Cardno LawsonTreloar

Shaping the Future

# SOUTH CREEK
# FLOODPLAIN RISK MANAGEMENT STUDY

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## Report Prepared for

Warringah Council

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# FOREWORD

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

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

The Policy provides for technical and financial support by the State Government through the following sequential stages:

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|---|---|
| 1. Formation of a Committee | Established by Council and includes community group representatives and State agency specialists. |
| 2. Data Collection | Past data such as 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 plan of management for the floodplain. |
| 6. Implementation of the Plan | Construction of flood mitigation works to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard. |

This report forms the fourth stage of the management process for the South Creek Floodplain. The South Creek Flood Study was prepared by Webb McKeown and Associates (WMA, 2006).

This report has been prepared for Warringah Council by Cardno Lawson Treloar Pty Ltd to examine floodplain risk management options to aid the preparation of a Floodplain Risk Management Plan.

# EXECUTIVE SUMMARY

Warringah Council commissioned Cardno Lawson Treloar to prepare a *Floodplain Risk Management Study* for South Creek and its main tributary, Wheeler Creek.

Flooding in South Creek can pose a high hazard to some residents living within close proximity to both South Creek and Wheeler Creek. This prompted Warringah Council through the Narrabeen Lagoon Joint Estuary and Floodplain Management Committee to prepare a comprehensive Floodplain Risk Management Plan for the South Creek Floodplain.

The purpose of this study is to identify and examine options for the management of flooding within the South Creek floodplain as a precursor to the preparation of the Floodplain Risk Management Plan. The study has been undertaken in accordance with the NSW Government's Floodplain Development Manual (2005).

### *The Catchment and Creeks*

The South Creek catchment has a total area of 7.3 $km^2$ with the receiving water being Narrabeen Lagoon.

***South Creek – looking upstream from Alkira Circuit (March 2005)***

***Wheeler Creek – looking upstream from Little Willandra Road (May 2007)***

South Creek is the major watercourse and Wheeler Creek, its tributary, flows east from Cromer Heights to join South Creek.

Highly urbanised areas exist within the South Creek catchment compared to predominantly non-urbanised areas within the Wheeler Creek catchment.

There are several local roads crossing the two creeks including:

- South Creek Road
- Willandra Road
- Toronto Avenue
- Little Willandra Road; and
- McIntosh Road.

These roads can be inundated during a flood event.

***Willandra Rd Crossing of South Creek (March 2007)***

### *The Issue of Flooding*

In the past, flooding within the South Creek catchment has caused property damage and posed a hazard to the residents living in close proximity to the watercourses.

Over recent decades, South Creek has experienced significant flood events including those in March 2003, April 1998 and November 1984.

***Flooding of Carcoola Road, Cromer, 1984***

### *Flood Behaviour - Existing Conditions*

Urban development in the catchment has altered portions of the waterways and floodplain areas considerably from their natural state. Flood flows in the urbanised lower parts of the catchment are complicated by bridge and culvert crossings. Filling of the floodplain and realignment of some of the reaches of the waterway has also impacted on the flow regime of the floodplain.

Flooding of South Creek is caused by a combination of geographic features of the catchment, along with development induced issues, causing a complex system of flow regimes and flooding mechanisms. The dominant characteristics that determine the existing flooding behaviour in South Creek include:

- the relatively steep catchment;
- Narrabeen Lagoon flood levels; and
- conduit blockage.

Full details of the flood modelling for the existing conditions can be sourced from the South Creek Flood Study (WMA, 2006).

The flood levels and extents from the Flood Study (WMA, 2006) indicate that a number of properties within the floodplain are susceptible to above-floor flooding, even in relatively frequent events, such as the 5 year ARI event.

### *Aims of the Study*

This *Floodplain Risk Management Study* investigates what can be done to reduce or manage the effects of flooding in the South Creek catchment. The *Floodplain Risk Management Plan* (the next stage) will recommend a mix of strategies to manage the risks of flooding.

Specific objectives of this study include:

- community consultation, to ensure community input is obtained at key milestones;
- a description and quantification of the flood issues in the South Creek catchment, including the likely cost of flooding to the community;
- the identification and assessment of potential floodplain risk management measures to reduce the risks and hazards of flooding;
- a review of issues relating to planning and development control within both the catchment and floodplain; and
- the assessment of options on a common basis to outline the best measures to reduce flood risk based on environmental, social, economic, financial and engineering considerations.

### *Impacts and Costs of Flooding*

The table below summarises the number of properties that would be flooded in a range of design flood events together with the flood damage that is likely to occur under present conditions.

*Impacts and Costs of Flooding - Total Number of Properties with Above Floor Flooding*

| Flood ARI | Properties with Over-floor Flooding | Flood Damage |
|---|---|---|
| 5 Year ARI | 14 | $ 648,000 |
| 20 Year ARI | 18 | $ 842,000 |
| 50 Year ARI | 32 | $1,461,000 |
| 100 Year ARI | 42 | $1,899,000 |
| PMF | 185 | $9,885,000 |
| Average Annual Damage | | $ 318,000 |
| Present Worth of Damage (50yr, 7%) | | $ 4,389,000 |

### *Options to Manage Flooding*

Using the merits-based approach advocated in the NSW State Government's Floodplain Development Manual (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; and
- emergency response modification measures.

A bank management plan has also been prepared as part of this study. The bank management plan

is provided in Appendix D. Those bank management measures which were considered to result in a significant reduction in flood risk have been incorporated into the Floodplain Risk Management Study options assessment.

***Options Assessment***

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.

***Recommended Options for Implementation***

The assessment found that the highest scored flood modification options (with positive social and environmental impact) to be recommended included:

- FM1 - Levee to Protect Properties on Toronto Avenue;
- FM2 - Enhance Toronto Ave Bridge;
- FM3 - Creek Widening and Revegetation Upstream of Toronto Ave;
- FM5 - Rehabilitate Creek and Construct Wetland;
- FM12 - Preparation and Implementation of Culvert Maintenance Strategy for Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek;
- FM13 - Enhance Willandra Road (lower) Culverts;
- FM20 - Detailed Assessment for Potential Debris Control Structures; and
- FM21 - Debris Control Structure on Wheeler Creek.

Property modification measures considered and recommended for the floodplain include:

- PM1 - Ongoing implementation of development controls and guidelines for building work;
- PM2 - Preparation of Flood-related Development Control Plan for Warringah LGA;
- PM3 - Guidelines for Public Domain Infrastructure;
- PM6 - Voluntary House Purchase Program – 1 Property;
- PM7 - Stringent OSD Requirements on any Proposed Development in the Catchment;
- PM8 - Analysis of Localised Flood Planning Level Requirements; and
- PM9 - Property Dossier of Severely Flood Affected Properties.

Emergency response modification measures proposed for the floodplain include:

- EM1 - Preparation and adoption of SES Local Flood Plan;
- EM3 - Information Transfers to SES;
- EM4 - Community education and awareness programs;
- EM5 - Targeted Flood Education Programs;
- EM6 - Flood depth markers placed on both sides of all roads crossing the creeks; and
- EM7 - Ongoing collection of flood information.

Bank management measures proposed for the floodplain for flooding purposes include:

- BM1 - Management of Weeds in South Creek Downstream of Carcoola Road.
- BM2 - Weed and Sediment Management in South Creek and Wheeler Creek.

The above listed flood, emergency and property modification measures and bank management measure ranked highly using a multi-criteria matrix assessment and are to be considered for inclusion in the Floodplain Risk Management Plan.

Those options selected for inclusion in the Plan are based upon both their likely benefit and the funding available from Council and the State Government.

Based on the options recommended above, the cost of implementing the Plan would be an estimated capital cost of approximately $4,020,000 and an annual recurrent cost of approximately $111,000. However, this does not include the construction of a wetland between Carcoola Road and Toronto Avenue (Option FM5). This option would cost $2.5 Million alone, with a recurrent cost of approximately $40,000. However, this option has significant hydraulic and environmental benefits and is therefore recommended for implementation should funding become available.

***The Next Step***

The next step is the preparation of the *Floodplain Risk Management Plan*. This plan will outline the floodplain risk management actions to be implemented in the South Creek floodplain and will include a prioritised action list.

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# GLOSSARY OF TERMS*

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|---|---|
| **Australian Height Datum (AHD)** | A common national surface level datum approximately corresponding to mean sea level. |
| **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. |
| **Creek Modification** | Widening or altering the creek channel in an environmentally compatible manner (i.e. including weed removal and stabilisation with suitable native endemic vegetation) to allow for additional conveyance. |
| **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 year ARI flood event. |
| **Development** | The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land. |
| **Discharge** | The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving, rather than how much it 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.<br><br>For the purposes of this document '*Flood*' refers to creek flooding only and not overland flow. |
| **Flood fringe** | The remaining area of flood-prone land after floodway and flood storage areas have been defined. |
| **Flood hazard** | That which has the potential to cause damage to the community. Provisional flood hazard is categorised in the Floodplain Development Manual (NSW Govt, 2005) as either High or Low Hazard. Provisional hazard categories are defined as a product of flood velocity and depth. |

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| **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 100 Year ARI 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 floodplains. The concept of FPLs supersedes the "Standard flood event". 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. |

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| **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. |
| **Integrated survey grid (ISG)** | ISG is a global co-ordinate system based on a Transverse Mercator Projection. The globe is divided into a number of zones, with the true origin at the intersection of the Central Meridian and the Equator. |
| **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. With regard to flooding, the objective of the management plan is to minimise and mitigate the risk of flooding to the community. 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 the Institution of Engineers, Australia. |
| **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. |

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| **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. |

* Many terms in this Glossary have been derived or adapted from the NSW Government *Floodplain Development Manual*, 2005.

# LIST OF ABBREVIATIONS

| | |
|---|---|
| **AAD** | Average Annual Damage |
| **AHD** | Australian Height Datum |
| **ARI** | Average Recurrence Interval |
| **BoM** | Bureau of Meteorology |
| **CMA** | Catchment Management Authority |
| **DCP** | Development Control Plan |
| **DECC** | Department of Environment and Climate Change |
| **DIPNR** | Department of Infrastructure, Planning and Natural Resources (now DECC or DWE) |
| **DLWC** | Department of Land and Water Conservation (now DECC or DWE) |
| **DWE** | Department of Water and Energy |
| **EPA** | Environmental Protection Authority (within DECC) |
| **FPL** | Flood Planning Level |
| **FRMP** | Floodplain Risk Management Plan |
| **FRMS** | Floodplain Risk Management Study |
| **km** | kilometres |
| **$km^2$** | Square kilometres |
| **LEP** | Local Environment Plan |
| **LGA** | Local Government Area |
| **m** | metre |
| **$m^2$** | Square metres |
| **$m^3$** | Cubic metres |
| **mAHD** | Metres to Australian Height Datum |
| **MHL** | Manly Hydraulics Laboratory |
| **MIKE11** | MIKE11 proprietary software package |
| **mm** | millimetre |
| **m/s** | metres per second |
| **NPWS** | National Parks and Wildlife Service (within DECC) |

| | |
|---|---|
| **NSW** | New South Wales |
| **OSD** | On-site Detention Policy |
| **PMF** | Probable Maximum Flood |
| **PWD** | Public Works Department New South Wales (now Department of Commerce or DECC) |
| **RTA** | Roads and Traffic Authority |
| **SCARM** | Standing Committee on Agriculture and Resource Management |
| **SEPP** | State Environmental Planning Policy |
| **SES** | State Emergency Service |
| **WBNM** | Watershed Bounded Network Model |

# 1. INTRODUCTION

This Floodplain Risk Management Study for South Creek has been undertaken by Cardno Lawson Treloar Pty Ltd for Warringah Council to identify and examine options for the management of flooding within the South Creek floodplain. The study has been undertaken in accordance with the NSW Government Floodplain Development Manual (2005).

A locality plan can be found in **Figure 1.1**.

## 1.1 Study Context

Flooding in South Creek can pose a hazard to the community that reside in close proximity to South Creek. This has prompted Warringah Council, through the Narrabeen Lagoon Joint Estuary and Floodplain Management Committee, to prepare a comprehensive Floodplain Risk Management Plan for the South Creek Floodplain. The staged movement towards the development of such a Plan is part of the NSW State Government's program to manage major flood impacts and hazards on floodplains, in accordance with the Floodplain Development Manual (NSW Government, 2005).

This study fulfils one of the multiple stages of the Floodplain Management Process which includes:

- Formation of a Committee
- Data Collection
- Flood Study
- **Floodplain Risk Management Study**
- Floodplain Risk Management Plan
- Implementation of Floodplain Risk Management Plan.

## 1.2 Study Purpose

The purpose of this study is to:

- review Council's existing environmental planning policies and instruments including Councils long-term planning strategies for the study area;
- identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;
- assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future;
- consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised;
- examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements;
- examine ways in which the creek and floodplain environment may be enhanced by preparing a strategy for vegetation planning that will create a valuable corridor of vegetation without having a detrimental effect on flooding; and
- identify modifications that are required to current policies in light of the investigations.

## 1.3 Study Objectives

The objectives of the study are to:

- reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk;
- reduce private and public losses due to flooding;
- where possible, protect and enhance the creek and floodplain environment;
- be consistent with the objectives of relevant state policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the *Environmental Planning and Assessment Act* 1979;
- recommend actions for incorporation in the management plan (the next stage) to reduce the existing risk of flooding, minimise future risk of flooding and manage the residual risk of flooding; and
- ensure actions recommended for incorporation in the management plan (the next stage) are sustainable in social, environmental, ecological and economic terms;

The development of a list of actions to be undertaken from the options considered in this study is part of the next stage; the Floodplain Risk Management Plan.

## 1.4 Study Methodology

The report format follows the study methodology outlined below:

- an overview of the features of the catchment and floodplain (also utilised in the assessment of the impact of proposed options) (Section 2);
- details of the stakeholder consultation undertaken for the study (Section 3);
- an overview of the existing flood behaviour and issues (Section 4);
- an assessment of the existing flood economic impact (flood damages) (Section 5);
- details of the proposed flood planning level and the selection process (Section 6);
- an overview of the existing emergency response arrangements (Section 7)
- an overview of the potential options for the management of flooding (Section 8);
- an assessment of those flood modification (or structural) options identified as being suitable for various parts of the South Creek floodplain (Section 9);
- an assessment of those property modification options identified as being suitable for various parts of the South Creek floodplain (Section 10);
- an assessment of those emergency response modification options identified as being suitable for the South Creek floodplain (Section 11);
- an assessment of bank management options identified as being suitable for the South Creek floodplain (Section 12);
- an economic assessment of potential options (Section 13);
- a multi-criteria matrix assessment of all possible options (Section 14); and
- recommendations and conclusions of the study for the next stage in the floodplain management process, the floodplain risk management plan (Section 15).

# 2. CATCHMENT AND FLOODPLAIN OVERVIEW

## 2.1 Catchment Topography

The South Creek catchment has a total area of 7.3 $km^2$ flowing to the southern end of Narrabeen Lagoon. The catchment is made up of two tributaries: South Creek and Wheeler Creek. South Creek is the major water course and Wheeler Creek flows east from Cromer Heights to join South Creek. The area draining to Wheeler Creek is primarily undeveloped bushland.

The catchment elevation varies from 168 mAHD in the upper reaches to nearly 0 mAHD at the ultimate downstream end. Downstream of Carcoola Road the floodplain area is relatively low lying, with an average elevation of 2.5 mAHD.

The majority of the South Creek catchment is made up of residential areas with many road crossings likely to be overtopped during a major flood event.

## 2.2 Land Use, Zoning and Tenure

The South Creek Flood Study (WMA, 2006) described the catchment to be comprised of the following land uses:

- 59% urban development including residential and commercial/light industrial development
- 41% open space and forested areas,

The Warringah Council Creek Management Strategy (MWH, 2004) details land use distribution in Warringah including the land adjacent to South Creek. Details of permissible land uses within the different LEP (2000) zones are discussed in **Section 2.12**.

Most of the South Creek riparian area is Council owned or Crown Land under the care, control, and management of Council. The upper reaches of Wheeler Creek are on land owned by the Department of Lands. Downstream of Maybrook Manor, Wheeler Creek flows predominantly through private property.

The advantage of having Council-owned land within the riparian zone of South Creek in the lower reaches, is the subsequent availability of access for creek works, maintenance and flood management.

Crown waterways are defined as those water bodies and watercourses where the associated beds are under Crown ownership and control (*i.e.*, NSW State Government or authority can be vested in the local Council). They include the ocean to three nautical miles seaward, most estuaries, major wetlands, lakes and rivers. In the case of marine waterways, the mean high water level is generally taken as the landward boundary (DLWC, 2001).

The beds of these waterways are legally Crown land, subject to all the provisions of the *Crown Lands Act* 1989 and this land is referred to sometimes as "submerged Crown land". However, as the control of these beds often determines the use and management of the entire waterway site, (*i.e.*, including the water above) the term "Crown waterway" is more common (DLWC, 2001). Portions of South Creek are crown waterways.

The Department of Lands and Warringah Council are the custodians and managers of Crown land within the South Creek catchment.

## 2.3 Main Channel and Tributaries

South Creek has its headwaters in Beacon Hill and flows through a bedrock controlled, discontinuous floodplain before its major tributary, Wheeler Creek, connects into the system at Cromer. The system then changes to an alluvial floodplain and eventually flows into the south-western corner of Narrabeen Lagoon, adjacent to Cromer Golf Course. The total length of the main stream is approximately 5km.

The catchment area is predominantly occupied by urban development (59%) including both residential and commercial/light industrial development, with the remainder comprised of open space and forested areas (41%) (WMA, 2006). The urban areas are comprised of over 40% imperviousness (MWH, 2004). Wheeler Creek runs east from Cromer Heights to the confluence at Cromer. The Wheeler Creek catchment exhibits less than 10% imperviousness (MWH, 2004).

The study creeks are shown in **Figure 2.1**.

The Warringah Council Creek Management Strategy (MWH, 2004) summarises the main changes to creek ecology and other values that are applicable in Warringah. The Strategy classified creek catchments into three groups based on the ecological values and the extent of catchment imperviousness. Wheeler Creek was classified in Group A (maintain at less than 10% connected impervious area). South Creek was classified Group C (no additional catchment constraints, but require development controls to prevent further deterioration).

South Creek runs through urbanised areas that facilitate weed invasion, increased sources of sediment, increased bank erosion and increased pollutant loads in the creek. Wheeler Creek is in good condition and retains its natural form in the upper reaches. Development of the catchment in the lower reaches has resulted in increased weed invasion potential and an increase in catchment-derived pollutants (*e.g.* nutrients).

A series of stormwater drainage systems feed into South Creek. Road areas and parks act as floodways during rare and extreme events. These include areas such as Wabash Reserve and other reserves adjacent to the creek.

Urban development in the catchment has considerably altered the waterways and floodplains from their natural state in some locations. In the lower parts of the catchment there are a number of bridge and culvert crossings. Local road links that traverse the floodplain include:

- South Creek Road;
- Willandra Road;
- Toronto Avenue;
- Carrington Avenue;
- Little Willandra Road; and
- McIntosh Road.

Other modifying actions to the main channel and tributaries include:

- historical land clearing for urban development purposes;
- filling of the floodplain (e.g. for urban development, for recreational space and former waste disposal landfill);
- encroachment of urban development on the floodplain;
- channelisation and drainage (de-silting, straightening, filling, embankment stabilisation);
- other activities causing bank and bed erosion;

- removal of native vegetation which would otherwise stabilise the channel banks; and
- significant weed invasion within both the channel and overbank areas (*e.g.* lantana, coral trees: see **Section 2.9**).

The downstream boundary of South Creek is influenced by the water level in Narrabeen Lagoon, which can in turn be affected by coastal and ocean conditions. Severe storm surges associated with ocean conditions may interact with catchment flood events to produce elevated water levels that are not due solely to catchment flooding impacts. However, the western basin of Narrabeen Lagoon (which South Creek drains to) is not likely to be as affected by ocean conditions as the eastern channel of the Lagoon.

A large portion of the channel, banks, and riparian areas of the lower reaches of South Creek are heavily infested with weed species.

## 2.4 Historical Flooding

South creek has experienced significant flooding in a number of events in the past. There is no rainfall gauge within the catchment; however, there are rainfall gauges in the adjacent catchments. These gauges are referred to as Middle Creek rainfall gauge and Cromer rainfall gauge. The locations of these gauges are shown on **Figure 2.2**.

The flood events noted in **Table 2.1** were noted by the community as being significant flood events within the South Creek floodplain. The Average Recurrence Intervals (ARIs) noted for each event are based on the rainfall intensities in the adjacent catchments.

**Table 2.1 Significant Historical Rainfall Events**

| Date | Average Recurrence Interval (ARI) | |
|---|---|---|
| | Middle Creek Gauge | Cromer Gauge |
| 10 April 1998 | 33 Year ARI | 6 Year ARI |
| 14 April 1999 | 16 Year ARI | 36 Year ARI |
| 15 December 2001 | 1.1 Year ARI | - |
| 3 February 2002 | 2.6 Year ARI | 1.9 Year ARI |
| 10 March 2003 | >100 Year ARI | 11 Year ARI |
| 22 April 2007 | - | 3.4 Year ARI |
| 24 April 2007 | 1.2 Year ARI | - |

There is a significant difference in rainfall intensities between the two rainfall gauges. Therefore it is entirely plausible that the rainfall intensity within the South Creek Catchment could vary significantly from those shown above. Therefore the ARIs provided in **Table 2.1** should only be used as a guide.

It is interesting to note, that while many residents commented that the April 2007 event was *one of the worst they had seen in 30 years*, neither gauge showed the rainfall intensities to be in excess of a 4 Year ARI event. It is possible that the rainfall intensity within the South Creek catchment was more intense than in the adjacent catchments. However, it is also possible that due to land use changes and the degradation of South Creek, that the flood impact was much more significant than had been experienced in the past.

## 2.5 Catchment and Creek Debris

Observations during minor flood events indicate that there is the potential for displacement and transport of a variety of types of material by floodwaters.

Debris types can include:

- coarse sands, gravel and boulders;
- weeds and other vegetation;
- tree branches; and
- anthropogenic material (*e.g.* garbage bins, mattresses, cars, shopping trolleys and general litter).

In addition, since the development at Red Hill (in the upper reaches of the catchment) residents have raised concern in regards to the increase in sediment transport into the creek system associated with the development.

## 2.6 Receiving Waters

For the design flood event assessments for the Flood Study (WMA, 2006), water levels within Narrabeen Lagoon were assumed for different rainfall events. These levels are reported in **Table 2.2** were taken from the Narrabeen Lagoon Flood Study (PWD, 1990).

**Table 2.2 Narrabeen Lagoon Peak Flood Levels (PWD, 1990)**

| Event (ARI) | Level in Narrabeen Lagoon |
|---|---|
| Extreme | 4.6m AHD |
| 100 Year | 2.9m AHD |
| 20 Year | 2.55m AHD |

Note: The 'Extreme' event was noted to be several times larger than the 100 Year ARI event – for the purposes of the Flood Study; this was considered to be the PMF.

Further details on the lagoon can be found in **Section 2.8**.

## 2.7 Geology, Soils, Sediments and Geomorphology

The general area surrounding South Creek is gently sloping in the low-lying areas with a steep escarpment rising to the west. The study site is based upon two sedimentary rock types: Hawkesbury sandstone and the Narrabeen Group.

*Soils*

The lower floodplain coastal lake area is described as the Newport Aeolian soil landscape by the 1:100 000 soil landscape map for Sydney (Chapman & Murphy, 1989). This consists of shallow windblown sands of the Newport Soil Landscape unit that overlie the Newport and Garie Formations of the Middle Triassic Narrabeen Group. The Narrabeen Group consists of interbedded laminate, shale and quartz to lithic quartz sandstone. In some instances the underlying material is Hawkesbury Sandstone. This is a medium to coarse-grained quartz sandstone with minor shale and laminate lenses. The soils are well-sorted siliceous sands overlying moderately deep buried soils including yellow podsolic soils with sandy topsoils on crests and gentle slopes, and deep podzols on steep slopes, lower slopes and in depressions. These soils experience high erosion, low fertility, and consist of non-cohesive topsoils.

The escarpment is a combination of colluvial (Hawkesbury soils) and erosional (Lambert soils) landscapes. The geology consists of Hawkesbury Sandstone of medium to coarse-grained quartz sandstone with minor shale and laminite lenses. Sandstones are either massive or cross-bedded sheet facies with vertical or subvertical joints sets. The combination of bedding planes and widely spaces joints gives sandstone outcrops a distinctive blocky appearance (Chapman & Murphy, 1989).

The soil limitations of the abovementioned soil types are a combination of extreme soil erosion hazard, mass movement (rock fall) hazard, steep slopes, rock outcrop, shallow, stony, highly permeable soil and low soil fertility (Chapman & Murphy, 1989). This has implications for the observed relatively high rates of sedimentation noted in the lower floodplain areas of South Creek.

*Acid Sulfate Soils*

The Hornsby/Mona Vale Acid Sulfate Soil Risk Map – Edition 2 (DLWC, 1997) indicates that there is a high probability of occurrence of acid sulfate soil (ASS) materials within the bottom sediments of Narrabeen Lagoon. If these materials were to be disturbed (*e.g.* via dredging) there may be a severe environmental risk. South Creek itself is shown to have ASS material either within one metre from the surface (severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing) or between one and three metres (environmental risk if ASS materials are disturbed by activities such as deep excavations (DLWC, 1997). Soil investigations would be necessary to assess these areas for acid sulfate potential. The surrounding residential areas have no reported occurrences of ASS.

*Contaminated Soils*

The existing environment consists of medium-density residential land use, public open spaces and forested areas. A search of the EPA Contaminated Land Register showed two known contaminated sites within Warringah LGA (EPA, June 2007). However, neither of these sites falls within the South Creek catchment. The EPA Contaminated Land Record is not an exhaustive index, and there may be unreported contamination present in the site. However, given the residential history of the majority of the floodplain, the potential for the presence of contamination is considered to be a relatively low risk. However, a possible source of contamination would be from the landfill areas within the St Matthews Farm Reserve, the north-western corner of which abuts South Creek.

Appropriate levels of investigation would be required for any area where works are proposed in order to evaluate the potential for contamination at any particular location (in accordance with the Contaminated Land Management Act, 1997).

## 2.8 Water Quality, River Flow and Associated Objectives

*South Creek*

As outlined in **Section 2.2**, the catchment is largely urbanised (59%) (residential and commercial / light industrial development) with the remainder comprised of open space and forested areas (41%) (WMA, 2006). The upper regions of the catchment (largely forested areas) are steeper; with grades of approximately 5%. The lower part of the catchment is moderately flat (approximately < 1% gradient). The major drainage flow paths and drainage systems are described in Section 2.3.

The modified flow regime of the creek has led to severe erosion in some locations, sediment transport and deposition, and weed infestation. The severity of the weed infestation is partly a result of the release of excess nutrients and invasion of exotic plants from private properties. Water quality has been seen to be exceed nutrient trigger levels for

ecosystem health both in the upper and lower regions of the catchment (Total Nitrogen (0.98 mg/L): ANZECC (2000) trigger level (0.35 mg/L), Total Phosphorous (0.08 mg/L): ANZECC trigger level (0.025 mg/L)) (Warringah Council, 2003). In contrast, faecal coliforms are at acceptable levels in the upper catchment but progressively deteriorate down the creek (MWH, 2004).

Sources of pollutants impacting upon water quality include:

- "Point" Sources – *e.g.* discharges from premises licensed by the DECC (EPA) within the catchment under the Protection of the Environment Operations Act (1997)
- "Non Point" Sources – *e.g.* discharges from diffuse sources (such as build up of pollutants on road surfaces, runoff from fertilised gardens).

Currently, there are no licensed point sources in the catchment area under the PoEO register held by the EPA (EPA, 2007).

The South Creek catchment area makes up 14% of the total Narrabeen Lagoon catchment and is considered to be the most polluted discharge source into the Lagoon (MWH, 2004).

*Narrabeen Lagoon*

The water quality of Narrabeen Lagoon is primarily dependant on its nature as an intermittently open and closed lagoon. The entrance of the Lagoon is generally closed up by wave and storm action from the ocean, while flooding and stormwater run-off tend to open up the lagoon entrance. As a consequence of this, especially in times of low rainfall, the water quality of the Lagoon can rapidly deteriorate. The rapid residential expansion of the 1950's – 1980's and inadequate sewerage systems (*i.e.* nutrient run-off from septic tanks, polluted groundwater), has led to periodically occurring algal blooms in the lagoon (Gordon, 2006). Concerns over flooding and water quality prompted the development of procedures for the manual opening of the lagoon entrance by Council. This has assisted with improving water quality in parts of the lagoon through increased flushing.

Lagoon water quality is affected by freshwater input from catchment runoff and, to a lesser extent, the effects of wind re-suspension of the bed sediments. The Lagoon is moderately deep in parts (> 2m) limiting wind re-suspension of sediments affecting the concentration of suspended solids, which has the potential to affect nutrient concentrations in the water column. Sediments are also delivered to the estuary via inflows from the surrounding catchments. Approximately 80% of the Narrabeen Lagoon Catchment is undisturbed native vegetation (contrasting with the South Creek Catchment area which is predominantly urbanised, except for the upper reaches of Wheeler Creek). However, sewer overflows from urban areas can be a significant source of nutrients and bacteria which degrade water quality. Sewer overflows tend to occur mostly during wet weather when the sewerage system's design capacity is exceeded.

Monitoring of the lower reaches of Narrabeen Lagoon (near Birdwood Park) has been conducted under the DECC Beachwatch / Harbourwatch program. Compliance for 2005-2006 averaged 84% for faecal coliforms and 55% for Enterococci. Bacteriological contamination was found to be strongly associated with rainfall events (DECC, 2007a). Even low rainfall events produced bacterial levels to rise above the median acceptable levels. This is indicative of a dry weather contamination issue, largely driven by limited flushing of the lagoon and the large number of stormwater outputs into the Lagoon.

## 2.9 Flora, Fauna and Riparian Areas

Areas supporting native flora and fauna and riparian areas in the South Creek catchment are moderate in their extent. The open space corridor along the majority of South and

Wheeler Creeks are important links between Dee Why Valley and Garigal National Park. Due to their location and size these corridors are highly susceptible to edge effects, where encroachment from surrounding properties degrades the quality of the area. This has led to further fragmentation of corridor links in and between bush reserves. The upper reaches of the South Creek catchment retain some stands of natural vegetation, while Wheeler Creek has established bushland areas in the upper reaches.

*Flora*

The Natural Vegetation of the Sydney Area 1:100,000 vegetation series map (Benson & Howell, 1994) shows the Warringah LGA to be mainly cleared with only small sections of vegetation scattered amongst the urban development. The predominant vegetation as classified by Benson and Howell (1994) are Coastal Sandstone Heath (shrub members of the *Banksia* genus and *Allocasurina* genus) located in the upper catchment, small sections Sydney Sandstone Complex (open-forest eucalypt woodland to closed eucalypt forest) in the mid to upper reaches of the catchment, a section of Estuarine Complex located along the eastern border of Cromer Golf Course and cleared areas primarily located in the lower reaches of the catchment consisting of suburban development. The South Creek confluence with Narrabeen Lagoon supports stands of Swamp Mahogany (*Eucalyptus robusta*).

A search of the Atlas of NSW Wildlife (DECC, 2007b) on 14 May 2007 revealed 15 flora species listed under the *Threatened Species Conservation Act* 1995 (TSC Act) in the Warringah LGA (**Table 2.3**).

Of these, there were three species (Heart-leaved Stringybark (*Eucalyptus camfieldii*), Narrow-leaved Black Peppermint (*Eucalyptus nicholii*), and Magenta Lilly Pilly (*Syzygium paniculatum*)) recorded as observed near the southern and western borders of the South Creek catchment. Both *E. camfieldii* and *E.nicholii* are small eucalypts generally found on sandstone soils in open forest. In contrast, *S. paniculatum* is a small tree associated with wet rainforest areas and is quite rare (Robinson, 2003). Two species (*Tetratheca glandulosa* and *Pimelea curviflora var. curviflora*) have been identified in the native stands towards the upper reaches of the catchment. Both of these are small spreading shrubs found in woodland undergrowth. *P.curviflora var. curviflora* in particular is known to have a restricted range and is quite rare (Robinson, 2003). As described above, the South Creek confluence with Narrabeen Lagoon supports stands of Swamp Mahogany (*Eucalyptus robusta*). The Swamp Mahogany is not listed as a Threatened Species but is listed as a Protected Species under the *National Parks and Wildlife Act* 1974. It is also listed as a major feed tree for Koalas under State Environmental Planning Policy 44 (Koala Habitat Protection). As Koalas have been located in the Warringah LGA (see below), the preservation of the Swamp Mahogany in the South Creek catchment is important. Other fauna, such as gliders and quolls, also utilise Swamp Mahoganies.

The weed infestation within South Creek is considered to be severe in a number of reaches. Lantana (*Lantana camara*) is present along the length of the creeks as is Bamboo (*Bambusa spp*.). Of serious concern is the increase in *Ludwigia peruviana*, a rapacious spreading shrub, similar in nature to Lantana. *Ludwigia peruviana* reproduces both through germination and vegetatively off broken branches. It is renowned as causing great ecological damage around freshwater ecosystems (Robinson, 2003) Both Lantana and *Ludwigia peruviana* are classified as category W2 noxious weeds under the *Noxious Weeds Act* 1993. W2 category weeds are required to be fully and continually suppressed and destroyed.

The presence of algal species along the creek is common and of concern to local residents. Details of particular speciation were not available.

**Table 2.3 Threatened Flora Species Listed under the TSC Act (1995) in Warringah LGA**

| Scientific Name | Common Name | Legal Status |
|---|---|---|
| *Tetratheca glandulosa* | - | Vulnerable |
| *Epacris purpurascens var. purpascens* | - | Vulnerable |
| *Eucalyptus camfieldii* | Heart-leaved Stringybark | Vulnerable |
| *Eucalyptus nicholii* | Narrow-leaved Black Peppermint | Vulnerable |
| *Eucalyptus scoparia* | Wallangarra White Gum | Endangered |
| *Leptospermum deanei* | - | Vulnerable |
| *Syzygium paniculatum* | Magenta Lilly Pilly | Vulnerable |
| *Grevillea caleyi* | Caley's Grevillea | Endangered |
| *Callistemon linearfolius* | Netted Bottle Brush | Vulnerable |
| *Persoonia hirsute* | Hairy Geebung | Endangered |
| *Diuris bracteate* | - | Endangered |
| *Microtis angusii* | Angus's Onion Orchid | Endangered |
| *Pimelea curviflora var curviflora* | | Vulnerable |
| *Lasiopetalum joyceae* | | Vulnerable |
| *Chamaesyce psammogeton* | Sand Spurge | Endangered |

*Fauna*

The South Creek catchment, being heavily urbanised, does not provide extensive habitat for native fauna. Ground dwelling fauna have been severely reduced due to predation by non-native species. A search of the Atlas of NSW Wildlife (DECC, 2007b) on 14 May 2007 revealed 45 species as listed under the TSC Act in the Warringah LGA (**Table 2.4**). Of these 45, seven species (Red-Crowned Toadlet (*Heleioporus australiacus*), Powerful Owl (*Ninox strenua*), Beach Stone-curlew (*Esacus neglectus*), Eastern Freetail-bat (*Mormopterus norfolkensis*), Southern Brown Bandicoot (*Isoodon obesulus obesulus*), Grey-headed Flying-fox (*Pteropus poliocephalus*), and Rosenberg's Goanna (*Varanus rosenbergi*)) were found within the bounds of the catchment. Many of these were located in the upper catchment natural forest stands in the Red Hill Reserve. In addition to these sightings, Koala (*Phascolarctos cinereus*) and the Swift Parrot (*Lathamus discolor*) have been recorded in areas surrounding the catchment and are mobile enough to potentially utilise the catchment. This high density of protected species in the vicinity of the catchment, and the increasing expansion of residential areas, highlights the importance of conserving the available natural reserve areas.

**Table 2.4 Threatened Fauna Species Listed under the TSC Act in Warringah LGA**

| Scientific Name | Common Name | Legal Status |
|---|---|---|
| ***Amphibia*** | | |
| *Litoria aurea* | Green and Golden Bell Frog | Endangered |
| *Heleioporus australiacus* | Giant Burrowing Frog | Vulnerable |
| *Pseudophryne australis* | Red-crowned Toadlet | Vulnerable |
| ***Aves*** | | |
| *Pandion haliaetus* | Osprey | Vulnerable |

| Scientific Name | Common Name | Legal Status |
|---|---|---|
| *Botaurus poiciloptilus* | Australasian Bittern | Vulnerable |
| *Ixobrychus flavicollis* | Black Bittern | Vulnerable |
| *Esacus neglectus* | Beach Stone-curlew | Endangered |
| *Calyptorhynchus lathami* | Glossy Black-Cockatoo | Vulnerable |
| *Charadrius leschenaultia* | Greater Sand-plover | Vulnerable |
| *Charadrius mongolus* | Lesser Sand-plover | Vulnerable |
| *Ptilinopus superbus* | Superb Fruit-Dove | Vulnerable |
| *Ptilinopus magnificus* | Wompoo Fruit-Dove | Vulnerable |
| *Phoebetria fusca* | Sooty Albatross | Vulnerable |
| *Thalassarche cauta* | Shy Albatross | Vulnerable |
| *Thalassarche melanophris* | Black-browed Albatross | Vulnerable |
| *Haematopus fuliginosus* | Sooty Oystercatcher | Vulnerable |
| *Haematopus longirostris* | Pied Oystercatcher | Vulnerable |
| *Gygis alba* | White Tern | Vulnerable |
| *Sterna fuscata* | Sooty Tern | Vulnerable |
| *Sterna albifrons* | Little Tern | Endangered |
| *Xanthomyza Phrygia* | Regent Honeyeater | Endangered |
| *Melithreptus gularis gularis* | Black-chinned Honeyeater | Vulnerable |
| *Macronectus giganteus* | Southern Giant Petrel | Endangered |
| *Macronectus halli* | Northern Giant Petrel | Vulnerable |
| *Puffinus assimilis* | Little Shearwater | Vulnerable |
| *Puffinus carneipes* | Flesh-footed Shearwater | Vulnerable |
| *Lathamus discolour* | Swift Parrot | Endangered |
| *Calidris alba* | Sanderling | Vulnerable |
| *Calidris tenuirostris* | Great Knot | Vulnerable |
| *Ninox connivens* | Barking Owl | Vulnerable |
| *Ninox strenua* | Powerful Owl | Vulnerable |
| *Tyto novaehollandiae* | Masked Owl | Vulnerable |
| *Callocephalon fimbriatum* | Gang-gang Cockatoo | Vulnerable |
| ***Mammalia*** | | |
| *Eubalaena australis* | Southern Right Whale | Vulnerable |
| *Cercartetus nanus* | Eastern Pygmy-possum | Vulnerable |
| *Dasyurus maculatus* | Spotted-tailed Quoll | Vulnerable |
| *Mormopterus norfolkensis* | Eastern Freetail-bat | Vulnerable |
| *Isoodon obesulus obesulus* | Southern Brown Bandicoot | Endangered |
| *Physeter macrocephalus* | Sperm Whale | Vulnerable |
| *Miniopterus schreibersii oceanensis* | Eastern Bentwing-bat | Vulnerable |
| *Phascolarctos cinereus* | Koala | Vulnerable |
| *Pteropus poliocephalus* | Grey-headed Flying-fox | Vulnerable |

| Scientific Name | Common Name | Legal Status |
|---|---|---|
| ***Reptilia*** | | |
| *Chelonia mydas* | Green Sea-Turtle | Vulnerable |
| *Dermochelys coriacea* | Leathery Turtle | Vulnerable |
| *Varanus rosenbergi* | Rosenberg's Goanna | Vulnerable |

*Aquatic Flora and Fauna*

A variety of common fish species are likely to occur within the lagoon and riparian areas of the catchment. A desktop search of the Department of Primary Industries (NSW Fisheries) database revealed that there are no known threatened species listed in this catchment. The modified nature of the South Creek system presents considerable barriers to fish passage.

One barrier to fish passage is the Cromer Golf Course weir, separating the fresh and estuarine ecosystems. The weir was established some time ago to allow the golf course to access fresh water for irrigation. However, the golf course no longer utilises this facility. The weir has since become one of only two access points for pedestrians wishing to access the riparian walking track within the golf course grounds. Residents have raised concerns over both the safety of this passageway and the perceived "choking" effect it has on the creek; reducing flow rate and encouraging sediment build-up. The removal of the weir would reduce the extent of the freshwater ecosystem, by allowing penetration of brackish lagoon waters. The area immediately upstream of the weir was observed to be highly choked with invasive weeds.

The Adams Emerald Dragonfly (*Archaeophyta adamsi*) listed as vulnerable in NSW, is potentially found in the greater Sydney metropolitan area. However, this species has not been recorded within the South Creek catchment.

## 2.10 Tourism and Recreation

The Narrabeen Lagoon foreshore area caters for a variety of human users. Recreational users can be categorised into 'active' users (those who require a vehicle, equipment or watercraft for their activity) and 'passive' users (those users not requiring a watercraft, vessel or specialised equipment). The majority of users of reserves and open space areas along the foreshore are passive users. No detailed studies of recreational uses were located in preparing this report. However, recreational activities on the foreshore of the lower reaches of South Creek near the confluence with the lagoon are likely to include:

- passive use of reserve and open space;
- golf;
- shore-based recreational fishing;
- picnicking;
- bushwalking;
- sightseeing;
- bird watching;
- walking and jogging;
- cycling;
- dog exercising;
- organised / team sports; and
- other recreational (eg yoga / tai chi).

Recreational facilities / areas within South Creek catchment are primarily reserves, parks, Cromer Golf course, and picnic areas.

## 2.11 Indigenous and Non-Indigenous Cultural Heritage

*Indigenous Heritage*

Preliminary investigations regarding indigenous heritage were undertaken by searching the DECC's Aboriginal Heritage Information Management System (AHIMS) (14 May 2007) for known or potential Aboriginal objects or places within or surrounding the South Creek catchment. The search identified 34 Aboriginal objects and Aboriginal places recorded in the South Creek catchment.

The following qualifications apply to an AHIMS search:

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

Many of the items identified in the AHIMS search occur close to the creek, particularly in the upper reaches of the catchment and Wheeler Creek. Any plans which will modify the surrounding creek environs must take the location of these items into consideration. It is likely that these items relate to the Guringai people of the Eora Nation; the traditional owners of the South Creek Area. Consultation is required with Aboriginal people that have a cultural association to the area to discuss any proposed modification to the creek system that may have an impact on their heritage.

*Non-Indigenous Heritage*

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

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

The database searches and the Warringah Local Environment Plan 2000 list 165 heritage listed items. Of these only three were seen to fall within the South Creek catchment boundaries:

- Beacon Hill and Governor Phillip Lookout Reserves;
- Narraweena Primary School; and
- James Wheeler Grave.

These sites are shown on **Figure 2.3**.

The Beacon Hill and Governor Phillip Lookout Reserves are listed on the Register of the National Estate, and are significant for their geological fossil record (established in 1912), and occupy seven hectares in the upper reaches (southern boundary) of the catchment. The Narraweena Primary School is representative of the educational infrastructure development of the 1950s. It is located on the south eastern boundary of the catchment,

approximately one kilometre from the main flow-path of the creek. Neither of these items is likely to be impacted by flooding or flood modification options.

James Wheeler Grave is listed as a Heritage item within the Warringah Local Environment Plan 2000. It is significant as it represents a rare surviving grave of one of Warringah's earliest land holders (James Wheeler first settled the area in 1842). The grave formed part of the site of Wheeler's South Creek farm of which there is also some evidence surviving. While located close to the confluence of South Creek with Narrabeen Lagoon, the grave is located outside of the PMF extent (Figure 4.1) and is unlikely to be impacted by flooding or flood modification options.

Narrabeen Lagoon has been proposed as a potential area for National Heritage on the Register of National Estate (it is currently listed as *indicative – awaiting formal proposal*). Many of the surrounding areas of native vegetation (Deep and Middle Creek) have been protected by incorporation into the Garigal National Park.

## 2.12 Legislation, Policies, Plans and Codes

Legislation, policies and plans relevant to the Study are listed in **Table 2.5**. A brief description is given of those most relevant to the South Creek floodplain.

**Table 2.5 Details of Relevant Environmental Planning Instruments**

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| Department of Environment and Climate Change (DECC) and Department of Water and Energy (DWE) | *Water Management Act* 2000 | In December 2000, the NSW Parliament passed the *Water Management Bill* with various aspects being progressively implemented from 1 January 2001. This Act repeals or amends all of the legislation summarised below.<br><br>• *Drainage Act 1939 No 29*<br>• *Miscellaneous Acts (Water Administration) Amendment Act 1986 No 205*<br>• *Water Act 1912 No 44*<br>• *Water (Amendment) Act 1936 No 31*<br>• *Water (Amendment) Act 1940 No 57*<br>• *Water (Amendment) Act 1976 No 33*<br>• *Water (Amendment) Act 1979 No 159*<br>• *Water (Soil Conservation) Amendment Act 1986 No 143*<br>• Water Administration Act 1986 No 195. |
| DWE | *Rivers and Foreshores Improvement Act* 1948 | This Act aims to provide for the carrying out of works for the removal of obstructions from and the improvement of rivers and foreshores and the prevention of erosion of lands by tidal and non-tidal waters. It also attempts to make provision for payments to be made by owners of lands benefited by such works. It is to be eventually repealed under the *Water Management Act* 2000. |
| DECC | State Government Flood | Elements of the policy can be found in the |

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| | Prone Land Policy 2001 | Floodplain Development Manual (2005). The policy aims to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property. The manual provides council with the framework for implementing the policy. |
| DECC | *Native Vegetation Act* 2003 | This act is designed to protect native vegetation in non-urban land. In general:<br><br>• If a vegetation management plan provides native vegetation on any specified land to which the plan applies this may not be cleared without development consent,<br>• a person must not carry out clearing unless: (a) development consent has been obtained for the clearing and is in force, and (b) the clearing is carried out in accordance with the development consent and the regional vegetation management plan.<br>The Act does not apply to lands under Part 5 of the EP&A Act, SEPP14, SEPP26 or designated development or urban land. This Act repeals the legislation of the *Native Vegetation Conservation Act* 1997. Warringah LGA is listed under Schedule 1 of the act as land excluded from operation of the Act. |
| Department of Primary Industries (DPI) (NSW Agriculture) | *Noxious Weeds Act* 1993 | The *Noxious Weeds Act* 1993, aims to ensure appropriate measures for the control of noxious weeds throughout NSW. Declared noxious weeds are gazetted and must be disposed of in accordance with the guidelines. |
| Department of Local Government (DLG) | *Local Government Act* 1993 | The *Local Government Act* 1993, primarily administered by the Department of Local Government, gives local councils the power to control and regulate the drainage of land and to construct drains in their locality. |
| DECC – Environment Protection Authority (EPA) | *Protection of the Environment Operations Act* 1997(POEO) | Consolidates the key pollution statutes under a single Act. It repealed; the *Clean Air Act* 1961, the *Clean Waters Act* 1970, the *Environmental Offences and Penalties Act* 1989, the *Noise Control Act* 1975, the *Pollution Control Act* 1970, and incorporates the major regulatory provisions of the *Waste Minimisation and Management Act* 1995. The POEO Act enables the explicit protection of the environment policies (PEPs) and more innovative approaches to reducing pollution. The Act also provides a single |

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| | | licensing arrangement to replace the different licences and approvals under existing separate Acts. Integration of EPA licensing with the development approval procedures under the EP&A Act 1979 provides public participation in the environmental assessment of activities that may be licensed by the EPA. |
| Department of Environment and Water Resources (C'wth) | *Environmental Protection and Biodiversity Conservation Act* 1999 | Establishes the obligation to preserve native species and ecological communities that are listed as endangered or vulnerable. |
| Department of Planning (DoP) | *Environmental Planning and Assessment Act* 1979 | The EP&A Act includes aims and objectives which set the tone for the application of the Act. A set of standard LEP templates are also included which provides standard guidelines, definitions and controls. A range of sections of the Act are relevant to floodplain management including Sections 117 and 149. Direction 30 (February 2007) under Section 117 obliges LGA's LEPs to be consistent with regional environmental strategies. |
| DECC | *Threatened Species Conservation Act* 1995 | The objectives of this act include:<br>▪ to conserve biological diversity and promote ecologically sustainable development,<br>▪ to prevent the extinction and promote the recovery of threatened species, populations and ecological communities,<br>▪ to protect the critical habitat of those threatened species, populations and ecological communities that are endangered,<br>▪ to eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities,<br>▪ to ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed,<br>▪ to encourage the conservation of threatened species, populations and ecological communities by the adoption of measures involving co-operative management. |
| DECC – National Parks and Wildlife Service (NPWS) | *National Parks and Wildlife Act* 1974 | The primary piece of legislation that protects Aboriginal objects and places in NSW through provisions and offences. Other sections make provision for the protection of native flora and fauna not |

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| | | listed as threatened or endangered. |
| DPI – NSW Fisheries | *Fisheries Management Act* 1994 | The objectives of this Act are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations. In particular:<br>▪ to conserve fish stocks and key fish habitats,<br>▪ to conserve threatened species, populations and ecological communities of fish and marine vegetation, and<br>▪ to promote ecologically sustainable development, including the conservation of biological diversity. |
| SES | *State Emergency and Rescue Act* 1989 | This Act defines an emergency due to an actual or imminent occurrence (such as fire, flood, storm, earthquake, explosion, accident, epidemic or warlike action) which:<br>▪ endangers, or threatens to endanger, the safety or health of persons or animals in the State, or<br>▪ destroys or damages, or threatens to destroy or damage, property in the State, being an emergency which requires a significant and co-ordinated response.<br>▪ The act makes detailed provisions for planning and action during emergencies as outlined above. |
| DoP | State Environmental Planning Policy (SEPP) (Seniors Living) 2004 | This policy permits housing for seniors or people with a disability wherever houses, flats, hospitals and special uses are permitted in urban areas or adjoining urban areas, except for some environmentally sensitive areas. It allows for the setting aside of local planning controls within guidelines outlined in the SEPP. Where inconsistencies occur this policy prevails over other planning (e.g. Warringah LEP 2000).<br>From 24 May to 26 June 2007, the NSW Government exhibited a draft amendment to the Seniors Living SEPP. |
| DoP | Various applicable SEPPs including: 4, 14, 19, 33, 26, 35, 55, 71 | Specific sections of this report make reference to SEPPs as required. |
| DoP | Sydney Regional Environment Plan No. 21 – Warringah Urban Release Areas | Amended the Warringah LEP 1985 and upheld in the Warringah LEP 2000. Rezones certain areas for residential purposes in order to increase the supply of land to the housing market. The plan contains provisions to protect both Narrabeen Lagoon and Aboriginal objects from any adverse impacts from the |

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| | | development of these areas. Council is required to consider watercourse impact on proposed developments. |
| Local Emergency Management Committee | Manly, Warringah and Pittwater DISPLAN (2004) | A detailed review of the DISPLAN is provided in Chapter 7. |
| Warringah Council | Warringah Council Local Environmental Plan (LEP) 2000 | The LEP divides Warringah Shire into 73 Localities based upon distinctive features of their natural and synthetic environment. Each Locality has a Locality Statement providing objectives for the future development, its future character and the type and form of the new development. Each Locality Statement also includes the categories of land uses that are or may be consistent with the desired future character (Table 2.6), standards to control the built form of development in that Locality as well as listing any heritage items contained in the Locality.<br><br>It should be noted that all developments in all localities are subject to the compliance requirements of Schedule 12 of the LEP 2000. Schedule 12 is responsible for Requirements for complying development.<br><br>Section 47 of the LEP outlines that development on flood affected land is to be sited and designed to minimize impacts of flooding on property and have regard to the existing flood regime. In particular:<br><br>• development is not to reduce flood storage area or impact upon the existing flood regime,<br>• habitable floor areas of buildings are to be at a level of at least 500mm above the 1% annual exceedance probability flood level, and<br>• buildings or works affected by flooding are to be constructed of flood compatible building materials. Flood affected land refers to land below the 1% annual exceedance probability flood level.<br><br>Part 3 of LEP 2000 outlines the consent requirements for developing/modifying reserve land (Public, Open Space, Regional Open Space, Arterial Road Reservation and specific unique reserves). |
| Warringah Council | Warringah Development Control Plan *(2005)* | The development control plan supplements the LEP and provides greater development details. These may |

| Administrating Body | Name of Statute / Policy / Plan | Details |
|---|---|---|
| | | not specifically relate to the control or management of flooding but have been prepared under the framework of the relevant REPs and LEP. |
| Warringah Council | Management Plan *(2006-2009)* | There are various plans of management operate within Warringah Council for open spaces and recreational areas. |

**Plans of Management and other Relevant Studies:**

The spatial extent of coverage of the relevant Plans of Management is shown in **Figure 2.4**.

*PPK Environment and Infrastructure, (2001), The Warringah Non Urban Land Study*

This Non Urban Land Study was undertaken to guide existing and future uses of Warringah's non-urban land. The study involved a review and investigation of earlier studies and the development of long term objectives and a policy framework for the future of non-urban lands.

*Jamieson Park Plan of Management (2000)*

The Plan of Management provides the framework for managing Jamieson Park, (including the southern section of parkland east of South Creek). The park comprises Crown land (with Council as trustee) and public land owned by the Department of Planning (DoP). The park has significant environmental, biodiversity and scenic values creating a diverse range of opportunities for recreational activities. DoP land is important in terms of public purpose and this area also contains items of cultural heritage significance.

The plan identifies the park's key values, role and purpose so that these assets may be protected and enhanced. The park is environmentally sensitive and susceptible to change. The plan examines water catchment and flow and identifies specific opportunities for re-direction of flows and nutrients to constructed freshwater wetlands within reclamation areas to aid in preservation.

*Red Hill and Golden Groves Parks Plan of Management (2000)*

The Plan of Management provides the framework for managing the 17 hectare Red Hill & Golden Grove Parks located within Beacon Hill. The areas have extensive natural bushland and opportunities for recreation. The plan identifies the filled quarry at Red Hill Park as an area to be developed for passive recreation. This development was carried out in accordance with the adopted Plan of Management and was officially opened in June 2001. The environmental values of the parks are seen as significant with the presence of Duffy's Forest Vegetation Community - a community listed under the *Threatened Species Conservation Act* 1995.

*Dee Why Valley and South Creek Open Space Corridor - Geographic Plan of Management (Clouston, 1996)*

The Plan of Management provides the framework for managing Dee Why Valley and the South Creek Corridor. Dee Why Valley is the major contributing stream to Dee Why Lagoon and South Creek is one of the four major streams which feed Narrabeen Lagoon. The riparian vegetation and creeks are essential corridors for the native fauna. The presence of endangered species as well as potential suitable habitat for other endangered species

highlights the environmental importance of the areas. Indigenous heritage locations are identified for protection within the plan. Cultural integration (sporting ovals, parks and multi-use tracks) are included within the scope of the Plan of Management. The necessity to remove weeds and sediment in South creek to maintain creek health is stressed.

The updated Dee Why Valley and South Creek Plan of Management is due for public exhibition and adoption in early 2008.

*Montgomery Watson Harza, (2004), The Warringah Council Creek Management Strategy*

The Warringah Council Creek Management Strategy details land use in the area and changes to the creeks. It details characteristics of South Creek and Wheeler Creek water samples and lists desired outcomes for both of these creeks. It further details a management study and plan for South Creek. Specifically it notes that, with regards to South Creek, increases in peak flows have widened and incised the creek in some areas, preventing bank stabilisation and revegetation.

*The Wheeler Creek Valley Biodiversity Survey (National Parks Association of NSW Inc, 2001)*

This project involved a study of terrestrial and aquatic communities within the Wheeler Creek catchment area. The area is owned by Warringah Council, Metropolitan Local Aboriginal Land Council, DECC (crown land), and private owners. The vegetation was seen to be largely high quality bushland (mainly Sydney Sandstone Heath) although degradation increases down the valley from stormwater run-off, weed plumes and other processes associated with urban development. The survey confirmed that there are multiple aboriginal carvings in the area. Overall the conclusion of this study is that the catchment remains in a remarkably pristine condition.

In response to the observed high biodiversity within the Wheeler Creek Valley the Survey made several recommendations including:

- no developmental actions be taken that would remove or damage any habitat until more study has been undertaken;
- that Council ensure appropriate environmental protection designation of the area within its regional and local planning schemes;
- that Council initiates consultation with the Metropolitan Local Aboriginal Land Council about protecting Aboriginal engravings from vandalism;
- that Council ensure that all approved and existing developments conform to existing requirements;
- that Council encourages universities, schools and other organisations to undertake scientific research in the valley;
- that no change in management or transfer of Crown Lands to other parties is made that would pre-empt or diminish retention of the natural values and Aboriginal significance of the area; and
- that an action plan for long term management of the Wheeler Creek valley aimed at retaining and enhancing its natural values and Aboriginal significance is developed taking into account the findings of this survey.

These recommendation are inline with the subsequent Warringah Council Creek Management Strategy (MWH, 2004), Warringah Council Development Control Plan 2005, and this flood study.

**LEP Locality Objectives**

The South Creek catchment covers eight distinct LEP Localities. The nature of compliant development and developmental restrictions of those Localities within in the South Creek Catchment are described in **Table 2.6**.

**Table 2.6 LEP Locality Objectives**

| Locality | Objectives |
|---|---|
| **B1:** Frenchs Forest East | This Locality will remain characterised by detached style housing in landscaped settings interspersed by a range of complementary and compatible uses. The relationship of the locality to the surrounding bushland will be reinforced by protecting and enhancing the spread of indigenous tree canopy and preserving the natural landscape including rock outcrops, remnant bushland and natural watercourses.<br><br>Development compliant with the aims of the locality:<br><br>▪ Single storey detached houses, being:<br>- construction of new single storey houses.<br>- alterations to single storey houses.<br>- additions to single storey houses.<br>- construction of carports, garages and outbuildings associated with a dwelling.<br>▪ Attached houses and apartment buildings, being:<br>- internal alterations to attached houses and apartment buildings (excluding balcony enclosures and other devices which are externally visible).<br>- construction of garages associated with these residential buildings.<br>- outbuildings associated with these residential buildings.<br>▪ Swimming pools<br>▪ Business uses, offices and shops, being:<br>- a different use resulting from change of use from one type of approved business, office or shop use to another type of business, office or shop use.<br>- internal alterations to business premises,<br>- offices and shops. |
| **B2:** Oxford Falls Valley | Future development of this locality will be limited to new detached style housing. There will be no new development on ridge tops or in places that will disrupt the skyline when viewed from Narrabeen Lagoon and the Wakehurst Parkway. The natural landscape including landforms and vegetation will be protected and, where possible, enhanced. A dense bushland buffer will be retained or established along Forest Way and Wakehurst Parkway. Development in the locality will not create siltation or pollution of Narrabeen Lagoon and its catchment and will ensure that ecological values of natural watercourses are maintained.<br><br>Development compliant with the aims of the locality:<br><br>▪ Single storey detached houses, being:<br>- construction of new single storey houses.<br>- alterations to single storey houses.<br>- additions to single storey houses.<br>- constructions of carports, garages and<br>- outbuildings associated with a dwelling.<br>▪ Swimming pools |

| Locality | Objectives |
|---|---|
| **B7:** Narrabeen Lake Suburbs | Future development of the Locality will remain characterised by detached style housing in landscaped settings interspersed by a range of complementary and compatible uses which are compatible with the residential nature of the locality. The land occupied by the Cromer Golf Club will continue to be used only as a recreation facility.<br><br>Development compliant with the aims of the locality:<br><br>▪ Single storey detached houses, being:<br>- construction of new single storey houses,<br>- alterations to single storey houses,<br>- additions to single storey houses,<br>- constructions of carports, garages and outbuildings associated with a dwelling.<br>▪ Attached houses and apartment buildings being:<br>- internal alterations to attached houses and apartment buildings (excluding balcony enclosures and other devices which are externally visible).<br>- construction of garages associated with these residential buildings.<br>- outbuildings associated with these residential buildings.<br>▪ Swimming pools<br>▪ Business uses, offices and shops being:<br>- different use resulting from a change of use from one type of approved business, office or shop use to another type of business, office or shop use.<br>- internal alterations to business premises, offices and shops. |
| **B8:** Red Hill | Locality development will remain characterised by detached style housing in landscaped settings interspersed by a range of complementary and compatible uses. Future development will relate to the existing topography and be visually unobtrusive when viewed from afar. The streets will be characterised by landscaped front gardens and consistent front building setbacks. Development is to integrate with the remaining indigenous tree canopy and remnants of the natural landscape such as rock outcrops.<br><br>Development compliant with the aims of the locality:<br><br>▪ Single storey detached houses, being:<br>- construction of new single storey houses,<br>- alterations to single storey houses,<br>- additions to single storey houses,<br>- constructions of carports, garages and outbuildings associated with a dwelling.<br>▪ Attached houses and apartment buildings, being:<br>- internal alterations to attached houses and apartment buildings (excluding balcony enclosures and other devices which are externally visible).<br>- construction of garages associated with these residential buildings<br>- outbuildings associated with these residential buildings.<br>▪ Swimming pools |

| Locality | Objectives |
|---|---|
| **B10:** Narrabeen Lake | The Locality will be preserved in its natural state surrounded by areas of open space which complement the lake. Maintenance dredging and minor low intensity structures, such as viewing and fishing platforms constructed of sensitive materials and colours may occur within the locality. The foreshore areas comprising community land within the locality may be developed only in a manner that is consistent with the relevant community land plan of management.<br><br>Apart from the development described above, development will not occur within this locality. |
| **E3:** Cromer Industrial | The Cromer Industrial locality will remain an industrial and employment centre incorporating industries and ancillary service uses and a range of compatible community and leisure uses. The present industrial character of the locality with establishments in landscaped settings will be maintained. Future development will incorporate building design, site planning and landscaping to address the streets and soften the visual impact of industrial buildings and particularly their associated driveway entrances, parking and delivery/dispatch areas as viewed from the street and public spaces.<br><br>Development compliant with the aims of the locality:<br><br>▪ Industrial uses, being:<br>- a different use resulting from a change of use from one type of approved industry or warehouse to another type of industry or warehouse<br>- alterations to approved industrial and warehouse buildings. |
| **Reserved Land** | Some areas are classified as reserved from either Local, Regional, State or Federal request. Within the South Creek Catchment the LEP 2000 Map indicates areas of Public Open Space, Open Space Reservation, Regional Open Space Reservation and Arterial Road Reservation. Consent for development must be obtained from Council or the relevant regulatory authority for development of these areas. |

## 2.13 Demographic Characteristics

The demographic characteristics of a catchment are an important consideration when developing a Floodplain Risk Management Plan. It is important to understand the current and past demographic trends such that flood management can be implemented appropriately (*i.e.* there is little point investing significant resources into a floodplain where the population is steadily decreasing).

Population size and past population increase or decline is important when considering the current and future flood risk in a floodplain. It is also important to consider demographic characteristics when preparing emergency response or evacuation procedures (*i.e*. information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community).

Demographic characteristics of the South Creek catchment based on the three suburbs comprising the catchment (Narraweena, Beacon Hill, and Cromer) are listed in **Table 2.7**. The catchment area does not encompass any of these suburbs entirely but is comprised of

sections of each. The major areas affected by flooding fall within the suburb of Cromer. Additional information is based on the Warringah LGA as a whole. Data was sourced from the Australian Bureau of Statistics 2001 Census.

In summary census data revealed that:

- There was little change in the population structure of the South Creek Catchment between 1996 and 2001. Population size growth is average at 7.6%. The age structure of the population for the suburbs composing the South Creek is shown in **Table 2.7**.

- Approximately 25% of the population of the South Creek catchment was born outside Australia, with most immigrants coming from the United Kingdom. Other significant sources of immigrants were Italy, New Zealand, and China.

- English is spoken in at least 80% of homes in the catchment area. Of the non-English speaking homes the most common languages are: Italian (2.5%), Chinese (2.3%), Serbian (0.6%), and Japanese (0.5%).

- Of the minor languages spoken at home, only Italian and German decreased the frequency of their use. Most significantly, the number of residences speaking Chinese at home increased by 4.4% in 2001 in comparison to 1996.

**Table 2.7 Demographic and Population Characteristics of the South Creek Catchment**

| POPULATION CHARACTERISTICS | NUMBERS |
|---|---|
| Total population(a) | 19,778 |
| Males(a) | 9,663 |
| Females(a) | 10,115 |
| Aboriginal population | 69 |
| Australian born | 13,962 |
| Overseas born(b) | 4,933 |
| Australian citizens | 17,586 |
| Australian citizens aged 18+ | 13,121 |
| Institutional population | 174 |
| **AGE DISTRIBUTION** | |
| Infants and children 0 to 17 years | 4,926 |
| Adults 18 to 64 years | 12,035 |
| Mature adults 65 years and over | 2,843 |
| **HOUSEHOLDS** | |
| Average household size (persons) | 2.84 |

| POPULATION CHARACTERISTICS | NUMBERS |
|---|---|
| Dwellings (total) | 7,213 |
| Owned | 3,374 |
| Purchasing | 1,824 |
| Renting | 1,271 |

(a) Includes overseas visitors.
(b) Includes 'Inadequately described', 'At sea', and 'Not elsewhere classified'.

# 3. CONSULTATION

A range of consultation has been and is to be undertaken as part of South Creek Flood Study (WMA, 2006) and the Floodplain Risk Management Study, including:

- Stakeholder Consultation through the Narrabeen Lagoon Joint Estuary Floodplain Management Committee;
- Community Consultation in the Field;
- Community Surveys; and
- Public Exhibition.

## 3.1 Stakeholder Consultation

The Floodplain Risk Management Committee responsible for South Creek is the Narrabeen Lagoon Joint Estuary Floodplain Management Committee. The Committee is comprised of various Council, Community and Stakeholder representatives. The composition of the committee consists:

- Warringah Council
  - Warringah Council Mayor
  - Two (2) Councillors
  - Director Services Group (or nominee)
- Pittwater Council
  - Pittwater Council Mayor
  - Two (2) Councillors
  - Director Urban and Environmental Assets (or nominee)
  - Director Environmental Planning and Community (or nominee)
- Administrative Support (non voting)
  - To be provided by Chairman's Council
- External
  - Eleven (11) community representatives.
  - Five (5) Stakeholder representatives;
    - one (1) Narrabeen Lagoon Committee/Northern Beaches Catchment Management Committee,
    - one (1) Manly Warringah Kayak Club,
    - one (1) Narrabeen Lakes Chamber of Commerce,
    - one (1) Narrabeen Lakes Sailing Club,
    - one (1) Anglers Action Group
  - Six (6) citizen members;
    - three (3) Warringah Council area
    - three (3) Pittwater Council area.
  - Seven (7) State Government representatives including:
    - Department of Environment and Climate Change (Specialist Flood Group)
    - Department of Planning
    - Sydney Water Corporation
    - Environment Protection Authority (DECC)
    - National Parks and Wildlife Service (DECC)
    - NSW Fisheries (DPI)
    - NSW Academy of Sport.

For this Floodplain Risk Management Study, an initial presentation was given to the committee by the study team in 2005. During an unforseen revision of the flood study, the floodplain risk management study was suspended and a further presentation was given to the Committee on 17 May 2007 by the study team, presenting a range of floodplain and bank management options. The draft FRMS&P were presented to the committee on 22 November 2007. Feedback was received informally during the meeting on these options and incorporated into the preparation of the draft report.

## 3.2 Community Consultation

Community consultation has been undertaken on numerous occasions in various manners throughout out the Flood Study and the Floodplain Risk Management Study. Community consultation included:

- Liaison with community representatives on the Narrabeen Lagoon Joint Estuary Floodplain Management Committee;
- Community Survey during the Flood Study;
- Community Brochure and Survey during the Floodplain Risk Management Study;
- Discussions with residents during field investigations; and
- Public exhibition of the Flood Study.

This will be supported by consultation during the exhibition of the Floodplain Risk Management Study and Plan.

*Community Survey – Flood Study*

As part of the Flood Study (WMA, 2006) an extensive community survey was carried out consisting of:

- advertisements in the local papers;
- a notice on Council's web site;
- a combined newsletter and questionnaire; and
- follow up phone calls and interviews with selected respondents.

The questionnaire was sent to those residents who lived within close proximity of the creek as well as to members of local community groups. Follow up telephone calls were made to those respondents who advised that their property had been inundated in the past or those who indicated that they knew levels of previous floods.

The purpose of the community consultation during the Flood Study phase was primarily to canvas the community to obtain details of historical flood levels and flooding behaviour.

Flood affected areas and related issues highlighted by the community and through the local resident survey undertaken during the Flood Study were:

- Wabash Reserve and other reserves adjacent to the creek.
- Carcoola Road Bridge
- Alkira Circuit Bridge
- Inundation of Cromer Golf Course
- Other issues include water quality and maintenance, gross pollutants and erosion.

*Community Brochure and Survey – Floodplain Risk Management Study*

Community consultation was undertaken in June 2007 by distributing an information brochure including a questionnaire within the extent of flood prone land (including some surrounding properties) in the South Creek Catchment. The brochure provided an outline of the floodplain risk management process and the objectives of this study. The questionnaire sought information about a particular recent flooding event (April 2007) and feedback on possible floodplain management options for the floodplain (described in full in **Section 8**). The brochure and questionnaire were delivered to approximately 850 letterboxes in the floodplain. Of these, 37 questionnaires were returned.

**Appendix A** contains a copy of the brochure.

A number of responses to the questionnaire provided comments on the proposed overland flow management options. These responses are presented in **Appendix B** (note that the names and addresses of the respondents have been removed to maintain privacy). **Table 3.1** summarises the rank assigned for each option according to the preference score provided in the responses and the number of responses for each option.

It should be noted that the community responses provided represent the community's preference for flood management options and the responses may not be informed by a detailed understanding of flood risks (*i.e.* likelihoods and consequences). Further more, the community surveys did not target those people directly affected by potential measures such as levees. A more comprehensive understanding of the community's preferences will be achieved through the public exhibition of this draft Floodplain Risk Management Study.

**Table 3.1 Resident Survey Summary**

| Option | Average Score | Rank |
|---|---|---|
| Removal of weeds from South Creek to improve creek flow. | **4.86** | **1** |
| Ongoing maintenance of stormwater pipes and culverts under bridge to reduce the likelihood of blockages during a flood event. | **4.82** | **2** |
| Creek widening and revegetation upstream of Toronto Ave to improve creek flow. | **4.57** | **3** |
| Widen the creek beneath the Toronto Ave road bridge to improve creek flow. | **4.28** | **4** |
| Rehabilitate creek and construct wetland on the right bank of South Creek between Carcoola Rd and Toronto Ave (to provide flood storage). | **4.33** | **5** |
| To reduce sediment loads, install a sediment retention basin upstream of Carcoola Rd. | **4.06** | **6** |
| Ongoing collection of flood information. | **4.48** | **7** |
| Increase stormwater flow under Carcoola Rd bridge, Willandra Rd bridge (upper and lower) and Alkira Cr bridge by increasing the culvert size. | **3.91** | **8** |
| Regrade part of the creek bank and portions of the Reserve along South Creek between Willandra Rd and Carcoola Rd to protect properties (the reserve would still be usable). | **4.00** | **9** |
| Ongoing implementation for development control and guidelines for building work. | **4.06** | **10** |
| Community education and awareness programs | **4.16** | **11** |
| Revision of SES Disaster Plan (DISPLAN) | **4.10** | **12** |
| For increase in flood storage, minor excavation on Council land (for example at corner of Willandra Rd and Ara Cres, areas would be returfed). | **3.61** | **13** |
| To improve creek flow, widen the creek at the confluence of South and Wheeler Creek and remove island. | **3.52** | **14** |
| Flood depth markers placed on both sides of all roads crossing the creeks. | **2.88** | **15** |
| Levees (up to two metres high) on Council land to protect properties. | **2.50** | **16** |

| Option | Average Score | Rank |
|---|---|---|
| Voluntary House Purchase Program (State Government Funded). | **2.57** | **17** |
| Voluntary House Raising Program (State Government Funded). | **2.59** | **18** |
| Provision of levee bank adjacent to Cromer Golf Course to reduce flooding of the course. | **2.22** | **19** |

**Note:** The community survey requested a response with a score from 1 to 5. The multi-criteria matrix scoring system (further detailed in **Section 14**) utilising a scoring system from -5 to 5. The community scores provided in this table have been adjusted to comply with the matrix scoring system. Due to the uncertainties and small number of responses, the community score in the matrix was weighted by 0.5. This weighting may be adjusted as a result of the responses received during the public exhibition period.

*Consultation during Site Investigations*

Detailed site investigations have been carried out on several occasions as part of the Floodplain Risk Management Study. During the time in the field consultants have spoken to numerous residents and visitors to the area about their experience with flooding along South Creek and their general concerns regarding flooding.

*Public Exhibition of Draft Floodplain Risk Management Study and Plan*

This draft report and the Floodplain Risk Management Plan, once adopted by Council for exhibition, were publicly exhibited for a period of one month at a range of locations. During this period Council arranged a community workshop to display the draft reports and made two Council representatives and one consultant available for the evening.

Those community members within the floodplain were given notification of the workshop via a mail-out. Approximately 20 community members attended the workshop.

A feedback form was made available during the public exhibition period. 17 individual responses were received along with a combined response from the residents of Ara Crescent. A number of written submissions were also received from residents and local community groups.

A summary of the responses is provided in **Appendix B**.

Comments received as a result of the exhibition period have been incorporated with the previous submissions and used in the finalisation of the reports.

*Dee Why Valley and South Creek Open Space Plan of Management Issues and Options Discussion Paper*

The Dee Why Valley and South Creek Open Space Plan of Management Issues and Options Discussion Paper were publicly exhibited from 2nd June until the 18th of June 2007. A summary document was prepared based on the comments page which was included in the issues and Options Discussion Paper. There were a total of 36 submissions.

With regard to issues and submissions that relate to this Floodplain Risk Management Study, the following actions were considered to be a priority:

- flood management and bank stabilisation (ranked 4th);
- removal of weeds and the replanting of native vegetation (ranked 1st and 2nd);
- creating a picnic ground at Lidwina Reserve (ranked 5th);
- South Creek Foreshore actions; and
- accessibility and use of reserves.

The following additional comments were also made:

- need to manage sedimentation of the creeks flowing into the lagoon;
- retain Lidwina Reserve for riparian access;
- agree to remove weir and bridge should be built to replace weir; and
- remove lantana completely from South Creek reserve.

The Dee Why Valley and South Creek Open Space Plan of Management will be publicly exhibited and adopted in early 2008. The South Creek Management Plan and the Plan of Management are complimentary and can be implemented and read in conjunction with one another.

# 4. EXISTING FLOOD BEHAVIOUR AND IMPACTS

## 4.1 Background

Full details of the flood modelling for the existing conditions can be sourced from the Final South Creek Flood Study (WMA, 2006).

The flood models established for the flood study formed the basis for:

- mapping of flood extents for existing conditions (**Section 4.7**);
- flood hazard and hydraulic categorisation for existing conditions (**Section 4.8**);
- flood damages assessment (**Section 5**);
- flood planning level determination (**Section 6**); and
- the hydraulic assessment of some of the flood modification options (**Section 9**).

The main natural tributaries that drain the catchment and which are included in the model are:

- South Creek; and
- Wheeler Creek.

## 4.2 Existing Flood Behaviour

Flooding of South Creek is caused by a combination of geographic features of the catchment, along with development-induced issues, causing a complex system of flow regimes and flooding mechanisms.

The characteristics that determine the existing flooding behaviour are detailed below.

## 4.3 Upper Reaches Character

The South Creek catchment is relatively steep for the majority of its length, with only a very small flat floodplain in its lower reaches. The steep slopes lead to rapid response times (*i.e.* the time from the commencement of rainfall to the peak flood level in an event is short). Steep catchment slopes result in short lead times for the flow to reach the main waterways. Once floodwaters enter the main waterways they also achieve high velocities (up to 4 m/s) due to the steep slopes of the creeks.

The combination of the slope and distance gives the catchment complex hydrograph timing which requires the use of fully dynamic hydraulic modelling systems to replicate the behaviour. The timing of all local hydrographs affects the flood levels in the lower reaches of the catchment, where the arrival of coincidental peak flows from upstream catchments and local catchments can lead to elevated peak flood levels.

## 4.4 Lower Reaches and Narrabeen Lagoon

In addition to runoff from the catchment, the reach of South Creek flooding downstream of Toronto Avenue can also be influenced by “backwater” effects resulting from Narrabeen Lagoon flooding. These two distinct flooding mechanisms may or may not result from the same storm. The South Creek catchment is much smaller in size (7.3 $km^2$) compared to the total area draining to Narrabeen Lagoon (54.7 $km^2$). Hence, for a given flood event, it is more likely that the Lagoon level would peak after the corresponding flood peak occurs in South Creek. However, this may not necessarily be the case. A conservative approach was adopted in the Flood Study (WMA, 2006), which assumed that the peak catchment flood level occurred concurrently with the peak Narrabeen Lagoon flood level (see **Table 4.1**).

**Table 4.1 Design Flood Levels - Narrabeen Lagoon (WMA, 2006)**

| Event | Flood Level (mAHD)<br>At Entrance to South Creek |
|---|---|
| PMF | 4.6 |
| 100 Year ARI | 2.9 |
| 50 Year ARI | 2.7 |
| 10 Year ARI | 2.22 |
| 5 Year ARI | 2.0 |

## 4.5 Conduit Blockage

Given the combination of urban development and natural bushland within the catchment, the potential blockage of culverts and stream crossings by debris can increase the flood levels experienced along both creeks.

The issue of culvert blockages is particularly relevant for South Creek. Field observations and related anecdotal evidence indicates that:

- Sedimentation is known to have partially blocked culverts at Carcoola Road and on Little Willandra Road (Wheeler Creek). In response to complaints Council has undertaken periodic cleaning of both sets of culverts;
- Accumulated vegetative debris has been observed at several of the crossings;
- One cell of the culverts at McIntosh Road is protected by a “cage” style debris control structure; and
- Numerous resident reports of partial culvert blockage occurring in the past have been recorded.

To quantify the impacts of potential blockages on design flood behaviour, several different blockage scenarios (**Table 4.2**) based on the 100 Year ARI event were simulated in the Flood Study (WMA, 2006) using the hydraulic model.

**Table 4.2 Blockage Assessment Modelling Scenarios – 100 Year ARI (WMA, 2006)**

| **Scenario** | Description |
|---|---|
| Base Case | No blockages |
| Scenario 1 | All culverts blocked except McIntosh Rd and Toronto Ave bridge |
| Scenario 2 | Only McIntosh Rd blocked |
| Scenario 3 | All culverts blocked except Toronto Ave Bridge |

The Flood Study (WMA, 2006) results indicated, as expected, that the inclusion of 100% blockage at all culverts has significant localised impacts on flood levels in the vicinity of all stream crossings. A detailed analysis of the detention capacity of the McIntosh Road basin was beyond the scope of the present study. However, the preliminary assessment undertaken as part of the Flood Study (WMA, 2006) indicates that the basin offers little detention capability for the 100 Year ARI event and it was recommended that the results from Scenario 3 be adopted for the establishment of design flood levels.

Hence, hydraulic modelling as part of the Flood Study (WMA, 2006) was undertaken for all other design events (5, 10 and 50 Year ARI and PMF) using the Scenario 3 blockage conditions.

Similarly, all hydraulic modelling undertaken for the assessment of Floodplain Risk Management Options within this study has been undertaken using the Scenario 3 blockage conditions.

## 4.6 Hydrologic and Hydraulic Modelling

The Flood Study (WMA, 2006) utilised two numerical modelling tools for flood assessment. The WBNM model was used for the purposes of hydrological modelling of the entire catchment and the one-dimensional hydraulic model, MIKE11, was used to estimate the flood levels and velocities throughout the floodplain.

The establishment of the MIKE11 model included the incorporation of various structures across the channel including:

- various pipe and box culverts;
- cross catchment flood connections and bypass mechanisms; and
- footbridges and the like across the channel.

Consistent with the quality and availability of historical flood data, the April 1998 event was used for calibration of the MIKE-11 model. Only a single reported flood level was available for the March 2003 flood. Despite the lack of data, this event was also run to provide a limited form of model verification.

The hydraulic model was then used with design rainfall conditions to simulate flood behaviour.

The flood behaviour for the 5, 10, 50 and 100 Year ARI and the extreme flood event (PMF) were investigated and the flood study determined the nature and extent of flooding for each event through the estimation of design flows, levels and velocities.

## 4.7 Flood Extent

Flood extents were prepared as part of the Flood Study (WMA, 2006) for the 5, 10, 50 and 100 Year ARI and PMF design events. The extent of the various design flood events is shown in **Figure 4.1**.

Flood levels were calculated at each cross section in the hydraulic model. The flood levels between the cross sections were calculated by interpolating between the calculated cross sections. Flood extents were determined using the interpolated cross sections and available ground survey.

It should be noted that the flood extent accuracy on individual properties may be refined further by property owners collecting detailed ground survey.

## 4.8 Flood Hazard and Categorisation

Flood Hazard and Hydraulic Categories were defined and mapped for the 100 Year ARI event. For the purposes of floodplain risk management in NSW, the floodplain is divided into one of three Hydraulic categories (floodway, flood storage or flood fringe) and two Hazard categories (Low or High).

Provisional ‘flood hazard’ was assessed within part of the Flood Study (WMA, 2006) in accordance with Appendix L of the Floodplain Development Manual (NSW Government, 2005). Hazard assessment was based on a relationship between the depth and velocity of floodwaters (Provisional hazard = depth x velocity). Two categories for provisional hazard (High and Low) were defined.

The Hydraulic categorisation was based on the hazard categories such that:

- Low Hazard = Flood Fringe; and
- High Hazard = Floodway.

Due to the steep nature of the catchment no Flood Storage was defined in the floodplain.

The 100 Year ARI Hazard and Hydraulic Categories are shown on **Figure 4.2**.

## 4.9 Property Flooding

The number of properties affected by flooding (by inundation of at least the garden area) is shown in **Table 4.3**. There are numerous vacant lots along the riparian corridor of South Creek and there are also several multi-dwelling properties within the floodplain, as such **Table 4.3**, also presents the number of buildings with over-floor flooding.

**Table 4.3 Properties Currently Affected by Flooding**

| Flood Event | No. of Flood Affected Properties | No. of Buildings with Over-Floor Flooding |
|---|---|---|
| 5 Year ARI | 65 | 14 |
| 10 Year ARI | 80 | 18 |
| 50 Year ARI | 112 | 32 |
| 100 Year ARI | 129 | 42 |
| PMF | 276 | 185 |

The range of over-floor flooding depths for the design events is shown below in **Table 4.4**.

**Table 4.4 Depth of Over-Floor Flooding**

| Depth (m) | 5 Year ARI | 10 Year ARI | 50 Year ARI | 100 Year ARI | PMF |
|---|---|---|---|---|---|
| 0.0 to 0.2 | 6 | 8 | 13 | 16 | 14 |
| 0.2 to 0.4 | 5 | 6 | 7 | 11 | 14 |
| 0.4 to 0.6 | - | 1 | 5 | 4 | 21 |
| 0.6 to 0.8 | 1 | - | 3 | 6 | 22 |
| 0.8 to 1.0 | 1 | 1 | 1 | 1 | 15 |
| 1.0 to 1.2 | 1 | 2 | 1 | 1 | 17 |
| 1.2 to 1.4 | - | - | 1 | 1 | 23 |
| 1.4 to 1.6 | - | - | 1 | 2 | 13 |
| 1.6 to 1.8 | - | - | - | - | 11 |
| 1.8 to 2.0 | - | - | - | - | 15 |
| 2.0 to 2.2 | - | - | - | - | 5 |
| 2.2 to 2.4 | - | - | - | - | 6 |
| 2.4 to 2.6 | - | - | - | - | 4 |
| 2.6 to 2.8 | - | - | - | - | 1 |
| 2.8 to 3.0 | - | - | - | - | - |
| 3.0 to 3.2 | - | - | - | - | 3 |
| 3.2 to 3.4 | - | - | - | - | - |
| 3.4 to 3.6 | - | - | - | - | - |
| 3.6 to 3.8 | - | - | - | - | 1 |

## 4.10 Major Access Road Flooding

There are a number of major access roads leading into and traversing the South Creek floodplain including:

- South Creek Road
- Willandra Road
- Toronto Avenue
- Little Willandra Road; and
- McIntosh Road.

South Creek Road traverses the edge of the floodplain at the downstream end of the catchment. Inundation of South Creek Road is not likely to occur on a frequent basis and would only affect a limited number of properties.

Willandra Road is major access road for the area. It is likely to be flood affected at the two locations where it crosses South Creek. Blockage of the culverts at these locations could result in considerable depths of flooding on the road.

Little Willandra Road is another major access road for the western portion of the catchment and floodplain. Little Willandra Road is likely to be inundated where it crosses Wheeler Creek.

A number of smaller roads cross South Creek including Toronto Avenue and McIntosh Road. These crossing are likely to be inundated, particularly as a result of culvert blockage.

The peak flood depths at these critical locations and duration of road flooding are shown in **Table 4.5**. It should be noted that overtopping occurs at most creek crossings for all events due the 100 percent blockage policy applied in the Flood Study. **Section 4.5** provides more detail on the blockage policy adopted. Further, the road continues to be overtopped for an extended period of time due to the blockage. The duration of road flooding shown in **Table 4.5** is the duration of flooding of the road to a depth of 0.1 metres or greater.

**Table 4.5 Major Access Road Flooding**

| | PMF | | 100 Year ARI | | 50 Year ARI | | 10 Year ARI | | 5 Year ARI | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Road** | **Peak Depth (m)** | **Duration[1]** | **Peak Depth (m)** | **Duration[1]** | **Peak Depth (m)** | **Duration[2]** | **Peak Depth (m)** | **Duration[2]** | **Peak Depth (m)** | **Duration[2]** |
| South Creek Road | 2.26 | 13 hr[3] | 0.53 | 12 hr[3] | 0.38 | 4 hr[3] | 0.05 | - | - | - |
| Willandra Road (lower) | 1.68 | 4.5 hr | 0.88 | 6 hr | 0.82 | 6.5 hr | 0.70 | 6.25 hr | 0.65 | 6.25 hr |
| Willandra Road (upper) | 1.90 | 5 hr | 0.94 | 6 hr | 0.87 | 5.5 hr | 0.74 | 5.5 hr | 0.68 | 5.25 hr |
| Little Willandra Road | 2.36 | 4.75 hr | 1.00 | 5.5 hr | 0.92 | 5 hr | 0.75 | 4.75 hr | 0.68 | 4.75 hr |
| Toronto Avenue | 2.38 | 2.5 hr | 0.04 | 10 min | - | - | - | - | - | - |
| McIntosh Road | 1.36 | 3.25 hr | 0.72 | 3.75 hr | 0.67 | 3.75 hr | 0.58 | 3.5 hr | 0.53 | 3.5 hr |

[1] The duration of road flooding shown is for the flood event which produced the peak flood depth, longer durations of overtopping may be experienced in longer events.
[2] In accordance with the Flood Study (WMA, 2006) only the 2 hour duration was run for the 50, 10 and 5 Year ARI flood events. Therefore duration of overtopping was only determined for the 2 hour duration storm event.
[3] Lagoon flooding dominates at this location; the critical duration flood event in the Lagoon is 12 hours for the PMF and 36 hours for the other events (PWD, 1990). The duration of overtopping was calculated assuming the peak flood level occurred at 36 hours and 12 hours for the PMF and all other events respectively and that the water levels increased and decreased linearly from and to 1 mAHD.

# 5. FLOOD DAMAGES AND INCONVENIENCE

## 5.1 Background

In the past, flooding of South Creek has caused property damage, blocked access and has been a general inconvenience to residents.

The economic impact of flooding can be defined by what is commonly referred to as 'flood damages'. **Table 5.1** categorises the various types of flood damages.

**Table 5.1 Types of Flood Damages**

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

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

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been used with assistance from DECC on the adoption of appropriate damage curves.

## 5.2 Floor Level and Property Survey

A detailed floor level and property survey was undertaken by Mepstead & Associates in June 2004. During the Flood Study, the original 2002 survey data was supplemented with additional ground survey undertaken in June 2004. The additional ground survey effectively extended the 2002 base data to cover the estimated flood extent.

Some of this data was collected by field survey and some by photogrammetric survey. The data set provided does not distinguish which points were by field survey and which were by photogrammetry.

In June 2007 additional floor level survey was collected by Cardno. The additional ground survey again extended the combined 2002 and 2004 data sets to cover the defined floodplain (PMF extent) for the existing conditions.

The floor level survey data includes details of each property including an evaluation of the type of property based on exterior characteristics as well as the building floor levels.

**Appendix C** provides floor level and property details for the South Creek floodplain.

## 5.3 Damage Analysis

The flood damage assessment was undertaken for the existing catchment conditions and for a number of flood management options. 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 recourse is generally made to damage curves from other catchments. DECC has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The DECC methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. However, correspondence at the outset of this project with DECC (then DNR) confirmed that the use of DECC curves was appropriate.

The following sections set out the methodology for the determination of damages within the South Creek floodplain.

### 5.3.1 Residential Damage Curves

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

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

Based on the property survey undertaken, there were several two storey, high-set, houses identified within the floodplain. To preserve the conservative nature of the study these houses were assessed using the two storeys, slab on ground, damages curve.

Damages are generally incurred on a property prior to any over-floor flooding. The DECC curves allow for a damage of $7,973 (February 2007 dollars) to be incurred when the water level reaches the base of the house (where the base of the house is determined as 0.5m below the floor level for slab on ground and 1.5m below the floor level for high-set). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up). According to the damage curves this amount of damage remains constant from the base of the house to the floor level of the house. It should be noted that the number of houses affected by over-ground flooding is significantly greater than those affected by over-floor flooding (**Table 4.3**).

Under this calculation method, the DECC curve this would result in $7,973 worth of damage for each property for a disproportionately large number of properties in the catchment. Similarly, this method does not accurately take into account the cost of garden damage for those properties where floods affect some portion of the property but do not approach the base of the house levels. Damages in these cases are likely to be substantially less than $7,973. This approach was considered to be unrealistically conservative. To account for these biases, external damages (those suffered from property flooding below floor level) were uniformly valued as $3,000 each. This figure was seen to

be an acceptable mean figure of all external damage. Over-floor flooding damage value was calculated as per the DECC curves.

Cromer Primary School (Dorothy Street, Cromer) lies within the South Creek floodplain and was incorporated as several large residential blocks to approximate the likely flood damage value that could be incurred.

**Other Parameters**

There are a number of input parameters required for the development of DECC curves, such as floor area and level of flood awareness. The DECC recommended default parameters have generally been adopted for this study. The average house size for Sydney is 240m$^2$ (Table D2, Draft DNR Guidelines, 2004). However, experience across Sydney suggests a floor area of 150m$^2$ is a conservative estimate of the floor area for residential dwellings within the floodplain. This value is based both on observations by surveyors and aerial photography. This value was considered representative for the South Creek floodplain.

With a floor area of 150m$^2$, the default contents value is $37,500. To account for the study area being a relatively wealthy area, this value has been increased to $50,000.

The Effective Warning Time has been assumed to be zero. A long Effective Warning Time allows residents to prepare for flooding by moving valuable household contents (*e.g*. the placement of valuables on top of tables and benches). The estimation of zero warning time is based on the steep nature and fast response of the catchment.

The South Creek Catchment is within a large metropolitan area, and it is assumed that there are no post-flood inflation costs. 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.

Larger dwellings, such as multi-unit housing, are not specifically accommodated under the DECC guidelines. The damage curve for a single storey, slab on ground house has therefore been used as an approximation of the damage of the apartments/ townhouses within the floodplain.

**Average Weekly Earnings**

The DECC curves are derived for late 2001, and were updated to represent August 2007 dollars. General recommendations by DECC are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). DECC proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for February 2007. Therefore all ordinates in the residential flood damage curves were updated to February 2007 dollars. In addition, all damage curves include GST as per DECC recommendations.

While not specified, it has been assumed that the curves provided by DECC were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the DECC guidelines, and February 2007 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au) (**Table 5.2**).

**Table 5.2 AWE Statistics**

| Month | Year | AWE |
|---|---|---|
| November | 2001 | $898.50 |
| February | 2007 | $1,070.40 |
| | | |
| Change | 19.13% | |

Consequently, all ordinates on the damage curves were increased by 19.13% and GST was added.

**Apartment Buildings**

There are no strict guidelines provided by DECC on the approach to be taken with apartment buildings. While the units form part of one structure, the contents value contained within a number of units would be expected to outweigh those found in a single house. In addition, external damage, such as that sustained by cars and other stored items in garages, would be increased.

This study has assumed that each unit within an apartment building is equal to half a house. Therefore, the damage sustained by 4 units on the ground floor of an apartment building would be approximately equal to the damage sustained by 2 houses.

Retirement village housing was assessed as per detached single dwelling housing.

### 5.3.2 Commercial Damage Curves

Commercial damage curves have been 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 properties. These have been used to factor these curves.

The Consumer Price Index (CPI) was used to bring the 1990 data to June 2007 dollars (this data was obtained from the Australian Bureau of Statistics website (www.abs.gov.au)). The CPI data is shown in **Table 5.3**.

**Table 5.3 CPI Statistics**

| Month | Year | CPI |
|---|---|---|
| June | 1990 | 102.50 |
| June | 2007 | 157.50 |
| | | |
| Change | 53.66% | |

Consequently, damages have been increased by 53.66% and GST has been included.

### 5.3.3 Industrial Damage Curves

No industrial properties were located within the South Creek floodplain. Consequently no industrial damage estimates were required.

### 5.3.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 5.1**. The commercial damage curves are for a property with a floor area of 100m$^2$.

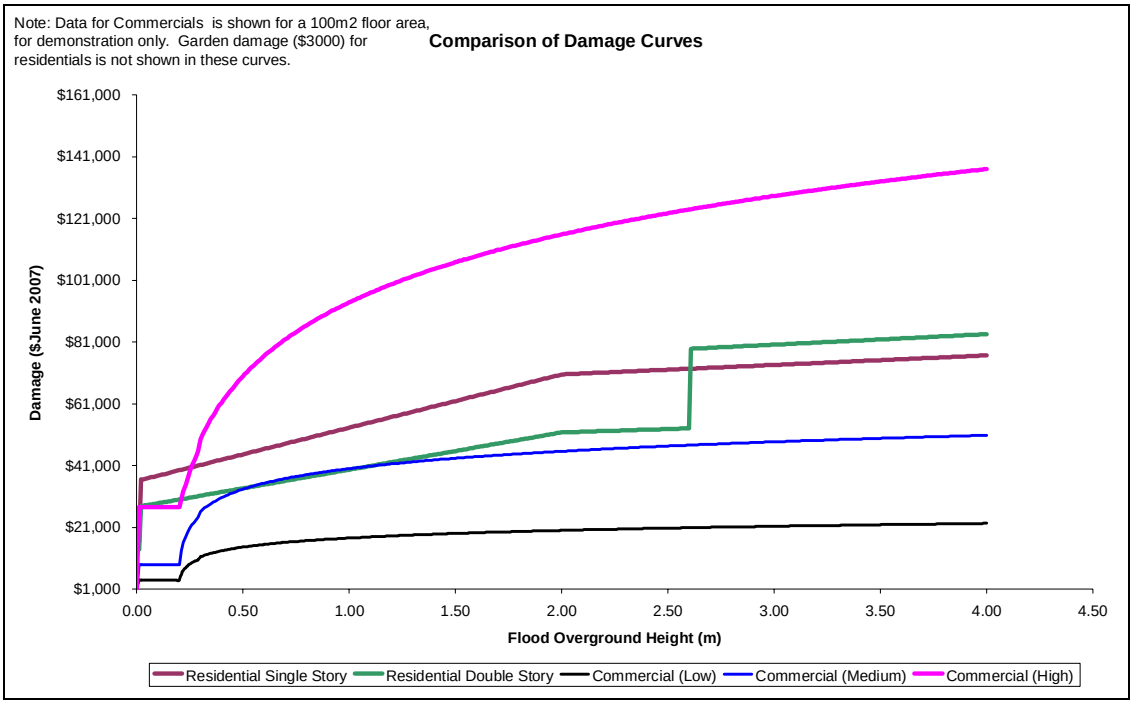



**Figure 5.1 Damage Curves Developed for the South Creek Catchment**

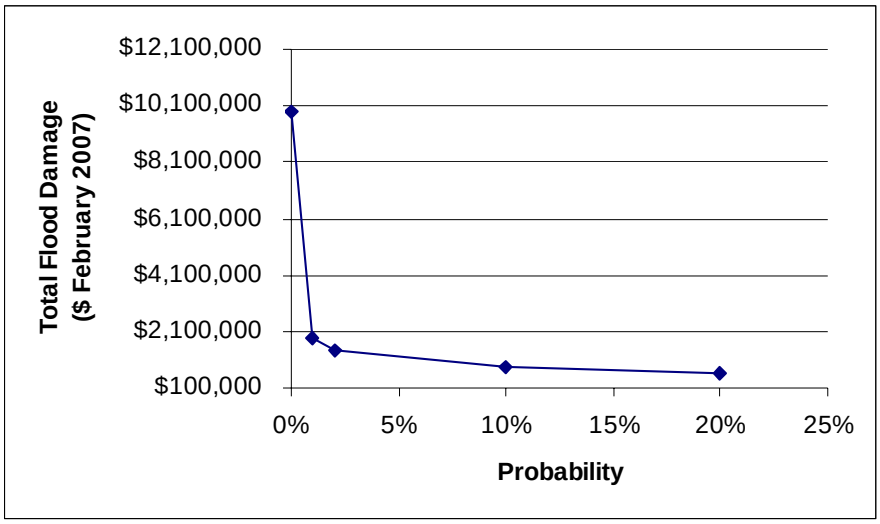
## 5.4 Average Annual Damage

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

Flood damages (for a design event) are calculated by using the 'damage curves' described in the sections 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.

AAD 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 (**Figure 5.2**). For example, the 100 year ARI design event has a probability of occurring of 1% in any given year, and as such the 100 year ARI flood damage is plotted at this point on the AAD curve (**Figure 5.2**). AAD is then calculated by determining the area under this curve.

Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (NSW Government, 2005).




Note: The probability of the PMF occurring is assumed as 0.0001%

**Figure 5.2 Average Annual Damage Curve for South Creek**

## 5.5 Results

**Table 5.4** shows the results of the flood damage assessments. Based on the analysis described in **Section 5.4** above, the average annual damage for the South Creek floodplain under existing conditions is approximately $340,000.

The average annual damage reflects of the likelihood of each design flood event in one year and the damages likely to occur as a result of that event. Whilst this is a useful tool for evaluating the benefit of flood management options and assessing the flood damage to an area over a long period of time, it is also important to note the actual damages estimated to occur as a result of each design flood event. The cost to the community of flood damage is not incurred as an average annual amount; the costs will be borne at one time by the damage incurred by a specific flood event. For example, a total of $1.9 Million worth of damages would be expected when a 100 Year ARI event occurs.

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

**Table 5.4 Flood Damage Assessment Summary**

| | No. Properties with Over-floor Flooding | Average Over-floor Flooding Depth (m) | No. Properties with Over-ground flooding | Total Damages ($Feb 2007) |
|---|---|---|---|---|
| **PMF** | | | | |
| **Residential** | 184 | 1.13 | 275 | $ 9,516,386 |
| **Commercial** | 1 | 1.75 | 1 | $ 368,455 |
| **PMF Total** | **185** | | **276** | **$ 9,884,841** |
| **100 Year ARI** | | | | |
| **Residential** | 42 | 0.41 | 128 | $ 1,889,460 |
| **Commercial** | 0 | - | 1 | $ 9,900 |
| **100 Year ARI Total** | **42** | | **129** | **$ 1,899,360** |
| **50 Year ARI** | | | | |
| **Residential** | 32 | 0.39 | 111 | $ 1,451,224 |
| **Commercial** | 0 | - | 1 | $ 9,900 |

| | No. Properties with Over-floor Flooding | Average Over-floor Flooding Depth (m) | No. Properties with Over-ground flooding | Total Damages ($Feb 2007) |
|---|---|---|---|---|
| **50 Year ARI Total** | **32** | | **112** | **$ 1,461,124** |
| **10 year ARI** | | | | |
| **Residential** | 18 | 0.36 | 79 | $ 832,368 |
| **Commercial** | 0 | - | 1 | $ 9,900 |
| **10 Year ARI Total** | **18** | | **80** | **$ 842,268** |
| **5 Year ARI** | | | | |
| **Residential** | 14 | 0.34 | 64 | $ 638,400 |
| **Commercial** | 0 | - | 1 | $ 9,900 |
| **5 Year ARI Total** | **14** | | **65** | **$ 648,300** |

## 5.6 Assumptions and Qualifications

A significant assumption in the calculation of the Average Annual Damage is that the damages in the 2 year ARI design event are zero, with a linear increase in damage up to the 5 year ARI design event. There is very little guidance in the Floodplain Development Manual (NSW Government, 2005) as to how the high probability end of the AAD curve should be established.

The event assumed to have zero Annual Average Damages can significantly impact on the value of the AAD (Thomson *et al*, 2006). If, for example, damages were assumed to be zero in the 1 year ARI design event, then the Average Annual Damage would be $501,708 (compared with the current 2 year approximation of $339,633). However, a 2 year ARI design event was considered to be a reasonable estimate of zero damage in the catchment. This design event approximately equates to the street drainage capacity in the catchment.

# 6. FLOOD PLANNING LEVEL REVIEW

## 6.1 Background

The Flood Planning Level (FPL) for the majority of areas across New South Wales has been traditionally based on the 100 year ARI flood level plus a freeboard. The freeboard for habitable floor levels is generally set between 0.3 - 0.5 m. A new *Guideline on development controls on low risk areas – Floodplain Development Manual* (NSW Government, 2007) states that unless there are 'exceptional circumstances', councils should adopt the 100 Year ARI (plus an appropriate freeboard) for residential development.

Warringah Council currently adopts an FPL of the 100 Year ARI flood level plus 0.5 metres for all properties within the 100 Year ARI flood extent (Warringah Local Environment Plan 2000).

A variety of factors are worthy of consideration in determining an appropriate FPL and whether 'exceptional circumstances' exist for the selection of an FPL other than the 100 Year ARI. 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 (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; and
- duty of care.

These issues are dealt with collectively in the following sections.

## 6.2 Likelihood of Flooding

As a guide, **Table 6.1** has been reproduced from the 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.

**Table 6.1 Probability of Experiencing a Given Size Flood or Higher in an Average Lifetime (70 years)**

| Likelihood of Occurrence in any year (ARI) | Probability of experiencing at least one event in 70 years (%) | Probability of experiencing at least two events in 70 years (%) |
|---|---|---|
| 1 in 10 | 99.9 | 99.3 |
| 1 in 20 | 97 | 86 |
| 1 in 50 | 75 | 41 |
| 1 in 100 | 50 | 16 |
| 1 in 200 | 30 | 5 |

Analysis of the data presented in **Table 6.1** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 year ARI 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 100 year ARI flood event as the basis for the flood planning level. 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 1 in 200 year magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the 200 Year ARI or up to the PMF) as the flood planning level for some types of development.

## 6.3 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. However, this impact has not been quantified as no sensitivity analysis was undertaken as part of the Flood Study (WMA, 2006) for increased imperviousness or increased catchment flows.

Changes to the land use can also result in changes in the assumed roughness of the floodplain. This can lead to changes in discharge characteristics and ultimately flood levels in the catchment. A sensitivity analysis was conducted as a part of the Flood Study (WMA, 2006) that assessed the effect of varying the floodplain roughness by +/- 25%. The results of this analysis showed that the highest increase in water level in the 100 year ARI design event was 0.2 metres at a number of locations (this is due to the accelerated response of the catchment resulting in coincidence of peak flows in the channel from various parts of the catchment).

Consideration could be given to provide a free board based on the results of this sensitivity analysis.

As outlined above, the Warringah Local Environment Plan 2000 states that habitable floor levels should be at a level of at least 500mm above the 100 Year ARI flood level for all land-uses (residential, commercial, industrial, *etc.*).

## 6.4 Damage Cost Differential Between Events

Based on the existing flood behaviour and the assessment of flood damages, the incremental difference in Average Annual Damage for different recurrence intervals is shown in **Table 6.2**. This table represents the incremental increase in AAD attributed to each design event.

**Table 6.2 Damage Differential Costs – All Damages**

| | Incremental AAD | Properties with Over-Floor Flooding | Average AAD per Property |
|---|---|---|---|
| up to 5 Year ARI | **$ 97,245** | **14** | **$ 6,946** |
| 5 Year to 10 Year | **$ 74,528** | **18** | **$ 4,140** |
| 10 Year to 50 Year | **$ 92,136** | **32** | **$ 2,879** |
| 50 Year to 100 Year | **$ 16,802** | **42** | **$ 400** |
| 100 Year to PMF | **$ 58,921** | **185** | **$ 318** |
| AAD (Total) | **$ 339,633** | | |

**Table 6.2** indicates that the largest incremental increase in AAD per property occurs up to the 5 Year ARI event, closely followed by the differential cost between 10 and 50 Year ARI events. Setting the flood planning level at the 5 Year ARI level would not be practical. Therefore the greatest savings in AAD per property (assuming that existing properties were replaced with similar properties set at the FPL) would be achieved if the FPL were set at the 50 Year ARI at a minimum.

## 6.5 Incremental Height Difference between Design Events

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

Based on the existing flood behaviour (Section 4 and WMA, 2006) the incremental peak height differences between events (as averaged across the catchment) is shown in **Table 6.3**.

**Table 6.3 Differences in Design Event Flood Levels (WMA, 2006)**

| Event | Diff PMF (m) | | Diff 100yr (m) | | Diff 50yr (m) | | Diff 10yr (m) | |
|---|---|---|---|---|---|---|---|---|
| | Avg | SD | Avg | SD | Avg | SD | Avg | SD |
| 100 year | 1.29 | 0.48 | - | - | - | - | - | - |
| 50 year | 1.39 | 0.52 | 0.11 | 0.04 | - | - | - | - |
| 10 year | 1.63 | 0.61 | 0.34 | 0.14 | 0.23 | 0.1 | - | - |
| 5 year | 1.73 | 0.64 | 0.44 | 0.18 | 0.33 | 0.14 | 0.1 | 0.04 |

Avg Average Difference

SD Standard Deviation of Differences, assuming the results are normally distributed, gives an indication of the spread of the differences between flood levels. For example, the average difference between the PMF level and the 100 year ARI level is 1.07 m, the standard deviation is of the same order as this difference.

**Table 6.3** indicates that the maximum difference between the PMF event and other design events gradually increases up to the 5 year ARI event (1.29m to 1.73m). The incremental differences between flood events are within the range of 0.1m to 0.2m, except for the PMF event. The adoption of the 100 year ARI event as the flood planning level is not significantly different from that of the 50 year ARI event (0.11m). Therefore, the adoption of the 100

year ARI event would provide an increased level of risk reduction over the 50 year, 10 year and 5 year ARI events for a small increase in elevation (and therefore reduced associated costs). The adoption of the PMF event as the flood planning level would result in more significant increases in levels over the 100 year ARI event (on average 1.29m) and may therefore potentially present an issue for the setting of flood planning levels in the catchment.

With regard to an appropriate freeboard, the hydraulic model results indicate that the maximum difference between the PMF event and the 100 year ARI event in the South Creek floodplain is 2.35m. The 95 percentile difference (value for which 95% of the difference values for the catchment are below) is 2.05m. An analysis of the statistics of the data set indicates that adopting a freeboard of 0.5m would result in the FPL being greater than the actual PMF level in about 4 percent of the floodplain. Whereas, adopting a freeboard of 0.7m or 0.9m would result in the FPL being greater than the PMF for approximately 13% and 26% of the floodplain (respectively).

## 6.6 Consequence of Adopting the PMF as a Flood Planning Level

Analysis of the flood damages (**Section 6.4**) indicates that the choice of the PMF event over the 100 year ARI event as the FPL would result in significant economic benefits to the community. However, the difference in average flood levels between the 100 year event and the PMF event (**Section 6.5**) indicates that the use of the PMF as the FPL would result in significantly higher levels (1.29 metres on average), and as a result higher economic costs (*e.g.* cost of redevelopment). These 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 Council's plans and policies.

The PMF is generally assigned a very low probability (reported to be of the order of 0.0001 - 0.000001% chance of occurrence each year, NSW Government, 2005). As such, the risk of exposure of buildings to the PMF remains, but is very low.

If the PMF were to be adopted as the flood planning level for all development, over 275 existing properties would be affected by this flood planning level (as compared with 128 properties affected by adopting the 100 Year ARI). This level of protection is considered likely to be an onerous task with regard to matters such as minor development and redevelopment to address this low level of risk to property and life. Given the very low probability of the event, the reduction in Average Annual Damage as a result of adopting the PMF as the flood planning level (through the redevelopment process and other programs such as house raising and voluntary purchase) is likely to be low.

However, given the risk of exposure outlined in **Table 6.1**, it is recommended that emergency response facilities be located outside of the floodplain and critical facilities (such as hospitals and areas that are difficult to evacuate in response to flash flooding) be limited to areas outside of the floodplain. Other critical facilities are suggested to have a floor level at the PMF or the 100 year ARI + 0.5 m, which ever is higher.

## 6.7 Environmental and Social Issues

Flood planning levels minimise the tangible and intangible damages to a property and over time the ongoing process of redevelopment will ultimately result in all properties being raised to a suitable level and the risk to community will be significantly reduced. This can promote feeling of security and reduce the emotional impacts of damages resulting from flooding.

Whilst flood planning levels are usually easily incorporated into the architectural designs for a property, the FPL can result in housing being placed higher than it otherwise would be. In

areas where the flood level is considerably higher than the ground level, this can lead to a reduction in visual amenity for surrounding property owners, and may lead to effects on property values. In some exceptional cases, this may also lead to conflict with other development controls.

## 6.8 Readiness, Warning, Response and Evacuation

The community has experienced a number of significant rainfall events in the last 30 years. The largest events recorded occurred on 10th March 2003 and 10th April 1998. Records from the nearby Middle Creek rainfall gauge for the 10th March 2003 indicate the 100 Year ARI design rainfall intensity for 30 minute to 2 hour durations were exceeded. In more recent memory, there was a moderately significant storm event in the catchment on the 24$^{th}$ April 2007. The rainfall intensities at the middle creek gauge indicate that this storm event did not exceed a 2 Year ARI event. Due to the relatively recent occurrence of significant flooding within the catchment (*i.e.* 2003), the community could be considered to be relatively "flood ready".

However, given the short critical duration for the catchment, the potential for warning, response and evacuation is very limited. As such, the adoption of a flood planning level that is elevated and rarer in occurrence, such as the PMF or 100 year ARI event, is an appropriate choice with regard to these factors. However, the PMF is an extremely rare event and its adoption as the FPL is highly unlikely. As such, the 100 year ARI event is a suitable choice for these factors. Given this recommendation, it is important that the community is reminded of the possibility of floods rarer than the FPL event occurring in the catchment. This is especially important when considering flood free evacuation routes. It is therefore important that suitable information for rarer floods (PMF) is provided to the community; such as the information presented in this report.

## 6.9 Climate Change – Sea Level Rise

Engineers Australia (2004) provide an engineering estimate for projected sea level increases as a result of climate change to 2100 with an average level of 0.5 m (a range of 0.1 – 0.9 m). These estimates are produced from a range of scenarios. Engineers Australia (2004) also report a central projected sea level rise for a 10 year planning period to be of the order of 0.1 m.

Thus, any freeboard allowed for in the assignment of flood planning levels should include a consideration of the potential impact of sea level rise and the impacts on Narrabeen Lagoon levels.

A sensitivity analysis was undertaken within the Flood Study (WMA, 2006) for variations in the Narrabeen Lagoon Level. The 100 Year ARI Narrabeen Lagoon flood level was increased by 9% (at the entrance to South Creek), there was a maximum increase in flood levels of 0.4 metres at the upstream side of the Toronto Avenue crossing. However, there was no reported impact at any other location.

## 6.10 Climate Change – Change in Rainfall Patterns

There are very limited quantitative studies available that can predict likely rainfall patterns under climate change scenarios. However, all of the global circulation models predict an increase in the total level of precipitation (Lowe, 2005). Hennessy *et al*. (2004) considered events from the 1 in 5 year event through to a 1 in 40 year event for the whole of NSW for a 1-day event duration and a 3-day event duration. These event durations are outside of the South Creek floodplain critical duration of 1 - 2 hours. Only limited information is available for durations shorter than 1 day.

For the south-east region, Hennessy *et al.* (2004) found that by 2070 it is likely there will be increases in 1 day event rainfall (~10%) during spring, summer, and autumn, and decreases during winter. In the case of 3 day events by 2070, a projected decrease in intensity was identified for coastal regions during autumn, winter and spring but an increase (~20%) during summer.

A sensitivity analysis was undertaken for catchment runoff as a part of the flood study. This analysis showed that for a 10% increase in rainfall depth, the maximum increase in water level in the 100 year ARI design event was 0.8 metres at McIntosh Road, with an average increase of approximately 0.1 metres.

Further information on the effect of climate change on rainfall is expected at the end of 2007 from the studies by the CSIRO commissioned by the Sydney Metro Catchment Management Authority.

## 6.11 Supplementary Factors

Two other factors need to be considered in FPL determination. They are:

- change in flow regime from supercritical to subcritical flow in open channels and overland flowpaths; and
- the impact of culvert/bridge blockage on design flood levels.

The first factor relates to the fact that local obstructions can cause supercritical flow (shallow fast flow) to become subcritical (deeper slower flow) with a resulting increase in design flood levels. This phenomenon can occur in the upper steeper parts of the catchment and is likely to be localised. In the lower parts of the catchment this phenomenon is also likely due to high flow velocity. The impact of this phenomenon is generally considered in the selection of an appropriate freeboard for the FPL.

The second factor has come to prominence with flooding in a similar catchment in Wollongong in 1998 and 1999 and other catchments where reasonably large culverts were blocked from debris floating down the creek. In the South Creek catchment, the debris is likely to be a combination of natural debris from the vegetated upper catchments and anthropogenic material.

A number of culverts and bridges are located along both South Creek and Wheeler Creek. Culvert blockage generally results in an increase in flood levels upstream of the culvert and a decrease in flood levels downstream. The design flood levels used for the determination of flood planning levels are the result of hydraulic modelling which assumes total blockage of all culverts and crossings except for the Toronto Avenue Bridge. Therefore, no additional allowance needs to be made in the freeboard selection for the impacts of culvert blockage.

## 6.12 Freeboard Selection

As outlined above, a freeboard ranging from 0.3 - 0.5m 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 generally accounts 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 creek obstructions *etc.*);
- wave action (*e.g.* such as wind-induced waves or wash from vehicles or boats); and
- climate change (affecting rainfall and ocean water levels).

The accuracy of ground survey used in the modelling is generally of the order of ±0.01m for each point surveyed. The accuracy of the rainfall inputs is more difficult to translate to a level accuracy. Instead, the effects of the overall hydrological response of the catchment on levels were considered via assessments of model sensitivity to changes in hydrological inputs and floodplain condition. A summary of the model sensitivity at selected locations is shown in **Table 6.4**.

**Table 6.4 Hydraulic Model Sensitivity (from WMA, 2006)**

| Location | Manning's n Model Sensitivity | | Rainfall Intensity Model Sensitivity | | 'C' Value Model Sensitivity | | Tailwater Model Sensitivity | |
|---|---|---|---|---|---|---|---|---|
| | 25% | -25% | 10% | -10% | 20% | -20% | 2mAHD | 3.8mAHD |
| Upstream of Toronto Ave | -0.1 | 0.1 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0.4 |
| 3189.362 Washington Ave | 0.1 | -0.1 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0 |
| Carcoola Road | 0.1 | -0.1 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0 |
| 2450.994 Carawa Rd | 0.2 | -0.2 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0 |
| 2263 Lidwina/Teresa Place Footbridge | 0.2 | -0.2 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0 |
| Upstream of Willandra Road (lower) | 0 | 0 | 0.1 | -0.1 | 0 | 0 | 0 | 0 |
| Alkira Circuit | 0 | 0 | -0.1 | 0.1 | -0.1 | 0.1 | 0 | 0 |
| McIntosh Road | -0.1 | 0.1 | 0.7 | -0.8 | -0.6 | 0.6 | 0 | 0 |
| Willandra Road (upper) | 0 | 0 | 0.1 | -0.1 | -0.1 | 0.1 | 0 | 0 |
| 298.385 Spilstead Place | 0.1 | -0.1 | 0 | -0.1 | -0.1 | 0 | 0 | 0 |
| Little Willandra Rd (Wheeler Creek) | 0.2 | -0.3 | 0.2 | -0.2 | -0.2 | 0.3 | 0 | 0 |

**Note:** Results provided as a relative change in level (in metres) compared to the 100 Year ARI base case event with no blockage

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

- uncertainty in flood modelling (~0.21 m = 0.2m of average model sensitivity Manning's selection + 0.01m of survey accuracy);
- afflux (local increase in flood level due to a small local obstruction not accounted for in the modelling) (0.1m);
- local wave action (~0.1 m) (truck wash etc);
- climate change – Sea Level Rise (0.1 m) for lower reaches only; and
- generally no allowance has been made in estimates to date to address changes in rainfall as a result of climate change. From **Table 6.4**, sensitivity analysis conducted as a part of the flood study indicates an average increase in flood levels of 0.14 metres and a maximum increase in flood levels of 0.7 metres as a result of a 10% increase in rainfall intensity.

Note that the provision for climate change is recommended for review on a periodic basis (at least every 5 years), as new information from research becomes available.

In the light of the above discussion, a freeboard of 0.5m would be appropriate for properties within the South Creek Floodplain.

While the above recommendation does include the impact of sea level rise due to climate change, it does not include impact of climate change on rainfall. If this factor were to be included in the freeboard determination, an additional allowance of approximately 0.2 – 0.5 metres would be required.

## 6.13 Recommended Flood Planning Levels and Freeboards

In light of the information presented in Sections 6.1 to 6.12, it is recommended that:

- the flood planning level (FPL) for residential areas be based on the 100 year ARI flood event plus 0.5m;
- where the adopted FPL is higher than the PMF, the FPL should be used;
- emergency services and flood evacuation centres should be prohibited within the floodplain; and
- critical facilities such as hospitals and aged care facilities should have flood free access.

# 7. CURRENT EMERGENCY RESPONSE ARRANGEMENTS

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

## 7.1 DISPLAN

Flood emergency management for the Warringah LGA is organised under the Manly Warringah and Pittwater Local Disaster Plan (DISPLAN) and has been issued under the authority of the *State Emergency and Rescue Management Act 1989*. The plan also covers the Pittwater and Manly LGAs. The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

- preparedness measures;
- conduct of response operations; and
- co-ordination of immediate recovery measures.

The plan also consists of a series of appendices, which include details of vulnerable services and areas.

The DISPLAN identifies the flood hazard to be a high probability hazard with major consequences. Generally, a sub-plan to the local DISPLAN, termed the Local Flood Plan, is prepared by the SES to effectively manage the flood emergency. The SES is currently preparing *The SES Storm, Tempest and Flood Counter Disaster Plan.* This will form the sub-plan to the DISPLAN which will address the flood hazard in the Warringah LGA. The Local Flood Plan will go into more detail that the DISPLAN regarding the roles and responsibilities of the various agencies during flood events.

The DISPLAN outlines the responsibilities and mitigation strategies for managing flood hazard as follows:

| | |
|---|---|
| **Warringah Council** | ▪ Regulate property development and construction through the Local Environment Plan and Development Control Plan;<br>▪ Provide and maintain appropriate drainage infrastructure;<br>▪ Work in partnership with SES for flood education and amend SES responsibilities accordingly; and<br>▪ Implement Floodplain Risk Management Plans. |
| **SES** | ▪ Prepare Storm and Tempest and Sub Plans; and<br>▪ Develop public education programs. |

## 7.2 SES/Emergency Service and Operations

The South Creek floodplain lies within the Sydney Northern Region of the State Emergency Service (SES). The Sydney Northern Region SES Office is located at Hornsby with SES Local Units located at Manly and Terrey Hills.

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 the South Creek Catchment is generally at the clean up stage.

Many of the emergency services for the area are not located within the South Creek Catchment. The closest emergency services are:

- the Narrabeen Ambulance Service located at 1391 Pittwater Road;
- Dee Why Fire Station located on the corner of Fisher Road and Francis Street in Dee Why;
- Dee Why Police Station located on St Davids Avenue;
- Beacon Hill Rural Fire Station located on Willandra Road Beacon Hill; and
- NPWS Offices and depots are located at Manly (North Head) and Forestville (Fergurson Street).

## 7.3 Flood Warning Systems

Due to the short timeframe of flash flooding in the catchment it is not possible or feasible to employ a flood warning system in the catchment. The Bureau of Meteorology (BOM), however, issues a 'severe weather warning' or a 'severe thunderstorm warning', which can be used as a surrogate warning system.

Systems to detect rainfall amounts for intense rainfall events (referred to as an ALERT system) are currently in place for the Sydney Metropolitan area. This system draws upon the Bureau of Meteorology's rainfall gauge network and includes those gauges located as part of the network of Automatic Weather Stations (AWS) that report on a regular basis. Data from this network is available in real-time at the Bureau of Meteorology Flood Forecasting Page at:

http://www.bom.gov.au/hydro/flood/nsw/sydney_metro.shtml

Details available include 24 hour rainfall totals and rainfall from the last hour in graphical format. Details of depths of rainfall recorded at specific gauges are also available.

The value of the system in providing flood warnings and the consequent timely actions by residents themselves or combat agencies remains an issue due to the very short times to flood peak from the onset of rainfall in catchments such as the South Creek.

The weather-based warnings (Severe Thunderstorm Warnings, Severe Weather Advices, Gale Warnings *etc*.) from BOM are generally faxed to all of the local media outlets as well as the SES. Flood Watches (from the Hydrology Section of the Bureau) are sent to the SES, who uses the local media to broadcast flood warning messages. A Recommended public 'course of action' will be included within SES warnings and subsequent media broadcasts. Templates for this information are incorporated into the Local Flood Plan.

## 7.4 Evacuation

The critical duration of flooding ranges from 30 minutes to 2 hours for all design flood events. Therefore, evacuation of residents away from their properties to avoid the peak of the flood would generally be not feasible. In this regard, the SES is not likely to play a significant role in evacuation during a flooding event. However, SES Volunteers will be deployed into areas where evacuation assistance is needed. Furthermore, SES is to correspond with other emergency services and council to ensure emergency action is coordinated affectively.

In some flood prone areas within the catchment, residents can seek refuge at a higher ground. However, such a practice is not recommended as the response during the flood emergency is likely to be uncoordinated, which can expose residents to a hazardous situation (particularly where access/egress roads are inundated). As such, the preferred approach is to remain within the property (sometime referred to as 'shelter-in-place') and move to the upper level of the residence, where available.

**Table 4.4** indicated that there are a number of properties in all design events that experience over-floor flooding of 0.4m or more. Five of the properties, which experience more than 0.4m of depth of over-floor flooding at the 5 Year ARI event, do not have a second storey on their house. In these cases “shelter-in-place” may not be appropriate. The SES should be notified which properties fall into this category and specific emergency procedures may need to be developed for these properties to manage the risk to life.

## 7.5 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 through the SES Local Emergency Operations Controller and support agencies including Police Services, Ambulance Services, Health Services and the Fire Brigade. Details and responsibilities of agencies are outlined in the DISPLAN.

Generally a Local Flood Plan provides greater details of the recovery operation in the aftermath of a flood event. As discussed above, this plan is currently in preparation.

# 8. IDENTIFICATION OF SUITABLE FLOODPLAIN RISK MANAGEMENT MEASURES

## 8.1 Overview of Available Measures

Measures available for the management of the flood risk are related to the way in which the risk is managed. Risk can be defined as being existing, future or residual risk:

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

The alternate approaches to managing risk are outlined below (after SCARM, 2000):

| | |
|---|---|
| Preventing/Avoiding risk | *i.e.* setting the planning level at the Probable Maximum Flood or not allowing development to be within the floodplain |
| Reducing likelihood of risk | *i.e.* relying on structural measures to reduce risk |
| Reducing consequences of risk | *i.e.* using development controls - design of structures to withstand flooding, allows a floodplain to be developed in lower areas |
| Transferring risk | via insurance - not viable given the non-insurability of most flood-prone areas |
| Financing risk | through natural disaster funding |
| Accepting risk | regardless of the options implemented, a continuing risk will be present. |

As a result, there are three types of measures for the management of flooding:

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

In addition, several Creek Bank Management Measures have also been identified. These measures not only assist in managing the risk of flooding, but also have an environmental benefit.

## 8.2 Methodology for Identifying Measures

The identification of measures included the following tasks:

- catchment inspection (multiple inspections);
- review of the flood study results;
- suggestions by the Floodplain Risk Management Committee;
- suggestions by residents via the questionnaire responses (Chapter 3);

- suggestions by Council technical personnel and the Department of Environment and Climate Change; and
- review of appropriate approaches as listed in the Floodplain Development Manual (2005).

Where technically possible, and within the scope of the study commissioned, all feasible options were included for assessment. Measures identified were separated into the three types and are described below.

## 8.3 Summary of Measures Identified

All measures identified were assigned a code depending on their type:

- 'FM' Prefix for Flood modification options (and an arbitrary number, numbered consecutively);
- 'PM' Prefix for Property modification options (and an arbitrary number, numbered consecutively);
- 'EM' Prefix for Emergency response modification options (and an arbitrary number, numbered consecutively); and
- 'BM' Prefix for Bank Management options (and an arbitrary number, numbered consecutively).

All identified options are shown in **Figure 8.1**.

It is worth noting that there is only limited scope for implementing 'flood modification' options along Wheeler Creek. This is for two reasons; firstly there is very limited land available to implement options along the lower reach. Secondly, the desire to maintain and enhance the pristine nature of the upper reaches of Wheeler Creek means that any options involving significant excavation or construction works in the upper reaches would not be favourable.

However, all 'property modification' and 'emergency response' options which apply to the entire floodplain and/or catchment still apply within the Wheeler Creek floodplain and catchment.

### 8.3.1 Flood Modification Measures

The flood modification measures considered as possible options for the South Creek floodplain are listed in **Table 8.1**.

**Table 8.1 Flood Modification Options**

| ID | Flood Modification Option Description |
|---|---|
| FM1 | Levees to protect properties on Toronto Avenue. |
| FM2 | Widen the creek beneath the Toronto Ave bridge to improve creek flow. |
| FM3 | Creek widening and revegetation upstream of Toronto Ave to improve creek flow. |
| FM4 | Levee to protect properties between Wabash Ave and Washington Ave. |
| FM5 | Rehabilitate creek and construct wetland on the right bank of South Creek between Carcoola Rd and Toronto Ave (to provide flood storage). |
| FM6 | Increase stormwater flow under Carcoola Rd bridge by increasing the culvert size. |
| FM7 | To reduce sediment loads, install a sediment retention basin upstream of Carcoola Rd. |
| FM8 | Levee to protect property at Carcoola Rd. |

| ID | Flood Modification Option Description |
|---|---|
| FM9 | To improve creek flow, widen the creek at the confluence of South and Wheeler Creek and remove island. |
| FM10 | Regrade the left creek bank and the reserve along South Creek between Willandra Rd and Carcoola Rd (the reserve would still be usable). |
| FM11 | Regrade the left creek bank and the reserve in sections along South Creek between Willandra Rd and Carcoola Rd (the reserve would still be usable). |
| FM12 | Ongoing maintenance of stormwater pipes and culverts under bridges to reduce the likelihood of blockages during a flood event. |
| FM13 | Increase stormwater flow under Willandra Rd bridge (lower) by increasing the culvert size. |
| FM14 | Regrading of right bank upstream of Willandra Rd (Lower) Crossing. |
| FM15 | Levee to protect properties at the end of Towradgi St. |
| FM16 | Increase stormwater flow under Alkira Circuit bridge by increasing the culvert size. |
| FM17 | Increase stormwater flow under Willandra Rd bridge (upper) by increasing the culvert size. |
| FM18 | Levee to protect properties on the left bank upstream of Willandra Rd (upper). |
| FM19 | Provision of levee bank adjacent to Cromer Golf Course to reduce flooding of the course. |
| FM20 | Detailed Assessment for Potential Debris Control Structures |

### 8.3.2 Property Modification Measures

The property modification measures considered as possible options for the South Creek floodplain are listed in **Table 8.2**.

**Table 8.2 Property Modification Options**

| ID | Property Modification Option Description |
|---|---|
| PM1 | Ongoing implementation of development controls and guidelines for building work. |
| PM2 | Preparation of Flood-related Section for Council's Development Control Plan. |
| PM3 | Guidelines for Public Domain Infrastructure. |
| PM4 | Voluntary House Raising Program. |
| PM5 | Voluntary House Purchase Program – 10 Properties |
| PM6 | Voluntary House Purchase Program – 1 Property |
| PM7 | Stringent OSD Requirements on any Proposed Development in the Catchment. |
| PM8 | Analysis of Localised FPL Requirements |
| PM9 | Property Dossier of Severely Flood Affected Properties |

## 8.4 Emergency Response Modification Measures

The property modification measures considered as possible options for the South Creek floodplain are listed in **Table 8.3**.

**Table 8.3 Emergency Response Modification Options**

| ID | Emergency Response Modification Measures |
|---|---|
| EM1 | Preparation and adoption of SES Local Flood Plan. |
| EM2 | Flood Warning Systems and Instrumentation |
| EM3 | Information Transfers to SES |
| EM4 | Community Education and Awareness Programs. |
| EM5 | Flood Depth Markers Placed on Both Sides of all Roads Crossing the Creeks. |
| EM6 | Ongoing Collection of Flood Information. |

Full details of these options are included in Sections 9, 10 and 11.

## 8.5 Bank Management Measures

A bank management plan has been prepared concurrently with this study by Cardno Lawson Treloar (*South Creek Bank Management Plan*, 2007). Several of the measures recommended for implementation in the bank management plan have potential flood benefits.

The bank management measures considered as likely to have a flood impact for the South Creek floodplain are listed in **Table 8.4**. Further details of these options are provided in **Appendix D** and **Section 12**.

**Table 8.4 Bank Management Options with Flooding Impacts**

| ID | Bank Management Option Description |
|---|---|
| BM1 | Management of Weeds in South Creek Downstream of Carcoola Road |
| BM2 | Monitor and excavate in South Creek Channel between Grover Ave and Wabash Ave as required to maintain a channel capacity commensurate with the current flow-sediment regime. |
| BM3 | The left bank downstream of Willandra Road (lower) is steep and sandy with poor vegetation cover. Bank battering is recommended along with revegetation. This may increase the conveyance of flow in the channel. |

## 8.6 Assessment of Options

Detailed descriptions and assessments of the options are provided in the following chapters. All floodplain risk management options are assessed for their:

- Likely reduction in flood risk;
- Economic benefits;
- Social impacts or benefits; and
- Environmental impacts or benefits.

The options were assessed both qualitatively and quantitatively depending on the nature of the option.

Eight scenarios were selected for quantitative assessment. The options were selected based upon the likely hydraulic improvement and the ability to incorporate the option into the hydraulic model. These scenarios included:

1. FM2 – Enhance Toronto Avenue Culvert.
2. FM3 – Creek Widening and Revegetation in the Lower Reaches.
3. FM9 – Widen the creek at the confluence of South and Wheeler Creek and remove island.
4. FM10 – Regrading the Left Bank Upstream of Carcoola Road.
5. FM11 – Regrading the Left Bank Upstream of Carcoola Road in Sections.
6. FM12 – Increased maintenance of Culverts and Creek Crossings to Reduce the Likelihood of Blockage.
7. FM5 – Rehabilitate and Construct Wetland.
8. BM1 – Weed Management Downstream of Carcoola Avenue.

Quantitative assessment involved hydraulic modelling of the option, damage analysis based on the model results, detailed costing of the implementation of the options and a benefit-cost analysis of the options.

For those options which were not assessed using hydraulic modelling, the reduction in flood risk and the likely benefit-cost ratio was estimated using an understanding of hydraulics, the flooding behaviour of South Creek and experience in the implementation of similar floodplain risk management options in similar settings.

Social and environmental factors were considered for all options (those assessed both quantitatively and qualitatively) by reviewing the summary of information in **Section 2** and allocating a score to the option. This is further described in **Chapter 12**.

When reviewing the potential options for a floodplain, it is important to keep in mind certain limitations and advantages within the floodplain. A summary of these issues is presented below. It should be noted that this summary is not exhaustive and detailed analysis of the proposed options are presented in the following sections of this report.

| | |
|---|---|
| The Nature of South Creek | The South Creek Floodplain is predominantly fairly steep. This limits the viability of options which endeavour to improve *flood storage* and necessitate the need for options which improve *flood conveyance*.<br><br>In addition, the area available for implementing flood management options adjacent to the creek is limited. Options such as off-line debris devices and significant widening of the creek require significant space. In many areas of the South Creek Floodplain, the required space is not available on public land and would require encroachment on private land for implementation. |
| Price | Often the implementation of expensive floodplain risk management options is limited by the availability of funding from Council, the State Government and the Commonwealth Government. |
| Levees | Levees can overtop, depending on their designed height. For example a levee constructed at the 100 Year ARI flood level will overtop in events greater than the 100 Year ARI. As such, levees create a false sense of flood protection and then when they do overtop they can result in a more hazardous environment with little, if any, warning of hazardous flooding.<br><br>If suitable drainage is not feasible there can be localised ponding behind the levee. |

| | |
|---|---|
| | On the other hand. If designed appropriately and the location permits, levee can provide very successful and relative cost effective means of protecting properties from flooding, particularly critical facilities (such as child care facilities). |
| Voluntary House Raising (VHR) and Voluntary House Purchase (VP) | Often VRH and VP are not well received by the community. However, these programs target those properties which are the most severely impacted by flooding and often there are no other solutions for reducing the flood risk on the properties.<br><br>It should still be noted that these programs are not compulsory and are voluntary on a property by property basis. |

# 9. FLOOD MODIFICATION OPTIONS ASSESSMENT

## 9.1 Overview

As outlined in **Section 8**, there are a number of opportunities for implementation of flood modification measures within the South Creek Floodplain. The options considered include those listed below.

| | |
|---|---|
| FM1 | Levees to protect properties on Toronto Avenue. |
| FM2* | Widen the creek beneath the Toronto Ave road bridge to improve creek flow. |
| FM3* | Creek widening and revegetation upstream of Toronto Ave to improve creek flow. |
| FM4 | Levee to protect properties between Wabash Ave and Washington Ave. |
| FM5* | Rehabilitate creek and construct wetland on the right bank of South Creek between Carcoola Rd and Toronto Ave (to provide flood storage). |
| FM6 | Increase stormwater flow under Carcoola Rd bridge by increasing the culvert size. |
| FM7 | To reduce sediment loads, install a sediment retention basin upstream of Carcoola Rd. |
| FM8 | Levee to protect property at Carcoola Rd. |
| FM9* | To improve creek flow, widen the creek at the confluence of South and Wheeler Creek and remove island. |
| FM10* | Regrade the left creek bank and the reserve along South Creek between Willandra Rd and Carcoola Rd (the reserve would still be usable). |
| FM11* | Regrade the left creek bank and the reserve in sections along South Creek between Willandra Rd and Carcoola Rd (the reserve would still be usable). |
| FM12* | Ongoing maintenance of stormwater pipes and culverts under bridges to reduce the likelihood of blockages during a flood event. |
| FM13 | Increase stormwater flow under Willandra Rd bridge (lower) by increasing the culvert size. |
| FM14 | Regrading of the vacant land upstream of Willandra Rd (Lower) crossing. |
| FM15 | Levee to protect properties at the end of Towradgi St. |
| FM16 | Increase stormwater flow under Alkira Circuit bridge by increasing the culvert size. |
| FM17 | Increase stormwater flow under Willandra Rd bridge (upper) by increasing the culvert size. |
| FM18 | Levee to protect properties on the left bank upstream of Willandra Rd (upper). |
| FM19 | Provision of levee bank adjacent to Cromer Golf Course to reduce flooding of the course. |
| FM20 | Detailed Assessment for Potential Debris Control Structures |

* Those options marked with an asterisk have been quantitatively assessed using hydraulic modelling.

Details of each option and the benefits and impacts are described below.

## 9.2 FM1 – Levees to Protect Properties on Toronto Avenue

The properties on the left bank of South Creek just downstream of the Toronto Avenue Bridge are significantly impacted by flooding. A childcare facility is one of these properties and therefore faces a significant flood risk. Flooding of the properties occurs primarily due to creek flooding overtopping the bank, rather than flooding from upstream overtopping of Toronto Avenue. The depth of over-ground flooding is, on average, 0.4m in these properties in the 100 Year ARI flood event.

To protect these properties from flooding in the 100 Year ARI event, the required levee would be at least 0.75m high on average. The levee is envisaged to be comprised of a low fence-like structure along the street front of the childcare facility (0.25m high), a wall structure adjacent to the creek just downstream of Toronto Avenue (varying from 0.25 at Toronto Avenue to 1.2m), and a grassed mound adjacent to the creek along the rear of the childcare facility and neighbouring residential properties (varying from 1.2m at its connection with the wall to 1m along the rear of the properties). The mound section of the levee would be graded (approximately 1 in 3) to reduce visual impact and allow access. The levee details are shown below in **Figure 9.1** with the proposed levee in green.

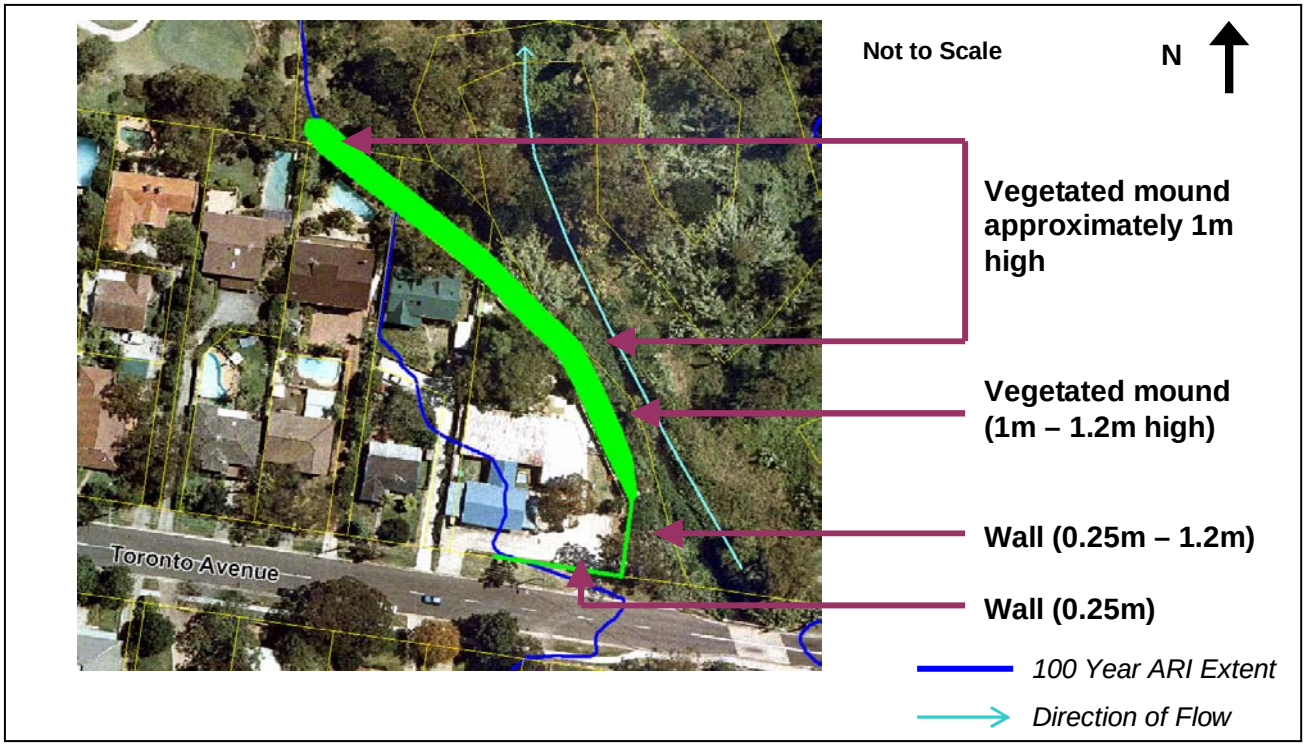



**Figure 9.1 Option FM1 – Toronto Avenue Levee**

The levee would be constructed on the Crown Land bordering the creek (*i.e.* no land to be associated with private residential properties). This would reduce any impact on local properties. The Crown Land is currently densely vegetated, predominately with weeds. The existing vegetation is fairly high and dense. If the proposed levee was revegetated with native mid-storey vegetation species, the riparian corridor could retain its connectivity whilst enhancing the diversity and habitat value for native species. In addition, the mid storey and ground cover vegetation would ensure that, even with a 1m high levee, the height of the vegetation would not exceed the existing vegetation height and therefore there would be no loss of visual amenity from the properties or the creek.

Any grasses used on the levee would be native grasses, endemic to the area. Mid-story vegetation would use native riparian vegetation that was present before development.

The proposed levee would protect 3 properties from flooding in all flood events, up to and including the 100 Year ARI. The properties would not be protected from events greater than this. Based on available ground survey, it is suggested that a levee higher than the proposed dimensions would be intrusive and may have a negative impact on visual amenity. During the detailed design stage, it may be found that a higher level could be acceptable, thereby providing for protection from more severe flood events.

Whilst the mound would protect the 3 properties it surrounds, any restriction of flood flow paths has the potential to impact on flood levels. The proposed levee is located fully within the 'Flood Fringe' extent with no portion of the levee within the 'Floodway'. Therefore, the construction of the levee will not impact on the primary flow path area and is unlikely to have any appreciable impact on flood levels. Further more, there are no flood affected properties (other than those protected by the levee) adjacent to the proposed levee. Therefore, even if there were a slight increase in flood levels as a result of the proposed levee, the increase is not expected to impact on any buildings or private property (*i.e*. the impact would be contained within the channel and the Golf Course). This would require confirmation through site specific hydraulic assessment if this option is to be implemented.

The proposed levee has been designed at the 100 Year ARI flood level (with no freeboard allowance). This means that the levee will overtop in events greater than the 100 Year ARI. As such, the levee could create a false sense of flood protection and then when it does overtop the result may be a more hazardous environment with little, if any, warning of hazardous flooding.

If suitable drainage is not able to be provided there can be localised ponding behind the levee. However, if designed appropriately with suitable drainage and the location permits, levees can provide very successful and relatively cost effective means of protecting properties from flooding, particularly critical facilities such as child care centres.

## 9.3 FM2 – Enhance Toronto Avenue Bridge

When unblocked, the Toronto Avenue Bridge can be expected to be overtopped in events greater than and including the 100 Year ARI. However, even in more frequent events, Toronto Avenue provides a constriction to the flow, increasing flood levels on the upstream side of the bridge. The existing bridge consists of concrete pylons supporting the road. The bridge could be reconfigured to minimise the construction of the flow.

The location of the Toronto Avenue Bridge and the proposed option is shown on **Figure 8.1**.

A review of the hydraulic model used in the Flood Study (WMA, 2006), supplemented by field inspections for this investigation, reveals that an over-estimation of the flow capacity under the bridge may be reported in the flood study. The model represents the case where no concrete piers are present (there are 2 piers). Therefore, the "base case", as presented in this study, is over-estimating the flow capacity.

For the purposes of assessing this option, it is assumed that the Flood Study scenario (the "base case" in this current study) actually represents the flood modification option (enhancing the culvert capacity at Toronto Avenue). To calculate the benefits of implementing this option the existing dimensions must be modelled for comparison. The existing dimensions of the Toronto Avenue Culvert were therefore modelled as part of this assessment.

A comparison of the "base case" (WMA, 2006) (Option FM2 for the purposes of this assessment), which over-estimates the existing conveyance, and the actual existing bridge dimensions, is shown in **Figure 9.2**. Overall the available conveyance area is less for the

existing dimensions than for those modelled for the “base case” in the Flood Study (WMA, 2006).

The reduced conveyance area in the existing dimensions chokes the flow at Toronto Avenue resulting in increased flood levels for all design events upstream of Toronto Avenue (a maximum increase in the 100 Year ARI event of 0.33m) and only a slight decrease in flood levels downstream of Toronto Avenue (a maximum decrease in the 100 Year ARI event of 0.01m). The increased flood levels, impact on the floodplain for a length of approximately 490 metres upstream of the bridge.

**Table 9.1** provides a summary of the number of properties with over-floor flooding for both the actual dimensions of the bridge and for the scenario modelled as part of the Flood Study (WMA, 2006). The scenario modelled as part of the flood study actually represents the proposed bridge enhancement. The results in terms of over-floor flooding show that the current hydraulic modelling under-estimates the number of properties with over flood flooding in the 50 Year ARI event by only one property.

**Table 9.1 Impact of Option FM2 on Over-floor Flooding**

| | Option FM2[1] | Existing[2] | Change |
|---|---|---|---|
| **PMF** | 185 | 185 | 0 |
| **100 Year ARI** | 42 | 42 | 0 |
| **50 Year ARI** | 33 | 32 | 1 |
| **10 Year ARI** | 18 | 18 | 0 |
| **5 Year ARI** | 14 | 14 | 0 |

[1] Represents the base case in this report and the existing case in the Flood Study
[2] Represents the existing bridge dimensions. The model was updated as part of this option assessment to represent these conditions.

The economic assessment provided in **Chapter 13** shows an increase in the average annual damages of $1,230 this means that the current assessments are underestimating the damages resulting from flooding by this amount on average. In comparison to the total AAD, the amount is considered within the accuracy of the estimate.

## 9.4 FM3 – Creek Widening and Revegetation Upstream of Toronto Ave

Immediately upstream of Toronto Avenue there is a turfed reserve (Wabash Reserve) on the left bank (looking downstream). This area contains children’s play equipment and is used by residents for passive recreation such as walking. It is a pleasant area to enjoy the amenity of the creek and riparian zone. However, the creek banks and channel are densely infested with weeds and thereby reduce the visual amenity and are impacting on ecological values.

The existing reserve is by no means a level area; there is the potential to regrade the banks of the creek and some of the reserve. The reserve would be regraded in such a manner as to retain the existing uses. The regraded slope of the reserve would not exceed 1V:10H (1 in 10). The play equipment would be replaced and the area returfed and revegetated as required. The regrading of the creek banks would provide an opportunity to remove the existing riparian vegetation (which is predominantly weeds) and revegetate with native, endemic species.

The regrading (particularly of the left bank) would reduce the steepness of the banks and potentially allow for greater visual access to the creek and therefore greater appreciation of South Creek by its users.

Regrading of the area is limited in some locations by the steepness of the banks and neighbouring properties and infrastructure. The extent of the proposed area to be regraded is shown in **Figure 9.3**.

The regrading of the creek banks allows for greater conveyance in the main channel and the regrading of the reserve areas (out of bank) allows for additional flood storage. This results in a decrease in flood levels for all design events upstream of Toronto Avenue (a maximum decrease in the 100 Year ARI event of 0.54m). The resultant reduction in levels extends upstream as far as the Carcoola Road crossing of South Creek.

Due to the alteration in the conveyance and hence the timing of the flows, this option results in a slight increase of flood levels downstream of Toronto Avenue. The increase in flood levels in more predominant in the more frequent flood events with a maximum increase in flood levels of 0.07m (5 and 10 Year ARI). However, this value reduces to only 0.01m in the 50 and 100 Year ARI events, with no increase in flood levels in the PMF.

**Table 9.2** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed Option FM3. In terms of the impact on flood affected properties, this option results in an overall reduction in over-floor flooding of 2 properties in the more frequent events.

**Table 9.2 Impact of Option FM3 on Over-floor Flooding**

| | Existing | Option FM3 | Change |
|---|---|---|---|
| **PMF** | 185 | 185 | 0 |
| **100 Year ARI** | 41 | 42 | -1 |
| **50 Year ARI** | 32 | 32 | 0 |
| **10 Year ARI** | 16 | 18 | -2 |
| **5 Year ARI** | 12 | 14 | -2 |

The economic assessment provided in **Chapter 13** shows a decrease in damages for all design events. The overall reduction in Average Annual Damages as a result of this option is approximately $21,300.

## 9.5 FM4 – Levee to Protect Properties between Wabash Ave and Washington Ave

The properties bordering the creek between Wabash and Washington Avenue are significantly impacted by flooding, with flood depths in the 100 Year ARI event of up to 1.5 metres. Flooding occurs on these residential properties due to South Creek exceeding its bank capacity and spilling out into the overbank area (including the subject properties).

It is possible to construct a levee around these properties to protect them from flooding. To protect these properties from flooding in the 100 Year ARI event, the levee would be a maximum of 1.4m high and on average 1m high. The levee is envisaged to comprise of a low block-work fence along both street frontages, increasing to a maximum height of 1.3m and 1m at the corner of the properties at the creek frontages on Wabash and Washington Avenue respectively. Alternatively for consistency the entire wall lengths could be set at 1.3m and 1m, comprising of a rendered front fence or the like to blend the feature into the local urban landscape.

Provisions would be required for the driveways of the affected properties. The driveways could have a “hump” over the elevation of the levee. However, this would be up to 1m high for some properties. This may result in slopes which do no conform to Council’s requirements and may have a visual impact. Landscaping could be integrated into the

design to minimise the visual impact. Alternatively, off-street parking could be provided at the end of Wabash Avenue and Washington Avenue. This would be dependant on land use and Council approval.

The levee along the creek frontage is envisaged to comprise of a gently sloping grassed mound, as to reduce the impact on the visual amenity. The average level of the grassed levee would be at 5 mAHD which, varies from 0.8 to 1.4m above the existing ground level. The grassed mound section of the levee would be graded (approximately 1 in 3) to reduce visual impact and allow access and maintenance (mowing). The levee details are shown below in **Figure 9.4** with the 100 Year ARI extent shown as a blue line and the proposed levee in green.

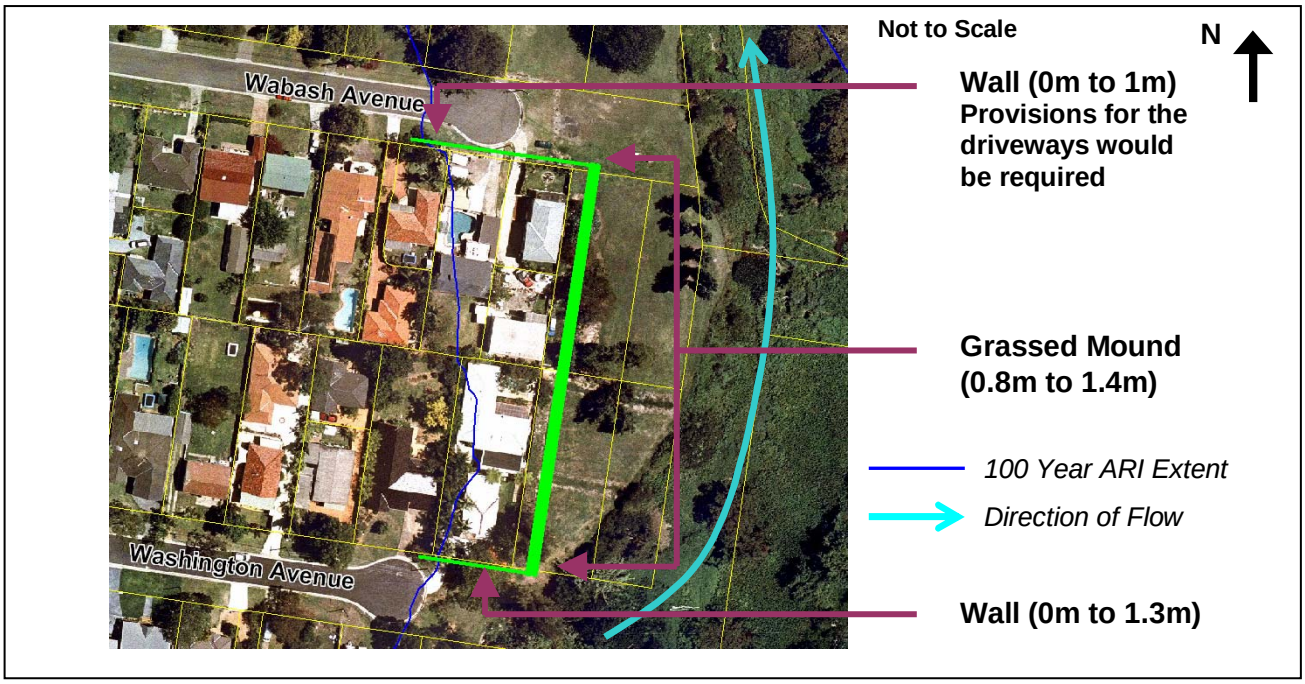



**Figure 9.4 Option FM4 – Wabash and Washington Avenue Levee**

The levee would be constructed on the public land bordering the creek and on the road reserve and not on private residential properties. This would reduce the impact on properties. The walls along the street front can be constructed in a manner that is in keeping with the existing streetscape and would be unlikely to have any negative aesthetic impacts. However, the grassed levee along the creek frontage, although designed sympathetically to the location, may have an impact on the aesthetics of the location. In deciding whether this option should be implemented, it is necessary to consider the values of the residents and community as to aesthetic impacts and flood impacts of properties.

The proposed levee would protect 3 properties from flooding in all flood events, up to and including the 100 Year ARI. The properties would not be protected from events greater than this. Based on available ground survey, it is suggested that a levee higher than the proposed dimensions would be intrusive and may have a negative impact on visual amenity. During the detailed design stage, it may be found that a higher level could be acceptable, thereby providing for protection from more severe flood events.

Whilst the mound would protect the 3 properties it surrounds, any restriction of flood flow paths has the potential to impact on flood levels. A large portion of the proposed levee is located within the Floodway extent. Therefore, the construction of the levee will impact on the primary flow path area and is likely to have an impact on flood levels. However, there are no flood affected properties (other than those protected by the levee) in the immediate vicinity of the proposed levee. It is unlikely that any impact of the levee would translate to

an area of great distance from the levee location. As such, any increase in flood level as a result of the proposed levee is unlikely to impact private properties or buildings (*i.e.* the impact is expected to be contained within the creek, reserve and road areas). This would require confirmation through further assessment if this option is to be implemented.

No hydraulic modelling was undertaken to quantify any impacts on flooding. This assessment is qualitative only.

The proposed levee has been designed at the 100 Year ARI flood level (with no freeboard allowance). This means that the levee will overtop in events greater than the 100 Year ARI. As such, the levee could create a false sense of flood protection and then when it does overtop the result may be a more hazardous environment with little, if any, warning of hazardous flooding.

In addition, if suitable drainage is not feasible there can be localised ponding behind the levee.

On the other hand, if designed appropriately and the location permits, levee can provide very successful and relative cost effective means of protecting properties from flooding.

## 9.6 FM5 - Rehabilitate Creek and Construct Wetland between Carcoola Rd and Toronto Ave

There is a low lying area adjacent to the South Creek main channel downstream of Carcoola Avenue. This area, in its natural state was most likely a wetland. Anecdotal evidence would suggest that this area has undergone significant sedimentation and visual inspections noted considerable weed infestation. The sediment accumulation and dense weeds are reducing the available flood storage area and increasing the hydraulic roughness, which reduces conveyance, thereby increasing flood levels. Council currently periodically clears dense weeds within this reach to improve conveyance. However, the weeds regrow quickly, again providing a potential impact on flows and flooding.

This option proposes to clear the majority of the vegetation and remove any excess sedimentation within the area shown in **Figure 9.5**. The area would then be rehabilitated to form a wetland using endemic wetland species. Wetlands provide a natural filter for flows. The establishment and maintenance of a wetland at this location would have benefits for water quality downstream in South Creek and in the receiving waters of Narrabeen Lagoon.

Members of the community have expressed a desire for a pedestrian creek crossing at this location. If a crossing were to be constructed it would need to be assessed to ensure it did not have any negative impact on flood levels. A crossing at this location would not have any flood benefit and has not been included as a component of this option. Council could pursue this separate from this study.

Hydraulic modelling has been undertaken to assess the impact of implementing this option. For the purposes of the modelling, it was assumed that, on average, a 0.3 metre depth of deposited sediments would be removed from the area. The hydraulic roughness values have been reduced from 0.2 to 0.1. A roughness of 0.2 is still a fairly conservative value for a wetland and allows for the possibility of weed regrowth and maximum roughness between maintenance weed removals.

Removing 0.3m of sediments will also assist in the reduction of weed regrowth. A significant portion of the seed stock is likely to be in the upper layer of sediment. Removing this sediment (with appropriate disposal) will remove the majority of the weed seed stock from the area.

Overall, this option results in a reduction in flood levels for all design events from the Carcoola Road crossing of South Creek to the downstream end of the wetland. The maximum reduction in the 100 Year event is 0.71m. However, there is a slight increase in flood levels in the more frequent events (5, 10 and 50 Year ARI) in the reach of the creek approximately 100m downstream of the wetland rehabilitation area. The increase in flood levels is contained to the riparian zone and does not impact on adjacent properties.

**Table 9.3** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option FM5. In terms of the impact on flood affected properties, this option results in an overall reduction in over-floor flooding of 12 properties in the 100 Year ARI event and a significant reduction in the number of properties with over-floor flooding in the PMF and other less frequent events.

**Table 9.3 Impact of Option FM5 on Over-floor Flooding**

| | Existing | Option FM5 | Change |
|---|---|---|---|
| **PMF** | 181 | 185 | -4 |
| **100 Year ARI** | 30 | 42 | -12 |
| **50 Year ARI** | 26 | 32 | -6 |
| **10 Year ARI** | 18 | 18 | 0 |
| **5 Year ARI** | 14 | 14 | 0 |

The economic assessment provided in **Chapter 13** shows a decrease in flood damages for all design events. The overall reduction in Average Annual Damages as a result of this option is approximately $23,100.

## 9.7 FM6 – Enhance Carcoola Road Culverts

The road crossing at Carcoola Road is comprised of 5 box culverts (1.8m x 3.3m each). This provides a significant amount of conveyance for flows within South Creek. However, residents have noted flood water overtopping Carcoola Road during flood events.

The location of the Carcoola Road Culverts and the proposed option for this site is shown on **Figure 8.1**.

The hydraulic model results show that the culverts will overtop in the 100 Year ARI design event even when no blockage occurs. Under a no blockage scenario, the road level is likely to overtop by a depth of 0.8 metres. However, for the purposes of determining flood planning levels the flood study (WMA, 2006) adopted a total blockage policy of all culverts (with the exception of Toronto Avenue). Under totally blocked conditions, Carcoola Road is likely to overtop in a 100 Year ARI event by a greater depth than when unblocked (1.45 metres).

The hydraulic model results indicate that, even if no blockage occurs, the culverts at Carcoola Road do not have the capacity to convey the flood waters in the 100 Year ARI event. As such, flood waters build up behind the culverts increasing flood levels upstream of Carcoola Road. However, due to the steep nature of the creek and the limited storage area behind the culvert, it is unlikely that enhancing the culvert will significantly reduce flood levels. This is further compounded by the fact that the existing culverts extend for almost the full width of the channel. As such it would only be possible to add one additional culvert cell or create a single span bridge so as to reduce the losses associated with the culvert walls. However, it is still expected that any impact on flood levels as a result of these actions would be minimal.

Alternatively, it may be possible to raise the road level and enhance the culvert size in a vertical direction. This would require a complete reconstruction of the creek crossing and the costs associated with these works would be expected to be substantial. However, it may have a more significant impact on flood levels.

As vertical enhancement of the culverts is the only real possibility at this location, this option has been assessed for its impact and benefits based on a vertical enhancement of the culvert, including the raising of the road level above the 100 Year ARI + 0.5m level and also incorporating bed level lowering in the channel downstream of the bridge to reduce flood levels on the downstream side.

Due to the blockage scenario adopted for the hydraulic modelling for South Creek (full blockage of all culverts, except for Toronto Avenue), this option is unable to be assessed using the hydraulic model. In fact, due to the blockage scenario, the increased height of the bridge would actually show an increase in flood levels upstream of Carcoola Road. Given these constraints, which are expected to be supported by actual blockage due to the nature of the catchment, this option has not been assessed quantitatively for impacts on flood levels and flood damages.

As a guide, if the culvert did not block, the maximum reduction in flood levels upstream of Carcoola Road, as a result of this option, is likely to be of the order of 0.3m and the extent of influence is unlikely to be greater than 150 to 200 metres upstream. The impact downstream will be governed by the depth excavated in the creek bed. The excavation would provide a pool in the creek and may provide habitat value. If the depth of excavation was of the order of 0.5m, it would be expected that the reduction in flood levels at this point would also be of the same order.

However, if the culverts did block, which is likely considering observations during flooding and the wooded nature of the catchment, flooding would increase on the upstream side of Carcoola Road (up to the level of the raised road), thereby worsening flooding for those properties adjacent to the creek.

## 9.8 FM7 – Sediment Retention Basin Upstream of Carcoola Rd

High sediment loads and deposition rates have been noted within the South Creek system. Deposition is particularly high in the reaches where the grade in South Creek becomes less. Large amounts of deposited sediment have been noted downstream of Carcoola Road, which is of a flatter grade. The deposited sediment itself reduces the conveyance and storage area for flood waters and the dense weeds, which can establish on the deposited material, worsen the condition significantly.

There is a potential site where an off-line sediment retention basin could be installed, upstream of Carcoola Road on the left bank. This location would allow for suitable access for maintenance and removal of retained sediment.

Details of this option are provided below in **Figure 9.6**.

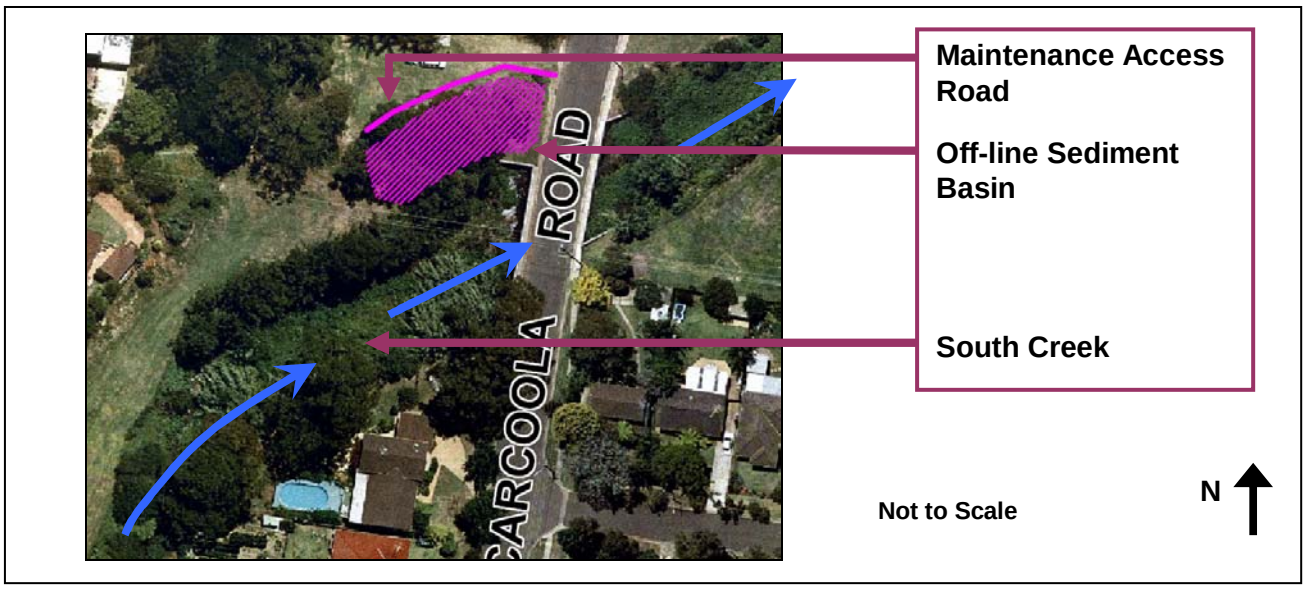



**Figure 9.6 Option FM7 – Sediment Basin**

The flood benefits of this option are difficult to quantify. It is likely that the reduced sediment loads would assist with maintaining the conveyance of the channel downstream of this location. It would also be beneficial if this option is implemented in conjunction with the wetland rehabilitation downstream (Option FM5). This would assist in maintaining the wetland health by reducing the amount of sediment entering the wetland.

However, it is unlikely that there would be any significant reduction in flood levels within the system as a result of this option. As such, there would be no appreciable reduction in flood damages as a result of this option. Therefore, the benefit-cost ratio for this option is likely to be very low.

## 9.9 FM8 – Levee to Protect Properties at Carcoola Rd

The properties bordering the creek on the left bank, just upstream of the Carcoola Road crossing of South Creek, are significantly impacted by flooding, with over-ground flood depths in the 100 Year ARI event of up to 1.7 metres. Flooding occurs on these residential properties due to South Creek exceeding its bank capacity and spilling out into the overbank area (including the subject properties).

It is possible to construct a levee around these properties to protect them from flooding. To protect these properties from flooding up to the 100 Year ARI event, the levee would need to be a maximum of 1.8m high and on average approximately 1m high. The maximum height of the levee is required on the south eastern corner of the lots (near the existing driveway). The ground levels on this portion of the properties are significantly lower than the rest of the properties.

The levee is envisaged to comprise of a solid fence along the street frontage. The fence needs to be approximately 1.55 metres high at the south eastern corner of the property reducing to nothing at the north eastern corner. The design of the fence would be flexible with the key objective being that the 100 Year ARI levels (plus a small freeboard) are met and the fence cannot be penetrated by water and must withstand hydrostatic pressures. The driveway accessing 40 Carcoola Road would need to be regraded and filled to match in with the fence level. However, this would result in a 30 percent grade on the driveway to match it back in with the street level. This is not an acceptable slope for access. To accommodate the driveway and a suitable slope, the wall would have to follow the driveway on the up hill side such that the high point of the driveway is in between the road and the

house. This would result in the raised level of the high point of the driveway being 1.55 metres and the slopes to the house and the road 13 and 17 percent respectively. This may have a visual impact; however, the slopes conform to Council's requirements for access. Landscaping treatments could be incorporated to minimise this impact.

The high point on the driveway would meet with the grassed mound which would form the levee around the southern and western boundaries of the properties. The grassed mound would be 1.55 metres high at its highest point where it meets the driveway and reducing to only 0.55 metres high at the south western corner of the properties. The grassed mound would continue around the western boundary of the properties reducing down to ground level at the northern end.

The levee details are shown below in **Figure 9.7** with the proposed levee in green.

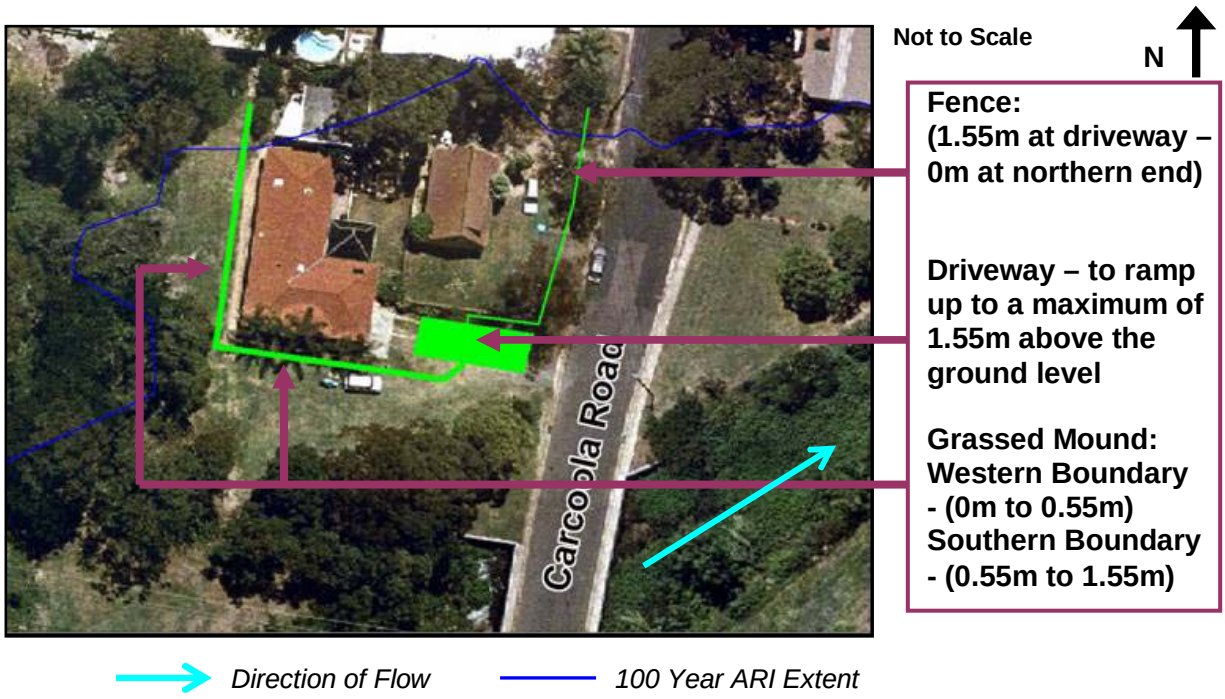



**Figure 9.7 Option FM8 – Carcoola Road Levee**

The levee would be constructed, where possible on public land and not on private residential properties. This would reduce the direct impact on properties. The fences along the street front can be constructed in a manner that is in keeping with the existing streetscape and would be unlikely to have any negative aesthetic impacts. However, the grassed levee along the creek frontage, although designed sympathetically to the location, may have a visual impact. In deciding whether this option should be implemented, it is necessary to consider the values of the residents and community as to aesthetic impacts and flood impacts of properties. Some work would be required on private property (e.g. driveway alterations) at no cost to the landowner but requires consent by the landowner.

The proposed levee would protect 3 properties from flooding in all flood events, up to and including the 100 Year ARI. The properties would not be protected from events greater than this. Based on available ground survey, it is suggested that a levee higher than the proposed dimensions would be intrusive and may have a negative impact on visual amenity. During the detailed design stage, it may be found that a higher level could be acceptable, thereby providing for protection from more severe flood events.

Whilst the mound would protect the 3 properties it surrounds, any restriction of flood flow paths has the potential to impact on flood levels. A large portion of the proposed levee is

located within the Floodway extent. Therefore, the construction of the levee will impact on the primary flow path area and is likely to have an impact on flood levels. Further more, there are flood affected properties (other than those protected by the levee) on the opposite side of the creek to the proposed levee. As such, any increase in flood level as a result of the proposed levee is likely to impact on these properties. This would require confirmation through further assessment if this option is to be implemented.

The proposed levee has been designed at the 100 Year ARI flood level (with no freeboard allowance). This means that the levee will overtop in events greater than the 100 Year ARI. As such, the levee could create a false sense of flood protection and then when it does overtop the result may be a more hazardous environment with little, if any, warning of hazardous flooding.

In addition, if suitable drainage is not feasible there can be localised ponding behind the levee.

On the other hand, if designed appropriately and the location permits, levees can provide very successful and relative cost effective means of protecting properties from flooding.

## 9.10 FM9 – Widen the Creek at the Confluence of South Creek and Wheeler Creek

Due to the large amount of sediment entering the creeks, an island has formed at the confluence of South and Wheeler Creeks. The island has subsequently become vegetated and over the years the vegetation has become very established, with very tall eucalyptus trees present. The establishment of vegetation exacerbates the sedimentation process and as a consequence the creek channel has become significantly choked at this location. This reduces the conveyance in the creeks and increases hydraulic losses at the confluence.

This option involves the removal of the island and associated vegetation. The extent of the island removal is shown in **Figure 9.8**. There would be minor regrading of the banks and bed associated with this option.

Hydraulic modelling has been undertaken to assess the impact of implementing this option. The appropriate cross sections were updated in the model to reflect the island removal and regrading. The roughness value (Manning's n) was not altered as it is assumed that vegetation would regrow quickly.

The results of the hydraulic assessment showed a reduction in flood levels for the length of South Creek from downstream of Willandra Road crossing (lower) to just downstream of the confluence of Wheeler and South Creeks. The impact covers a total length of South Creek of approximately 210 metres and has a maximum reduction in flood levels of 0.12m in the 100 Year ARI event. There is also a reduction in flood levels in the lower reach of Wheeler Creek; the model results showing a maximum reduction in flood levels of 0.1m. The hydraulic modelling also showed that there was no adverse impact on flooding as a result of implementing this option.

This option does not result in the increase in flood levels at any location within the floodplain.

**Table 9.4** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option FM9. In terms of the impact on flood affected properties, this option has very little impact, with only 1 less property with over floor flooding in the PMF and no reduction in the number of properties with over floor flooding in other design events.

**Table 9.4 Impact of Option FM9 on Over-floor Flooding**

| | Existing | Option FM9 | Change |
|---|---|---|---|
| **PMF** | 184 | 185 | -1 |
| **100 Year ARI** | 42 | 42 | 0 |
| **50 Year ARI** | 32 | 32 | 0 |
| **10 Year ARI** | 18 | 18 | 0 |
| **5 Year ARI** | 14 | 14 | 0 |

The only minor impact on over-floor flooding presented above is reflected in the minor reduction in the Average Annual Damages of $1,100. The economic assessment for this option is provided in more detail in **Chapter 13**.

## 9.11 FM10 – Regrading of Lidwina Place Reserve and Tyagarah Reserve

The majority of the left bank of South Creek between Willandra Road and Carcoola Road is characterised by a grassed public reserve with isolated trees and along the banks there is dense vegetation (predominantly weeds). The reserve areas are highly valued by the community and residents for their visual amenity and recreational uses. This option involves the regrading of the reserve areas and the upper left bank to improve flow conveyance during flood events. The extent the proposed regrading is shown on **Figure 9.9**.

The existing creek bank is fairly steep; this option proposes to batter back the bank from approximately 1 metre above the bottom of the bank and regrade the reserve areas. The reserve areas would have a maximum slope (towards the creek) of 1V:1H. This slope is a gentle slope and would allow for the continued use of the reserves as passive recreation areas. An example cross section is shown below in **Figure 9.10** to provide an indication of the regrading. The scale is skewed in the vertical direction to show detail, indicative dimensions are provided to guide the reader.

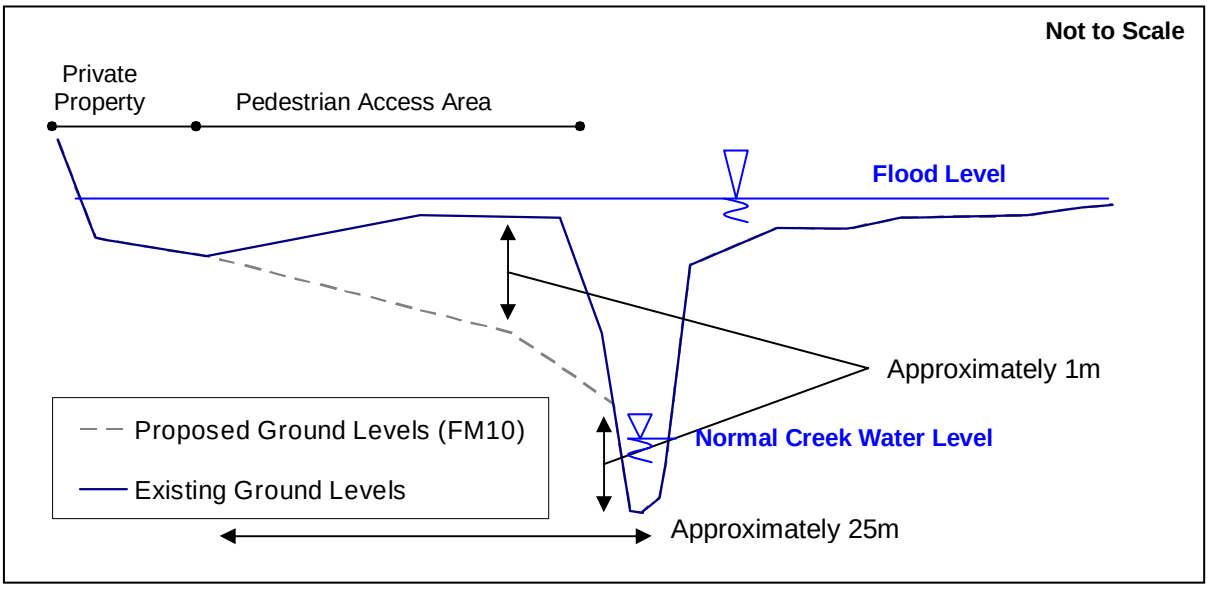



**Figure 9.10 Option FM10 – Example Creek Cross Section Demonstrating Proposed Changes**

In addition to the regrading of the banks and reserve areas, this option proposes to remove the island formed at the confluence of Wheeler and South Creeks (as proposed in Option FM9).

This option would result in significant removal of existing vegetation along the reserve and the creek bank. Council's vegetation mapping shows the vegetation within the extent of the option to be a combination of:

- Cleared/Developed Lands; and
- Highly Disturbed Vegetation.

Therefore, the impact of the clearing and regrading would not be significant in terms of the impacts on existing flora. In addition, the area would be revegetated with native endemic species along the creek bank and within reserve where possible. The overall result would be a benefit for flora and fauna along this reach.

Hydraulic modelling has been undertaken to assess the impact of implementing this option. The set up of the model involved updating the appropriate cross sections along the reach (in a manner similar to that shown above in **Figure 9.10**). The regraded areas were assumed to have a roughness value (Manning's n) equal to the value currently representing the grassed reserve.

This option results in a decrease in flood levels in all design events for the reach of South Creek between the Willandra Road crossing (lower) and the Carcoola Road crossing and the lower reach of Wheeler Creek (maximum decrease in the 100 Year ARI of 0.3m). However, there is a slight increase in flood levels for a length of 130m upstream of Carcoola Road (maximum increase in the 100 Year ARI of 0.12m). This will impact on residential property flooding.

**Table 9.5** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option FM10. The larger events have an overall decrease in the number of properties with over-floor flooding. However, in the 5 Year ARI event, there are an additional 2 properties with over-floor flooding (over-floor depth of 0.03m and 0.01m in the 5 Year ARI event).

As a result of this option 24 properties experience an increase in 100 Year ARI flood levels, of these properties 7 experience over-floor flooding. The maximum increase in over-floor flooding in the 100 Year ARI event is 0.11m.

As a result of this option 60 properties experience a decrease in 100 Year ARI flood levels, 28 of these properties have a reduction in the 100 Year ARI flood level of greater than 0.2m. Of the 60 properties, 16 experience over-floor flooding in the existing case. As a result of this option 5 of these properties no longer experience over-floor flooding.

**Table 9.5 Impact of Option FM10 on Over-floor Flooding**

| | Existing | Option FM10 | Change |
|---|---|---|---|
| **PMF** | 180 | 185 | -5 |
| **100 Year ARI** | 37 | 42 | -5 |
| **50 Year ARI** | 29 | 32 | -3 |
| **10 Year ARI** | 16 | 18 | -2 |
| **5 Year ARI** | 16 | 14 | 2 |

Whist there may be an increase in properties with over-floor flooding in the more frequent events, the total number of properties inundated during the more extreme events is

decreased and therefore the average annual damages decreases by approximately $6,600 due to the implementation of this option. The benefit-cost ratio for this option is 0.01. This means that the reduction in flood damages is less than the cost of implementing the option.

Further details as to the economic assessment of this option are provided in **Chapter 13**.

## 9.12 FM11 – Regrading Lidwina Place Reserve and Tyagarah Reserve in Sections

This option is similar to FM10 in that it proposes to regrade the reserve areas and the upper left bank of South Creek and remove the island formed at the confluence of South Creek and Wheeler Creek. However, this option proposes to only regrade the reserve and bank in sections. This option endeavours to “stagger” the flow through this reach, thereby altering the timing of the peak flow and attempting to reduce the peak flood levels within and downstream of the reach.

The extent of the proposed regrading is shown on **Figure 9.11**.

Hydraulic modelling was undertaken in a similar manner to Option FM10 to assess the impact of implementing this option. This option resulted in a decrease in flood levels in all design events for the reach of South Creek between the Willandra Road crossing (lower) and the Carcoola Road crossing and the lower reach of Wheeler Creek (maximum decrease in the 100 Year ARI of 0.29m). However, there is a slight increase in flood levels for a length of 130m upstream of Carcoola Road (maximum increase in the 100 Year ARI of 0.08m).

**Table 9.6** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed Option FM11. The larger events have a decrease in the number of properties with over-floor flooding. However, in the 5 Year ARI event, there is an additional property with over floor flooding (over-floor depth of 0.02m in the 5 Year ARI event).

As a result of this option 24 properties experience an increase in 100 Year ARI flood levels, of these properties 6 experience over-floor flooding. The maximum increase in over-floor flooding in the 100 Year ARI event in 0.08m.

As a result of this option 46 properties experience a decrease in 100 Year ARI flood levels, 21 of these properties have a reduction in the 100 Year ARI flood level of greater than 0.2m. Of the 46 properties, 12 experience over-floor flooding in the existing case. As a result of this option 4 of these properties no longer experience over-floor flooding.

**Table 9.6 Impact of Option FM11 on Over-floor Flooding**

| | Existing | Option FM11 | Change |
|---|---|---|---|
| **PMF** | 180 | 185 | -5 |
| **100 Year ARI** | 38 | 42 | -4 |
| **50 Year ARI** | 28 | 32 | -4 |
| **10 Year ARI** | 16 | 18 | -2 |
| **5 Year ARI** | 15 | 14 | 1 |

The results show that this option, compared with Option FM10, provides some of the flood benefits associated with FM10 but reduces the increase in flood levels and hence increase in properties with over-floor flooding.

The overall reduction in flood damages as a result of implementing this option is approximately $12,100. Whilst the actual number of properties with over-flood flooding is not reduced as significantly as with the implementation of FM10, the increase in over-floor flooding in the 5 Year ARI is less and the average annual damages is reduced by a slightly larger amount.

The benefit-cost ratio for this Option is 0.07. This means that the reduction in flood damages is less than the fee of implementing the option.

Further details as to the economic assessment of this option are provided in **Chapter 13**.

## 9.13 FM12 – Preparation and Implementation of Culvert Maintenance Strategy

Numerous community submissions to Council have highlighted the issues associated with blockage of the culverts and bridge crossings along South Creek. These locations have been noted by residents, Council staff and Cardno Lawson Treloar to block regularly, thereby increasing the impact of flooding on surrounding properties.

Council currently maintains all culverts and creek crossings in the Warringah Local Government Area. However, due to the large amount of debris being transported down South Creek, the maintenance program for South Creek may need to be updated to increase the frequency and timing of maintenance.

This option proposes to develop a maintenance strategy for the major culverts along South Creek and Wheeler Creek. The locations of the culverts are shown in **Figure 8.1**. The maintenance strategy would provide a practical guide for Warringah Council to both maintain and document maintenance for the culverts along South Creek and Wheeler Creek.

The strategy should, as a minimum, involve quarterly maintenance inspections and an inspection of the culverts after high rainfall events. A summary table should be provided which indicates when maintenance activities are required and a checklist should also be been provided to record observations and any further actions that may be required.

It may be appropriate for Council to prepare a culvert maintenance strategy for the entire LGA. However, within the LGA wide strategy special consideration should be given to the high likelihood of culvert blockage in the South Creek floodplain and the sensitivity of flood levels within the floodplain to blockage occurrence.

Increased removal of debris could also have environmental benefits in terms of water quality. The litter and polluting debris (such as rubber tyres and containers of unspecified liquid) would be removed along with the vegetation debris.

Due to the nature of the catchment and the large debris loads, it is unlikely that any maintenance program could completely eliminate the potential for blockage of the culverts and creek crossings in South Creek and Wheeler Creek.

Hydraulic modelling has been undertaken to assess the impact of implementing this option. It has been assumed that due to increased maintenance the risk of blockage of the culverts would be reduced. For the purposes of modelling the culverts were blocked by 75 percent instead of 100 percent. The blockage was assumed to occur from the bottom of the culvert, leaving the remaining upper 25 percent of the culvert available to convey flows.

It should be noted that the findings of the analysis of this option, are significantly dependant on the assumption that only 75 percent blockage can be achieved. There is no documented evidence or reference material which can be utilised to determine the level of maintenance

that would be required to achieve this value, nor whether only 75 percent blockage is even achievable in South Creek.

This option resulted in a decrease in flood levels for almost the entire length of South Creek (except the most upper reach) and approximately 400 metres of the lower reaches of Wheeler Creek. The maximum decrease in flood levels in the 100 Year ARI event was 0.31m, however, the reduction actually increased in the smaller events, with a 0.48m decrease in the 5 Year ARI event.

**Table 9.7** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option FM12. This option provides the greatest benefit (in terms of over-floor flooding) in events smaller than the 50 Year ARI event and has a significant benefit in all flood events.

**Table 9.7 Impact of Option FM12 on Over-floor Flooding**

| | Existing | Option FM12 | Change |
|---|---|---|---|
| **PMF** | 182 | 185 | -3 |
| **100 Year ARI** | 38 | 42 | -4 |
| **50 Year ARI** | 22 | 32 | -10 |
| **10 Year ARI** | 11 | 18 | -7 |
| **5 Year ARI** | 7 | 14 | -7 |

The economic assessment provided in **Chapter 13** shows a significant reduction in the overall flood damages of approximately $101,000. Whilst there would be no significant capital costs associated with this option, there would be fairly significant ongoing costs and potential environmental impacts associated with access and machinery. The benefit-cost ratio for this option is 4.42, showing a significant economic benefit as a result of implementing this option.

## 9.14 FM13 – Enhance Willandra Road (lower) Culverts

The road crossing at Willandra Road (lower) is comprised of two box culverts (1.55m x 3m each). These culverts provide a significant amount of conveyance for flows within South Creek. However, residents have noted flood water backing up behind Willandra Road during flood events and in some cases overtopping the road.

The location of the Willandra Road (lower) Culverts and the proposed option for this site is shown on **Figure 8.1**.

The hydraulic model results show that the culverts will overtop in the 100 Year ARI design event even when no blockage occurs in the culverts. However, for the purposes of determining flood planning levels the flood study (WMA, 2006) adopted a total blockage policy of all culverts (with the exception of Toronto Avenue).

The hydraulic model results indicate that, even if no blockage occurs, the culverts at Willandra Road do not have the capacity to convey the flood waters in the 100 Year ARI event (there is only 0.3 m difference between the fully blocked and fully unblocked 100 Year ARI flood levels). The limited capacity of the culverts results in flood waters building up behind the culverts, increasing flood levels upstream of Willandra Road.

The existing culverts at Willandra Road span almost the entire width of the creek. Therefore it is not possible to enhance the culverts significantly across the creek. However, the creek invert upstream of the culverts becomes fairly flat further contributing to the build-up of

floodwaters at this location. It may be possible to excavate the creek channel at this location to improve flow conveyance.

The improved flow conveyance is likely to decrease the flood levels upstream of Willandra Road by up to 0.5m. Due to the steep nature of the creek, there is unlikely to be any consequential increase in flood levels downstream of the culverts. There may need to be some compensatory excavation on the downstream end of the culverts to ensure this.

The flood benefit is likely to extend for approximately 100m upstream of Willandra Road and would impact approximately 6 residential properties on the right bank of South Creek, along Ara Crescent.

Due to the blockage scenario adopted for the hydraulic modelling for South Creek (full blockage of all culverts, except for Toronto Avenue), this option is unable to be assessed using the hydraulic model. In fact, due to the blockage scenario, the increased height of the culvert would actually show an increase in flood levels upstream of Willandra Road. Given this impact, this option has not been assessed quantitatively for impacts on flood levels and flood damages.

Before implementation this option would require detailed hydraulic assessments to ensure there would be no adverse impacts on adjacent properties. As no hydraulic modelling of this option has currently been undertaken and the works proposed have significant costs associated with them it is recommended that should this option proceed, a detailed cost estimate is undertaken to compare against the hydraulic assessment to re-evaluate the benefit cost ratio associated with this option.

## 9.15 FM14 – Regrading of right bank upstream of Willandra Rd (Lower) Crossing

There is a small vacant block of land upstream of Willandra Road, on the right bank. The flood extents show that when the flood waters build up behind Willandra Road, there is a significant encroachment onto the area on the right bank.

This option proposes to excavate the reserve to allow for additional storage of flood waters. This may alleviate flooding for the properties immediately adjacent to and opposite the reserve. However, to achieve any flood benefit the reserve would need to be excavated to such an extent that it would not longer be usable for passive recreation or access to the creek. Even if significant excavation was undertaken it is unlikely that the benefit to the surrounding properties would be significant.

The location of this land and the extent of regrading are shown on **Figure 9.12**.

## 9.16 FM15 - Levee to Protect Properties at the End of Towradgi St

There is one property bordering the creek on the right bank at the end of Towradgi Road which is significantly impacted by flooding, with flood depths in the 100 Year ARI event of up to 3 metres. The neighbouring properties are also impacted by flooding to a lesser degree. Flooding occurs on these residential properties due to South Creek exceeding its bank capacity and spilling out into the overbank area (including the subject properties).

It is possible to construct a levee around these properties to protect them from flooding. To protect these properties from flooding up to the 100 Year ARI event, the levee would need to be a maximum of 4m high; however, this high value would only be for a very short section of the levee due to a low portion of the bank and so would not appear to be so high. For the entire length of the levee, the top of the levee would be below the ground level at

the end of Towradgi Street. This would result in minimal visual impact of the levee from the street.

The levee would comprise, where possible, of a grassed mound. Where space prohibits the use of the mound a solid fence-like structure could be implemented instead.

The levee details are shown below in **Figure 9.13** with the 100 Year ARI extent shown as a blue line, the proposed levee in green and property boundaries in yellow.

The levee would be constructed, where possible on public land and not on private residential properties. This would reduce the impact on properties.

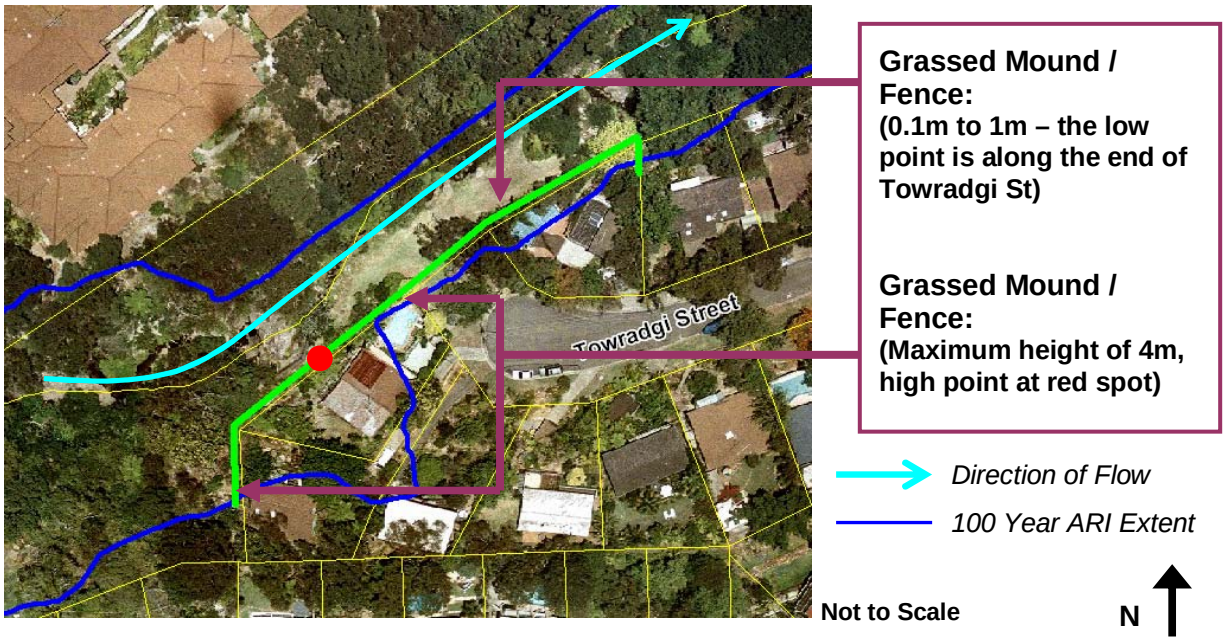



**Figure 9.13 Option FM15 – Towradgi Street Levee**

The proposed levee would protect 3 properties from flooding in all flood events, up to and including the 100 Year ARI. The properties would not be protected from events greater than this. Based on available ground survey, it is suggested that a levee higher than the proposed dimensions would be intrusive and may have a negative impact on visual amenity. During the detailed design stage, it may be found that a higher level could be acceptable, thereby providing for protection from more severe flood events.

Due to the steep channel it is unlikely that the construction of the flow in South Creek would adversely impact on flood levels.

Whilst the mound would protect the 3 properties it surrounds, any restriction of flood flow paths has the potential to impact on flood levels. A large portion of the proposed levee is located within the Floodway extent. Therefore, the construction of the levee will impact on the primary flow path area and is likely to have an impact on flood levels. However, the creek is very steep at this location at this would reduce the likelihood of increased flood levels as a result of the proposed levee. Further more, the creek bank on the opposite side of the creek is fairly steep and high and protects the properties from flooding and any increase in flood levels as a result of the proposed levee is unlikely to exceed the creek bank at this location. Any increase in flood levels would not be translated upstream of the levee due to the waterfall.

There are residential properties on the downstream end of the proposed levee. However, any increase in flood levels as a result of the levee is unlikely to cause over-floor flooding on these properties and due to the steep nature of the properties in unlikely to increase the extent of property flooding by any appreciable amount. This would require confirmation through further assessment if this option is to be implemented.

The proposed levee has been designed at the 100 Year ARI flood level (with no freeboard allowance). This means that the levee will overtop in events greater than the 100 Year ARI. As such, the levee could create a false sense of flood protection and then when it does overtop the result may be a more hazardous environment with little, if any, warning of hazardous flooding.

In addition, if suitable drainage is not feasible there can be localised ponding behind the levee.

On the other hand, if designed appropriately and the location permits, levees can provide very successful and relative cost effective means of protecting properties from flooding.

## 9.17 FM16 – Enhance Alkira Circuit Culverts

The road crossing at Alkira Circuit is comprised of four circular culverts with a diameter of 1.35m. The hydraulic model results show that the Alkira Circuit Bridge will overtop in the 100 Year ARI design event even when no blockage occurs in the culverts (by approximately 0.5m). However, for the purposes of determining flood planning levels the flood study (WMA, 2006) adopted a total blockage policy of all culverts (with the exception of Toronto Avenue). Under totally blocked conditions, Alkira Circuit is likely to overtop in a 100 Year event by a greater depth than when unblocked (approximately 1.5m).

The location of the Alkira Circuit Culverts and the proposed option for this site is shown on **Figure 8.1**.

The hydraulic model results indicate that, even if no blockage occurs, the culverts at Alkira Circuit do not have the capacity to convey the flood waters in the 100 Year ARI event. As such, flood waters build up behind the culverts increasing flood levels upstream of Alkira Circuit. However, due to the steep nature of the creek and the limited storage area behind the culvert it is unlikely that enhancing the culvert will significantly reduce flood levels.

To enhance the culverts, the existing 4 circular culverts could be replaced with 2 box culverts. This would increase the capacity of the culverts through increased flow area and reduced frictional losses due to the culverts walls.

Due to the blockage scenario adopted for the hydraulic modelling for South Creek (full blockage of all culverts, except for Toronto Avenue), this option is unable to be assessed using the hydraulic model. The proposed enhancement of the culverts would not have any impact on the model results for a fully blocked scenario. As such, this option can not be assessed quantitatively for impacts on flood levels and flood damages.

If the culverts were able to be enhanced to convey the full 100 Year ARI flood flows through culvert enhancement, and no blockage occurred, the maximum reduction in flood levels upstream of Alkira Circuit is likely to be of the order of 0.5m and the extent of influence is unlikely to be greater than 20 to 30 metres upstream. The creek flows through a waterfall downstream of Alkira Circuit; therefore it is unlikely that there will be any impact on flood levels on the downstream side of the bridge.

## 9.18 FM17 – Enhance Willandra Road (upper) Culverts

The road crossing at Willandra Road is comprised of one box culvert (3m x 1.5m) and one small circular culvert. The hydraulic model results show that the Willandra Road Bridge will overtop in the 100 Year ARI design event even when no blockage occurs in the culverts (by approximately 0.3m). However, for the purposes of determining flood planning levels the flood study (WMA, 2006) adopted a total blockage policy of all culverts (with the exception of Toronto Avenue).

The location of the Willandra Road (upper) Culverts and the proposed option for this site is shown on **Figure 8.1**.

The hydraulic model results indicate that, even if no blockage occurs, the culverts at Willandra Road do not have the capacity to convey the flood waters in the 100 Year ARI event. As such, flood waters build up behind the culverts increasing flood levels upstream of Willandra Road until the road overtops. When blockage occurs this situation is worsened. However, due to the steep nature of the creek it is likely that any reduction in flood levels as a result of this option will only be contained to the area immediately upstream of Willandra Road.

To enhance the culverts, the existing culverts could be replaced with a single box culvert approximately 6m wide and 2m high. This would increase the capacity of the crossing through increased flow area and reduced frictional losses due to the culvert walls.

Due to the blockage scenario adopted for the hydraulic modelling for South Creek (full blockage of all culverts, except for Toronto Avenue), this option is unable to be assessed using the hydraulic model. The proposed enhancement of the culverts would not have any impact on the model results for a fully blocked scenario. As such, this option can not be assessed quantitatively for impacts on flood levels and flood damages.

As a guide, if blockage did not occur, the maximum reduction of flood levels in the 100 Year would be achieved if the culvert could be enhanced to convey the full 100 Year ARI flood flows through culvert without restriction. This is unlikely, but if it were possible, the maximum reduction in flood levels upstream of Willandra Road is likely to be of the order of 1.08 metres. However, this reduction in flood levels would only extend for approximately 70m upstream of Willandra Road (decreasing in magnitude). There may also be a corresponding increase in flood levels downstream of the crossing; however, due to the steep gradient of the creek the increase would most likely not be significant. Further the increase in flood levels is unlikely to impact on property flooding and is likely to be contained within the channel.

There are 3 flood affected properties within the predicted extent of influence of this option. Two of these properties experience over-floor flooding in a 100 Year ARI event. It is likely that as a result of implementing this option that these properties would no longer experience over-floor flooding in events up to and including the 100 Year ARI. All three properties would still experience property flooding but it would be reduced.

## 9.19 FM18 – Levee to Protect Properties on the Left Bank Upstream of Willandra Rd (upper)

There are two properties bordering South Creek on the left bank upstream of Willandra Road which are significantly impacted by flooding, with flood depths on the property in the 100 Year ARI event of up to 1 metre. Both properties experience over-floor flooding in the 100 Year ARI event. Flooding occurs on these residential properties due to South Creek exceeding its bank capacity and spilling out into the overbank area (including the subject properties).

It is possible to construct a levee around these properties to protect them from flooding. To protect these properties from flooding up to the 100 Year ARI event, the levee would need to be a maximum of 1.5m high.

The levee would comprise, where possible, of a grassed mound. Where the levee extends along Willandra Road, the driveway accessing the subject properties will either have to be removed or redesigned to go over the levee. This would require a maximum height above the ground level of 0.8 metres. Given the ground levels at the street kerb and the garage, the driveway would require the maximum slope on the street side of approximately 9 percent. This is within Council accepted driveway design slopes. Detailed design of the driveway would be required to ensure compliance with Council's requirements.

The levee details are shown below in **Figure 9.14** with the 100 Year ARI extent shown as a blue line, the proposed levee in green and property boundaries in yellow.

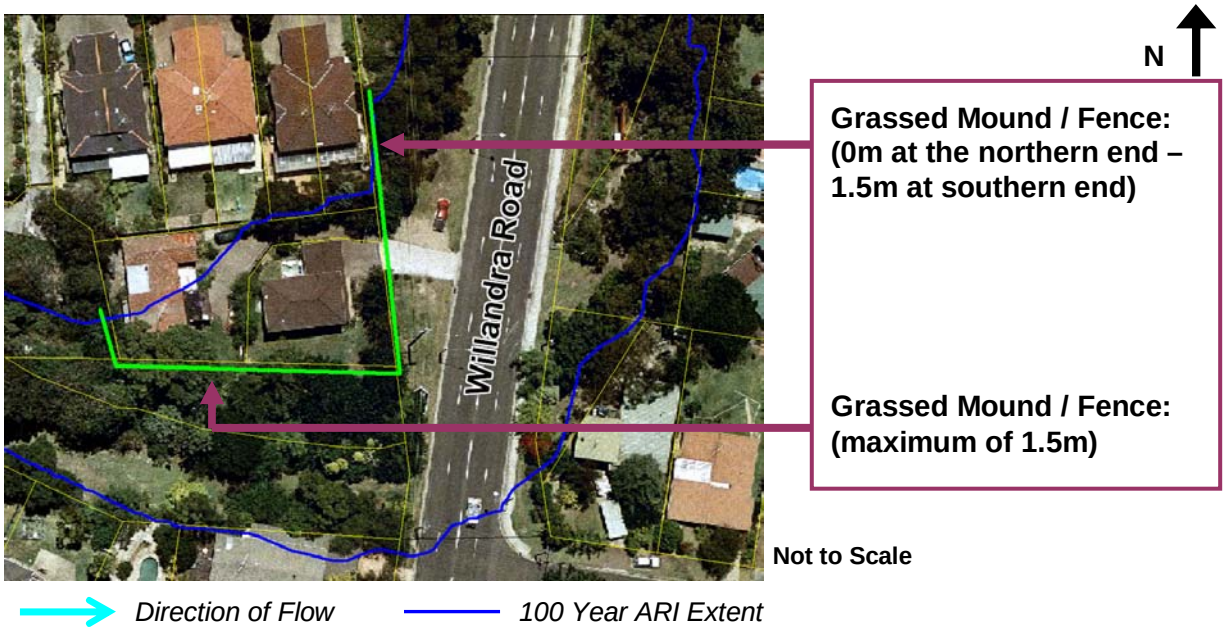



**Figure 9.14 Option FM18 – Willandra Road (upper) Levee**

The levee would be constructed, where possible on public land and not on private residential properties. This would reduce the impact on properties.

The proposed levee would protect 2 properties from flooding in all flood events, up to and including the 100 Year ARI. The properties would not be protected from events greater than this. Based on available ground survey, it is suggested that a levee higher than the proposed dimensions would be intrusive and may have a negative impact on visual amenity. During the detailed design stage, it may be found that a higher level could be acceptable, thereby providing for protection from more severe flood events.

Whilst the mound would protect the 2 properties it surrounds, any restriction of flood flow paths has the potential to impact on flood levels. A large portion of the proposed levee is located within the Floodway extent. Therefore, the construction of the levee will impact on the primary flow path area and is likely to have an impact on flood levels. Further more, there are flood affected properties (other than those protected by the levee) on the opposite side of the creek to the proposed levee. As such, any increase in flood level as a result of the proposed levee is likely to impact on these properties. This would require confirmation through further assessment if this option is to be implemented.

The proposed levee has been designed at the 100 Year ARI flood level (with no freeboard allowance). This means that the levee will overtop in events greater than the 100 Year ARI. As such, the levee could create a false sense of flood protection and then when it does overtop the result may be a more hazardous environment with little, if any, warning of hazardous flooding.

In addition, if suitable drainage is not feasible there can be localised ponding behind the levee. On the other hand, if designed appropriately and the location permits, levees can provide very successful and relative cost effective means of protecting properties from flooding.

## 9.20 FM19 – Levee Adjacent to Cromer Golf Course

Cromer Golf Course currently experiences significant inundation during all of the design events assessed. However, flooding does not impact on the club house in any events up to and including the PMF. Flooding occurs on the golf course due to two flooding mechanisms. South Creek flooding occurs on the golf course as a result of flood waters exceeding the left bank and spreading out onto the gold course. In addition to the South Creek flooding, the golf course is also flooded as a result of flooding in Narrabeen Lagoon. Flooding from South Creek is of a relatively short duration compared with flooding from Narrabeen Lagoon.

This option proposes to construct a levee along the left bank of South Creek adjacent to Cromer Golf Course, to protect the golf course from flooding. The levee would only protect the golf course from South Creek flooding and as such the golf course would still experience flooding from Narrabeen Lagoon.

The proposed location of the levee is shown in **Figure 9.15**.

The loss of flood storage and conveyance, as a result of the implementation of this option, would be significant. As a result of this loss of flood storage and flood conveyance, flood levels would be likely to rise considerably in South Creek; this would have a significant impact on the properties along South Creek Road and James Wheeler Place. The result flood damages associated with the impacts on these properties would be far in excess of those currently experienced by the golf course.

It should be noted that improvements to Golf Courses are not normally funded under the NSW State Government's flood program, even if there are local flood benefits to the golf course.

## 9.21 FM20 – Debris Control Structures

Numerous community submissions to Council have highlighted the issues associated with blockage of the culverts and bridge crossings along South Creek. These locations have been noted by residents, Council staff and Cardno Lawson Treloar to block regularly, thereby increasing the impact of flooding on surrounding properties.

Large floating debris (or drift), typically in the form of fallen trees and branches, is frequently transported in natural streams under flood conditions. In the past, bank clearing and channel modification have been utilised to reduce the source of debris, however there are significant detrimental effects on aquatic and riparian habitats which render these options unsuitable.

The most common debris control method utilises the periodic removal of accumulated debris at culverts and bridge. While generally effective, it incurs a recurring cost. It also assumes a slow and gradual accumulation of debris, permitting a judicious scheduling of

removal, and hence offers no protection against a large event, during which large amounts of debris may quickly become established, blocking the culvert or bridge. Increased debris removal programs have been described in Option FM12 (**Section 9.13**).

In conjunction with an increased maintenance schedule, it may be appropriate to develop structural methods to control debris. This option proposes that a detailed assessment of South Creek and Wheeler Creek should be undertaken to identify any suitable structural measures to control debris in these creeks. Structural measures have many configurations and constructed from many materials.

There are various types of structural measures available for culverts and bridges. These measures can have many shapes and can be constructed using various materials. A range of measures that may be suitable for South Creek and Wheeler include:

- **Debris Deflectors** are structures placed at the culvert inlet or upstream of bridges to deflect the major portion of the debris away from the culvert entrance or bridge. They are normally "V"-shaped in plan with the apex upstream.
- **Debris Racks** are structures placed across the stream channel to collect the debris before it reaches the culvert entrance. Debris racks are usually vertical and at right angles to the streamflow, but they may be skewed with the flow or inclined with the vertical.
- **Debris Fins** are walls built in the stream channel upstream of the culvert or bridge. Their purpose is to align the debris with the culvert or bridge so that the debris would pass through without accumulating at the inlet.

Photographic examples of these types of debris control structures are provided in **Figure 9.16**.

The space available to implement these debris control structures is limited in South Creek and Wheeler Creek. Further, a debris control structure located at a culvert or bridge may simply block itself during a storm event. It may be possible at some locations to implement a debris control structure some distance upstream of the culvert or bridge. However, detailed hydraulic modelling would be required to determine any impact on flood levels upstream of the debris control structure. It is not appropriate to increase flood levels on upstream properties in an attempt to decrease flood levels on another, even if the overall result is a reduction in damages.

## 9.22 FM21 – Debris Management on Wheeler Creek

There are a number of properties potentially affected by flooding along the lower reach of Wheeler Creek. The primary flood affected property upstream of Little Willandra Road primarily is the Willandra Bungalows Retirement Village. Flooding of this property is significantly impacted by the blockage of the culverts under Little Willandra Road.

In the 100 Year ARI flood event, there are 2 buildings within the Willandra Bungalows with over-floor flooding and at some locations at the downstream end of the property there are flood depth of over 2 m. The access road to the Northern Portion of the property from Little Willandra Road is inundated in the 100 Year ARI flood event to depth of 0.5m.

In comparison, when there is no blockage at the Little Willandra Road Culverts the northern access road is not inundated and only one property has over-floor flooding in the 100 Year ARI event.

Therefore, not only does the blockage of the culverts worsen flooding within the Retirement Village it poses a very significant flood access issue for the northern portion of the site.

At most locations within the South Creek floodplain, it is likely that the implementation of the debris control structure would likely worsen flooding immediately adjacent to and upstream of the debris control structure. However, this situation does not apply within Wheeler Creek. If a debris control structure were to be placed upstream of the Retirement Village, it would capture debris before it arrived at Little Willandra Road and would therefore significantly reduce the likelihood of blockage of the culverts. Further, any increase in flood levels upstream of the debris control structure would not impact on any residential properties or any utilities or services.

The proposed location of the debris control structure is shown in **Figure 9.17**.

# 10. PROPERTY MODIFICATION OPTIONS ASSESSMENT

As outlined in **Sections 6 and 7**, there are a number of opportunities for the use of planning legislation, plans, policies, or guidelines for the management of flood liable areas of the South Creek catchment. **Table 10.1** provides a summary of the options identified.

**Table 10.1 Property Modification Options**

| ID | Property Modification Option Description |
|---|---|
| PM1 | Ongoing implementation of development controls and guidelines for building work. |
| PM2 | Preparation of Flood-related Section for Council's Development Control Plan. |
| PM3 | Guidelines for Public Domain Infrastructure. |
| PM4 | Voluntary House Raising Program. |
| PM5 | Voluntary House Purchase Program – 10 Properties. |
| PM6 | Voluntary House Purchase Program – 1 Property. |
| PM7 | Stringent OSD Requirements on any Proposed Development in the Catchment. |
| PM8 | Analysis of Localised Flood Planning Level Requirements |
| PM9 | Property Dossier of Severely Flood Affected Properties to Assist with Customising Site Specific Mitigation Measures. |

Details of each option and the benefits and impacts are described below.

## 10.1 PM1 – Ongoing Implementation of Development Controls and Guidelines for Building Work

Development controls are a considerable preventative measure for the management of the continuing risk of flooding. Development control plans (DCPs) typically contain another layer of development control to provide more detail and supplement local environmental plans. However, much of the detail which would commonly be contained in many other development control plans is incorporated into Warringah Local Environmental Plan 2000 (WLEP2000).

With regard to development controls relating to development in the floodplain, WLEP2000, states in Section 47 (Flood Affected Land):

> *Development on flood affected land is to be sited and designed to minimize impacts of flooding on property and have regard to the existing flood regime. In particular:*
>
> - *development is not to reduce flood storage area or impact upon the existing flood regime,*
> - *habitable floor areas of buildings are to be at a level of at least 500mm above the 1% annual exceedance probability flood level, and*
> - *buildings or works affected by flooding are to be constructed of flood compatible building materials.*
>
> *For the purposes of this clause, flood affected land means land below the 1 per cent annual exceedance probability flood level.*

This option proposes to continue implementing the controls for development in the floodplain as outlined in the WLEP2000.

## 10.2 PM2 – Preparation of Floodprone Lands Development Control Plan for Warringah LGA

Council is currently preparing a *Floodprone Lands Development Control Plan (DCP).* This DCP will support the guidelines set out in the WLEP2000 and provide specific controls relating to development in the floodplain.

The DCP will be prepared to ensure development is appropriate within the floodplain. The floodplain controls proposed for incorporation into the DCP would include development restrictions based on Hazard and Hydraulic Categorisation and development type, minimum floor levels would be based on a recommended *Flood Planning Level* and considerations with regard to emergency evacuation routes.

It is recommended that the DCP should include an attachment for each of the floodplains within the Warringah LGA. Each attachment would highlight the specific flooding issues relating to each of the floodplains. These attachments could be prepared during the Floodplain Risk Management Study and Plan for each floodplain.

A recommended South Creek DCP attachment has been provided in **Appendix E**.

The implementation of the DCP will result in more appropriate controls on development in the floodplain and hence a reduction to the risk to life and property as a result of flooding. In addition, the use of the South Creek attachment in the DCP will ensure appropriate controls are applied specific to development in the South Creek Floodplain.

## 10.3 PM3 – Guidelines for Public Domain Infrastructure

Given the ongoing need for various forms of infrastructure in the floodplain, the following guiding principles have been prepared for consideration for inclusion in either an appropriate technical policy (such as a Stormwater Design Code) or within the *Floodprone Lands DCP*:

- stormwater system guidelines (outlets to have appropriate scour protection, be checked for surcharge as a result of mainstream flooding);
- creek/channel crossing guidelines for services (new crossings to be buried below the channel invert (with an appropriate minimum cover) or where possible set at the 100 year ARI or the PMF, the impact of the structure on flood levels to be assessed by hydraulic modelling including the potential blockage);
- new channel crossings and footbridges (to have a clear span with a diagonal greater than 6m where possible, to be set with their obvert at the 100 year ARI or the PMF depending on their purpose and the impact of the structure on flood levels to be assessed by hydraulic modelling including the potential blockage);
- handrail and guard-rail issues for culverts (impact of the replacement of a handrail or guard-rail that is higher than any current handrail or guard-rail to be assessed by hydraulic modelling);
- flood levels to be considered in the design process for the installation or upgrade of any sewage pumping stations; and
- other public infrastructure proposed in the floodplain, but not listed above, be checked for any hydraulic impacts and be subject to a risk assessment (particularly utilities such as energy and telecommunications, which will require accessibility to flood information to aid design).

## 10.4 PM4 – House Raising Program

There are a total of 185 properties which experience over-floor flooding in the PMF. If some of these properties could be raised, such that the floor levels are above the FPL, this would reduce the damages incurred by flooding on those properties. Should these properties be raised to the Flood Planning Level (100 Year ARI + 0.5m) the dwelling would have flood protection in all events, up to and including the 100 Year ARI event.

House Raising involves raising an existing house (by progressively raising the piers and associated floor area). Details of the construction sequence to achieve "raising" will be dependant on the individual dwelling. This option is not applicable for properties which are "slab on ground" construction.

There are 14 properties with over-floor flooding in the 5 Year ARI flood event. These properties are considered to be severely flood affected. However, only 4 of these properties are built on piers. Likewise of the 18 properties with over-floor flooding in the 10 Year ARI event, only 6 of these are built on piers. In fact, of the 42 properties which experience flooding in the 100 Year ARI event, only 21 are built on piers.

It is not cost effective to raise all 21 of these properties above the FPL, as in many of these cases the above floor flooding depth is less than 0.1m. Therefore, there would be significant costs involved with raising the house without a significant reduction in damages.

This option, therefore, proposes to raise the 6 properties which have over-floor flooding in the 10 Year ARI and are built on piers. It has been assumed that the cost of raising a house above the FPL would be approximately $80,000.

**Table 10.2** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option PM3. This option raises 6 properties to a level of 0.5m above the 100 Year ARI Flood Level.

**Table 10.2 Impact of Option PM4 on Over-floor Flooding**

| | Existing | Option PM4 | Change |
|---|---|---|---|
| **PMF** | 185 | 185 | 0 |
| **100 Year ARI** | 42 | 36 | -6 |
| **50 Year ARI** | 32 | 26 | -6 |
| **10 Year ARI** | 18 | 12 | -6 |
| **5 Year ARI** | 14 | 10 | -4 |

House raising provides a flood free evacuation area and significantly reduces the flood risk for occupants and does not require the demolition and or replacement of existing residences. However, voluntary house raising is not compulsory. As such, of those properties which are eligible for the funding, not all property owners may be willing to undertake it.

Voluntary House Raising is funded with assistance from the State Government. However, due to the relatively expensive nature of the program, limited availability of Government and/or Council funding can be a major constraint to undertaking house raising.

The economic assessment provided in **Chapter 13** shows a significant reduction in the average annual damages (AAD) if this option is implemented. The reduction in AAD is $55,000. When comparing the reduction in flood damages and the cost of implementing this option, it can be seen that there would be a positive economic outcome from this option for the community. The resultant benefit-cost ratio is 1.78. Further details on the calculation of benefit-cost ratios are provided in **Chapter 13**.

## 10.5 PM5 – Voluntary House Purchase (10 Properties)

There are 10 properties predicted to experience over-floor flooding of more than 0.1m depth in the 5 Year ARI event. These properties are considered to be severely flood affected. As discussed above, house raising is only an option for those properties which are on piers. An alternative to house raising is voluntary purchase.

Voluntary purchase is the optional purchase of pre-selected properties jointly by Council and the State Government. Those properties are commonly converted into public open space or similar. The resultant land use is generally more compatible with the flood risk and therefore the resultant flood damages are negated for those properties.

It should be noted, that a property owner is under no obligation to sell their property. It has been assumed that the average cost of purchasing a property in the South Creek Floodplain would be approximately $850,000.

Voluntary House Purchase is funded with assistance from the State Government. However, due to the relatively expensive nature of the program, limited availability of Government and/or Council funding can be a major constraint to undertaking Voluntary House Purchases.

If the 10 most severely flood affected properties (regardless of construction type) in the South Creek floodplain were purchased under the proposed scheme there would be a reduction of over-floor flooding of 10 properties in all design events (**Table 10.3**). This corresponds to an estimated reduction in Average Annual Damages of $122,000. However, when comparing the reduction in flood damages and the cost of implementing this option, it can be seen that cost of implementing this option for outweighs the economic benefits of the option. The resultant benefit-cost ratio is 0.21. Further details of the economic assessment of this option are provided in **Chapter 13**.

**Table 10.3 Impact of Option PM5 on Over-floor Flooding**

| | Existing | Option PM5 | Change |
|---|---|---|---|
| **PMF** | 185 | 175 | -10 |
| **100 Year ARI** | 42 | 32 | -10 |
| **50 Year ARI** | 32 | 22 | -10 |
| **10 Year ARI** | 18 | 8 | -10 |
| **5 Year ARI** | 14 | 4 | -10 |

## 10.6 PM6 – Voluntary House Purchase Investigation (1 Property)

There is one property in the South Creek floodplain which is predicted to experience severe property and over-floor flooding in all design events. The building on this property is “slab on ground” construction.

It may be appropriate to provide the option of Voluntary House Purchase to the property owner of this one property. Based on the above estimate for property purchase, the cost of implementing this option has been estimated at $850,000. The actual cost of implementation would be dependant on valuation and would require detailed assessment if this option were pursued.

This option would result in one less flood affected property in all design events.

The benefit-cost ratio for this option is 0.24. Further details of the economic assessment of this option are provided in **Chapter 13**.

## 10.7 PM7 – Review of Draft OSD Policy

On site detention (OSD) for new or redeveloped areas is a means of managing the increased rate of runoff from the site that is generated as a result of the development. A variety of different approaches have been formulated and adopted across New South Wales as an attempt to ensure that existing flood conditions are not worsened by incremental development throughout a catchment. On site detention works on the principle of controlling the peak discharge from a site, but generally does not address the additional volume of runoff generated. Stormwater retention and reuse is a means of managing the additional volume generated as a result of additional impervious surfaces within a new development.

Warringah Council currently has a Draft On-Site Stormwater Detention Rainwater Reuse Policy for Alterations and Additions and New Single Residential Dwellings. This policy should be supported by catchment specific recommendations to ensure any development in the catchment does not have an impact on all flooding up to and including the 100 Year ARI flood event.

Catchment specific volume and discharge requirements should be specified for each catchment.

## 10.8 PM8 – Analysis of Localised Flood Planning Level Requirements

Warringah Council's Flooding DCP and this FRMS recommend the adoption of a Flood Planning Level (FPL) using the 100 Year ARI plus 0.5m. The analysis and discussion presented in **Section 6** suggest that, on average, across the floodplain this is the most appropriate FPL.

However, as described in **Section 6.12** and **Table 6.4** there are some areas (*i.e.* near McIntosh Road) that are sensitive to changes in rainfall and other model parameters. The sensitivity analysis shows a difference in flood levels at this location greater than 0.5m. It may be appropriate to apply a freeboard greater than 0.5m to the 100 Year ARI flood levels in this case.

It is recommended that any further analysis of this nature is done on an LGA wide basis to consider where this situation may occur for other floodplains in the Warringah LGA. This will allow for consistency in any planning decisions relating to localised FPLs.

## 10.9 PM9 – Property Dossier of Severely Flood Affected Properties

There may be several properties in the floodplain which experience significant flooding and for which there are no suitable flood risk management measures. It is recommended that, following the scoring and ranking of all options for the South Creek floodplain, the properties which still experience significant flooding should be targeted for inclusion in a "Property Dossier".

The property dossier would endeavour to consider these few selected properties in more detail than is within the scope of this floodplain-wide study. The dossier would evaluate the opportunities for "shelter-in-place" and evacuation from these properties as well as customised site specific flood proofing opportunities (e.g. raising of power-points, incorporation of seals to prevent the ingress of floodwaters and alternate floor covering). The SES would be notified of the greater flood risk faced by these properties so that they

could be targeted in the event of a flooding emergency. It may be necessary to provide subsidies to flood proof a portion of these properties.

# 11. EMERGENCY RESPONSE MODIFICATION OPTION ASSESSMENT

As outlined in **Section 7**, there are a number of opportunities for the emergency response management in the flood liable areas of the South Creek catchment. Implementing flood emergency measures is an effective means of reducing the costs of flooding and managing the continuing and residual risk to the area. Improved emergency response and warning measures and increased community awareness assist in making the community feel safe and reduce the risk to life as a result of flooding. **Table 11.1** provides a summary of the options identified.

**Table 11.1 Emergency Response Modification Options**

| ID | Emergency Response Modification Measures |
|---|---|
| EM1 | Preparation and Adoption of SES Local Flood Plan |
| EM2 | Flood Warning Systems and Instrumentation. |
| EM3 | Information Transfers to SES. |
| EM4 | Community education and awareness programs. |
| EM5 | Targeted Flood Education Programs |
| EM6 | Flood depth markers placed on both sides of all roads crossing the creeks. |
| EM7 | Ongoing collection of flood information. |

Details of each option and the benefits and impacts are described below.

## 11.1 EM1 – Preparation and Adoption of SES Local Flood Plan

**Section 7.1** outlines the current status and contents of the Warringah LGA DISPLAN. The DISPLAN identifies the flood hazard to be a high probability hazard with major consequences. Generally, a sub-plan to the local DISPLAN termed as Local Flood Plan is prepared by the SES to effectively manage the flood emergency. The SES is currently preparing the Manly, Warringah and Pittwater Local Flood Plan. This will form the sub-plan to the DISPLAN which will address the flood hazard in the Warringah LGA.

The following issues are recommended for inclusion in the sub-plan:

- prepare for the closing of roads, in association with the RTA and Council at the crossings of South Creek and Wheeler Creek. Details of road inundation is provided in **Section 4.10**;
- reference to the timing of flooding for the system should be included somewhere in the plan (e.g. less than 2 hours to the peak flood level from the onset of rain);
- reference to the potential for high velocity floodwaters and associated risks should be included to alert crews to the potential to the high velocity of floodwaters (up to 4 m/s in some locations);
- if evacuations are required then evacuees should be directed to those locations which are outside of the floodplain, via non-flood affected road;
- numbers of properties inundated are detailed in this report and as such the Local Flood Plan20000 can be updated with this information; and
- the over-floor flooding analysis undertaken in this study will be provided to Council in a spreadsheet format. As such, this information can be utilised to identify properties where ‘shelter-in-place’ is suitable. Where it is not suitable, the SES may need to concentrate their efforts on those properties.

## 11.2 EM2 – Flood Warning Systems and Instrumentation

The current Flood Warning Systems available for the South Creek floodplain are outlined in **Section 7.3**. Weather-based warnings (Severe Thunderstorm Warnings, Severe Weather Advices and Gale Warnings *etc*.) from the BOM are generally faxed to all of the local media outlets as well as the SES. Flood Watches (from the Hydrology Section of the Bureau) are only sent to the SES who then disseminates the information to the local media.

It should be noted that, due to the flash flooding nature of the floodplain, no precise flood warnings could be issued. The flood warnings for the South Creek floodplain would be in the form of more general warnings relating to sever weather warning. Current warnings advice, such as a severe weather warning could be issued as an automatic fax advice from the SES once a Flood Watch is received to the following major areas:

- Council
- RTA
- Selected Schools (*e.g.* Cromer Primary School), Community Groups and/or Clubs (*e.g.* Cromer Golf Club)
- Other areas as appropriate.

## 11.3 EM3 – Information Transfer to SES

The findings of the Flood Study (WMA, 2006) and this Floodplain Risk Management Study provide an extremely useful data source for the State Emergency Service. Information could be provided from the findings of the studies in two forms:

- electronic information (flood extent mapping, flood hazard mapping and depths of over-floor flooding in geographic information system format); and
- Laminated plans (hard copies of flood extent and hazard mapping) in laminated plan format for use in the operations centre to assist with directing teams to the most likely affected localities.

To overcome any issues associated with power loss or difficulty with accessing information in an emergency, laminated plans of flood information could be provided to the SES for use by the Divisional Controller at the SES operations centre.

## 11.4 EM4 – Community Education and Awareness Programs

Flood awareness is an essential form of communication for people residing on a floodplain. The affected community must be made aware, and remain aware, of their role in the overall floodplain management strategy for their area. This includes the defence of their property and evacuation of themselves if required. Given the short duration of flooding and the hazardous nature of a number of roads within the area, where possible residents should be encouraged to seek refuge via vertical evacuation (where flood-free second level areas are available).

Flood awareness is an ongoing issue and requires 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 recent history of the area. The more recent and frequent the flooding, the greater the awareness.

One difficulty with flood emergency planning is to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be enforced to ensure new residents are informed, the level of awareness within long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. An effective awareness program requires ongoing commitment by everyone within the floodplain and catchment.

It is recommended that the following awareness campaigns be considered for the South Creek floodplain:

- preparing Flood Safe brochures for the South Creek Floodplain;
- issue of other SES information brochures with a fridge magnet may be a more effective means of ensuring people retain information;
- continued use of media;
- development of a Schools Package; and
- information dissemination to be undertaken via information in Council rates notices for all affected properties on a regular basis.

## 11.5 EM5 – Targeted Flood Education Programs

There area a number of sensitive properties within the floodplain such as childcare centres and retirement villages. Any property that poses an additional risk to its users or occupiers should be targeted for specific education programs. These education programs should provide the following information to the property owner, manager and occupier:

- details of the flooding behaviour in the South Creek floodplain;
- flood levels and extents for the properties;
- notification of any structures or buildings which may be inundated during a flood event and likelihood of that occurring;
- an emergency response plan specific to that property and it occupiers; and
- identification of flood free access roads.

The education programs should be tailored to each property and should be developed by the Council, the land owner or manager and the SES. The emergency response plan should consider the appropriateness of ‘shelter-in-place’ and/or evacuation.

## 11.6 EM6 – Road Flood Depth Markers

Flood depth markers provide guidance as to the depth of flooding at a specific location. Depth markers are commonly located on roads that are periodically inundated and present a traffic or pedestrian hazard.

In addition to providing guidance to drivers and pedestrians on the depth hazard, the markers can also be used by roaming crews of the SES to provide updates on the nature of the changing flood threat in an area. For example, a depth marker reading, in association with a prediction of the likelihood of continuing rainfall can provide some guidance as to the return interval of the flood. This advice can then be used to assist with preparations for road closures and evacuations.

Flood depth markers are recommended to be installed at the following locations:

- Willandra Road (upper) – South Creek;
- McIntosh Road – South Creek;
- Alkira Circuit – South Creek;
- Willandra Road (lower) – South Creek;
- Carcoola Road – South Creek;
- Toronto Avenue – South Creek; and
- Little Willandra Road – Wheeler Creek.

It is recommended that at two twin-sided markers be installed at each location. One marker should be placed on each side of the road and at the location of the likely maximum depth of flooding. **Figure 8.1** shows the locations where flood depth markers are proposed.

## 11.7 EM7 – Ongoing Collection of Flood Information

This would involve the preparation of a flood data collection form and 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 (WMA, 2006) and this Floodplain Risk Management Study.

# 12. BANK MANAGEMENT OPTIONS

## 12.1 Overview

A bank management plan has been prepared concurrently with this study by Cardno Lawson Treloar (*South Creek Bank Management Plan*, 2007). The bank management plan has been included in **Appendix D** of this study. Several of the measures recommended for implementation in the bank management plan have potential flood benefits. Those measures likely to have a flood benefit have been incorporated into this study for assessment against the other floodplain risk management options.

The bank management measures considered as likely to have a flood impact for the South Creek floodplain are listed in **Table 12.1**.

**Table 12.1 Bank Management Options**

| ID | Bank Management Option Description |
|---|---|
| BM1* | Management of weeds in the South Creek channel downstream of Carcoola Road. |
| BM2 | Weed management along South Creek |
| BM3 | Monitor and excavate in South Creek Channel between Grover Ave and Wabash Ave as requires to maintain a channel capacity commensurate with the current flow-sediment regime. |
| BM4 | The left bank downstream of Willandra Road (lower) is steep and sandy with poor vegetation cover. Bank battering is recommended along with revegetation. This may increase the conveyance of flow in the channel. |

* The asterisk indicated that Option BM1 has been quantitatively assessed using hydraulic modelling.

BM3 is commensurate with FM5 (Rehabilitate Creek and Construct Wetland) and as such no further analysis has been undertaken on BM3 as part of the Floodplain Risk Management Study.

BM4 is not considered to have a significant flood impact and as such no further analysis has been undertaken as part of the Floodplain Risk Management Study.

Details of Option BM1 and BM2 are provided below. These options have been incorporated into the options assessment for this Floodplain Risk Management Study. Further details of the other Bank Management Options are provided in **Appendix D**.

## 12.2 BM1 – Weed Management Downstream of Carcoola Road

South Creek has weed issues along the majority of its length. Field investigations identified the reach immediately downstream of the Carcoola Avenue crossing to have significant weed infestation, which may be impacting on flood behaviour.

This option proposes to remove the dense weeds along this reach (approximately 135m in length) and revegetate with endemic floral species which have less impact on the flood behaviour. The extent of weed management is shown in **Figure 12.1**.

In addition to the potential flood benefit as a result of this option, there would be a significant benefit in terms of environmental values. The existing channel vegetation is dominated by weed species and native species are being limited by the dominant weed growth. The removal of weed species and introduction of endemic species will provide significant habitat value for native fauna species within the riparian corridor.

This option was incorporated into the hydraulic model by reducing the roughness value (Manning's n). The existing roughness value (as defined in the Flood Study, 2006) is 1.25 on the banks and 1 in the channel. The proposed roughness value is 0.25 on the banks and 0.2 in the channel. These values are still fairly high, allowing for significant revegetation to encourage increased biodiversity along the creek.

The hydraulic model results showed that this option resulted in the reduction of flood levels in South Creek downstream of Carcoola Road, for a length of approximately 120 metres, with a maximum decrease of approximately 0.2m in all design events.

**Table 12.2** provides a summary of the number of properties with over-floor flooding in both the existing case and under the proposed option BM1. This option provides a benefit (in terms of over-floor flooding) in the 100 and 50 Year ARI events.

**Table 12.2 Impact of Option BM1 on Over-floor Flooding**

| | Existing | Option BM1 | Change |
|---|---|---|---|
| **PMF** | 185 | 185 | 0 |
| **100 Year ARI** | 36 | 42 | -6 |
| **50 Year ARI** | 30 | 32 | -2 |
| **10 Year ARI** | 18 | 18 | 0 |
| **5 Year ARI** | 14 | 14 | 0 |

The economic assessment provided in **Chapter 13** shows a significant reduction in the overall average annual flood damages of approximately $6,000.

## 12.3 BM2 – Weed and Sediment Management in South Creek and Wheeler Creek

The South Creek Bank Management Plan (Cardno Lawson Treloar, 2008) provided in **Appendix D** proposes to manage weeds and excessive sedimentation at various locations along South Creek. The Bank Management Plan surmised that the presence of the weeds in the channel is 'choking' the flow, increasing flow velocities in some locations, which may be contributing to bank erosion noted in the field.

From a flood perspective, it is expected that the removal of weeds from the channel would improve flow conveyance within the channel and therefore reduce flood levels on the adjacent banks.

The locations identified as part of the Bank Management Study (Cardno Lawson Treloar, 2008) are shown on **Figure 12.2**. Additional details are provided in **Appendix D**.

Most of the sites identified require ongoing weed maintenance rather than immediate removal of large quantities of weeds. Removing large quantities of weeds can leave the bank exposed and increase the risk of bank erosion if a large flow event occurs before revegetation is possible.

The reach upstream of Carcoola Road requires significant removal of sediment and as such there would be a significant upfront cost involved in removing this. However, the capital cost for this option is relatively low compared with the ongoing maintenance costs. It is critical that weed management is ongoing.

There is strong community support for weed management along South Creek and Wheeler Creek.

# 13. ECONOMIC ASSESSMENT OF OPTIONS

## 13.1 Preliminary Costing of Options

A preliminary cost estimate of all proposed options has been prepared to assist with the comparative assessment of options. The costs were prepared (where appropriate) with the assistance of the Cordell Building Cost Guide.

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

The preliminary costing for all of the identified options is provided in the multi-criteria matrix provided in **Chapter 14**.

It is possible to quantitatively assess the economic benefit of some of the options (*i.e.* those which are hydraulically modelled and those with known benefits such as house raising). For those options, a benefit-cost ratio can be calculated.

A summary of the estimated capital costs for those options which have been quantitatively assessed is provided below in **Table 13.1**.

**Table 13.1 Capital Costs of Quantitatively Assessed Options**

| Option | Capital Cost Estimate | Recurrent Cost Estimate[1] | Details |
|---|---|---|---|
| FM1 | $115,000 | $1,000 | Levee to protect properties on Toronto Ave |
| FM2* | $138,000 | $0 | Enhance Toronto Ave Culverts |
| FM3* | $1,790,000 | $5,000 | Creek Widening and Revegetation Upstream of Toronto Ave |
| FM4 | $132,000 | $0 | Levee to Protect Properties between Wabash Ave and Washington Ave |
| FM5* | $2,500,000 | $40,000 | Rehabilitate Creek and Construct Wetland |
| FM7 | $180,000 | $10,000 | Sediment Retention Basin |
| FM8 | $98,000 | $0 | Levee to Protect Properties at Carcoola Rd |
| FM9* | $630,000 | $5,000 | Widening of South Creek (removal of island) |
| FM10* | $6,080,000 | $10,000 | Regrading of Lidwina Place Reserve and Tyagarah Reserve |
| FM11* | $2,310,000 | $10,000 | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve |
| FM12* | $40,000 | $20,000 | Ongoing Maintenance of Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek |
| FM15 | $87,000 | $1,000 | Levee to Protect Properties at the end of Towradgi Street |
| FM18 | $80,000 | $1,000 | Levee to protect properties on Willandra Road |
| FM19 | $669,000 | $5,000 | Levee to protect Cromer Golf Course |
| PM4 | $480,000 | $0 | Voluntary House Raising Program |

| Option | Capital Cost Estimate | Recurrent Cost Estimate[1] | Details |
|---|---|---|---|
| PM5 | $8,500,000 | $0 | Voluntary House Purchase Program - 10 properties |
| PM6 | $850,000 | $0 | Voluntary House Purchase Program - 1 property |
| BM1* | $416,000 | $10,000 | Management of Weeds in South Creek Downstream of Carcoola Road |

[1] An example of recurrent cost includes inspections and clearing of debris on an annual basis.
* Those options assessed using the hydraulic model.

## 13.2 Average Annual Damage for Quantitatively Assessed Options

In a similar fashion to **Chapter 5**, the total damage costs were evaluated for each of the options assessed by modelling (quantitative assessment). The average annual damage (AAD) for each of the options is showed comparatively against the existing case ($339,633) in **Table 13.2**.

**Table 13.2 Average Annual Damage for Quantitatively Assessed Options**

| Option | Details | AAD | Reduction in AAD due to Option* |
|---|---|---|---|
| FM1 | Levee to protect properties on Toronto Ave | $335,767 | $ 3,866 |
| FM2* | Enhance Toronto Ave Culverts | $337,091 | $ 2,542[1] |
| FM3* | Creek Widening and Revegetation Upstream of Toronto Ave | $318,324 | $ 21,309 |
| FM4 | Levee to Protect Properties between Wabash Ave and Washington Ave | $302,411 | $ 37,222 |
| FM5* | Rehabilitate Creek and Construct Wetland | $316,492 | $ 23,141 |
| FM7 | Sediment Retention Basin | $339,633 | $ - |
| FM8 | Levee to Protect Properties at Carcoola Rd | $328,005 | $ 11,628 |
| FM9* | Widening of South Creek (removal of island) | $338,519 | $ 1,114 |
| FM10* | Regrading of Lidwina Place Reserve and Tyagarah Reserve | $333,010 | $ 6,623 |
| FM11* | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve | $327,503 | $ 12,129 |
| FM12* | Ongoing Maintenance of Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek | $238,470 | $ 101,162 |
| FM15 | Levee to Protect Properties at the end of Towradgi Street | $323,162 | $ 16,471 |
| FM18 | Levee to protect properties on Willandra Road | $328,357 | $ 11,276 |
| FM19 | Levee to protect Cromer Golf Course | $339,633 | $ - |
| PM4 | Voluntary House Raising Program | $277,634 | $ 61,999 |
| PM5 | Voluntary House Purchase Program - 10 properties | $210,758 | $ 128,875 |
| PM6 | Voluntary House Purchase Program - 1 property | $325,132 | $ 14,501 |

| Option | Details | AAD | Reduction in AAD due to Option* |
|---|---|---|---|
| BM1* | Management of Weeds in South Creek Downstream of Carcoola Road | $333,625 | $ 6,008 |

[1] FM2 represents the actual dimensions of Toronto Avenue Bridge, when compared with the dimensions modelled in the Flood Study (WMA, 2006) for the "existing case" it is shown that the Flood Study currently under estimates the damages in the floodplain by $2,539.
* Those options assessed using the hydraulic model.

The results shown in **Table 13.2** indicate that the maximum reduction in average annual damage (AAD) was $129,000 (compared with an existing case with an AAD of $340,000 (38%)). This reduction, for Option PM5 (Voluntary House Purchase Program) provides a significant decrease in damage value. Option FM12 (Increased maintenance of Culverts and Creek Crossings to Reduce the Likelihood of Blockage) as a stand-alone option results in the next greatest reduction of AAD by $101,000 on the existing case. The main reason for this reduction in AAD is the blockage risk was reduced to 75% in the upper reaches of the floodplain model. This markedly reduces the number of houses (particularly in the upper reaches) affected by over-floor flooding. This outcome clearly demonstrates the importance of maintaining clear flow paths in the upper-reaches of the South Creek catchment. Another option to produce a substantial reduction in AAD was the PM4 (Voluntary House Raising Program (State Government Funded)) option. This option reduced AAD by almost $62,000. However, as with Option PM5, this would only benefit a small number of specific houses with little overall benefit to the other flood affected properties.

Whilst the AAD may be reduced greatly for some options, this reduction needs to be offset against the capital and recurrent costs of the option. This is described below.

## 13.3 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, reported in **Chapter 5**) was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data reported in **Chapter 5** derived from a floor level and property survey along with damage curves derived for other, similar areas. The PMF, 100 year, 50 year, 10 year, 10 year and 5 year ARI 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 13.3** summarises the overall economics of each option which was able to be economically assessed. The indicator adopted to rank options on economic merit is the benefit-cost ratio (B/C).

- 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 13.3 Summary of Economic Assessment of Management Options**

| Option | AAD | Reduction in AAD due to Option | NPW of Benefit | Capital Cost Estimate | Recurrent Cost Estimate | NPW of Options | B/C | Rank |
|---|---|---|---|---|---|---|---|---|
| FM1 | $335,767 | $3,866 | $53,347 | $115,000 | $1,000 | $128,801 | 0.41 | 7 |
| FM2* | $337,091 | $2,542 | $35,077 | $138,000 | $0 | $138,000 | 0.25 | 8 |
| FM3* | $318,324 | $21,309 | $294,075 | $1,790,000 | $5,000 | $1,859,004 | 0.16 | 11 |
| FM4 | $302,411 | $37,222 | $513,688 | $132,000 | $0 | $132,000 | 3.89 | 2 |
| FM5* | $316,492 | $23,141 | $319,363 | $2,500,000 | $40,000 | $3,052,030 | 0.10 | 13 |
| FM7 | $339,633 | $0 | $0 | $180,000 | $10,000 | $318,007 | 0.00 | 17 |
| FM8 | $328,005 | $11,628 | $160,472 | $98,000 | $0 | $98,000 | 1.64 | 6 |
| FM9* | $338,519 | $1,114 | $15,375 | $630,000 | $5,000 | $699,004 | 0.02 | 15 |
| FM10* | $333,010 | $6,623 | $91,401 | $6,080,000 | $10,000 | $6,218,007 | 0.01 | 16 |
| FM11* | $327,503 | $12,129 | $167,392 | $2,310,000 | $10,000 | $2,448,007 | 0.07 | 14 |
| FM12* | $238,470 | $101,162 | $1,396,117 | $40,000 | $20,000 | $316,015 | 4.42 | 1 |
| FM15 | $323,162 | $16,471 | $227,306 | $87,000 | $1,000 | $100,801 | 2.26 | 3 |
| FM18 | $328,357 | $11,276 | $155,611 | $80,000 | $1,000 | $93,801 | 1.66 | 5 |
| FM19 | $339,633 | $0 | $0 | $669,000 | $5,000 | $738,004 | 0.00 | 17 |
| PM4 | $277,634 | $61,999 | $855,632 | $480,000 | $0 | $480,000 | 1.78 | 4 |
| PM5 | $210,758 | $128,875 | $1,778,572 | $8,500,000 | $0 | $8,500,000 | 0.21 | 10 |
| PM6 | $325,132 | $14,501 | $200,121 | $850,000 | $0 | $850,000 | 0.24 | 9 |
| BM1* | $333,625 | $6,008 | $82,916 | $416,000 | $10,000 | $554,007 | 0.15 | 12 |

NPW - Net Present Worth is calculated using 7% interest over 50yrs.
* Those options assessed using the hydraulic model.

The benefit-cost analysis shown in **Table 13.3** indicates that the following options have the greatest economic benefit for expenditure:

- FM12 - Ongoing maintenance of stormwater pipes and culverts under bridges to reduce the likelihood of blockages during a flood event;
- FM4 - Levee to Protect Properties between Wabash Ave and Washington Ave;
- FM15 - Levee to Protect Properties at the end of Towradgi Street;
- PM4 - Voluntary House Raising Program (State Government Funded);
- FM18 - Levee to protect properties on Willandra Road; and
- FM8 - Levee to Protect Properties at Carcoola Rd.

The remaining options listed in **Table 13.3** show varied levels of economic benefit, but all have benefit-cost ratios less than 1. However, these options may provide other social and environmental benefits, which are accounted for in the multi-criteria matrix assessment in **Section 14**.

Further, those options listed above which have a benefit-cost ratio greater than 1, may have other limitations such as minor flood level increases, environmental impacts and lack of community support.

## 13.4 Economic Assessment of Desktop Assessed Options

Given the overall benefits of those options where a desktop assessment was utilised, a detailed economic analysis of those options was not undertaken. Instead, a judgement on the economic benefits of the options was made. This is described in **Section 14**.

# 14. COMPARATIVE ASSESSMENT OF OPTIONS

## 14.1 Overview

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

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criteria as shown in Table 14.1.

## 14.2 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain outlined in Chapter 2 as well as the community preferences outlined in Chapter 3.

The criterion adopted includes:

| | |
|---|---|
| Technical | Likely Overall Hydraulic Improvement |
| Economic | Capital and Operating Costs<br>Reduction in Risk to Property |
| Social | Reduction in Social Disruption |
| | Reduction in Risk to Life |
| Environmental | Meeting of River Flow and Water Quality Objectives<br>Fauna/Flora |
| Community | Community Support |
| Council | Council Support |
| Policy/Legislation | Compatible with Policies and Plans |

The scoring system is shown in **Table 14.1** for the above criteria.

**Table 14.1 Details of Scoring System Adopted**

| CRITERIA | SCORE | | | | |
|---|---|---|---|---|---|
| | -2 | -1 | 0 | 1 | 2 |
| Likely Overall Hydraulic Improvement | N/A | N/A | No impact | Flood Level Decrease (0.05 - 0.5 m decrease in peak average flood level across the floodplain) | Flood Level Decrease (>0.5 m decrease in peak average flood level across the floodplain) |
| Negative Hydraulic Impact | Negative impact (> 0.1 m increase in average peak flood level at any location) | Negative impact (> 0.01 m increase in average peak flood level at any location) | No Impact | N/A | N/A |
| Capital and Operating Costs | 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* | Major increase in AAD | Slight increase in AAD | No Improvement | Slight decrease in AAD | Major decrease in AAD |
| Reduction in Risk to Life | 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 | 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 |
| Compatible with Water Quality and River Flow Objectives | Completely incompatible | Slightly incompatible | Neutral | Compatible | Completely Compatible |
| Fauna/Flora Impact | High negative impact | Slight negative impact | No impact | Some benefit | Considerable benefit |
| Council Attitude | Strong disagreement | Disagreement | Neutral/No response | Support | Strong support |
| Compatible with Policies and Plans | Completely incompatible | Slightly incompatible | Neutral | Compatible | Completely Compatible |
| Community support | Strong disagreement | Disagreement | Neutral/No response | Support | Strong support |

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

*Likely Overall Hydraulic Improvement*

The likely hydraulic improvement assesses the peak reduction in flood levels at any location as a result of an option. Issues related to the reduction of flood hazard and related social disruption and risk to life are considered as separate criteria. Where an option was not modelled, engineering judgement as to the likely overall improvement was applied by experienced floodplain hydraulic specialists.

*Likely Negative Hydraulic Impact*

The likely hydraulic impact assesses the peak increase in flood levels at any location as a result of an option. It is possible for an option to both decrease flood levels in one location while increasing flood levels in another. Hence a score for both of these scenarios has been included.

It should also be noted, that if an option has an increase in flood levels of greater than 0.05m and this increase impacted on residential or commercial properties, then that option was not considered appropriate for inclusion in the Plan.

*Economic Assessment Overview*

The economic assessment involved an appreciation of both:

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

Capital and operating costs for major structural options were assessed as described in Section 13, whilst a judgement of the likely capital and recurrent costs was made by experienced engineers.

*Social Impact Assessment*

The social impact assessment involved an appreciation, based on the information collated in Section 2, of both:

- Reduction in Social Disruption; and
- Reduction in Risk to Life.

In general, recent flood events within the area (*e.g.* 2003) have led to a general awareness of flooding in the area. 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.

*Environmental Assessment*

The environmental impact assessment involved an appreciation, based on the information collated in Section 2, of both:

- Compatibility of the Option with Water Quality and River Flow Objectives; and
- Fauna/Flora Impact.

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

The management goal reported by the ICMC (1994) is to ensure the long term management of urban watercourse corridors maintains and enhances:

- the safe conveyance of runoff;
- channel stability;
- biological diversity;
- good water quality; and
- an aesthetic and recreative urban landscape.

*Community*

The community support for a particular option was derived by converting the community responses received in the consultation period **(Appendix B)** discussed in **Section 3** to a numerical score. The responses were summed and averaged for each option. To account for bias due to non-response (a response of "0" was viewed more favourably than a non-response) averages were weighted by the number of responses received for each option. These averages were then ranked and assigned a resultant score ranging from -4 to +4. This increased score range (*c.f.* -2 to +2 for other variables) gives the community attitude a higher weighting.

*Council Support*

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

*Policy/Legislation*

A single Policy/Legislation criterion was applied such that the option should be compatible with current Policies and Plans. This was based on an assessment of related policies and plans outlined in **Section 2**.

## 14.3 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criterion is shown in its entirety in **Appendix F**. The total score for each option was calculated by equally weighting each consideration and summing the total.

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 F**.

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 F** is not "absolute" and the proposed scoring and weighting should be reviewed carefully as part of the process of finalising the overall Floodplain Risk Management Plan.

## 14.4 Summary of Outcomes

**Table 14.2** summarises the highest ranking options which are recommended for inclusion in the Floodplain Risk Management Plan. Those options selected for inclusion in the Plan are based upon both their likely benefit and the funding available from Council and the State Government.

If the top 24 ranking options are included in the Floodplain Risk Management Plan, the estimated total capital cost of implementing the Plan would be $6,520,000. This is in excess of the funding likely to be available for flood mitigation works in the South Creek floodplain. However, it should be noted that Option FM5 (rehabilitate and construct wetland) comprises $2.5M of the cost of implementing the Plan.

Option FM5 (the wetland) ranks very highly in the Matrix. However, it is possible that funding will not be available of the amount required to implement this option. It has therefore been deemed appropriate to propose a Plan of a total budget of $4,020,000 with the option of rehabilitating and constructing the wetland as a separate item, should funding become available.

Further, it should also be noted that Options FM5 and FM3 are mutually exclusive. That is, if one option is implemented then the other will not be required. Option FM5 has a higher rank (*i.e.* more benefit) than FM3. However, there is a significant difference in the cost of implementation; FM3 has a capital cost of $1.8M compared with $2.5M for option FM5. Both have been recommended for inclusion in the Plan, with FM5 having a higher priority (should funding become available) and FM3 only to be implemented if it is not possible to implement FM5.

**Table 14.2 Floodplain Risk Management Measures Recommended for Inclusion in the South Creek Floodplain Risk Management Plan**

| ID | Description | Estimated Capital Cost | Estimated Recurrent Cost |
|---|---|---|---|
| FM12* | Preparation and Implementation of Culvert Maintenance Strategy for Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek | $ 40,000 | $ 20,000 |
| FM21 | Debris Control Structure | $ 30,000 | $ 2,000 |
| FM5* | Rehabilitate Creek and Construct Wetland | $ 2,500,000 | $ 40,000 |
| EM5 | Targeted Flood Education Programs | $ 40,000 | $ 10,000 |
| PM1 | Ongoing implementation of development controls and guidelines for building work | $ - | $ 1,000 |
| PM7 | Review of Draft OSD Policy | $ 10,000 | $ - |
| PM9 | Property Dossier of Severely Flood Affected Properties | $ 30,000 | $ - |
| BM1* | Management of Weeds in South Creek Downstream of Carcoola Road | $ 416,000 | $ 10,000 |
| PM6 | Voluntary House Purchase Further Investigation - 1 property | $ 850,000 | $ - |
| EM2 | Flood Warning Systems and Instrumentation | $ 1,000 | $ 1,000 |
| FM1 | Levee to protect properties on Toronto Ave | $ 115,000 | $ 1,000 |
| FM20 | Detailed Assessment for potential Debris Control Structures | $ 30,000 | $ - |
| BM2 | Weed and Sediment Management in South Creek and Wheeler Creek | $ 200,000 | $ 50,000 |
| FM13 | Enhance Willandra Road (lower) Culverts | $ 219,000 | $ - |
| PM2 | Preparation of Flood Related Development Control Plan for Warringah LGA | $ 20,000 | $ 2,000 |
| EM7 | Ongoing collection of flood information | $ - | $ 2,000 |
| FM2* | Enhance Toronto Ave Culverts | $ 138,000 | $ - |
| EM4 | Community education and awareness programs | $ 10,000 | $ 2,000 |
| EM3 | Information Transfers to SES | $ 2,000 | $ - |

| ID | Description | Estimated Capital Cost | Estimated Recurrent Cost |
|---|---|---|---|
| PM8 | Analysis of Localised Flood Planning Level Requirements | $ 20,000 | $ 1,000 |
| FM3* | Creek Widening and Revegetation Upstream of Toronto Ave | $ 1,790,000 | $ 5,000 |
| EM6 | Flood depth markers placed on both sides of all roads crossing the creeks | $ 14,000 | $ - |
| PM3 | Guidelines for Public Domain Infrastructure | $ 15,000 | $ 2,000 |
| EM1 | Preparation and Adoption of SES Local Flood Plan | $ 30,000 | $ 2,000 |
| **Total Cost of Implementing Plan (excluding FM5)** | | **$ 4,020,000** | **$ 111,000** |

[1] Options FM3 and FM5 are mutually excusive (*i.e.* only one of these options should be implemented). Funding availability will determine which option proceeds.

[2] This is fully funded so there would be no cost to Council or the State Government.

# 15. RECOMMENDATIONS AND CONCLUSIONS

This report presents the findings of a floodplain risk management study for South Creek and Wheeler Creek. The investigations and consultation undertaken as part of this process identified a number of issues for the floodplain. Based on these issues, a series of floodplain management measures were developed.

The assessment of management options provided in **Sections 8 to 14** facilitates the identification of the most beneficial options (in terms of hydraulics, economics, environmental and social issues). This assessment was based on a primarily technical review and any community and stakeholder feedback will be incorporated into the final report. This could lead to changes in the proposed options and their ranking. However, under the existing assessment the top ranked options resulted in an estimated capital cost of implementation of approximately $4,020,000 and an annual recurrent cost of approximately $111,000. This does not include the construction of a wetland between Carcoola Road and Toronto Avenue (Option FM5). This option would cost $2.5 Million alone, with a recurrent cost of approximately $40,000. However, this option has significant hydraulic and environmental benefits and is therefore recommended for implementation should funding become available.

The recommendations of this study have been incorporated in to the South Creek Floodplain Risk Management Plan. Public consultation was undertaken during the exhibition of this study and the Plan. This additional consultation and review lead to the refinement of this study and the final recommended floodplain risk management options for implementation.

# 16. QUALIFICATIONS

This report has been prepared by Cardno Lawson Treloar for Warringah Council and as such should not be used by a third party without prior approval.

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 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 results of the study are based on the following assumptions/conditions:

- Design flood extents are approximate between cross sections of the model. Where surveyed levels are not available, flood extents are based on the ground survey data provided by Council and the interpolation of model results.
- The local pit and pipe stormwater drainage system is not modelled.
- The report relies on the accuracy of the survey data provided by Council.
- Cost estimates provided for options in this report are preliminary only and more detailed cost estimates should be prepared during the detailed design phase.

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

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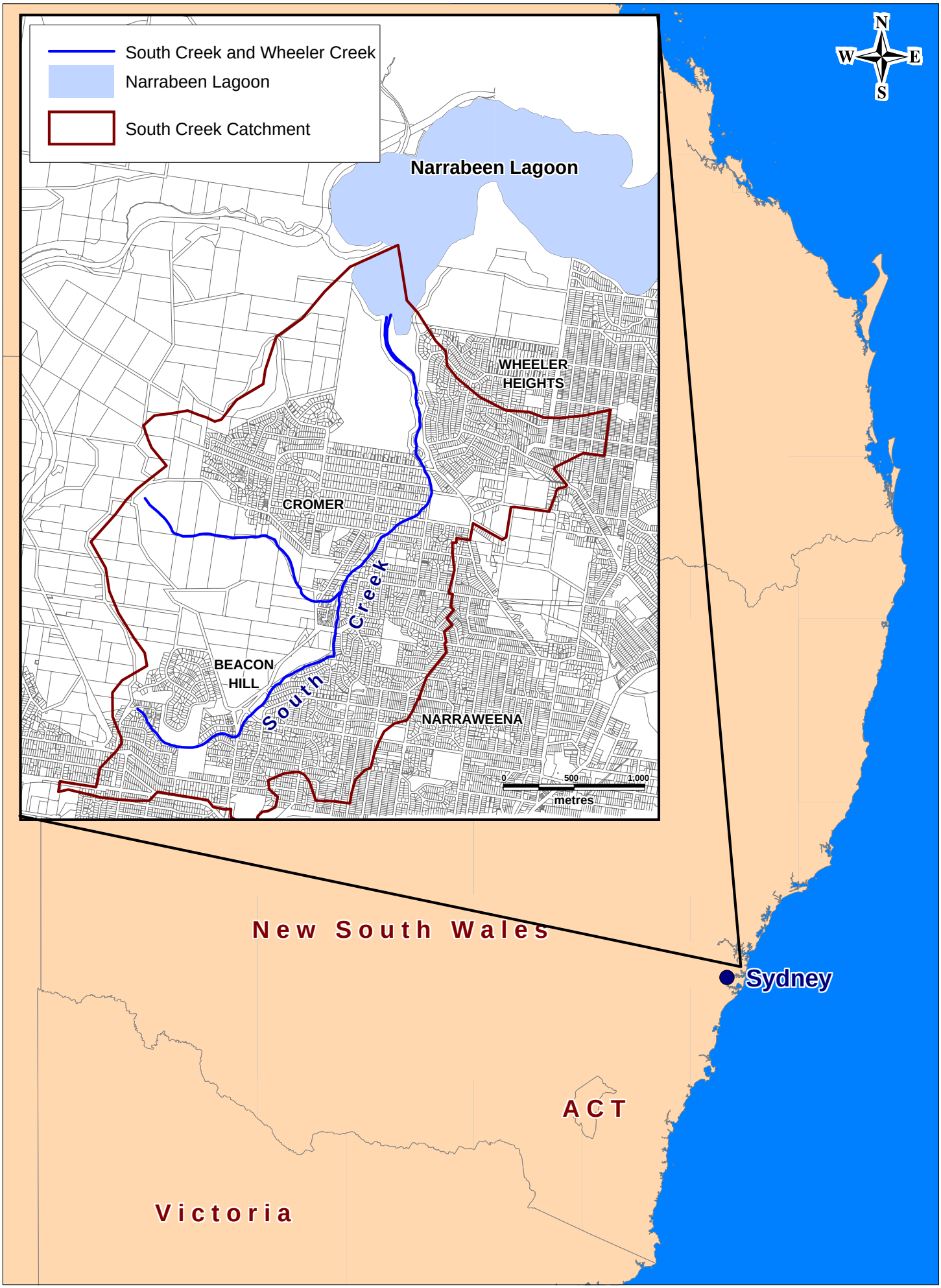
# FIGURES

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South Creek Floodplain Risk Management Study

FIGURE 1.1
LOCALITY PLAN

J2434/R2100/V4
4 February 2008

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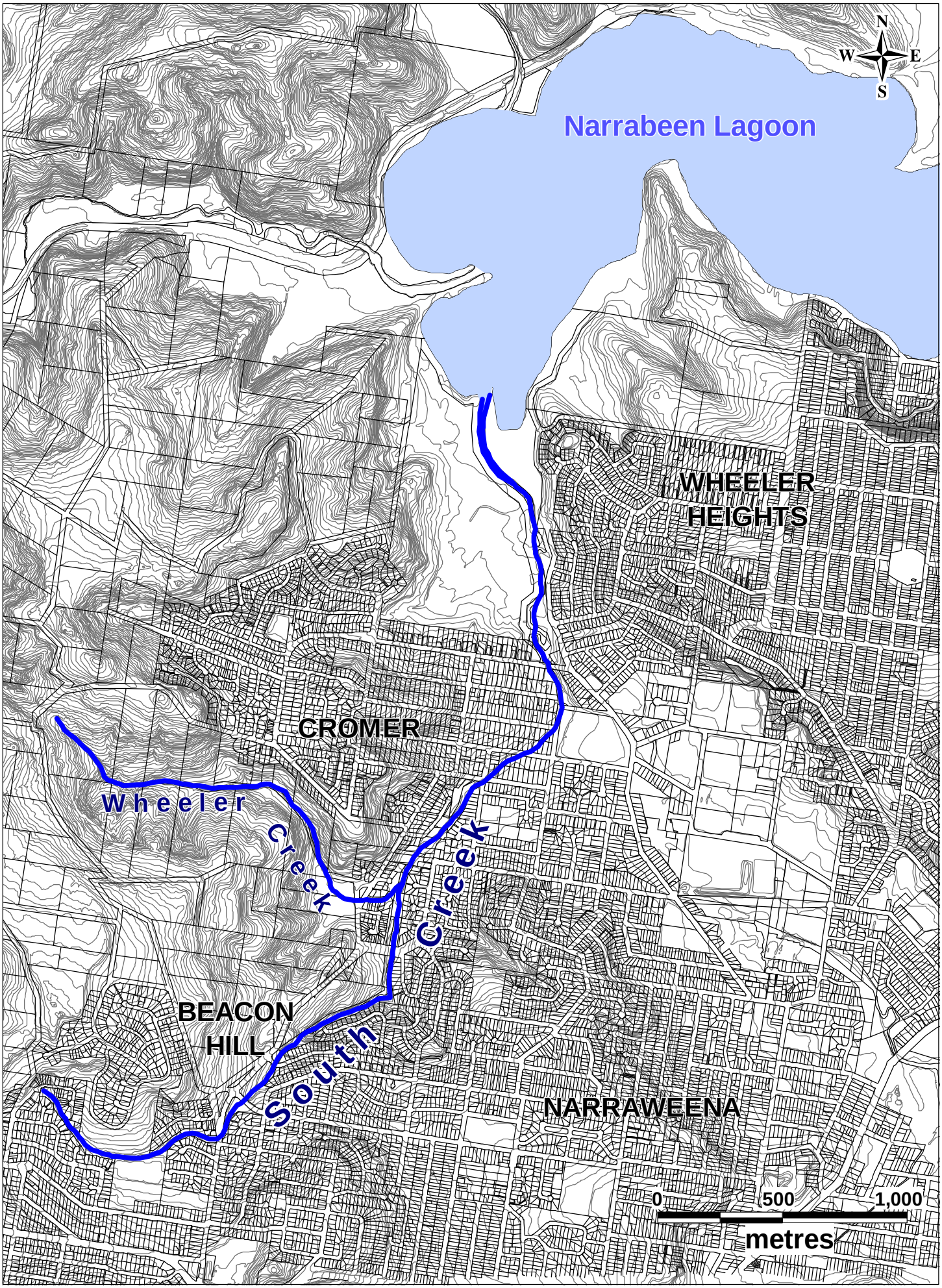


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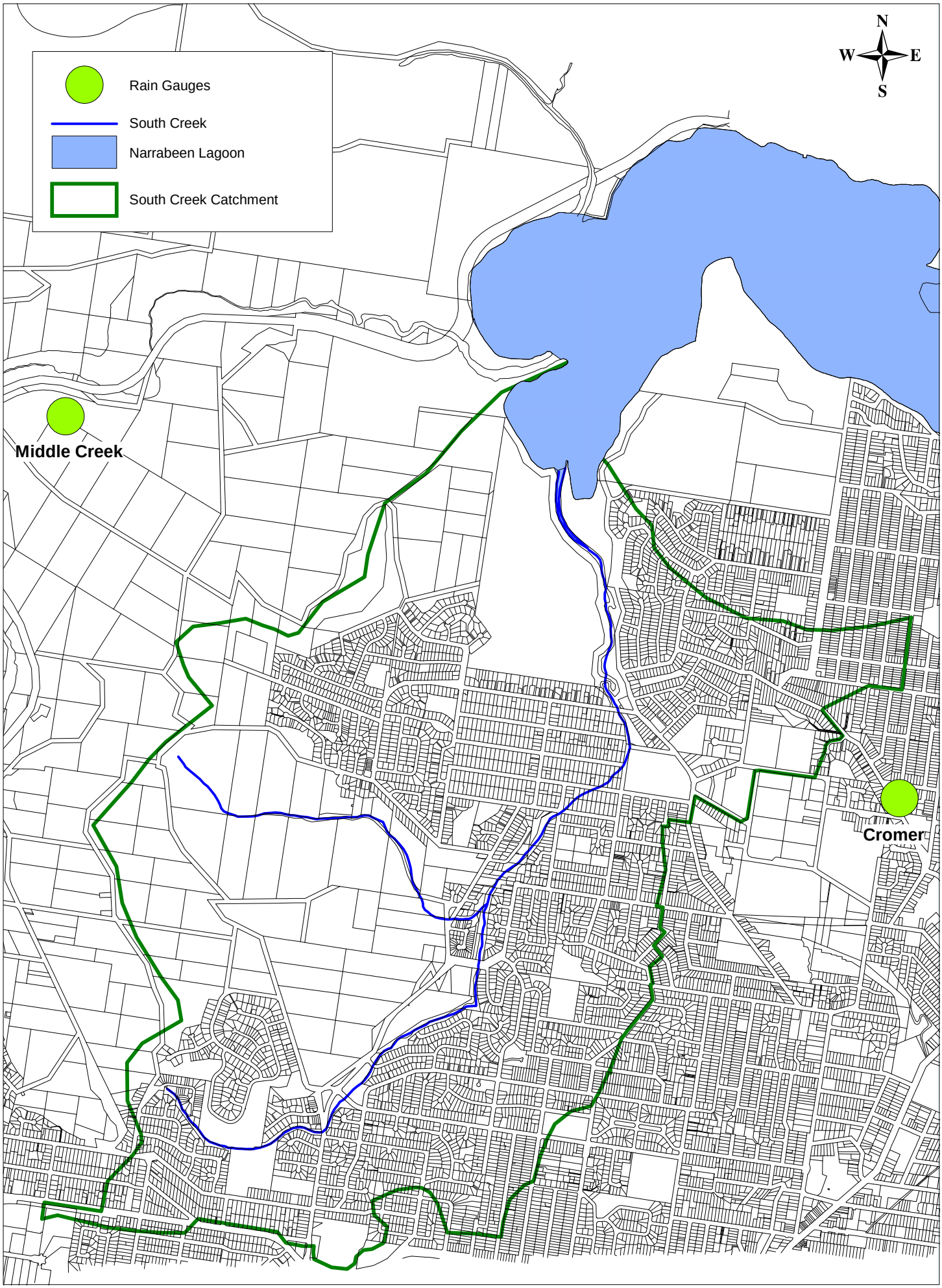
South Creek Floodplain Risk Management Study

FIGURE 2.1
STUDY CREEKS

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 2.1 - Creeks.Wor

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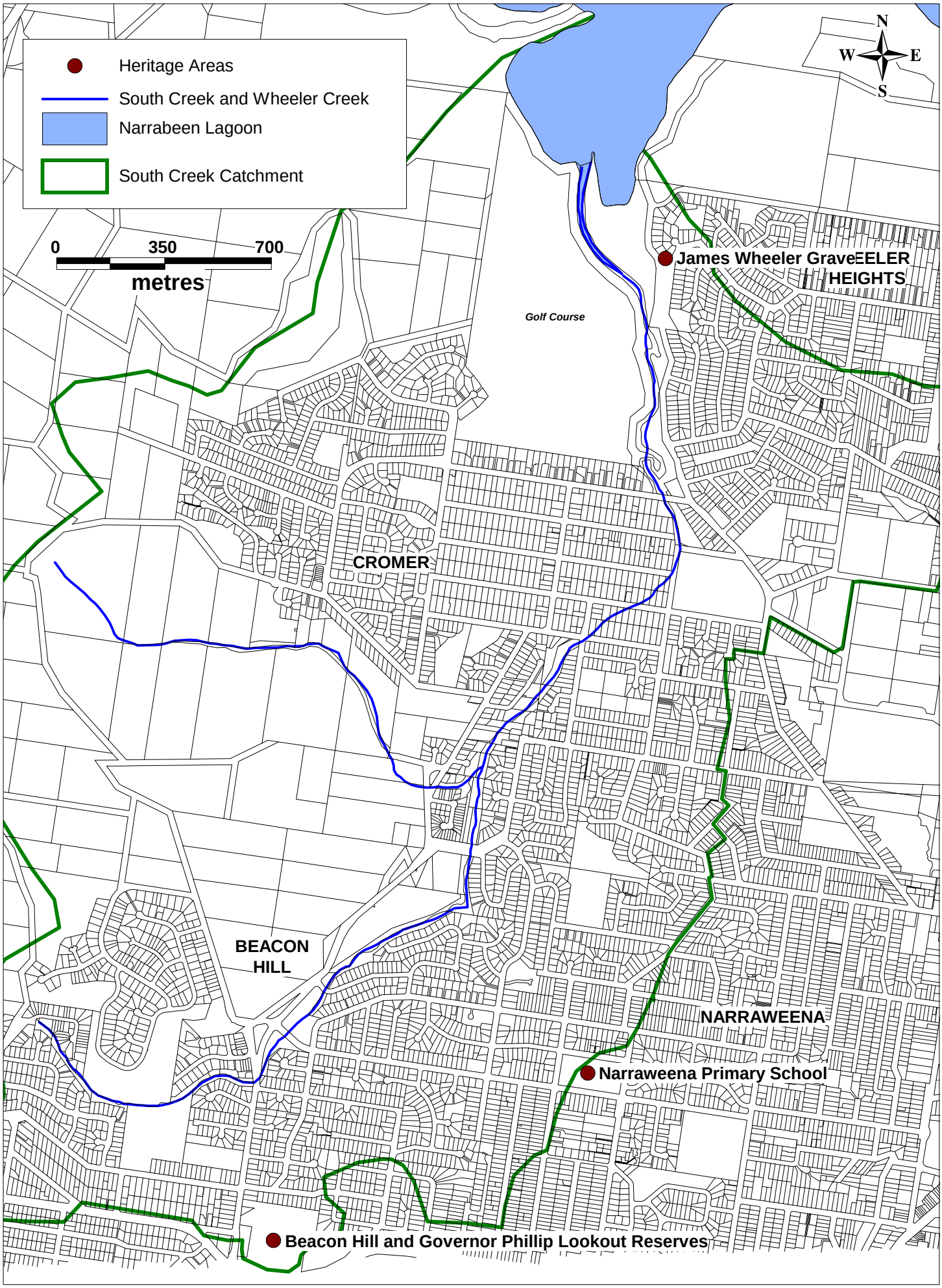
South Creek Floodplain Risk Management Study

FIGURE 2.2
Rain Gauges

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 2.2 - Management Plan.Wor

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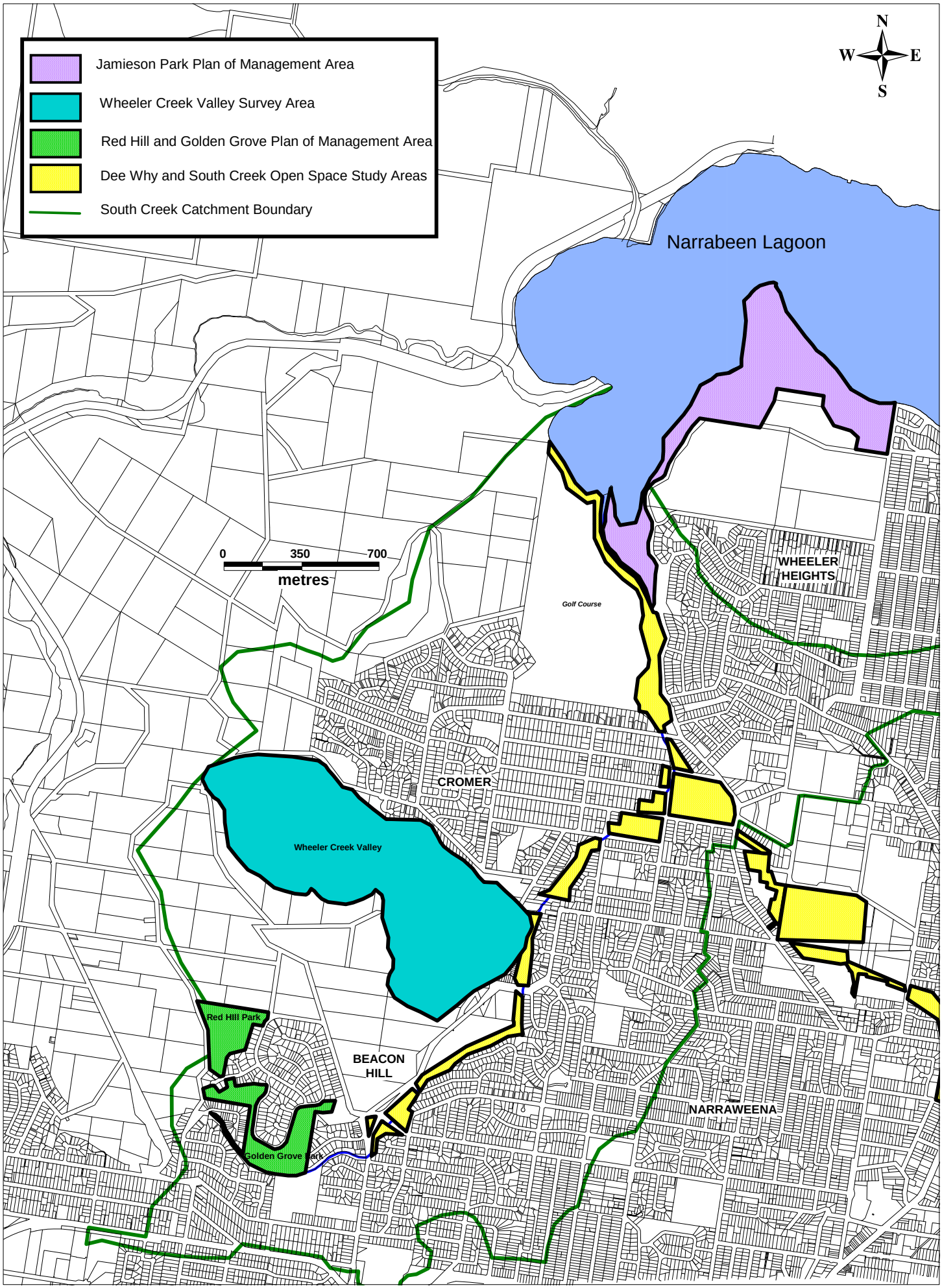
South Creek Floodplain Risk Management Study

FIGURE 2.3
HERITAGE AREAS

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 2.3 - Heritage.Wor

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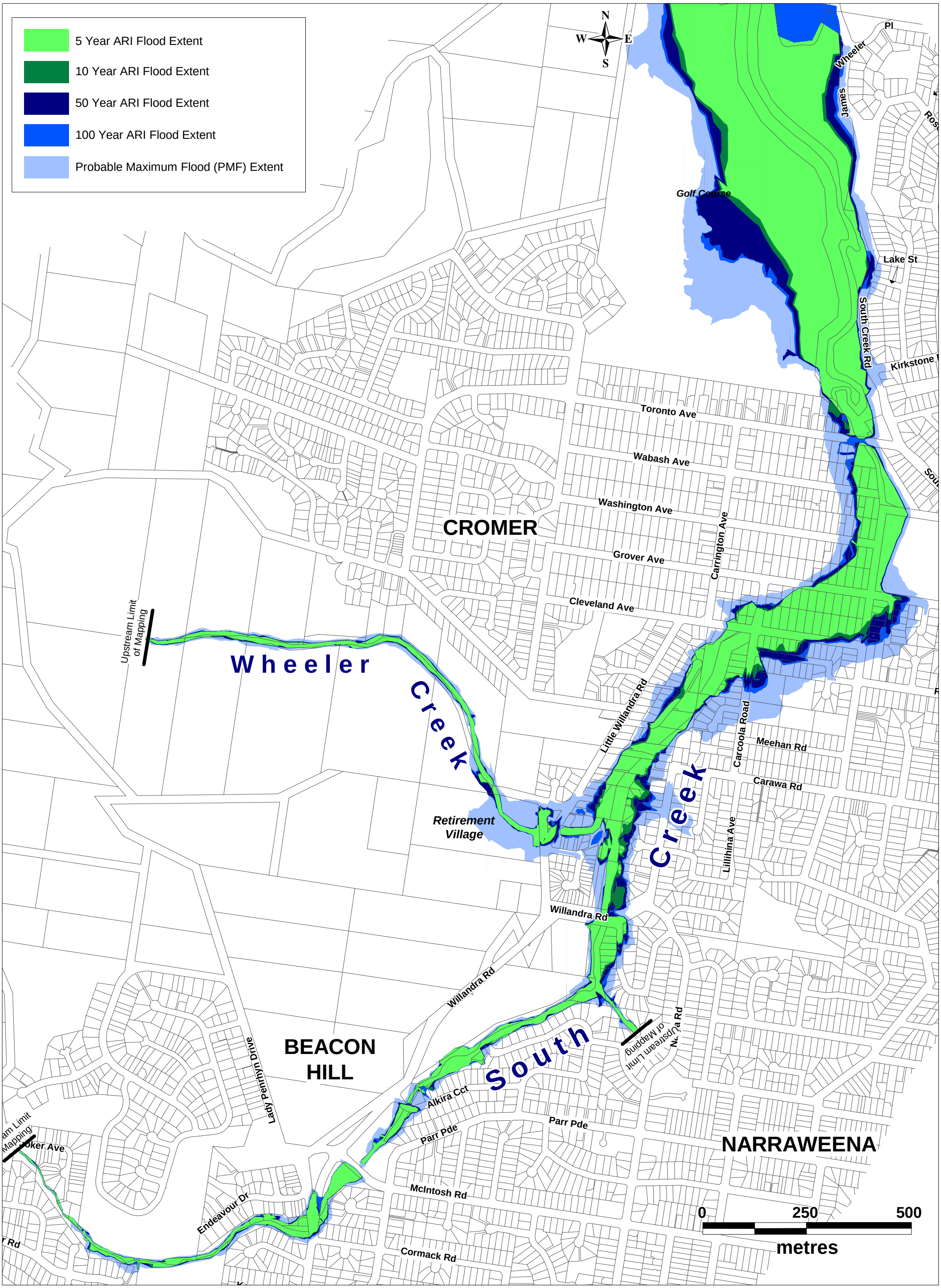
South Creek Floodplain Risk Management Study

FIGURE 2.4
MANAGEMENT PLAN AREAS

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 2.4 - Management Plan.Wor

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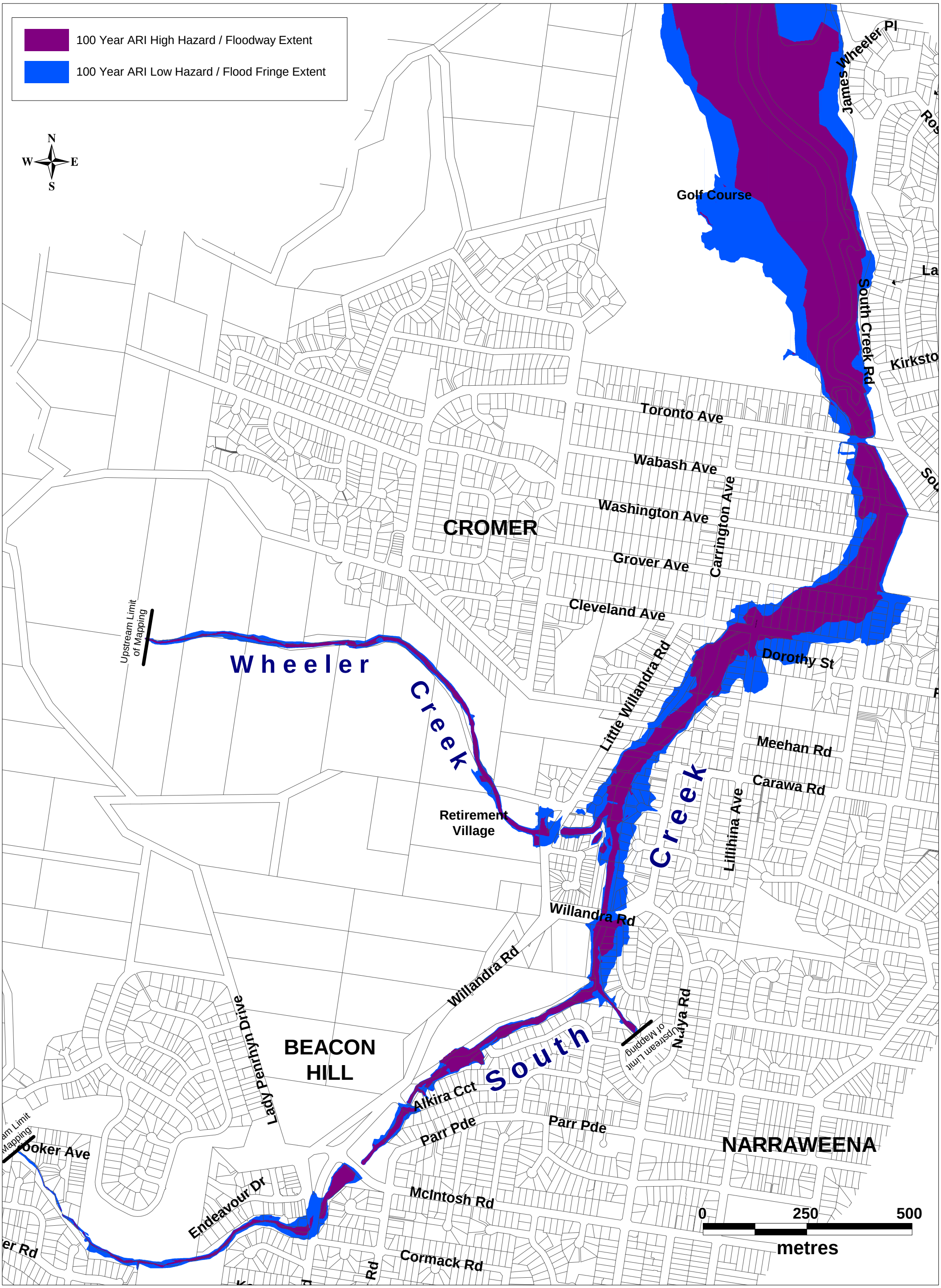
J2434/R2100/V4
4 February 2008

South Creek Floodplain Risk Management Study

FIGURE 4.1
FLOOD EXTENTS

J2434\Figures\Floodplain Risk Management Study V4\Figure 4.1 - Flood Extents.Wor

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4 February 2008

South Creek Floodplain Risk Management Study

FIGURE 4.2
100 YEAR ARI FLOOD HAZARD AND HYDRAULIC CATEGORIES

J2434\Figures\Floodplain Risk Management Study V4\Figure 4.2 - Hazard.Wor

**OPTIONS NOT SHOWN ON PLAN**

**Flood Modification Options**

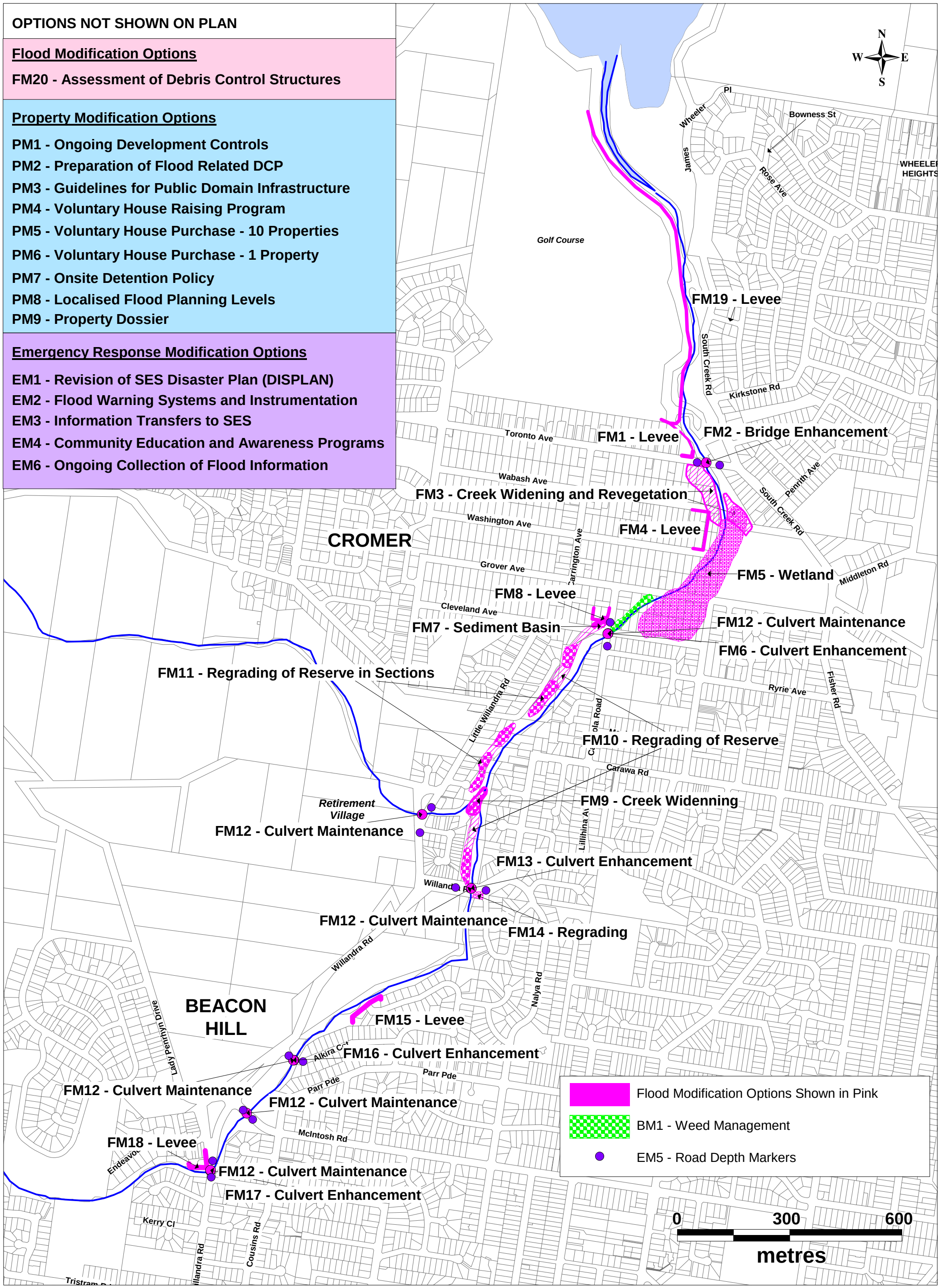
**FM20 - Assessment of Debris Control Structures**

**Property Modification Options**

**PM1 - Ongoing Development Controls**
**PM2 - Preparation of Flood Related DCP**
**PM3 - Guidelines for Public Domain Infrastructure**
**PM4 - Voluntary House Raising Program**
**PM5 - Voluntary House Purchase - 10 Properties**
**PM6 - Voluntary House Purchase - 1 Property**
**PM7 - Onsite Detention Policy**
**PM8 - Localised Flood Planning Levels**
**PM9 - Property Dossier**

**Emergency Response Modification Options**

**EM1 - Revision of SES Disaster Plan (DISPLAN)**
**EM2 - Flood Warning Systems and Instrumentation**
**EM3 - Information Transfers to SES**
**EM4 - Community Education and Awareness Programs**
**EM6 - Ongoing Collection of Flood Information**

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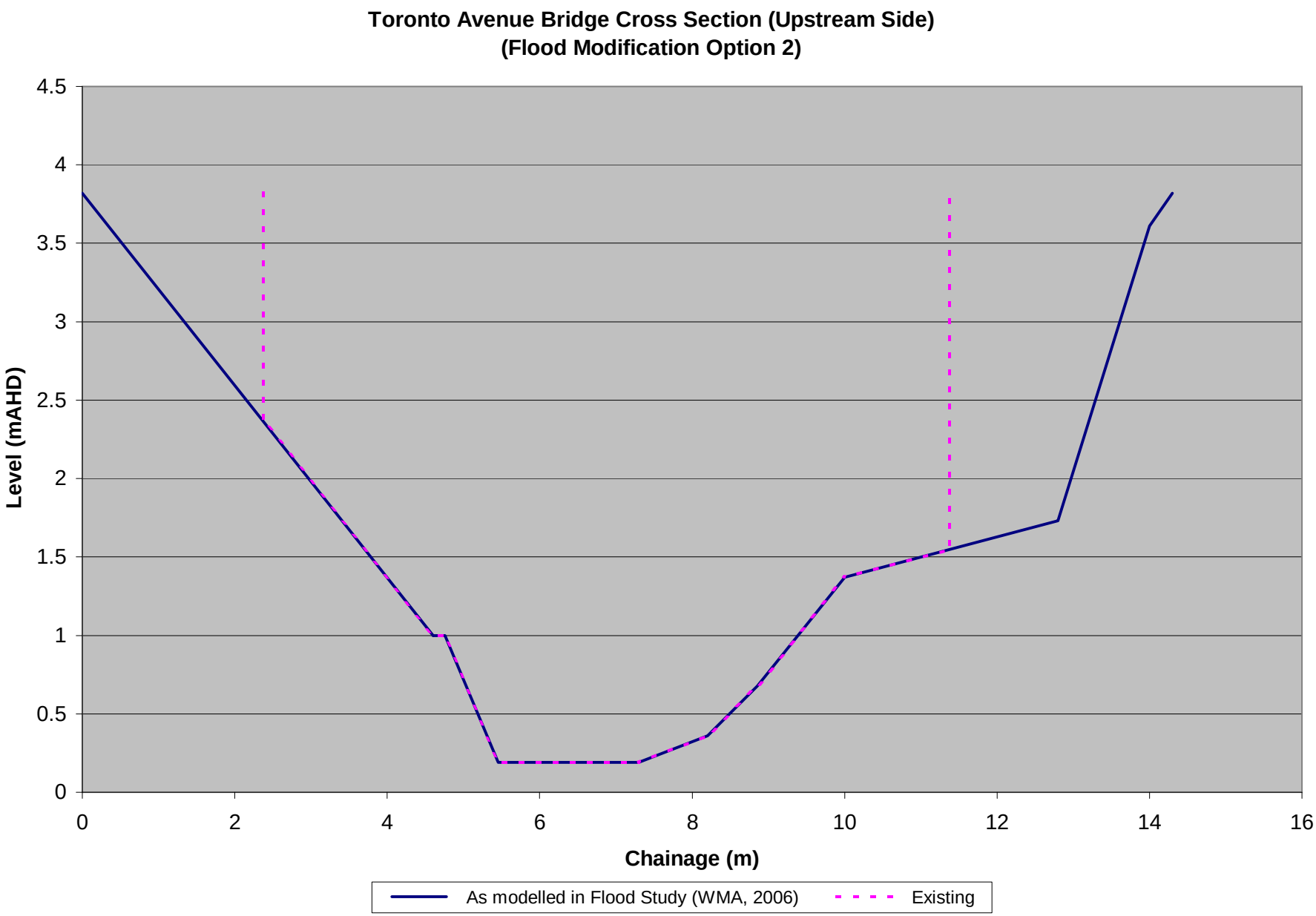
J2434/R2100/V4
4 February 2008

South Creek Floodplain Risk Management Study

FIGURE 8.1
FLOOD RISK MANAGEMENT OPTIONS

J2434\Figures\Floodplain Risk Management Study V4\Figure 8.1 - Options.Wor

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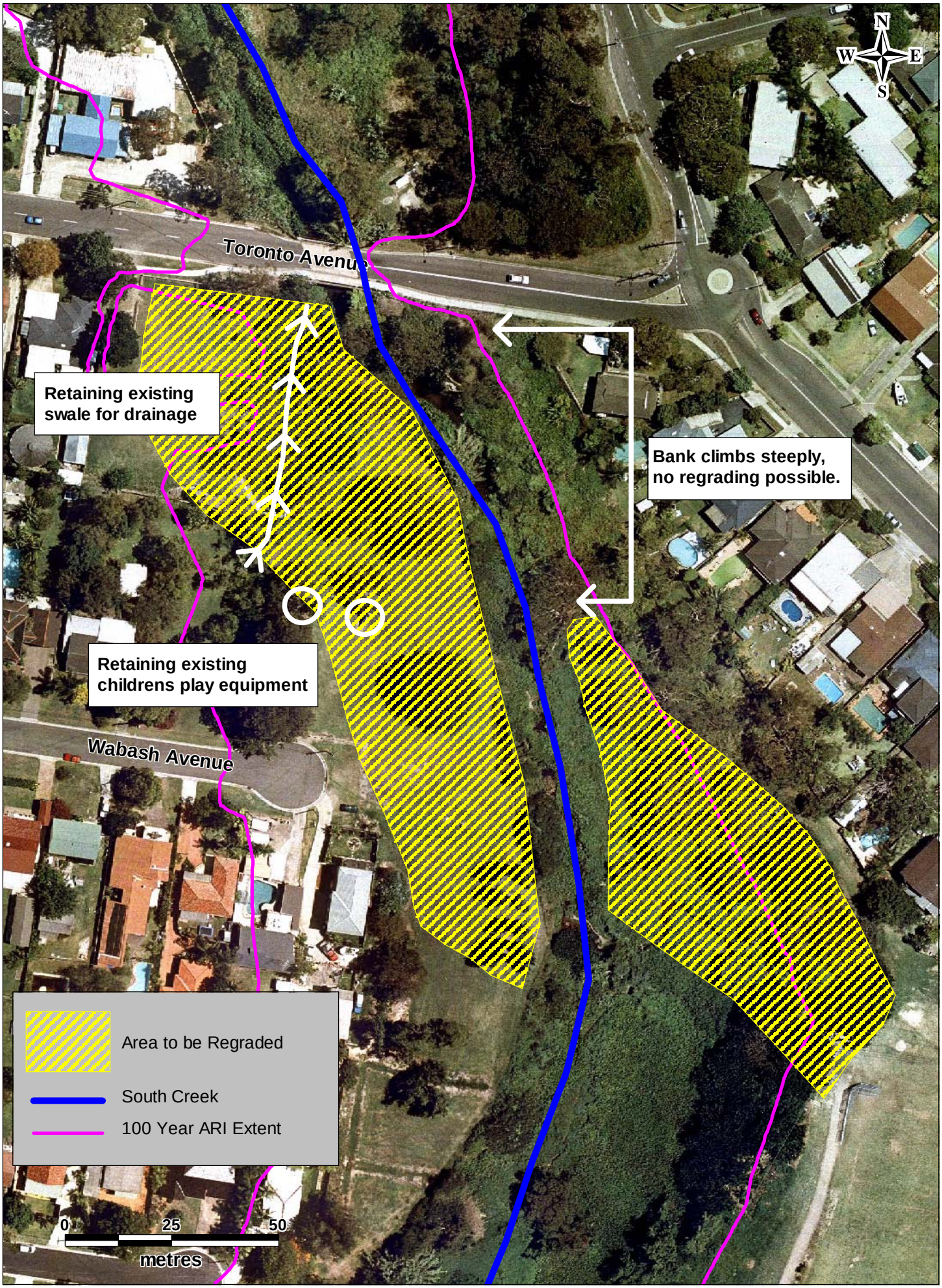
J2434/R2210/V4
4 February 2008

FIGURE 9.2
FM2 TORONTO AVENUE BRIDGE ENHANCEMENT

J:\WR\J2434 - South Creek FPMSP\Figures\Floodplain Risk Management Study v4\Figure 9.2 - FM2

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South Creek Floodplain Risk Management Study

FIGURE 9.3
OPTION FM3

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.3 - FM3.Wor


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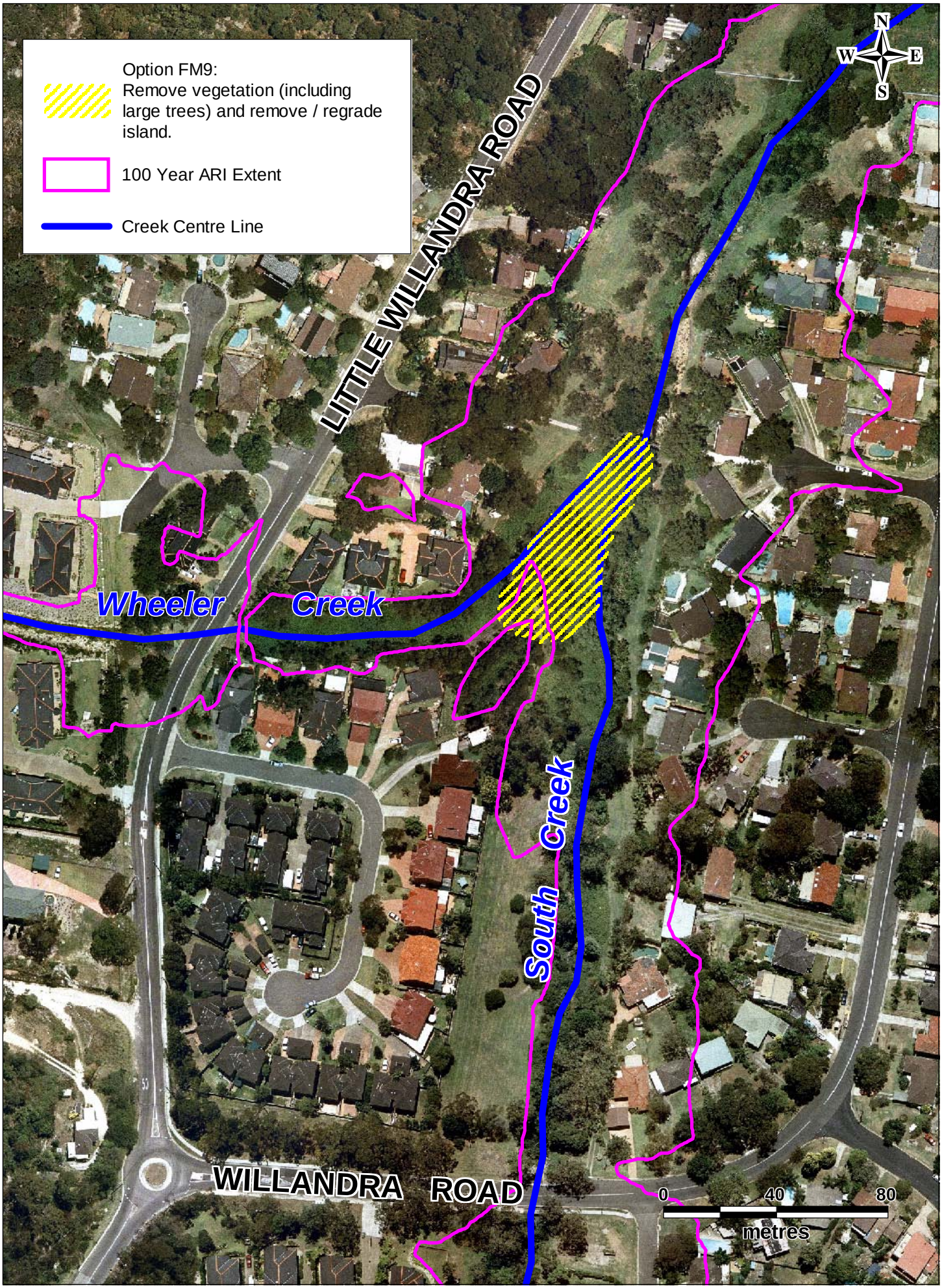
FIGURE 9.5
OPTION FM5

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.5 - FM5.Wor

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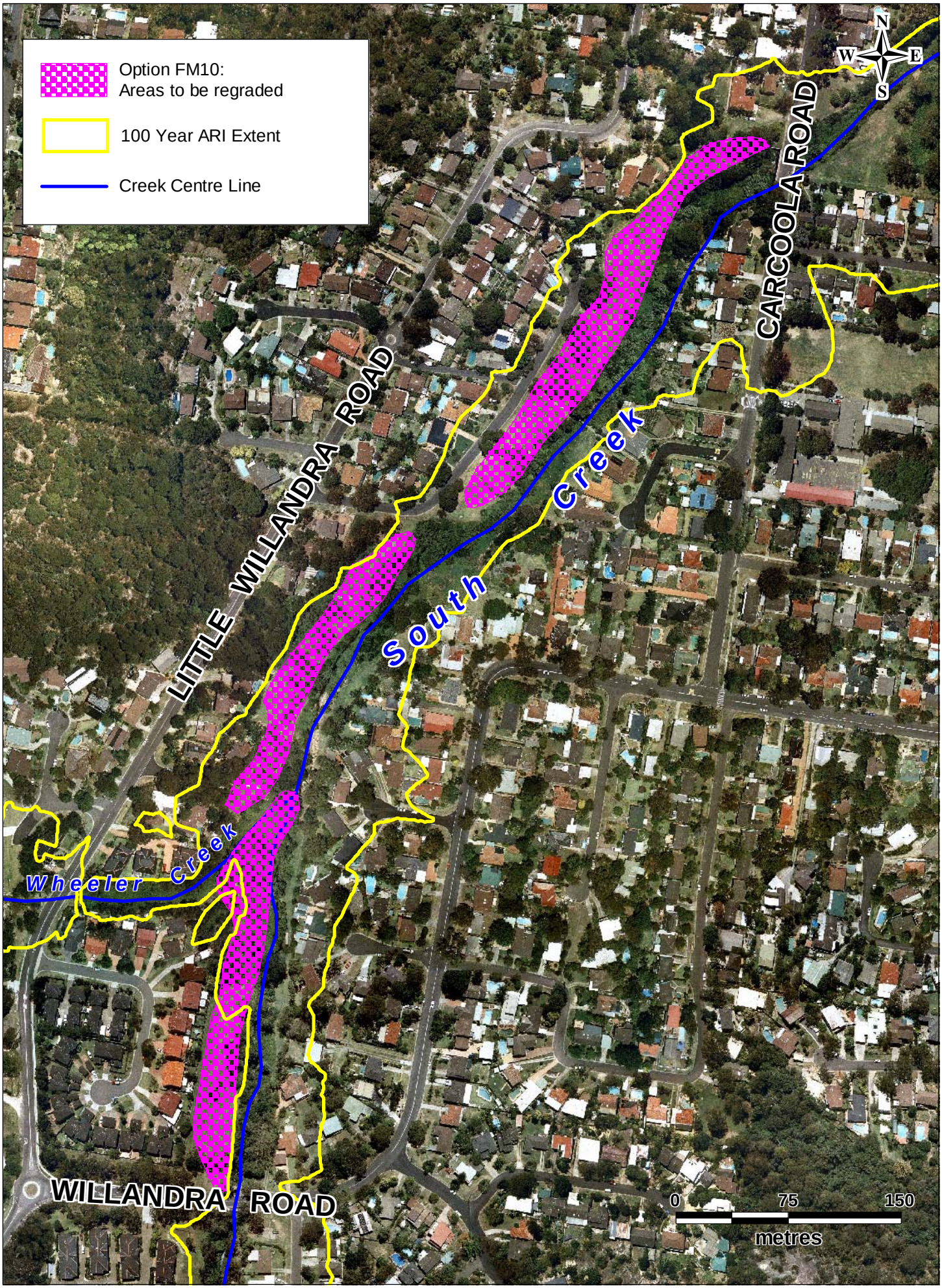
South Creek Floodplain Risk Management Study

FIGURE 9.8
OPTION FM9

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.8 - FM9.Wor



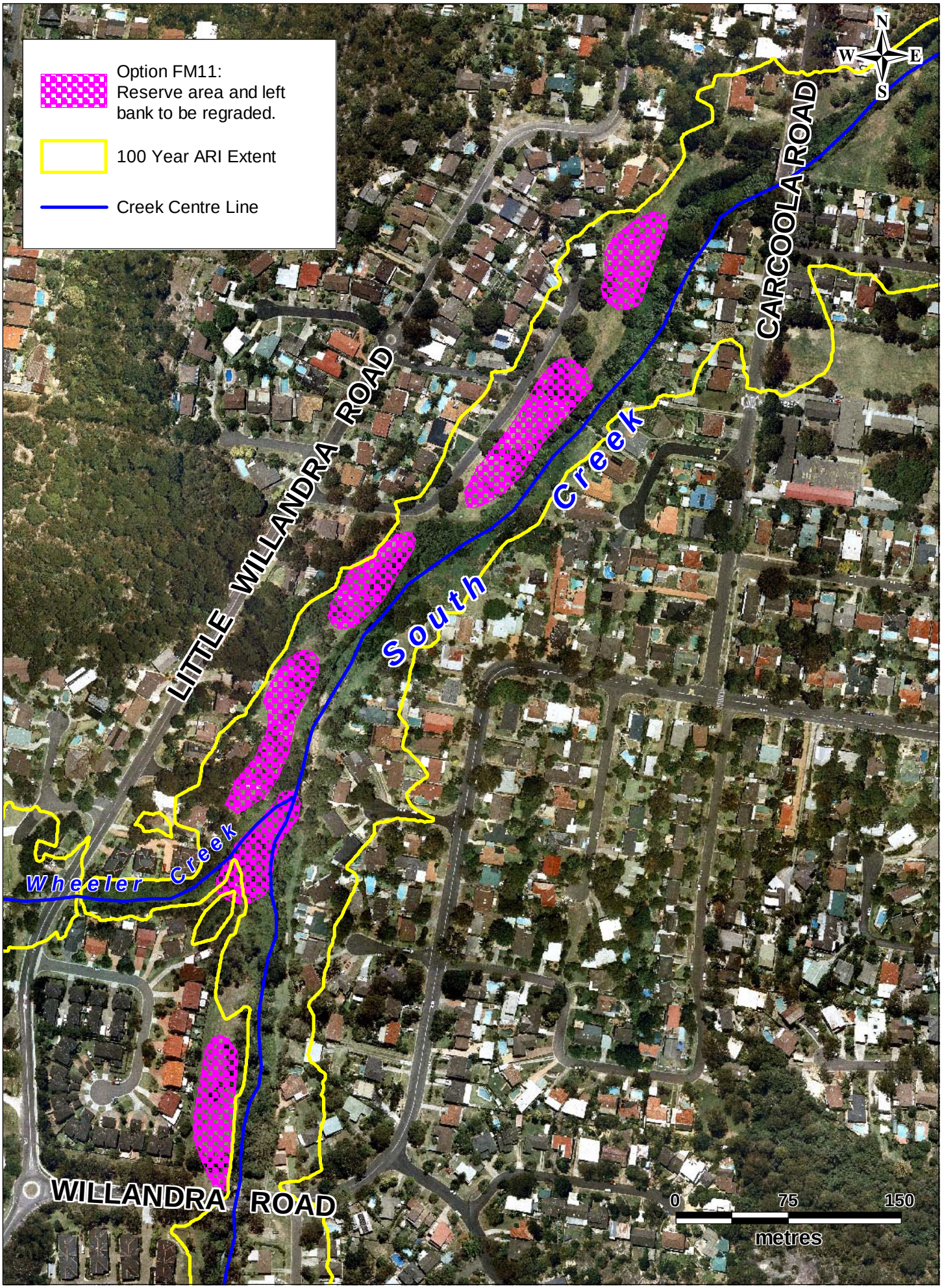

Cardno Lawson Treloar

South Creek Floodplain Risk Management Study

FIGURE 9.9
OPTION FM10

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.9 - FM10.Wor

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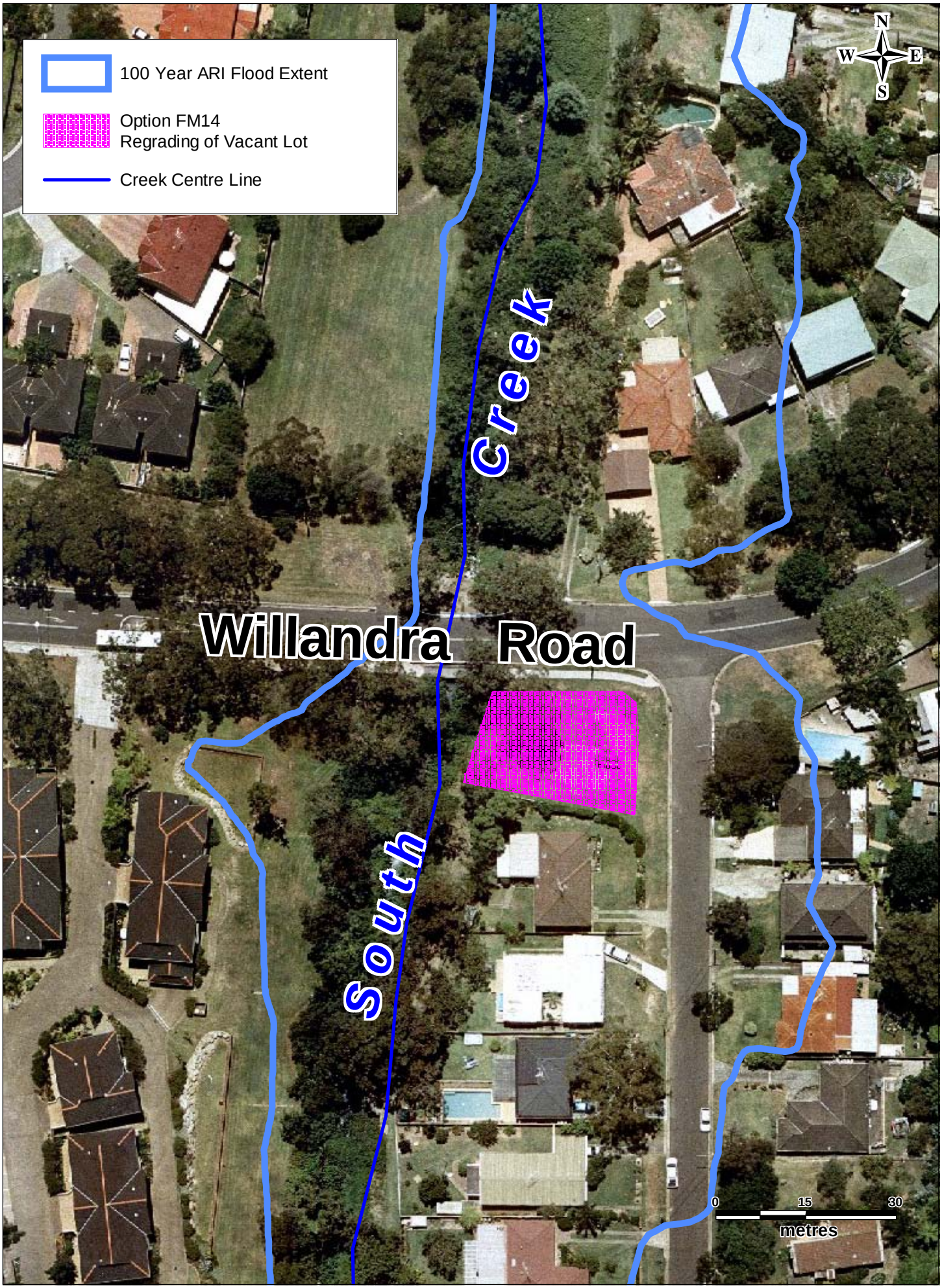
South Creek Floodplain Risk Management Study

FIGURE 9.11
OPTION FM11

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.11 - FM11.Wor

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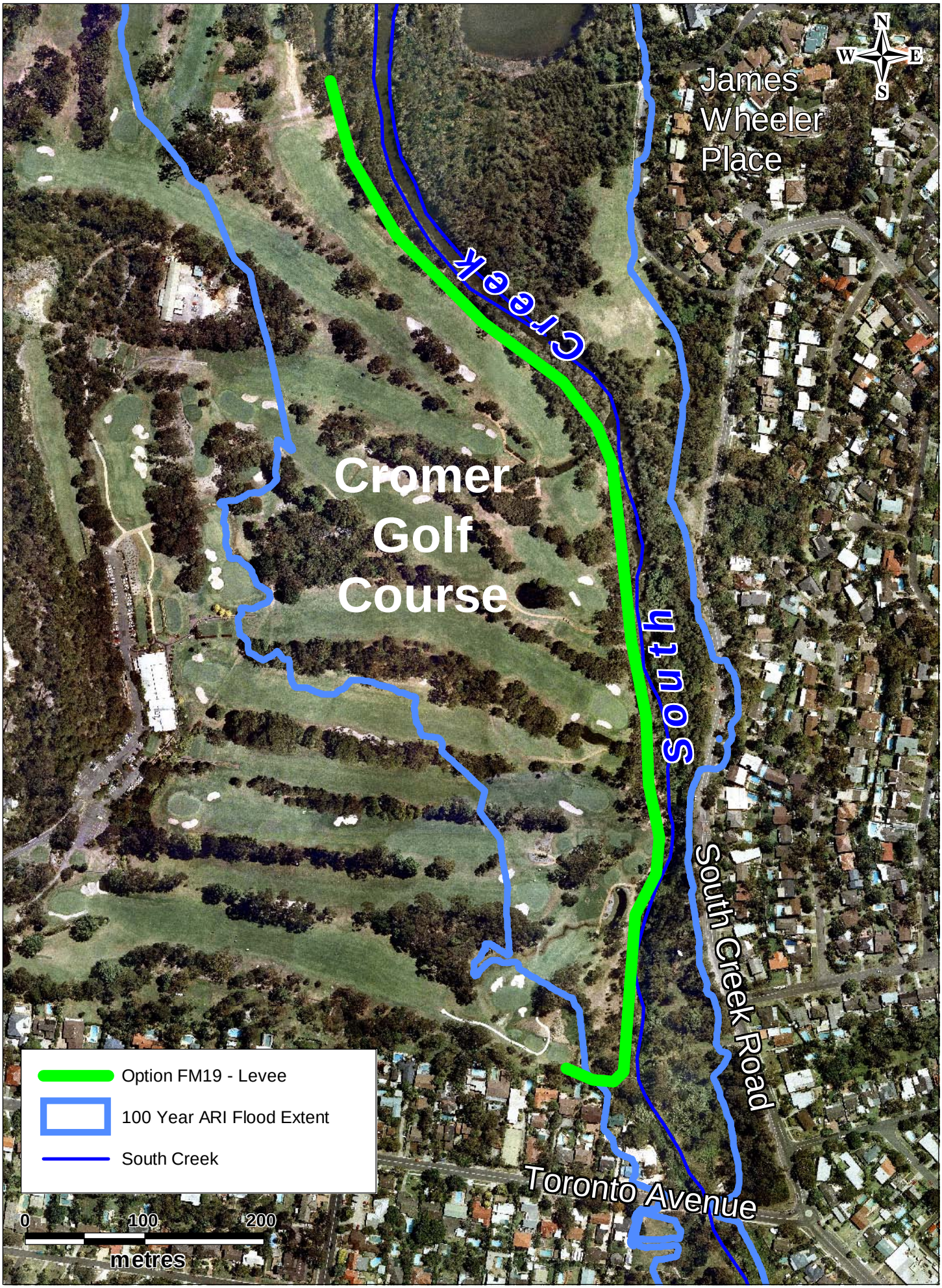
South Creek Floodplain Risk Management Study

FIGURE 9.12
OPTION FM14

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.12 - FM14.Wor

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South Creek Floodplain Risk Management Study

FIGURE 9.15
OPTION FM19

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.15 - FM19.Wor

## Examples of Debris Control Structures

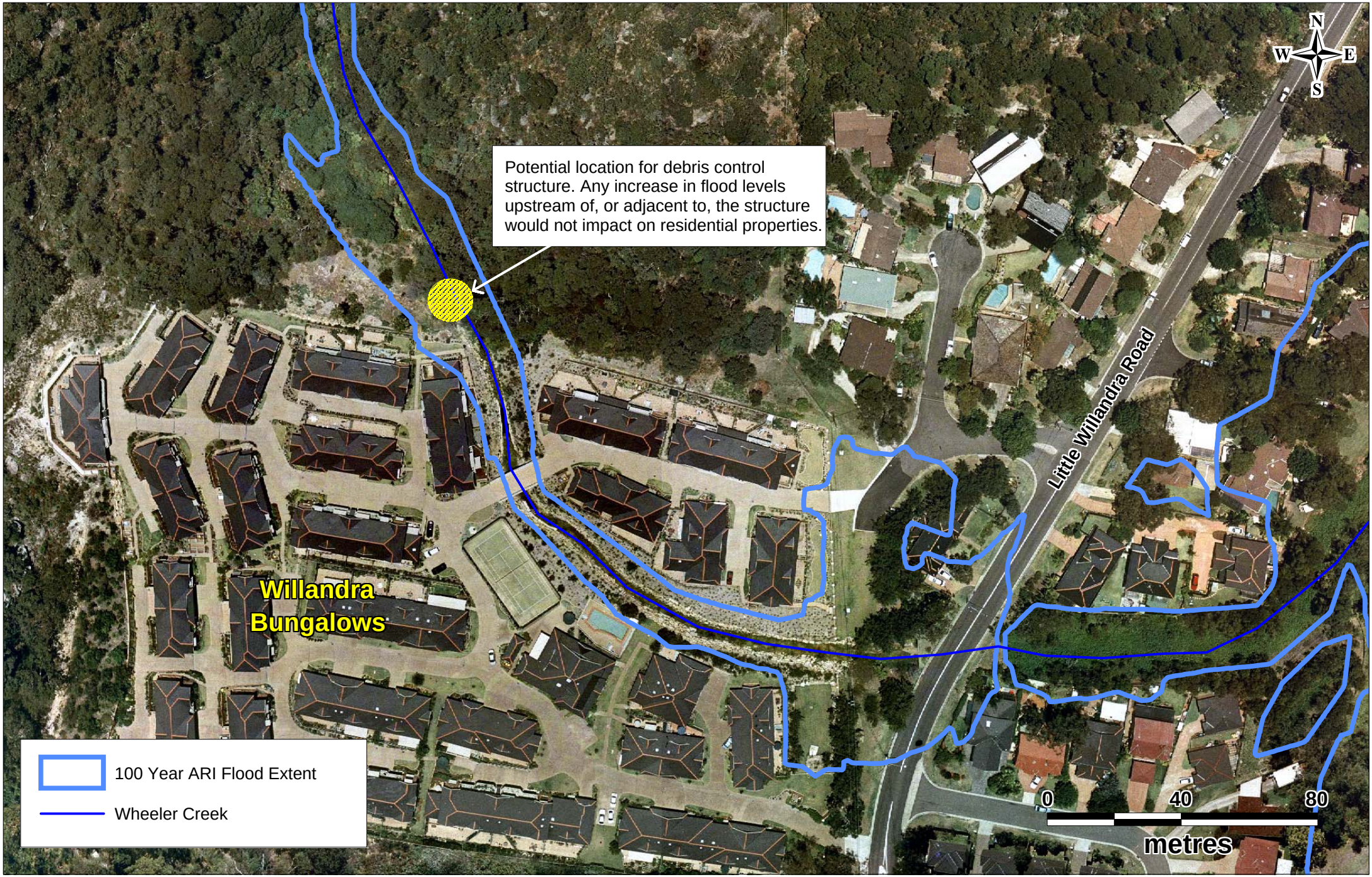
**Steel rail debris deflector (looking downstream).**

**Debris deflectors (looking upstream)**

**Steel rail debris rack (looking upstream)**

**Timber debris fins with sloping leading edge**

**Source:** FHWA (2006), *Debris Control Structures Evaluation and Countermeasures Hydraulic Engineering Circular No. 9*, accessed 10 October 2007, <http://www.fhwa.dot.gov/engineering/hydraulics/pubs/04016/hec0905.cfm>

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South Creek Floodplain Risk Management Study

FIGURE 9.17
OPTION FM21

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 9.17 - FM21.Wor


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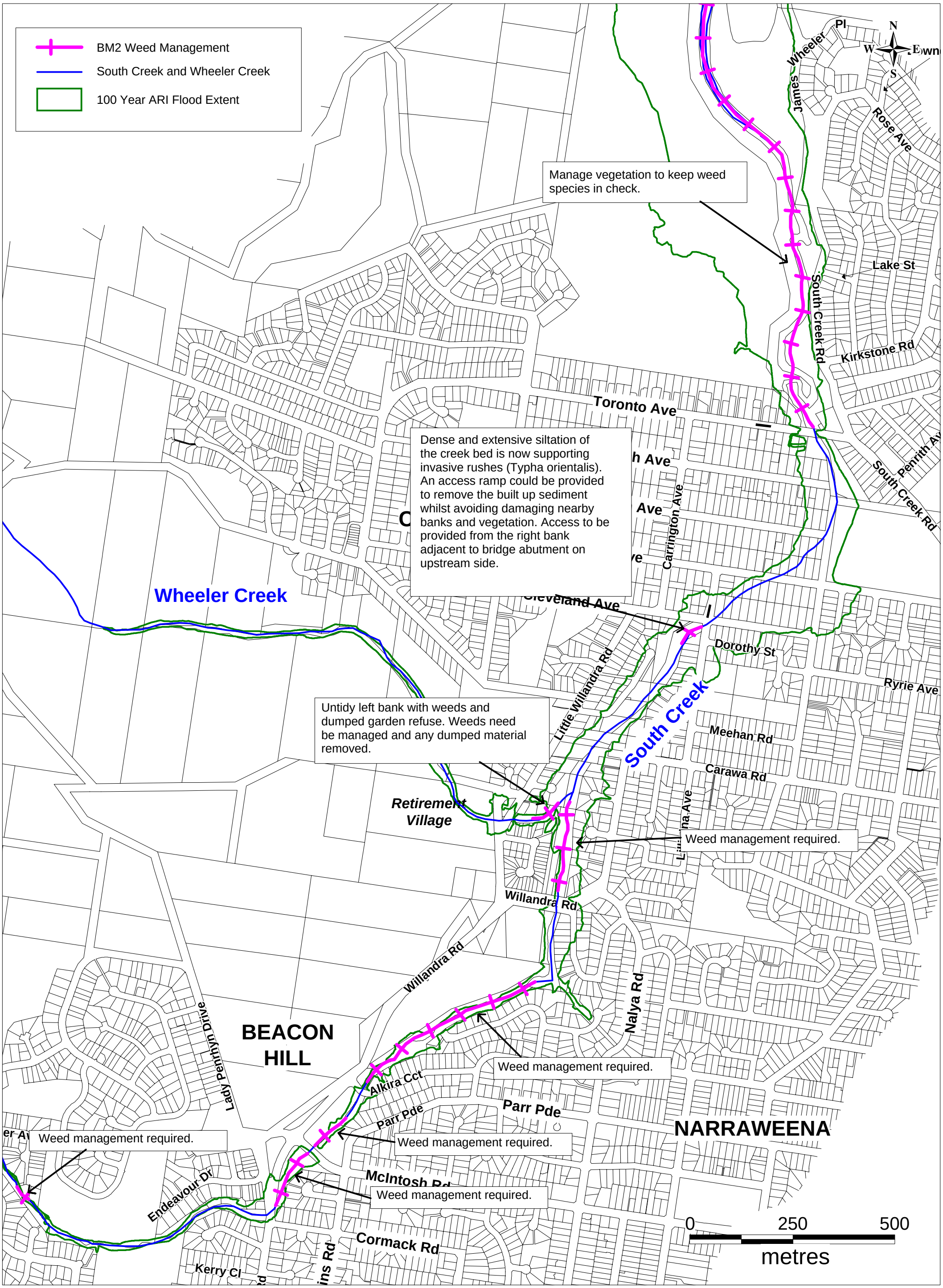
South Creek Floodplain Risk Management Study

FIGURE 12.1
OPTION BM1

J2434/R2100/V4
4 February 2008

J2434\Figures\Floodplain Risk Management Study V4\Figure 12.1 - BM1.Wor

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J2434/R2100/V4
4 February 2008

South Creek Floodplain Risk Management Study

FIGURE 12.2
OPTION BM2

J2434\Figures\Floodplain Risk Management Study V4\Figure 12.2 - BM2.Wor

# APPENDIX A

## Community Brochure and Feedback Form

| Description of option | Preference (please circle) | Comments |
|---|---|---|
| Regrade part of the creek bank and portions of the reserve along South Creek between Willandra Rd and Carcoola Rd to protect properties (the reserve would still be usable). | 1 2 3 4 5 | |
| Ongoing maintenance of stormwater pipes and culverts under bridges to reduce the likelihood of blockages during a flood event. | 1 2 3 4 5 | |
| For increase in flood storage, minor excavation on Council land (for example at corner of Willandra Rd and Ara Cres, areas would be returfed). | 1 2 3 4 5 | |
| Provision of levee bank adjacent to Cromer Golf Course to reduce flooding of the course. | 1 2 3 4 5 | |
| Ongoing implementation of development controls and guidelines for building work. | 1 2 3 4 5 | |
| Voluntary House Raising Program (State Government Funded). | 1 2 3 4 5 | |
| Voluntary House Purchase Program (State Government Funded). | 1 2 3 4 5 | |
| Ongoing collection of flood information. | 1 2 3 4 5 | |
| Revision of SES Disaster Plan (DISPLAN). | 1 2 3 4 5 | |
| Community education and awareness programs. | 1 2 3 4 5 | |

Note: Banks are named left and right when looking downstream.

Additional comments are also welcome. Please attach additional pages as required.

Please fill out, tear off and return by Friday 22 June to:

Cardno Lawson Treloar Pty Ltd
Level 2, 910 Pacific Highway, Gordon, 2072

OR fax 9499 3033

OR email your comments to: emma.maratea@cardno.com.au

# South Creek Floodplain (including Wheeler Creek)

# Community Information Guide and Feedback Form

June 2007

*Flooding of Carcoola Road, 1984 (WMA, 2006)*

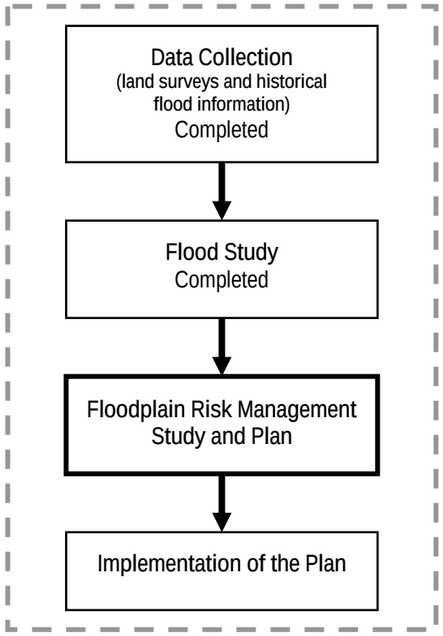
Warringah Council

Cardno Lawson Treloar

Department of Environment & Climate Change NSW

## South Creek Floodplain Risk Management Study and Plan

Warringah Council is preparing a floodplain management program for the South Creek catchment. The floodplain management process is part of the NSW State Government's Flood Prone Land Policy which is comprised of the following stages:




Council has engaged Cardno Lawson Treloar Pty Ltd to conduct a Floodplain Risk Management Study (FRMS) and prepare a Floodplain Risk Management Plan (FRMP) for South Creek catchment area (figure 1).

The Floodplain Risk Management Plan will recommend management options to reduce flooding. This will be based on an assessment of social, economic, environmental and cultural impacts. **Council is looking for your input as the community's preferred options will be considered.**

These studies are being prepared in coordination with the **Narrabeen Lagoon Joint Estuary/Floodplain Management Committee** which is convened by Warringah and Pittwater Councils and consists of community representatives, councillors, council staff and state government agencies such as NSW Department of Environment and Climate Change and NSW State Emergency Service.

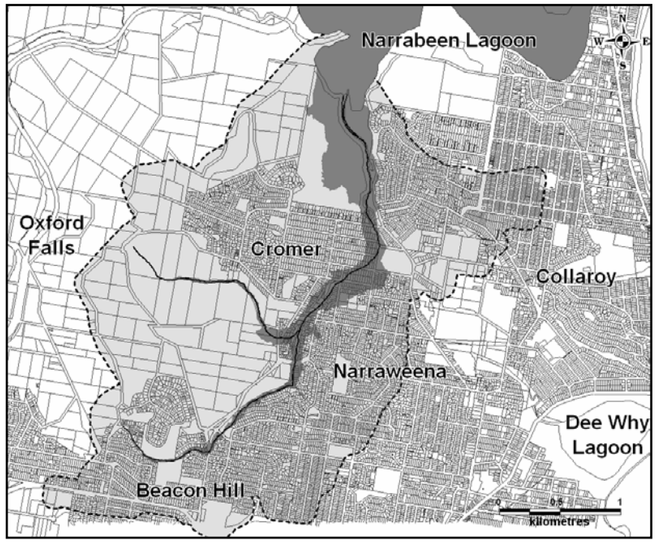



**Figure 1: South Creek catchment**




## Flood Management

There are several options available to manage the risk of flooding to properties in the South Creek Floodplain. These include:

**Flood modification** – structural works such as creek rehabilitation, detention basins, levee banks, larger stormwater pipes (culverts) under roads, and pollution traps.

**Property modification** – modifications to individual properties, such as house raising, flood proofing, the adoption of development control policies and building codes, or the rezoning of land.

**Emergency response modification** – modifications to the way emergency response is currently handled (by emergency management organisations, such as the State Emergency Service).

## Evaluating Flood Management Options

Several potential flood risk management measures have been identified for the South Creek floodplain.

To evaluate the most appropriate measures, an assessment of all potential options will be undertaken. This involves computer modelling of selected options, benefit-cost analysis and a detailed ranking system.

The ranking system assesses the impact of the options of economic, social and environmental factors. **From this feedback form, community support or opposition to the options will be evaluated. This will help determine the flood management measures that will be included in the Floodplain Risk Management Plan for implementation.**

## Frequently Asked Questions

*What is the South Creek catchment?* The land area and tributary streams draining to South Creek (see the map on the previous page).

*What is a Floodplain?* The area of land subject to inundation by floods up to the Probable Maximum Flood (PMF).

*Why does flooding occur?* Flooding is a natural process that occurs periodically as a result of rainfall in a catchment area. The size of a flood event depends on the amount of rain falling and the length of time it falls. In general, flooding causes more damage in built-up areas where the flow of water is restricted by fences and buildings, and where creeks have been altered.

*How likely are these floods?* Floods are referred to in terms of their likelihood. For example, the 100-year flood has approximately a one per cent chance of occurring in any one year while the Probable Maximum Flood (PMF) is the largest flood that could possibly occur at a particular location. The NSW Government has identified these as the most appropriate floods to use for planning.

*More details?* Contact Katrina Brown at Warringah Council on 9942 2111 or Louise Collier, Project Manager, South Creek Floodplain Risk Management Study at Cardno Lawson Treloar on 9499 3000.

### Anzac Day Flood - 2007

Many people would be aware that the South Creek Catchment experienced significant rainfall on the 24th and 25th of April this year (2007).

Council is trying to obtain information of this event for their records and to incorporate into future flood estimations.

Please contact Council (details on back page) if you have any information about this event, such as flood levels (for example a flood mark on a building), flood extent or photographs of flooding.

# Community Feedback

Local residents' knowledge is very valuable; please take the time to fill in this feedback form.

Please return by FRIDAY 22 JUNE 2007.

Could you please provide us with the following details. We may wish to contact you to discuss some of the information with you. Please be assured your details will remain confidential.

Name: _____ Daytime phone: _____

Address: _____ Email: _____

_____

_____

As a local resident, you may have witnessed flooding/drainage problems and may have your own ideas on how best to solve the problems. Which of the following general management options would you prefer for South Creek (1 = least preferred, 5 = most preferred)? Please also provide comments.

| Description of option | Preference (please circle) | Comments |
|---|---|---|
| Levees (up to two metres high) on Council land to protect properties. | 1 2 3 4 5 | |
| Removal of weeds from South Creek to improve creek flow. | 1 2 3 4 5 | |
| Widen the creek beneath the Toronto Ave road bridge to improve creek flow. | 1 2 3 4 5 | |
| Creek widening and revegetation upstream of Toronto Ave to improve creek flow. | 1 2 3 4 5 | |
| Rehabilitate creek and construct wetland on the right bank of South Creek between Carcoola Rd and Toronto Ave (to provide flood storage). | 1 2 3 4 5 | |
| Increase stormwater flow under Carcoola Rd bridge, Willandra Rd bridge (upper and lower) and Alkira Cr bridge by increasing the culvert size. | 1 2 3 4 5 | |
| To reduce sediment loads, install a sediment retention basin upstream of Carcoola Rd. | 1 2 3 4 5 | |
| To improve creek flow, widen the creek at the confluence of South and Wheeler Creek and remove island. | 1 2 3 4 5 | |
| Flood depth markers placed on both sides of all roads crossing the creeks. | 1 2 3 4 5 | |

# SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

## FEEDBACK FORM

Could you please provide us with the following details? We may wish to contact you to discuss some of the information with you. Please be assured your details will remain confidential.

Name: _____ Daytime phone: _____

Address: _____ Email: _____

_____

As a local resident, you may have witnessed flooding/drainage problems and may have your own ideas on how best to solve the problems. As a result of reading the South Creek Floodplain Risk Management Study, which of the following management options would you prefer for South Creek? Please also provide comments.

| -2 (strongly disagree) | -1 (disagree) | 0 (unsure) | 1 (agree) | 2 (strongly agree) |
|---|---|---|---|---|

| ID | Description | Preference (please circle) | | | | | Comments |
|---|---|---|---|---|---|---|---|
| FM1 | Levee to protect properties on Toronto Ave. | -2 | -1 | 0 | 1 | 2 | |
| FM2 | Enhance Toronto Ave Culverts. | -2 | -1 | 0 | 1 | 2 | |
| FM3 | Creek Widening and Revegetation Upstream of Toronto Ave. | -2 | -1 | 0 | 1 | 2 | |
| FM4 | Levee to Protect Properties between Wabash Ave and Washington Ave. | -2 | -1 | 0 | 1 | 2 | |
| FM5 | Rehabilitate Creek and Construct Wetland. | -2 | -1 | 0 | 1 | 2 | |
| FM6 | Enhance Carcoola Rd Culverts. | -2 | -1 | 0 | 1 | 2 | |
| FM7 | Sediment Retention Basin. | -2 | -1 | 0 | 1 | 2 | |
| FM8 | Levee to Protect Properties at Carcoola Rd. | -2 | -1 | 0 | 1 | 2 | |
| FM9 | Widening of South Creek (removal of island). | -2 | -1 | 0 | 1 | 2 | |
| FM10 | Regrading of Lidwina Place Reserve and Tyagarah Reserve. | -2 | -1 | 0 | 1 | 2 | |
| FM11 | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve. | -2 | -1 | 0 | 1 | 2 | |
| FM12 | Ongoing Maintenance of Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek. | -2 | -1 | 0 | 1 | 2 | |
| FM13 | Enhance Willandra Road (lower) Culverts | -2 | -1 | 0 | 1 | 2 | |

| ID | Description | Preference (please circle) | | | | | Comments |
|---|---|---|---|---|---|---|---|
| FM14 | Regrading of South Creek Right Bank upstream of Willandra Road (Lower) crossing. | -2 | -1 | 0 | 1 | 2 | |
| FM15 | Levee to Protect Properties at the end of Towradgi Street. | -2 | -1 | 0 | 1 | 2 | |
| FM16 | Enhance Alkira Circuit Culverts. | -2 | -1 | 0 | 1 | 2 | |
| FM17 | Enhance Willandra Road (upper) Culverts. | -2 | -1 | 0 | 1 | 2 | |
| FM18 | Levee to protect properties on Willandra Road. | -2 | -1 | 0 | 1 | 2 | |
| FM19 | Levee to protect Cromer Golf Course. | -2 | -1 | 0 | 1 | 2 | |
| FM20 | Detailed Assessment for potential Debris Control Structures. | -2 | -1 | 0 | 1 | 2 | |
| PM1 | Ongoing implementation of development controls and guidelines for building work. | -2 | -1 | 0 | 1 | 2 | |
| PM2 | Preparation of Flood Related Development Control Plan for Warringah LGA. | -2 | -1 | 0 | 1 | 2 | |
| PM3 | Guidelines for Public Domain Infrastructure. | -2 | -1 | 0 | 1 | 2 | |
| PM4 | Voluntary House Raising Program (State Government Funded). | -2 | -1 | 0 | 1 | 2 | |
| PM5 | Voluntary House Purchase Program (State Government / Council Jointly Funded) - 10 properties. | -2 | -1 | 0 | 1 | 2 | |
| PM6 | Voluntary House Purchase Program (State Government / Council Jointly Funded) - 1 property. | -2 | -1 | 0 | 1 | 2 | |
| PM7 | Stringent OSD Requirements on any Proposed Development in the Catchment. | -2 | -1 | 0 | 1 | 2 | |
| PM8 | Analysis of Localised Flood Planning Level Requirements. | -2 | -1 | 0 | 1 | 2 | |
| PM9 | Property Dossier of Severely Flood Affected Properties. | -2 | -1 | 0 | 1 | 2 | |
| EM1 | Revision of SES Disaster Plan (DISPLAN). | -2 | -1 | 0 | 1 | 2 | |
| EM2 | Flood Warning Systems and Instrumentation. | -2 | -1 | 0 | 1 | 2 | |
| EM3 | Information Transfers to SES. | -2 | -1 | 0 | 1 | 2 | |
| EM4 | Community education and awareness programs. | -2 | -1 | 0 | 1 | 2 | |
| EM5 | Flood depth markers placed on both sides of all roads crossing the creeks. | -2 | -1 | 0 | 1 | 2 | |
| EM6 | Ongoing collection of flood information.. | -2 | -1 | 0 | 1 | 2 | |
| BM1 | Management of Weeds in South Creek Downstream of Carcoola Road. | -2 | -1 | 0 | 1 | 2 | |

*Thankyou for taking the time to complete this form*

Please return to Warringah Council by 5pm on Friday November 30, 2007, addressed to the General Manager, Warringah Council, 725 Pittwater Road, Dee Why. Comments may also be emailed to council@warringah.nsw.gov.au

# APPENDIX B

## Summary of Community Responses

COMMENTS

| Option | 1) Levees (up to two metres high) on Council land to protect properties. | 2) Removal of weeds from South Creek to improve creek flow. | 3) Widen the creek beneath the Toronto Ave road bridge to improve creek flow. | 4) Creek widening and revegetation upstream of Toronto Ave to improve creek flow. | 5) Rehabilitate creek and construct wetland on the right bank of South Creek between Carcoola Rd and Toronto Ave (to provide flood storage). | 6) Increase stormwater flow under Carcoola Rd bridge, Willandra Rd bridge (upper and lower) and Alkira Cr bridge by increasing the culvert size. | 7) To reduce sediment loads, install a sediment retention basin upstream of Carcoola Rd. | 8) To improve creek flow, widen the creek at the confluence of South and Wheeler Creek and remove island. | 9) Flood depth markers placed on both sides of all roads crossing the creeks. | 10) Regrade part of the creek bank and portions of the Reserve along South Creek between Willandra Rd and Carcoola Rd to protect properties (the reserve would still be usable). | 11) Ongoing maintenance of stormwater pipes and culverts under bridge to reduce the likelihood of blockages during a flood event. | 12) For increase in flood storage, minor excavation on Council land (for example at corner of Willandra Rd and Ara Cres, areas would be returfed). | 13) Provision of levee bank adjacent to Cromer Golf Course to reduce flooding of the course. | 14) Ongoing implementation for development control and guidelines for building work. | 15) Voluntary House Raising Program (State Government Funded). | 16) Voluntary House Purchase Program (State Government Funded). | 17) Ongoing collection of flood information. | 18) Revision of SES Disaster Plan (DISPLAN) | 19) Community education and awareness programs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Survey Reference Number | | | | | | | | | | | | | | | | | | | |
| 1 | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | |
| 4 | | | If it does not adversely affect houses. | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | |
| 6 | | Curbing and guttering of South Creek Road downstream of Toronto Ave. | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | No need, if all the above are done. |
| 8 | | Sth creek is chocked with excessive noxious weeds. | | All creeks need rehabilitation to re-establish proper flowing creeks. | | Will reduce lakes filling with sediment. | | | | | | | | | | | | | |
| 9 | Not necessary. | Yes, proper maintenance. | Yes, proper maintenance. | Yes, proper maintenance. | Brilliant. | Brilliant. | Waste of money if above is managed. | Brilliant. | We don't live in Qld, no point. | Doesn't make sense, do you mean levies? | Yes, if so. | Proper council management. | | Nice word for proper managed development. | | | Yes. | Yes. | Yes. |
| 10 | If necessary. | Lantana is a huge problem. Please remove in my lifetime. | Anything to improve flow. | Creek is in shocking state. 40 years ago you could canoe on it and it was visible from Sth Creek Rd. | Yes to rehabilitate creek. | If necessary. | If necessary. | Anything to improve flow. | If necessary. | If necessary. | Always. | If necessary. | Does not seem necessary (I am member of club). | Always. | If necessary. | If necessary. | Info always good. | Know nothing about this. | Of what? We know creek & environs are a total mess. |
| 11 | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | Yes, Yes, Great Idea | | | | | | | Will fill up with weeds | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | |
| 19 | Would not be necessary if the creek bed was cleared and cleaned. | Part of the problem and a big part of the solution. | | Would have a beautification effect on the parklands as a bonus. | It was like that many years ago. | If the creek flows properly and uninterrupted then this would probably not be needed. | | | Probably not needed if other measures are implemented. | | | | Probably not needed if other options are implemented. | | Probably not needed if other options are implemented. | As above. | | | Would be most helpful and beneficial - especially to new owners. |
| 20 | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | |
| 22 | | Very important. | | | | Very important. | | | | | | | | | This would be unnecessary if creek maintained. | | | | |
| 23 | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | Would like more information. | Further information re this and location of confluence. | | | | | | | | | | | |
| 25 | Detracts from natural surroundings. Graffiti ugly. | Also to enhance beauty and golf course views. | | | Also good for local wildlife. | | Good for lake management. | | Unsightly. | Also tidy up area. | | | | | | | | | Should be utilised. |
| 26 | Unsightly. Security issues. | More amenable. | Acceptable. | Acceptable. | Changes the landscape. | Acceptable. | Requires maintenance. | Changes the landscape. | Creates awareness of the nature of the area. | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | Do not agree if it means the possible flooding of south creek road at its lowest point. | | | | | | |
| 29 | | | Very important. | Very important. | Not correct? | A must. | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | I don't know what this is. | | | | |
| 31 | | | | | | | | | | | | | | | | | | | |
| 32 | Any protection of property is welcome. | This should have been done on a regular basis for 30 years. | | Do not revegetate - no more vegetation to become out of control. | ? | This was done a decade or so ago and has not been maintained. Debris does not get removed. | Great if this would help. | If this will help downstream; yes! | No. | In the flood of 1975 the bank was raised on the west side of the creek causing water to flow through 38 Carcoola Rd. Do not want that again. | This is what we have paid rates for and in hasn't been done for many years as you can see. | | Who plays golf in a flood. | | No good if your on a council approved slab. | No. | | | |
| 33 | Unsightly. Security issues. | From Toronto ave down. | Flow depends on where it is flowing too. | A built lake does more harm than extra width. | Is this a cost effective measure. | Up creek detention would help downstream at times of flash flooding. | On-going cost to clear out. | Too major not necessary. | This will help with awareness. | | | | At whose expense? The club should pay 50%. | | | | | | The flood prone blocks definitely. |
| 34 | | Creek flows severely affected by weed infestation. | | This would also help stabilise creek banks. | | | | | | | | | | | | | | | |
| 35 | | | | | | | | | | | | | | | | | | | |
| 36 | If made of dirt & strengthened with plant roots - nothing artificial. | Very important - amount of noxious weeds at the moment is disgraceful and very bad for local ecosystems. | | | Constructing wetland is a very good idea. | | | | This should have been implemented a long time ago to assist in research for the flood management plans. | | Should be a part of Council maintenance anyway. | | | | | | Very important to ensure management is working. | | |
| 37 | The main action required is regular maintenance of creek bed. | | | | Not sure - don't know enough. | | | Don't have this knowledge. | Won't help when it floods. | | | ? | ? | ? | ? | ? | | | |

| Survey Reference Number | GENERAL COMMENTS |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | Lived in Wabash since 1961. Can remember swimming across Carcoola Rd Bridge. There was no vehicle access when this happened. There was only a footbridge across the creek at Toronto Ave. |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | We have lived in Sth Creek Road 40 years. Have constantly requested removal of weeds. South Creek was beautiful originally. Absolutely disgusted with neglect. |
| 11 | |
| 12 | |
| 13 | |
| 14 | Revegetation of the creek banks between Toronto & Alkira with native vegetation should be a priority. The creek banks are completely chocked with noxious weeds which narrow the creek. Clearing the banks without re-vegetation will lead to more sedimentation problems. Appropriate native plants will allow creek flow in floods. Don't widen without rehabilitation as it just leaves room for more weeds like at the Carcoola Rd Bridge. |
| 15 | |
| 16 | |
| 17 | |
| 18 | I have observed, over 33 years, creek depth and width multiplying drastically and flooding severely at times, with high risk in the future due to obstruction and erosion of creek area itself. Particularly from Carawa Rd through and including bridge areas near Cromer Public School (now widened and cleared but the risk still remains in the future). I believe permanent cementing/rock securing of the wall areas is required for most of this area before a large stream becomes a raging river with even higher flooding levels, resulting in even further erosion and widening etc. of the present creek in parts of this area. I don't believe the catchment to hold water is the long term answer due the severe erosion eventuating in 33 years to date. Maybe engineers will see my reasoning as it costs far more in the long term to band-aid in the interim. Tyagara Park is a high risk flood prone area with surrounding homes. |
| 19 | |
| 20 | Actions 2- 8 have to be done as one to enable the clear flow of water down to Narrabeen Lake to stop flooding after heavy rain. Only doing one or two of these would be a waste of both time and money. |
| 21 | |
| 22 | We have lived backing onto the creek since 1980 and have no photos of the ANZAC day flood but the creek at the rear of our property rose to above ground level and picked up logs etc and scattered them around. I have never seen the bamboo and vegetation as thick in the creek and I feel maintenance has been lacking. The water level rose up to the footbridge from Tyagara reserve to Pitta Place. My husband regularly cleans out the creek at the rear of our property and could fill a garbage bag with debris and garbage collected in there. |
| 23 | |
| 24 | |
| 25 | |
| 26 | |
| 27 | |
| 28 | |
| 29 | I enclose the questionnaire completed. However, I note there is only one question that relates to the flooding of South Creek north of Toronto Ave bridge to Narrabeen Lagoon. My residence is located in the lowest point of South Creek Road opposite this northern section of South Creek and looking at the floodplain map my home would be flooded by a PMF. And your questionnaire is seeking to prevent the Cromer golf course from becoming flooded and all the properties upstream of Toronto Avenue bridge. What plan is under consideration for properties on south creek road for the prevention of flood inundation by a PMF? I have lived at this location for 40 years and have seen South Creek very swollen but no flooding of the road, but your study shows it is possible. Does your plan include the removal of the weir and rocks in this section of South Creek and the clearance of the creek and drainage culverts of weed growth in this section. I consider the plan has merit but without doing a complete plan on South Creek to Narrabeen Lagoon the upper southern end could still have flood problems. |
| 30 | |
| 31 | |
| 32 | Unfortunately I did not receive the South Creek FPRMS until after the due date. I have owned the property since 1969 and built the existing home in 1974 and lived here since. We have had many changes in that time, some better for a time and then retrograde, owing to lack of maintenance by Council. In the early years the flow of the creek was altered to come close to my property at the back most corner. This has since silted up and is just a bank of weeds and trees. The worst flood affecting me occurred in 1975 March 11. After the flooding that occurred 24/25 April 2007 the Council cleaned rubbish either side of Carcoola Rd bridge which helped a little in the recent downpours. Massive work needs to be done, dredging and removal of weeds in the creek to bring it back to its natural flow. I was disappointed that Carcoola Rd was not marked on either map when this is obviously a major floodplain. As far as voluntary house purchase by government, definitely not! If legal permission is given to build, it is up to the authorities to fix the problem. |
| 33 | Width is a slower flow and more likely to get clogged. Narrower is faster and more likely to keep itself clean. Two key points should be noted: 1) 84 flood caused by Narrabeen Lake too full. 2) The creek from Carcoola Rd to the lake was blocked with debris and vegetation. From the Toronto bridge onward the flow should not be impeded. Close monitoring of the Lake is essential. |
| 34 | |
| 35 | |
| 36 | |
| 37 | |

COMMUNITY RESPONSES - NOVEMBER 2007

| | FM1 | FM2 | FM3 | FM4 | FM5 | FM6 | FM7 | FM8 |
|---|---|---|---|---|---|---|---|---|
| | Levee to protect properties on Toronto Ave. | Enhance Toronto Ave Culverts. | Creek Widening and Revegetation Upstream of Toronto Ave. | Levee to Protect Properties between Wabash Ave and Washington Ave. | Rehabilitate Creek and Construct Wetland. | Enhance Carcoola Rd Culverts. | Sediment Retention Basin. | Levee to Protect Properties at Carcoola Rd. |
| 1 | 4 | 0 | 2 | 2 | 2 | 1 | 1 | 0 |
| 2 | | | | | 2 | | | |
| 4 | | 2 | 2 | | 2 | | | |
| 5 | -2 | 1 | 2 | 0 | 2 | 2 | 2 | -2 |
| 6 | 0 | 2 | 2 | 0 | 2 | 2 | 2 | |
| 8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 9 | 0 | 0 | 1 | 0 | -2 | 1 | 0 | 1 |
| 10 | 1 | 0 | 0 | 1 | -1 | 1 | 0 | 1 |
| 11 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | 0 | 1 | 0 | 1 | 1 | -1 | 0 |
| 14 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 |
| 15 | 1 | 0 | -1 | 1 | -1 | 1 | 0 | 1 |
| 16 | 1 | 2 | 1 | 1 | -2 | 2 | 1 | 1 |
| 17 | 0 | 0 | 1 | -1 | -2 | 1 | 0 | 0 |
| 18 | 0 | 0 | 0 | -1 | -1 | 1 | -1 | 1 |
| **TOTAL** | **6** | **8** | **14** | **3** | **2** | **15** | **4** | **5** |
| **Number of Responses** | **1** | **6** | **12** | **7** | **13** | **13** | **7** | **9** |
| **Average** | **6.0** | **1.3** | **1.2** | **0.4** | **0.2** | **1.2** | **0.6** | **0.6** |
| **Previous Score (June 07)** | 0 | 2 | 1 | 0 | 2 | 2 | 2 | 0 |
| | | | | | | | | |
| **Overall Score** | 3.0 | 1.7 | 1.1 | 0.2 | 1.1 | 1.6 | 1.3 | 0.3 |

| | FM9 | FM10 | FM11 | FM12 | FM13 | FM14 | FM15 | FM16 |
|---|---|---|---|---|---|---|---|---|
| | Widening of South Creek (removal of island). | Regrading of Lidwina Place Reserve and Tyagarah Reserve. | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve. | Ongoing Maintenance of Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek. | Enhance Willandra Road (lower) Culverts | Regrading of South Creek Right Bank. | Levee to Protect Properties at the end of Towradgi Street. | Enhance Alkira Circuit Culverts. |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 | | | | | | | |
| 4 | 2 | | | 2 | | | | |
| 5 | 1 | 1 | 2 | 2 | | -2 | -2 | 1 |
| 6 | 1 | 2 | 2 | 2 | 2 | 2 | 1 | 1 |
| 8 | 1 | 0 | 1 | 2 | 2 | 2 | 0 | -2 |
| 9 | 2 | 1 | 1 | 2 | 2 | 2 | 0 | -2 |
| 10 | 1 | -1 | -1 | 2 | 2 | 2 | 1 | -2 |
| 11 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | -2 |
| 12 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| 13 | 1 | 1 | 0 | 2 | 2 | 2 | -1 | -2 |
| 14 | 1 | 0 | 0 | 1 | 2 | 0 | 0 | -2 |
| 15 | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 0 |
| 16 | 2 | 1 | 0 | 2 | 2 | 2 | 1 | -2 |
| 17 | 1 | 1 | -1 | 1 | 2 | 2 | 0 | -2 |
| 18 | 1 | 1 | 1 | -2 | 2 | 2 | 0 | -2 |
| **TOTAL** | **18** | **8** | **6** | **20** | **24** | **20** | **1** | **-16** |
| **Number of Responses** | **14** | **10** | **9** | **14** | **13** | **13** | **7** | **12** |
| **Average** | **1.3** | **0.8** | **0.7** | **1.4** | **1.8** | **1.5** | **0.1** | **-1.3** |
| **Previous Score (June 07)** | 2 | 2 | 2 | 1 | 2 | 2 | 0 | 2 |
| | | | | | | | | |
| **Overall Score** | 1.6 | 1.4 | 1.3 | 1.2 | 1.9 | 1.8 | 0.1 | 0.3 |

| | FM17 | FM18 | FM19 | FM20 | PM1 | PM2 | PM3 | PM4 |
|---|---|---|---|---|---|---|---|---|
| | Enhance Willandra Road (upper) Culverts. | Levee to protect properties on Willandra Road. | Levee to protect Cromer Golf Course. | Detailed Assessment for potential Debris Control Structures. | Ongoing implementation of development controls and guidelines for building work. | Preparation of Flood Related Development Control Plan for Warringah LGA. | Guidelines for Public Domain Infrastructure. | Voluntary House Raising Program (State Government Funded). |
| 1 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0 |
| 2 | | | | | | | | |
| 4 | | | | 2 | | | | |
| 5 | 1 | -2 | -2 | 1 | 1 | 1 | 1 | 0 |
| 6 | 1 | 1 | -2 | 2 | 2 | 2 | 2 | 1 |
| 8 | -2 | 0 | -2 | 0 | 2 | 0 | 0 | -1 |
| 9 | -2 | -2 | -2 | 2 | 1 | 1 | 0 | -2 |
| 10 | -2 | 1 | -2 | 0 | 0 | 0 | 0 | 0.5 |
| 11 | -2 | 0 | -2 | 0 | 0 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | 0 | -1 | -2 | 1 | 2 | 0 | 0 | 0 |
| 14 | -2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 15 | -1 | 1 | -2 | 0 | 1 | 1 | 1 | 0 |
| 16 | -2 | 0 | -2 | 2 | 1 | 1 | 1 | 0 |
| 17 | -2 | 0 | -2 | 1 | 2 | 0 | 0 | -2 |
| 18 | -2 | -2 | -2 | 1 | 1 | 0 | 0 | -1 |
| **TOTAL** | **-15** | **-2** | **-19** | **13** | **14** | **6** | **5** | **-4.5** |
| **Number of Responses** | **12** | **9** | **14** | **10** | **11** | **6** | **5** | **7** |
| **Average** | **-1.3** | **-0.2** | **-1.4** | **1.3** | **1.3** | **1.0** | **1.0** | **-0.6** |
| **Previous Score (June 07)** | 2 | 0 | -1 | 1 | 2 | 2 | 2 | 0 |
| | | | | | | | | |
| **Overall Score** | 0.4 | -0.1 | -1.2 | 1.2 | 1.6 | 1.5 | 1.5 | -0.3 |

COMMUNITY RESPONSES - NOVEMBER 2007

| | PM5 | PM6 | PM7 | PM8 | PM9 | EM1 | EM2 | EM3 |
|---|---|---|---|---|---|---|---|---|
| | Voluntary House Purchase Program (State Government / Council Jointly Funded) - 10 properties. | Voluntary House Purchase Program (State Government / Council Jointly Funded) - 1 property. | Stringent OSD Requirements on any Proposed Development in the Catchment. | Analysis of Localised Flood Planning Level Requirements. | Property Dossier of Severely Flood Affected Properties. | Revision of SES Disaster Plan (DISPLAN). | Flood Warning Systems and Instrumentation. | Information Transfers to SES. |
| 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 |
| 2 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | 1 | 2 | 1 | 1 | 1 | 0 | | |
| 6 | -1 | 0 | 2 | | 2 | 1 | -1 | 2 |
| 8 | -1 | 1 | 2 | 0 | 0 | 1 | -2 | 1 |
| 9 | -1 | 1 | 2 | 1 | 1 | 1 | -1 | 1 |
| 10 | 0.5 | 0.5 | 2 | 1 | -1 | 1 | 1 | 2 |
| 11 | -1 | 1 | 2 | 0 | 0 | 0 | -1 | 0 |
| 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 13 | -2 | 0 | 2 | 1 | -1 | -1 | -1 | -1 |
| 14 | 0 | 0 | 0 | 2 | 0 | 2 | 1 | 1 |
| 15 | 0 | 0 | 1 | 0 | 1 | 0 | -1 | 2 |
| 16 | 0 | 0 | 2 | 1 | 1 | 1 | -1 | 1 |
| 17 | -2 | 0 | 2 | 0 | -1 | 0 | -2 | 1 |
| 18 | -1 | 0 | 2 | 1 | 0 | 1 | -1 | 1 |
| **TOTAL** | **-7.5** | **5.5** | **22** | **9** | **3** | **7** | **-9** | **11** |
| **Number of Responses** | **10** | **6** | **13** | **9** | **9** | **9** | **12** | **11** |
| **Average** | **-0.8** | **0.9** | **1.7** | **1.0** | **0.3** | **0.8** | **-0.8** | **1.0** |
| **Previous Score (June 07)** | 0 | 0 | 2 | 2 | 0 | 2 | 2 | 2 |
| | | | | | | | | |
| **Overall Score** | -0.4 | 0.5 | 1.8 | 1.5 | 0.2 | 1.4 | 0.6 | 1.5 |

COMMUNITY RESPONSES - NOVEMBER 2007

| | EM4 | EM5 | EM6 | BM1 | BM2 |
|---|---|---|---|---|---|
| | Community education and awareness programs. | Flood depth markers placed on both sides of all roads crossing the creeks. | Ongoing collection of flood information.. | Management of Weeds in South Creek Downstream of Carcoola Road. | Weed and Sediment Management |
| 1 | 0 | 0 | 1 | 1 | |
| 2 | | | | 2 | |
| 4 | | | | 2 | |
| 5 | 1 | | 2 | 2 | |
| 6 | 2 | 1 | 1 | 2 | |
| 8 | 1 | -1 | 2 | -2 | |
| 9 | -1 | -1 | 1 | 1 | |
| 10 | 0 | 1 | 2 | 2 | |
| 11 | 0 | -1 | 2 | 2 | |
| 12 | 0 | 0 | 0 | 0 | |
| 13 | 0 | -2 | 1 | 1 | |
| 14 | 1 | 0 | 1 | 2 | |
| 15 | -1 | 1 | 1 | 1 | |
| 16 | 1 | -1 | 1 | 2 | |
| 17 | 0 | -2 | 2 | 0 | |
| 18 | 1 | 0 | 2 | 1 | |
| **TOTAL** | **5** | **-5** | **19** | **19** | |
| **Number of Responses** | **9** | **10** | **14** | **15** | |
| **Average** | **0.6** | **-0.5** | **1.4** | **1.3** | **2.0** |
| **Previous Score (June 07)** | 2 | 0 | 2 | 1 | 2 |
| | | | | | |
| **Overall Score** | 1.3 | -0.3 | 1.7 | 1.1 | 2.0 |

| ID | General Comments |
|---|---|
| 2 | Levee at Toronto Ave would exacerbate the problem of water stagnating on the property |
| 2 | Best options would include dredging the creek regularly |
| 2 | Best options would include keeping weeds at bay |
| 2 | Best options would include having the option of opening the lake at Narrabeen to prevent backwater up the creek |
| 3 | Lived in the area for 38 years. Has seen property flooding approximately 20 years ago. Within a few hours the water had come up to the front door (12 inches from ground level). |
| 3 | The creek has been left to fill up with trees and other debris. |
| 3 | Could smaller machine be brought in more regularly to clear the creek rather than large machines and expensive works after a long time has passed? |
| 4 | Did not receive a survey in June 2007. |
| 4 | The proposed levee at Toronto Ave has the potential to trap and exacerbate flood damage to these properties by trapping water inside the levee. Careful consideration should be given to the potential adverse affects of retaining water inside the levee. |
| 4 | The exec summary recommends that the flood affected properties shown in the Study be reflected on Section 149 certificates. Does this mean that my property is not currently designated as flood affected by Council? If so, how much notice will I receive from Council that the status is likely to change in the future? |
| 7 | There is NO options presented that suggests a starting point would be to clear the whole area of vegetation and silt. Many residents suggest this but the study gives options of large scale public works in ad hoc areas. |
| 7 | The residents are concerned of the potential for devaluation of the properties by declaring their properties to a specific flood prone grading. In many cases a 1/5 year flood risk will devalue greatly the value and perhaps make their homes unsaleable and uninsurable. There is no allowances made in the study except for 1 property on the financial loss for many people. People bought homes or built in good faith and with approval from council at some time. Why has anybody got the right to cause this financial burden? The only winners as I can see are the big insurance companies. |
| 7 | The Council has taken approx 2 years to make these plans at I estimate at a vast financial cost. The two studies June and October allowed very little for community consultation. This could have been avoided if there was ongoing community consultation. The only method of consultation is the Narrabeen Catchment Committee, which I understand has a very vocal lobby on recreational use of Narrabeen Lake. This C'tee is jointly hosted with Pittwater Council. How little time can be given to discuss our specific concerns? |
| 7 | In discussion by telephone with Katrina Brown of Council she stated the Community would make decisions on what options were accepted. If all residents are given little or no information how can they make informed decisions. The response rate to the two studies is so low that statistically are on no consequence. basically there is no response to make decisions. It would be very convenient for council that future litigants can be diverted to community responsibility. |
| 7 | Page 20 - LEP locality does not mention Narraweena as in catchment area |
| 7 | Page 21 - LEP future development Red Hill - the future development of Red Hill and any other roads and drainage. This will exacerbate flooding. |

| | |
|---|---|
| 7 | Page 26 - This is not Community Consultation. The questions in this survey does not pertain the this area having any flood problems. Why? |
| 7 | Page 29 - Upper reaches have high velocity. |
| 7 | Page 47 - Hydraulic sensitivity No value for this area. Check 6.4 why is it 0. |
| 7 | Page 53 - Summary of measures identified. Limited properties affected on Wheeler Creek. The desire to maintain and enhance the pristine nature of the upper reaches of Wheeler Creek means excavation or construction works is not favourable. WHO DECIDED THIS AND WHAT ABOUT ALL THE CONSTRUCTION WORKS AT UPPER WILLANDRA ROAD. *Just because it is only a small number doesn't mean that it shouldn't be helped.* |
| 7 | Page 54 - Next page gives an option of flood modification. FM17 Willandra Upper culvert make the flooding worse for the people at Ara Cres. |
| 7 | Page 90 - Bank Management measures. Figure 5. A priority High, Mod-High and Mod priority given to middle upper reach. How does this fit in with page 53. Contradiction? Want this to be implemented ASAP. |
| 7 | Levee proposed for Toronto Ave. Levee to protect 3 properties. Enhance Toronto Ave bridge Creek Widening & revegetation Upstream of Toronto Ave. with no change expected. This would give greater appreciation of South Creek. Dah!!! |
| 7 | Page 61 - this would also help with overfloor flooding of 2 properties. Page 63 Levee at Wabash and Washington Ave to protect 3 properties. Page 65 - Construct wetland between Carcoola Road and Toronto Ave. Reduction of 12 properties with over floor flooding. Page 68 - Carcoola Road levee protects 3 houses. *All of these items have been ticked in the feedback. Written next to them is:* Can a levee be looked at for Ara. block wall. Is there space? Would water be trapped behind the levee from the east? |
| 7 | Page 70 - Regrading of Lidwina Place Reserve and Tyagarah Reserve. The overall result would be a benefit for flora and fauna along this reach. |
| 7 | Page 71 - This would also decrease flood levels between Willandra Road Lower and Carcoola Road. Cost benefit, less than cost to implement. (providing you have an accurate damage costs) |
| 7 | Page 73 - Maintenance of culverts may need to be updated. |
| 7 | Enhance Willandra Road Lower Culvert. Vertical enhancement would reduce upstream flooding. Not been quantitatively. Excavation of culvert could reduce flooding by 0.5m. No mention of the number of properties affected anywhere in report from this area. Don't know or don't want to know. Cracking the houses from vibrations 1974. April 2007. Can increasing the culverts and bridge help with the vibrations. 2 have been flooded downstream of the bridge. 2 by 4 through the culverts Anzac Day. building. Came up to the guttering in 24 April 2007 and 1974. Why isn't this culvert being enhanced. |
| 7 | Page 78 - Enhance Willandra Road Upper Culverts. Increase in flood levels downstream. |
| 7 | Levee to protect Golf Course. How about protecting peoples homes first. |
| 7 | Fluvial geomorphic assessment states that South Creek Middle Reach is stable except for downstream of McIntosh Road (ARA CRES END-UNSTABLE). Garden waste has been dumped causing high nutrient levels. Although bank regeneration has been identified as a priority by engineers, Council has not even included this option in the ranking schedule. |
| 7 | Overall the initial statement saying ' not many houses get affected adjacent to the creek' has had a severe impact on any work being done in this area. |
| 16 | There has been little done on [the removal of weeds] since I moved here in 1968. The only maintenance is done after flooding occurs. Note - call to clean the creek has fallen on deaf Council ears for the last 39 years. |

# APPENDIX C

# Floor Level and Property Data

| | | | Property Characters | | | | | Location (MGA) | | Property Levels | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Street Name** | **Street No.** | **Subdivision No.** | **Property type (Residential, Commercial)** | **(Small, Medium, Large)** | **No. of Storeys** | **Do people live on ground floor? (Y or N)** | **(slab on ground, pier/high set)** | **Easting** | **Northing** | **Ground Level (m AHD)** | **Floor Level (m AHD)** |
| Alkira Cct | 21 | | Residential | Medium | 2 | Yes | Slab | 339279 | 6264566 | 67.59 | 67.89 |
| Alkira Cct | 22 | | Residential | Medium | 2 | No | Pier | 339338 | 6264642 | 57.10 | 60.38 |
| Alkira Cct | 23 | | Residential | Medium | 2 | No | Pier | 339260 | 6264560 | 68.52 | 71.86 |
| Alkira Cct | 24 | | Residential | Medium | 2 | No | Pier | 339324 | 6264637 | 56.91 | 60.55 |
| Alkira Cct | 25 | | Residential | Medium | 2 | No | Pier | 339237 | 6264555 | 68.77 | 71.34 |
| Alkira Cct | 26 | | Residential | Medium | 2 | Yes | Slab | 339310 | 6264631 | 57.43 | 57.44 |
| Alkira Cct | 28 | | Residential | Medium | 2 | Yes | Pier | 339296 | 6264626 | 58.23 | 61.96 |
| Alkira Cct | 30 | | Residential | Medium | 2 | Yes | Slab | 339281 | 6264618 | 59.12 | 65.85 |
| Alkira Cct | 32 | | Residential | Medium | 2 | Yes | Pier | 339260 | 6264609 | 64.51 | 67.32 |
| Ara Cr | 1 | | Residential | Small | 1 | Yes | Pier | 339771 | 6265018 | 13.23 | 14.31 |
| Ara Cr | 10 | | Residential | Small | 1 | Yes | Pier | 339718 | 6264942 | 12.93 | 13.71 |
| Ara Cr | 12 | | Residential | Medium | 1 | Yes | Pier | 339718 | 6264927 | 13.39 | 14.58 |
| Ara Cr | 14 | | Residential | Small | 1 | Yes | Pier | 339720 | 6264911 | 13.63 | 14.93 |
| Ara Cr | 16 | | Residential | Small | 1 | Yes | Pier | 339723 | 6264895 | 13.96 | 15.37 |
| Ara Cr | 18 | | Residential | Medium | 2 | Yes | Slab | 339726 | 6264878 | 14.20 | 14.53 |
| Ara Cr | 2 | | Residential | Small | 1 | Yes | Pier | 339722 | 6265008 | 11.98 | 13.17 |
| Ara Cr | 20 | | Residential | Medium | 2 | Yes | Slab | 339730 | 6264852 | 13.91 | 16.54 |
| Ara Cr | 22 | | Residential | Medium | 2 | Yes | Slab | 339743 | 6264849 | 17.20 | 19.40 |
| Ara Cr | 3 | | Residential | Medium | 2 | Yes | Pier | 339771 | 6265000 | 13.31 | 14.24 |
| Ara Cr | 4 | | Residential | Small | 1 | Yes | Pier | 339719 | 6264988 | 12.11 | 13.24 |
| Ara Cr | 5 | | Residential | Small | 1 | Yes | Pier | 339770 | 6264985 | 13.46 | 14.28 |
| Ara Cr | 6 | | Residential | Small | 1 | Yes | Pier | 339717 | 6264973 | 12.38 | 13.10 |
| Ara Cr | 7 | | Residential | Small | 1 | Yes | Pier | 339770 | 6264968 | 14.23 | 15.05 |
| Ara Cr | 8 | | Residential | Small | 1 | Yes | Pier | 339717 | 6264957 | 12.53 | 13.62 |
| Ara Cr | 9 | | Residential | Medium | 2 | No | Pier | 339769 | 6264944 | 15.03 | 19.05 |
| Badana Pl | 3 | | Residential | Medium | 1 | Yes | Slab | 340431 | 6265677 | 7.64 | 8.95 |
| Badana Pl | 5 | | Residential | Medium | 1 | Yes | Slab | 340442 | 6265685 | 8.48 | 8.81 |
| Birinta St | 3 | | Residential | Medium | 2 | Yes | Pier | 339768 | 6264758 | 26.99 | 29.31 |
| Birinta St | 4 | | Residential | Medium | 2 | Yes | Slab | 339755 | 6264775 | 23.47 | 25.67 |
| Birinta St | 5 | | Residential | Medium | 2 | Yes | Pier | 339778 | 6264794 | 25.65 | 26.52 |
| Bolta Pl | 1 | A | Residential | Small | 2 | Yes | Slab | 339594 | 6265225 | 10.82 | 12.05 |
| Bolta Pl | 10 | A | Residential | Medium | 2 | Yes | Slab | 339665 | 6265143 | 12.24 | 13.67 |
| Bolta Pl | 10 | | Residential | Medium | 2 | Yes | Slab | 339667 | 6265151 | 12.20 | 13.69 |
| Bolta Pl | 11 | | Residential | Medium | 2 | Yes | Slab | 339664 | 6265134 | 12.31 | 13.99 |
| Bolta Pl | 2 | A | Residential | Medium | 2 | Yes | Slab | 339616 | 6265222 | 10.87 | 12.01 |
| Bolta Pl | 2 | | Residential | Small | 2 | Yes | Slab | 339608 | 6265223 | 11.07 | 11.86 |
| Bolta Pl | 24 | | Residential | Medium | 2 | Yes | Slab | 339585 | 6265185 | 13.22 | 13.52 |
| Bolta Pl | 3 | A | Residential | Small | 2 | Yes | Slab | 339628 | 6265221 | 10.73 | 11.52 |
| Bolta Pl | 4 | A | Residential | Small | 2 | Yes | Slab | 339640 | 6265220 | 10.54 | 11.51 |
| Bolta Pl | 4 | B | Residential | Small | 2 | Yes | Slab | 339649 | 6265220 | 10.62 | 11.51 |
| Bolta Pl | 5 | | Residential | Small | 1 | Yes | Slab | 339659 | 6265215 | 11.11 | 11.58 |
| Bolta Pl | 5 | A | Residential | Small | 1 | Yes | Slab | 339663 | 6265231 | 10.69 | 11.11 |
| Bolta Pl | 7 | | Residential | Medium | 1 | Yes | Slab | 339676 | 6265203 | 10.70 | 11.69 |
| Bolta Pl | 8 | A | Residential | Medium | 2 | Yes | Slab | 339671 | 6265176 | 11.25 | 11.84 |
| Bolta Pl | 8 | | Residential | Medium | 2 | Yes | Slab | 339674 | 6265185 | 11.19 | 11.85 |
| Bolta Pl | 9 | A | Residential | Medium | 2 | Yes | Slab | 339668 | 6265160 | 11.94 | 12.60 |
| Bolta Pl | 9 | | Residential | Medium | 2 | Yes | Slab | 339670 | 6265168 | 11.36 | 12.58 |
| Boyer Rd | 36 | | Residential | Medium | 2 | Yes | Slab | 338534 | 6264194 | 99.91 | 100.32 |
| Boyer Rd | 38 | | Residential | Medium | 2 | Yes | Slab | 338551 | 6264192 | 99.24 | 99.72 |
| Boyer Rd | 40 | | Residential | Medium | 2 | Yes | Slab | 338565 | 6264186 | 99.25 | 99.56 |
| Boyer Rd | 42 | | Residential | Medium | 2 | Yes | Slab | 338577 | 6264172 | 99.66 | 100.32 |
| Brooker Ave | 52 | | Residential | Large | 2 | Yes | Pier | 338324 | 6264473 | 116.87 | 119.61 |
| Brooker Ave | 66 | | Residential | Large | 2 | Yes | Slab | 338384 | 6264405 | 111.76 | 114.47 |
| Brooker Ave | 68 | | Residential | Large | 2 | Yes | Slab | 338399 | 6264390 | 110.34 | 113.71 |
| Brooker Ave | 87 | | Residential | Medium | 2 | Yes | Slab | 338411 | 6264339 | 106.05 | 109.99 |
| Brooker Ave | 89 | | Residential | Medium | 2 | Yes | Slab | 338435 | 6264326 | 104.06 | 109.95 |
| Carawa Rd | 102 | | Residential | Medium | 1 | Yes | Pier | 339898 | 6265469 | 9.80 | 11.73 |
| Carawa Rd | 102 | C | Residential | Small | 1 | Yes | Slab | 339930 | 6265478 | 9.89 | 10.51 |
| Carawa Rd | 108 | | Residential | Medium | 1 | Yes | Pier | 339850 | 6265425 | 8.78 | 11.37 |
| Carcoola Rd | 14 | | Residential | Large | 2 | Yes | Pier | 340002 | 6265496 | 9.28 | 10.09 |
| Carcoola Rd | 15 | | Residential | Medium | 1 | Yes | Pier | 340114 | 6265802 | 5.97 | 7.31 |
| Carcoola Rd | 16 | | Residential | Medium | 1 | Yes | Pier | 340009 | 6265512 | 9.22 | 10.00 |
| Carcoola Rd | 17 | | Residential | Medium | 1 | Yes | Pier | 340116 | 6265818 | 7.11 | 8.63 |
| Carcoola Rd | 18 | | Residential | Medium | 1 | Yes | Pier | 340012 | 6265527 | 8.81 | 9.24 |
| Carcoola Rd | 22 | | Residential | Large | 2 | Yes | Slab | 340017 | 6265560 | 8.12 | 8.63 |
| Carcoola Rd | 24 | | Residential | Small | 1 | Yes | Pier | 340004 | 6265578 | 6.32 | 8.41 |
| Carcoola Rd | 26 | | Residential | Medium | 2 | Yes | Slab | 340010 | 6265592 | 6.89 | 8.05 |
| Carcoola Rd | 28 | | Residential | Medium | 2 | Yes | Slab | 340015 | 6265607 | 7.30 | 7.86 |
| Carcoola Rd | 30 | | Residential | Medium | 2 | Yes | Slab | 340021 | 6265622 | 7.03 | 6.97 |
| Carcoola Rd | 32 | | Residential | Large | 2 | Yes | Slab | 340024 | 6265636 | 6.81 | 6.94 |
| Carcoola Rd | 34 | | Residential | Medium | 1 | Yes | Slab | 340027 | 6265651 | 6.63 | 7.23 |
| Carcoola Rd | 36 | | Residential | Medium | 1 | Yes | Pier | 340030 | 6265666 | 6.55 | 7.24 |
| Carcoola Rd | 38 | | Residential | Medium | 2 | Yes | Pier | 340035 | 6265688 | 6.00 | 6.41 |
| Carcoola Rd | 40 | A | Residential | Medium | 2 | Yes | Slab | 340063 | 6265783 | 5.77 | 6.85 |
| Carcoola Rd | 40 | | Residential | Medium | 2 | No | Pier | 340043 | 6265785 | 6.55 | 7.89 |
| Carcoola Rd | 42 | | Residential | Large | 2 | Yes | Slab | 340056 | 6265809 | 7.37 | 7.81 |
| Cleveland Ave | 31 | | Residential | Small | 1 | Yes | Slab | 339980 | 6265717 | 7.96 | 9.75 |
| Cleveland Ave | 33 | | Residential | Large | 2 | Yes | Slab | 339964 | 6265720 | 8.65 | 8.52 |
| Cleveland Ave | 34 | | Residential | Large | 2 | Yes | Slab | 339982 | 6265784 | 8.26 | 11.86 |
| Cormack Rd | 2 | | Residential | Medium | 2 | Yes | Slab | 339032 | 6264288 | 87.08 | 87.58 |
| Dalpura St | 1 | | Residential | Medium | 1 | Yes | Pier | 340372 | 6265796 | 4.45 | 5.51 |
| Dalpura St | 10 | | Residential | Medium | 1 | Yes | Pier | 340415 | 6265725 | 5.67 | 6.49 |
| Dalpura St | 11 | | Residential | Medium | 1 | Yes | Pier | 340360 | 6265718 | 5.46 | 5.68 |
| Dalpura St | 12 | | Residential | Medium | 1 | Yes | Pier | 340415 | 6265709 | 5.93 | 6.74 |
| Dalpura St | 14 | | Residential | Medium | 1 | Yes | Slab | 340405 | 6265686 | 6.49 | 7.04 |
| Dalpura St | 16 | | Residential | Medium | 1 | Yes | Slab | 340389 | 6265681 | 5.89 | 7.12 |
| Dalpura St | 2 | | Residential | Large | 2 | Yes | Pier | 340422 | 6265788 | 5.19 | 6.30 |
| Dalpura St | 3 | | Residential | Large | 2 | Yes | Pier | 340370 | 6265781 | 4.68 | 5.41 |
| Dalpura St | 4 | | Residential | Medium | 1 | Yes | Pier | 340420 | 6265773 | 5.28 | 6.12 |
| Dalpura St | 5 | | Residential | Large | 1 | Yes | Slab | 340367 | 6265765 | 5.06 | 5.81 |
| Dalpura St | 6 | | Residential | Medium | 1 | Yes | Pier | 340417 | 6265757 | 5.44 | 6.39 |
| Dalpura St | 7 | | Residential | Medium | 1 | Yes | Slab | 340365 | 6265749 | 5.24 | 5.42 |
| Dalpura St | 8 | | Residential | Medium | 1 | Yes | Pier | 340415 | 6265741 | 5.57 | 6.02 |
| Dalpura St | 9 | | Residential | Medium | 1 | Yes | Pier | 340363 | 6265734 | 5.32 | 5.75 |
| Dorothy St | 10 | | Residential | Small | 1 | Yes | Pier | 340253 | 6265678 | 6.11 | 6.97 |
| Dorothy St | 11 | | Residential | Small | 1 | Yes | Pier | 340186 | 6265635 | 6.58 | 7.53 |
| Dorothy St | 12 | | Residential | Small | 1 | Yes | Pier | 340235 | 6265680 | 6.30 | 7.07 |
| Dorothy St | 13 | | Residential | Small | 1 | Yes | Pier | 340171 | 6265638 | 6.46 | 7.49 |
| Dorothy St | 14 | | Residential | Small | 1 | Yes | Pier | 340220 | 6265682 | 6.43 | 7.05 |
| Dorothy St | 15 | | Residential | Medium | 2 | Yes | Slab | 340125 | 6265644 | 6.33 | 7.03 |
| Dorothy St | 16 | | Residential | Small | 1 | Yes | Pier | 340205 | 6265685 | 6.25 | 6.78 |
| Dorothy St | 17 | | Residential | Small | 1 | Yes | Pier | 340110 | 6265647 | 6.58 | 7.26 |
| Dorothy St | 18 | | Residential | Small | 1 | Yes | Pier | 340190 | 6265687 | 6.09 | 6.68 |
| Dorothy St | 19 | | Residential | Small | 1 | Yes | Pier | 340095 | 6265649 | 6.77 | 7.34 |
| Dorothy St | 20 | | Residential | Medium | 1 | Yes | Pier | 340175 | 6265689 | 5.89 | 6.43 |
| Dorothy St | 21 | | Residential | Small | 1 | Yes | Pier | 340078 | 6265651 | 6.52 | 7.36 |
| Dorothy St | 22 | | Residential | Small | 1 | Yes | Pier | 340160 | 6265691 | 5.49 | 6.35 |
| Dorothy St | 24 | | Residential | Medium | 2 | Yes | Pier | 340144 | 6265694 | 5.52 | 6.51 |
| Dorothy St | 26 | | Residential | Small | 1 | Yes | Pier | 340129 | 6265696 | 5.65 | 6.70 |
| Dorothy St | 28 | | Residential | Small | 1 | Yes | Pier | 340114 | 6265698 | 5.63 | 6.52 |
| Dorothy St | 30 | | Residential | Small | 1 | Yes | Pier | 340099 | 6265701 | 5.29 | 6.55 |
| Dorothy St | 32 | | Residential | Medium | 2 | Yes | Pier | 340084 | 6265703 | 5.26 | 6.49 |
| Dorothy St | 5 | | Residential | Medium | 1 | Yes | Pier | 340223 | 6265621 | 7.59 | 8.67 |
| Dorothy St | 6 | | Residential | Medium | 1 | Yes | Pier | 340267 | 6265645 | 7.41 | 8.51 |
| Dorothy St | 7 | | Residential | Medium | 2 | Yes | Pier | 340224 | 6265638 | 6.96 | 7.73 |
| Dorothy St | 8 | | Residential | Medium | 2 | Yes | Pier | 340267 | 6265671 | 6.39 | 7.31 |
| Dorothy St | 9 | | Residential | Small | 1 | Yes | Pier | 340201 | 6265633 | 6.92 | 7.69 |
| Douglass Pl | 3 | | Residential | Medium | 2 | Yes | Slab | 339771 | 6265187 | 10.59 | 11.76 |
| Douglass Pl | 4 | | Residential | Large | 2 | Yes | Pier | 339760 | 6265191 | 9.93 | 10.82 |
| Douglass Pl | 5 | | Residential | Large | 1 | Yes | Pier | 339759 | 6265215 | 9.78 | 10.45 |
| Douglass Pl | 6 | | Residential | Small | 1 | Yes | Pier | 339761 | 6265232 | 9.51 | 10.58 |
| Douglass Pl | 7 | | Residential | Large | 2 | Yes | Pier | 339765 | 6265249 | 9.46 | 10.14 |
| Douglass Pl | 8 | | Residential | Small | 1 | Yes | Pier | 339783 | 6265249 | 9.80 | 12.23 |
| Douglass Pl | 9 | | Residential | Medium | 2 | Yes | Pier | 339800 | 6265244 | 11.76 | 12.38 |
| Egan Pl | 12 | | Residential | Small | 1 | Yes | Pier | 338819 | 6264226 | 93.86 | 95.33 |
| Egan Pl | 13 | | Residential | Small | 1 | Yes | Pier | 338828 | 6264253 | 93.57 | 95.23 |
| Egan Pl | 18 | | Residential | Medium | 2 | Yes | Pier | 338911 | 6264275 | 89.19 | 91.13 |
| Egan Pl | 20 | | Residential | Medium | 2 | Yes | Pier | 338938 | 6264262 | 88.97 | 90.06 |
| Egan Pl | 21 | | Residential | Medium | 2 | Yes | Pier | 338949 | 6264254 | 88.45 | 90.51 |
| Endeavour Dr | 1 | A | Residential | Medium | 2 | Yes | Slab | 338978 | 6264344 | 88.98 | 89.31 |
| Endeavour Dr | 1 | | Residential | Medium | 2 | Yes | Slab | 338987 | 6264346 | 87.84 | 89.31 |
| Grover Ave | 15 | | Residential | Medium | 1 | Yes | Pier | 340463 | 6265773 | 7.26 | 8.32 |
| Grover Ave | 17 | | Residential | Medium | 1 | Yes | Pier | 340447 | 6265775 | 6.19 | 7.19 |
| Grover Ave | 2 | | Residential | Medium | 2 | No | Pier | 340218 | 6265865 | 6.00 | 8.35 |
| Grover Ave | 2 | A | Residential | Medium | 1 | Yes | Slab | 340209 | 6265874 | 8.44 | 9.37 |
| Grover Ave | 25 | | Residential | Medium | 2 | Yes | Slab | 340050 | 6265835 | 9.53 | 9.89 |
| Grover Ave | 27 | | Residential | Medium | 1 | Yes | Pier | 340029 | 6265830 | 9.52 | 11.95 |
| Grover Ave | 4 | | Residential | Medium | 2 | Yes | Slab | 340199 | 6265876 | 7.41 | 9.10 |
| Lidwina Pl | 1 | | Residential | Medium | 2 | Yes | Pier | 339794 | 6265279 | 10.34 | 11.75 |
| Lidwina Pl | 2 | | Residential | Medium | 2 | Yes | Pier | 339776 | 6265283 | 9.24 | 10.44 |

| | | | Property Characters | | | | | Location (MGA) | | Property Levels | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Street Name | Street No. | Subdivision No. | Property type (Residential, Commercial) | (Small, Medium, Large) | No. of Storeys | Do people live on ground floor? (Y or N) | (slab on ground, pier/high set) | Easting | Northing | Ground Level (m AHD) | Floor Level (m AHD) |
| Lidwina Pl | 3 | | Residential | Medium | 1 | Yes | Pier | 339769 | 6265291 | 9.03 | 9.82 |
| Lidwina Pl | 4 | | Residential | Medium | 2 | Yes | Slab | 339775 | 6265332 | 8.78 | 9.71 |
| Lidwina Pl | 5 | | Residential | Small | 1 | Yes | Slab | 339786 | 6265334 | 8.78 | 9.10 |
| Lidwina Pl | 6 | | Residential | Medium | 1 | Yes | Slab | 339805 | 6265330 | 8.82 | 9.49 |
| Little Willandra Rd | 22 | | Residential | Medium | 1 | Yes | Slab | 339836 | 6265611 | 9.31 | 10.31 |
| Little Willandra Rd | 24 | | Residential | Medium | 2 | Yes | Slab | 339825 | 6265588 | 8.99 | 10.49 |
| Little Willandra Rd | 26 | | Residential | Medium | 2 | Yes | Slab | 339815 | 6265575 | 9.46 | 10.52 |
| Little Willandra Rd | 28 | | Residential | Medium | 2 | Yes | Slab | 339806 | 6265560 | 9.60 | 12.32 |
| Little Willandra Rd | 39 | | Residential | Medium | 1 | Yes | Slab | 339620 | 6265338 | 12.13 | 13.73 |
| Little Willandra Rd | 50 | | Residential | Medium | 1 | Yes | Pier | 339706 | 6265392 | 9.02 | 11.35 |
| Little Willandra Rd | 5 | a | Residential | Small | 1 | Yes | Slab | 339406 | 6265331 | 13.67 | 13.93 |
| Little Willandra Rd | 5 | b | Residential | Small | 1 | Yes | Slab | 339439 | 6265314 | 13.55 | 13.79 |
| Little Willandra Rd | 5 | c | Residential | Small | 1 | Yes | Slab | 339404 | 6265308 | 13.86 | 13.89 |
| Little Willandra Rd | 5 | d | Residential | Small | 1 | Yes | Slab | 339376 | 6265294 | 14.60 | 14.86 |
| Little Willandra Rd | 5 | e | Residential | Small | 1 | Yes | Slab | 339412 | 6265283 | 13.87 | 13.95 |
| Little Willandra Rd | 5 | f | Residential | Small | 1 | Yes | Slab | 339465 | 6265257 | 13.32 | 13.72 |
| Little Willandra Rd | 5 | g | Residential | Small | 1 | Yes | Slab | 339419 | 6265259 | 14.13 | 14.45 |
| Little Willandra Rd | 5 | h | Residential | Small | 1 | Yes | Slab | 339411 | 6265232 | 14.45 | 14.60 |
| Little Willandra Rd | 5 | i | Residential | Small | 1 | Yes | Slab | 339456 | 6265225 | 14.11 | 14.28 |
| Little Willandra Rd | 5 | j | Residential | Small | 1 | Yes | Slab | 339500 | 6265239 | 13.09 | 13.76 |
| Little Willandra Rd | 5 | k | Residential | Small | 1 | Yes | Slab | 339496 | 6265217 | 13.16 | 13.75 |
| Little Willandra Rd | 5 | l | Residential | Small | 1 | Yes | Slab | 339517 | 6265192 | 12.86 | 13.00 |
| Little Willandra Rd | 5 | m | Residential | Small | 1 | Yes | Slab | 339533 | 6265220 | 9.96 | 12.12 |
| Little Willandra Rd | 5 | n | Residential | Small | 1 | Yes | Slab | 339484 | 6265317 | 13.98 | 14.10 |
| Little Willandra Rd | 5 | o | Residential | Small | 1 | Yes | Slab | 339525 | 6265308 | 12.82 | 13.11 |
| Little Willandra Rd | 5 | p | Residential | Small | 1 | Yes | Slab | 339487 | 6265290 | 13.81 | 13.56 |
| Little Willandra Rd | 5 | q | Residential | Small | 1 | Yes | Slab | 339510 | 6265279 | 13.33 | 13.72 |
| Little Willandra Rd | 5 | r | Residential | Small | 1 | Yes | Slab | 339537 | 6265276 | 12.67 | 13.41 |
| Little Willandra Rd | 52 | | Residential | Large | 2 | Yes | Pier | 339698 | 6265378 | 9.32 | 12.48 |
| Little Willandra Rd | 56 | | Residential | Medium | 1 | Yes | Slab | 339685 | 6265359 | 9.56 | 10.90 |
| Little Willandra Rd | 58 | | Residential | Medium | 2 | Yes | Slab | 339676 | 6265344 | 9.83 | 10.71 |
| Little Willandra Rd | 6 | | Residential | Medium | 1 | Yes | Pier | 339915 | 6265704 | 6.05 | 13.35 |
| Little Willandra Rd | 60 | | Residential | Medium | 1 | Yes | Pier | 339658 | 6265313 | 9.95 | 10.92 |
| Little Willandra Rd | 62 | | Residential | Medium | 1 | Yes | Slab | 339648 | 6265298 | 10.08 | 10.49 |
| Little Willandra Rd | 64 | | Residential | Small | 2 | Yes | Slab | 339671 | 6265277 | 9.96 | 10.77 |
| Little Willandra Rd | 66 | | Residential | Small | 2 | Yes | Slab | 339641 | 6265276 | 10.62 | 12.15 |
| Little Willandra Rd | 68 | | Residential | Small | 2 | Yes | Slab | 339623 | 6265275 | 11.09 | 12.03 |
| Milpera Pl | 11 | | Residential | Medium | 2 | Yes | Pier | 339917 | 6265285 | 11.04 | 11.09 |
| Milpera Pl | 13 | | Residential | Medium | 1 | Yes | Pier | 339914 | 6265269 | 10.48 | 11.15 |
| Milpera Pl | 15 | | Residential | Medium | 2 | Yes | Slab | 339908 | 6265246 | 11.00 | 11.54 |
| Mirra Pl | 7 | | Residential | Medium | 1 | Yes | Pier | 340446 | 6265723 | 7.37 | 8.45 |
| Mirra Pl | 8 | | Residential | Medium | 1 | Yes | Pier | 340451 | 6265749 | 6.66 | 7.84 |
| Parr Pde | 172 | | Residential | Medium | 2 | No | Pier | 339240 | 6264522 | 70.85 | 74.02 |
| Parr Pde | 174 | | Residential | Medium | 2 | No | Pier | 339227 | 6264517 | 70.18 | 73.24 |
| Parr Pde | 176 | | Residential | Medium | 1 | Yes | Pier | 339210 | 6264508 | 70.50 | 72.78 |
| Pinta Pl | 2 | | Residential | Medium | 2 | Yes | Slab | 339982 | 6265563 | 7.90 | 8.21 |
| Pinta Pl | 3 | | Residential | Medium | 1 | Yes | Slab | 339970 | 6265551 | 8.19 | 8.41 |
| Pinta Pl | 4 | | Residential | Medium | 1 | Yes | Slab | 339957 | 6265533 | 8.28 | 9.03 |
| Pinta Pl | 5 | | Residential | Medium | 1 | Yes | Slab | 339946 | 6265521 | 8.63 | 9.26 |
| Pinta Pl | 6 | | Residential | Small | 1 | Yes | Slab | 339939 | 6265506 | 8.96 | 10.57 |
| Pinta Pl | 8 | | Residential | Medium | 2 | Yes | Pier | 339954 | 6265474 | 9.38 | 10.68 |
| Pinta Pl | 9 | | Residential | Medium | 1 | Yes | Slab | 339975 | 6265472 | 9.57 | 9.81 |
| Ryrie Ave | 24 | | Residential | Small | 1 | Yes | Pier | 340364 | 6265660 | 5.54 | 10.36 |
| Ryrie Ave | 26 | | Residential | Medium | 2 | Yes | Slab | 340345 | 6265663 | 5.41 | 9.79 |
| Samarai Pl | 4 | | Residential | Medium | 2 | Yes | Slab | 339066 | 6264318 | 86.35 | 86.70 |
| Samarai Pl | 5 | | Residential | Medium | 2 | Yes | Slab | 339066 | 6264333 | 85.94 | 86.30 |
| Samarai Pl | 6 | | Residential | Medium | 1 | Yes | Pier | 339066 | 6264349 | 85.56 | 87.16 |
| Samarai Pl | 7 | | Residential | Medium | 2 | Yes | Pier | 339072 | 6264369 | 84.41 | 86.07 |
| South Creek Rd | 212 | | Residential | Medium | 1 | Yes | Pier | 340394 | 6266328 | 5.02 | 6.54 |
| South Creek Rd | 214 | | Residential | Medium | 1 | Yes | Pier | 340386 | 6266346 | 4.35 | 5.53 |
| South Creek Rd | 216 | | Residential | Medium | 2 | Yes | Pier | 340369 | 6266388 | 4.78 | 6.63 |
| South Creek Rd | 218 | | Residential | Medium | 2 | Yes | Slab | 340365 | 6266401 | 4.54 | 6.49 |
| South Creek Rd | 220 | | Residential | Medium | 1 | Yes | Pier | 340364 | 6266416 | 5.39 | 8.41 |
| South Creek Rd | 222 | | Residential | Medium | 1 | Yes | Pier | 340363 | 6266434 | 5.78 | 8.70 |
| South Creek Rd | 234 | | Residential | Large | 2 | Yes | Pier | 340358 | 6266530 | 4.10 | 5.49 |
| South Creek Rd | 236 | | Residential | Large | 2 | Yes | Slab | 340362 | 6266546 | 3.53 | 4.09 |
| South Creek Rd | 238 | | Residential | Medium | 1 | Yes | Pier | 340367 | 6266557 | 4.10 | 7.29 |
| South Creek Rd | 240 | | Residential | Medium | 2 | Yes | Slab | 340375 | 6266587 | 3.50 | 4.30 |
| South Creek Rd | 242 | | Residential | Medium | 2 | Yes | Slab | 340378 | 6266605 | 3.84 | 3.65 |
| South Creek Rd | 244 | | Residential | Medium | 1 | Yes | Pier | 340382 | 6266620 | 5.42 | 9.80 |
| South Creek Rd | 258 | | Residential | Medium | 1 | Yes | Pier | 340359 | 6266726 | 6.12 | 9.36 |
| Spilstead Ave | 18 | | Residential | Medium | 2 | Yes | Slab | 338452 | 6264239 | 102.21 | 102.70 |
| Teresa Pl | 2 | | Residential | Medium | 2 | Yes | Pier | 339707 | 6265347 | 8.66 | 9.94 |
| Teresa Pl | 6 | | Residential | Medium | 1 | Yes | Slab | 339674 | 6265301 | 9.72 | 10.44 |
| Toronto Ave | 2 | | Commercial | Small | 1 | Yes | n/a | 340279 | 6266233 | 3.22 | 4.17 |
| Toronto Ave | 4 | | Residential | Small | 1 | Yes | Pier | 340249 | 6266228 | 3.76 | 5.67 |
| Toronto Ave | 4 | A | Residential | Medium | 2 | Yes | Pier | 340256 | 6266243 | 2.62 | 3.99 |
| Toronto Ave | 6 | | Residential | Large | 2 | Yes | Slab | 340236 | 6266252 | 3.72 | 4.13 |
| Toronto Ave | 7 | | Residential | Large | 1 | Yes | Pier | 340262 | 6266161 | 4.69 | 5.40 |
| Toronto Ave | 9 | A | Residential | Medium | 1 | Yes | Slab | 340239 | 6266150 | 7.01 | 7.88 |
| Toronto Ave | 9 | | Residential | Medium | 1 | Yes | Pier | 340243 | 6266174 | 5.54 | 7.29 |
| Towradgi St | 46 | | Residential | Large | 2 | Yes | Pier | 339662 | 6264814 | 16.76 | 24.19 |
| Towradgi St | 48 | | Residential | Large | 2 | Yes | Pier | 339639 | 6264819 | 13.98 | 20.54 |
| Towradgi St | 50 | | Residential | Medium | 2 | Yes | Pier | 339621 | 6264810 | 17.40 | 21.65 |
| Towradgi St | 52 | | Residential | Medium | 2 | Yes | Pier | 339604 | 6264799 | 17.53 | 21.91 |
| Towradgi St | 56 | | Residential | Medium | 1 | Yes | Pier | 339570 | 6264779 | 20.19 | 28.38 |
| Towradgi St | 58 | | Residential | Medium | 2 | Yes | Pier | 339550 | 6264771 | 24.38 | 26.10 |
| Towradgi St | 63 | | Residential | Medium | 1 | Yes | Pier | 339426 | 6264696 | 34.55 | 44.24 |
| Towradgi St | 64 | | Residential | Medium | 2 | Yes | Pier | 339492 | 6264752 | 26.62 | 32.27 |
| Towradgi St | 65 | | Residential | Large | 2 | Yes | Pier | 339398 | 6264698 | 32.55 | 44.02 |
| Towradgi St | 66 | | Residential | Medium | 2 | No | Pier | 339475 | 6264744 | 27.18 | 35.82 |
| Towradgi St | 67 | | Residential | Large | 2 | Yes | Slab | 339408 | 6264712 | 31.73 | 32.30 |
| Towradgi St | 68 | | Residential | Medium | 2 | Yes | Pier | 339449 | 6264741 | 30.07 | 31.55 |
| Tyagarah Pl | 11 | | Residential | Medium | 2 | Yes | Pier | 339864 | 6265583 | 7.95 | 8.96 |
| Tyagarah Pl | 13 | | Residential | Medium | 1 | Yes | Pier | 339875 | 6265605 | 7.72 | 9.00 |
| Tyagarah Pl | 15 | | Residential | Medium | 2 | Yes | Slab | 339884 | 6265618 | 7.49 | 8.33 |
| Tyagarah Pl | 17 | | Residential | Medium | 2 | Yes | Slab | 339891 | 6265632 | 6.94 | 8.89 |
| Tyagarah Pl | 19 | | Residential | Medium | 2 | Yes | Slab | 339899 | 6265645 | 6.51 | 8.90 |
| Tyagarah Pl | 21 | | Residential | Medium | 1 | Yes | Slab | 339904 | 6265662 | 7.05 | 8.87 |
| Tyagarah Pl | 23 | | Residential | Medium | 2 | Yes | Pier | 339916 | 6265676 | 6.51 | 8.76 |
| Tyagarah Pl | 25 | | Residential | Medium | 1 | No | Slab | 339933 | 6265673 | 5.54 | 9.15 |
| Tyagarah Pl | 3 | | Residential | Medium | 2 | Yes | Pier | 339818 | 6265524 | 8.47 | 9.70 |
| Tyagarah Pl | 5 | | Residential | Medium | 2 | Yes | Pier | 339832 | 6265537 | 8.30 | 9.62 |
| Tyagarah Pl | 7 | | Residential | Medium | 1 | Yes | Slab | 339843 | 6265556 | 8.23 | 9.29 |
| Tyagarah Pl | 9 | | Residential | Medium | 2 | Yes | Slab | 339855 | 6265569 | 8.16 | 8.80 |
| Wabash Ave | 1 | | Residential | Medium | 2 | Yes | Slab | 340323 | 6266017 | 3.22 | 3.50 |
| Wabash Ave | 1 | A | Residential | Medium | 2 | Yes | Slab | 340327 | 6266042 | 3.63 | 4.02 |
| Wabash Ave | 3 | | Residential | Medium | 2 | Yes | Slab | 340310 | 6266032 | 4.00 | 4.16 |
| Wabash Ave | 4 | | Residential | Medium | 1 | Yes | Pier | 340274 | 6266109 | 4.84 | 6.48 |
| Wabash Ave | 5 | A | Residential | Small | 1 | Yes | Slab | 340288 | 6266035 | 5.72 | 6.25 |
| Wabash Ave | 5 | | Residential | Small | 1 | Yes | Pier | 340298 | 6266044 | 5.00 | 6.46 |
| Wabash Ave | 6 | | Residential | Large | 2 | Yes | Pier | 340254 | 6266112 | 5.66 | 6.94 |
| Wabash Ave | 7 | | Residential | Large | 2 | No | Slab | 340280 | 6266037 | 5.85 | 6.41 |
| Wabash Ave | 9 | | Residential | Small | 1 | Yes | Pier | 340265 | 6266039 | 6.94 | 8.13 |
| Waroon Rd | 0 | a | Residential | Large | 2 | Yes | Slab | 340170 | 6265520 | 9.19 | 10.36 |
| Waroon Rd | 0 | b | Residential | Large | 2 | Yes | Slab | 340091 | 6265532 | 8.34 | 9.05 |
| Waroon Rd | 0 | c | Residential | Large | 2 | Yes | Slab | 340175 | 6265582 | 7.26 | 8.64 |
| Waroon Rd | 0 | d | Residential | Large | 2 | Yes | Slab | 340099 | 6265593 | 7.14 | 7.65 |
| Waroon Rd | 12 | | Residential | Medium | 1 | Yes | Pier | 340294 | 6265652 | 7.45 | 8.67 |
| Waroon Rd | 14 | | Residential | Medium | 2 | Yes | Pier | 340296 | 6265667 | 6.78 | 8.00 |
| Waroon Rd | 16 | | Residential | Medium | 1 | Yes | Pier | 340298 | 6265682 | 6.26 | 7.28 |
| Washington Ave | 11 | | Residential | Medium | 1 | Yes | Pier | 340246 | 6265919 | 6.97 | 9.77 |
| Washington Ave | 4 | | Residential | Small | 1 | Yes | Pier | 340316 | 6265981 | 3.90 | 5.49 |
| Washington Ave | 8 | | Residential | Small | 1 | Yes | Pier | 340276 | 6265976 | 6.59 | 7.28 |
| Washington Ave | 8 | A | Residential | Medium | 1 | Yes | Slab | 340280 | 6266000 | 6.18 | 7.11 |
| Washington Ave | 9 | | Residential | Medium | 1 | Yes | Pier | 340266 | 6265917 | 5.69 | 8.08 |
| Willandra Rd | 137 | | Residential | Medium | 2 | Yes | Slab | 339779 | 6265033 | 13.20 | 17.75 |
| Willandra Rd | 155 | | Residential | Medium | 1 | Yes | Pier | 339875 | 6265246 | 11.68 | 14.06 |
| Willandra Rd | 157 | | Residential | Medium | 1 | Yes | Pier | 339877 | 6265261 | 10.71 | 12.80 |
| Willandra Rd | 159 | | Residential | Medium | 1 | Yes | Pier | 339880 | 6265276 | 10.29 | 10.93 |
| Willandra Rd | 161 | | Residential | Medium | 2 | Yes | Slab | 339882 | 6265291 | 10.32 | 10.41 |
| Willandra Rd | 163 | | Residential | Medium | 1 | Yes | Pier | 339884 | 6265307 | 10.17 | 10.53 |
| Willandra Rd | 165 | | Residential | Medium | 1 | Yes | Pier | 339886 | 6265324 | 10.47 | 11.92 |
| Willandra Rd | 167 | | Residential | Medium | 1 | Yes | Pier | 339889 | 6265341 | 11.13 | 12.37 |

| | | | Property Characters | | | | | Location (MGA) | | Property Levels | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Street Name** | **Street No.** | **Subdivision No.** | **Property type (Residential, Commercial)** | **(Small, Medium, Large)** | **No. of Storeys** | **Do people live on ground floor? (Y or N)** | **(slab on ground, pier/high set)** | **Easting** | **Northing** | **Ground Level (m AHD)** | **Floor Level (m AHD)** |
| Willandra Rd | 184 | | Residential | Small | 1 | Yes | Pier | 339732 | 6265098 | 10.76 | 11.55 |
| Willandra Rd | 186 | | Residential | Medium | 1 | Yes | Pier | 339738 | 6265084 | 10.89 | 11.80 |
| Willandra Rd | 188 | | Residential | Medium | 1 | Yes | Pier | 339756 | 6265092 | 10.86 | 12.40 |
| Willandra Rd | 190 | | Residential | Medium | 2 | No | Pier | 339768 | 6265100 | 10.93 | 14.92 |
| Willandra Rd | 192 | | Residential | Medium | 1 | Yes | Pier | 339783 | 6265107 | 13.37 | 15.68 |
| Willandra Rd | 198 | | Residential | Medium | 2 | Yes | Pier | 339777 | 6265140 | 10.39 | 10.93 |
| Willandra Rd | 200 | | Residential | Small | 1 | Yes | Pier | 339779 | 6265157 | 10.39 | 13.60 |
| Willandra Rd | 212 | | Residential | Medium | 1 | Yes | Slab | 339822 | 6265268 | 11.33 | 13.06 |
| Willandra Rd | 214 | | Residential | Medium | 1 | Yes | Pier | 339825 | 6265284 | 10.24 | 12.03 |
| Willandra Rd | 216 | | Residential | Medium | 2 | Yes | Slab | 339831 | 6265317 | 9.50 | 9.65 |
| Willandra Rd | 218 | | Residential | Medium | 1 | Yes | Slab | 339834 | 6265333 | 9.32 | 10.16 |
| Willandra Rd | 220 | | Residential | Medium | 2 | Yes | Slab | 339835 | 6265349 | 11.09 | 11.87 |
| Willandra Rd | 222 | | Residential | Medium | 1 | Yes | Pier | 339838 | 6265365 | 10.12 | 11.91 |
| Willandra Rd | 224 | | Residential | Large | 2 | Yes | Slab | 339817 | 6265373 | 8.84 | 10.82 |
| Willandra Rd | 226 | | Residential | Small | 1 | Yes | Pier | 339832 | 6265388 | 8.62 | 11.87 |
| Willandra Rd | 228 | | Residential | Small | 1 | Yes | Pier | 339847 | 6265408 | 9.05 | 11.18 |
| Willandra Rd | 224 | A | Residential | Large | 2 | Yes | Pier | 339792 | 6265361 | 8.67 | 9.10 |
| Willandra Rd | 64 | | Residential | Medium | 2 | Yes | Slab | 338978 | 6264264 | 87.69 | 87.75 |
| Willandra Rd | 66 | A | Residential | Medium | 2 | Yes | Slab | 338984 | 6264310 | 87.00 | 87.61 |
| Willandra Rd | 66 | | Residential | Medium | 2 | No | Slab | 338971 | 6264313 | 87.29 | 89.00 |
| Willandra Rd | 81 | | Residential | Small | 1 | Yes | Slab | 339606 | 6264872 | 16.60 | 14.92 |
| Willandra Rd | 81 | A | Residential | Small | 2 | Yes | Slab | 339647 | 6264880 | 14.46 | 14.46 |

# APPENDIX D

# South Creek Bank Management Report

# APPENDIX E

## South Creek Recommended Development Controls

# RECOMMENDED SOUTH CREEK FLOODPLAIN ATTACHMENT TO FLOODPRONE LANDS DCP

## SOUTH CREEK FLOOD BEHAVIOUR

The South Creek catchment is relatively steep for the majority of its length, with only a relatively small flat floodplain section in its lower reaches. Due to the steep slopes, the time from the beginning of a storm event to the time at which the peak flood level occurs is relatively short. At most locations in the South Creek floodplain, the time to the peak flood level is less than 2 hours.

The steep catchment also results in high velocities in the floodplain. This is evident in the large proportion of the floodplain which is categorised as High Hazard or Floodway.

In addition to runoff from the catchment, the reach of South Creek downstream of Toronto Avenue can also be influenced by backwater effects resulting from Narrabeen Lagoon flooding.

## SOUTH CREEK FLOODPLAIN SPECIFIC DEVELOPMENT CONTROL ISSUES

Due to the "flashy" nature of flooding in the South Creek floodplain, evacuation is not always a realistic option (*i.e.* the flood waters would have already started to recede before the SES could coordinate the evacuation of affected properties). As such, a 'shelter-in-place' strategy is often the only option.

The development controls relating to 'shelter-in-place', outlined in Warringah Council's Floodplain Management DCP, should apply to <u>all</u> development applications which involve development within the South Creek floodplain.

For <u>all</u> development applications submitted, it should be ensured that the existing or proposed building provides a suitable **protected 'safe haven'** that is structurally designed to withstand flood forces and is above the **Flood Planning Level**.

## DEFINITIONS

| | |
|---|---|
| **Protected** | Including an enclosed area, removed from the rain. This may comprise of an enclosed balcony (with at least 3 walls, a roof and a solid floor – no spacings between timbers) or an internal room. |
| **Safe Haven** | An area which can comfortably accommodate the occupants of the dwelling or the expected number of users of the structure (*e.g.* a community hall). A first aid kit should be stored within this area. |
| **Flood Planning Level** | Flood levels selected for planning purposes. In general, for residential, commercial and industrial development in Warringah, it is the flood levels derived from the 100 Year ARI flood event, plus the addition of a 500 mm Freeboard. |

# APPENDIX F

## Multi-Criteria Matrix Assessment of Options

**SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY MULTI-CRITERIA MATRIX - ORDERED BY ID**

| ID | Category of Measure | Locality | Type of Measure | 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 | Peak Reduction in Water Levels (100yr ARI) | Peak Increase in Water Levels (100yr ARI) | Score on Benefit Cost Ratio | Likely Overall Hydraulic Improvement | Negative Hydraulic Impacts | Capital and Operating Costs | Reduction in Risk to Property | Reduction in Risk to Life | Reduction in Social Disruption | Water Quality and Flow | Fauna & Flora | Community Criteria | Council Support | Compatible with Policies and Plans | TOTAL SCORE | RANK on TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FM1 | Flood Modification | Downstream of Toronto Ave, on South Creek left bank | Levee to protect properties on Toronto Ave | $115,000 | $1,000 | $128,801 | $3,866 | 1 | $53,347 | 0.41 | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 1 | 0.4 | 2 | 1 | 11.4 | **11** |
| FM2* | Flood Modification | Toronto Ave Crossing of South Creek | Enhance Toronto Ave Culverts | $138,000 | $0 | $138,000 | $2,542 | 1 | $35,077 | 0.25 | 0.33 | 0.10 | 1 | 2 | -2 | 1 | 1 | 1 | 1 | 1 | 1 | 1.7 | 1 | 0 | 9.7 | **17** |
| FM3* | Flood Modification | South Creek - Upstream of Toronto Ave | Creek Widening and Revegetation Upstream of Toronto Ave | $1,790,000 | $5,000 | $1,859,004 | $21,309 | 6 | $294,075 | 0.16 | 0.00 | 0.01 | 1 | 0 | -1 | -1 | 1 | 1 | 1 | 2 | 2 | 1.1 | 2 | 0 | 9.1 | **21** |
| FM4 | Flood Modification | South Creek Left Bank - between Wabash and Washington Ave | Levee to Protect Properties between Wabash Ave and Washington Ave | $132,000 | $0 | $132,000 | $37,222 | 11 | $513,688 | 3.89 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.2 | 0 | -1 | 4.2 | **35** |
| FM5* | Flood Modification | South Creek between Carcoola Rd and Toronto Ave | Rehabilitate Creek and Construct Wetland | $2,500,000 | $40,000 | $3,052,030 | $23,141 | 7 | $319,363 | 0.10 | 0.71 | 0.00 | 1 | 2 | 0 | -2 | 1 | 1 | 2 | 2 | 2 | 1.1 | 1 | 2 | 13.1 | **3** |
| FM6 | Flood Modification | Carcoola Rd crossing of South Creek | Enhance Carcoola Rd Culverts | $434,000 | $0 | $434,000 | NC | N/A | N/A | N/A | 0.30 | 0.00 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1.6 | 0 | 0 | 7.6 | **27** |
| FM7 | Flood Modification | South Creek upstream of Carcoola Rd | Sediment Retention Basin | $180,000 | $10,000 | $318,007 | $0 | 0 | $0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1.3 | 1 | 1 | 6.3 | **31** |
| FM8 | Flood Modification | Upstream of Carcoola Rd on South Creek left bank | Levee to Protect Properties at Carcoola Rd | $98,000 | $0 | $98,000 | $11,628 | 3 | $160,472 | 1.64 | -0.10 | 0.10 | 2 | 1 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.3 | 0 | -1 | 5.3 | **34** |
| FM9* | Flood Modification | Confluence of South Creek and Wheeler Creek | Widening of South Creek | $630,000 | $5,000 | $699,004 | $1,114 | 0 | $15,375 | 0.02 | 0.12 | 0.00 | 1 | 1 | 0 | -1 | 1 | 1 | 1 | 1 | -1 | 1.6 | 0 | 0 | 5.6 | **33** |
| FM10* | Flood Modification | South Creek Left Bank between Willandra Road and Carcoola Road | Regrading of Lidwina Place Reserve and Tyagarah Reserve | $6,080,000 | $10,000 | $6,218,007 | $6,623 | 2 | $91,401 | 0.01 | 0.30 | 0.12 | 1 | 2 | -2 | -2 | 1 | 1 | 2 | 1 | 1 | 1.4 | 0 | 0 | 6.4 | **30** |
| FM11* | Flood Modification | South Creek Left Bank between Willandra Road and Carcoola Road | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve | $2,310,000 | $10,000 | $2,448,007 | $12,129 | 4 | $167,392 | 0.07 | 0.29 | 0.08 | 1 | 2 | -1 | -2 | 1 | 1 | 2 | 1 | 1 | 1.3 | 0 | 0 | 7.3 | **29** |
| FM12* | Flood Modification | Toronto Ave, Carcoola Rd, Willandra Rd (upper and lower crossing), Alkira Cct, McIntosh Ave and Little Willandra Road. | Preparation and Implementation of Culvert Maintenance Strategy for Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek | $40,000 | $20,000 | $316,015 | $101,162 | 30 | $1,396,117 | 4.42 | 0.31 | 0.00 | 2 | 2 | 0 | 0 | 2 | 1 | 2 | 2 | 1 | 1.2 | 1 | 2 | 16.2 | **1** |
| FM13 | Flood Modification | Willandra Road (Lower) Crossing of South Creek | Enhance Willandra Road (lower) Culverts | $219,000 | $0 | $219,000 | NC | N/A | N/A | N/A | 0.50 | 0.00 | 1 | 2 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 1.9 | 0 | 0 | 10.9 | **14** |
| FM14 | Flood Modification | Upstream of Willandra Road (Lower) Crossing | Regrading of South Creek Right Bank | $160,000 | $0 | $160,000 | NC | N/A | N/A | N/A | 0.01 | 0.00 | -1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1.8 | 0 | 0 | 2.8 | **38** |
| FM15 | Flood Modification | South Creek Right Bank at the end of Towradgi Street | Levee to Protect Properties at the end of Towradgi Street | $87,000 | $1,000 | $100,801 | $16,471 | 5 | $227,306 | 2.26 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.1 | 0 | -1 | 4.1 | **36** |
| FM16 | Flood Modification | Alkira Cct Crossing of South Creek | Enhance Alkira Circuit Culverts | $254,000 | $0 | $254,000 | NC | N/A | N/A | N/A | 0.50 | 0.00 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0.3 | 0 | 0 | 6.3 | **31** |
| FM17 | Flood Modification | Willandra Road (Upper) Crossing of South Creek | Enhance Willandra Road (upper) Culverts | $258,000 | $0 | $258,000 | NC | N/A | N/A | N/A | 1.08 | 0.00 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0.4 | 0 | 0 | 8.4 | **26** |
| FM18 | Flood Modification | South Creek Left Bank upstream of Willandra Road (upper) Crossing | Levee to protect properties on Willandra Road | $80,000 | $1,000 | $93,801 | $11,276 | 3 | $155,611 | 1.66 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 1 | 1 | 1 | 0 | 0 | -0.1 | 0 | 0 | 3.9 | **37** |
| FM19 | Flood Modification | South Creek Left Bank Adjacent to Cromer Golf Course | Levee to protect Cromer Golf Course | $669,000 | $5,000 | $738,004 | $0 | 0 | $0 | 0.00 | 0.00 | 0.20 | 0 | 0 | -2 | -1 | 0 | -1 | -1 | -1 | -1 | -1.2 | -1 | -2 | -11.2 | **39** |
| FM20 | Flood Modification | Along South Creek and Wheeler Creek | Detailed Assessment for potential Debris Control Structures | $30,000 | $0 | $30,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1.2 | 2 | 2 | 11.2 | **12** |
| FM21 | Flood Modification | Wheeler Creek, Upstream of Willandra Bungalows | Debris Control Structure | $30,000 | $2,000 | $57,601 | NC | N/A | N/A | N/A | 0.80 | 0.00 | 1 | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 1.6 | 2 | 2 | 13.6 | **2** |
| PM1 | Property Modification | Catchment Wide | Ongoing implementation of development controls and guidelines for building work | $0 | $1,000 | $13,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.5 | 2 | 2 | 12.5 | **5** |
| PM2 | Property Modification | Catchment Wide | Preparation of Flood Related Development Control Plan for Warringah LGA | $20,000 | $2,000 | $47,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.5 | 2 | 0 | 10.5 | **15** |
| PM3 | Property Modification | Catchment Wide | Guidelines for Public Domain Infrastructure | $15,000 | $2,000 | $42,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | -0.3 | 2 | 0 | 8.7 | **23** |
| PM4 | Property Modification | Selected locations throughout the floodplain | Voluntary House Raising Program (State Government Funded) | $480,000 | $0 | $480,000 | $61,999 | 18 | $855,632 | 1.78 | 0.00 | 0.00 | 2 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | -0.4 | 0 | 2 | 7.6 | **27** |
| PM5 | Property Modification | Selected locations throughout the floodplain | Voluntary House Purchase Program - 10 properties | $8,500,000 | $0 | $8,500,000 | $128,875 | 38 | $1,778,572 | 0.21 | 0.00 | 0.00 | 1 | 0 | 0 | -2 | 2 | 2 | 2 | 0 | 1 | 0.5 | 0 | 2 | 8.5 | **25** |
| PM6 | Property Modification | 1 selected location in the floodplain | Voluntary House Purchase Further Investigation - 1 property | $850,000 | $0 | $850,000 | $14,501 | 4 | $200,121 | 0.24 | 0.00 | 0.00 | 1 | 0 | 0 | -1 | 2 | 2 | 2 | 0 | 1 | 1.8 | 1 | 2 | 11.8 | **9** |
| PM7 | Property Modification | Catchment Wide (doesn't include properties within the 100 Year ARI extent) | Review of Draft OSD Policy | $10,000 | $0 | $10,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 1.5 | 2 | 2 | 12.5 | **5** |
| PM8 | Property Modification | Warringah LGA | Analysis of Localised Flood Planning Level Requirements | $20,000 | $1,000 | $33,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0.2 | 2 | 0 | 9.2 | **20** |
| PM9 | Property Modification | South Creek Floodplain | Property Dossier of Severely Flood Affected Properties | $30,000 | $0 | $30,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.4 | 2 | 2 | 12.4 | **7** |
| EM1 | Emergency Response Modification | Warringah LGA | Preparation and Adoption of SES Local Flood Plan | $30,000 | $2,000 | $57,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0.6 | 2 | 2 | 8.6 | **24** |
| EM2 | Emergency Response Modification | N/A | Flood Warning Systems and Instrumentation | $1,000 | $1,000 | $14,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 2 | 1 | 0 | 0 | 1.5 | 2 | 2 | 11.5 | **10** |
| EM3 | Emergency Response Modification | N/A | Information Transfers to SES | $2,000 | $0 | $2,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1.3 | 2 | 2 | 9.3 | **19** |
| EM4 | Emergency Response Modification | Catchment Wide | Community education and awareness programs | $10,000 | $2,000 | $37,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | -0.3 | 2 | 2 | 9.7 | **17** |
| EM5 | Emergency Response Modification | Sensitive Localities | Targeted Flood Education Programs | $40,000 | $10,000 | $178,007 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 1.7 | 2 | 2 | 12.7 | **4** |
| EM6 | Emergency Response Modification | All Road Crossing of South Creek and Wheeler Creek | Flood depth markers placed on both sides of all roads crossing the creeks | $14,000 | $0 | $14,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1.1 | 2 | 1 | 9.1 | **21** |
| EM7 | Emergency Response Modification | N/A | Ongoing collection of flood information | $0 | $2,000 | $27,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 10 | **16** |
| BM1* | Bank Management | South Creek, Downstream of Carcoola Road | Management of Weeds in South Creek Downstream of Carcoola Road | $416,000 | $10,000 | $554,007 | $6,008 | 2 | $82,916 | 0.15 | 0.22 | 0.00 | 1 | 2 | 0 | -1 | 1 | 1 | 1 | 1 | 2 | 0 | 2 | 2 | 12 | **8** |
| BM2 | Bank Management | South Creek and Wheeler Creek | Weed and Sediment Management in South Creek and Wheeler Creek | $200,000 | $50,000 | $890,037 | NC | N/A | N/A | N/A | 0.10 | 0.00 | 1 | 1 | 0 | -1 | 1 | 1 | 1 | 1 | 2 | 0 | 2 | 2 | 11 | **13** |

** Option assessed using hydraulic modelling*

**SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY MULTI-CRITERIA MATRIX - ORDERED BY ID**

| ID | Category of Measure | Locality | Type of Measure | 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 | Peak Reduction in Water Levels (100yr ARI) | Peak Increase in Water Levels (100yr ARI) | Score on Benefit Cost Ratio | Likely Overall Hydraulic Improvement | Negative Hydraulic Impacts | Capital and Operating Costs | Reduction in Risk to Property | Reduction in Risk to Life | Reduction in Social Disruption | Water Quality and Flow | Fauna & Flora | Community Criteria | Council Support | Compatible with Policies and Plans | TOTAL SCORE | RANK on TOTAL SCORE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FM12* | Flood Modification | Toronto Ave, Carcoola Rd, Willandra Rd (upper and lower crossing), Alkira Cct, McIntosh Ave and Little Willandra Road. | Preparation and Implementation of Culvert Maintenance Strategy for Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek | $40,000 | $20,000 | $316,015 | $101,162 | 30 | $1,396,117 | 4.42 | 0.31 | 0.00 | 2 | 2 | 0 | 0 | 2 | 1 | 2 | 2 | 1 | 1.2 | 1 | 2 | 16.2 | **1** |
| FM21 | Flood Modification | Wheeler Creek, Upstream of Willandra Bungalows | Debris Control Structure | $30,000 | $2,000 | $57,601 | NC | N/A | N/A | N/A | 0.80 | 0.00 | 1 | 2 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 1.6 | 2 | 2 | 13.6 | **2** |
| FM5* | Flood Modification | South Creek between Carcoola Rd and Toronto Ave | Rehabilitate Creek and Construct Wetland | $2,500,000 | $40,000 | $3,052,030 | $23,141 | 7 | $319,363 | 0.10 | 0.71 | 0.00 | 1 | 2 | 0 | -2 | 1 | 1 | 2 | 2 | 2 | 1.1 | 1 | 2 | 13.1 | **3** |
| EM5 | Emergency Response Modification | Sensitive Localities | Targeted Flood Education Programs | $40,000 | $10,000 | $178,007 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 1 | 2 | 2 | 0 | 0 | 1.7 | 2 | 2 | 12.7 | **4** |
| PM1 | Property Modification | Catchment Wide | Ongoing implementation of development controls and guidelines for building work | $0 | $1,000 | $13,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.5 | 2 | 2 | 12.5 | **5** |
| PM7 | Property Modification | Catchment Wide (doesn't include properties within the 100 Year ARI extent) | Review of Draft OSD Policy | $10,000 | $0 | $10,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 0 | 1.5 | 2 | 2 | 12.5 | **5** |
| PM9 | Property Modification | South Creek Floodplain | Property Dossier of Severely Flood Affected Properties | $30,000 | $0 | $30,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.4 | 2 | 2 | 12.4 | **7** |
| BM1* | Bank Management | South Creek, Downstream of Carcoola Road | Management of Weeds in South Creek Downstream of Carcoola Road | $416,000 | $10,000 | $554,007 | $6,008 | 2 | $82,916 | 0.15 | 0.22 | 0.00 | 1 | 2 | 0 | -1 | 1 | 1 | 1 | 1 | 2 | 0 | 2 | 2 | 12 | **8** |
| PM6 | Property Modification | 1 selected location in the floodplain | Voluntary House Purchase Further Investigation - 1 property | $850,000 | $0 | $850,000 | $14,501 | 4 | $200,121 | 0.24 | 0.00 | 0.00 | 1 | 0 | 0 | -1 | 2 | 2 | 2 | 0 | 1 | 1.8 | 1 | 2 | 11.8 | **9** |
| EM2 | Emergency Response Modification | N/A | Flood Warning Systems and Instrumentation | $1,000 | $1,000 | $14,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 2 | 1 | 0 | 0 | 1.5 | 2 | 2 | 11.5 | **10** |
| FM1 | Flood Modification | Downstream of Toronto Ave, on South Creek left bank | Levee to protect properties on Toronto Ave | $115,000 | $1,000 | $128,801 | $3,866 | 1 | $53,347 | 0.41 | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 2 | 2 | 1 | 0 | 1 | 0.4 | 2 | 1 | 11.4 | **11** |
| FM20 | Flood Modification | Along South Creek and Wheeler Creek | Detailed Assessment for potential Debris Control Structures | $30,000 | $0 | $30,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 0 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 0 | 1.2 | 2 | 2 | 11.2 | **12** |
| BM2 | Bank Management | South Creek and Wheeler Creek | Weed and Sediment Management in South Creek and Wheeler Creek | $200,000 | $50,000 | $890,037 | NC | N/A | N/A | N/A | 0.10 | 0.00 | 1 | 1 | 0 | -1 | 1 | 1 | 1 | 1 | 2 | 0 | 2 | 2 | 11 | **13** |
| FM13 | Flood Modification | Willandra Road (Lower) Crossing of South Creek | Enhance Willandra Road (lower) Culverts | $219,000 | $0 | $219,000 | NC | N/A | N/A | N/A | 0.50 | 0.00 | 1 | 2 | 0 | 0 | 2 | 1 | 1 | 1 | 1 | 1.9 | 0 | 0 | 10.9 | **14** |
| PM2 | Property Modification | Catchment Wide | Preparation of Flood Related Development Control Plan for Warringah LGA | $20,000 | $2,000 | $47,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 1.5 | 2 | 0 | 10.5 | **15** |
| EM7 | Emergency Response Modification | N/A | Ongoing collection of flood information | $0 | $2,000 | $27,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 0 | 0 | 0 | 2 | 0 | 0 | 1 | 1 | 0 | 2 | 2 | 2 | 10 | **16** |
| FM2* | Flood Modification | Toronto Ave Crossing of South Creek | Enhance Toronto Ave Culverts | $138,000 | $0 | $138,000 | $2,542 | 1 | $35,077 | 0.25 | 0.33 | 0.10 | 1 | 2 | -2 | 1 | 1 | 1 | 1 | 1 | 1 | 1.7 | 1 | 0 | 9.7 | **17** |
| EM4 | Emergency Response Modification | Catchment Wide | Community education and awareness programs | $10,000 | $2,000 | $37,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | -0.3 | 2 | 2 | 9.7 | **17** |
| EM3 | Emergency Response Modification | N/A | Information Transfers to SES | $2,000 | $0 | $2,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 1 | 0 | 0 | 0 | 1.3 | 2 | 2 | 9.3 | **19** |
| PM8 | Property Modification | Warringah LGA | Analysis of Localised Flood Planning Level Requirements | $20,000 | $1,000 | $33,801 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | 0.2 | 2 | 0 | 9.2 | **20** |
| FM3* | Flood Modification | South Creek - Upstream of Toronto Ave | Creek Widening and Revegetation Upstream of Toronto Ave | $1,790,000 | $5,000 | $1,859,004 | $21,309 | 6 | $294,075 | 0.16 | 0.00 | 0.01 | 1 | 0 | -1 | -1 | 1 | 1 | 1 | 2 | 2 | 1.1 | 2 | 0 | 9.1 | **21** |
| EM6 | Emergency Response Modification | All Road Crossing of South Creek and Wheeler Creek | Flood depth markers placed on both sides of all roads crossing the creeks | $14,000 | $0 | $14,000 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 0 | 2 | 0 | 0 | 0 | 1.1 | 2 | 1 | 9.1 | **21** |
| PM3 | Property Modification | Catchment Wide | Guidelines for Public Domain Infrastructure | $15,000 | $2,000 | $42,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 2 | 2 | 1 | 1 | 0 | 0 | -0.3 | 2 | 0 | 8.7 | **23** |
| EM1 | Emergency Response Modification | Warringah LGA | Preparation and Adoption of SES Local Flood Plan | $30,000 | $2,000 | $57,601 | NC | N/A | N/A | N/A | 0.00 | 0.00 | 1 | 0 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 0.6 | 2 | 2 | 8.6 | **24** |
| PM5 | Property Modification | Selected locations throughout the floodplain | Voluntary House Purchase Program - 10 properties | $8,500,000 | $0 | $8,500,000 | $128,875 | 38 | $1,778,572 | 0.21 | 0.00 | 0.00 | 1 | 0 | 0 | -2 | 2 | 2 | 2 | 0 | 1 | 0.5 | 0 | 2 | 8.5 | **25** |
| FM17 | Flood Modification | Willandra Road (Upper) Crossing of South Creek | Enhance Willandra Road (upper) Culverts | $258,000 | $0 | $258,000 | NC | N/A | N/A | N/A | 1.08 | 0.00 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0.4 | 0 | 0 | 8.4 | **26** |
| FM6 | Flood Modification | Carcoola Rd crossing of South Creek | Enhance Carcoola Rd Culverts | $434,000 | $0 | $434,000 | NC | N/A | N/A | N/A | 0.30 | 0.00 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1.6 | 0 | 0 | 7.6 | **27** |
| PM4 | Property Modification | Selected locations throughout the floodplain | Voluntary House Raising Program (State Government Funded) | $480,000 | $0 | $480,000 | $61,999 | 18 | $855,632 | 1.78 | 0.00 | 0.00 | 2 | 0 | 0 | 0 | 2 | 1 | 1 | 0 | 0 | -0.4 | 0 | 2 | 7.6 | **27** |
| FM11* | Flood Modification | South Creek Left Bank between Willandra Road and Carcoola Road | Regrading in Sections of Lidwina Place Reserve and Tyagarah Reserve | $2,310,000 | $10,000 | $2,448,007 | $12,129 | 4 | $167,392 | 0.07 | 0.29 | 0.08 | 1 | 2 | -1 | -2 | 1 | 1 | 2 | 1 | 1 | 1.3 | 0 | 0 | 7.3 | **29** |
| FM10* | Flood Modification | South Creek Left Bank between Willandra Road and Carcoola Road | Regrading of Lidwina Place Reserve and Tyagarah Reserve | $6,080,000 | $10,000 | $6,218,007 | $6,623 | 2 | $91,401 | 0.01 | 0.30 | 0.12 | 1 | 2 | -2 | -2 | 1 | 1 | 2 | 1 | 1 | 1.4 | 0 | 0 | 6.4 | **30** |
| FM7 | Flood Modification | South Creek upstream of Carcoola Rd | Sediment Retention Basin | $180,000 | $10,000 | $318,007 | $0 | 0 | $0 | 0.00 | 0.00 | 0.00 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 1.3 | 1 | 1 | 6.3 | **31** |
| FM16 | Flood Modification | Alkira Cct Crossing of South Creek | Enhance Alkira Circuit Culverts | $254,000 | $0 | $254,000 | NC | N/A | N/A | N/A | 0.50 | 0.00 | 0 | 2 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0.3 | 0 | 0 | 6.3 | **31** |
| FM9* | Flood Modification | Confluence of South Creek and Wheeler Creek | Widening of South Creek | $630,000 | $5,000 | $699,004 | $1,114 | 0 | $15,375 | 0.02 | 0.12 | 0.00 | 1 | 1 | 0 | -1 | 1 | 1 | 1 | 1 | -1 | 1.6 | 0 | 0 | 5.6 | **33** |
| FM8 | Flood Modification | Upstream of Carcoola Rd on South Creek left bank | Levee to Protect Properties at Carcoola Rd | $98,000 | $0 | $98,000 | $11,628 | 3 | $160,472 | 1.64 | -0.10 | 0.10 | 2 | 1 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.3 | 0 | -1 | 5.3 | **34** |
| FM4 | Flood Modification | South Creek Left Bank - between Wabash and Washington Ave | Levee to Protect Properties between Wabash Ave and Washington Ave | $132,000 | $0 | $132,000 | $37,222 | 11 | $513,688 | 3.89 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.2 | 0 | -1 | 4.2 | **35** |
| FM15 | Flood Modification | South Creek Right Bank at the end of Towradgi Street | Levee to Protect Properties at the end of Towradgi Street | $87,000 | $1,000 | $100,801 | $16,471 | 5 | $227,306 | 2.26 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 2 | 1 | 1 | 0 | 0 | 0.1 | 0 | -1 | 4.1 | **36** |
| FM18 | Flood Modification | South Creek Left Bank upstream of Willandra Road (upper) Crossing | Levee to protect properties on Willandra Road | $80,000 | $1,000 | $93,801 | $11,276 | 3 | $155,611 | 1.66 | 0.00 | 0.10 | 2 | 0 | -2 | 1 | 1 | 1 | 1 | 0 | 0 | -0.1 | 0 | 0 | 3.9 | **37** |
| FM14 | Flood Modification | Upstream of Willandra Road (Lower) Crossing | Regrading of South Creek Right Bank | $160,000 | $0 | $160,000 | NC | N/A | N/A | N/A | 0.01 | 0.00 | -1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1.8 | 0 | 0 | 2.8 | **38** |
| FM19 | Flood Modification | South Creek Left Bank Adjacent to Cromer Golf Course | Levee to protect Cromer Golf Course | $669,000 | $5,000 | $738,004 | $0 | 0 | $0 | 0.00 | 0.00 | 0.20 | 0 | 0 | -2 | -1 | 0 | -1 | -1 | -1 | -1 | -1.2 | -1 | -2 | -11.2 | **39** |

** Option assessed using hydraulic modelling*