SOUTH CREEK
FLOODPLAIN RISK MANAGEMENT PLAN

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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 liable 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:

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	Implementation of flood response and property modification measures (including mitigation works, planning controls, flood warnings, flood readiness and response plans, environmental rehabilitation, ongoing data collection and monitoring).

This report forms the fifth stage of the management process for the South Creek Floodplain. The South Creek Flood Study was prepared by Webb McKeown and Associates (WMA, 2006) and the South Creek Floodplain Risk Management Study was prepared by Cardno Lawson Treloar (2007a).

This report has been prepared for Warringah Council by Cardno Lawson Treloar Pty Ltd to outline floodplain risk management actions to be implemented.

EXECUTIVE SUMMARY

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

Flooding in South Creek can pose a hazard resulting in significant risks to personal safety and property losses to some residents living in close proximity to both South Creek and Wheeler 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 purpose of this study is to identify and examine options for the management of the risks from flooding within the South Creek floodplain. The study has been undertaken in accordance with the NSW Government's Floodplain Development Manual (2005) by having regard to the impacts on flooding, social, environmental and economic aspects on a merits basis. The Plan takes into account comments received from the community at different stages of the project.

The detailed assessment of the flood risk management options is provided in the *Floodplain Risk Management Study* (Cardno Lawson Treloar, 2008). This *Floodplain Risk Management Plan* presents those options recommended for implementation in the South Creek floodplain.

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 near Narrabeen Lagoon (June 2005)

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

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

Highly urbanised areas exist within the South Creek catchment compared to 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 in the event of a flood.

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 the past decades, South Creek has experienced significant flood events including those in March 2003, April 1998 and November 1984. However, such flooding is not as severe as would be experienced from more extreme (but possible) storm events, which have been considered in this study / plan.

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 Average Recurrence Interval (ARI) event.

Floodplain Risk Management Study

A *Floodplain Risk Management Study* was undertaken to investigate what can be done to reduce or manage the effects of flooding in the South Creek floodplain. The Study identified a mix of strategies to manage the risks of flooding.

Specific objectives of the 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 following table summarises the number of properties that would be flooded in different 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

Design Flood Event	Number of 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 (i.e. worst case flood)	185	$9,885,000
Average Annual Damage		$ 340,000
Present Worth of Damage (50yr, 7%)		$4,692,000

(ARI – Average Recurrence Interval)

Options to Manage the Risks from 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 was also prepared as part of the Floodplain Risk Management Study

(Cardno Lawson Treloar, 2007b). Those bank management measures which were considered to have a significant flooding impact were incorporated into the Floodplain Risk Management Study options assessment.

An extensive list of options was assessed against a range of criteria (technical, economic, environmental and social).

Hydraulic modelling of the flood modification options was undertaken along with an assessment of the economic, social, environmental, land use, heritage and planning issues.

Actions for Implementation

Flood modification works to be implemented as part of this Plan include:

- 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 Downstream of Carcoola Road;
- FM12 - Preparation and Implementation of Culvert Maintenance Strategy;
- 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 to be implemented as part of this Plan 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 – Investigations into Voluntary House Purchase – 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 to be implemented as part of this Plan include:

- 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; and
- EM7 - Ongoing collection of flood information.

Bank management measures to be implemented as part of this Plan include:

- BM1 - Management of Weeds in South Creek Downstream of Carcoola Road; and
- 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 have therefore been included in this Floodplain Risk Management Plan.

Several of the flood management measures recommended for inclusion in the Plan were assessed using a hydraulic model. These measures are presented in the table below. The model results provided information to calculate the reduction in flood damages and the reduction in over-floor flooding due to the implementation of each of the flood management measures.

Option	**Reduction in Average Annual Flood Damages**	**Reduction in No. of Properties with Over-floor Flooding[1]**
FM1 - Levee to Protect Properties on Toronto Avenue	$3,866	3
FM2 - Enhance Toronto Ave Bridge	$2,542	0
FM3 - Creek Widening and Revegetation Upstream of Toronto Ave	$21,309	1
FM5 - Rehabilitate Creek and Construct Wetland Downstream of Carcoola Road	$23,141	12
FM12 - Preparation and Implementation of Culvert Maintenance Strategy	$101,162	4
PM6 – Investigations into Voluntary House Purchase – 1 Property	$14,501	1
BM1 - Management of Weeds in South Creek Downstream of Carcoola Road	$6,008	6

[1] **In the 100 Year ARI Flood Event**

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

The cost of implementing the Plan is 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 action has significant hydraulic and environmental benefits and is therefore recommended for implementation should funding become available.

The Next Step

The next step in the Floodplain Management process is the implementation of the Plan. For major capital works this will require application to appropriate bodies for funding, further investigations, detailed design (in the case of flood modification options) prior to actual construction of works. Implementation of the Plan would most likely need to be staged depending on the priority of the options and the availability of funds.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

GLOSSARY OF TERMS*

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. 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.

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.

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.

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

Warringah Council, through the Narrabeen Lagoon Joint Estuary Floodplain Management Committee, has sought to prepare this Floodplain Risk Management Plan for the South Creek Floodplain in accordance with the New South Wales Government's flood prone land policy. Cardno Lawson Treloar was commissioned to prepare this Plan in accordance with the NSW *Floodplain Development Manual* (2005). The area of interest is shown below in a Locality Plan (**Figure 1.1**).

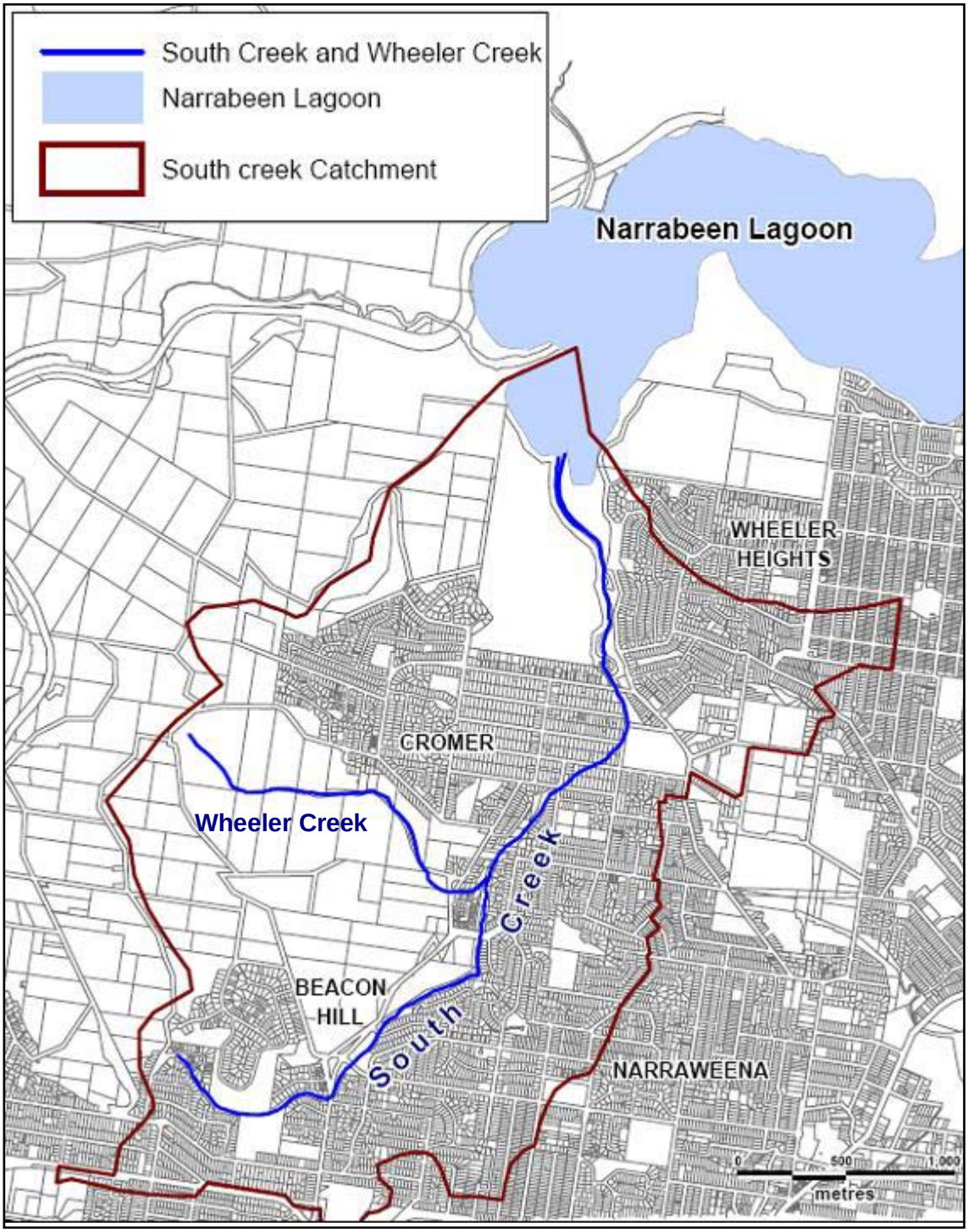

Figure 1.1 Locality Plan

1.1 Study Context

The preparation of this plan follows on from the Flood Study (WMA, 2006) and Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) and forms the fifth stage of the Floodplain Risk 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.

As prescribed in the floodplain management process, the Narrabeen Lagoon Joint Estuary Floodplain Management Committee was formed. Warringah Council, under the direction of this Committee, previously commissioned the Flood Study (WMA, 2006) and have now commission Cardno Lawson Treloar to concurrently undertake the Floodplain Risk Management Study and Floodplain Risk Management Plan. To develop the Plan, the findings of the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) were extensively utilised.

1.2 Study Purpose

The purpose of this plan is 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;
- ensure that the floodplain management plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Councils obligations under relevant Acts and has the support of the local community;
- ensure that the floodplain management plan is fully integrated with the flood response procedure and other relevant catchment management plans; and
- establish a program for implementation and a mechanism for the funding of the plan and should include priorities, staging, funding, responsibilities, constraints and monitoring.

1.3 Related Plans of Management and Strategies

There are a wide range of related plans of management and strategies that have been considered during the preparation of this plan. These include:

- The Warringah Council Creek Management Strategy (MWH, 2004);
- Warringah Development Control Plan (2005);
- Sydney Regional Environment Plan No. 21 – Warringah Urban Release Areas;
- Warringah Council Local Environmental Plan (LEP) 2000; and
- Manly, Warringah and Pittwater DISPLAN (2004).

1.4 Community Consultation

Community consultation was undertaken as part of the preparation of the South Creek Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) through a resident survey in June 2007 on possible floodplain management options.

Both the Floodplain Risk Management Study and the Floodplain Risk Management Plan have been publicly exhibited concurrently during October and November 2007. Community comments were received via written submissions and the returned feedback forms provided during the public exhibition period.

The responses received during both consultation periods have been incorporated into the final documents.

1.5 Plan Outline

This Plan covers the following details:

- Summary of catchment characteristics (**Section 2**);
- Description of the existing flood behaviour and impacts (**Section 3**);
- Summary of flood modification actions for implementation (**Section 4**);
- Summary of property modification actions for implementation (**Section 5**);
- Summary of emergency response modification actions for implementation (**Section 6**);
- Summary of bank management action for implementation (**Section 7**); and
- Implementation action plan (**Section 8**).

2. CATCHMENT CHARACTERISTICS

The South Creek catchment has a total area of 7.3 km^2 flowing from the top of the catchment to the southern end of Narrabeen Lagoon. The catchment is made up of two major 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 that are likely to be overtopped during a major flood event.

A summary of the South Creek catchment characteristics is provided below in **Table 2.1**.

Table 2.1 Catchment Characteristics

Catchment Area	7.3km^2	
Maximum Ground Level in Catchment	168m AHD at Beacon Hill	
Minimum Ground Level in Catchment	0 m AHD at Narrabeen Lagoon	
Land Use	Non Urban (Open Space and Forested Areas)	41%
	Urban (Residential, Commercial, and Light Industrial).	59%
Number of Culvert and Bridge Crossings in Study Area	8	
Social Characteristics	Aged 18 years and over	66.3%
	Aged 65 years and over	14.4%
	Total Aboriginal Persons	0.003%
	Australian born	70.6%
	Main Other Countries of Origin	UK, New Zealand, Italy
	English Speaking	80.1%
	Owning a Private Dwelling	46.7%
	Average Household Size	2.84 persons

3. EXISTING FLOOD BEHAVIOUR AND IMPACTS

3.1 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;
- flood hazard and hydraulic categorisation for existing conditions;
- flood damages assessment;
- flood planning level determination; and
- the hydraulic assessment of some of the flood modification options.

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

- South Creek; and
- Wheeler Creek.

3.2 Historical Flooding and 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.

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 the past decades, South Creek has experienced significant flood events including those in March 2003, April 1998, April 1992 and November 1984.

Examples of historic flooding, sourced during the Flood Study (WMA, 2006), are shown below.

	
South Creek Flooding (View of the creek looking upstream from Carcoola Road) April 1992. Note debris. (Source, WMA, 2006)	***South Creek Flooding - downstream side of Toronto Avenue (Date Unspecified). (Source, WMA, 2006)***

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

3.3 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). The peak flood level occurs for most events in a 2 hour flood event. However, the time till the peak flood level occurs is less than 2 hours. 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 flood timing which requires the use of fully dynamic hydraulic modelling systems to replicate the behaviour. The rate at which flows generated in the upper reaches of the catchment arrive at the downstream end 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.

3.4 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, which includes the South Creek catchment). 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 3.1**).

Table 3.1 Design Flood Levels - Narrabeen Lagoon (WMA, 2006)

Event	Flood Level (mAHD) 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

3.5 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 (Wheelers Creek). In response to complaints Council has undertaken periodic cleaning of both sets of culverts (see below);
- 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.

	***Upstream side of Carcoola Road Culverts following Clearance and Sediment and Weeds in August 2003 (Source: WMA, 2006)***
	***Upstream Side of Carcoola Road Culverts – Note substantial sediment in the bed and adjacent encroachment of weeds since previous clearing in August 2003 (June 2005)***
	***Upstream Side of Carcoola Road Culverts – Following repeated clearance of weeds and sediment - Note encroachment of sediment and weeds continuing (May 2007)***

To quantify the impacts of potential blockages on design flood behaviour, several different blockage scenarios (**Table 3.2**) based on the 100 Year ARI event were simulated in the Flood Study (WMA, 2006) using the hydraulic model.

Table 3.2 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 the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) was undertaken using the Scenario 3 blockage conditions.

3.6 Flood Extents and Impact

Flood extents for the range of design floods evaluated are shown in **Figure 3.1**.

Flood impact can be measured by water levels and velocities, which can be translated to impacts in economic and social terms for various design flood events for varying recurrence intervals.

Under the existing conditions, the flood impact in terms of number of properties affected and estimated economic impacts were estimated within the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) and are shown below in **Table 3.3**.

Table 3.3 South Creek Flood Impacts

Design Flood Event	**Number of 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		$ 340,000
Present Worth of Damage (50yr, 7%)		$4,692,000

The above table indicates that under present conditions, the average annual damage, *i.e.* the cost each year of the impact of floods to the community, is approximately $340,000.

The average annual damage is reflective 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. For example approximately $1.9 million worth of damages would be incurred should a single 100 Year ARI event occur.

Financial and community attitude surveys and analysis undertaken for other areas in the Sydney region (eg 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.

The peak flood depths at these critical locations and duration of road flooding are shown in **Table 3.4**. 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. 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 3.4** is the duration of flooding of the road to a depth of 0.1 metres or greater.

Table 3.4 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.

3.7 Flood Hazard and Categorisation

Warringah Council is in the process of writing a comprehensive DCP that will make use of classifying areas of the floodplain by the potential risk associated with these areas referred to as hazard or hydraulic categories. Development controls may vary depending on the hazard or hydraulic category.

Flood Hazard and Hydraulic Categories were defined and mapped for the 100 Year ARI and PMF events. 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 for this study 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 3.2**.

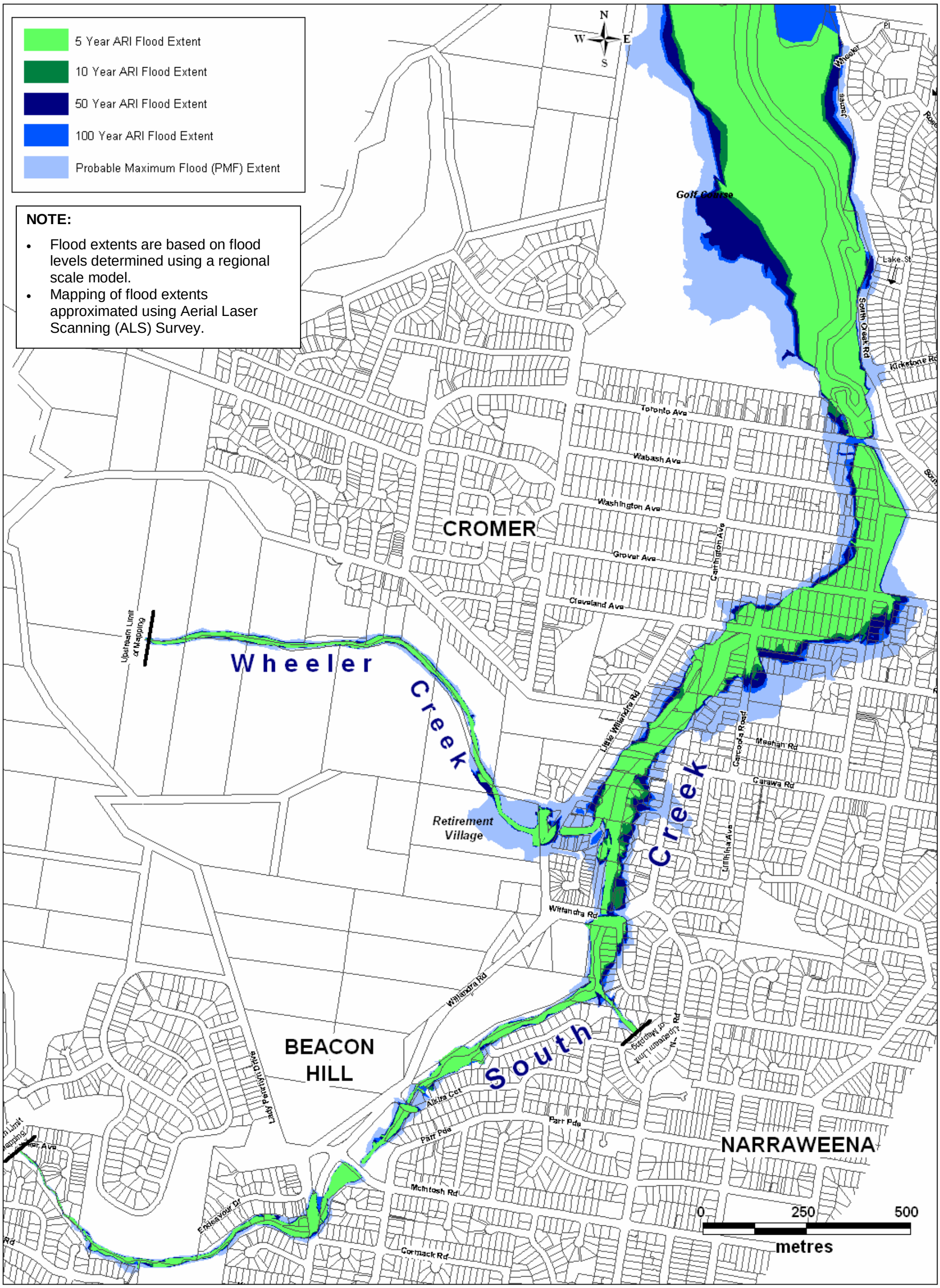

Figure 3.1 Design Flood Extents

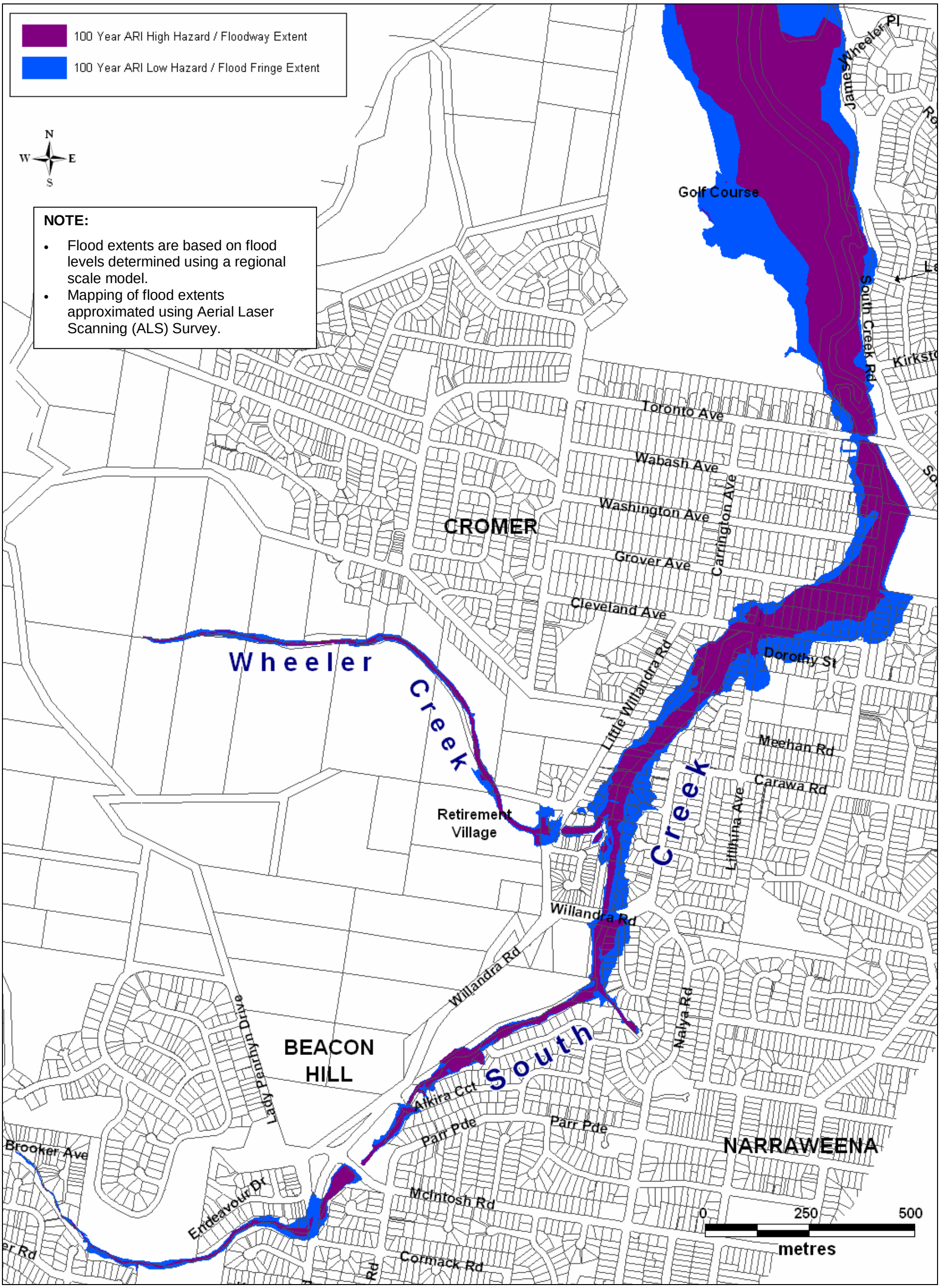

Figure 3.2 100 Year ARI Flood Hazard and Hydraulic Categories

4. FLOOD MODIFICATION ACTIONS

4.1 Overview

To manage the existing flood risk defined in **Section 3**, a range of flood modification measures were considered as part of the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a).

These options were reviewed and those identified to be the most effective in reducing the incidence of property flooding with specific regard to over-floor flooding, whilst providing social and environment benefits (or at least minimal impacts) were selected for inclusion in this Floodplain Risk Management Plan.

Those flood modification measures which are to be implemented as part of the Floodplain Risk Management Plan (*i.e.* 'actions') are listed below in **Table 4.1.** The reference identification details (ID) from the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) are shown within the table.

Table 4.1 Flood Modification Measures for Implementation

FM1	Levee to protect properties on Toronto Ave
FM2	Enhance Toronto Ave Culverts
FM3[1]	Creek Widening and Revegetation Upstream of Toronto Ave
FM5[1]	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
FM21	Debris Control Structure

[1] Options FM3 and FM5 are proposed for a similar location. However, due to limitation of funding it is likely that only one of these options would be implemented. Further details on this issue are provided in **Section 8**.

All floodplain risk management measures to be implemented in South Creek are shown on **Figure 8.1**. Further details on the flood modification actions listed above are provided in the following sections.

4.2 Levees to Protect Properties on Toronto Avenue (FM1)

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 is affected by a significant flood risk. Flooding of the properties occurs primarily due to creek flooding overtopping the bank, rather than flooding from upstream overtopping Toronto Avenue. The depth of 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 would comprise a low fence 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 4.1** with the proposed levee in green.

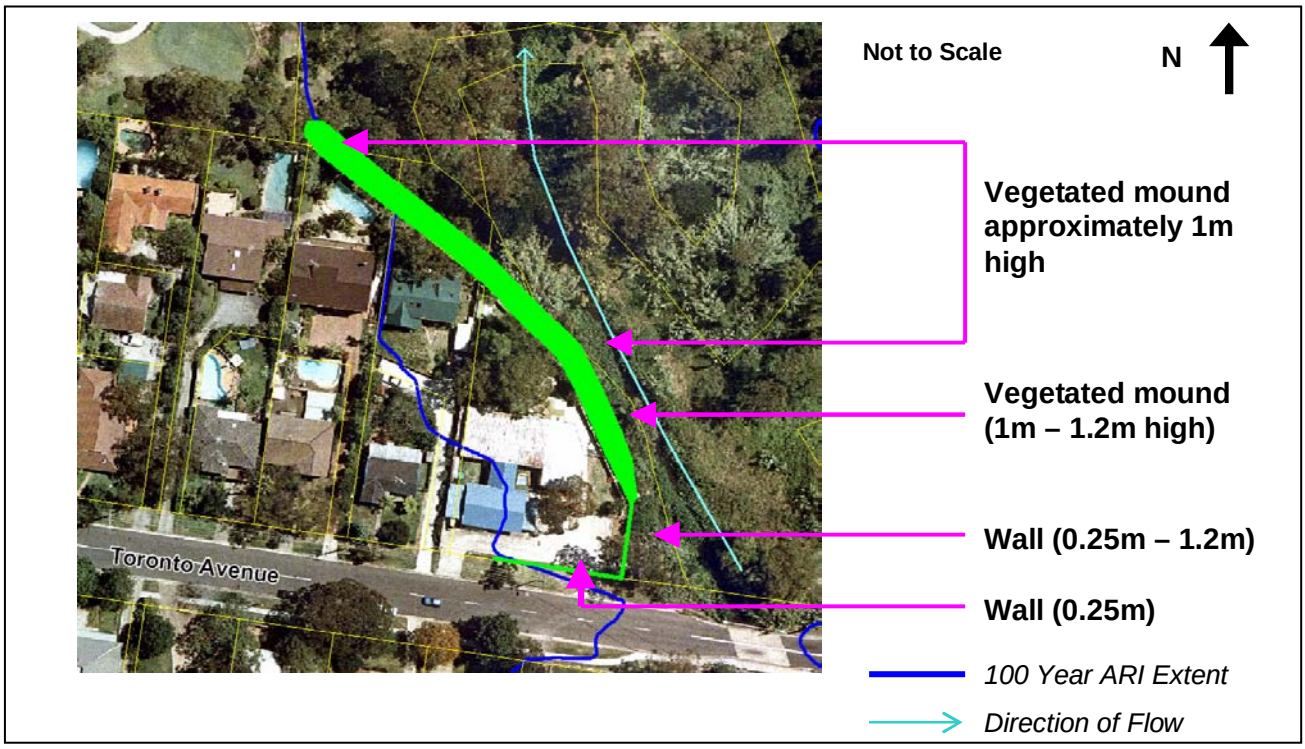

Figure 4.1 Toronto Avenue Levee (FM1)

The levee would be constructed on the Crown Land bordering the creek (*i.e.* no land to be associated with private residential 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.

Implementation of floodplain risk management actions should be in coordination with the Dee Why Valley and South Creek Corridor Plan of Management.

Suitable drainage would be incorporated into the design to limit any ponding of water behind the levee.

The proposed levee would protect three 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 may be intrusive and may have an 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.

4.3 Enhance Toronto Avenue Bridge (FM2)

When unblocked, the Toronto Avenue culvert 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 reconfiguration of the bridge should endeavour to increase the conveyance area underneath the bridge. This could be achieved by replacing the existing pylons whilst widening the channel. It may be necessary to reinforce the bridge deck due to the increased spacing between the pylons.

4.4 Creek Widening and Revegetation Upstream of Toronto Ave (FM3)

Immediately upstream of Toronto Avenue there is a turfed reserve on the left bank (Wabash Reserve). 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 and 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 4.2**.

It should be noted that Action FM5 (details provided in **Section 4.5**) is also recommended for implementation. Both actions FM3 and FM5 are recommended for a similar location. It has been recommended that only one of these measures should proceed. Action FM5 ranked very highly (third) in the *Floodplain Risk Management Study* (Cardno Lawson Treloar, 2007a) due to its significant hydraulic and environmental benefits. However, the cost of implementing FM5 is approximately $2.5 Million (plus $40,000 per year in maintenance costs). It may be difficult to secure this amount of funding. In the event that funding is not available, action FM3 has been recommended for implementation in its place. The capital cost of implementing this option is $1.8 Million (plus $5,000 per year in maintenance costs). However, the hydraulic and environmental benefits are not as significant as those achieved by implementing action FM5.

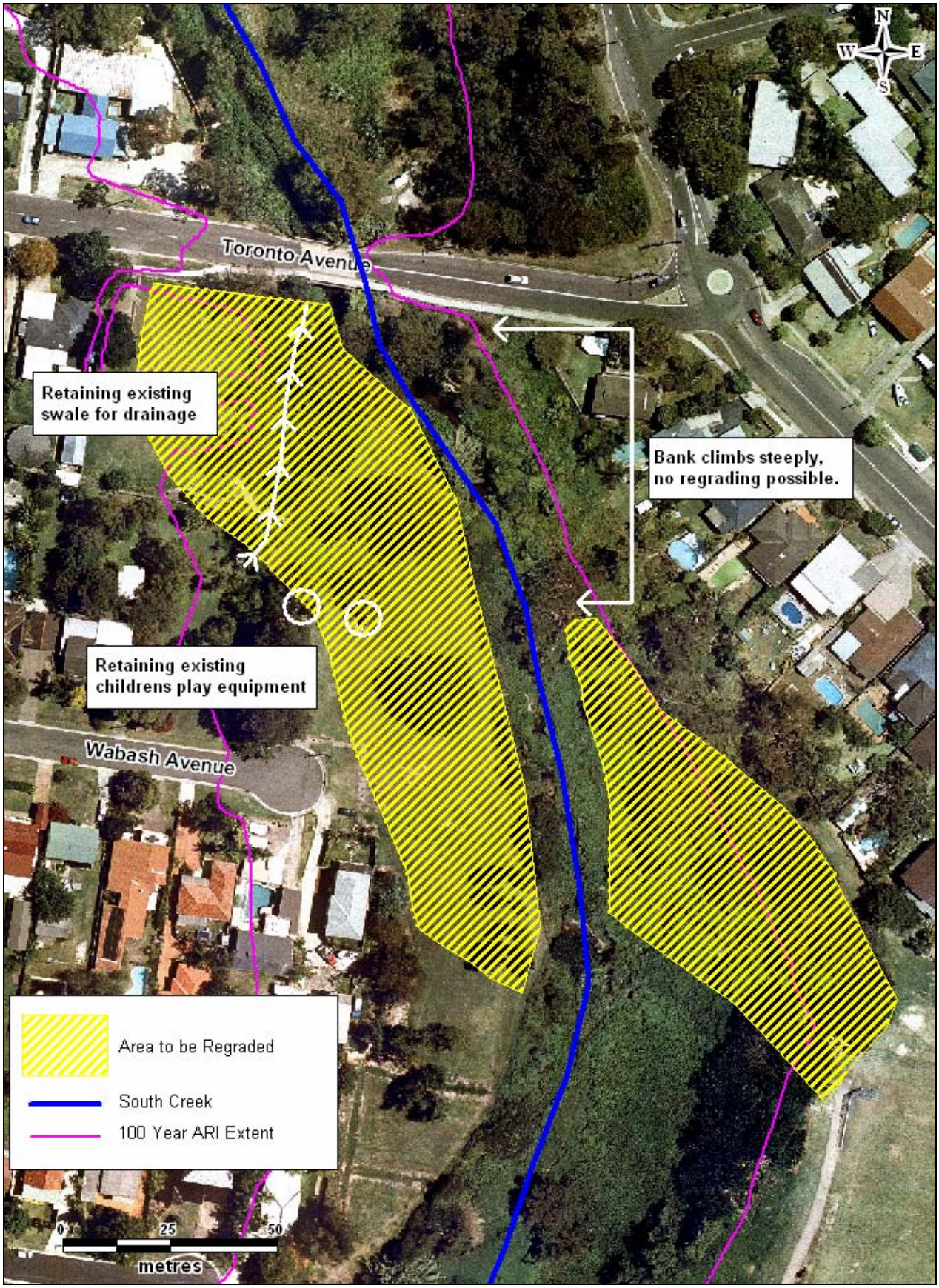

Figure 4.2 Creek Widening and Revegetation (FM3)

4.5 Rehabilitate Creek and Construct Wetland between Carcoola Rd and Toronto Ave (FM5)

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 flood modification action involves clearing the majority of the vegetation (weeds) and remove any excess sedimentation within the area shown in **Figure 4.3**. 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.

Removing any excess sedimentation (assumed to be approximately 0.3m) 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 weed seed stock from the area.

As discussed in **Section 4.4**, it should be noted that Action FM3 is recommended for implementation also. Both actions FM3 and FM5 are recommended for a similar location. It has been recommended that only one of these options should proceed. Action FM5 ranked very highly (third) in the *Floodplain Risk Management Study* (Cardno Lawson Treloar, 2007a) due to the significant hydraulic and environmental benefits. However, the cost of implementing Action FM5 is approximately $2.5 Million (plus $40,000 per year in maintenance costs). It may be difficult to secure this amount of funding. In the event that funding is not available. FM3 has been recommended for implementation in its place. The capital cost of implementing this flood modification measure is $1.8 Million (plus $5,000 per year in maintenance costs). However, the hydraulic and environmental benefits are not as significant as those achieved by implementing Action FM3.

Figure 4.3 Rehabilitate Creek and Construct Wetland (FM5)

4.6 Preparation and Implementation of Culvert Maintenance Strategy (FM12)

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 of maintenance.

It is proposed 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.

4.7 Enhance Willandra Road (lower) Culverts (FM13)

The road crossing at Willandra Road (lower) is comprised of two box culverts (1.55m x 3m each). 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).

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, to make it deeper at this location and replace the existing culverts with larger culverts 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.

Before implementation this option would require detailed hydraulic assessments to ensure there would be no adverse impacts on adjacent properties and to confirm the flood benefit of implementing the option.

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

4.8 Debris Control Structures (FM20)

As outlined above, blockage of the culverts and bridge crossings is a key issue for the South Creek floodplain.

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 bridges. 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 Action FM12 (**Section 4.6**).

In conjunction with an increased maintenance schedule, it may be appropriate to develop structural methods to control debris. Therefore, 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 may be 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 4.4**.

The space available to implement these debris control structure 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.

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>

Figure 4.4 Debris Control Structures (FM20)

4.9 Debris Management on Wheeler Creek (FM21)

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. When considering the flood risk associated with this site it is important to note that the occupants would be elderly and less mobile, therefore vehicle evacuation (rather than pedestrian) may be necessary. 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 8.1**.

Before implementation, investigations would be required to determine the most appropriate location and type of structure and its impact due to the sensitive nature of the creek and riparian zone.

5. PROPERTY MODIFICATION ACTIONS

To manage the future risk as a result of development within the floodplain, a range of property modification measures were considered as part of the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a).

These measures were reviewed and those identified to be the most effective in reducing the incidence property flooding with specific regard for over-floor flooding, whilst providing social and environment benefits (or at least minimal impacts) were selected for inclusion in this Floodplain Risk Management Plan.

Those property modification actions which are to be implemented as part of the Floodplain Risk Management Plan are listed below in **Table 5.1.**

The reference identification details (ID) from the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) are shown within the table.

Table 5.1 Property Modification Actions

ID	Property Modification Action 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.
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

All floodplain risk management measures to be implemented in South Creek are shown on **Figure 8.1**. Further details on the property modification actions listed above are provided in the following sections.

5.1 Ongoing Implementation of Development Controls and Guidelines for Building Work (PM1)

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.

Warringah Council should continue implementing the controls for development in the floodplain as outlined in the WLEP2000 until Council adopts a new LEP and appropriate Floodprone Lands DCP.

5.2 Preparation of Floodprone Lands Development Control Plan for Warringah LGA (PM2)

Council is currently preparing a *Floodprone Lands Development Control Plan (DCP).* This DCP will provide additional controls to the current LEP; providing 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 A**.

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.

5.3 Guidelines for Public Domain Infrastructure (PM3)

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).

5.4 Voluntary House Purchase Investigation (1 Property) (PM6)

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 as is therefore unsuitable for house raising.

It is appropriate for Council to undertake a detailed assessment of flooding on this property. This would involve the collection of detailed ground and floor survey and a site specific flood assessment.

If the property is deemed to experience sever flooding, similar to, or worse than, the flooding behaviour identified as part of the South Creek Floodplain Risk Management Study, the property owner should be offered the option of Voluntary House Purchase.

5.5 Review of Draft OSD Policy (PM7)

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.

5.6 Analysis of Localised Flood Planning Level Requirements (PM8)

Warringah Council’s Flooding DCP and the FRMS (Cardno Lawson Treloar, 2007a) recommend the adoption of a Flood Planning Level (FPL) using the 100 Year ARI plus 0.5m. The analysis and discussion presented in the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) suggest that, on average, across the floodplain this is the most appropriate FPL.

However, it was also noted 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 as the flood planning level for these areas.

It is recommended that any further analysis of this nature is done in conjunction with the other floodplains in the Warringah LGA. This will allow for consistency in any planning decisions relating to localised FPLs.

5.7 Property Dossier of Severely Flood Affected Properties (PM9)

There are 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.

6. EMERGENCY RESPONSE MODIFICATION ACTIONS

The flood and property modification measures outlined in Chapters 4 and 5, have been proposed to manage the existing and future flood risk. However, the implementation of these measures does not rule out the flood risk entirely. The residual flood risk is managed through emergency response modification measures.

A range of emergency response modification actions were considered as part of the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a).

These measures were reviewed and those identified to be the most effective in aiding to reduce the risk to life and property were selected for inclusion in this Floodplain Risk Management Plan.

Those emergency response modification actions which are to be implemented as part of the Floodplain Risk Management Plan are listed below in **Table 6.1**.

The reference identification details (ID) from the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) are shown within the table.

Table 6.1 Emergency Modification Actions

ID	Details
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.

All floodplain risk management actions to be implemented in South Creek are shown on **Figure 8.1**. Further details on the emergency modification measures listed above are provided in the following sections.

6.1 Preparation and Adoption of SES Local Flood Plan (EM1)

The Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) 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 crossing of South Creek and Wheeler Creek. Details of road inundation is provided in **Section 3.6**;
- 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.

6.2 Flood Warning Systems and Instrumentation (EM2)

The current Flood Warning Systems available for the South Creek floodplain are outlined in the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a). Weather-based warnings (Severe Thunderstorm Warnings, Severe Weather Advices, Gale Warnings *etc*.) from the Bureau of Meteorology 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, Community Groups and/or Clubs; and
- Other areas as appropriate.

6.3 Information Transfer to SES (EM3)

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.

6.4 Community Education and Awareness Programs (EM4)

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 a suitable second level is 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 (2003). 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 implemented for the South Creek floodplain:

- preparing FloodSafe brochures for the South Creek Floodplain;
- issue of other SES information brochures with a fridge magnet;
- 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.

6.5 Targeted Flood Education Programs (EM5)

There are 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 its 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;
- include drills for places of business as appropriate; 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.

6.6 Road Flood Depth Markers (EM6)

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. The locations are shown in **Figure 8.1**.

6.7 Ongoing Collection of Flood Information (EM7)

This action involves 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 the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a).

7. BANK MANAGEMENT ACTIONS

7.1 Overview

A bank management plan has been prepared by Cardno Lawson Treloar (*South Creek Bank Management Plan*, 2007b). The bank management plan is available as **Appendix G** of the *Floodplain Risk Management Study* (Cardno Lawson Treloar, 2007a). Several of the measures recommended for implementation in the bank management plan have potential flood benefits. Those measures that were likely to have a flood benefit were incorporated into the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) for assessment against the other floodplain risk management options.

Those bank management measures which are to be implemented as part of the Floodplain Risk Management Plan are listed below in **Table 7.1.**

The reference identification details (ID) from the Floodplain Risk Management Study (Cardno Lawson Treloar, 2007a) are shown within the table.

Table 7.1 Bank Management Actions

ID	Bank Management Measures
BM1	Management of weeds in the South Creek channel downstream of Carcoola Road
BM2	Weed and Sediment Management in South Creek and Wheeler Creek

All floodplain risk management actions to be implemented in South Creek are shown on **Figure 8.1**. Further details on the bank management action listed above are provided in the following section.

7.2 Weed Management Downstream of Carcoola Road (BM1)

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 bank management action 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 7.1**.

In addition to the potential flood benefit as a result of this action, 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.

Figure 7.1 Weed Management Downstream of Carcoola Road (BM1)

7.3 Weed and Sediment Management in South Creek and Wheeler Creek (BM2)

The South Creek Bank Management Plan (Cardno Lawson Treloar, 2008b) provided in Appendix D of the South Creek Floodplain Risk Management Study (Cardno Lawson Treloar, 2008a) 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 South Creek Bank Management Study (Cardno Lawson Treloar, 2008b) are shown on **Figure 7.2**.

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.

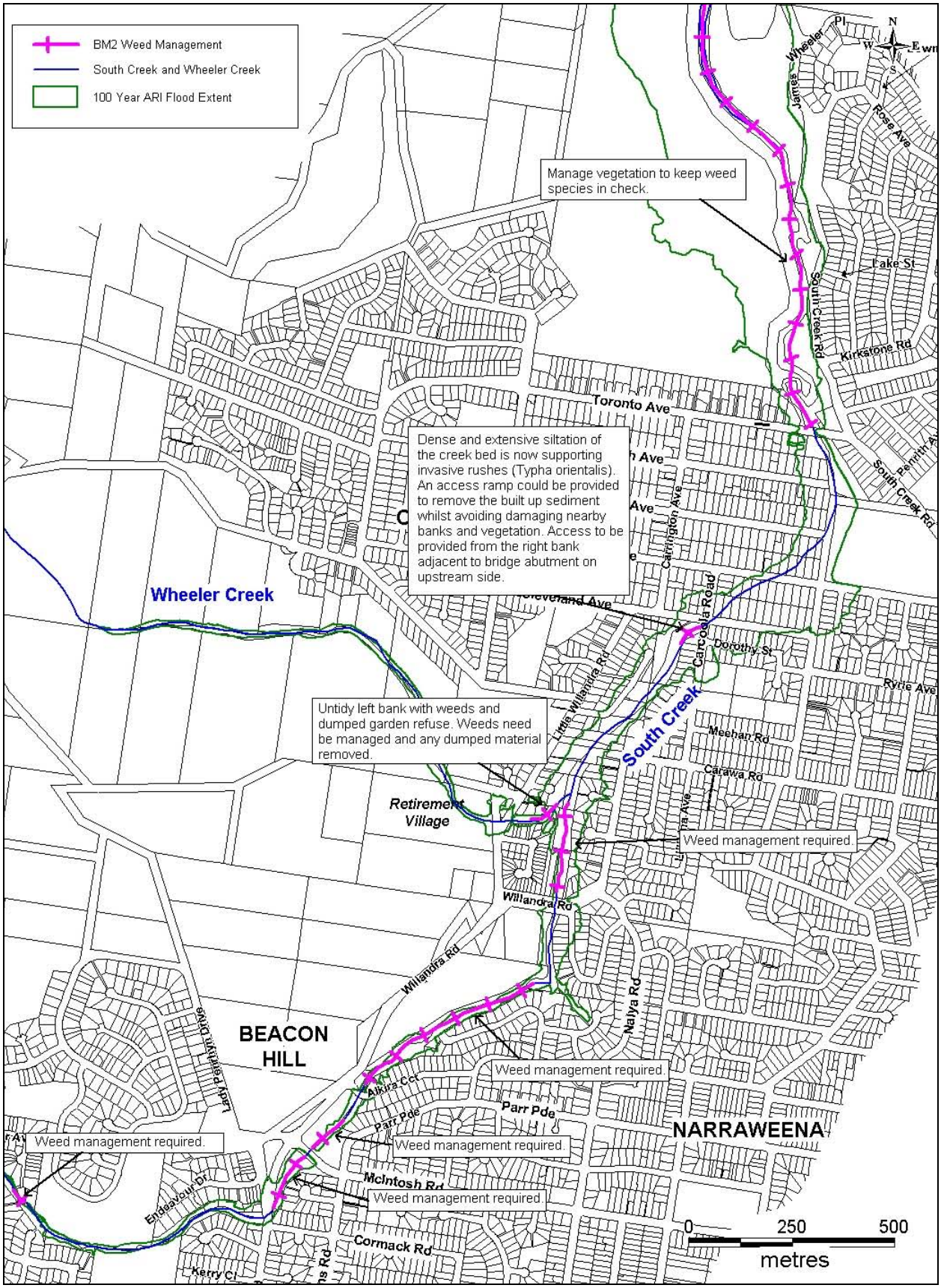

Figure 7.2 Weed and Sediment Management in South Creek and Wheeler Creek (BM2)

8. IMPLEMENTATION PROGRAM

The implementation program essentially forms the action list for this Plan. This implementation plan is shown on **Table 8.1 and Table 8.2** on the following pages and is divided into two parts:

- major works (substantial capital expenditure); and
- minor works, planning tasks or further investigation actions.

In terms of staging of works, the order in which the actions are shown in the Action Plan should be viewed as a guide to the order in which works or studies should be undertaken. In addition, the works have been prioritised as “High”, “Medium” and “Low”.

The implementation actions are also shown spatially in summary form on **Figure 8.1**.

The next steps to progress the floodplain management process from this point onwards are:

1. Council to adopt the Plan and submit an application for funding assistance through the NSW Government’s Floodplain Management Program and other agencies as appropriate; and
2. As funds become available implement the measures in accordance with the established priorities.

The allocation of funding under the NSW Government’s Floodplain Management Program depends on the eligibility of the measure (e.g. flood risk reduction benefits, costs, level of community / Council support etc), priority of the measure and availability of both Council and Government funds.

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

It should be noted, that whilst Action FM5 (the wetland) ranks very highly in the Matrix; it is possible that funding will not be available of the amount required to implement this flood modification measure. Further, it should also be noted that FM5 and FM3 are mutually exclusive. That is, if one measure is implemented then the other will not be required. 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 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 8.1 Implementation Plan – Major Works[1]

ID	Description	Reduction in No. of Properties with Above Floor Flooding[2]	Benefit: Cost Ratio	Estimated Cost		Priority
				Capital	Recurrent[3]	
FM12	Preparation and Implementation of Culvert Maintenance Strategy for Stormwater Pipes and Culverts under Crossings of South Creek and Wheeler Creek	6	4.42	$ 40,000	$ 20,000	High
FM21	Debris Control Structure on Wheeler Creek	N/A	N/A	$ 30,000	$ 2,000	High
FM5[4]	Rehabilitate Creek and Construct Wetland between Carcoola Rd and Toronto Ave	22	0.10	$2,500,000	$ 40,000	High
BM1	Management of Weeds in South Creek Downstream of Carcoola Road	2	0.15	$ 416,000	$ 10,000	High
PM6	Voluntary House Purchase Program (State Government / Council Jointly Funded) - 1 property	N/A	0.24	$ 850,000	$ -	Medium
FM1	Levee to protect properties on Toronto Ave	2	0.41	$ 115,000	$ 1,000	Medium
BM2	Weed and Sediment Management in South Creek and Wheeler Creek	N/A	N/A	$ 200,000	$ 50,000	Medium
FM13	Enhance Willandra Road (lower) Culverts	N/A	N/A	$ 219,000	$ -	Medium
FM2	Enhance Toronto Ave Culverts	-1	0.25	$ 138,000	$ -	Low
FM3[4]	Creek Widening and Revegetation Upstream of Toronto Ave	1	0.16	$1,790,000	$ 5,000	Low
EM6	Flood depth markers placed on both sides of all roads crossing the creeks	N/A	N/A	$ 14,000	$ -	Low

[1] Implementation is dependant on the availability of funds and Council resources.
[2] Flooded above floor level in the 100 Year ARI event.
[3] Recurrent costs are not eligible for subsidy under the State/Commonwealth Floodplain Management Program.
[4] Mutually exclusive (*i.e.* only one of these options should be implemented). Funding availability will determine which option proceeds.
N/A – Note Available

Table 8.2 Implementation Plan – Minor Works, Planning Tasks & Further Investigations[1]

ID	Description	Reduction in No. of Properties with Above Floor Flooding[2]	Benefit: Cost Ratio	Estimated Cost		Priority
				Capital	Recurrent[3]	
EM5	Targeted Flood Education Programs	N/A	N/A	$ 40,000	$ 10,000	High
PM1	Ongoing implementation of development controls and guidelines for building work	N/A	N/A	$ -	$ 1,000	High
PM7	Review of Draft OSD Policy	N/A	N/A	$ 10,000	$ -	High
PM6	Voluntary House Purchase Further Investigation - 1 property	N/A	0.24	$ 850,000	$ -	High
EM2	Flood Warning Systems and Instrumentation	N/A	N/A	$ 1,000	$ 1,000	High
FM20	Detailed Assessment for potential Debris Control Structures	N/A	N/A	$ 30,000	$ -	Medium
PM2	Preparation of Flood Related Development Control Plan for Warringah LGA	N/A	N/A	$ 20,000	$ 2,000	Medium
EM4	Community education and awareness programs	N/A	N/A	$ 10,000	$ 2,000	Medium
EM3	Information Transfers to SES	N/A	N/A	$ 2,000	$ -	Medium
PM3	Guidelines for Public Domain Infrastructure	N/A	N/A	$ 15,000	$ 2,000	Medium
EM1	Preparation and Adoption of SES Local Flood Plan	N/A	N/A	$ 30,000	$ 2,000	Medium
PM8	Analysis of Localised Flood Planning Level Requirements	N/A	N/A	$ 20,000	$ 1,000	Low
EM7	Ongoing collection of flood information	N/A	N/A	$ -	$ 2,000	Ongoing

[1] Implementation is dependant on the availability of funds and Council resources.
[2] Flooded above floor level in the 100 Year ARI event.
[3] Recurrent costs are not eligible for subsidy under the State/Commonwealth Floodplain Management Program.
N/A – Note Available

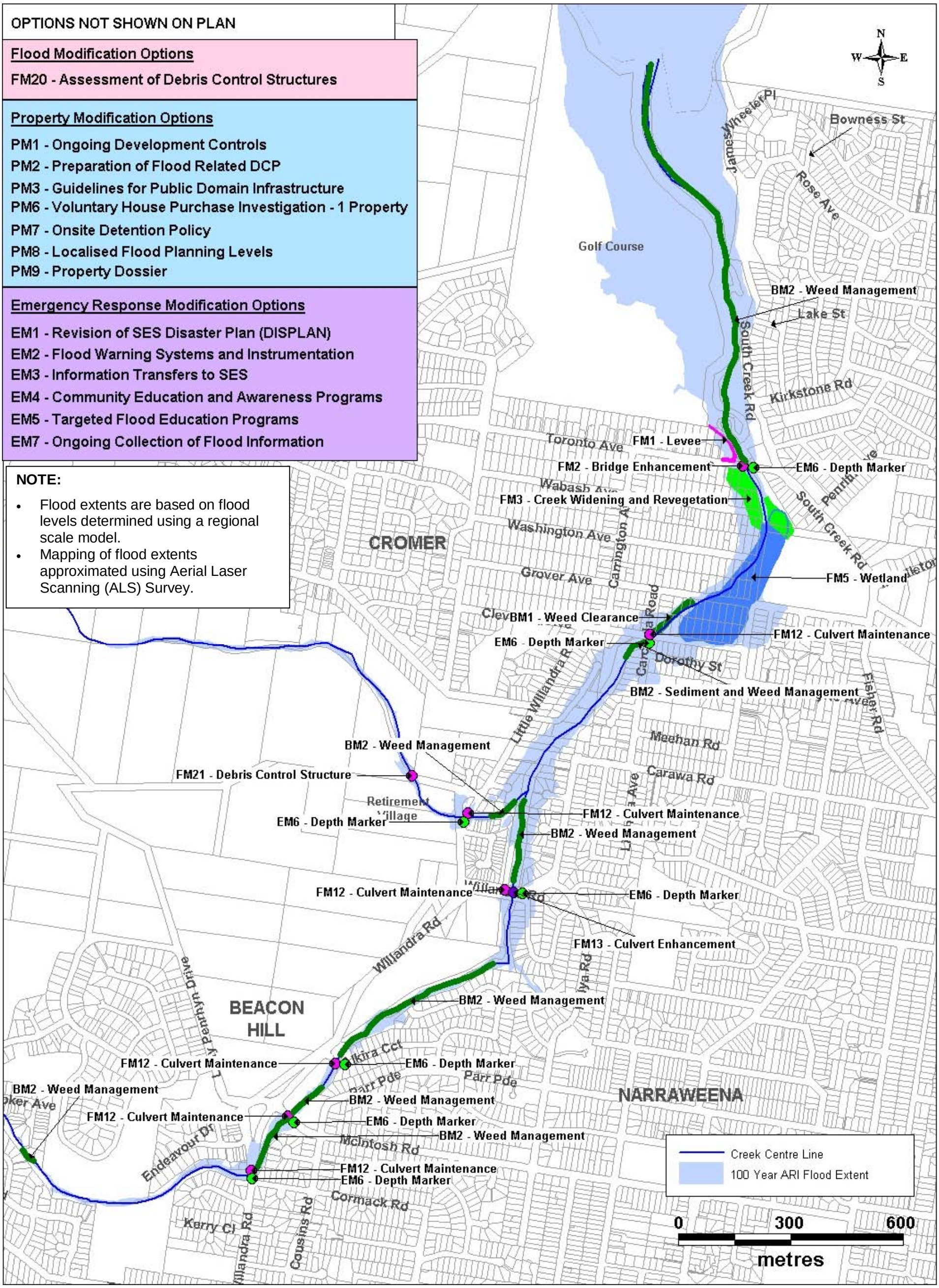

Figure 8.1 South Creek Floodplain Risk Management Plan

9. REFERENCES

Cardno Lawson Treloar, (2008a), *South Creek Floodplain Risk Management Study*, Prepared for Warringah Council.

Cardno Lawson Treloar, (2008b), *South Creek Bank Management Study*, Prepared for Warringah Council.

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APPENDIX A

South Creek Recommended Development Controls

RECOMMENDED SOUTH CREEK FLOODPLAIN ATTACHMENT TO FLOODPRONE LANDS DCP

SOUTH CREEK FLOOD BEHAVIOUR

South Creek Catchment is relatively steep for the majority of its length, with only a very small flat floodplain in its lower reaches. Due to the steep slopes, the time from the beginning of a storm event till the time at which the peak flood level occurs is relatively short. At most locations in the South Creek floodplain, the time till 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 flooding 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 all properties in the floodplain). As such, 'shelter-in-place' evacuation is often the only option.

The development controls relating to 'shelter-in-place' evacuation, 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'** 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.