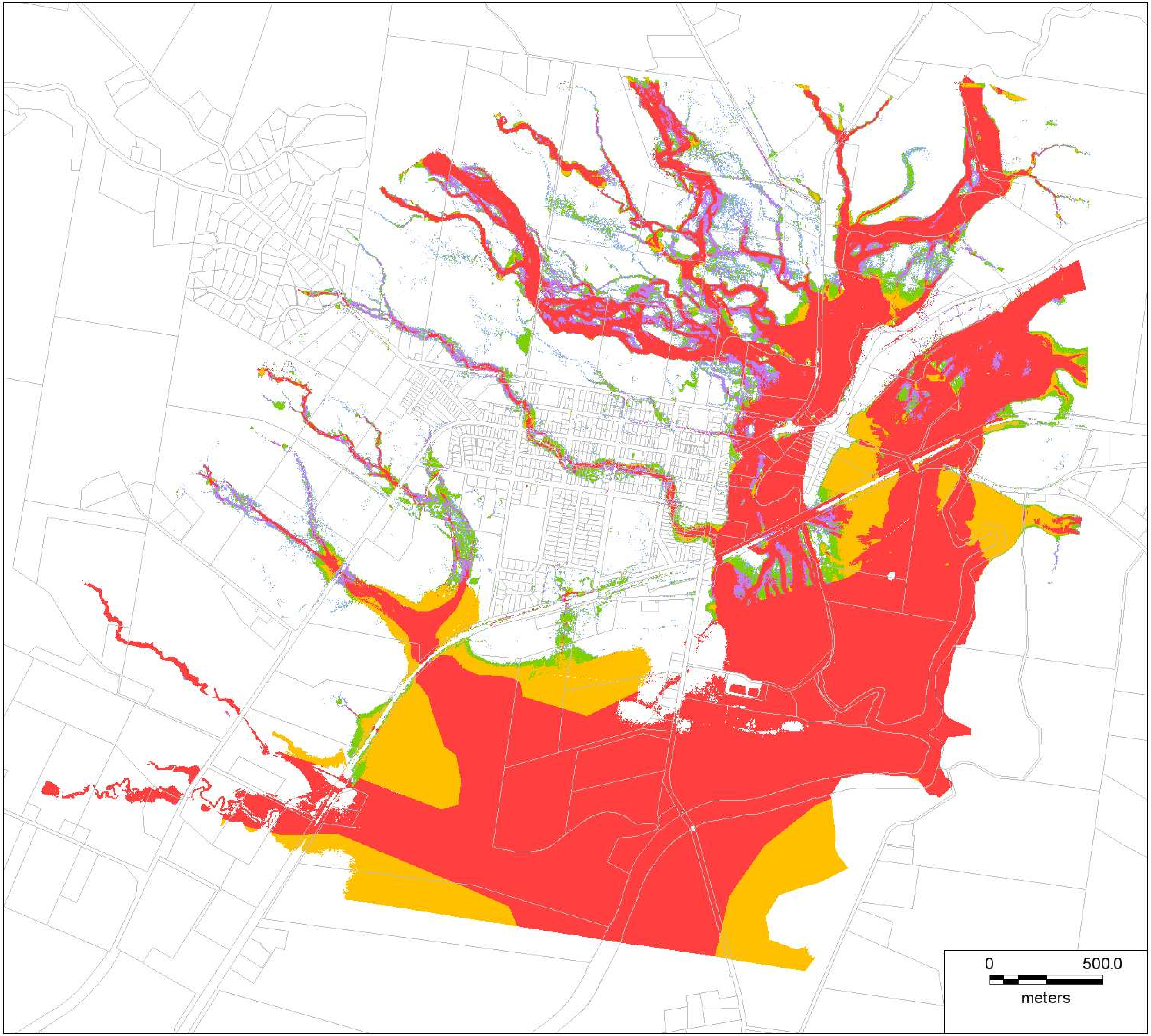


FIGURE D.15

5% AEP HAZARD & HYDRAULIC CATEGORIES

Berry FRMSP

- Cadastre
- High Hazard Floodway
- High Hazard Flod Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

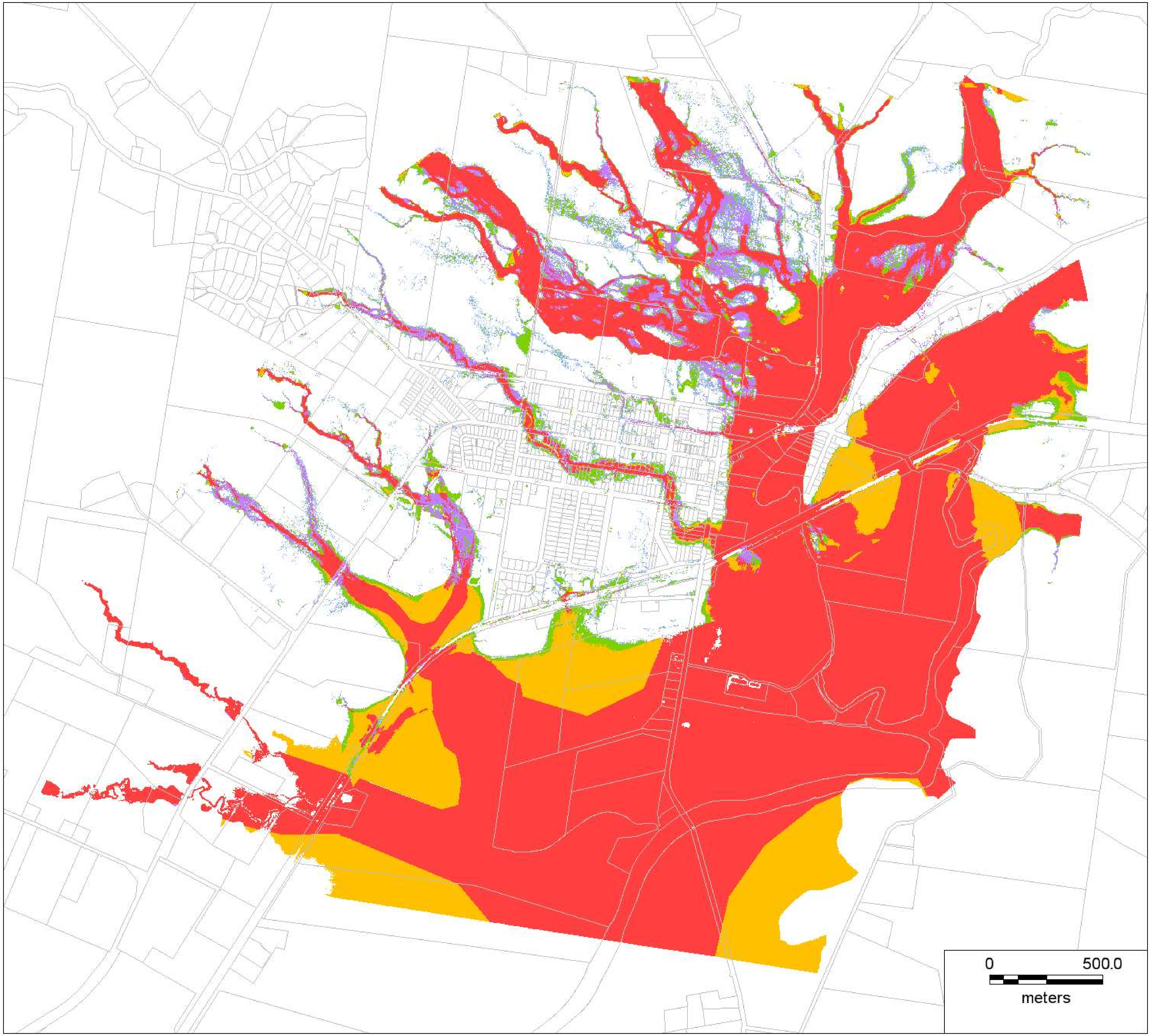


FIGURE D.16

1% AEP
HAZARD &
HYDRAULIC CATEGORIES

Berry FRMSP

- Cadastre
- High Hazard Floodway
- High Hazard Flod Storage
- High Hazard Flood Fringe
- Low Hazard Floodway
- Low Hazard Flood Storage
- Low Hazard Flood Fringe

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

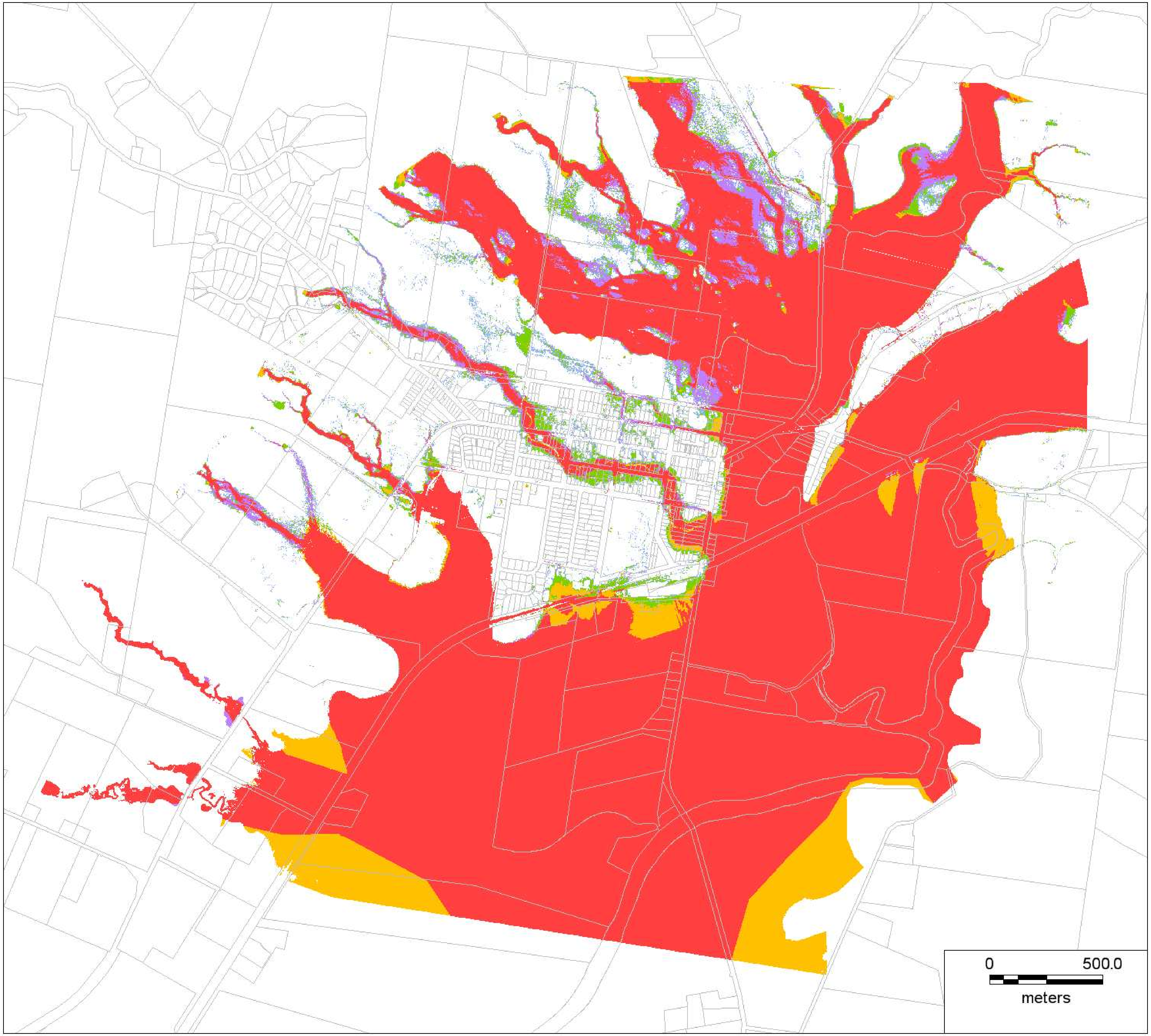


FIGURE D.17

PMF
HAZARD &
HYDRAULIC CATEGORIES

Berry FRMSP

Cadastre
High Hazard Floodway
High Hazard Flod Storage
High Hazard Flood Fringe
Low Hazard Floodway
Low Hazard Flood Storage
Low Hazard Flood Fringe

Cardno

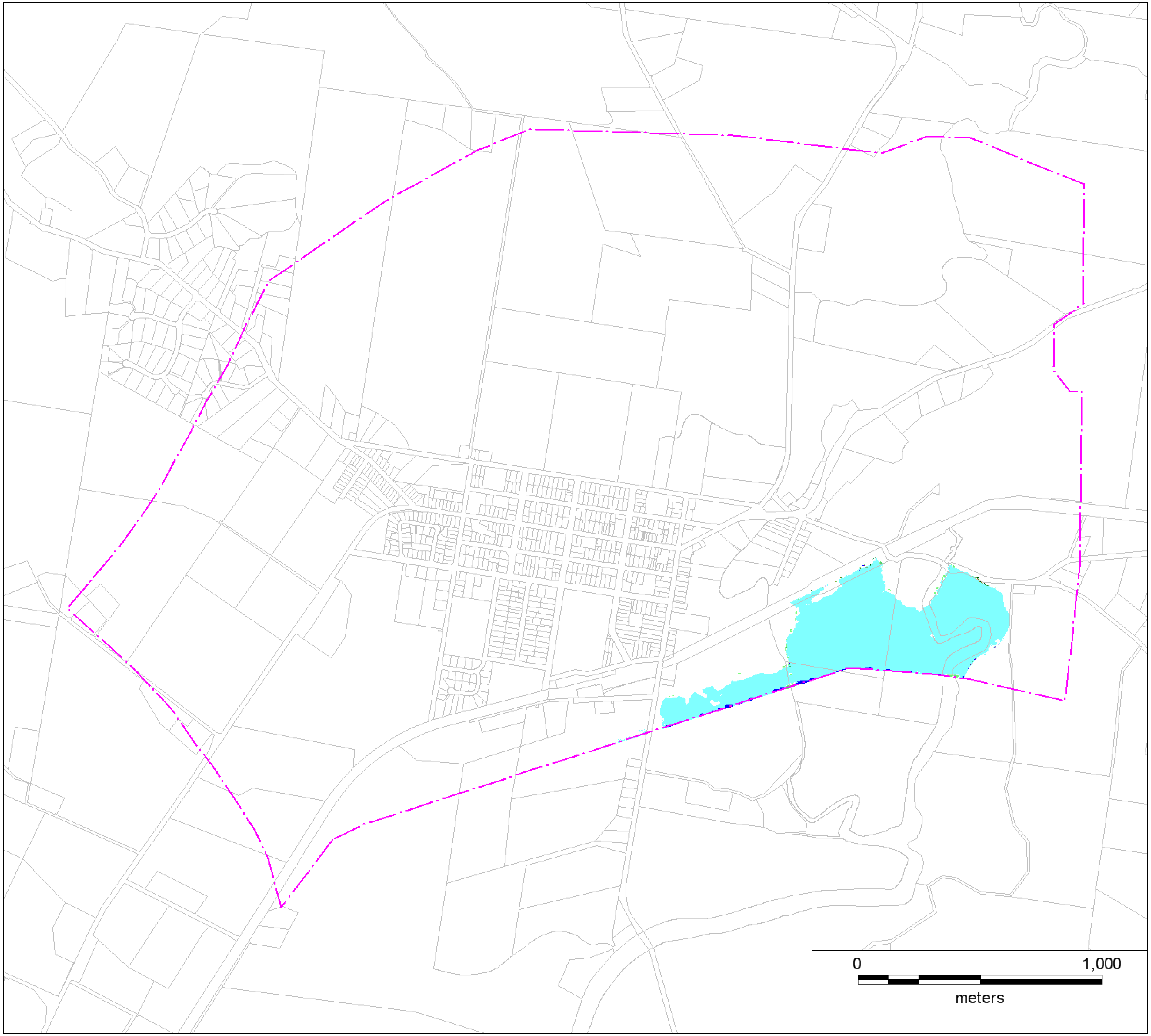
Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 September 2011
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_01_Figure_7-8_2yr_Depth.mxd 02

FIGURE F.1

2050 SEA LEVEL
0% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP



Model Extent

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

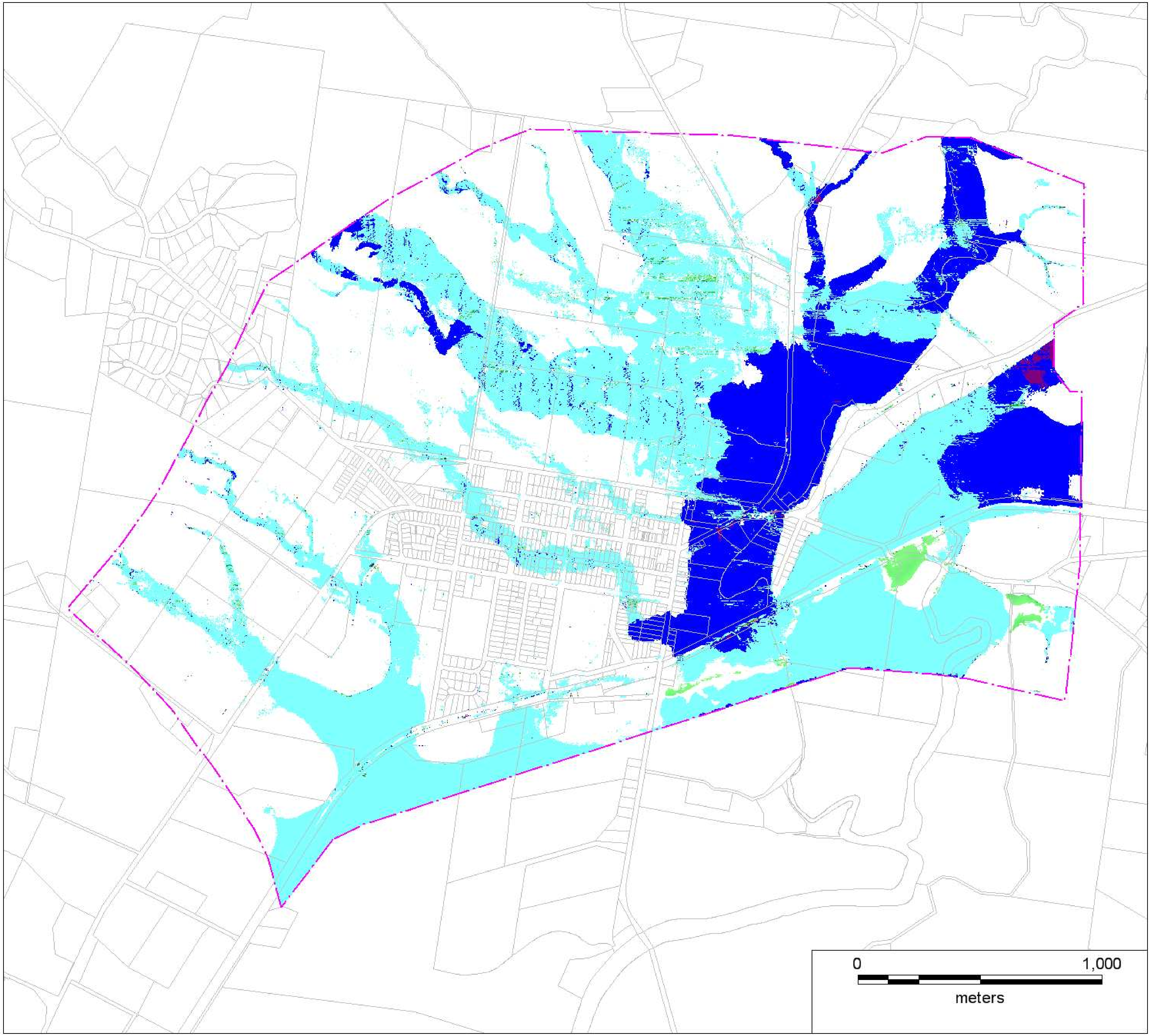


FIGURE F.2

2050 SEA LEVEL 10% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

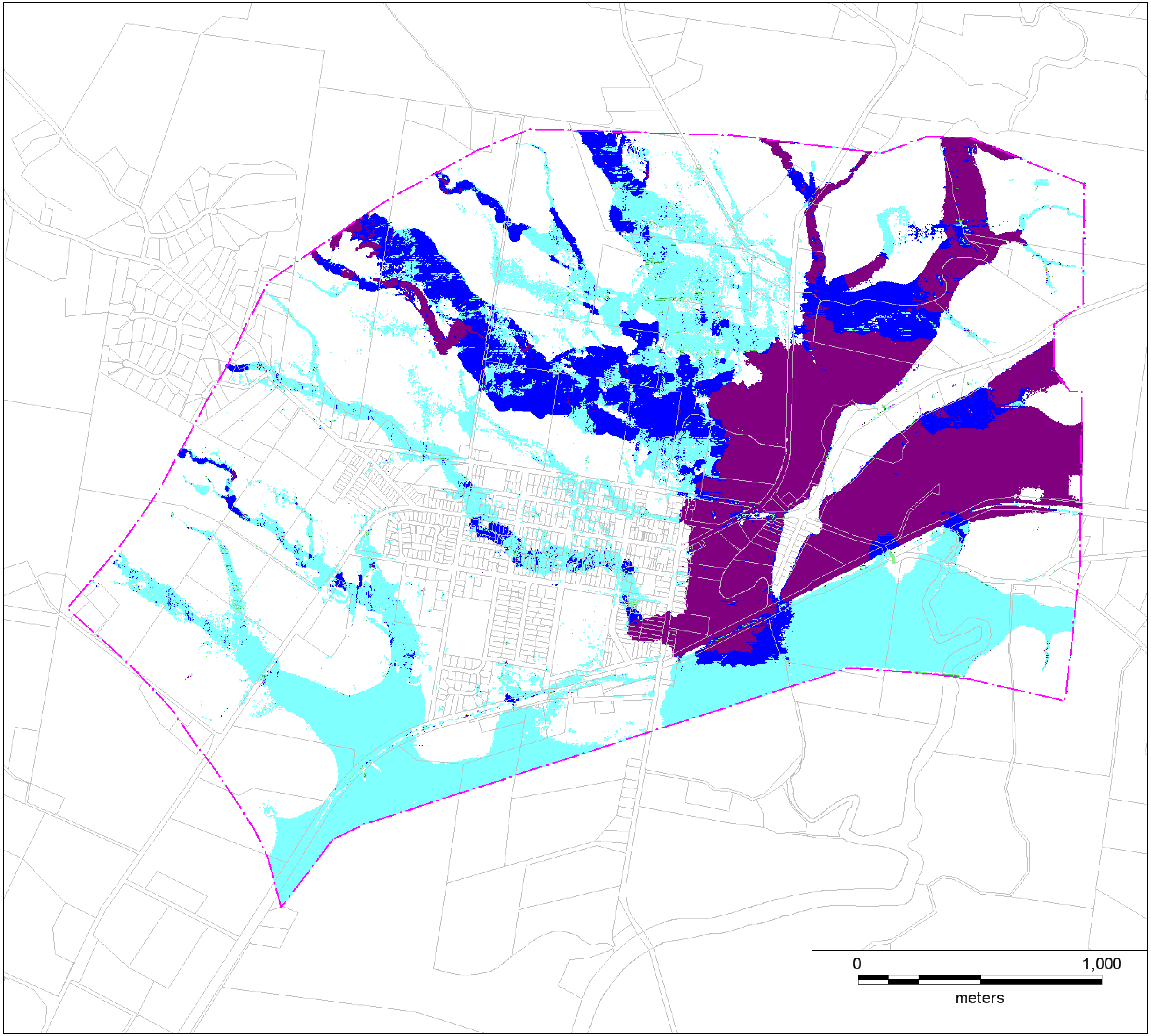


FIGURE F.3

2050 SEA LEVEL
20% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference
metres

>0.5
0.2 to 0.5
0.1 to 0.2
0.01 to 0.1
-0.01 to -0.1
-0.1 to -0.2
-0.2 to -0.5
<-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

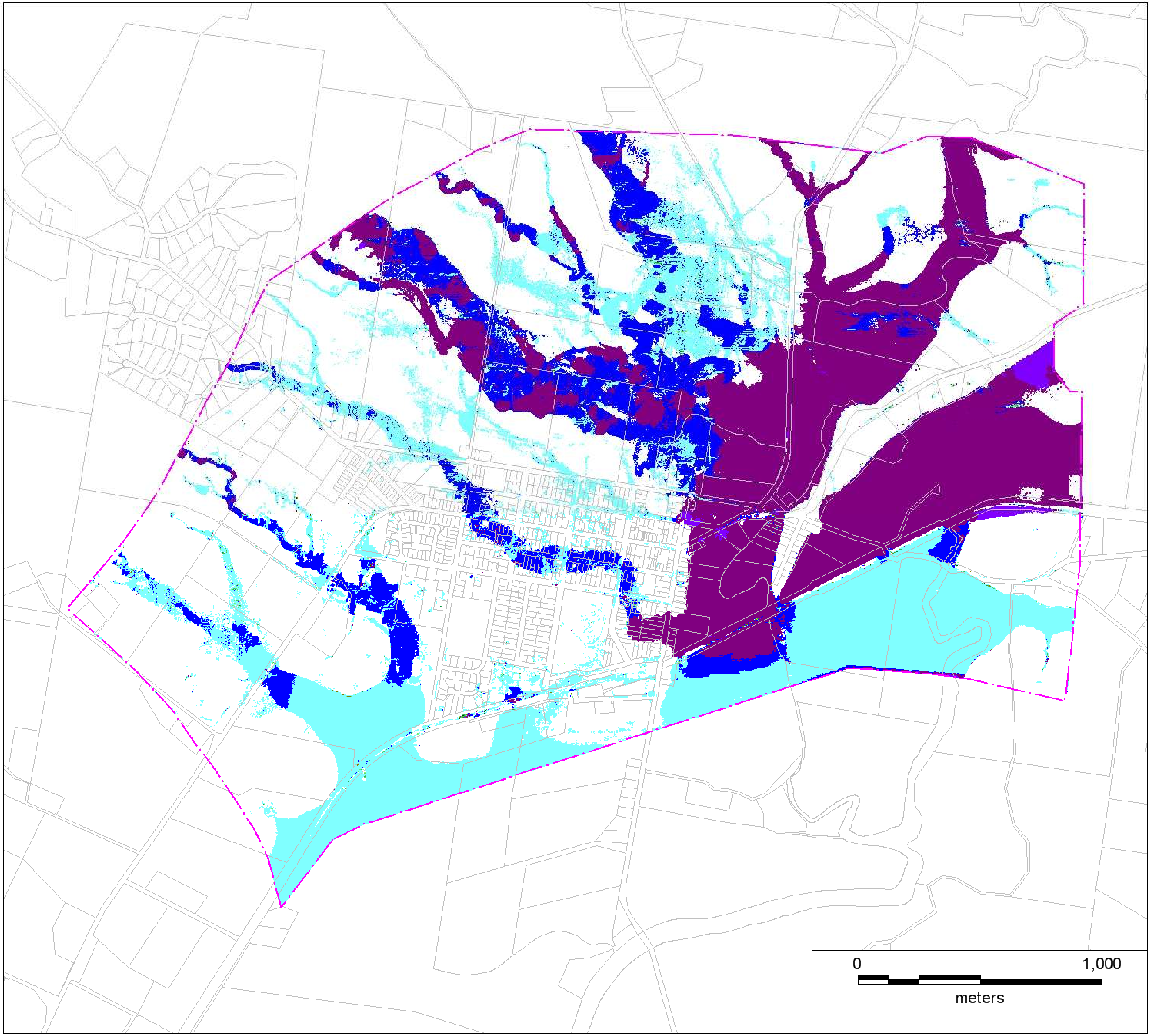


FIGURE F.4

2050 SEA LEVEL
30% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

N

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

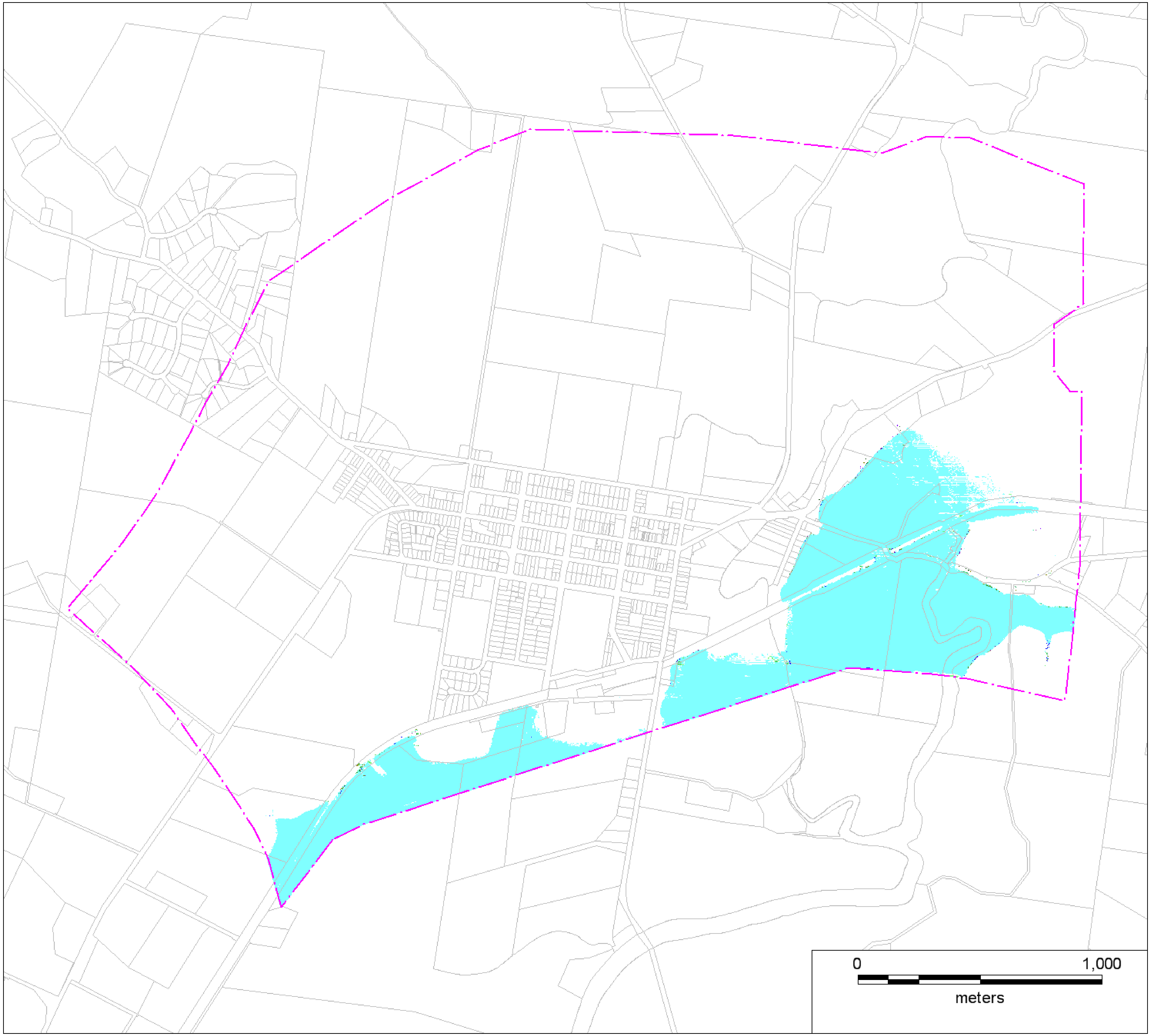


FIGURE F.5

2100 SEA LEVEL 0% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

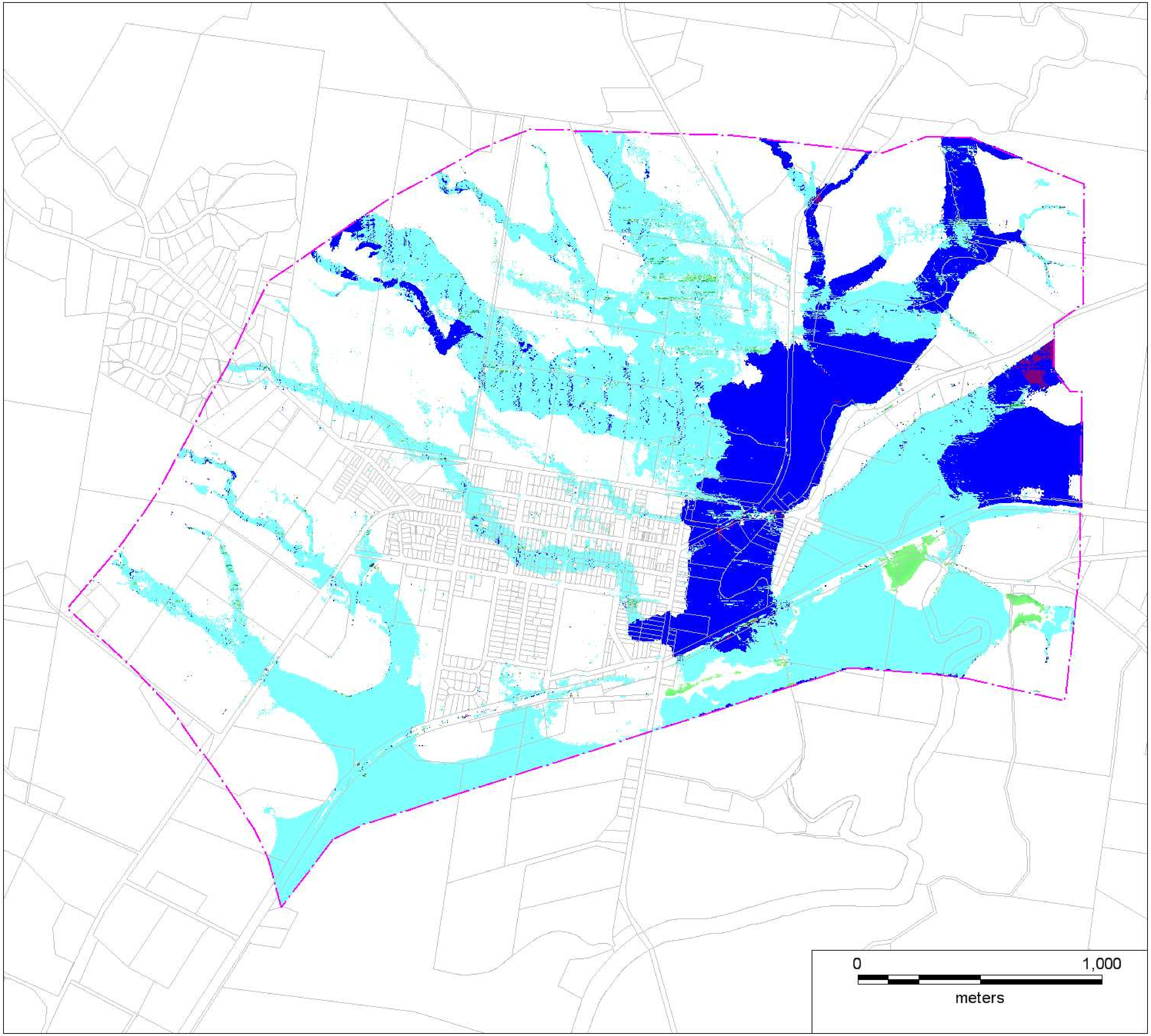


FIGURE F.6

2100 SEA LEVEL 10% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

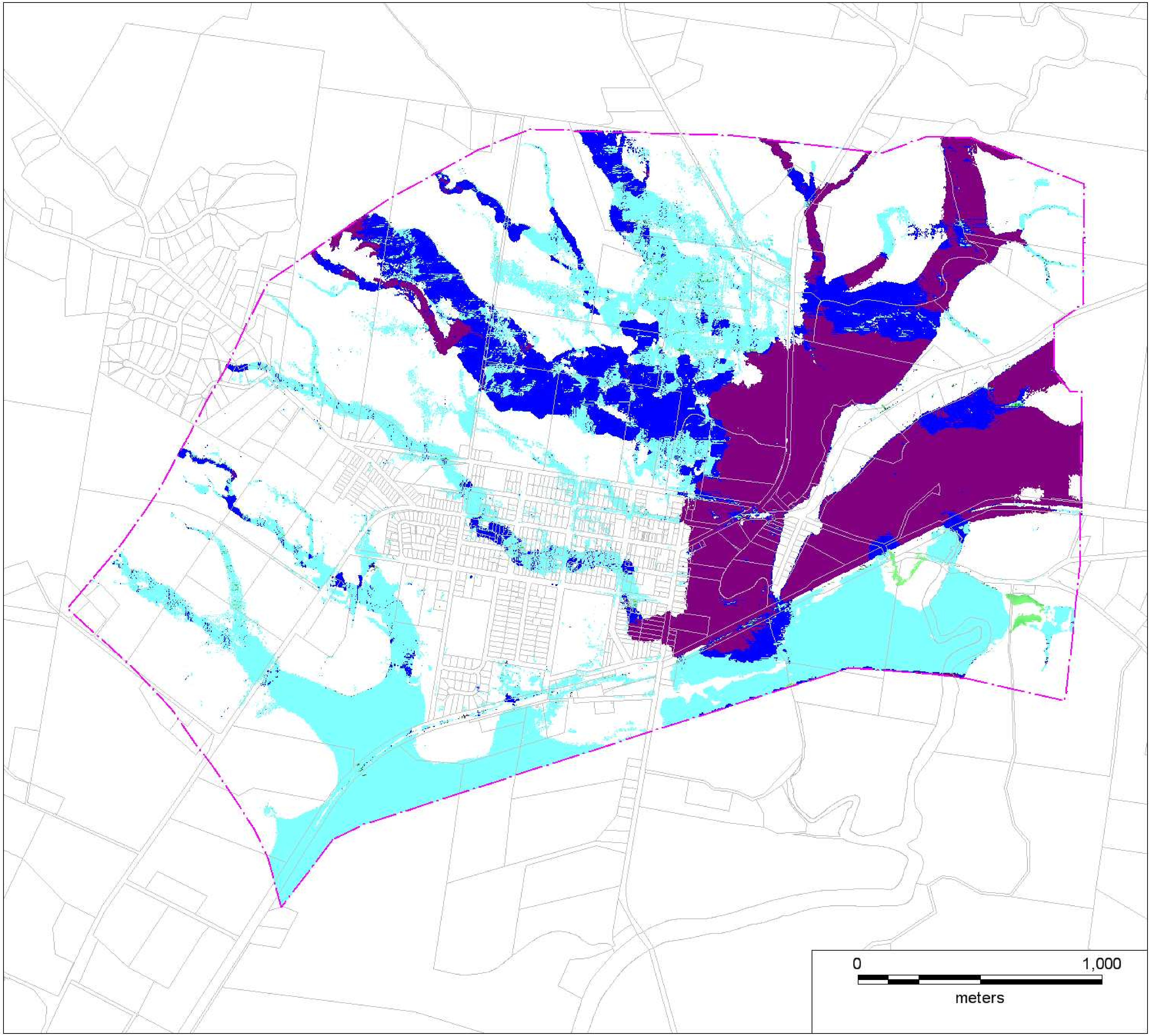


FIGURE F.7

2100 SEA LEVEL
20% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

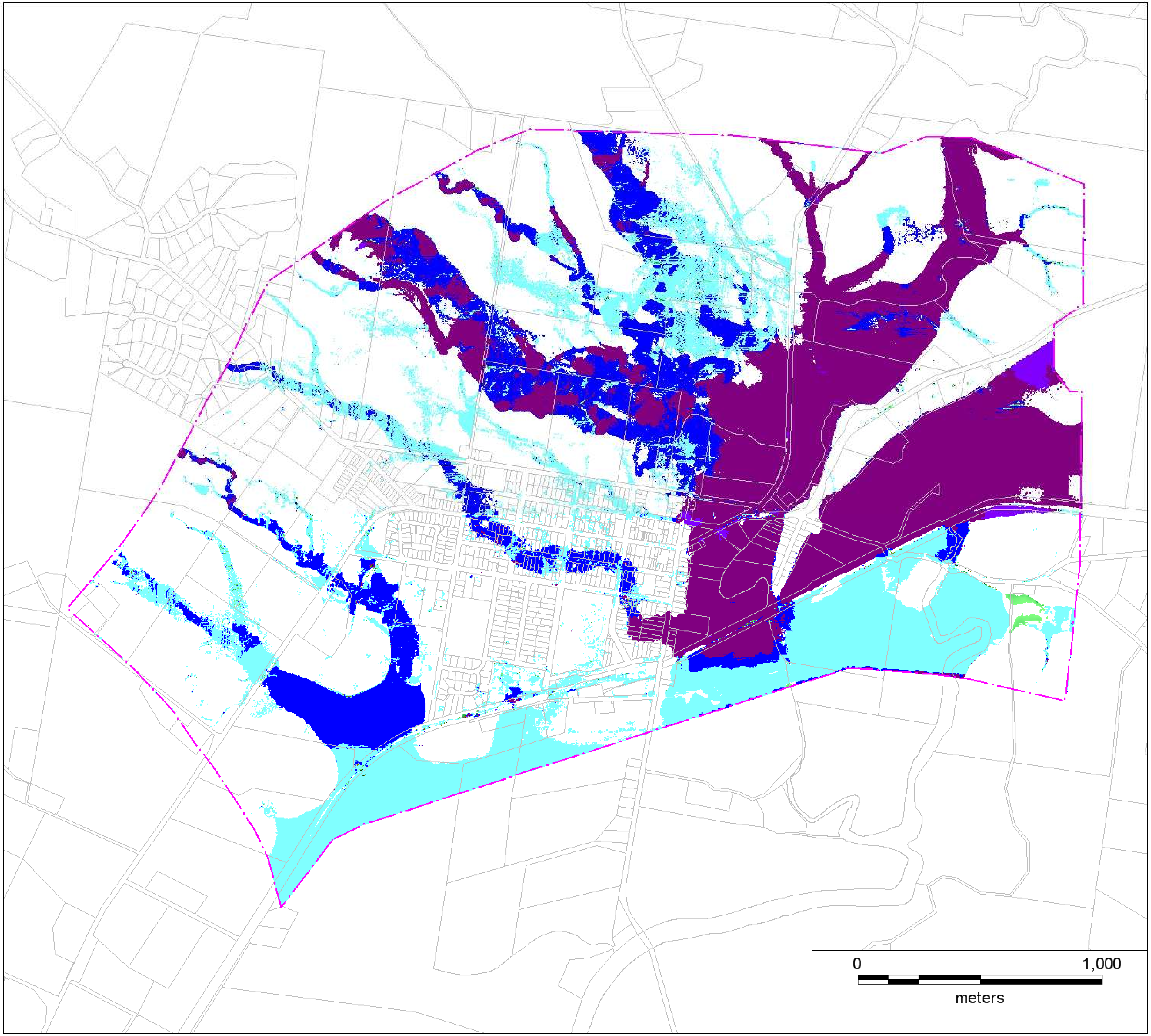


FIGURE F.8

2100 SEA LEVEL
30% RAINFALL INCREASE

PEAK LEVEL DIFFERENCES

Berry FRMSP

Model Extent

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

FIGURE F.9

FLOOD EXTENT COMPARISON

Berry FRMSP

Model Extent
Cadastre
Existing Flood Extent
2100 30% Rainfall Flood Extent

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 21 May 2012
Coordinate System: Zone 56/1 ISG
GIS MAP REF:
W4858_04_Figure_2.2_100yr_Depth.mxd 02

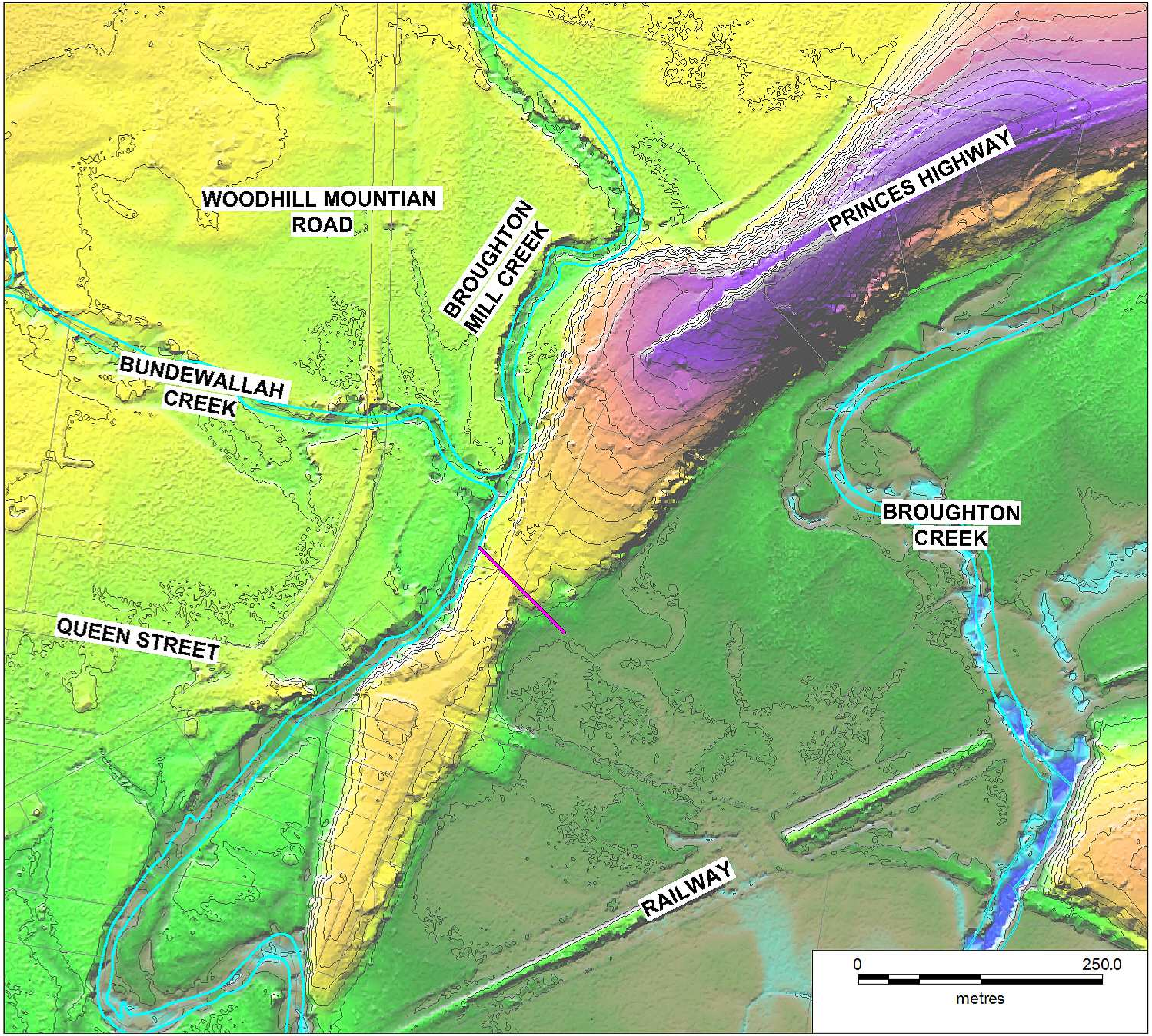


FIGURE I.1

BROUGHTON MILL CREEK DIVERSION

CULVERT LOCATION

Cadastre
Contour (2m Interval)
Creeks
Diversion Culvert

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 30 July 2012
Coordinate System: Zone 56/1 ISG

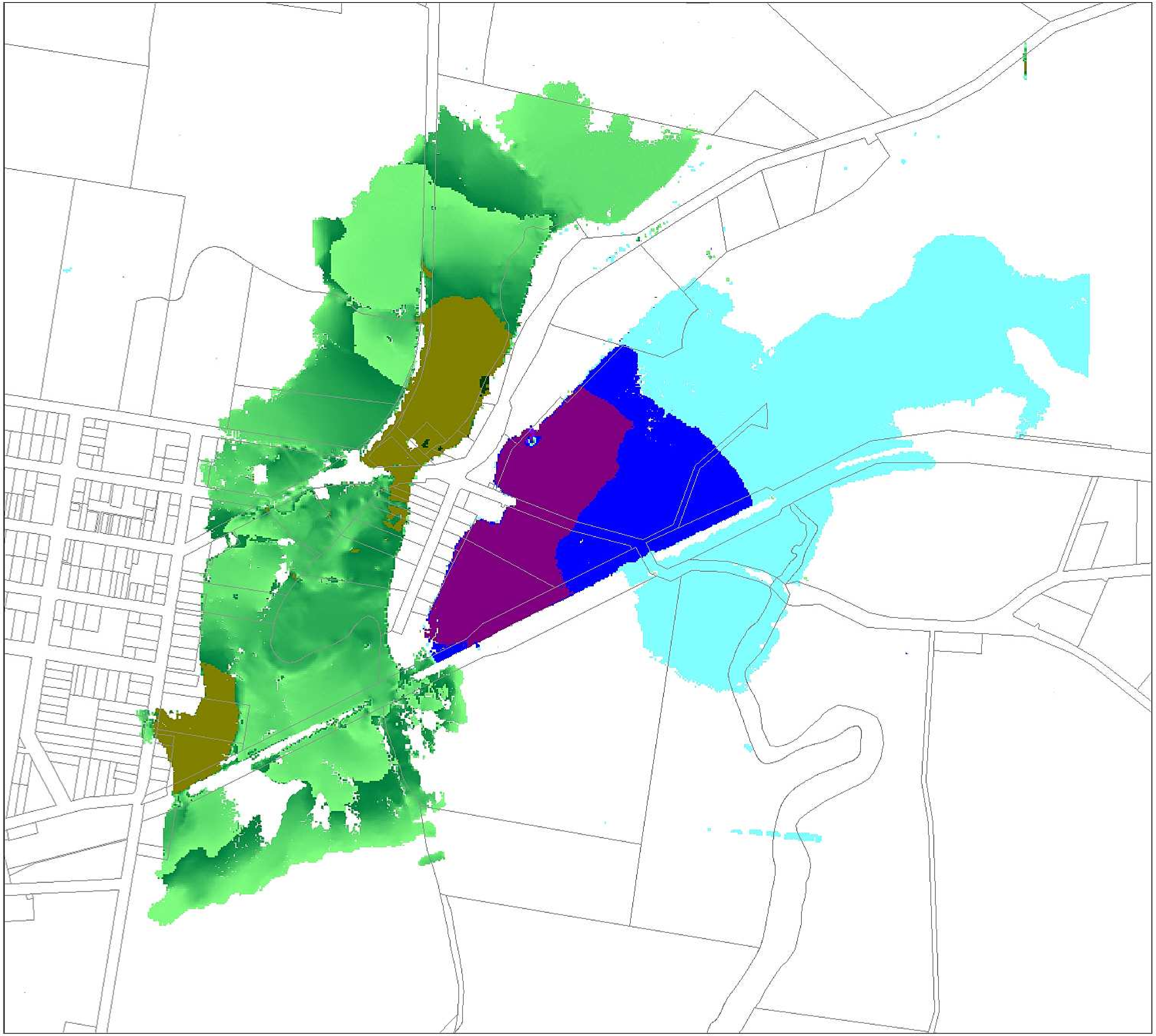


FIGURE I.3

BROUGHTON MILL CREEK DIVERSION

PEAK WATER LEVEL DIFFERENCE

10% AEP

Cadastre

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 August 2012
Coordinate System: Zone 56/1ISG

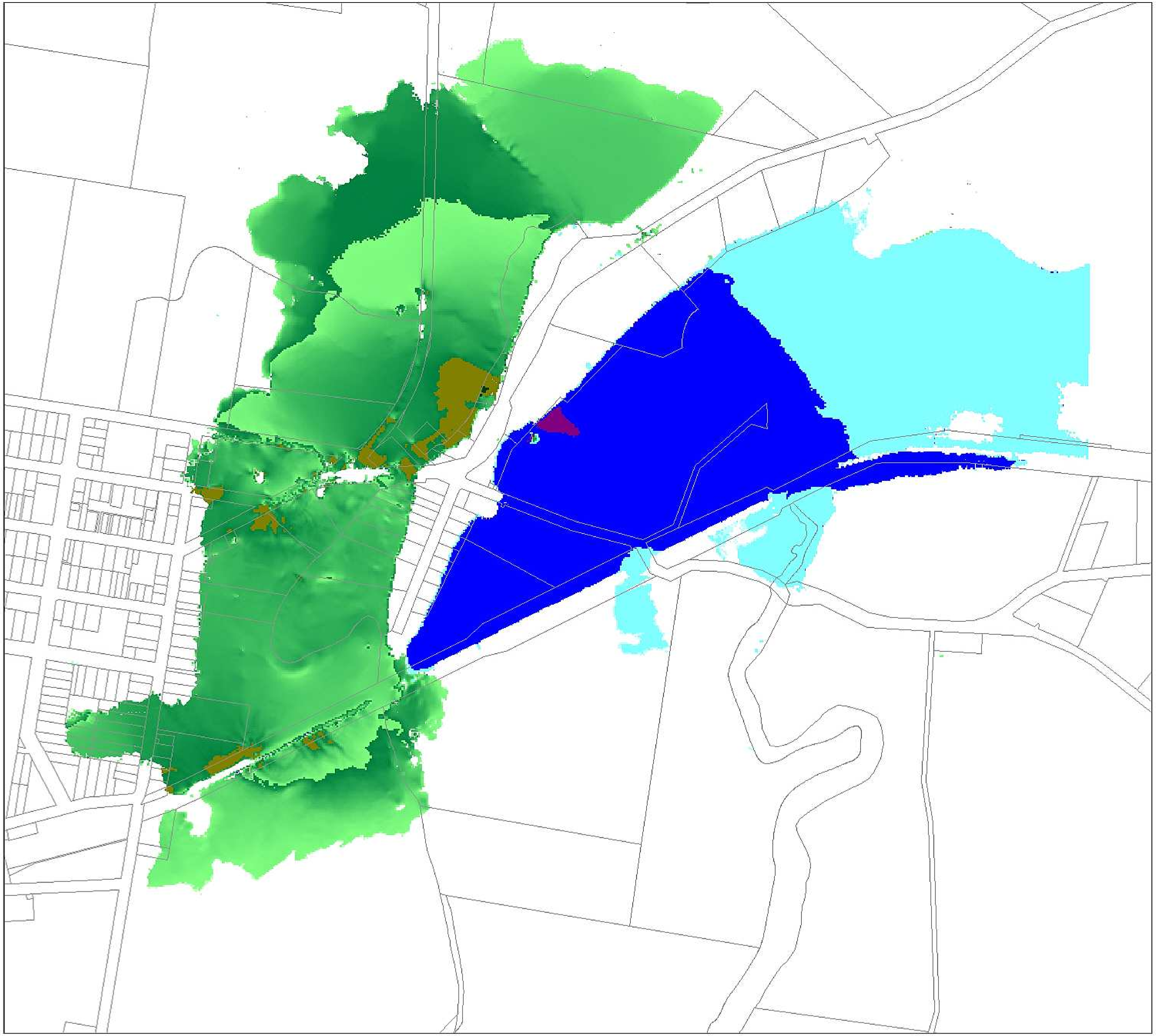


FIGURE I.4

BROUGHTON MILL CREEK DIVERSION

PEAK WATER LEVEL DIFFERENCE

1% AEP

Cadastre

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 August 2012
Coordinate System: Zone 56/1 ISG

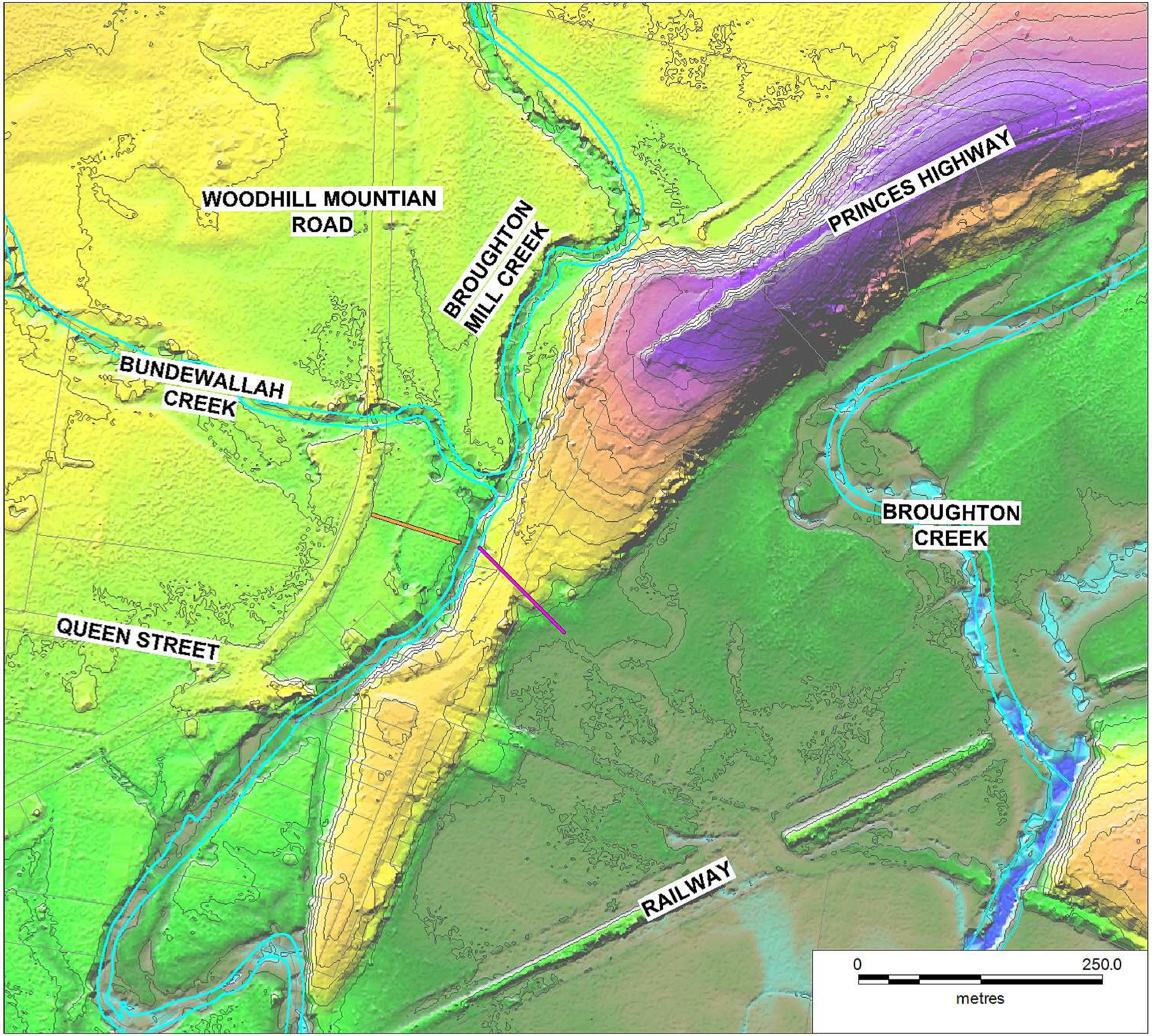


FIGURE I.5

BROUGHTON MILL CREEK DIVERSION

LEVEE LOCATION

- Cadastre
- Contour (2m Interval)
- Creeks
- Diversion Culvert
- Levee Location

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 30 July 2012
Coordinate System: Zone 56/1ISG

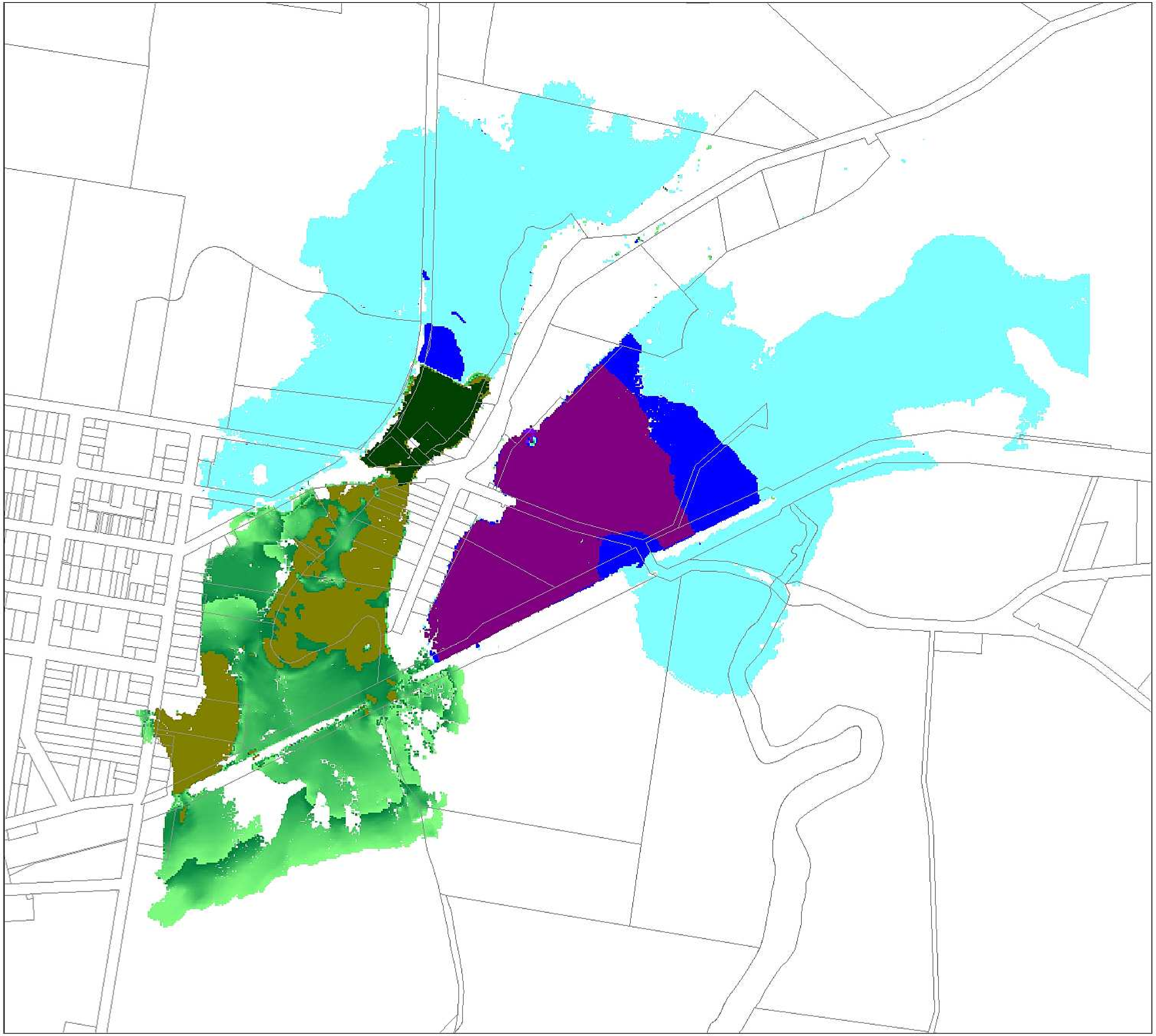


FIGURE I.6

BROUGHTON MILL CREEK DIVERSION WITH LEVEE

PEAK WATER LEVEL DIFFERENCE

10% AEP

Cadastre

Peak Water Level Difference
metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 August 2012
Coordinate System: Zone 56/1 ISG

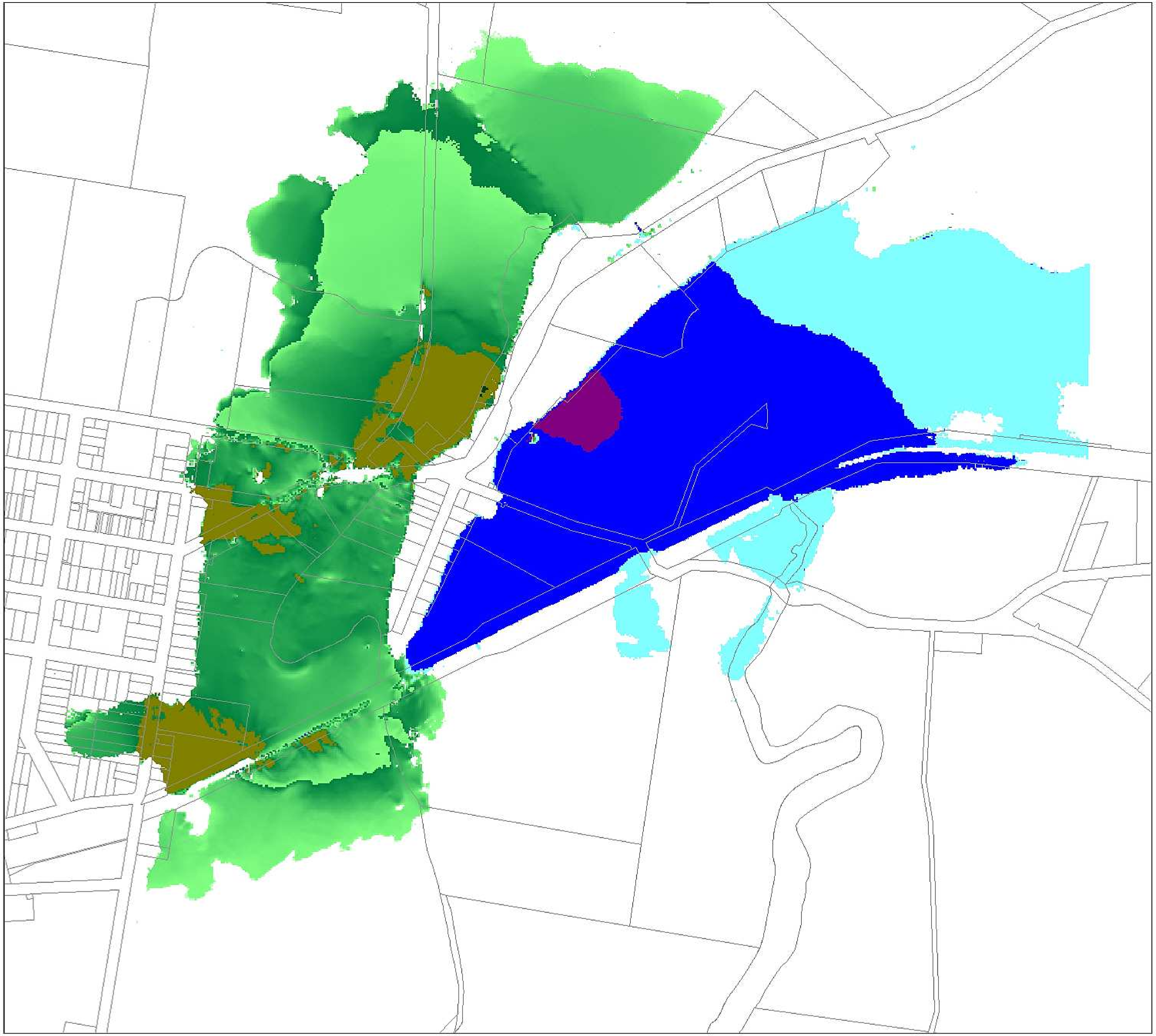


FIGURE I.7

BROUGHTON MILL CREEK DIVERSION WITH LEVEE

PEAK WATER LEVEL DIFFERENCE

1% AEP

Cadastre

Peak Water Level Difference

metres

- >0.5
- 0.2 to 0.5
- 0.1 to 0.2
- 0.01 to 0.1
- -0.01 to -0.1
- -0.1 to -0.2
- -0.2 to -0.5
- <-0.5

Cardno

Map Produced by Cardno NSW/ACT Pty Ltd
Date: 8 August 2012
Coordinate System: Zone 56/1ISG