Allans Creek Floodplain Risk Management Study

Report Prepared For

Wollongong City Council

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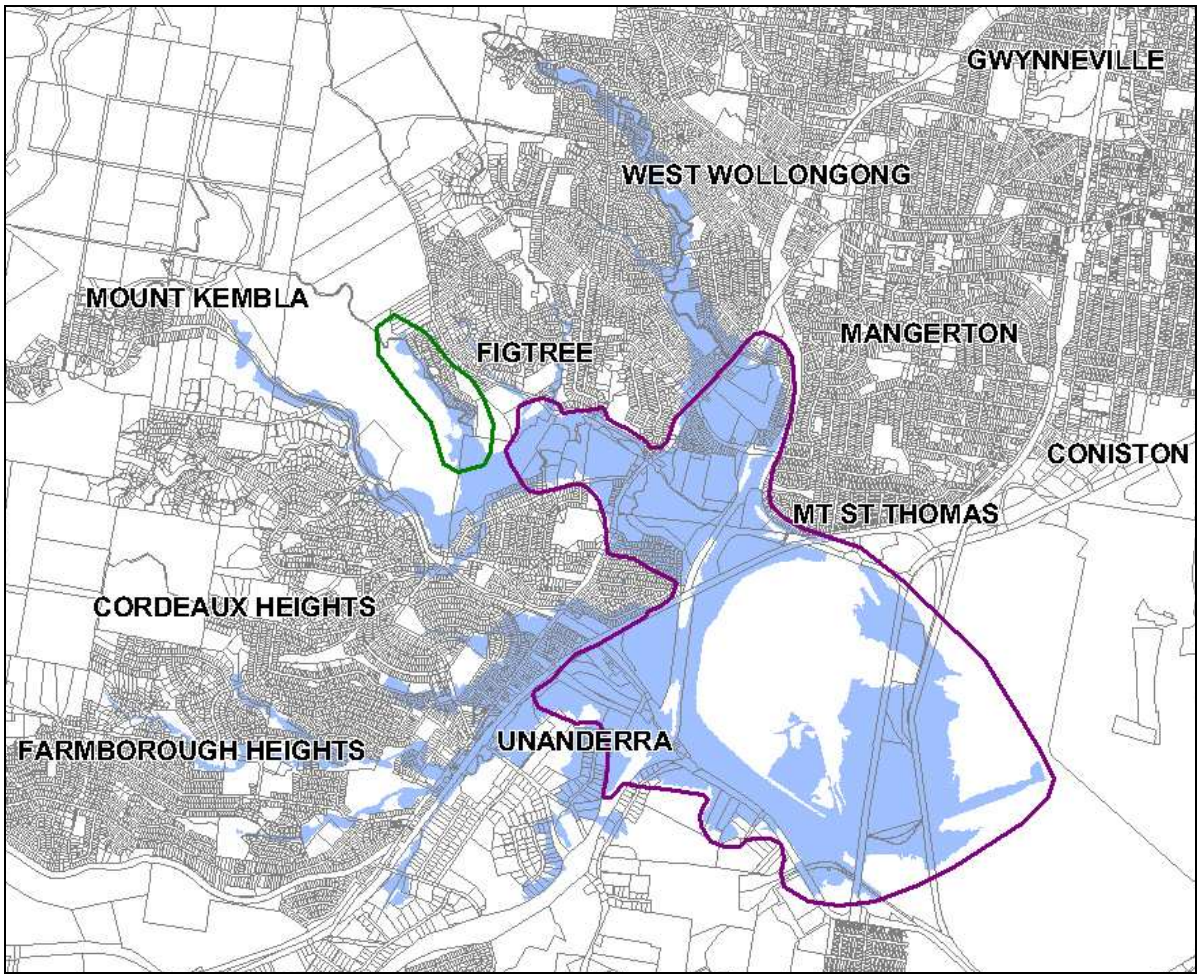
IMPORTANT INFORMATION

Due to the implementation of actions from the Allans Creek Floodplain Risk Management Plan and subsequent detailed investigations, the Allans Creek Flood Study (2006) has been updated to represent the current catchment conditions. These updates have resulted in two Addendum reports (Cardno Lawson Treloar, 2008, ref: R2346v3 and Cardno Lawson Treloar, 2009 ref: W4789v4), which supersedes a number of results presented in this study. It is therefore imperative that this Floodplain Risk Management Study is read in conjunction with the Addendum reports. Peak water levels, flows and velocities presented in this report for some areas have been superseded and must be taken from the Addendum reports. Figures showing flood extents have been superseded for the entire floodplain and must be read from the Addendum reports. It is the responsibility of the reader to ensure they have read the Addendum report before using the presented data.

The areas impacted by the Addendum reports are shown on the following page.

Area Impacted by Addendum 1 (Cardno Lawson Treloar, 2008, Ref: R2346v3) and Addendum 2 (Cardno Lawson Treloar, 2009, Ref: W4789v4)



NOTE: Flood levels, velocities and flows have been updated within the area shown above. Flood extents for the entire floodplain have been updated in Addendum 1, except for flood extents for the Darragh Drive area, which have been updated in Addendum 2.

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 mitigation works to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

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	Construction of flood mitigation works to protect existing development. Use of Environmental Planning Instruments to ensure new development is compatible with the flood hazard.

The Allans Creek Floodplain Management Committee was formed in 1995. Data Collection and the Flood Study were carried out concurrently with this study. This report forms the fourth stage of the management process for the Allans Creek Floodplain.

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

EXECUTIVE SUMMARY

Wollongong City Council commissioned Lawson and Treloar (now Cardno Lawson Treloar) to undertake a *Floodplain Risk Management Study* for the Allans Creek catchment.

The Allans Creek catchment and floodplain is a highly urbanised area within the Wollongong City Council local government area. The catchment of 42 km^2 lies to the south west of the Wollongong CBD and rises up to the Illawarra escarpment.

The main natural tributaries that drain the catchment are:

- Allans Creek
- American Creek
- Brandy and Water Creek (and tributary)
- Branch Creek (and tributary)
- Byarong Creek
- Charcoal Creek (and tributaries)
- Ghost Creek
- Jenkins Creek
- Nudjia Creek
- Running Brook.

A series of urbanised drainage systems also feed into these main tributaries along with a series of road areas and parks that act as floodways during rare and extreme events. These include:

- Arrow Avenue
- Bellevue Road
- Berkeley Road
- Blackman Parade
- Cleverdon Crescent
- Cordeaux Heights
- Cummins Creek
- Figtree Park
- Five Islands Road
- F6 Freeway (and tributary)
- Govett Crescent
- Grace Street
- Hargreaves Street
- Princes Highway (and tributary)
- O'Briens Road
- Railway
- Resolution Drive
- Rickard Road
- Various Drains in the Unanderra area
- Sheringa Grove
- Springhill Road
- Tresnan Road
- Wallawa Street/Bellevue Road
- Westfield (Figtree).

The Catchment and Creeks

The catchment is characterised by steep upper slopes with limited development and a floodplain with a mix of residential, commercial and industrial development. The Creek systems are highly modified in some locations, consisting of concrete pipes and open channels draining ultimately through the Bluescope Steel industrial area to Port Kembla.

Development of Port Kembla Harbour in the mid 1900s has resulted in the lowland and former estuarine areas of the Allans Creek catchment being more modified than in any other catchment of the Illawarra region (Forbes Rigby, 2002).

In most other areas the creeks are in a natural condition but their integrity is compromised by the impacts of catchment development.

Major transport routes through the catchment include the F6 Freeway, the Princes Highway and the Illawarra Railway Line. These major links cross the various tributary creeks with bridges and/or culverts, which are major controls to flooding.

The Issue of Flooding

In the past, flooding within the Allans Creek catchment has caused property damage and posed a high hazard to the residents living in close proximity to major watercourses and drainage channels in the area. Additionally major transport links and local roads have been inundated by flood waters making evacuation difficult. Flooding of developed areas within the catchment has been reasonably frequent in recent times. Over the past decades, Allans Creek has experienced significant flood events including those in March 1975, March 1978, March 1983, October 1983, February 1984, June 1991, August 1998 and October 1999.

Due to the large nature of the catchment and the significant variation in the amount of rainfall across the catchment, the August 1998 and October 1999 events were of varying magnitudes depending on the locality. For example, the August 1998 event was most

severe in the northern parts of the catchment, whilst the October 1999 event was most severe in the southern parts of the catchment. During both of these events a number of properties were affected and a significant cleanup operation was required following the flood.

In the 1998 and 1999 flood events, significant blockage of culverts was observed throughout the floodplain. These blockages resulted in flood levels being elevated in areas upstream of structures that blocked and in some cases, the creation of flow diversion paths.

Flood Behaviour - Existing Conditions

The rainfall characteristics of the Illawarra Escarpment, the steep topography and the high probability of culverts blocking during flood events exacerbate the flood behaviour of the area in comparison to other urban areas in New South Wales (Lawson and Treloar, 2006).

Design flows for the catchment were calculated using a hydrological model (RAFTS). To calculate design flood levels and velocities, a MIKE11 hydraulic model was established and calibrated to available historical flood information. This included the use of information relating to the blockage of culverts. The information available on conduit blockage was utilised, along with information from other catchments, to develop a blockage policy.

Design flood events were considered using the hydrologic and hydraulic models. These events included the 5, 10, 20, 50, 100 year ARI and the Probable Maximum Flood (PMF) in accordance with current practice.

The findings of the study indicate that a number of properties within the floodplain are susceptible to above-floor flooding, even in the 5 year ARI event.

Aims of the Study

This *Floodplain Risk Management Study* has investigated what can be done to minimise the effects of flooding in the Allans Creek catchment. The *Floodplain Risk Management Plan* (the next stage) will recommend a strategy to meet this objective.

Specific objectives of this study include:

- the implementation of a community consultation strategy, to ensure community input is obtained at key times throughout the study
- a description and quantification of the flood issues in the Allans 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
- the assessment of options on a common basis to outline the best measures to reduce flood risk based on environmental, social, economic, financial and engineering considerations.

Impacts and Costs of Flooding

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

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

Flood (ARI)	Res.	Com.	Indus.	Flood Damage ($'000,000)
5 yr	44	12	4	10
10 yr	65	13	7	16
20 yr	230	18	29	111
50 yr	276	21	33	130
100 yr	317	25	34	146
PMF	507	64	64	378
Average Annual Damage				13.5
Present Worth of Damage (50 yr, 7%)				186

Options to Manage Flooding

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

These options included:

- flood modification measures,
- property modification measures, and
- emergency response modification measures.

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

Flood Risk Precincts

Wollongong City Council has adopted an approach of classifying areas of the floodplain by the potential risk associated with these areas referred to as 'flood risk precincts'. This is in accordance with the flood-related development control plan - *Managing Our Flood Risks* (DCP 54, 2004). This document specifies the following definitions for the application of flood risk precincts for the Local Government Area:

- **High Flood Risk Precinct** - Most development should be restricted in this precinct. Stringent development controls are applied.

- **Medium Flood Risk Precinct** - In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls, and

- **Low Flood Risk Precinct** - The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and below the PMF, most land uses would be permitted within this precinct.

Options Assessment

Hydraulic modelling of the flood modification options was undertaken along with an assessment of the economic, social, environmental, land use, heritage and planning issues. The assessment found that the highest scored flood modification options that have positive social and environmental impact included:

- Modification of the American Creek culverts under the F6 Freeway
- Riparian corridor management for the entire creek system
- Debris control structures for a range of locations
- Improvements at the Princes Highway Bridge crossing of Byarong Creek and Associated Upstream Creek Works
- Creek works on Byarong Creek between the Princes Highway and The Avenue
- Amplification of The Avenue culverts (Byarong Creek)
- Creek modification works and flood detention area between Lindsay Maynes Park and Upstream of Railway, Unanderra
- Creek works for American Creek between Gibsons Road and Princes Highway
- Creek works on Charcoal Creek between Blackman Parade and Tallegalla Street
- Removal of F6 median strip
- Bund on western side of Govett Crescent
- Program of house raising and voluntary purchase (depending on construction type and level of risk) for the limited number of properties not benefited by proposed works
- Implementation of a voluntary house raising program.
- Stormwater Drainage and Overland flow path modifications – Arrow Avenue/Bellevue Road.
- Lowering of the floodplain on the western bank of Brandy and Water Creek at the Southern end of Darragh Drive.

Property modification measures considered and recommended for the floodplain include:

- Development Controls
- Guidelines for infrastructure
- House Raising Program
- Voluntary Purchase Program
- Provision of a Flood Refuge within the Figtree Gardens Caravan Park
- Zoning Modifications
- Rewording Of Section 149 Certificates
- Policy preparation and revisions (e.g. Caravan Park Policy and On-Site Detention Policy)
- Data Collection Strategies
- Public Awareness and Education for Property matters.

Emergency response modification measures proposed for the floodplain include:

- Periodic Revision Of Displan/Flood Sub Plan Preliminary Assessments for the establishment of a Trial SMS Service
- Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system)
- Relocation Of Combat Agency Headquarters (Police)
- Electronic Information Transfer Agreement For Council Held Information To SES
- Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES
- Public Awareness and Education.

The following measures ranked highly using a multi-criteria matrix assessment and are to be considered for inclusion in the Floodplain Risk Management Plan:

- Riparian corridor management of channels and associated vegetation
- Public Awareness and Education
- Electronic information transfer agreements
- Debris Control Structure(s)
- Issue information relating to Flood Extents to the SES
- Adoption of a Development Control Matrix
- Guidelines For Infrastructure
- Rewording Of Section 149(5) Certificates.

Key Findings

The flood modification options assessed using modelling that have the greatest cost:benefit ratio (greater than 0.5) are:

- Construction of a bridge to replace the culverts at the American Creek Crossing of the F6 Freeway, C:B of 0.96, 74 properties with over-floor flooding eliminated at the 100 year ARI (Option 1, details in Section 8.2.1, Identifier FM55)
- Construction of a range of bridges and works in the lower floodplain near the F6 Freeway, C:B of 0.69, 121 properties with over-floor flooding eliminated at the 100 year ARI (Option 11, details in Section 8.2.11, Identifiers FM18, FM20, FM37, FM38, FM 55, FM59).

It is important to note that the bridge at the American Creek crossing of the F6 Freeway (Option 1, FM55) forms part of the works associated with the works in the lower floodplain (Option 11). Thus, it is recommended that the American Creek bridge is constructed first, followed by the other works associated with Option 11. The lower floodplain works have significant social benefits, resulting in the reduction of over-floor flooding for over 120 properties.

In addition to these works, a range of properties are eligible for house raising. A total of 48 properties were specifically identified for house raising, with the benefit:cost ratio being the most substantial of any option considered, at 6.25.

The results of multi-criteria matrix assessment indicates that there is substantial benefit to be gained by implementing a range of cost-effective measures. The matrix approach indicates that there are essentially two approaches that can occur concurrently:

- those that require major capital investment with associated major or minor recurrent expenditure (generally major capital works)
- those that require minor capital investment with associated major or minor recurrent expenditure (generally minor works or planning).

Both approaches are required to manage the floodplain in a holistic sense. As a consequence, a mixture of the two approaches are recommended. The two types of activities can run concurrently through the life of the implementation of the Floodplain Risk Management Plan.

A key finding of the assessment of all of the options is that there is no complete set of options that can be economically implemented to remove the risk of flooding entirely from the floodplain. A large range of options were evaluated and many are identified as being suitable for implementation, yet the need for ongoing management of the residual or continuing risks in the floodplain will require management. This management, through appropriate emergency preparation and response, will aid in reducing future flood damages in the catchment.

The Next Step

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

GLOSSARY OF TERMS*

Annual Exceedence Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1%AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Reccurence Interval (ARI)	The long term average number of years between the occurrence of a flood as big as or larger than, the selected event. For example, the 100 year ARI flood event will occur on average once every 100 years.
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 in 1 year or 100%AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.

Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.

High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
High Flood Risk Precinct	This has been defined as the area within the envelop of land subject to a high hydraulic hazard (in accordance with the provisional criteria outlined in the Floodplain Development Manual) in a 100 year flood event together with all land within a corridor 10m from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would significantly and adversely effect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.
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.
Low Flood Risk Precinct	This has been defined as all other land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within either the High Flood Risk (and Interim Riverine Corridor) or the Medium Flood Risk Precinct, where risk of damages are low for most land uses. The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and most land uses would be permitted within this precinct.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.

Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Medium Flood Risk Precinct	This has been defined as land below the 100 year flood level (plus 0.5m freeboard) that is not within the High Flood Risk (and Interim Riverine Corridor) Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined by the Floodplain Development Manual). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.
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 Exceedence 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
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AMG	Australian Mapping Grid
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
CMB	Catchment Management Board
DCP	Development Control Plan
DHI	Danish Hydraulics Institute
DIPNR	Department of Infrastructure, Planning and Natural Resources (now Department of Natural Resources and Department of Planning)
DLWC	Department of Land and Water Conservation (now Department of Natural Resources)
DNR	Department of Natural Resources
DoP	Department of Planning
DPWS	Department of Public Works and Services (now Department of Commerce)
DUAP	Department of Urban Affairs and Planning (now Department of Planning)
EPA	Environmental Protection Authority (now Department of Environment and Conservation)
EPI	Environmental Planning Instrument
ESD	Ecologically Sustainable Development
FPL	Flood Planning Level
FRMC	Floodplain Risk Management Committee
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
GIS	Geographic Information System
GSDM	Generalised Short Duration Method
ha	hectare
HAT	Highest Astronomical Tide

IEAust	Institution of Engineers, Australia (now referred to as Engineers Australia)
IFD	Intensity Frequency Duration
km	kilometres
km^2	Square kilometres
L&T	Lawson & Treloar
LAT	Lowest Astronomical Tide
LEP	Local Environment Plan
LGA	Local Government Area
LIC	Land Information Centre
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	Metres to Australian Height Datum
MHIs	Maximum Height Indicators
MHL	Manly Hydraulics Laboratory
MHWL	Mean High Water Level
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MIKE11	MIKE11 proprietary software package
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
mm	millimetre
m/s	metres per second
MSL	Mean Sea Level
NPWS	National Parks and Wildlife Service (now within the Department of Environment and Conservation)
NSW	New South Wales
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWD	Public Works Department New South Wales

RAFTS	RAFTS proprietary software package
REP	Regional Environmental Plan
RTA	Roads and Traffic Authority
SCA	Sydney Catchment Authority
SCARM	Standing Committee on Agriculture and Resource Management
SEPP	State Environmental Planning Policy
SES	State Emergency Service
SRA	State Rail Authority (now RailCorp)
WBNM	Watershed Bounded Network Model
WCC	Wollongong City Council

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1. INTRODUCTION

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

A locality plan can be found in Figure 1.1.

1.1 Study Context

Flooding in Allans Creek has caused property damage and continues to pose a high hazard to some residents living within close proximity to the major creeks and drainage channels in the area. This has prompted Wollongong City Council, through the Allans Creek Floodplain Management Committee, to prepare a comprehensive Floodplain Risk Management Plan for the Allans Creek Floodplain. The staged movement toward the development of such a Plan is part of the NSW State Government's program to manage major flood impacts and hazards on floodplains, in accordance with the Floodplain Development Manual (NSW Government, 2005).

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

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

This study was originally commissioned in 1995 as part of a series of studies including:

- the revision and integration of the existing flood studies for the area (PWD, 1991, WCC, 1994) (a separate report)
- preparation of a floodplain risk management study (this report)
- preparation of a floodplain risk management plan (a separate report).

The study was jointly funded by Council and the Department of Natural Resources. The Department also assists in the provision of specialist advice on flooding and related matters.

The original flood study revision was presented in draft form to Council immediately prior to major flooding in August 1998. The catchment was subsequently subjected to major flooding again in October 1999.

During the time between and after the floods of August 1998 and October 1999, all three components outlined above were suspended in order to gather all available

data on the two floods and undertake some local studies to define specific flood behaviour on a smaller scale.

As a result, considerable revision was undertaken to reschematise and recalibrate the models based on the information obtained from the two floods and significant additional ground survey. This work is reported in a detailed separate report, the Flood Study (Lawson and Treloar, 2006).

Options were then identified with the knowledge of the behaviour of the two floods and the experience gained by emergency service personnel (SES), Council and related organisations. The identification and assessment of these options is a key objective of this study.

1.2 Study Objectives

The objectives of the study are to:

- implement a community consultation strategy, to ensure community input is obtained at key times throughout the study
- describe and quantify flood issues in the Allans Creek catchment including an assessment of the likely cost of flooding to the community
- identify and assess potential floodplain risk management measures to reduce the risks and hazards of flooding
- review of issues relating to planning and development control within both the catchment and floodplain
- review issues relating to emergency management within both the Allans Creek Floodplain and issues relating to adjacent floodplain areas, and
- assess options on a common basis to outline the best measures to reduce flood risk based on environmental, social, economic, financial and engineering considerations.

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

1.3 Study Methodology

The report format follows the study methodology, which involved:

- An overview of the features of the catchment and floodplain (also utilised in the assessment of the impact of proposed options) (Section 2)
- Details of the stakeholder consultation undertaken for the study (Section 3)
- An overview of the existing flood behaviour and issues (Section 4)
- An assessment of the existing flood economic impact (flood damages) (Section 5)
- Details of the proposed flood planning level and the selection process (Section 6)
- An overview of the potential options for the management of flooding (Section 7)
- An assessment of those flood modification (or structural) options identified as being suitable for various parts of the Allans Creek floodplain (Section 8)
- An assessment of those property modification options identified as being suitable for various parts of the Allans Creek floodplain (Section 9)

- An assessment of those emergency response modification options identified as being suitable for the Allans Creek floodplain (Section 10)
- A multi-criteria matrix assessment of all possible options (Section 11)
- Recommendations and conclusions of the study for the next stage in the floodplain management process, the floodplain risk management plan (Section 12).

2. CATCHMENT AND FLOODPLAIN OVERVIEW

2.1 Catchment Topography

The Allans Creek catchment, to the south-west of the Wollongong CBD, drains a catchment area of approximately 42km^2 from the Illawarra Range to the Port Kembla Inner Harbour. The Allans Creek catchment is shown in Figure 1.1.

The Allans Creek catchment is characterised by a low flat floodplain west of Port Kembla, which is dominated by the backdrop of the Illawarra Escarpment. The escarpment rises to a height of 530m AHD at Mt Kembla, but more impressive is the slope of the escarpment, which rises the last 500m over a horizontal distance of approximately 3km. The steep western areas of the catchment, near the Illawarra Escarpment are mainly forested or rural in nature, while closer to the coast the catchment floodplain is relatively flat with a blend of industrial, residential and commercial development.

2.2 Land Use, Zoning and Tenure

Land use within the catchment has changed considerably over the last century. The most notable change within the catchment has been the significant acceleration of land use change between 1948 and 1993, during which time the area of urban industrial land increased from 10% of the catchment to 56% (Forbes Rigby, 2002).

The current land use proportions within the catchment from the Wollongong City Council Local Environment Plan (1990) were extracted using GIS tools and are detailed in Table 2.1 and are shown in Figure 2.1. It should be noted that whilst some areas are zoned for a particular use, they may not yet have been developed for that purpose (e.g. land zoned 2(a)).

Table 2.1 Land Use in the Catchment

Zone	Area (ha)	Percentage of Total
1 (Non Urban Zone)	415.10	9.77%
2(a1) (Special Low Density Residential Zone	13.96	0.33%
2(a) (Low Density Residential Zone)	1036.00	24.40%
2(b) (Medium Density Residential Zone)	63.36	1.49%
3(a) (General Business Zone)	9.55	0.22%
3(b) (Neighbourhood Business Zone)	2.44	0.06%
3(d) (Commercial Services Zone)	4.98	0.12%
4(a) (Light Industrial Zone)	104.00	2.45%
4(b) (Heavy Industrial Zone)	623.90	14.69%
5(a) (Special Uses Zone)	4.37	0.10%
5(b) (Special Uses Zone)	43.04	1.01%
5(c) (Special Uses Zone)	154.60	3.64%
6(a) (Public Recreation Zone)	206.20	4.86%
6(b) (Private Recreation Zone)	18.87	0.44%
6(c) (Tourism Zone)	4.76	0.11%
7(a) (Special Environmental Protection Zone)	204.90	4.82%
7(b) (Environmental Protection Conservation Zone)	496.10	11.68%

Zone	Area (ha)	Percentage of Total
7(c) (Environmental Protection Residential Zone)	162.70	3.83%
7(c1) (Environmental Protection Rural Residential Zone)	10.51	0.25%
8(b) (State Recreation Areas Zone)	665.60	15.67%
9(b) (Road Reservation Zone)	1.71	0.04%
Total	**4246.64**	**100%**

The dominant land use within the catchment is low density residential (24%). Residential development is predominantly located in the middle to lower reaches of the catchment. The suburbs of Cordeaux Heights, Cringila, Farmborough Heights, Figtree, Mangerton, Mount Keira, Mount Kembla, Port Kembla North, Unanderra and West Wollongong are incorporated in the study area. Significant commercial and industrial areas (14%) are located in the lower portions of the catchment leading to Port Kembla Harbour which is the downstream boundary of the Creek system. The headwaters of the catchment are characterised by State Recreation areas (15%) and Conservation Zone areas (11%). Another important characteristic is the proportion of non-urban lands (Zone 1, approximately 10%) in the upper reaches of the catchment with the potential for rezoning and possible future land release and subdivision for residential development.

Details of permissible land uses within the different LEP (1990) zones are discussed in Section 2.11.

A complex issue of tenure and responsibility is presented in the matter of the tenure of the land in the floodplain. A significant portion of the actual channel as well as the riparian zone of the creek systems lies within private ownership. Examples where this is not the case are limited to public reserve areas within the catchment. As such, Council has limited access to those areas in private ownership for the maintenance of the continuity of the overall creek system.

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

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

The Department of Lands and Wollongong City Council are the custodians and managers of Crown land within the Allans Creek catchment.

2.3 Main Channel and Tributaries

Allans Creek and its tributaries are highly modified systems with both piped and open channel sections. Open channel sections range from natural sections in the upper reaches and grassed, natural and concrete lined in the lower reaches.

The main natural tributaries that drain the catchment are:

- Allans Creek
- American Creek
- Brandy and Water Creek (and tributary)
- Branch Creek (and tributary)
- Byarong Creek
- Charcoal Creek (and tributaries)
- Ghost Creek
- Jenkins Creek
- Nudjia Creek
- Running Brook.

A series of urbanised drainage systems also feed into these main tributaries along with a series of road areas and parks that act as floodways during rare and extreme events. These include:

- Arrow Avenue
- Bellevue Road
- Berkeley Road
- Blackman Parade
- Cleverdon Crescent
- Cordeaux Road
- Cummins Creek
- Figtree Park
- Five Islands Road
- F6 Freeway (and tributary)
- Govett Crescent
- Grace Street
- Hargreaves Street
- Princes Highway (and tributary)
- O'Briens Road
- Railway
- Resolution Drive
- Rickard Road
- Various Drains in the Unanderra area
- Sheringa Grove
- Springhill Road
- Tresnan Road
- Wallawa Street/Bellevue Road
- Westfield (Figtree).

Tributary creek systems are shown in Figure 2.2.

The result is a hydrologically complex system in the lower reaches, with varied catchment timing and differences in flood peaks providing several flooding mechanisms (Lawson and Treloar, 2006).

Urban development in the catchment has considerably altered the waterways and floodplains from their natural state in some locations. The lower parts of the catchment are complex with over 70 bridge and culvert crossings. Major transport links that traverse the floodplain are the F6 freeway, the Princes Highway and the Illawarra Railway.

Other modifying actions to the main channel and tributaries include:

- Filling of the floodplain (e.g. for urban development, for old tip sites, for recreational space)
- Encroachment of urban development on the floodplain (e.g. residential development sited on the top of the channel banks in some instances or over the channel in other instances)
- Encroachment of industrial development on the floodplain in the lower reaches
- Realignment/creek straightening and channelisation and/or concrete lining of some of the creek channels and resulting bank and bed erosion
- Other activities causing bank and bed erosion
- Removal of native vegetation which would otherwise stabilise the channel banks
- Significant weed invasion within both the channel and overbank flows (e.g. lantana, coral trees, see Section 2.8).

A further complication is the modified outlet (i.e. the construction of Port Kembla Harbour) and the influence of the ocean via Port Kembla Harbour, where severe storm surge may also interact with flood timing to produce elevated water levels that are not due solely to catchment flooding impacts. Further discussion of Port Kembla harbour can be found in Section 2.5.

2.4 Catchment and Creek Debris

Observations during a series of historical flood events (most recently the 1998 and 1999 flood events) indicated the potential for displacement and transport of a significant volume of a variety of types of material by floodwaters.

Debris types included:

- coarse sands, gravel and boulders (see Section 2.6 on erosive hazard of much of the soils in the upper portions of the catchment)
- weeds and other vegetation
- tree branches
- anthropogenic material (e.g. Sulo bins, mattresses, cars, shopping trolleys etc).

The effect of the transport of this debris during historical events was to block a number of culverts and handrails in the floodplain resulting in elevated flood levels (due to afflux at structures) and some diversion of flood flows.

As a result, following the 1998 and 1999 floods, Council has adopted a blockage policy to ensure that this aspect of the flood behaviour is included in the planning components of floodplain management. This policy and its implications for this study are discussed in Section 4.2.5. Full details of the effects of blockages on flood

behaviour in the Allans Creek system are located in the Allans Creek Flood Study (Lawson and Treloar, 2006).

2.5 Receiving Waters - Port Kembla

Allans Creek drains to Tom Thumb Lagoon and Port Kembla Harbour through the Bluescope Steel industrial area. Allans Creek is tidal as far upstream as the F6 Freeway. The tidal range details for Port Kembla Harbour are listed in Table 2.2.

Table 2.2 Tidal Range at Port Kembla (after Department of Defence, 2001)

Tide	Level (m LAT)	Level (m AHD)
HAT	2.0	1.17
MHWS	1.5	0.67
MHWN	1.3	0.47
MSL	0.9	0.07
MLWN	0.6	-0.23
MLWS	0.3	-0.53
LAT	0.0	-0.83

For the design flood event assessments for the Flood Study (Lawson and Treloar, 2006), a tidal boundary was developed for the downstream limit of the model. The tidal boundary used was an average tidal boundary that represented the mean high water level (MHWL) within Port Kembla. The tide was synchronised such that the peak of the high tide corresponded to the peak of the flood hydrograph at the downstream boundary for the critical duration in that reach. This is a conservative approach from a probabilistic perspective. The expected water level in the harbour will be approximately mean sea level (MSL, approximately 0 mAHD).

The Port Kembla Ports Corporation (PKPC) reports that a significant load of debris is deposited in the Harbour each year from the Allans Creek system. The PKPC commissioned a study (Forbes Rigby, 2002), in association with DNR and Council to consider current issues with regard to the riparian and geomorphological aspects of the Allans Creek system and to identify possible management options to reduce the load of debris arriving at the Port.

2.6 Geology, Soils, Sediments and Geomorphology

The catchment geology comprises Triassic age, Narrabeen Group sandstone and siltstone overlying Permian age Illawarra Coal Measures with talus foothill slopes (Forbes Rigby, 2000). Quaternary deposits of alluvium, sands and silts are present on the floodplains and in the swamps (Forbes Rigby, 2000).

Soil maps of the south coast area cover the entire catchment and indicate the following soil types as outlined in Table 2.3.

Table 2.3 Soil Types and Locations (after Hazelton et al, 1990)

Code	Name	Grouping	Allans Creek Location and Comment
xx	Disturbed	Disturbed	Lower portions of the catchment and floodplain in the Bluescope Steel and Port areas.
fa	Fairy Meadow	Swamp	Mid portions of the catchment and floodplain. Limited by flood hazard, low wet bearing strength, highly permeable soils and high seasonal water tables.
gw	Gwynneville	Residual	Mid portions of the catchment and floodplain and American Creek area. Limited by extreme erosion hazard, steep slopes, mass movement hazard, local flooding, reactive subsoils and impermeable low wet bearing strength clay subsoils.
bk	Berkeley	Residual	Mid portions of the catchment and floodplain. Limited by mass movement hazard, extreme erosion hazard, reactive subsoils and in local areas can impede drainage.
ie	Illawarra Escarpment	Colluvial	Upper portions of the catchment and Byarong Creek. Limited by mass movement and rockfall hazard, steep slopes and extreme erosion hazard, reactive, low wet bearing strength sub soils, low to moderate soil fertility.

Table 2.3 indicates that there are a number of soil types within the catchment that have been identified to have an erosion hazard (e.g. Gwynneville residual soils which have an extreme hazard). This issue of erosion hazard has implications for the types of floodplain management works that are appropriate and also has implications for the manner in which any works are constructed (particularly with regard to the management of erosion during the construction process). Once eroded from either the catchment, banks or bed of the channels, sediment can then be transported down the channel in a single or a series of events.

Reinfeld and Nanson (2001) report on the geomorphology of the Illawarra area with respect to flood impacts, particularly with reference to the August 1998 event. Some details specific to the Allans Creek system are included in their investigations. They report that:

- erosion of the channel banks as a result of the 1998 flood was widespread in streams within the escarpment foothills (mainly those areas that are developed for urban or rural purposes)
- examples of erosion include bank erosion along Byarong Creek where basalt boulders, approximately 800 mm in diameter placed for protection works prior to the event around the outsides of bends were undermined and transported for short distances downstream before being deposited in 1 - 1.5m thick poorly sorted bars
- in areas where residential development had encroached on streams (resulting in infilling of the floodplain and steepening of channel banks to maximise developable area), undermining and resulting bank collapse (of a variety of fill and building materials including brick, concrete, rock and gabions) was common
- channels throughout the region were scoured due to the erosion of benches and the partial retreat of banks, especially along the outsides of bends and at culvert outlets

- blockage of culverts and bridges affected local hydraulics resulting in scour where flows re-entered streams
- bridges and culverts also contributed to stream bed aggradation through blockage and subsequent reduction of peak flow velocities
- upstream knickpoint migration through alluvium in streams on the coastal plain resulted in significant erosion as well as in escarpment streams cutting through colluvial materials
- substantial sediment and woody debris deposition was widespread over floodplains along streams
- cobble-dominated sediment fans were deposited in areas of reduced channel gradient on escarpment benches and in escarpment foothills.

The net effect of these significant changes in the geomorphology of the creeks from a floodplain management perspective is the change in cross sectional area at different points in the floodplain that may result in a variation in the hydraulic behaviour of the system. This may result in hydraulic controls (through constrictions where deposition has occurred and an associated increase in the local flood planning level) or a change in the timing of the peak flow in the lower reaches. There are also implications for erosion risks threatening development. It is likely that future large events will also result in similar significant changes to the channels and floodplains and that as a result, modifications to the setbacks for buildings from the channels and creek systems will play an important policy option for Council to minimise the risks of property damage for future development. The impacts of sedimentation also need to be considered in the sensitivity of flood planning level determination.

Whilst the larger bed load material is generally not transported far downstream, the final destination for finer-graded eroded materials and debris is Port Kembla Harbour. A study to investigate issues of sediment generation, transport and deposition, along with current riparian vegetation management issues within the major tributaries of the Allans Creek catchment has recently been completed (Forbes Rigby, 2002). This study found that:

- investigations/calculations by the Port Kembla Ports Corporation found that the August 1998 event resulted in a net loss of around 400,000 m^3 from both the inner and outer harbour areas, suggesting that large flood events can lead to a reduction in sediment in the harbour, however smaller flood events may re-mobilise sediments deposited in the middle reaches of Allans Creek during historical events (such as August 1998) and contribute to accretion of sediments in the harbour.
- detailed information is not held by the PKPC on dredge volumes from periodic dredging of the Harbour, but around 20,000 m^3 is dredged every 3 - 5 years to maintain the harbour at its current depth
- analysis of chart data from the period 1980 - 1999 indicates that approximately 40,000 m^3 of additional sediment has accumulated in the western basin (most likely source is Allans Creek. However, given that 20,000 m^3 of material is dredged every 3 - 5 years then the volume is likely to be greater than this and estimates indicate a total sediment accretion of 60,000m^3
- approximately 4700 tonnes/year of sediment is delivered from Allans Creek to the Harbour (these estimates do not differentiate whether the source is continuous or episodic). Large flood events such as occurred in August 1998 can lead to

massive sediment export rates typically 10 times higher than the rate which could be expected during a typical wet year.

It is therefore fundamental that strategies to manage creek bank erosion and other sediment sources (such as construction sites) are implemented to mitigate the impacts of such erosion on flood behaviour and stream integrity.

In addition to the erosive hazard of some of the soil types, some soils in the area have a risk of being acid sulfate. Acid sulfate soils are located in the lower portions of the catchment area and detailed risk maps have been prepared by the Department of Natural Resources (DLWC, 1997, Edition 2) showing high risk areas downstream of the F6 Freeway. Given the potential presence of these soil types it is important that any proposed floodplain management works that require excavation be accompanied by appropriate geotechnical investigations and precautionary management planning.

2.7 Water Quality, River Flow and Associated Objectives

Allans Creek is the main freshwater inflow to Port Kembla. It receives runoff from urban development and open space and stormwater pipe discharges. The water quality of the entire system is variable from a likely good quality in the upper reaches where the streams are not impacted by development to degraded in the lower reaches where impacts of development are considerable.

Forbes Rigby (2002) report that there are 19 licensed discharges under the NSW EPA load based licensing program. These discharges are located in the lower portions of Allans Creek (within the industrial area) and also within the upper portions of the American Creek system (upstream of the upper limit of the defined floodplain) at Mount Kembla.

Forbes Rigby (2000) also report that there are 17 formal sewer overflow points within the catchment from the Sydney Water sewer system. These are spread throughout the catchment but are generally located within the creekline corridor within the floodplain. As such, it is likely that these systems will overflow in times of flood and may result in a health risk.

DLWC (2000) reports water quality and river flow interim environmental objectives for the Allans Creek system (part of the Illawarra catchments). These are summarised in Table 2.4.

Table 2.4 Interim Water Quality and River Environmental Flow Objectives*

Area of System	Water Quality Objectives	River Flow Objectives	Comments
Mainly Forested Areas	Protection of: • aquatic ecosystems • visual amenity • secondary contact recreation • primary contact recreation • drinking water at point of supply – disinfection only	Protection of: • maintain natural flow variability • maintain natural rates of change in water levels • minimise effects of weirs and other structures	• High level protection should be given to flows and water quality in the least affected streams • Relative health and naturalness of these streams should be protected
Waterways Affected by Urban Development	Protection of: • aquatic ecosystems • visual amenity • secondary contact recreation (within 5 years) • primary contact recreation (longer term objective)	Protection of: • important rises in water levels • maintain natural flow variability • maintain natural rates of change in water levels • minimise effects of weirs and other structures	• Some urban waterways are considerably modified, a return to pristine aquatic ecosystems is unlikely and impractical • Action is needed to reduce stormwater and sewage discharges • Flooding highlighted as a concern
Uncontrolled Streams	Protection of: • aquatic ecosystems • visual amenity • secondary contact recreation • primary contact recreation • livestock water supply • irrigation water supply • homestead water supply	Protection of: • protect pools in dry times • protect natural low flows • maintain natural flow variability • maintain groundwater for ecosystems • minimise effects of weirs and other structures	• Water quality affected by clearing of riparian areas • Plans for rural/residential housing will further intensify development impacts on water quality • Strict controls on future development will be needed
Estuaries/Harbours	Protection of: • aquatic ecosystems • visual amenity • secondary contact recreation • primary contact recreation • aquatic foods (cooked)	Protection of: • maintain wetland and floodplain inundation • manage groundwater for ecosystems • minimise effects of weirs and other structures • maintain or rehabilitate estuarine processes and habitats	• Reference is made to Port Kembla Harbour and Allans Creek • Local urbanised/industrial channels discharge stormwater runoff into the Harbour • Industrial discharges have some limited impact on water quality in the Harbour • Although not disturbed, acid sulfate soils still underlay some areas and should not be further disturbed • The impacts of tidal

Area of System	Water Quality Objectives	River Flow Objectives	Comments
			barriers should be minimised.

* Specific definitions of the objectives can be found in DLWC (2000)

To ensure overall compatibility of the floodplain management study and the river flow and water quality objectives, the objectives set out in Table 2.4 have been used as criterion for the assessment of options. This is discussed further in Chapter 11.

2.8 Flora, Fauna and Riparian Areas

The coastal plain was cleared over the past 140 years to make way for rural settlement and subsequent urban and industrial development. This development has left very few examples of the dry sclerophyll forest that existed in these lower rainfall areas of the catchment (Forbes Rigby, 2002).

A proportionally greater amount of escarpment vegetation has been preserved compared to the coastal plain, principally due to the steeper terrain in these locations which does not lend itself to agriculture and development and has therefore escaped past clearing activities. This remnant vegetation is instead subject to modern pressures from weed invasion, fire and clearing for new development (Forbes Rigby, 2002). Available data suggests that the amount of tree clearing in the escarpment has reduced and that there is presently a more extensive tree cover in the catchment than existed 50 years ago (particularly in the middle and upper reaches of Brandy and Water Creek, American Creek and Byarong Creek Catchments) (Forbes Rigby, 2002).

The riparian corridors that follow Allans Creek and its various tributaries have been subject to similar pressures having been subject to extensive clearing and intensive development. In general there are very few examples left of pristine riparian vegetation other than in the uppermost reaches of the larger streams in the catchment. Healthy riparian vegetation is important as it assists with improving bank stabilisation, water quality and is an important movement corridor for aquatic and terrestrial species. Unfortunately, the movement of water through the riparian corridor provides a vector for transport of weed propagules. As a result, much of the riparian vegetation in the catchment is infested with weed species (Forbes Rigby, 2002).

The State of the Environment report (Wollongong City Council, 2000) reports that:

- Vegetation in the catchment varies from heath in the higher areas through forested escarpment to cleared slopes and coastal scrub around the estuary.
- Wildlife corridors between the coastal plain and the escarpment have been compromised by urban and rural development. As such, opportunities to restore these corridors may be an appropriate action in association with the joint objective of establishing corridors that function for both flood conveyance and water quality improvement objectives.
- The Wollongong LGA has a rich diversity of flora with nine species listed as threatened (TSC Act, 1995). A voluntary conservation agreement exists for the Ribbonwood Road, Farmborough Heights area which is outside of the floodplain but within the catchment. There are three ecological communities listed under Schedule 1 of the TSC Act (1995). None of these communities are known to lie

within the Allans Creek floodplain area. There are also a series of rare or regionally restricted ecological communities in the LGA. The Wollongong LGA has a large number of threatened (endangered or vulnerable) fauna species (TSC Act, 1995) including snail, amphibian, reptile, bird and mammal species
- Whilst some studies have been carried out, Council has not conducted studies on the specific habitats of these species on a city-wide basis.

All of these features will need to be considered in detailed investigations into the implementation of preferred floodplain management options.

As such, only broad information was available for this study. Some site specific investigations were undertaken to further enhance the knowledge of species within general areas identified as potential areas for the implementation of structural options.

In addition to those species endemic to the area and identified for protection, there are conversely a wide range of weed species within the Allans Creek floodplain. Weeds consist of both noxious weeds (Noxious Weeds Act, 1993) and environmental weeds.

Similarly, there are a number of tree species that are not endemic to the area. In particular, the presence of Coral Trees (*Erythrina x sykesii*) and Willows (*Salix* sp.) is of considerable concern for the Allans Creek floodplain. These trees can be found on the banks or within the channels of the majority of the tributaries of Allans Creek. During the floods of 1998 and 1999 the debris from these trees caused considerable blockage. Bank and bed erosion resulting in the undermining and collapse of these trees was also an issue. It is recommended that the progressive removal and replacement of these species with appropriate endemic species be undertaken.

A flora and fauna assessment was undertaken on the 7 October 1998 as part of this study and involved observational assessment for a number of key sites within the floodplain for a maximum of 45 minutes. During the time of the inspection, the condition of the vegetation and faunal habitats was assessed. The weather during the survey was sunny and clear. Findings of the inspections are listed in Table 2.5.

Background material to assist with assessments included:

- Wollongong City Council (1990) *An Environmental Assessment of Allans Creek Catchment*.
- Beadle, N. C. W., Evans, O. D. and Carolin, R. C. (1991) *Flora of the Sydney Region*.
- Fairley and Moore (1989) *Native Plants of the Sydney Region.*

Flora and Fauna survey sites are shown in Figure 2.3.

Table 2.5 Flora and Fauna Survey of Key Sites within the Study Area (after PPK, 1998)

Site	Description
Byarong Creek at Uralba Street	At the time of the inspection, this section of the creek had been cleared of native vegetation and has a variety of introduced grasses including buffalo. The right bank was more overgrown, but it also consists of introduced grasses. Both banks, in the state at the time of the inspection were stable and the water in the creek, clear, with little evidence of algae. Habitat value of this site is largely limited to the rock retaining wall, the waterway and the overgrown right bank. During the survey there was evidence of frogs and skinks. Should an option be proposed for this site, there is no significant vegetation that would need to be cleared. However, care would need to be taken to ensure that construction runoff is prevented from entering the creek.
Byarong Creek at Thames Street (Harry Graham Park)	This area is utilised as sporting fields and is therefore largely turfed, but some areas remain exposed. On the left bank, adjacent to the back fences of residential blocks, backing onto the park from Thames Street are six semi-mature to mature landscaping trees including two Camphor laurel trees (an introduced species), a juvenile persoonia and three juvenile eucalypts. Should an option be proposed for this site and the trees need to be cleared, permission may be required from Council for removal given the maturity of the trees (regardless of whether they are introduced). Owing to the disturbed nature of the site, there is little value as habitat for native fauna and the existing vegetation is not remnant native bushland.
American Creek, Upstream of Princes Highway, Figtree	The site is within the grounds of a school, the area mainly dominated by playing fields. The existing vegetation at the time of the survey includes a row of landscaping trees running along the Princes Highway including *Eucalyptus gummifera*, *Eucalyptus maculata*, *Grevillea floribunda* and *Callistemon linearis*. The trees are of varying age, with the tallest being an *E. maculata* and two *E. gummifera*'s which are approximately 15 m high. Aligning the rear of the properties to the south-west, adjoining the Princes Highway are a number of juvenile landscaping trees, most of which are no more than 1.5 m high. The site offers little value as habitat for flora and fauna as sites of this type are common throughout the catchment, and there is no available ground cover habitat, other than mowed grass.
American Creek, O'Donnell Drive, Figtree	This area is highly disturbed with an extensive weed infestation from the fence line down to the creek. Some of the existing weed species include lantana, scotch thistle, weeping willow, blackberry and castor oil plant. The site offers little value as a native remnant. However, the dense nature of the weed infestations, particularly towards the creek, does offer habitat for birds and small ground dwelling animals such as lizards. This area is not considered to be significant as there are many examples of disturbed sites such as this along the creek line.
Allans Creek, Resolution Drive, Unanderra	The site consists of an existing concrete lined channel. Adjoining lands have been cleared and are weed infested. The only area that contains some habitat significance is the wetland contained within the carpark on the eastern side of Resolution Drive. This wetland offers

Site	Description
	suitable habitat for wetland bird species. Should any option be constructed upstream of this area, sediment control measures would need to be installed to prevent the wetland from being contaminated.

In general, any proposed works should include the installation of suitable erosion and sediment control measures to prevent downstream effects in the waterways. Any trees removed are to be assessed according to Council's tree preservation policies. Appropriate landscaping with species endemic to the region should also be undertaken. Further assessment would be necessary following finalisation of design specifications.

The *Riparian Corridor Management Study* (DIPNR, 2004) covers the Allans Creek catchment and considered three categories of riparian environmental objectives, being:

- Category 1 Environmental Corridor – provide biodiversity linkages ideally between one key destination to another
- Category 2 Terrestrial and Aquatic Habitat – provides basic habitat and preserves the natural features of a watercourse
- Category 3 Bank Stability and Water Quality – has limited (if any) habitat value but contributes to the overall basic health of a catchment.

Mapping of the three category areas indicates that the upper reaches (upstream of urban development and upstream of the limits of hydraulic modelling for the purposes of this study) are commonly identified as having a Category 1 objective (Environmental Corridor). Where urban development is present and essentially encroaches on the creeklines, Category 3 is assigned (Bank Stability and Water Quality) (e.g. the majority of the length of Byarong Creek). Some minor tributaries in the upper reaches and some of the smaller creek systems are assigned a Category 2 (Terrestrial and Aquatic Habitat) (e.g. Charcoal Creek).

Three zones were identified within riparian land:

- Core riparian zone – which is ideally fully vegetated with local provenance vegetation
- Vegetated Buffer – which is not necessarily as heavily vegetated and protects the core riparian zone from edge effects such as weed invasion, and
- Asset Protection Zone – also known as fire protection zone which has reduced vegetation to help protect adjacent assets from bushfires (e.g. housing).

No detailed mapping of the riparian corridor has been undertaken for Allans Creek to date.

2.9 Tourism and Recreation

Tourism and recreation occur across the entire floodplain and catchment area. A significant number of parks are located within the catchment (for both formal sporting activities and informal or passive recreational pursuits). The majority of sporting fields contain amenities blocks and larger fields contain stands for spectators and

more elaborate amenities facilities (including carparking). The majority of sports fields are located adjacent to the creek systems and are occasionally inundated as a result of overbank flows. The duration of inundation of the fields is likely to be of a short period. However, the impact of inundation as a result of the deposition of sediment and debris may result in the fields being unplayable for a longer period.

Sporting fields and park areas within the floodplain include:

- Harry Graham Park
- Roy Johanson Park
- Sid Parrish Park
- Lysaght Oval
- Lindsay Maynes Park
- Figtree Park
- park upstream of Koloona Avenue
- O'Briens Road Reserve
- Todd Park
- Unanderra Park.

In addition to the recreational amenities, hotels, motels and a caravan park are located within the floodplain. The details of these are discussed in Chapters 9 and 10.

2.10 Aboriginal and European Cultural Heritage

A preliminary Aboriginal archaeology study was undertaken as part of this investigation for five key sites within the Allans Creek floodplain.

A review of the Wollongong City Aboriginal Heritage Planning study prepared by Mary Dallas Consulting Archaeologists (1955) was undertaken. This study documented the Aboriginal archaeological resources within the city of Wollongong. The study included a search of the NSW National Parks and Wildlife Service's (NPWS) of Aboriginal Sites database, it postulated a predictive model of Aboriginal site location based on the location patterns in the city and devised a strategy for the future planning and management of sites and sensitive areas in the city. Apart from this review of available reports, no further field assessments were undertaken for this study.

Overall, the implications of the review of this study are that the Wollongong City area has been greatly affected by urban development. Part and existing management practices have resulted in the destruction of many pre-existing Aboriginal archaeological sites. Five key sites (the same as those outlined in Section 2.8) were assessed in particular:

- Byarong Creek at Uralba Street
- Byarong Creek at Thames Street (Harry Graham Park)
- American Creek, Upstream of Princes Highway, Figtree
- American Creek, O'Donnell Drive, Figtree
- Allans Creek, Resolution Drive, Unanderra.

These five sites lie on the alluvial plains, which have been largely developed for industrial, commercial and residential purposes. As such, it is unlikely that there would be any existing Aboriginal sites in the five study areas.

The NPWS database identified 1538 Aboriginal sites within the city boundaries. Most of these are located in the Woronora and Metropolitan Water Catchment on the plateau.

The study identified one Aboriginal site that was within close proximity to one of the possible sites for the implementation of floodplain management options. The site is located about 100 m west of the western boundary of Figtree High School, along American Creek. However, it is unlikely that this site would be affected by any proposed works (e.g. along Gibsons Road and the eastern boundary of the school adjacent to the Princes Highway).

Overall, owing to the developed nature of five of the possible construction sites and the specifications in the Mary Dallas Consulting Archaeologists study (1995) showing no evidence of archaeological sites in the immediate vicinity of the five proposed sites, it is unlikely that any proposed works in these locations would have any significant impact on Aboriginal archaeological sites. However, this study is by no means comprehensive and further studies would be required if the proposed flood mitigation works are to proceed.

A number of items of local, regional or state significance are located within the Wollongong City Council area. Only items of local significance are affected by flooding. These items, listed in the LEP (1990) include:

- Unanderra Station Masters Residence - Local Significance (Built Item)
- Unanderra Public School - Local Significance (Built Item)
- The Figtree - Local Significance (Landscape Item)
- Historical house at 183 Princes Highway, Unanderra - Local Significance (Built Item).

The location of these sites are shown in Figure 2.4

2.11 Legislation, Policies, Plans and Codes

Policies and plans relevant to the Study are listed in Table 2.6. A brief description is given of those most relevant to the Allans Creek floodplain.

Table 2.6 Details of Relevant Environmental Planning Instruments

Administrating Body	Name of Policy/Plan	Details
DNR	Water Management Act, 2000	In December 2000, the NSW Parliament passed the *Water Management Bill* with various aspects being progressively implemented from 1 January 2001. This Act repeals or amends all of the legislation summarised below. • *Drainage Act 1939 No 29* • *Miscellaneous Acts (Water Administration) Amendment Act 1986 No 205* • *Rivers and Foreshores Improvement Act 1948 No 20* • *Water Act 1912 No 44* • *Water (Amendment) Act 1936 No 31* • *Water (Amendment) Act 1940 No 57* • *Water (Amendment) Act 1976 No 33* • *Water (Amendment) Act 1979 No 159* • *Water (Soil Conservation) Amendment Act 1986 No 143* • Water Administration Act 1986 No 195.
DNR	State Government Flood Prone Land Policy, 2001	Elements of the policy can be found in the Floodplain Development Manual (2005).
DNR	Native Vegetation Conservation Act, 1997	This act is designed to protect native vegetation in non-urban land. In general: • If a vegetation management plan provides native vegetation on any specified land to which the plan applies may not be cleared without development consent, • a person must not carry out clearing unless: (a) development consent has been obtained for the clearing and is in force, and (b) the clearing is carried out in accordance with the development consent and the regional vegetation management plan. The Act does not apply to lands under SEPP14, SEPP26 or designated development or urban land.
Department of Primary Industries (NSW Agriculture)	Noxious Weeds Act, 1993	The Noxious Weeds Act, 1993, aims to ensure appropriate measures for the control of noxious weeds throughout NSW.
DLG	Local Government Act, 1993	The Local Government Act 1993, primarily administered by the Department of Local Government, gives local councils the power to control and regulate the drainage of land and to construct drains in their locality.

Administrating Body	Name of Policy/Plan	Details
Department of Environment and Conservation (formerly the EPA)	Protection of the Environment Operations (POEO) Act 1997	Consolidates the key pollution statutes under a single Act. It replaces; the Clean Air Act 1961, the Clean Waters Act 1970, the Environmental Offences and Penalties Act 1989, the Noise Control Act 1975, the Pollution Control Act 1970, and incorporates the major regulatory provisions of the Waste Minimisation and Management Act 1995. The POEO Act enables the explicit protection of the environment policies (PEPs) and more innovative approaches to reducing pollution. The Act also provides a single licensing arrangement to replace the different licences and approvals under existing separate Acts. Integration of EPA licensing with the development approval procedures under the EP&A Act 1979 provides public participation in the environmental assessment of activities that may be licensed by the EPA.
DoP	Environmental Planning and Assessment Act, 1979	The EP&A Act includes aims and objectives which set the tone for the application of the Act. A set of model provisions is also included which provides standard guidelines, definitions and controls. These model provisions may be adopted as part of an LEP. It is worth noting that the Wollongong LEP (1990) does not adopt the model provisions of the Act. A range of sections of the Act are relevant to floodplain management including Sections 117 and 149.
DoP	State Environmental Planning Policy (SEPP) (Seniors Living) 2004	This policy permits housing for seniors or people with a disability wherever houses, flats, hospitals and special uses are permitted in urban areas or adjoining urban areas, except for some environmentally sensitive areas. Where inconsistencies occur this policy prevails over other planning instruments (e.g. The Wollongong LEP).
DoP	Various other SEPPs including: 4, 14, 19, 33, 35, 55	Reference should be made to specific SEPPs. Specific sections of this report make reference to SEPPs as required.

Administrating Body	Name of Policy/Plan	Details
DoP	Illawarra Regional Environment Plan No. 1	The Illawarra REP No. 1 was proclaimed in 1986 and applies to the area. Relevant clauses include: • Clause 28 requires Council to consider existing information on flooding when preparing an LEP that covers rural land. Such an LEP is to introduce development standards or other controls to minimise the effects of flooding. • Clause 65 prohibits Council from changing the zoning of land from rural to urban unless it has considered the flooding issues and consulted with DNR (the then Department of Public Works). • Clause 66 requires Council to investigate flooding when it wishes to prepare an (amending) LEP over existing urban land. A Plan of Management should be prepared and should ensure that the effects of flooding are minimal. In accordance with Clause 66(2) of the REP, a LEP to control development of flood prone land shall be prepared and indicate appropriate controls relating to floor heights, access, infill and land clearing to ensure the effects of flooding on the development are minimal. Others clauses of the REP address issues such as water quality, estuarine areas etc. The application of the REP has, at least partially, addressed the problems of flooding in new development areas in the period after 1986. The present LEP (1990) was prepared in part in accordance with these principles of the REP. The REP also states that Caravan Parks should not be established on flood liable land unless the applicant for development consent has demonstrated that adequate safeguards to life and property have been incorporated into the proposed development.

Administrating Body	Name of Policy/Plan	Details
Department of Environment and Conservation (NPWS)	Threatened Species Conservation Act, 1995	The objectives of this act include: • to conserve biological diversity and promote ecologically sustainable development, • to prevent the extinction and promote the recovery of threatened species, populations and ecological communities, • to protect the critical habitat of those threatened species, populations and ecological communities that are endangered, • to eliminate or manage certain processes that threaten the survival or evolutionary development of threatened species, populations and ecological communities, • to ensure that the impact of any action affecting threatened species, populations and ecological communities is properly assessed, • to encourage the conservation of threatened species, populations and ecological communities by the adoption of measures involving co-operative management.
Department of Environment and Conservation (NPWS)	NPWS Act, 1974	Section 90 of this Act makes reference to the protection of the Aboriginal sites and places.
Department of Primary Industries (NSW Fisheries)	Fisheries Management Act, 1994	The objectives of this Act are to conserve, develop and share the fishery resources of the State for the benefit of present and future generations. In particular: • to conserve fish stocks and key fish habitats, • to conserve threatened species, populations and ecological communities of fish and marine vegetation, and • to promote ecologically sustainable development, including the conservation of biological diversity.
Southern Rivers Catchment Management Authority/DNR	Catchment Management Authorities Act, 2003	The Southern Rivers CMA and its former entity the Southern Catchment Management Board prepared a catchment blueprint for the area (2002). The blueprint is a 10-year plan for integrated catchment management. Issues identified include: Waterway management: • Water quality • Water Quantity and Use • Riparian Zone Management • Dams & river structures Land management • Natural constraints • Land use planning

Administrating Body	Name of Policy/Plan	Details
		• Soil erosion • Soil degradation Habitat management • Loss of native vegetation and habitat • Degradation of habitat • Pest animals • Weed invasion Human settlement management • Residential development • Inappropriate urban practices.
SES	Wollongong DISPLAN (2004)	A detailed review of the DISPLAN is provided in Chapter 9.
SES	State Emergency and Rescue Act, 1989	This Act defines an emergency due to an actual or imminent occurrence (such as fire, flood, storm, earthquake, explosion, accident, epidemic or warlike action) which: • endangers, or threatens to endanger, the safety or health of persons or animals in the State, or • destroys or damages, or threatens to destroy or damage, property in the State, being an emergency which requires a significant and co-ordinated response. The act makes detailed provisions for planning and action during emergencies as outlined above.
WCC	The City of Wollongong Local Environmental Plan (LEP) 1990	The LEP was proclaimed in the Government Gazette on 28 December 1990. A series of amendments have been prepared since that date and most have been adopted. Further amendments are in various stages of being prepared but have not yet been gazetted. As described in Table 2.1 of this report, land within the Allans Creek floodplain falls within 21 separate zones. Details of these zones and their objectives from the LEP are set out in Table 2.7. The LEP controls development within Wollongong. In accordance with Clause 10 within any zone of the LEP, a development proposal requires Council's consent if it is: • development below high water mark • development or filling of land forming part of the bed of a river, creek, bay, lagoon or natural watercourse, including any area subject to periodic inundation. Particularly notable clauses include: • Clause 10 of the LEP (1990) states that development consent is required from Council for the clearing or partial clearing

Administrating Body	Name of Policy/Plan	Details
		of vegetation, including noxious weeds, on land other than for the clearing or partial clearing of vegetation carried out for Bush fire purposes. • Clause 19 Foreshore Development - states that Council may by resolution, fix a line in respect to any land fronting a river or creek. The erection of a building is prohibited between the foreshore building line and the river or the creek. • Clause 35 provides for the compulsory acquisition (by Council) of land within Zone No. 9 (Reservation Zone). This clause sets out the circumstances under which compulsory acquisition (purchase) can be instigated by the owner and sets limits to development that Council can consider or approve in this zone. • Clause 41 provides for Council to undertake flood mitigation works, since the clause states that 'nothing in this plan shall be construed as restricting or prohibiting or enabling Council to restrict or prohibit (a) the carrying out of development of any description specified in Schedule 3' of which section 11 is 'The carrying out or causing to be carried out by a council engaged in flood mitigation works or by the Water Administration Ministerial Corporation of any work for the purposes of soil conservation, irrigation, afforestation, reafforestation, flood mitigation, water conservation or river improvements in pursuance of the provisions of the Water Act 1912, the Irrigation Act 1912, the Farm Water Supplies Act, 1946 or the Rivers and Foreshores Improvement Act, 1948, except: (a) the erection of buildings, the installation or erection of plant or other structures or erections and the reconstruction or alteration of buildings so as materially to affect the design or external appearance thereof, or(b) the formation or alteration of any means of access to a road'. It should be noted that the LEP is now under revision as part of the Planning Reforms initiative guided by the Department of Planning for all Council's in NSW. Additionally, some of the Acts outlined above are in transition to the Water Management Act, 2000 outlined above. The review of the LEP will be undertaken within the framework of the *Wollongong Futures* Project which will produce a vision and goals for the city, and ensure that all subsequent plans support that vision.

Administrating Body	Name of Policy/Plan	Details
WCC	*Development Control Plans*	Council has a total of 48 DCPs to address a variety of issues across the City. These may not specifically relate to the control or management of flooding but have been prepared under the umbrella of the REP and LEP. Specific details of relevant DCPs include: • DCP No 99/1 Complying Development • DCP No 99/2 Exempt Development • DCP No 6 - Commercial & Industrial Development • Draft DCP No 9 - Draft Multi Dwelling Residential Development • Draft DCP 54- Managing Our Flood Risks. This DCP should be read in conjunction with the Stormwater Design Code (see below).
WCC	*Technical Policies*	Council has developed a series of technical policies, which guide developers and others in the planning of their projects. Specific details of relevant technical policies are outlined below.
WCC	• On Site Detention	Council's policy is dated 2002 and applies to all land within the LGA. The objective of the draft policy is to maintain a standard of control of peak discharges from developments that is less than existing natural discharges. The policy specifies a permissible site discharge and site storage requirement for all catchments within the LGA.
WCC	• Drainage Design Code	Council's code of 1994 is under revision and applies to all land within the LGA. The revised code is currently in draft form and covers matter such as: • flow estimation for major and minor flows • pit inlet design • hydraulic design of minor systems (pits and pipes to be designed for the 10 year ARI event) • hydraulic design of major systems (for the 100 year ARI event and checked for the PMF) • management of stormwater from developments.
WCC	• Technical Policy 94/27 Rural Residential Development	All existing and mature natural vegetation must be retained and the landscaping of areas include watercourses, ridgelines and green corridors. Clause 11 of the policy states that natural drainage principles must be applied to all new development. Stormwater runoff must rely on the natural drainage within the constraints of the existing topography.

Administrating Body	Name of Policy/Plan	Details
WCC	*Strategic Planning Projects*	In some areas of environmental sensitivity, Council has prepared Strategic Planning Projects to advise the community of possible future controls which may be applied to those areas. These may be considered as a pre-cursor to an amending LEP or DCP. The Mount Kembla - Farmborough Heights Strategic Planning Project includes a map which shows indicative future zonings for some of the more sensitive escarpment land immediately adjoining the State Recreation Areas. These indicative zones recognise the importance of planning effectively to minimise future flooding effects and make adequate provision for the protection of vegetated land and land which may be impacted by flooding.
WCC	*Stormwater Management Plan*	The NSW EPA required all Council's in NSW to prepare a Stormwater Management Plan for urban areas. This plan (Forbes Rigby, 2000) sets a strategic direction for the management of all coastal catchments in the Wollongong LGA including the Allans Creek catchment.
WCC	*Plans of Management*	Various plans of management operate within the Allans Creek area for open space and recreational areas. These plans, whilst not reviewed in detail here, are relevant for the management of riparian lands.

Table 2.7 LEP Zone Objectives

Zone	Objectives
No. 1 (Non-Urban Zone)	The objectives of the zone are - a) to provide a rural atmosphere on the outskirts of the city of Wollongong and to act as a reservoir from which land suitable for (i) urban development to cater for planned natural urban growth, or (ii) environmental protection can be drawn; and b) to allow agricultural and peri-urban pursuits which are not likely to - (i) inhibit or prejudice the present environmental quality of future development potential of the land; or (ii) lead to a demand for further public services or render then more difficult or expensive to provide once urban development takes place.
No 2(a) (Low Density Residential Development)	The objectives of the zone are - a) to provide land primarily for detached housing with gardens in an environment free from commercial and unsympathetic buildings; and b) to allow some diversity of activities and housing types provided - (i) densities, scale and height are comparable to those of detached housing (ii) there is little increase in traffic generation; and (iii) there will be no significant detraction from the character of the locality or the amenity of any existing or proposed development nearby.
No 2(a1) (Special Low Density Residential Zone)	The objectives of the zone are - a) to cater for residential development in selected areas affected by environmental hazards, a limited supply of infrastructure or a lack of adequate utility services, and b) to allow some diversity of activities that will not prejudice the objective referred to in paragraph (a) from being achieved or detrimentally affect the environmental quality or character of the locality of the amenity of the locality.
No. 2(b) (Medium Density Residential Zone)	The objectives of the zone are - a) to cater for a wide range of housing types, essentially domestic in scale and character; b) to allow for a range of residential densities and for urban consolidation in appropriate locations; and c) to allow some diversity of activities and densities provided - (i) scale and height are comparable to those of the locality; (ii) there is little increase in traffic generation; and (iii) there will be no significant detraction from the character of the locality or the amenity of any existing or proposed development nearby.
No. 2(c) (High Density Residential Zone)	The objectives of the zone are: (a) to allow for high density residential development close to the regional centre, and (b) to allow some diversity of activities and densities provided i. scale and height are comparable with those in the locality ii. there is little increase in traffic generation iii. there will be no significant detraction from the character of

Zone	Objectives
	the locality or the amenity of any existing or proposed development nearby
No. 3(a) (General Business Zone)	The objectives of the zone are - a) to focus and consolidate retail and small business development in accessible locations; and b) to allow development for other purposes if those purposes will not prejudice the objective referred to in (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development nearby.
No. 3(b) (Neighbourhood Business Zone)	The objectives of the zone are - a) to allow for businesses and neighbourhood activities which serve the local community and are limited in scale; and b) to allow some diversity of activities of densities, scale and height comparable with those of the locality, and with little increase in traffic generation, that will not prejudice the objective referred to in (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development nearby.
No. 3(d) (Commercial Services Zone)	The objectives of the zone are - a) to allow large scale sale rooms or showrooms trading in bulky goods and small scale services, which are not establishments normally found in a business area, to locate close to business areas; and b) to allow some diversity of activities which will not prejudice the objective referred to in paragraph (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development in the locality.
No. 4(a) (Light Industrial Zone)	The objectives of the zone are - a) to cater for a wide range of manufacturing and service activities which will not interfere with the amenity of nearby residents; and b) to allow some diversity of activities of densities, scale and height comparable with those of the locality, and with little increase in traffic generation, that will not prejudice the objective referred to in (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development nearby.
No. 4(b) (Heavy Industrial Zone)	The objectives of the zone are - a) to provide suitable areas for those industrial enterprises which should be kept well away from residential neighbourhoods; b) to make best use of public utilities and infrastructure required by substantial enterprises; and c) to allow some diversity of activities which will not prejudice the objective referred to in paragraph (a) and (b) from being achieved or significantly detract from the operation of existing or proposed industrial enterprises.
No. 5 (Special Uses Zone)	The objective of the zone is to cater for the provision of community and public facilities and services.
No. 6(a) (Public Recreation Zone)	The objectives of the zone are - (a) to identify areas where recreation facilities for the general use of the community for active and passive recreation may be developed, and (b) to cater for the development of a wide range of facilities for the benefit of nearby communities.

Zone	Objectives
No. 6(b) (Private Recreation Zone)	The objectives of the zone are - a) to identify areas where private recreation facilities are and may be developed; and b) to allow some diversity of activities which will not prejudice the objective referred to in paragraph (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development in the locality.
No. 6(c) (Tourism Zone)	The objectives of the zone are - a) to identify areas of, and encourage tourist orientated development in, designated tourism precincts; and b) to allow some diversity of activities which will not prejudice the objective referred to in paragraph (a) from being achieved or significantly detract from the character of the locality or the amenity of any existing or proposed development in the locality.
7(a) (Special Environmental Protection Zone)	The objectives of the zone are - a) to protect environmentally important lands having special aesthetic, ecological or conservational value, b) to identify and protect the foreshore environment which enhances the visual amenity and possesses ecological or conservational value, c) to identify and protect lands forming part of the catchment areas for water supply d) to allow some diversity of activities on degraded land which will not prejudice the objectives referred to in paragraphs (a), (b), and (c) from being achieved or significantly detract from the environmental or visual quality or character of the locality of the amenity or operation of any existing or proposed development in the locality.
7(b) (Environmental Protection Conservation Zone)	The objectives of the zone are - a) to protect environmentally important lands having special conservational, aesthetic, or scenic qualities which enhance the environment, b) to identify and protect escarpment areas which enhance the visual amenity and possess special aesthetic or conservational value, and c) to allow some diversity of activities on degraded land which will not prejudice the objectives referred to in paragraphs (a) and (b) from being achieved or significantly detract from the environmental or visual quality or character of the locality of the amenity or operation of any existing or proposed development in the locality.
7(c) (Environmental Protection Residential Zone)	The objectives of the zone are - a) to cater for limited residential and village development in selected areas possessing special environmental qualities or which may be affected by environmental hazards, and b) to allow some diversity of activities which will not prejudice the objectives referred to in paragraph (a) from being achieved or significantly detract from the environmental or visual quality or character of the locality of the amenity or operation of any existing or proposed development in the locality.
7(c1) (Environmental Protection Rural Residential Zone)	The objectives of the zone are - a) to provide for rural residential development to occur in the city b) to ensure that such development is an effective transition between

Zone	Objectives
	urban and environmentally sensitive land such as the escarpment fringe, c) to enable a limited range of buildings and land uses which are compatible with adjoining environmentally sensitive land, and d) to ensure that any development is accompanied by significant environmental enhancement.
8(a) National Parks, State Conservation Areas and Nature Reserves Zone	The objectives of the zone are: (a) to identify land that is reserved or dedicated under the *National Parks and Wildlife Act 1974*, and (b) to allow for the management and appropriate use of that land as provided for in the *National Parks and Wildlife Act 1974*.
8(b) National Parks, State Conservation Areas and Nature Reserves (Proposed) Zone)	The objectives of the zone are: (a) to identify land that is to be reserved or dedicated under the *National Parks and Wildlife Act 1974*, and (b) to protect the values of that land for which it is proposed to be so reserved or dedicated.
9(b) (Reservation Zone)	The objectives of the zone are - a) to ensure that land required for future essential services, roads, open space and community purposes is clearly designated b) to provide for the acquisition of land within the zone c) to permit development of land within the zone where it is not immediately required, and d) to allow continued use of land within the zone until it is required.

In general, it is considered that Zones 2(b), 3(a), 3(b) and 5 are not appropriate zonings for flood prone land since:

- 2(b) given the current level of exposure of number of people within the floodplain already, it is considered inappropriate to encourage increased densities of persons at risk in the floodplain (this only increases the burden on combat agencies such as the SES)
- 3(a) and 3(b) may result in the exposure of high value items in the floodplain which may not be covered by insurance - this could be somewhat overcome by DCP provisions to require stock to be located above the PMF level but this may not be practical for some business types
- 5 would result in the exposure of critical and community facilities to flood waters.

This is consistent with the former Section 117(2) of the Environmental Planning and Assessment Act (1979) Directive G25 (now repealed), which is described in Section 9. At the time of preparation of this report new Section 117 directions were understood to be in preparation.

Details of a review of zonings and development control options for the floodplain are also outlined in Section 9.

2.12 Demographic Characteristics

Demographic characteristics of the Wollongong City Council area were derived from the Australian Bureau of Statistics from the 2001 census. Relevant data to assist with describing the characteristics of the Allans Creek catchment are shown in Table 2.8.

Table 2.8 Demographic Data for Wollongong Area from 2001 Census*

Details	Proportion of Population
Aged 15 years and over	79.9%
Aged 65 years and over	14.2%
Median Age	36 years
Total Indigenous Persons	1.47%
Australian born	71.1%
Main Other Countries of Origin	UK, Macedonia, Italy
English Speaking Only	77.7%
Living in a Private Dwelling	97.7%

* note that total persons in Wollongong Statistical Area was 181,612

The 1999-2000 State of the Environment Report outlines that the highest growth rate in population occurred between 1986 and 1996 in the suburbs of Cordeaux Heights and Figtree. Most common non-English languages spoken at home include Macedonian, Italian, Greek, Spanish, Chinese, Portuguese, German, Arabic, Serbian, Turkish.

It should be noted that the State of the Environment report (WCC, 2000) indicates that an 11% increase in the population range of 65+ is likely to occur by 2006. The report also states that the average household size is 2.7 persons. Both of these figures are relevant and useful for the assessment of emergency response modification options in Chapter 10.

2.13 Stormwater Management Plan

A number of actions were identified in the Wollongong Coastal Stormwater Management Plan (Forbes Rigby, 2000) that are relevant to the Allans Creek Catchment and Floodplain. These are listed along with their priority for implementation in Table 2.9.

Table 2.9 Stormwater Management Plan Actions

Structural Actions	Non-Structural Actions
• Assess need for stormwater treatment measures along designated heavy vehicle routes through the City, especially in the Allans Creek catchment (Priority 43) • Investigate the use of existing open space for the retrofit of water treatment ponds downstream of urban areas (Priority 48) • Upgrade standards for the design, construction and maintenance of creek crossings to ensure that they provide for adequate fish passage, and that they do not accelerate the erosion of adjacent stream beds and banks (Priority 66) • Rework surface drainage of playing fields to provide long linear wetlands along field perimeter. Stormwater drainage from adjacent housing to be directed through these wetlands (Priority 82). • Improve existing riparian vegetation and provide controlled public access at selected locations (Priority 90). • Liaise with RAC regarding a weed audit of south coast railway line and prioritise areas for remedial action (Priority 93) • Investigate the construction of an off-line wetland on American Creek, upstream of the South Coast Freeway at Figtree (Priority 95) • Gross pollutant traps to be installed in key locations downstream of commercial areas (Priority 100) • Investigate the construction of an off-line wetland on Allans Creek upstream of the Princes Highway at Unanderra (Priority 105).	• Maintain buffer strips as a sediment control structures along creek banks adjacent to Council's playing fields and enhance to provide riparian vegetation (Priority 1) • Review and monitor protocol for 'cleaning out' of blocked/silted/overgrown watercourses using environmental best management practices in consultation with DNR (Priority 6) • Assess merits of program to progressively bring riparian land into public ownership (Priority 26) • Review street and pit cleaning program to ensure industry best practice and co-ordination with other operators activities (Priority 30) • Determine most effective strategy to rehabilitate riparian lands including: identification (mapping) of degraded lands, zoning impediments, sources of funding, acquisition of private lands etc (Priority 34) • Identify sources of pollution within Allans Creek (Priority 37) • Encourage use of stormwater reuse in industrial situations (Priority 45) • Encourage residents with backyards adjacent to creeks to maintain grassed buffer filter strips to intercept runoff and not to throw clippings into the creek (Priority 54) • Ensure that water quality and river health objectives are addressed in the development of Floodplain Management Plans (Priority 57).

3. CONSULTATION

A range of consultation has been undertaken as part of the Allans Creek study including:

- public meetings
- distribution of questionnaires and information brochures
- community stalls
- consultation with local representatives via the Allans Creek Floodplain Management Committee.

3.1 Public Meeting

A public meeting was held at the Nareena Hills High School on the 21 May 1996. This meeting was chaired by the Lord Mayor with a presentation by Lawson and Treloar to attendees (approximately 10 persons). Council and DNR technical personnel also attended this meeting. The meeting was generally an opportunity for information dissemination on the objectives of the study and invited responses from the community with regard to the provision of historical flood information and comment on the overall process.

Responses were received reporting on the flood history of the area and provided some photographs. This information was utilised for the flood study (Lawson and Treloar, 2006). General information provided indicated that flooding (even as far back as 1961) has been caused by trees and logs blocking bridge structures and other crossings of the creek.

3.2 Post Flood Questionnaires

Following the 1998 event, a flood survey was sent out to identify the number of properties affected, the nature of damages and to allow for comments to be provided. The number of properties in the Allans Creek floodplain reported to have been affected by the 1998 event was 334. The number of properties with reported above-floor flooding was 89. The number of properties that reported damages was 182 (with dollar value estimates ranging from $10 - $166,590. The total reported value of damage was $1.8 million. This can be compared with the residential direct tangible damage analysis for August 1998 (Chapter 5) based on numerical modelling which calculated a comparative value of $5 million. The difference in the two values relates to the likely underestimation of damage by residents (which is likely to have assumed the actual cost of damage to an old item rather than new for old replacement for items) and potential data loss in the survey process since all residents may not have completed questionnaires.

A summary of the survey responses received is included as Table 3.1.

Table 3.1 Summary of Findings of August 1998 Flood Survey

Catchment	Number of Responses Received	Suggestions Offered for Resolving Flooding Issues		
		Clean Creek/Drain	Bridge/Culvert Issue	Restrict Upstream Development
Byarong Creek	283	124	18	14
Branch Creek	136	49	1	7
Brandy and Water Creek	2	-	-	-
American Creek	71	25	-	8
Allans Creek	223	69	2	4
Total	**715**	**267**	**21**	**33**

Similarly, following the 1999 event, surveyors were sent to properties affected by flooding to record details of flood levels for individual properties. No questionnaires were distributed as part of the survey; instead an automated approach to the collection of data was undertaken.

3.3 Site Inspections and Site Meetings with Local Resident Groups

A number of site inspections were carried out by the Lawson and Treloar study team both prior to the recent flood events, immediately following those events (the next day) and in subsequent months during the course of the study. During these inspections, informal discussions with residents were undertaken to ascertain their views on the matter of flooding and discuss their experiences.

In addition to the numerous formal site meetings with residents attended by Council technical personnel and elected representatives over the course of the study and following the 1998 and 1999 floods, a specific meeting was held with residents of the Koloona Avenue area to discuss possible options for this location as well as resident concerns. This meeting was requested by the residents of this area.

The meeting was held on site on Saturday 4 November, 2000 and was attended by both elected Council representatives as well as Council technical personnel and Lawson and Treloar. Residents presented a list of concerns and a preliminary list of possible options for the areas were discussed. This list was later expanded for the whole of catchment options consultation discussed below in Section 3.4.

3.4 Options Consultation and Community Stall

A preliminary list of options were presented to the Allans Creek Floodplain Management Committee both for comment and for the Committee to rank the options in their order of preference at the meeting of 3 May 2001. Comments from the Committee were then compiled and a final list of options were developed for technical feasibility assessment. Once the feasibility assessments were undertaken, community newsletters were prepared to invite community comment on the options for three separate areas of the floodplain:

- Byarong Creek (and tributaries)
- American Creek (and tributaries)
- Charcoal Creek and the southern portions of the floodplain.

Copies of these newsletters are included as Appendix A.

To ensure maximum response, the newsletters were distributed by Council immediately following the summer school holiday period in late January-early February 2002. The distribution was followed by a community stall held at Westfield Shopping Centre, Figtree, in the centre of the floodplain area, on Saturday 16th February and Saturday 23rd February 2002. Residents were invited to return their written responses to either the stall or by fax/post/email.

Details of the distribution of newsletters and the responses received are shown in Table 3.2. Overall, a return rate of 5% is within the expected range for such a large floodplain. The return rate is indicative of the issue that there are a number of properties within the floodplain that have not yet experienced a flood (even though the 1998 and 1999 events were considered severe events by the community).

Table 3.2 Summary of Community Consultation Responses for February 2002 Consultation Period

DETAIL	BYARONG CREEK	AMERICAN CREEK	CHARCOAL CREEK	ENTIRE FLOODPLAIN
Total Number of Affected Lots/Residences (up to PMF)	640	252	740	1632
Total Number of Questionnaires Returned or Written Responses Received	58	11	14	83
Return Rate	9.1%	4.4%	1.9%	5.1%

Council representatives, Committee members and Lawson and Treloar representatives were present at the stall between 9am and 4pm on the two Saturday's to maximise opportunities for replies and discussion of options. Laminated posters with images of possible options and details of the floodplain management process were displayed for information and additional response forms were available for interested community members to complete.

Over the two Saturday's, representatives discussed the issues with over 150 people. Full details of written responses to the questions contained within the newsletters in Appendix A received can be found in Appendix B. The responses have been accounted for in the multi-criteria matrix assessment of all options in Section 11. In particular, Table 11.2 outlines the manner in which responses were converted to a weighted score for use in the options analysis.

3.5 Allans Creek Floodplain Management Committee

Through the life of the project, the Allans Creek Floodplain Management Committee, consisting of a range of representatives, has met on a regular basis to discuss matters related to the study.

The Committee membership includes representatives from the community, elected Council, Council technical personnel, Department of Natural Resources, State Emergency Service, Roads and Traffic Authority, Port Kembla Ports Corporation and commercial and industrial land holders.

The Committee has provided an essential link between the study team and community providing vital details of flood behaviour, review of the work of the study team and suggestions for options to manage flooding.

3.6 Public Exhibition of Study

An exhibition of the Draft Study was available at Wollongong Library and Unanderra Library from 18 April 2005 to 13 May 2005. The exhibition was advertised in *The Advertiser* and letters were sent to all residents within the floodplain advising of the exhibition with a newsletter and feedback questionnaire.

Council's floodplain management personnel fielded queries from the community at a community stall and a poster display of the Draft Plan at Westfield Figtree on both Saturday 30 April 2005 and Saturday 7 May 2005 between 10am - 2pm. All interested persons were welcome to view the display and discuss the draft study.

A total of 26 written comments in the form of correspondence or completed feedback questionnaires were received from the community. Comments were used to refine the Study prior to its completion. Comments from Council and State Agencies were also included in this final version of the Floodplain Risk Management Study.

4. EXISTING FLOOD BEHAVIOUR AND IMPACTS

4.1 Background

Full details of the flood modelling for the existing conditions can be sourced from the Allans Creek Flood Study (Lawson and Treloar, 2006). As outlined in Chapter 1, the Flood Study was carried out in conjunction with this Floodplain Risk Management Study.

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

- the hydraulic assessment of some of the flood modification options (Section 7)
- mapping of flood extents (Section 4.4)
- flood risk precinct categorisation (Section 4.6)
- flood damages assessment (Section 5), and
- flood planning level determination (Section 6).

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

- Allans Creek
- American Creek
- Brandy and Water Creek (and tributary)
- Branch Creek (and tributary)
- Byarong Creek
- Charcoal Creek (and tributaries)
- Ghost Creek
- Jenkins Creek
- Nudjia Creek
- Running Brook.

The result is a hydrologically and hydraulically complex system, with the timing of the arrival of flows at different locations and the relative magnitude of flows resulting in complex flooding mechanisms.

Urban development in the catchment has altered a number of the waterways and floodplain areas considerably from their natural state. Flood flows in the urbanised lower parts of the catchment are complicated by over 70 bridge and culvert crossings. Filling of the floodplain and realignment and lining of some of the creek channels has also impacted on the original flow regime of the floodplain. Major transport links that traverse the floodplain are the F6 freeway, the Princes Highway and the Illawarra Railway, all forming hydraulic controls across the major tributaries.

4.2 Existing Flood Behaviour

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

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

4.2.1 Orographic Rainfall

The Illawarra Escarpment forms part of the Illawarra ranges. It is characterised by steep cliffs 200-300m high approximately 10km from the coast. The peak of the ranges is approximately 500 m high behind Wollongong. The steep rise in elevation combined with the proximity to the coast generates unique localised meteorological effects. The orographic lifting of moist air masses generates intense rainfall bursts at the base of the escarpment that can result in flash flooding of the catchment.

This rainfall mechanism is one of the major causes of flooding in the Allans Creek catchment.

4.2.2 Steep Rainfall Gradients

The orographic nature of the rainfall leads to highly variable localised rainfall throughout the catchment. In the lower reaches of the catchment the rainfall intensities are generally far lower than those recorded on the escarpment. This leads to differing flood mechanisms, and flood timings throughout the catchment. Creeks in the upper reaches of the catchment generally have a shorter critical duration, due to the high intensity bursts experienced as a result of the orographic effect, whereas the lower reaches have a longer critical storm duration in the order of six hours. This difference in critical storm duration is due to the greater catchment area contributing to the flood and the complex routing of the escarpment rainfall to the lower reaches.

An analysis of this phenomenon can be found in more detail in Little and Babister (1999) and Evans and Bewick (1999).

4.2.3 Steep Slopes in the Upper Catchment

The steep slopes in the upper catchment lead to faster response times in the upper catchments (i.e. the time to the peak flood level in an event is short). Steep catchment slopes result in short lead times for the flow to reach the main upper catchment 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 lower reaches of the catchment have flatter subcatchments and flatter creek slopes, which result in a longer time to reach the peak flood level.

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

4.2.4 Lower Floodplain Areas

The lower reaches of the catchment generally merge to form one large floodplain system.

The catchment below the Princes Highway forms a single broad floodplain area. Natural and artificial controls detain water in portions of the lower regions leading to widespread flooding. Major artificial hydraulic controls in this region are the Illawarra Railway, the F6 freeway and its access ramps, and the Princes Highway.

4.2.5 Conduit Blockage

Conduit blockage has been shown to have a major effect on the flooding mechanisms of the catchment (Rigby and Silveri, 2001). Blockages of culverts in both the 1998 and 1999 floods caused flood flow diversion leading to new flood paths and increased flood damage. Critical culverts that were shown to block are the Princes Highway Culverts on all major crossings, Byarong Creek at The Avenue and the F6 Freeway, Byarong Creek at Koloona Avenue and Byarong Creek at Uralba Street.

Extensive consultation between Wollongong City Council, the Department of Natural Resources, Lawson and Treloar and other consultants preparing similar studies for adjacent areas, led to the development of a design blockage policy to be used in the modelling of peak water levels for design flood behaviour under the existing conditions and for the assessment of flood modification options.

The policy adopted by Council to represent blockage throughout the catchment is as follows.

i. 100% blockage for structures with a major diagonal opening width of <6m

ii. 25% bottom up blockage for structures with a major diagonal width of >6m.

    For bridge structures involving piers or bracing, the major diagonal length is defined as the clear diagonal opening between piers/bracing, not the width of the channel at the cross section.

iii. 100% blockage for handrails over structures covered in (i) and for structures covered in (ii) when overtopping occurs.

Additionally, for the purposes of this study, it was determined that the conduit blockage criteria would apply only to recurrence intervals equal to or rarer than the 20 year ARI. That is, there are no conduits blocked in the determination of 5 year and 10 year ARI flood levels.

There are a large number of blockage combinations for culverts and application of the Blockage Policy for all combinations would result in a very large number of model assessments. However, after careful review of the hydraulic behaviour of all the creeks in the catchment, eight different combinations of blockages were selected. The criterion for selection for these blockage scenarios was to establish the highest possible flood level primarily to ensure that the flood planning levels are appropriately estimated.

Since cross-catchment flows occur only at few places in the Allans Creek catchment and the impact for a particular creek, upstream of the applied blockage, is isolated, it was possible to combine the blockage impact assessment for a number of creeks.

The following blockage scenarios were considered for design model runs for various ARI's and durations. The descriptions include reference to the relevant model branch which are shown in Figure 2.2.

- DESIGN1: All culverts open, no blockage
- DESIGN2: All culverts blocked as per Blockage Policy
- DESIGN3: The Princes Highway is the first major hydraulic control for various creeks in the catchment. The following culverts/bridges were blocked as per the Blockage Policy to determine the impact of the Princes Highway.
    - Allans Branch at Princes Highway
    - American Creek at Princes Highway
    - Byarong Creek at Princes Highway
    - Charcoal Creek at Princes Highway
    - Jenkins Creek at Princes Highway
    - Unanderra Drain at Princes Highway
    - Freeway Branch at Coal Co. Railway

  The rest of the culverts were kept open.

- DESIGN4: Unanderra - Dapto railway line and the Freeway are the next major controls. Their impact along with the impact of blocking other culverts on some major tributaries was modelled. The following culvert/bridges were blocked:
    - Jenkins Creek at Railway
    - Charcoal Creek at Railway
    - Allans branch at Railway
    - Unanderra Drain at Railway
    - Freeway branch at Five Islands Road
    - Byarong Creek at The Avenue
    - Branch Tributary at O'Briens Road
    - Branch Creek at O'Briens Road
    - Cordeaux Heights branch at Gibson Road
    - American Creek at Cordeaux Road.

- DESIGN5: This run established the impact of the Freeway on Byarong and American Creeks. Additionally, it included the impact of other culverts.
    - Byarong Creek at Freeway
    - American Creek at Freeway
    - Highway branch at Berkeley Road
    - Freeway branch at Berkeley Road
    - Allans Creek at Blackman Parade

- DESIGN6: This model run was a combination of various blockages, which were considered important.
    - Byarong Creek at Railway
    - Highway branch at Five Islands Road
    - Freeway branch at Freeway Ramp
    - Unanderra Drain at Freeway

- DESIGN7: This run considered the impact of Freeway alone. The following culverts/bridges were blocked:

- Freeway branch at Freeway
- Highway branch at Freeway
- Unanderra Drain at Freeway

- DESIGN8: This run considered blockages in Byarong creek and American Creek at the Freeway. Charcoal Creek was also included. The blocked culverts were:
  - Byarong Creek at Princes Highway
  - Byarong Creek at The Avenue
  - Byarong Creek at Freeway
  - American Creek at Freeway
  - Charcoal Creek at Tallegalla Street.

4.3 Hydrologic and Hydraulic Modelling

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

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

- Various pipe and box culverts (over 90 culverts)
- Cross catchment flood connections and bypass mechanisms
- Footbridges and the like across the channel.

The model was established, calibrated and verified using the historical flood level data from four events - 1984, 1991, 1998 and 1999. The hydraulic model was then used with design rainfall conditions to simulate flood behaviour.

The flood behaviour for the 100 year ARI, 50 year ARI, 20 year ARI, 10 year ARI, 5 year ARI and the extreme flood event (PMF) were investigated and the flood study determined the nature and extent of flooding for each event through the estimation of design flows, levels and velocities. Design flood envelopes were produced for each ARI event based on a number of combinations of blockages. A guide to the peak flood flows at some key locations is provided in Table 4.1. The flood data presented is for the peak flood condition from either the open or closed condition. For a full list of both the open and closed condition discharges at all crossings, see Appendix G in the Allans Creek Flood Study (Cardno Lawson Treloar, 2006). Table 4.1 shows PMF flows up to three times the 100 year ARI flows in some locations which is commensurate with the extreme nature of this type of event.

Table 4.1 Flood Behaviour at Key Locations

Location	PMF			100 year ARI			50 year ARI			20 year ARI			10 year ARI			5 year ARI		
	H (m AHD)	Q (m^3/s)	V (m/s)	H (m AHD)	Q (m^3/s)	V (m/s)	H (m AHD)	Q (m^3/s)	V (m/s)	H (m AHD)	Q (m^3/s)	V (m/s)	H (m AHD)	Q (m^3/s)	V (m/s)	H (m AHD)	Q (m^3/s)	V (m/s)
Byarong Creek																		
U/S Koloona Ave	36.02	387	1.4	35.51	214	1.3	35.42	184	1.4	35.27	144	1.3	34.74	117	1.3	34.51	93	1.3
U/S Princes Hwy	17.61	448	0.7	17.11	210	0.5	17.03	177	0.5	16.90	138	0.5	16.06	111	0.4	15.85	91	0.4
U/S The Avenue	14.41	716	2.6	13.09	289	2.6	12.97	204	2.6	12.80	152	2.6	9.93	88	2.5	9.62	72	2.4
American Creek																		
U/S Princes Hwy	14.27	956	1.5	12.79	367	1.5	12.61	310	1.6	12.38	239	1.6	11.67	188	1.5	11.36	155	1.5
U/S Freeway*	13.81	1355	0.7	12.55	512	0.6	12.50	454	0.6	12.15	374	0.7	8.23	294	0.7	7.92	241	0.6
Jenkins Creek																		
U/S Princes Hwy	18.53	79	1.2	18.28	38	1.2	18.22	33	1.1	18.13	25	1.2	15.00	21	1.1	14.71	19	1.1
Charcoal Creek																		
U/S Blackman Pde	26.60	103	1.0	26.19	52	0.9	26.11	45	0.9	25.98	35	0.9	25.62	28	0.9	25.48	22	0.9
U/S Princes Hwy	17.46	360	1.7	16.88	124	1.4	16.80	96	1.4	16.71	74	1.5	15.04	58	1.4	14.48	47	1.4
Allans Creek																		
U/S Springhill Rd	10.43	1279	0.8	10.06	545	1.6	9.98	476	1.6	9.78	385	1.6	9.44	334	1.4	7.93	261	1.3

Note: H Flood Height (mAHD)
Q Discharge (m^3/s)
V Velocity (m/s)
*American Creek flows reported at the Freeway include cross catchment flow from Byarong Creek

The sensitivity of the model to variations in model parameters such as roughness and catchment inflows was found to be of the order of ± 0.3 m. However, it should be noted that local variations in the amount of blockage of a culvert could result in a greater variation in levels than ± 0.3 m. Further information on the sensitivity of the model can be found in the Flood Study (Lawson and Treloar, 2006).

4.4 Flood Extent

The extent of the various design flood events is shown in Figure 4.1. The number of properties affected by flooding (by inundation of at least the garden area) are shown in Table 4.2.

Table 4.2 Properties Currently Affected by Flooding

ARI	Residential	Small Commercial	Industrial	Total
PMF	785	76	72	933
100 year	590	37	37	664
50 year	555	36	36	627
20 year	498	31	32	561
10 year	265	22	14	301
5 year	217	21	11	249

- Note – Results include the blockages policy as applied in Section 4.2.5
- Total number of properties are those properties where a floor level has been defined. The number affected at the PMF varies from the value in Table 3.2 as the value in Table 3.2 includes an estimate of the total number of allotments affected by flooding which include park and creek allotments as defined by the cadastre and allotments where no dwelling is present.
- 'Small Commercial' - Westfield Figtree contains a significant number of small commercial premises but these have been considered as a lumped value for the entire Shopping Complex.

It should be noted that the flood extent maps were prepared from the detailed survey cross-sections and interpolated between cross-sections using contour information at 2 metre spacings derived from the Land Information Centre (LIC) and provided by Council for the study. Thus, the accuracy of these maps is limited by this information and therefore the extent maps should be used only as a guide to the extent of flooding. For a detailed analysis of the likely inundation extent of a particular property, a detailed topographic survey and a site specific flood study may be required.

4.5 Flood 'Hot Spot' Identification

A number of flood 'hot spots' were identified during the course of the study. The results of the flood study aid in quantifying the impact of flooding on these areas. Table 4.3 provides a comparison of a number of properties affected in these hot spot locations for the August 1998 event, the 10 year ARI event and the 100 year ARI event. For the purposes of Table 4.3, 'Affected' is defined as inundation of at least the garden area during the event reported.

Table 4.3 Characteristics of Hot Spot Areas

Location	Number of Properties Affected in August 1998	Number of Properties Affected at 10 yr ARI	Number of Properties Affected at 100 year ARI
Koloona Avenue (Byarong Creek)	14	14	15
Harry Graham Park (Byarong Creek)	3	2	7
Govett Crescent/Suttor Place (American Creek)	2	2	11
Old Five Islands Road (Unanderra)	3	3	7
Arrow Avenue (Byarong Creek)	39	31	41
Rickard Road (Charcoal Creek)	20	23	30
Preston & Seddon Streets (Byarong Creek)	29	9	31
The Avenue to Lysaght Oval (Byarong Creek/American Creek)	47	24	60

4.6 Flood Hazard

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

1. Size of Flood
2. Effective Warning Time
3. Flood Readiness
4. Rate of Rise of Floodwaters
5. Depth and Velocity of Floodwaters
6. Duration of Flooding
7. Evacuation Problems
8. Effective Flood Access; and
9. Type of Development.

Hazard categorisation based on all of the above factors is part of establishing a Floodplain Risk Management Plan. Provisional flood hazard is flood hazard categorisation based on hydraulic principals only (depth and velocity). When provisional flood hazard is considered in conjunction with the above listed factors it provides comprehensive assessment of the flood hazard, known as the “true hazard”.

In the Allans Creek floodplain many of the above factors are not applicable in terms of affecting hazard definition. However, to provide a thorough assessment process, all of the above factors have been addressed in this report and a reasoning as to their inclusion or exclusion has been provided.

4.6.1 Provisional Flood Hazard

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

Provisional hazard has been calculated for the 100 Year ARI flood event using data from the Allans Creek Flood Study (Lawson and Treloar, 2004) (Figure 4.2). The provisional hazard is defined accurately only at each of the model cross-sections (at each survey point along the cross section). Between cross-sections, the hazard has been interpolated using engineering judgement and available topographic data.

4.6.2 True Flood Hazard

Provisional flood hazard categorisation based around the hydraulic parameters described above, does not consider a range of other factors that influence the "true" flood hazard. Therefore provisional hazard categorisation has been assessed in conjunction with the factors listed in Section 4.6 (which are discussed in detail below) to determine true hazard categories. This assessment was carried out in consultation with a range of stakeholders. Discussions were held in Wollongong with representatives of the Department of Natural Resources, Council and the State Emergency Service on the 23 November 2005 and 20 April 2006. The assessments below reflect the outcomes of discussions held at these workshops.

- *Size of Flood*

The size of a flood and the damage it causes varies from one event to another. For the purposes of this study, flood hazard has been assessed for the 100 Year ARI event. It was agreed that the 100 Year ARI event was the appropriate event to categorise "true" high hazard for the Allans Creek Floodplain.

- *Effective Warning Time*

The effective warning time can also be described as the actual time for people to undertake appropriate actions (such as lift or transport belongings and/or evacuate) and is always less than the total warning time available to emergency service agencies. This is related to the time needed to alert people to the imminence of flooding and to have them begin effective property protection and/or evacuation procedures.

The Allans Creek catchment has an area of approximately 4,200 ha and is characterised by a low flat floodplain west of Port Kembla, which is dominated by the backdrop of the Illawarra Escarpment. The steep western areas of the catchment, near the Illawarra Escarpment, are mainly forested or rural in nature. Closer to the coast the catchment floodplain is relatively flat with a blend of industrial, residential and commercial development. The steep characteristics of the upper catchment result in a fairly short critical duration flood event at the 100 Year ARI of 2 hours in the upper reaches which increases to about 6 hours in the lower floodplain. This

results in a very limited warning time available to residents and visitors in the catchment.

The SES Division responsible for the Allans Creek floodplain does not currently have any predictive capabilities for flooding events to assist with the evaluation of warning time. Therefore, warning time as a true hazard factor is not applicable to the Allans Creek floodplain and as such does not have an impact on flood hazard categorisation.

- *Flood Readiness*

Flood readiness can greatly influence the time taken by flood-affected residents and visitors to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is prompt, efficient and effective. Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. With the 1998 and 1999 floods occurring in recent memory there is likely to be a relatively high degree of flood readiness amongst long term residents, even those not directly affected by flooding. However, it is difficult to quantify flood readiness on a spatial extent since the two recent events had varying intensities across the catchment and therefore impact on resident perceptions of flood behaviour between localities. It is impossible to adequately define one area to be more 'flood ready' than another and it would be remiss to reduce flood hazard across the whole catchment based on a high degree of flood readiness. Consequently, the flood hazard definition has not been altered to reflect flood readiness.

- *Rate of Rise of Floodwaters*

The rate of rise of floodwater affects the consequences of a flood. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. The catchment and floodplain characteristics affect the rate of rise. Due to the steep nature of the catchment and upper reaches of the floodplain, the Allans Creek floodplain has a very high rate of rise, with floodwaters rising as quickly as 7 - 8 metres per hour in some locations.

It was determined through the workshop process, that due to the high rate of rise in many locations in the floodplain, rate of rise could have an influence on the flood hazard extent. As such, areas with a high rate of rise have been assessed for inclusion in the "true" high hazard extent.

A rate of rise of 1m per hour has been adopted to indicate high hazard. However, if an area has a rate of rise greater than 1m/h this does not automatically result in the area being considered as high hazard. For instance, if the rate of rise is very high but flood depths only reach 200mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, a flood depth criterion in conjunction with a high rate of rise was considered appropriate to define additional areas for inclusion in high hazard definition.

A flood depth of 500mm was selected as the trigger depth for high hazard where the rate of rise was equal to or greater than 1m/hr. A 500mm flood depth is well within

the range of available information as to when vehicles become unstable even with no velocity (Figure L1, NSW Government, 2005).

Figure 4.3 shows a comparison of the provisional high hazard extent and the true high hazard mapping to include areas which have both a rate of rise of floodwaters greater than 1m/hr and a depth greater than 500mm. In general the additional areas to be included as high hazard due to rate of rise criteria are within the 10m riparian buffer zone used to determine the high risk precinct (Section 4.7). As such, most areas would already have been classified as 'high risk precinct'. The most significant area of additional high hazard extent is in the vicinity of Figtree Park to the north east of the Westfield Shopping Centre in Figtree. A large portion of this area is flooded to a depth of 500mm or greater in 30 minutes, resulting in a potential hazard risk.

- *Depth and Velocity of Floodwaters*

As outlined above provisional hazard mapping is determined from a relationship between velocity and depth. An assessment of this relationship was carried out at each cross section for maximum depth and velocity couplings for the 100 year ARI flood event (Figure 4.2).

- *Duration of Flooding*

The duration of flooding or length of time a community, town or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Within the Allans Creek floodplain the duration of flooding was assessed based on the 100 Year ARI critical duration flood event. The assessment was based upon the length of the hydrograph for selected cross sections.

This assessment did not take into account over bank flooding, simply elevated water levels. As such, properties higher than the creek bed at any location will have a flooding duration less than the total duration of flooding reported at that cross section. Consequently, the approach may yield an outcome indicating neighbouring properties with a different flooding duration, if one is significantly higher in level than the other. However, to overcome this limitation a complex assessment on a property by property basis would be required. The approximate approach, considering the duration of flooding estimated from the elevated floodwaters in the creek, is adequate for the purposes of this true hazard assessment. It should also be noted that longer durations of flooding can occur from events more frequent than the 100 Year ARI.

Due to the steep nature of the catchment the duration of flooding within the floodplain is relatively short. The duration of flooding ranges from 2 hours in portions of the upper reaches of the floodplain to 12 hours in the lower, flatter areas of the floodplain. There are no locations which have a flooding duration greater than 24 hours. On this basis the hazard mapping was not altered due to the "duration of flood" criterion.

- *Evacuation Problems*

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

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

Generally development types which would pose evacuation problems (such as aged care facilities, hospitals and schools) are not permitted within the high risk precincts. DCP54 provides full details of land use categories permissible within the floodplain.

Evacuation problems are an important factor in floodplain management and future planning controls. However, as a true hazard factor it does not affect the hazard categorisation of the floodplain.

- *Effective Flood Access*

The availability of effective access routes from flood prone areas can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions.

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

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

To consolidate these categories and determine the implication of flood access issues on hazard mapping, criteria were set to establish effective flood access. It was determined that effective access is a road which is flooded by less than 300mm of water. For the purposes of this assessment 300mm is the threshold depth at which vehicles become unstable, even at very low velocities. However, further to this, a property or area is only considered to be without effective access if the access is flooded by 300mm of water for more than 24 hours. As there are no areas which are flooded for more than 24 hours within the Allans Creek floodplain, this criteria does not apply to any location in Allans Creek. Therefore, the hazard mapping has not been altered due to effective flood access issues.

- *Type of Development*

The degree of hazard to be managed is also a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and change management strategies in existing development areas. Wollongong City Council has a development control policy (DCP54) which considers and manages development within floodplains. The DCP defines prohibited land uses for high, medium and low risk precincts (Section 4.7).

The following land use categories are prohibited in high risk precincts (high hazard at the 100 Year ARI and riparian zones):

- Essential community facilities
- Critical utilities
- Subdivision
- Residential
- Commercial and Industrial
- Tourist Related Development.

The following land use categories are prohibited in medium risk precincts (low hazard – to the flood planning level extent – 100 Year ARI + 0.5m):

- Essential community facilities
- Critical utilities.

The following land use categories are prohibited in low risk precincts (PMF extent but no high or low hazard)

- Essential community facilities.

A full list of land use categories and land use types are provided in DCP54.

Through the workshop process it was determined that the hazard category of individual properties would not be altered due to current land use type.

- *Summary of True Hazard*

Due to the nature of flooding in Allans Creek many of the factors do not alter the provisional hazard mapping. A summary of the factors which affect flood hazard are presented in Table 4.4.

Table 4.4: Factors Affecting Flood Hazard

Factor	Outcome of Study
Size of Flood	True high hazard to be determined by 100 Year ARI
Effective Warning Time	The whole floodplain has a very short effective warning time and therefore, no particular areas would be subject to a higher hazard category on the basis of this.
Flood Readiness	Generally flood readiness in Allans Creek floodplain is assumed to be fairly high, however no particular areas could be defined as being more or less flood ready than another. Therefore, flood hazard has not been altered due to flood readiness.
Rate of Rise of Floodwaters	Rate of rise of floodwaters is generally very high in the Allans Creek floodplain. Areas which have a rate of rise greater than 1m/hour and reach a flood depth of greater than 500mm have been categorised as high hazard.
Depth and Velocity of Floodwaters	Provisional Flood Hazard Mapping (Figure 4.2).
Duration of Flooding	No properties are flooded for a duration of 24 hours or more, therefore no additional properties have been defined as high hazard due to duration of flooding.
Evacuation Problems	Due to the regulations on permissible development within the floodplain and the SES policy of shelter in place for areas affected by flash flooding (ie encouraging people to stay in their homes rather than evacuate), no additional properties were defined as high hazard due to evacuation problems.
Effective Flood Access	There are no areas in the Allans Creek floodplain which are inundated to 300mm for a period greater than 24 hours, therefore no additional properties have been defined as high hazard due to effective flood access.
Type of Development.	This does not affect hazard mapping extents, however this will be incorporated into the development control matrix.

The final “true” hazard mapping translation for the 100 Year ARI is presented in Figure 4.4. The low hazard extent corresponds to the Flood Planning Level (100 Year ARI + 0.5m) extent.

4.7 Flood Risk Precincts

Wollongong City Council has adopted an approach of classifying areas of the floodplain by the potential risk associated with these areas referred to as 'flood risk precincts'. This is in accordance with the flood-related development control plan - *Managing Our Flood Risks* (DCP 54, 2004). This document specifies the following definitions for the application of flood risk precincts for the Local Government Area:

- **High Flood Risk Precinct** - This has been defined as the area within the envelope of land subject to a high hydraulic hazard (in accordance with the provisional criteria outlined in the Floodplain Development Manual) in a 100 year flood event together with all land within a corridor 10m horizontally from the top of the creek bank. The high flood risk precinct is where high flood damages, potential risk to life, evacuation problems would be anticipated or development would significantly and adversely effect flood behaviour. Most development should be restricted in this precinct. In this precinct, there would be a significant risk of flood damages without compliance with flood related building and planning controls.

- **Medium Flood Risk Precinct** - This has been defined as land below the 100 year flood level (plus 0.5m freeboard) that is not within the High Flood Risk Precinct. It is land subject to low hydraulic hazard (in accordance with the provisional criteria outlined by the Floodplain Development Manual). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

- **Low Flood Risk Precinct** - This has been defined as all other land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified within either the High Flood Risk (and Interim Riverine Corridor) or the Medium Flood Risk Precinct, where risk of damages are low for most land uses. The Low Flood Risk Precinct is that area above the 100 year flood (plus 0.5m freeboard) and most land uses would be permitted within this precinct.

To determine the extents of the flood risk precincts for the Allans Creek floodplain, the results of the hydraulic modelling (Section 4.3) were processed. The riparian corridor area was mapped by identifying the top of channel banks from surveyed cross section detail and aerial photography and a 10 metre buffer map was created. This map and the 100 year ARI 'true' high hazard map were combined to create an envelope which represents the High Flood Risk Precinct.

The result of this process is a plan of the flood risk precincts shown in Figure 4.5.

It should be noted that the Flood Risk Precincts are defined accurately only at each of the model cross-sections and interpolation has been carried out between cross-sections using 2m LIC contour data. As such, the plan is a broad-scale planning tool and the assessment of individual properties using this plan is not recommended. For the purposes of development control, individual properties should be assessed using site specific survey.

It should be noted that the hazard-related portion of the definition of high risk (i.e. velocity-depth relationship) is appropriate for able-bodied adults only. In the case where children, elderly or disabled persons are affected by floodwaters, lower velocity-depth products are still likely to be hazardous. Thus, portions of the medium risk precinct may be high risk for children, elderly or disabled persons.

5. FLOOD DAMAGES AND INCONVENIENCE

5.1 Overview

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

Previous flood events detailed in the Allans Creek Flood Study (Lawson and Treloar, 2006), have caused significant flooding and disrupted traffic. Floodwaters have inundated many properties as well as caused above-floor flooding. Available records indicate that, in general, the 1998 flood produced the highest observed water levels and the most property damage. However, the 1999 event was similar but was more severe for some areas.

Resident reports gathered during surveys following the 1998 flood event (Section 3) indicate damages were incurred at:

- Residential properties - gardens, sheds, garages and above-floor flooding
- Commercial properties
- Industrial properties
- Infrastructure damage (considered as infrastructure related to either residential, commercial or industrial areas).

In addition to above-floor flooding, inconvenience due to road or footpath inundation has also been reported in the Allans Creek Flood Study (Lawson and Treloar, 2006). Detail of the overtopping of major road and rail services is contained in Section 10.

An assessment of the flood damages for design floods for the existing condition was undertaken. Table 5.1 shows the number of properties currently affected by above-floor flooding for the various design events.

Table 5.1 Properties Currently Affected by Above-Floor Flooding

ARI	Residential	Small Commercial	Industrial	Total
PMF	507	64	64	635
100 year	317	25	34	376
50 year	276	21	33	330
20 year	230	18	29	277
10 year	65	13	7	85
5 year	44	12	4	60

- Note – Results include the blockages policy as applied in Section 4.2.5
- 'Small Commercial' - Westfield Figtree contains a significant number of small commercial premises but these have been considered as a lumped value for the entire Shopping Complex.

5.1.1 Flood Damages Assessment

Flood damages can be assessed by a number of means including the use of programs such as FLDAMAGE or ANUFLOOD. Lawson & Treloar have developed a method that directly utilises MIKE11 hydraulic model result files (Section 4.3) along

with details including floor level, property survey details and damage curves and outputs this data to a MapInfo GIS format of the direct damage costs.

Direct damage costs are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs. The nature of the different types of costs are outlined in Table 5.2. Indirect and intangible costs are difficult to assess and have been evaluated as functions of the direct costs. For example, indirect costs for residential damages were assumed to be 30% of the direct costs, indirect costs for commercial and industrial damages were assumed to be 50% of the direct costs. Additionally, damage to infrastructure (e.g. roads, utilities etc) was assumed to be 50% of the direct costs for residential, commercial and industrial areas. Intangible costs were assumed to be 100% of the direct costs for residential areas and 50% of direct costs for commercial and industrial areas.

Table 5.2 Types of Flood Damages

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

5.1.2 Floor Level and Property Survey

A detailed floor level and property survey was commissioned as part of this investigation and carried out in 1996.

This floor level survey included details of each property within the known extent of the floodplain at the time of the survey. The details of each property included an evaluation of the type of property based on exterior characteristics whilst surveying the floor levels. Following the 1998 and 1999 flood events and as a result of the implementation of the blockages policy (Section 4.2.5), the extent of the floodplain was revised. As a result, additional properties were found to lie within the floodplain that were not included in the 1996 property and floor level survey. Given the limited likelihood of overfloor flooding in these areas (except possibly at the Probable Maximum Flood), the details of these properties were estimated from available data rather than surveyed in the field.

A number of categories of property were identified within the floodplain including:

- Residential
- Small Commercial
- Major Commercial
- Industrial.

5.1.3 Stage - Damage Curves

Based on the property details surveyed in the field, each property was assigned a stage-damage curve. Stage-damage curves are basically the likely cost of damage for a property based on the level of flooding above floor level. Two scenarios are usually considered in the preparation of stage-damage curves:

- the case where the community is 'prepared' for a flood (as a result of flood warnings or general flood awareness) and
- the case where the community is 'unprepared' for a flood (as a result of flash flooding or being unaware that the area floods).

Since the time to flood peak for the Allans Creek floodplain is extremely fast (15 minutes from the onset of rainfall in some locations), it is generally not possible to ensure that the majority of the community is 'prepared' for a flood (particularly given the very limited nature of the present flood warning systems as detailed in Section 10). Flood awareness in the area varies greatly, with some residents being extremely aware of the flooding potential of the Creek, whilst others have no prior knowledge of the flood history of the area or have no knowledge of the potential extent of flooding in an extreme event. As a result, only the 'unprepared' case has been considered as part of this study. By considering this case, flood damages estimates will be conservative.

Stage-damage curves for the project were derived from the FLDAMAGE, Planning and Natural Resources Specialist Flood Unit required that all damage curves adopted from published data were to be doubled to account for recent research on flood damage (Blong, 2000). This reflects the changes in estimates from the residual value to replacement cost.

In addition to the FLDAMAGE curves, and given the limited published data on flood damages to industrial premises, a survey of local commercial and industrial premises within the floodplain was carried out in order to make a valid assessment of the likely damage costs to these types of properties. A questionnaire was prepared and distributed to the operators/proprietors for completion, responses were received from eight premises in the floodplain and site specific damage curves were prepared. A composite series of damage curves were then prepared from this information.

Overall, the compiled data classifies properties using the following identifiers:

FA Medium Residential (adapted from FLDAMAGE)
FB Large Residential (adapted from FLDAMAGE)
FC Commercial (adapted from FLDAMAGE)
G Industrial, Medium – High Value, Single Storey (from locally derived data)
H Large industrial, High Value (from locally derived data)
I Large industrial, Low Value (from locally derived data)
J Large Commercial (e.g. Large Shopping Centre) (from locally derived data).

The property details outlined above were then linked to these classifications to allow for the damage assessment. Damage curves adopted are shown in Appendix D.

Table 5.3 provides an overview of the existing damage costs incurred at the various design events. The average annual damage cost calculated from the various design events is approximately $13.5 million. The present value of this damage assuming a 50 year period at a discount rate of 7% is $186.3 million.

Table 5.3 Existing Flood Damage Costs*

	Tangible										Intangible				Total	Total for Land Use		
	Residential		Small Commercial		Industrial		Infrastructure (Residential Areas)	Infrastructure (Small Commercial Areas)	Infrastructure (Industrial Areas)	Total Tangible Damages	Residential	Small Commercial	Industrial	Total Intangible Damages	Total Damages	Total Residential Damages	Total Small Commercial Damages	Total Industrial Damages
ARI (yrs)	Direct	Indirect	Direct	Indirect	Direct	Indirect												
PMF	$28.7 m	$8.6 m	$6.0 m	$3.0 m	$112.9 m	$56.5 m	$14.4 m	$3.0 m	$56.5 m	$289.7 m	$28.7 m	$3.0 m	$56.5 m	$88.2 m	$377.9 m	$80.4 m	$15.1 m	$282.4 m
100	$15.5 m	$4.7 m	$2.3 m	$1.1 m	$38.7 m	$19.3 m	$7.8 m	$1.2 m	$19.3 m	$110.0 m	$15.5 m	$1.2 m	$19.3 m	$36.0 m	$146.0 m	$43.5 m	$5.8 m	$96.7 m
50	$13.6 m	$4.1 m	$2.0 m	$1.0 m	$34.6 m	$17.3 m	$6.8 m	$1.0 m	$17.3 m	$97.9 m	$13.6 m	$1.0 m	$17.3 m	$32.0 m	$129.9 m	$38.2 m	$5.1 m	$86.6 m
20	$10.9 m	$3.3 m	$1.4 m	$ 0.7 m	$30.8 m	$15.4 m	$5.4 m	$0.7 m	$15.4 m	$83.9 m	$10.9 m	$0.7 m	$15.4 m	$27.0 m	$110.9 m	$30.5 m	$3.5 m	$77.0 m
10	$2.8 m	$ 0.8 m	$0.6 m	$0.3 m	$2.7 m	$1.3 m	$1.4 m	$0.3 m	$1.3 m	$11.5 m	$2.8 m	$0.3 m	$1.3 m	$4.4 m	$15.9 m	$7.9 m	$1.4 m	$6.6 m
5	$2.0 m	$0.6 m	$0.3 m	$0.2 m	$1.3 m	$0.6 m	$1.0 m	$0.2 m	$0.6 m	$6.8 m	$2.0 m	$0.2 m	$0.6 m	$2.8 m	$9.6 m	$5.6 m	$0.8 m	$3.2 m

*AAD = $13.5 million and has been calculated assuming zero damage at the 2 year ARI. Present Value of AAD for 7% Discount Rate and 50 year period is $186.3 million.

Table 5.4 Proportions of Total Damage

	Residential	Small Commercial	Industrial
PMF	21%	4%	75%
100 yr ARI	30%	4%	66%
50 yr ARI	29%	4%	67%
20 yr ARI	27%	4%	69%
10 yr ARI	49%	9%	42%
5 yr ARI	58%	9%	33%

As a comparison, the reported value of damage for the entire LGA for the 1998 flood event was $75 million (Hunt and Kofod, 2000). Analysis of the flood model results for the 1998 event for Allans Creek alone produced a comparable result of $45 million in total damages. The estimate of $45 million for Allans Creek included intangible costs that are unlikely to be included in the $75 million estimate outlined above. Thus the damage values have a reasonable calibration to a real flood situation. It is worth also comparing this value with the estimated damages for the 100 year ARI under existing case for Allans Creek of $146 million (Table 5.3). Note that the 1998 event was not a 100 year ARI event for the entire area and not all culverts and handrails were blocked in the same manner as the adopted blockages policy.

The damages assessment for the existing condition reported in Table 5.3 forms a basis for the purposes of comparison of the potential economic benefits of proposed floodplain management options, in particular flood modification options (Section 8).

6. FLOOD PLANNING LEVEL REVIEW

6.1 Background

The flood planning level for the majority of areas across New South Wales has been traditionally adopted as the 100 year ARI. Habitable floor levels are traditionally set with a freeboard of between 0.3 - 0.5 m above this level.

A variety of options exist for Council to consider as being appropriate flood planning levels. Most importantly, the flood behaviour and the risk posed by the flood behaviour to life and property in different areas of the floodplain and different types of land use need to be accounted for in the setting of a flood planning level.

The following factors were considered in the setting of the flood planning levels:

- likelihood of flooding
- consequences of different flood events - incremental height difference between each recurrence interval event
- consequences of different flood events - damage cost differential between different events
- consequence of height of floors required to be raised to the PMF level.
- consequences of adopting the PMF as the standard for the number of dwellings below the PMF

A summary of the outcome of the assessment of each factor and its implications for setting of flood planning levels is included as a recommendation in Section 6.7.

6.2 Likelihood of Flooding

As a guide, Table 6.1 has been reproduced from SCARM (2000) to indicate the likelihood of the occurrence of an event occurring in an average lifetime to indicate the potential risk to life.

Table 6.1 Probability of Experiencing a given size flood or higher in an average lifetime (70 years) (after SCARM, 2000)

Likelihood of Occurrence in any year (AEP)	Probability of experiencing at least one event in 70 years (%)	Probability of experiencing at least two events in 70 years (%)
10% (c.f. 10 year ARI)	99.9	99.3
5% (c.f. 20 year ARI)	97	86
2% (c.f. 50 year ARI)	75	41
1% (c.f. 100 year ARI)	50	16
0.5% (c.f. 200 year ARI)	30	5

Thus, the data in Table 6.1 indicates that there is a 50% chance of a 1%AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1%AEP flood event as the flood planning level. Given the social issues associated

with a flood event and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of persons and property where possible to these types of events within their life period.

Note that there still remains a 30% chance of exposure to at least one flood of a 0.5% AEP magnitude over a 70 year period. This gives rise to the consideration of the adoption of the PMF as the flood planning level for some demographic categories (such as persons within Aged Care facilities).

6.3 Incremental Height Difference Between Events

Based on the existing flood behaviour (Lawson and Treloar, 2006) the incremental peak height difference between events as averaged across the catchment is shown in Table 6.2.

Table 6.2 Differences in Event Flood Levels (after Lawson and Treloar, 2006)

	Difference PMF - 100 yr	Difference 100 - 50 yr	Difference 50 yr - 20 yr	Difference 20 - 10 yr	Difference 10 - 5 yr
Averages	1.07 m	0.13 m	0.18 m	0.59 m	0.18 m
SD	1.13 m	0.11 m	0.15 m	0.82 m	0.24 m

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

Table 6.2 indicates that the effects of culvert blockages are such that the most noticeable difference in average flood level occurs first between the 20 year ARI and the 10 year ARI (0.59 m). Another major difference is between the 100 year ARI and the PMF (1.07 m). With each reported flood event, the maximum difference is generally of the order of 0.15 m. In general the steepness of the catchment results in only very minor differences between the various events with the maximum range of difference between the PMF and the 5 year ARI of the order of only 2.12 m (with a standard deviation of 1.7 m).

Thus the adoption of a flood planning level of the 100 year ARI is not a considerable difference from the 20 year ARI (0.31 m) and would provide an appropriate level of risk reduction for a small increase in elevation. The adoption of a flood planning level of the PMF is a more significant increase in level over the 100 year ARI (1.07 m) and would therefore potentially present an issue for the setting of minimum habitable floor levels for the floodplain. However, the difference is relatively manageable when compared to other floodplains such as the Hawkesbury Nepean, where the PMF level is greater than 10 m higher than the 100 year ARI level (NSW Government, 2005).

Given the generally flat nature of industrial areas, the potential cost to set a floor level at the 100 year ARI may be prohibitive during the construction phase (requiring significant quantities of fill to be imported to achieve flood planning levels). As a consequence, the setting of floor levels for this type of development at the 20 year ARI event may be appropriate. However, appropriate site layout to protect significant

assets and the inclusion of refuge within each site up to the PMF for all on-site personnel is recommended.

6.4 Damage Cost Differential Between Events

Based on the existing flood behaviour and the assessment of flood damages, the incremental difference in the damage for different recurrence intervals is shown in Table 6.3.

Table 6.3 Damage Differential Costs - All Damages

Event	Total Damage	Diff PMF	Diff 100 year	Diff 50 year	Diff 20 year	Diff 10 year	Diff 5 year
PMF	$377.9 m	-	-	-	-	-	-
100 year	$146.0 m	$231.9 m	-		-	-	-
50 year	$129.9 m	$248 m	$16.1 m	-	-	-	-
20 year	$110.9 m	$267 m	$35.1 m	$19 m	-	-	-
10 year	$15.9 m	$362 m	$130.1 m	$114 m	$95 m	-	-
5 year	$9.6 m	$368.3	$136.4 m	$120.3 m	$101.3 m	$6.3 m	-

Table 6.3 indicates that the initiation of considerable damage commences between the 10 year ARI and the 20 year ARI (an increment of $95 million) and between the 100 year ARI and the PMF (an increment of $231.9 million). The increment between the 10 year ARI and the 20 year ARI is also significantly related to the likelihood of blockages occurring in events of the magnitude of the 20 year ARI flood and greater (i.e. blockages are less likely to occur in events such as the 10 year ARI and the 5 year ARI).

This indicates that a significant value of assets are located below the 20 year ARI but above the 10 year ARI flood level and from historical information, are affected by the impacts of the potential blockage of culverts and bridges.

However, a review of the nature of the total damages from Table 5.3 indicates that industrial damages accounts for around 70% of the total damages at the less frequent events. Therefore, in consideration of purely residential damages, a separate assessment of the damage differential costs is appropriate in the consideration of the flood planning level and these are shown in Table 6.4.

Table 6.4 Damage Differential Costs - Residential Damages

Event	Total Damage	Diff PMF	Diff 100 year ARI	50 year ARI	20 year ARI	10 year ARI	5 year ARI
PMF	$80.4 m	-	-	-	-	-	-
100 year ARI	$43.5 m	$36.9 m	-	-	-	-	-
50 year ARI	$38.2 m	$42.2 m	$5.3 m	-	-	-	-
20 year ARI	$30.50 m	$49.9 m	$13 m	$7.7 m	-	-	-
10 year ARI	$7.9 m	$72.5 m	$35.6 m	$30.3 m	$22.6 m	-	-
5 year ARI	$5.6 m	$74.8 m	$37.9 m	$32.6 m	$24.9 m	$2.3 m	-

Table 6.4 indicates that in the case of residential damages alone, the initiation of considerable damage commences between the 10 year ARI and the 20 year ARI (an increment of $22.6 million) and between the 100 year ARI and the PMF (an increment of $36.9 million).

This indicates that, similarly to the industrial damage assessments, a significant value of assets are located below the 20 year ARI but above the 10 year ARI flood level. As for the total damages case, this is also due to the impact of culvert blockages.

Whilst, in the Allans Creek floodplain, it may be appropriate to set the FPL for industrial areas at the 20 Year ARI flood level, Council requires a consistent approach to Flood Planning Levels across the LGA. As a result, it is suggested that assets be located above the 100 year ARI flood level or be flood proofed to the 100 Year ARI flood level as a minimum.

6.5 Consequence of Adopting the PMF as a Flood Standard

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

If the PMF were to be adopted as the flood planning level for all development, over 500 existing properties would be affected by this flood planning level. This level of protection is considered likely to be an onerous task with regard to matters such as minor development and redevelopment to address this low level of risk to property and life. Given the very low probability of the event, the reduction in annual average damage as a result of adopting the PMF as the flood planning level (through the redevelopment process and other programs such as house raising and voluntary purchase) is likely to be low.

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

6.6 Flood Behaviour in the Allans Creek - Freeboard Selection

As outlined above, a freeboard ranging from 0.3 - 0.5 m is commonly adopted.

An analysis was undertaken of the 100 year ARI, 100 year ARI + 0.5 m and the PMF levels in order to identify if any trends exist in order to base an appropriate judgement on what constitutes an appropriate freeboard for a development with habitable floor levels.

Details of specific flood levels can be derived from the Appendices of the Allans Creek Flood Study (Lawson and Treloar, 2006).

Overall the following was identified:

- there are areas where the 100 year ARI + 0.5m is less than the PMF level (e.g. lower reaches of the floodplain, but scattered areas as well throughout the floodplain)
- there are areas where the 100 year ARI + 0.5 m is approximately equal to the PMF level (e.g. middle reaches of the floodplain, but also scattered areas throughout the floodplain)
- there are areas where the 100 year ARI + 0.5 m is greater than the PMF level (e.g. in the upper reaches of the floodplain, but also scattered areas throughout the floodplain)
- there are areas where the 100 year ARI + 0.5 m may be greater or less than the PMF level.

There was no clear trend to support a zoned approach to the adoption of a range of freeboard values (such as the upper reaches being of one category and the lower reaches being another, or one creek system having one category as compared to another system having a different category).

6.7 Recommended Flood Planning Levels and Freeboards

As a result, it is recommended that:

- critical facilities should be omitted from the floodplain (Sections 6.2 and 6.5)
- the flood planning level (FPL) for industrial areas be set at the 100 year ARI with appropriate controls on site layout and refuges (Section 6.3)
- the flood planning level (FPL) for residential areas be set at the 100 year ARI (Sections 6.1) with the adoption of 0.5 m continue to be an appropriate freeboard for residential development (Section 6.6)
- as a result of the residential FPL, residential assets should be relocated where possible (through the redevelopment process and other programs such as Voluntary House Raising) to above the 100 year ARI flood level + 0.5 m and all new development be ensured that the floor levels are at or above the 100 year ARI + 0.5 m.

7. IDENTIFICATION OF SUITABLE FLOODPLAIN RISK MANAGEMENT MEASURES

7.1 Overview of Available Measures

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

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

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

- Preventing/Avoiding risk — i.e. setting the planning level at the Probable Maximum Flood or not allowing development to be within the floodplain
- Reducing likelihood of risk — i.e. relying on structural measures to reduce risk (not viable for planning levels in the Allans Creek floodplain. The potential for implementation of flood modification options is limited by economic, social and environmental constraints)
- Reducing consequences of risk — i.e. using development controls - design of structures to withstand flooding, allows a floodplain to be developed in lower areas
- Transferring risk — via insurance - not viable given the non-insurability of most flood-prone areas
- Financing risk — through natural disaster funding
- Accepting risk — regardless of the options implemented, a continuing risk will be present.

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

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

7.2 Methodology For Identifying Measures

The identification of measures included the following tasks:

- catchment inspection (multiple inspections)
- review of the flood study results
- suggestions by the Floodplain Risk Management Committee
- suggestions by residents via the questionnaire responses (Chapter 3)
- suggestions by Council technical personnel and the Department of Natural Resources
- review of appropriate approaches as listed in the Floodplain Development Manual (2005).

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

7.2.1 Flood Modification Measures

The following flood modification measures were considered as possible options:

- bypass floodways and other flow redistribution works
- channel capacity improvements (depth, slope, reduction in roughness, widening)
- removal of local obstructions or constrictions
- levees or flood walls
- storage - both concentrated and distributed (storage reservoirs, retarding basins, reach and floodplain storage, catchment storage) - reservoirs and basins are not realistic for the Allans Creek catchment but distributed and floodplain storage were investigated
- stormwater drainage and flow path improvements
- debris control structures - Austroads (1994) states that where there is a likelihood of a culvert being affected by an accumulation of debris at the inlet, consideration should be given to the installation of a debris control structure. Recommendations include:
    - use of design precautions - providing a smooth, well designed inlet, avoiding multiple cells, increasing the size of the culvert (where multiple cells are unavoidable, provision of a streamlined upstream pier wall end may help to align floating debris)
    - relief culvert(s) - at a higher level than the main culvert permitting the water to bypass when blocked
    - debris control structures - various types can be found in the Hydraulic Engineering Circular No 9 - US Federal Highway Administration, 1971).

It is important to note that it is Council policy that a debris control structure cannot be implemented as a stand-alone option for the purpose of lowering flood planning levels. Instead, a debris control structure can only be implemented as part of a holistic solution on a catchment basis. This may involve creek modification/rehabilitation to reduce the source of debris and the installation of structures throughout the catchment.

7.2.2 Property Modification Measures

The following property modification options were identified as being suitable for the Allans Creek floodplain:

- Development Controls
- House Raising Program
- Voluntary Purchase Program
- Zoning Modifications
- Rewording Of Section 149 Certificates
- Policy preparation and revisions (e.g. Caravan Park Policy and On-Site Detention Policy)
- Data Collection Strategies
- Public Awareness and Education.

Full details of these options are included in Chapter 9.

7.2.3 Emergency Response Modification Measures

The following emergency response modification options were identified as being suitable for the Allans Creek floodplain:

- Revision of Flood Sub-Plan portion of the DISPLAN
- Flood Warning Systems and Instrumentation
- Relocation Of Combat Agency Headquarters
- Information Transfers to SES
- Public Awareness and Education (e.g. Locality Based Brochures, Annual Remembrance Day (17th August) and Schools Package).

Full details of these options are included in Chapter 10.

7.3 Summary of Measures Identified

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

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

A total of 65 Flood modification options, 14 Property modification options and 10 Emergency response modification options were identified. All measures identified are listed in their entirety in Appendix C.

In general, all of the options identified lie within the area that is covered by the hydraulic model established for the Flood Study (as discussed in Section 4.3). Some areas have been reported to be affected by flooding upstream of the model upper boundaries as shown in Figure 2.2.

Given that the model and therefore the definition of the floodplain and all related data (such as property floor levels and the like) does not extend to these areas, no assessment of flood modification options for these areas was made as part of this study. Recommendations for local area investigations to resolve these issues can be found in Chapter 11.

7.3.1 Measures Identified For Quantitative Assessment

Of the 59 flood modification options identified, a series of combinations of options were identified for quantitative assessment. Note that the option numbering for modelling was prepared to facilitate the modelling process and the corresponding prefix approach to option numbering is shown in brackets for correlation purposes. The option combination assessments included:

- Option 1 (FM55) — Bridge Construction to replace American Creek Culverts under F6
- Option 2 (FM20, FM39) — Bridge Construction to replace culverts between The Avenue to the F6 Freeway Ramp (Byarong Creek)
- Option 3 (FM3, FM24, FM 30, FM38, FM40, FM43, FM46, FM48, FM50) — Creek Modification
- Option 4 (FM49) — Tallegalla Street Footbridge Elevation
- Option 5 (FM4, FM11, FM14, FM17, FM36, FM48, FM51, FM52) — Creek-Line-Park Contouring to form Detention Basins
- Option 6 (FM12) — Lindsay Park Primary School Footbridge Elevation
- Option 7 (FM2, FM5) — Bridge Construction to replace Koloona Avenue Culverts
- Option 8 (FM18, FM20, FM39, FM56) — Byarong/American Creek Hydraulic Improvements
- Option 9 (FM28) — American Creek Riparian Corridor Creation and Flood Bypass Channel
- Option 10 (FM27) — Culverts Under Driveway at End of Suttor Place
- Option 11 (FM18, FM20, FM37, FM38, FM 55, FM59) — Byarong/American Creek Hydraulic Improvements and Voluntary Purchase.

The locations of these options are shown in Figure 7.1. Details of the assessment of these options can be found in Chapter 8 and Chapter 11.

Note that Option FM29, a detention basin on Brandy and Water Creek, was investigated as part of the preparation of the July 2002 draft of the floodplain management study (Lawson and Treloar, 2002). The results of hydraulic modelling of this option indicate that the timing of the arrival of the peak flows and the associated effects of detention on the local area results in minimal improvement in flood levels downstream due to the change in the phasing of the arrival of peak flows. As a consequence, this option has not been included in detail in subsequent reports.

7.3.2 Measures for Qualitative Assessment

All options that were not identified for quantitative assessment were assessed in a qualitative manner using engineering judgement with a knowledge of the behaviour of the Allans Creek floodplain.

The locations of these options are shown in Figure 7.2. Details of the assessment of these options can be found in Chapters 9, 10 and 11.

7.3.3 Measures Identified Related to Stormwater Management Plan

Section 2.13 (Table 2.9) outlines all of those strategies identified as part of the stormwater management plan for the Allans Creek catchment. The following strategies (listed with their priority in the Stormwater Management Plan) have been identified as being able to be integrated into the floodplain management options to be assessed as part of this study:

- maintain buffer strips as sediment control structures along creek banks adjacent to Council's playing fields and enhance to provide riparian vegetation (Priority 1) (relates to FM3, FM24, FM30, FM38, FM40, FM43, FM46, FM48)
- Improve existing riparian vegetation and provide controlled public access at selected locations (Priority 90) (also relates to FM3, FM24, FM 30, FM38, FM40, FM43, FM46, FM48)
- review and monitor protocol for 'cleaning out' of blocked/silted/overgrown watercourses using environmental best management practices in consultation with DNR (Priority 6) (relates to FM21, FM41, FM 54)
- assess merits of program to progressively bring riparian land into public ownership (Priority 26) (also relates to FM3, FM24, FM 30, FM38, FM40, FM43, FM46, FM48)
- review street and pit cleaning program to ensure industry best practice and co-ordination with other operators activities (Priority 30) (a general maintenance issue)
- encourage use of stormwater reuse in industrial situations (Priority 45) (relates to PM9)
- encourage residents with backyards adjacent to creeks to maintain grassed buffer filter strips to intercept runoff and not to throw clippings into the creek (Priority 54) (relates to PM12)
- ensure that water quality and river health objectives are addressed in the development of Floodplain Risk Management Plans (Priority 57) (described in Section 2.7).

8. FLOOD MODIFICATION OPTIONS ASSESSMENT

8.1 Overview

All flood modification options were assessed against the following criterion:

- hydraulic performance
- economic benefits
- social factors
- environmental factors.

As discussed in Section 7.3.1, a series of 11 option combinations were identified for quantitative assessment. These are outlined in Section 8.2. As an overall guide, modelling discussed in Section 8.2 showed that the maximum reduction in flood levels at any one location is in the order of between 0.1 and 1.5 m for the options assessed.

The performance of other options identified which were not assessed using hydraulic modelling are described in Section 8.3.

Economic assessments were carried out for those options assessed using hydraulic modelling by:

- assessing the reduction in annual average damage
- assessing the likely cost of the option
- calculating a benefit-cost ratio.

Economic assessments for the other options were carried out by making a qualitative assessment of the likely benefit-cost ratio.

Social and environmental factors were considered by reviewing the summary of information in Chapter 2 and allocating a score to the option. This is further described in Chapter 11.

8.2 Details of Hydraulic Model Assessments

8.2.1 Option 1 – Bridge Construction to replace American Creek Culverts under F6 Freeway

Flooding of the lower reaches of American Creek is exacerbated by culvert blockage. Flooding during the 1998 and 1999 events occurred in the area around O'Donnell Drive, Platypus Close, Northview Terrace and the Figtree Gardens Caravan Park. This flooding was primarily caused by the blockage of the F6 Freeway culverts. This option provides a means by which the risk of culvert blockage can be minimised.

The current configuration of the culverts is a series of eight cells 3.65 m x 3.5 m. This would be modified by constructing a bridge with a waterway area of four cells 7.3 m wide x 3.51 m high.

The proposed design shown in Figure 8.1 would be to protect properties in the local area against flooding by upgrading the present culverts under F6 Freeway to a series of bridge openings all with a minimum diagonal length of 6m. The use of a diagonal greater than 6m reduces the risk of blockage of the spans and associated backwater flooding and flow diversions.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 1.5 m.

Table 8.1 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.1 Difference in Number of Properties Affected by Above Floor Flooding for Option 1

ARI	Existing Case	With Option 1	Change
PMF	635	629	6
100 year	376	302	74
50 year	330	249	81
20 year	277	200	77
10 year	85	85	0
5 year	60	60	0

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.2 Option 2 - Bridge Construction to replace culverts between The Avenue and the F6 Freeway Ramp (Byarong Creek)

Flooding of the lower reaches of Byarong Creek is exacerbated by culvert blockage. Extensive flooding during the 1998 and 1999 events occurred in the area between Arrow Avenue and Cleverdon Crescent as this area acted as a flow diversion path. This flooding was in part caused by the blockage of The Avenue culverts and the F6 Freeway culverts. This option provides a means by which the risk of culvert blockage can be reduced.

The proposed design shown in Figure 8.2 would be to protect properties in the local area against flooding by upgrading the present culverts under The Avenue, the F6 Freeway and the F6 Freeway ramp to a series of bridge structures all with a minimum diagonal span length of 6m. The use of a diagonal greater than 6m reduces the risk of blockage of the spans and associated backwater flooding and flow diversions.

This diameter reduces the risk of blockage to 25% rather than the present 100% blocked in accordance with observations collated and reported in Council's policy (Section 4.2.5).

The sizing of the bridge spans is detailed in Table 8.2. It is important to note that Table 8.2 indicates that the existing culvert configurations have an overall structure waterway area that actually reduces between The Avenue and the F6 Freeway

structures. For example, the waterway area for The Avenue is 41.6 m^2, whilst the waterway area for the F6 Freeway is 33.6 m^2 and the F6 Freeway Ramp is 27.6 m^2. The proposed configurations for the structures retain a similar concept due to the constraints associated with the surrounding areas (The Avenue is 43.8 m^2, the F6 Freeway is 36.6 m^2 and the F6 Freeway Ramp is 36.6 m^2). The proposed structures concentrate on reducing the losses associated with the number of spans in the existing structures.

Table 8.2 Option 2 Culvert Cell and Bridge Conditions - Existing and Proposed

Location	Existing Configuration	Proposed Configuration
The Avenue	2 cells of 3.65 m x 2.95 m 2 cells of 3.65 m x 2.75 m	2 spans of 7.3 m x 3 m
F6 Freeway	4 cells of 3.05 m x 2.5 m	2 spans of 6.1 m x 3 m
F6 Freeway Ramp	3 cells of 3.35 m x 2.75 m	2 spans of 6.1 m x 3 m

The proportion of blockage that applies to the enhanced culverts is 25% of the culvert area. This means that the culverts that convey almost zero flow due to blockage under the existing conditions will convey a greater proportion of flow in the upgraded conditions.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.7 m.

Table 8.3 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.3 Difference in Number of Properties Affected by Above Floor Flooding for Option 2

ARI	Existing Case	With Option 2	Change
PMF	635	624	11
100 year	376	349	27
50 year	330	298	32
20 year	277	236	41
10 year	85	85	0
5 year	60	60	0

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.3 Option 3 – Creek Modification

Creek modification works are proposed to involve:

- Weed/debris removal from creek channel
- Establishment of appropriate vegetation surrounding the existing channel for a corridor up to 20 m either side of the creek centreline (or of the order of 10 m from the top of bank).

- Bank re-grading and stabilisation without significant modification to the channel cross section (where geomorphic processes are found to be consistent with this approach, or where property is threatened).

These works are consistent with the works proposed in the *Allans Creek Catchment Riparian Management Plan* (Forbes Rigby, 2002). The recently prepared *Riparian Corridor Management Strategy* (DIPNR, 2004) states that it is critical to ensure that any riparian rehabilitation works recommended do not increase flood levels suffered by existing development. To ensure this is the case, some compromises may be required to the level of rehabilitation that can be achieved, such as less dense vegetation or 'flood compatible' vegetation that is flexible and offers less resistance to flood flows.

Locations proposed for modification were selected by model review, site inspection and through consultation with both Council and the Committee. These locations are shown in Figure 8.3 and include:

- Byarong Creek along the reach of the creek upstream of Koloona Avenue
- American Creek from Cordeaux Road to the Princes Highway
- Allans Creek along Lindsay Maynes Park up to the Princes Highway
- Charcoal Creek from Rickard Road to the Princes Highway
- Freeway Creek Modification in the park upstream of Berkeley Road.

The proposed works are subject to the following constraints that would need to be satisfied in the detailed design stage to achieve erosion control and ecological objectives in line with flood risk reduction outcomes. The constraints are:

- underground services cross under the creek bed - detailed design of the bank stabilisation works will require consideration of the channel bed and bank levels required to provide appropriate cover for these services
- environmental and geomorphic processes of the Creek systems (in particular American Creek) will govern the nature of the creek modification works
- assessment of likely future channel changes as a result of the works (e.g. slope may decrease)
- consultation with the community and appropriate government agencies
- consultation with the appropriate landowners.

The hydraulic model schematisation for this option was implemented by a variation to the roughness of the channel and floodplain in the reach of interest and a minor variation in channel cross section. The roughness under the existing conditions for the reaches is of the order of a Manning's n of 0.15 whilst the roughness of the rehabilitated conditions is assumed to be of the order of a Manning's n of up to 0.2. The primary effect will be the stabilisation of the channel banks and the associated reduction in potential culvert blockage material.

The option was assessed for all reaches simultaneously (i.e. the combined effect of modification works) and also included the effect of the placement of debris control structures at the first culvert downstream of the creek modification works.

Additionally, the upgrade of the Berkeley Road culverts (Option FM50) was included in the assessment of this option.

In accordance with the findings of Section 7.2.1, it is important to note that a debris control structure cannot be implemented as a stand-alone option. Instead, a debris control structure can only be implemented as part of a holistic solution that involves both creek modification (i.e. reducing the source of material that could block a culvert downstream) and the installation of a structure. Consequently, this was represented in the model solely by altering the amount of blockage of the culvert to 25%. Debris control structures were assumed at the following locations;

- Upstream Of Koloona Avenue, to protect the Koloona Avenue culverts
- Lindsay Maynes Park to protect the culverts under the Princes Highway on Allans Creek
- American Creek just upstream of Figtree High School, to protect the Princes Highway Bridge.
- Charcoal Creek just upstream of Normandie Place to protect the Tallegalla Street footbridge.
- Just upstream of Berkeley Road at two locations to protect the culverts under Berkeley Road.

These locations were selected to minimise their impact on existing development.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.9 m but can result in a local increase in flood level of up to 1.4 m. Increases in levels are primarily due to the improved efficiency of the channel (where roughness is reduced) resulting in the flood wave arriving at downstream locations earlier, which may be coincident with the arrival of flood peaks from other locations.

Table 8.4 shows the number of properties affected before and after the option is implemented by over-floor flooding.

Table 8.4 Number of Properties Affected by Flooding for Option 3

ARI	Existing Case	With Option 3	Change
PMF	635	630	5
100 year	376	390	-14
50 year	330	323	7
20 year	277	275	2
10 year	85	82	3
5 year	60	59	1

Thus this option, if fully implemented, has the potential to increase flooding at the 100 year ARI flood event indicated by the negative value for number of properties affected by overfloor flooding (-14). Thus, with the option in the form assessed in this report, 14 additional properties would be affected by overfloor flooding. It is recommended that further investigation of the impact of each area individually be considered before implementing any of the individual components of the overall

option. A compromise on the density of riparian vegetation assumed for this assessment may be required in order for this option to be implemented.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.4 Option 4 – Tallegalla Street Footbridge Elevation

Analysis of the existing flood condition showed that the blockage of the Tallegalla Street footbridge under design blockage conditions causes afflux behind the bridge and backwater flooding to properties upstream of the bridge. In the 1998 event approximately 60% of the bridge blocked. Consequently, properties immediately upstream of the area within the floodplain of Charcoal Creek at this location are exposed to higher flood levels than would be expected without the footbridge in place. A locality plan and details can be found in Figure 8.4.

The proposed design would replace the existing bridge with a similar bridge constructed with a deck obvert at a higher elevation. The proposal has a ramp up to the bridge deck, which was set at the 100 year ARI flood level determined under the existing conditions.

The benefits of this proposal are such that the bridge is likely to no longer block in lower recurrence intervals, and the greater span (across the diagonal from the bottom of the bridge deck) will reduce blockage impacts. Secondly, as the bridge soffit is to be raised to the existing 100 year ARI flood level it is unlikely that there will be afflux caused by the bridge deck (assuming that the current approaches are maintained), except at events greater than the 100 year ARI.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.2 m but can result in a local increase in flood level of up to 0.1 m.

Table 8.5 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.5 Number of Properties Affected by Above Floor Flooding for Option 4

ARI	Existing Case	With Option 4	Change
PMF	635	634	1
100 year	376	372	4
50 year	330	330	0
20 year	277	277	0
10 year	85	85	0
5 year	60	60	0

Based on the analysis outlined above, the improvement to only four properties at the 100 year ARI means that this option is not recommended for inclusion in the Floodplain Risk Management Plan.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.5 Option 5 – Creek-Line-Park Contouring to form Detention Basins

As discussed in the flood study (Lawson and Treloar, 2006), the flooding of Allans Creek and tributaries can be largely attributed to the volume of flow from the Illawarra escarpment in rainfall events. This problem has been exacerbated by development within the catchment that has generally lead to an increase in runoff volume and an increase in the peak discharge in the channels. To reduce flood levels by addressing this problem requires a catchment-wide holistic approach to the provision of flood storage and attenuation of flood flows.

The option of re-contouring the existing parkland areas that border the creek systems of Allans Creek and its tributaries was therefore investigated. This option included the lowering of the ground level in the park areas such that floodwaters can temporarily fill the parks providing a greater floodplain storage area before floods exceed the storage area and flow into the developed parts of the floodplain.

Parks assessed in this option and the approximate volume of detention include:

- Park upstream of Koloona Avenue (Option FM4) (8000 m^3)
- Roy Johanson Park (Option FM11) (6800 m^3)
- Harry Graham Park (Option FM14) (25500 m^3)
- Figtree Park (Option FM17) (91000 m^3)
- Sid Parrish Park/Lysaght Oval (Option FM36) (16000 m^3)
- Factory Road Park/Tallegalla Park (Option FM48) (4200 m^3)
- Unanderra Park (Option FM51) (2200 m^3)
- Todd Park (Option FM52) (6000 m^3).

These areas are shown in Figure 8.5.

Hydraulically, this option was modelled through altering the surveyed cross sections to represent a new creek and floodplain profile. Cross sections of park areas identified to be lowered were modified such that the level of the playing fields are set approximately 1m lower than the current (surveyed) state. The volume of this fill removal was determined within the hydraulic model by assessing the change in area of the cross section, and the length of creek represented by that cross section.

It is important to note that at the 20 year ARI event, this option in its entirety worsens flooding in lower reaches due to the change in timing of the arrival of flood flows as a result of the detention. Consequently, it is recommended that each of the individual components of the overall option be evaluated separately if selected through the multi-criteria matrix assessment (Section 11) for implementation to consider the individual benefits and impacts.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.5 m but can result in a local increase in flood level of up to 0.13 m.

Table 8.6 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.6 Number of Properties Affected by Above Floor Flooding for Option 5

ARI	Existing Case	With Option 5	Change
PMF	635	625	10
100 year	376	366	10
50 year	330	325	5
20 year	277	283	-6
10 year	85	77	8
5 year	60	53	7

Based on the analysis outlined above, this option is not recommended for inclusion in its entirety in the Floodplain Risk Management Plan. However, as outlined above, individual components are recommended for consideration for inclusion in the Plan with appropriate further consideration of their individual impacts on flood risk.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.6 Option 6 – Lindsay Park Primary School Footbridge Elevation

In a similar manner to Option 4, analysis of the existing flood condition showed that the Lindsay Park Primary School footbridge causes a backwater effect upstream of the bridge. Properties within the floodplain of Byarong Creek at this location are exposed to higher flood levels than would otherwise occur if the bridge was not present, leading to an increase in flooding. A locality plan and details can be found in Figure 8.6.

The proposed design would replace the existing steel truss bridge with a bridge built with its obvert at a higher elevation. The proposal is for a ramp up to the bridge deck, which is to be set at the 100 year ARI flood level determined under the existing conditions.

Similarly to Option 4, the benefits of this proposal are for the immediate locality. The bridge is no longer likely to block in events less than the 100 year ARI and the greater span (across the diagonal from the bottom of the bridge deck) will allow for a lower blockage factor of 25% to be applied to the bridge. Secondly as the bridge deck is to be set at the existing 100 year ARI flood levels there will be no head loss caused by the bridge deck as presently happens when water backs up behind the structure. The existing approaches have been assumed to have been retained.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.36 m.

Table 8.7 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.7 Number of Properties Affected by Above-Floor Flooding for Option 6

ARI	Existing Case	With Option 6	Change
PMF	635	634	1
100 year	376	375	1
50 year	330	327	3
20 year	277	276	1
10 year	85	85	0
5 year	60	60	0

Based on the analysis outlined above with such a limited number of properties that have a reduction in above floor flooding, this option is not recommended for inclusion in the Floodplain Risk Management Plan.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.7 Option 7 – Enhancement of Koloona Avenue Culverts

During both the 1998 and 1999 floods the Koloona Avenue culverts blocked effectively 100% and overtopped the road deck. Partial blockage of the handrail also exacerbated flood levels further as water backed up behind the structure. Properties adjoining Byarong Creek upstream of Koloona Avenue and on Koloona Avenue experienced increased flood levels due to this blockage. A locality plan and details can be found in Figure 8.7.

At present the crossing is composed of four cells of varying size (1 cell 2.1 m x 3.9 m, 1 cell 2.1 m x 4.1 m and 2 cells 2.1 m x 3.6 m). Under the present design blockage criteria, and as shown in 1998 and 1999, these culverts are prone to blockage. It is proposed to replace these culverts with a clear span bridge to allow for greater flow conveyance and provide less chance of blockage during a flood (Option FM5). Alternatives to the provision of a clear span bridge at this location include:

- Removal of the bridge and closure of the road (creation of a cul-de-sac, Option FM6)
- Voluntary purchase of affected properties in the local area (Table 8.8, part of Option PM4).

These other options are considered as alternatives in the multi-criteria matrix in Section 11.

The easement across which the culverts are built has a width of 20m. The option assessed is for a bridge to be built from bank to bank with a span of 20 m and a clear height of 2.5 m. This span reduces the risk of potential blockage to 25% as well as increasing the conveyance of the creek section. The increase in obvert (bottom of the bridge deck) has been provided to prevent the formation of a backwater at the 100 year ARI design event. Preliminary assessments indicate that the bridge deck depth to accommodate this configuration would need to be a minimum of

approximately 1.0 m. This presents some design issues with respect to the existing road centreline level being of the order of 34.2 mAHD. The proposed bridge and required deck depth would result in a road level of a minimum of approximately 34.8 mAHD on the upstream side (an increase in 0.6 m when compared with the existing road centreline nominal level as a guide). It is likely that this increase could be accommodated on the northern side of the crossing but with some design issues on the southern side and a transition would be required which may present some design issues associated with access to existing properties.

This option was assessed with design blockage consideration for both Koloona Avenue and Uralba Street (the next crossing downstream of Koloona Avenue) bridges. This allowed for the determination of any possible impacts downstream of the proposed bridge enhancement.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.4 m, but can result in a local increase in flood level of up to 0.2 m. The option does not substantially result in a change to the number of properties affected by overfloor flooding (Table 8.8). The increase in levels is primarily due to the improved efficiency of the structure, resulting in the flood wave arriving at downstream locations earlier, which may be coincident with the arrival of flood peaks from other locations. This clear span bridge option will still be overtopped by up to 0.7m in a 100 Year ARI flood event.

Table 8.8 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.8 Number of Properties Affected by Above Floor Flooding for Option 7

ARI	Existing Case	With Option 7	Change
PMF	635	635	0
100 year	376	373	3
50 year	330	327	3
20 year	277	275	2
10 year	85	81	4
5 year	60	58	2

Whilst the option was strongly supported by the community as the most appropriate solution to the local flooding issues, the option does not provide sufficient benefit to all of the affected properties in the locality and Voluntary Purchase of some properties is still required. The option does reduce overfloor flooding for several properties upstream of bridge. However, over floor flooding is actually worsened downstream. As such, even though there is an overall reduction in the number of properties with overfloor flood due to this option, it is not recommended to implement an option which increases flooding elsewhere. It is recommended to apply Voluntary Purchase or Voluntary House Raising (Sections 9.3 - 9.4) rather than a structural option.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.8 Option 8 – Byarong Creek Hydraulic Improvements

This option is a continuation of Options 1 and 2 (Section 8.2.2 & 8.2.1). The purpose of this option is to reduce the volume of flood flows that bypass the Princes Highway bridge and flow into the Arrow Avenue area through to Cleverdon Crescent. This area as a whole contains a large number of flood affected residential and commercial properties and as such, the reduction of flood levels in this area is likely to have a significant benefit for both residential and commercial properties.

Details of the option are shown in Figure 8.8. This option combination was proposed to incorporate a range of flood modification options, which can lead to flood abatement in this region (representing the likely ultimate condition in flood mitigation given local constraints).

The component options assessed include:

- Enhancement of the Princes Highway bridge to remove debris and vegetation to provide a clear span of greater conveyance area than is currently available. No structural modifications are proposed.
- Replacement of The Avenue culverts with a bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Replacement of the F6 Freeway culverts on Byarong Creek with a bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Replacement of the F6 Freeway Ramp culverts with a bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Creek modification and floodplain reshaping in the reach of the creek from Harry Graham Park to the F6 Freeway. Thus attempting to improve the conveyance of the creek and increasing the storage volume of the floodplain.
- Replacement of the F6 Freeway culverts on American Creek with a bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Removal of the median mound on the F6 Freeway for the entire length of overtopping, such that the control level of the F6 Freeway is the road deck level.

The combination of these options leads to a greater conveyance of the creeks and culverts within the target reach of the channel, as well as provide storage, such that a greater volume of flow can be accommodated in the area.

As described in Options 1 and, 2 the size of the bridge spans are as follows:

- Princes Highway – The structural span to remain the same. Existing debris and weeds removed from the creek and batters stabilised where possible to maximise flow area and improve the conveyance of the creek.
- The Avenue culverts – 2 spans of 7.3 m x 3 m
- The F6 Freeway Byarong Creek– 2 spans of 6.1 m x 3 m

- The F6 Ramp – 2 spans of 6.1 m x 3 m.
- The F6 Freeway American Creek – 4 spans of 7.3 m x 3.5 m.

The philosophy of the sizing approach to the bridge spans is described in Section 8.2.2.

The creek improvements were schematised in the model via the modification of cross sections such that the creek had a 7m wide base. Batter slopes for the in-bank section of the creek were assumed to be at 1V:2H to 1V:3H depending on the slope of the bank under the existing conditions and the location of the creek in relation to dwellings. Beyond the creek bank a batter slope of 1V:5H was assumed until the design cross section intersected with the existing condition cross section. The creek bed levels were unchanged in the modification works as was the location of the creek centreline. Roughness values of Manning's 0.15 for the creek and 0.04 for the overbank were assumed for this reach to represent the effect of a roughness reduction likely to be afforded by the creek modification works.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 2.2 m.

Table 8.9 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.9 Number of Properties Affected by Above Floor Flooding for Option 8

ARI	Existing Case	With Option 8	Change
PMF	635	615	20
100 year	376	269	107
50 year	330	222	108
20 year	277	180	97
10 year	85	85	0
5 year	60	58	2

Table 8.9 indicates that this option has significant benefit for properties in the lower floodplain.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.9 Option 9 – American Creek Riparian Corridor Creation

This option involved the assessment of:

- lowering the left bank of American Creek by approximately 1 m over a creek line distance of 260 m
- creation of a riparian buffer area within the lowered portion
- considering separate roughness values for different components of the channel and floodplain (Manning's n of 0.04 for channel and grassed overbank and Manning n of 0.2 for a riparian buffer width on the left bank of 40m)

- No assessment of modifications to the right bank of American Creek have been incorporated in this option as this bank is developed (Govett Crescent). The riparian area, to be created, forms part of the modification of the system.

The lowering of the left bank effectively forms a bypass channel across the width of the floodplain as shown in Figure 8.9. This figure also shows the location of the assumed 40m riparian zone.

This option was assessed with a debris control structure upstream of the Princes Highway Bridge. The construction of the debris control structure in association with the creek works reduces the risk of blockage of the Princes Highway bridge (100% to 25%).

There are a number of locations where underground services cross under the creek bed and the floodplain. A review of the available obvert details of water, electricity and gas services indicate that these services are located sufficiently below the invert of the proposed cross section. A Sydney Water Corporation water main runs under the floodplain and acts as the critical structure limiting the ultimate depth to which the floodplain can be lowered. It is important that any detailed design of works involve the consideration of these services.

Reduction in flood levels for this option occur as a result of the greater proportion of the flood flow at 100 year ARI flowing across the floodplain in the bypass area. The lower roughness of the floodplain left bank (which would carry a substantial portion of flow) causes a decrease in flood levels through this reach of American Creek beyond that associated with the change in floodplain geometry alone.

Hydraulic modelling indicates that there is a decrease in peak 100 year ARI flood level on American Creek. This reduction in peak water level further increases if a debris control structure was implemented which would reduce the risk of blockage of the Princes Highway bridge (from 100% blocked under existing conditions to 25% blocked). There is no increase in water levels upstream of the Princes Highway as the conveyance through the constriction in the floodplain, at the end of Suttor place, prevents any increase in flood levels downstream.

This option also relies on regular maintenance (inspections at yearly intervals should determine the need for maintenance) of the bypass channel capacity and condition (both cross sectional area and vegetative cover). There is scope for sediment and debris accumulation within the bypass channel during any event where flow exceeds the creek banks and flows down the bypass channel. This is due to the lower velocity of floodwaters on the floodplain, which could result in the deposition of coarse and suspended sediment. Over time this may lead to a gradual aggradation of the floodplain, reducing the flood mitigation potential of the option. Stabilisation of creek banks and bed for areas that are currently eroding or unstable in the area of interest and upstream, should reduce the potential for sediment scour during a flood event. Recommended methods of stabilisation should be with either vegetation or structural means (e.g. rock treatments) where vegetation is not feasible due to bank or bed slope or velocity of flow. These works should reduce the potential for channel aggradation within the area of interest over time.

In schematising this option a concept design slope was assumed for the bypass channel to ensure flow is translated. Proper maintenance of the bypass channel slope will be required to ensure invert levels are maintained at design levels.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.65 m.

Table 8.10 shows the number of properties affected before and after the option is implemented by above floor flooding.

Table 8.10 Number of Properties Affected by Above Floor Flooding for Option 9

ARI	Existing Case	With Option 9	Change
PMF	635	629	6
100 year	376	373	3
50 year	330	328	2
20 year	277	277	0
10 year	85	85	0
5 year	60	60	0

Additionally, construction of a bund at the north-western end of Govett Crescent (Option FM25) will result in mainstream flooding not entering the street via an alternate path at the upstream end, affecting the properties of Govett Crescent. Thus a complementary approach of the two options is recommended.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.10 Option 10 – Culverts Under Driveway at End of Suttor Place

The accessway to a dwelling on Suttor Place, Figtree forms a constriction within a portion of the floodplain that acts hydraulically as a weir when flows exceed the channel banks of American Creek in the locality. The location of the accessway is shown in Figure 8.10.

Three possible modifications to the accessway at Suttor Place were considered:

- single 6 m diagonal span culvert through the accessway to convey flood flows (lower bound of likely flood level reduction)
- dual 6 m diagonal span culvert through the accessway to convey flood flows
- complete removal of the accessway (upper bound of likely flood level reduction).

The 6 m diagonal was chosen to reduce the risk of 100% blockage. The risk of blockage would otherwise nullify any benefit that could be achieved by a culvert of diagonal span less than 6 m as the culvert would need to be considered as blocked. A debris control structure was not appropriate at this location due to the lack of a hydraulically suitable bypass location.

Preliminary investigations of the three possible approaches indicated that the approach that provides the greatest benefit and is most feasible is the dual 6m diagonal span culverts. As a consequence, the details of this alternative are presented in this report. The replacement of a portion of the driveway with a precast unit (e.g. Humedeck or Ingal Super Cor culvert or similar - e.g. two SC-22B Multi-Plate Super Cor box culverts of maximum span of 6.3 m and internal rise of 1.65 m of 4 m invert length) and associated works is the recommended approach.

Available plans indicate that there are no services running underneath the accessway to 16 Suttor Place that would restrict the placement of any of the modification options listed above. Services in the area are limited to a Sydney Water sewer main that is located at the Suttor Place end of the accessway, away from the proposed location of the culverts.

Hydraulic modelling undertaken for the modification to the accessway at Suttor Place indicates that there would be a decrease in peak water level in American Creek along the length of Govett Crescent at the 100 year ARI. This decrease occurs even in the case where the Princes Highway is 100% blocked. The greatest reduction in water level is just upstream of the proposed dual 6m diagonal span culverts.

The increase in flood levels downstream of the accessway and upstream of the Princes Highway are negligible at the 100 year ARI flood for this option.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 0.1 m.

Table 8.11 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.11 Number of Properties Affected by Above Floor Flooding for Option 10

ARI	Existing Case	With Option 10	Change
PMF	635	635	0
100 year	376	375	1
50 year	330	330	0
20 year	277	277	0
10 year	85	85	0
5 year	60	60	0

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.2.11 Option 11 – Byarong/American Creek Hydraulic Improvements and Voluntary Purchase

This option is a variation of Option 8 (Section 8.2.8). The purpose of this option is to reduce the volume of flood flows that bypass the Princes Highway bridge and flow into the Arrow Avenue area through to Cleverdon Crescent and alleviate flooding in

the areas adjacent to American Creek between The Avenue, the Princes Highway and O'Donnell Drive.

Details of the option are shown in Figure 8.11. This option combination was proposed to incorporate a range of flood modification options, which can lead to flood abatement in this region.

The component options assessed include:

- Enhancement of the Princes Highway bridge to remove debris and vegetation to provide a clear span of greater conveyance area than is currently available. No structural modifications are proposed.
- Voluntary purchase of 9 properties in Arrow Avenue and The Avenue to facilitate creek widening.
- Replacement of The Avenue culverts with a clear span bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Creek modification and floodplain reshaping in the reach of Byarong Creek from Harry Graham Park to the F6 Freeway. Thus attempting to improve the conveyance of the creek and increasing the storage volume of the floodplain.
- Creek modification in the main reach and side arm of American Creek from the Princes Highway to the F6 Freeway
- Creation of an overland flow path to link overflows from Byarong Creek formally with American Creek adjacent to the F6 Freeway (lowering Lysaght Oval)
- Replacement of the F6 Freeway culverts on American Creek with a clear span bridge to increase the diagonal length to greater than 6m such that the risk of blockage is greatly reduced and the design blockage factor is reduced from 100% to 25%.
- Removal of the median mound on the F6 Freeway for the entire length of overtopping, such that the control level of the F6 Freeway is the road deck level.

The combination of these options leads to a greater conveyance of the creeks and culverts within the target reach of the channel, as well as provide storage, such that a greater volume of flow can be accommodated in the area.

The proposed size of the bridge spans are as follows:

- Princes Highway – The structural span to remain the same. Existing debris and weeds removed from the creek and batters stabilised where possible to maximise flow area and improve the conveyance of the creek.
- The Avenue - clear span of 15 m
- The F6 Freeway American Creek - clear span of 30 m x 7 m.

The creek improvements were schematised in the model via the modification of cross sections such that the creek had a 7m wide base. Batter slopes for the in-bank section of the creek were assumed to be at 1V:2H to 1V:3H depending on the slope of the bank under the existing conditions and the location of the creek in relation to dwellings. Beyond the creek bank a batter slope of 1V:5H was assumed until the design cross section intersected with the existing condition cross section. The creek

bed levels were unchanged in the modification works as was the location of the creek centreline. Roughness values of Manning's 0.15 for the creek and 0.04 for the overbank were assumed for this reach to represent the effect of a roughness reduction likely to be afforded by the creek modification works.

As a guide, the maximum reduction in flood level as a result of this option at the 100 year ARI is of the order of 2.9 m.

Table 8.12 shows the number of properties affected before and after the option is implemented by above-floor flooding.

Table 8.12 Number of Properties Affected by Above Floor Flooding for Option 11

ARI	Existing Case	With Option 11	Change
PMF	635	604	31
100 year	376	255	121
50 year	330	212	118
20 year	277	173	104
10 year	85	92	-7
5 year	60	66	-6

Table 8.12 indicates that this option has significant benefit for properties in the lower floodplain. However, the nature of the opening out of the creekline and bridge structures will result in an increase in flooding of a small number of properties in the more recurrent events. The primary reason for this is related to the observed nature of debris generation being less likely during more frequent events. It is recommended that a refinement of the option at detailed design phase be undertaken to eliminate any additional properties affected. It should be noted that those properties with additional overfloor flooding have been identified for either voluntary purchase or voluntary house raising or have very limited overfloor flooding.

An analysis of the option for economic benefits is provided in Section 8.4 and a full multi-criteria matrix assessment of the option is provided in Section 11.

8.3 Assessment of Hydraulic Performance via Desktop Assessment

Examples of options assessed in a generic way using a desktop assessment include:

- stormwater drainage and overland flow path improvements
- flap gates on culverts
- levees/bunding
- debris control structures
- culvert/bridge amplification (where modelling not undertaken)
- general maintenance of creek/channel systems
- detention systems in the upper reaches of the catchment
- lowering of floodplain on the west bank of Brandy and Water Creek to protect properties at the southern end of Darragh Drive.

8.3.1 Stormwater Drainage and Overland Flow Path Improvements

Stormwater drainage design requirements are dealt with extensively in the Drainage Design Code (1994).

Specific sites identified for further drainage pipe network investigations include the drainage network in the vicinity of Arrow Avenue, Bellevue Road and the Princes Highway (Option FM16). The amplification of existing pipes or duplication of pipes are possible options, in conjunction with ensuring pit inlets to the pipe system are of sufficient capacity. An option to reduce erosion of the banks in Byarong Creek is to consider the realignment of stormwater pipe outlets, in particular, the outlet upstream of Koloona Avenue (Option FM1).

The concept of overland flow path improvements to aid the conveyance of stormwater runoff and flood flows should be considered as part of any stormwater drainage system improvements proposed by Council. In particular, consideration of the acquisition of an easement in the Uralba Street area in the vicinity of Nos 33 and 35 Uralba Street (Option FM10) is an option to provide an overland flow path in this area. Similarly, the creation of a channel adjacent to Lysaght Oval and the F6 Freeway (Option FM37) is a possible improvement for the conveyance of overland flows in this area and the area between Blackman Parade and Normandie Place for a flood bypass channel to better convey overland flows (Option FM44).

In general, the drainage system network is likely to be capable of conveying runoff from the local catchments for events from the 2 year ARI up to the 100 year ARI events. The performance of many systems is conditional on the outlets not being drowned by flood flows in the main creek systems (for outlet controlled systems) and that the inlet pits perform to their design level (i.e. they are not blocked). Flooding from the stormwater pipe network is therefore caused as a result of two mechanisms.

Any stormwater drainage headwall to the creek system should be orientated such that the flow exiting the headwall does not scour the opposite bank or the stream bed and should have appropriate energy dissipation works to ensure that the outlet does not exacerbate the already highly erosional soils present in the catchment and floodplain.

8.3.2 Flap Gates on Culverts

Flap gates on culverts discharging into Creek systems are a mechanism for preventing surcharge into street areas as a result of mainstream flooding. An example of where this option has been considered is on the outlets of the pipes from Govett Crescent draining to American Creek (Option FM26). However, they can become blocked or vandalised and consequently be either permanently open or closed. As a result, the operation of these gates during a flood is not always satisfactory. In more frequent flooding events when discharge to the creek is possible, they may obstruct flow from the street due to poor operation thereby resulting in street flooding which otherwise would not have occurred.

Therefore implementation of flap gates is not recommended for inclusion in the Floodplain Risk Management Plan.

8.3.3 Levees/Bunding

An effective measure for some areas is to provide bunding or earthmound levees to safeguard against creek flooding of properties adjacent to the creek. Such a measure may have some impact on flood levels where the levees will restrict the flow path. It should be noted that if bunding/levees are implemented then alternate drainage or overland flow paths will be required for the areas immediately behind the levees which would otherwise drain through the area that will be blocked off.

Examples of where this solution is proposed are at Langson Avenue (Option FM7), Thames Street (Option FM13), Preston Avenue (Option FM19), at the western end of Govett Crescent (Option FM25), adjacent to Figtree High School (Option FM33), in the O'Donnell Drive area (Option FM35), in the vicinity of the Coronata Drive area (Option FM61) and upstream of Baker Crescent (Option FM62).

The removal of levees or features that act as levees is also recommended in areas where this can reduce flood levels. Option FM59, the removal of a portion of the median strip on the F6 freeway which acts as a levee is an example of this option.

Preliminary details of the proposed levees, used in the estimate of preliminary costing for these options, are provided in Appendix E. Detailed concept designs and associated flood impact hydraulic assessments of any of the proposed levees will be required to evaluate the benefits of the proposals quantitatively prior to proceeding with the implementation of these options.

8.3.4 Debris Control Structures

Debris control structures are a means of preventing blockage of culverts via the capture of debris upstream in areas where an afflux (as a result of the blockage of such a structure) can be accommodated. The strategic placement of these structures in accessible locations in association with the modification and stabilisation of the creek and channel systems should reduce the volume of debris and therefore the risk of blockage of culverts resulting in elevated peak flood levels.

Debris control structures are proposed within a number of options considered in Section 8.2 (Figure 8.3) including upstream of:

- Byarong Creek – Upstream of Koloona Avenue Bridge (Option FM2)
- Byarong Creek – Upstream of Whelan Avenue (Option FM8)
- Byarong Creek – Upstream of The Avenue (Option FM58)
- American Creek – Upstream of Cordeaux Road (Option FM23)
- American Creek – Upstream of Princes Highway Bridge (part of Option FM30)
- Charcoal Creek – Upstream of Tallegalla Street Footbridge (part of Option FM48)
- Allans Creek – Upstream of Princes Highway Bridge (Option FM56)
- Unanderra Industrial area – Upstream of Berkeley Road (two crossings) (Option FM57)
- American Creek – Upstream of Alukea Road (to alleviate flood risks to properties in Derribong Drive) (Option FM60).

Whilst this type of option will reduce the risk of blockage induced flooding it will not reduce flood planning levels as they cannot be implemented in a fail-safe manner. That is, it will reduce impacts of real floods to existing development but new development cannot and therefore should not rely on such structures for flood mitigation.

8.3.5 Culvert/Bridge Amplification

In some locations, culverts or bridges can be amplified such that their diagonal span becomes greater than 6m and therefore are less likely to block (as identified in Council's Conduit Blockage Policy, Section 4.2.5).

The benefits of this option would be to reduce peak flood levels in areas immediately upstream of the site where the proposed amplification is implemented. Conversely, amplification is generally likely to result in an increase in flood levels on the downstream side. Some options are considered in detail for the benefits/impacts in Section 8.2. Areas identified for possible amplification in addition to those considered in Section 8.2 include:

- Uralba Street culvert (Option FM9)
- Princes Highway Bridge, Byarong Creek (Option FM15)
- O'Briens Road culverts (Option FM31)
- Figtree High School footbridge (Option FM32)
- Figtree Caravan Park access road culverts (FM34)
- Princes Highway Bridge, Charcoal Creek (near Factory Road) (Option FM45)
- Berkeley Road culverts (Option FM50).

8.3.6 Creek Maintenance and Riparian Corridor Management Programs

A considerable source of material for the blockage of culverts is eroded bank vegetation, sediment and gravel that is scoured and transported from natural creek channels during the course of a flood event. As a result, strategies to manage the processes causing accelerated erosion of creek and channel systems are a critical component of the management of flood risk within the Allans Creek catchment.

There are three forms of creek management works that have been identified as part of the Allans Creek Floodplain Risk Management Study. They can be classified as follows:

- **Creek Maintenance:** removal of the debris (day to day basis)
- **Riparian Corridor Management:** weed/vegetation management
- **Creek Modification:** bank stabilisation

Vegetation management is currently undertaken by Council for Council-owned portions of the creek. Council does not have access to privately owned sections of the creek. Similarly, bank stabilisation works and removal of large obstacles within creek beds is also undertaken by Council in Council-owned portions of the creek. However, there are limited strategies to manage the changes on the hydrologic regime to manage the cumulative impact of past works in the creek systems (such as

creek straightening and piping) that are commonly the cause of accelerated erosion processes throughout the catchment.

It is recommended that a program be developed from both technical and strategic perspectives and expanded to ensure that appropriate creek management practices occur. This should be complementary with any proposed creek modification option to be implemented (Section 8.2.3). This should be undertaken within the context of a creek management strategy such as the *Allans Creek Riparian Management Plan* recommended by Forbes Rigby (2002) and the *Riparian Corridor Management Strategy* (DIPNR, 2004).

Corridor management and maintenance options identified include:

- Byarong Creek corridor management and maintenance (Option FM21)
- American Creek corridor management and maintenance (Option FM41)
- Maintenance of the flood detention area upstream of Berkeley Road (Option FM53)
- Charcoal Creek corridor management and maintenance (Option FM54).

The development of a detailed creek management strategy is therefore recommended for inclusion in the Floodplain Risk Management Plan. It will need to identify strategies for creek stabilisation consistent with best management practice including the need to address ecologic, geomorphic and water quality and quantity objectives.

8.3.7 Detention Systems/Flood Storage Areas

The attenuation of flows in the upper reaches of the catchment may delay some of the peak flows arriving at the lower, more vulnerable areas. This option has not been canvassed in great detail, due to the detailed planning nature of identifying suitable land for the purposes of retarding basins. Section 9.8.2 (Option PM10) identifies the need for a detailed study of this kind.

However, Option FM22 (Mount Kembla Park) and Option FM42 (Charcoal Creek near Waples Road) may be suitable locations for the attenuation of flows in the upper reaches of the catchment. Other areas for flood storage are dependent on Voluntary Purchase agreements being reached (Section 9.4) and include areas upstream and downstream of Koloona Avenue (Options FM63, 64 and 65). These areas would need to be considered in association with Option FM61 (Levee in the vicinity of Coronata Drive) and Options FM3 and FM4 (Detention and Debris Control Structure) as an overall scheme for the Upper Byarong Creek area. Further detailed assessments of these options in combination need to be undertaken for these options to proceed.

Areas identified for possible detention in the floodplain in addition to those considered in Section 8.2 include Lindsay Maynes Park (Option FM47).

8.3.8 Lowering of Floodplain on the West Bank of Brandy and Water Creek

The east bank of Brandy and Water Creek in the vicinity of Darragh Drive has a number of residential lots which experience overfloor flooding in the 100 Year ARI flood event. The west bank of the creek could be lowered to increase conveyance and reduce overfloor flooding in the Darragh Drive properties.

Preliminary calculations would suggest that up to 34,000 m^3 of excavation would be required over an approximate creek length of 300m to reduce flood levels to be approximately contained within the banks of the creek at the 100 year ARI. To more accurately calculate this value and to undertake further design of the creek bank, detailed survey is required of both the creek and floodplain levels along the length of the creek of interest. The acquisition of property floor levels for dwellings in the area is also required.

Further consideration of this option is recommended as an action for inclusion in the Floodplain Risk Management Plan.

8.4 Economic Assessment of Modelled Options

The economic evaluation of each option was assessed by considering the reduction in the amount of flood damage incurred by various events and comparing this value with the cost of the option for those options assessed using modelling (Section 8.2).

The existing condition (or the 'do nothing' option, reported in Chapter 5) was used as the base case to compare the performance of options assessed by modelling. Inputs for the assessment include those data reported in Section 5.1.2 derived from a floor level and property survey along with damage curves derived for other, similar areas. The PMF, 100 year, 50 year, 20 year, 10 year and 5 year ARI events were considered for this evaluation. Preliminary costs of each option were prepared and a benefit cost analysis of each option was undertaken on a purely economic basis (Section 8.4.2).

8.4.1 Preliminary Costing of Options

Preliminary costs of the options proposed have been prepared to assess the benefit-cost ratio of each option assessed by modelling. The costs were prepared with the assistance of the Cordell *Building Cost Guide*.

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

Details of preliminary costings for the 11 flood modification options assessed by modelling are provided in Appendix F. A summary of the estimated capital and recurrent (e.g. maintenance) costs of each option are listed in Table 8.13.

Table 8.13 Capital Costs of Proposed Flood Modification Options

Option	Capital Cost	Recurrent Cost*	Details
Option 1	$11,550,000	$2,000	Bridge and Associated Works at American Creek Crossing of the F6
Option 2	$18,050,000	$2,000	Bridge and Associated Works at Byarong Creek Crossing of the F6, F6 On-ramp and The Avenue
Option 3	$6,650,000	$10,000	Creek Modification.
Option 4	$300,000	$500	Lindsay Park Primary Footbridge
Option 5	$16,800,000	$10,000	Basins in the parks (8 in total)
Option 6	$600,000	$500	Tallegalla Street Footbridge
Option 7	$1,200,000	$1,000	For new Koloona Ave Bridge
Option 8	$33,750,000	$2,000	For Byarong Ck Improvements (The Avenue, Byarong Creek at F6, Byarong Creek at Off-ramp and American Ck F6 Crossing
Option 9	$2,600,000	$5,000	Flood Bypass Channel Construction - American Creek
Option 10	$300,000	$500	Suttor Place Accessway Modifications (assume twin culverts)
Option 11	$22,200,000	$5,000	Works at The Avenue, American Creek F6 Crossing, Works in the channels and surrounds between these structues and Voluntary Purchase

*An example of recurrent cost includes inspections and clearing of debris on an annual basis

8.4.2 Annual Average Damage for Options

In a similar fashion to Chapter 5, the total damage costs were evaluated for each of the options assessed by modelling.

The results shown in Table 8.13 indicate that the maximum reduction in average annual damage (AAD) was of the order of $1.1 million (compared with an existing case with an AAD of $13.5 million). This reduction, for Options 8 and 11 (Works in the Lower Byarong and American Creek areas, which combines Option 2 and Option 1 with varying permutations) is a significant value. Option 1 (Amplification of the American Creek culvert under the F6), as a stand-alone option results in the next greatest reduction of AAD by $0.8 million on the existing case. The main reason for these reductions in AAD afforded by these options is their widespread nature across the entire portion of the lower floodplain. The other options proposed generally only have a benefit for those areas immediately surrounding the proposed option.

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

8.4.3 Benefit Cost Ratio of Options

Table 8.14 summarises the overall economics of each option assessed by modelling. The indicator adopted to rank options on economic merit is the benefit cost ratio (B/C). Where the B/C is close to or greater than 1 the option is more economically viable than other options.

Table 8.14 Summary of Economic Assessment of Major Structural Options

Option	AAD	Reduction in AAD due to Option	NPW of Benefit	Capital Cost	Recurrent Cost	NPW of Options	B/C	Rank
Existing Case	$13.5 m	-	-	-	-	-	-	-
Option 1	$12.7 m	$0.8 m	$11.2 m	$11,550,000	$2,000	$11.6 m	0.96	2
Option 2	$13.1 m	$0.4m	$5.9 m	$18,050,000	$2,000	$18.1 m	0.33	6
Option 3	$13.4 m	$0.1 m	$2.0 m	$6,650,000	$10,000	$6.8 m	0.30	7
Option 4	$13.5 m	$0.002 m	$0.24 m	$300,000	$500	$306,900	0.79	3
Option 5	$13.3 m	$0.2 m	$2.2 m	$16,800,000	$10,000	$16.9 m	0.13	9
Option 6	$13.5	$0.001 m	$0.1 m	$600,000	$500	$606,900	0.18	8
Option 7	$13.4 m	$0.1 m	$1.7 m	$1,200,000	$1,000	$1.2 m	1.39[1]	1
Option 8	$12.3 m	$1.14 m	$15.7 m	$33,750,000	$2,000	$33.8 m	0.46	5
Option 9	$13.5 m	$0.001 m	$0.1 m	$2,600,000	$5,000	$2.7 m	0.04	10
Option 10	$13.5 m	$0.000 m	$0.01 m	$300,000	$500	$306,900	0.03	11
Option 11	$12.4 m	$1.12 m	$15.5 m	$22,200,000	$5,000	$22.3 m	0.69	4

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

[1] - It should be noted that this value does not include the voluntary purchase of properties with worsened flooding conditions as a result of this option.

The benefit cost analysis shown in Table 8.14 indicates that the options rank in the following order in terms of benefit for expenditure on economic terms alone:

- Clear span bridge at Koloona Avenue (Option 7). It should be noted that while this option does reduce overfloor flooding for several properties upstream of the bridge, overfloor flooding is actually worsened downstream. As such, it is not appropriate to implement an option which increases flooding elsewhere.
- Amplification of the American Creek culverts under the F6 (Option 1)
- Creek modification (Option 4)
- Combination of works in the lower Byarong Creek/American Creek Floodplain (Option 11).

Other options show varied levels of economic benefit, but all have benefit:cost ratios less than 1. However, these options may provide other social and environmental benefits, which are accounted for in the multi-criteria matrix assessment in Chapter 11.

8.5 Economic Assessment of Desktop Assessed Options

Given the overall benefits of those options where a desktop assessment was utilised, a detailed economic analysis of those options was not undertaken. Instead, a judgement on the economic benefits of the options was made. This is described in Section 11.

8.6 Social and Environmental Assessment of Modelled Options and Desktop Assessed Options

Details of the social and environmental assessments are outlined in Section 11 for both modelled options and desktop assessed options.

9. PROPERTY MODIFICATION OPTION ASSESSMENT

As outlined in Section 7, there are a number of opportunities for the use of planning legislation, plans, policies, or guidelines for the management of flood liable areas of the Allans Creek catchment.

In general a number of options have been considered including:

- Development Controls
- Guidelines for Public Domain Infrastructure
- House Raising Program
- Voluntary Purchase Program
- Provision of a Flood Refuge within the Figtree Gardens Caravan Park
- Zoning Modifications
- Section 149 Certificates
- Policy preparation and revisions (e.g. Caravan Park Policy and On-Site Detention Policy)
- Data Collection Strategies
- Public Awareness and Education for Property matters.

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

9.1 Development Controls

Development controls are a considerable preventative measure for the management of the continuing risk of flooding.

There are two categories of development for land that is currently appropriately zoned in the LGA:

- exempt and complying development (i.e. does not need a development application to Council)
- all other development (which requires a development application to Council) which, for the purposes of this review, can be defined as being:
  - minor development
  - redevelopment
  - infill development
  - greenfield and brownfield subdivision.

Currently, types of development that are 'exempt' are listed in Council's DCP/Technical Policy 99/2, *Exempt Development*. This Policy has reasonably stringent requirements to ensure that development that is exempt from development application requirements by Council does not result in flood impacts.

To ensure development is appropriate within the floodplain, for all types of development that require a development application in the floodplain, Council has prepared a Development Control plan for flooding (DCP 54, 2004). This approach is based on the flood risk precincts prepared (Section 4.6) and draws upon a detailed matrix of requirements based on land use type and the proposed development. This

approach was originally presented for the Towradgi Creek Floodplain Risk Management Study (Bewsher Consulting, 2002) and has since been refined and adopted for assessing development in all floodplains in the local government area.

Council also has a Drainage Design Code (1994) which should be read in conjunction with DCP 54.

Option PM1, shown in Table 9.1 and accompanying descriptor Table 9.1a is consistent with the approach described in Council's Development Control Plan *'Managing Our Flood Risks'*. Table 9.1 and the accompanying table are an adaptation of this approach to address the specific flood behaviour of the Allans Creek system. The approach is consistent with the findings of the flood planning level review (Chapter 6) and related findings in Chapter 4 of this report.

Table 9.1 has been prepared to recognise the following issues:

- Emergency services and flood evacuation centres should be prohibited in the floodplain
- Key infrastructure such as communications facilities (e.g. telephone exchanges) and electricity substations are to be protected and located outside of the floodplain where possible
- Need for development applications to be supported by a flood impact assessment prepared by an appropriately qualified engineer. This would require the demonstration of the impacts of flooding on the development and surrounding areas.
- Prohibition or strict controls for any development within all areas associated with high flood risk
- Flood proofing of new development, extensions or improvements with appropriate water resistant materials such that flood damage to the structure will be negligible
- Development can only proceed with consent from Council, on land that is subject to periodic inundation if the development is not likely to:
  – impede the flow of water
  – aggravate the consequences of flood waters on land having regard to siltation, destruction of vegetation and erosion
  – increase the level of flood waters in the area, or
  – endanger the safety of persons who occupy the land in the event of a flood
- Set floor heights for new dwellings and new parts of a dwelling to an acceptable level of flood risk and applicable to specific land uses (floor levels may vary between residential, commercial and industrial development)
- Where substantial development is to occur, raise floor heights of any existing dwellings to an acceptable level of flood risk to match any new parts of the dwelling
- Ensure adequate freeboard is incorporated into the design of new homes or the raising of any existing dwellings
- Strategic site planning for all sites including:
  – the provision of suitable evacuation routes (if safe and effective evacuation routes cannot be provided, the proposed land-use is inappropriate)
  – consideration of the topography of the site with regard to the variation of flood hazard and the siting of development (buildings may be better located on

higher ground of a site where the impact of flood behaviour and potential damage will be reduced and evacuation can be facilitated)

– orientation and type of fences (fences can obstruct flood flows, increase levels and possibly hamper evacuation).

- Require appropriate construction supervision and certification for developments in high risk precincts.

Table 9.1 Option PM1 - Proposed Development Control Matrix*

Planning Consideration	Flood Risk Precincts (FRP's)																							
	Low Flood Risk^								Medium Flood Risk^								High Flood Risk^ (and Interim Riverine Corridor)							
	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Essential Community Facilities	Critical Utilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
Floor Level		3										2, 6 or 7	1,2 or 5	2	1	2,4					1		1	2,4,6
Building Components		2										1	1	1	1	1					1		1	1
Structural Soundness		3		3		3						3	2	3	2	2					1		1	1
Flood Affectation		2	2		2	2					1	1	1	1	1	2					1		1	1
Evacuation		2,4	*	3,4	4	3,4					*	3,4	1,4	3,4	1	1					*		1	1
Management & Design		4,5	1								1		2,3,5	2,3,5	2,3,5,6	2,3,5					2,3,5		2,3,5	2,3,5

	Not Relevant		Unsuitable Land Use	*	Refer to *'Management & Design'* planning consideration for subdivision	Industrial Only, Commercial Not Permitted

Floor Level

1	For industrial land use only - All Floor Levels to be equal to or greater than the 100 year flood unless justified by site specific assessment
2	Habitable floor levels to be equal to or greater than the 100 year flood plus 0.5m (freeboard)
3	All Floor Levels to be equal to or greater than the PMF level plus 0.5m (freeboard)
4	Floor levels to be as close to the design floor level as practical & no lower than the existing floor level when undertaking alterations or additions
5	Floor levels of shops to be as close to the design floor level as practical. Where below the design floor level, more than 30% of the floor area to be above the design floor level or premises to be flood proofed below the design floor level
6	Garage floor level to be no lower than 300 mm above finished adjacent ground
7	Garage floor level to be no lower than the 100 year ARI flood level minus 300 mm or 300 mm above the finished adjacent ground (whichever is the greater)

Building Components & Method

1	All structures to have flood compatible building components below or at the 100 year flood level plus 0.5m (freeboard)
2	All structures to have flood compatible building components below or at the PMF level plus 0.5m (freeboard)

Structural Soundness

1	IEAust NPER Structural Engineers report to certify that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year flood plus 0.5m (freeboard)
2	Applicant to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a 100 year flood plus 0.5m (freeboard)
3	IEAust NPER Structural Engineers report to demonstrate that any structure can withstand the forces of floodwater, debris & buoyancy up to & including a PMF plus 0.5m (freeboard)

Flood Affectation

1	IEAust NPER Hydraulic Engineers report required to certify that the development will not increase flood affectation elsewhere, includes medium and high density residential proposals
2	The impact of the development on flooding elsewhere to be considered, includes low density residential

Evacuation	
1	Reliable access for pedestrians required during a 100 year flood
2	Reliable access for pedestrians and vehicles required during a PMF event
3	Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF, or a minimum of 20 sq m of the dwelling/premises to be above the PMF level.
4	The development is to be consistent with any relevant flood evacuation strategy or similar plan
Management and Design	
1	Applicant to demonstrate that potential development as a consequence of a subdivision proposal can be undertaken in accordance with DCP54
2	Site Emergency Response Flood plan required (except for single dwelling-houses) where floor levels are below the PMF
3	Applicant to demonstrate that area is available to store goods above the 100 year flood plus 0.5m (freeboard)
4	Applicant to demonstrate that area is available to store goods above the PMF plus 0.5m (freeboard)
5	No external storage of materials below the design floor level which may cause pollution or be hazardous during any flood

* adapted from DCP54 for Towradgi Creek and modified for the Allans Creek Floodplain
^ Flood Risk Precinct Definitions for Allans Creek - see Section 4.7

See DCP 54 for a Schedule of Land Use Types Consistent with the Wollongong City Council LEP, 1990.
Any proposed development will also need to be consistent with Other Council requirements including Council's OSD Policy and Drainage Design Code.

Table 9.1(a) Schedule of Land Use (Definitions of descriptors are those listed in the Wollongong LEP, 1990)

Land Use	Descriptor
Essential Community Facilities	• Place of Assembly • Community Facility which may provide an important contribution to the notification and evacuation of the community during flood events • Hospitals • Institutions • Educational Establishments • Police, Fire and Ambulance Stations and SES Facilities

Critical Utilities	• Telecommunications facilities
	• Public Utility (exclusive of emergency services such as police, fire and ambulance) which:
	  • may cause pollution of waterways during flooding, or
	  • is essential to evacuation during periods of flood, or
	  • if affected during flood events would unreasonably affect the ability of the community to return to normal activities after flood events.

Subdivision and Dual Occupancy	• Subdivision of land involving the creation of new allotments • Dual Occupancy development.
Residential and Related	• Boarding Houses • Camp or Caravan Site - Long term sites only • Cottage Industry • Dwelling • Dwelling House • Dwelling in 7(c) Zone (also is dealt with under the provisions of DCP 95/9) • Granny Flat • Health Consulting Rooms • Home employment • Housing for aged or disabled persons (SEPP Seniors Living) • Group homes • Residential flats • Serviced apartments • Utility installations (other than critical utilities outlined above)
Commercial or Industrial	• Brothels • Bulky goods salesroom or showroom • Commercial premises • Community facilities • Hazardous industry • Heliports

Land Use	Descriptor
	• Industry • Licensed premises • Light industrial retail outlet • Motel • Motor Showroom • Offensive or hazardous storage establishment • Place of Worship • Recreation facility • Registered Club • Restaurant • Sawmill • Service Station • Sex Shop • Shop • Shop top Housing (not defined in the LEP, 1990 - consists of residential type dwellings over commercial (shop) type developments))
Tourist Related Development	• Camp or Caravan site - short term sites only
Recreation	• Leisure area • Recreation areas
Non-Urban Uses	• Agriculture • Extractive industry • Forestry • Helicopter landing site • Intensive agriculture • Mine

Concessional Development	• In the case of residential development:
	  • an addition or alteration to an existing dwelling of not more than 10% or 30 m^2 (whichever is the lesser) of the habitable floor area
	  • the construction of an outbuilding with a maximum floor area of 20 m^2
	  • redevelopment for the purposes of substantially reducing the extent of flood affectation to the existing building.
	• Minor ancillary structures (e.g. toilet or kiosks)

9.2 Guidelines for Public Domain Infrastructure

Given the ongoing need for various forms of infrastructure in the floodplain, the following guiding principles have been prepared for consideration for inclusion in either an appropriate technical policy (such as the Drainage Design Code, 1994) or within the *Managing Our Flood Risks* Development Control Plan (DCP 54):

- 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 for installation or upgrade of any sewage pumping stations
- Other infrastructure proposed in the floodplain, but not listed above, be checked for any hydraulic impacts.

This option is identified as Option PM2.

9.3 House Raising Program

House raising is a possible option that has been given detailed consideration as part of this study (Option PM3). It should be noted that two properties in the floodplain (both in Preston Street, Figtree) were raised privately by the owners following the 1998 and 1999 floods. Discussions with residents involved in the process indicated that those residents have experienced significantly less ongoing stress during heavy rainfall periods with regard to the potential for their house to flood.

Whilst house raising can reduce the occurrence of above floor flooding, there are issues related to the practice including:

- the potential for damage to items on a property other than the raised dwelling (such as gardens, sheds and their contents, garages, cars, etc)
- unless a dwelling is raised above the level of the PMF, the potential for above floor flooding still exists
- evacuation will still be required in extreme events if the dwelling is not raised to the PMF level
- evacuation may be required (e.g. medical emergency during a flood event) even if no above floor flooding occurs. This evacuation is likely to be hampered by floodwaters surrounding a property

- need to ensure the new footings and piers can withstand flood-related forces, house raising is generally only suitable for low hazard areas, however all properties have been considered as part of this assessment
- potential conflict with height restrictions imposed for a specific Zone or locality within the local government area (for properties to be raised a significant level, e.g. greater than 1m).

To identify which properties would be suitable for house raising, information on the nature of the construction of each property within the floodplain gathered for the flood damages assessment (outlined in Chapter 5) was utilised. Some properties may have been altered since the time of the survey (e.g. house raising may have already occurred or a dwelling may have been reconstructed). However, apart from those properties known to have been raised (i.e. those in Preston Street) it has been assumed that the properties are as surveyed for the purposes of this assessment.

The criteria applied to determine properties that are eligible for house raising are those properties still affected following the implementation of large scale flood modification works (e.g. Option 11, Section 8.2.11) and have the following characteristics:

- occurrence of above floor flooding in the 20 year ARI flood event,
- foundation construction type - only piered structures considered, AND
- wall construction type - all wall construction types except for full brick considered,
- single storey dwellings only.

The property survey included assessments of foundation construction type; identified as being either slab on ground or a piered structure. Only those properties on piers were assessed as it was considered prohibitive to raise dwellings constructed as a slab on ground.

Affected properties that are constructed on piers included a variety of wall construction types including:

- brick
- brick veneer
- fibro
- weatherboard
- cladded.

All wall types were included in this assessment, except for full brick as this was also considered unlikely and/or prohibitive to raise dwellings constructed of full brick. Frost and Rice (2003) indicate that brick veneer properties were generally more difficult to raise than other properties but undertook a pilot project to evaluate the potential for the raising of such properties. This project identified that it is possible to successfully raise brick veneer properties. Similarly, observations by Lawson and Treloar of the raising of a brick veneer property in the Pittwater Local Government Area indicate that it is possible to undertake raising of brick veneer properties. Accordingly these types of properties have been included in this assessment.

A flood level was assigned to each eligible property for the 20 year and 100 year ARI floods based on the existing flood behaviour for Allans Creek (as outlined in Section 4.3). All eligible properties were then sorted based on the above criteria. The height which the eligible properties would need to be raised was calculated by estimating the difference between the existing floor level and the design 100 year ARI +0.5 m freeboard level.

Once properties were identified using the above criterion, an additional assessment of those properties surrounding eligible properties was undertaken. Those properties that met some of, but not all of the criteria identified above, but for social and equity issues were considered appropriate for eligibility. These additional considerations also involved an evaluation of other issues such as the rate of rise of floodwaters and difficulty of evacuation in the particular locality. Other properties which met the criteria, but were essentially on the threshold of meeting the criteria, were omitted for inclusion based on equity issues for surrounding properties which did not otherwise qualify.

As a guide, the maximum increase in floor elevation required for a dwelling was assumed to be of the order of 1.5 m above existing floor levels to re-establish the current floor level to the flood planning level (i.e. 100 year ARI + 0.5m). In some cases, this criterion was relaxed where the property was located within a cluster of properties that met the criteria outlined above. In a number of cases the 100 year ARI + 0.5 m is above the PMF level. In other cases, an additional freeboard would be required to raise the property to have a habitable floor level above the PMF. It is recommended that as properties are raised, a review of the height to which they need to be raised be undertaken if emergency constraints indicate raising the property an additional height is warranted.

A breakdown of the numbers of identified properties and associated costs are listed in Table 9.2. An assumed cost of the order of $40,000 is considered reasonable for each property as a preliminary assessment.

Table 9.2 Breakdown of Properties for House Raising

Street	Number of Properties Identified	Likely Total Cost
Arrow Avenue	13	$520,000
Euroka Street	2	$80,000
Koloona Avenue	1	$40,000
Normandie Place	5	$200,000
Princes Highway	2	$80,000
Rickard Road	14	$560,000
Tallegalla Street	1	$40,000
Thames Street	3	$120,000
Uralba Street	1	$40,000
Wallawa Street	6	$240,000
Total	**48**	**$1,920,000**

Details of individual properties identified for voluntary house raising have been provided to Council in a 'Commercial in Confidence' Appendix to this report. Identified property owners will be contacted by Council for discussions regarding their interest in being involved in a Voluntary House Raising Program. The success of such a program is contingent on joint funding from the Department of Natural Resources and the meeting of the relevant subsidy criteria as applied by the Department.

An assessment of the reduction of the annual average damage was made through the elevation of properties. It was assumed for the purposes of AAD calculation that the properties still had the same amount of above floor flooding at the PMF. The reduction in Average Annual Damage as a result of house raising was found to be from $13.5 million under the existing case to $12.6 million. Thus, over a period of 50 years and at a discount rate of 7%, the net present value of the reduction in damages achieved by voluntary house raising would be $12 million.

Therefore, if the cost of raising a property is assumed to be approximately $40,000 per property (regardless of the height to be raised), the total cost of a house raising program for those properties which meet the criteria is $1.92 million. This estimate assumes that the program is implemented for all properties at the same time (i.e. no discounting applied). Should this option be considered appropriate, a program for house raising should be prepared to schedule properties on a priority basis via ranking the eligible list by 'height to be raised' or on a locality by locality basis. The program schedule will need to include an allowance for the preparation to develop appropriate agreements with property owners. It is recommended that the experience of Fairfield City Council, outlined in Frost and Rice (2003) be considered in detail in the development of the scheme.

The cost benefit ratio of this option is 6.25, which is considerably higher than all of the structural options outlined in Table 8.13.

9.4 Voluntary Purchase Program

Voluntary purchase is a possible option that has also been given detailed consideration as part of this study (Option PM4). It should be noted that voluntary purchase has been undertaken by Council, with financial assistance from the NSW State Government (via the Department of Natural Resources) of two properties in Preston Street, Figtree, within the Allans Creek floodplain following the 1998 and 1999 floods.

In high hazard areas of the floodplain an alternative to the construction of flood modification options to mitigate high flood hazard to existing properties at risk is the use of voluntary purchase. This option would free both residents and emergency service personnel and volunteers from the hazard of future floods. This can be achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be rezoned to a flood compatible use, such as recreation or parkland (NSW Government, 2005) or possibly redeveloped in a manner that is consistent with the flood hazard.

The criteria determined by Council to determine properties that are eligible for voluntary purchase are:

- occurrence of above floor flooding in the 20 year ARI flood event, AND/OR
- greater than 1 m depth of above floor flooding in the 100 year ARI flood event, AND
- foundation construction type – generally only slab on ground structures considered. Where a series of properties of mixed construction were identified in one locality, those properties of alternate construction types were also considered.

Information on the nature of the construction of each property within the floodplain gathered for the flood damages assessment (outlined in Chapter 5) was utilised for the assessment of the maximum number of properties in the Allans Creek floodplain that may be eligible. Some properties may have been altered since the time of the survey (e.g. a dwelling may have been reconstructed with different foundations or enhanced by the addition of a storey). However, it has been assumed that the properties are as surveyed for the purposes of this assessment.

As for the house raising assessment (Section 9.3), each residential property surveyed was assessed for the construction of floors - identified as being either slab on ground or piers. As outlined above, generally only those properties constructed as a slab on ground were identified as possible options for voluntary purchase as part of this assessment since the remainder of properties are constructed on piers and the flood risk would generally be more cost effectively managed through a house raising program. Other properties may well be eligible based on their exposure to high hazard floods and where offered by a resident for purchase and should be considered on a merits basis by Council as funds become available.

It is important to note that some properties were not surveyed specifically for their ground level and floor level and an interpolated value was adopted. These interpolated values suggest that an additional 10 properties may also meet the voluntary purchase criteria applied. It is recommended that detailed ground survey be undertaken to determine whether the relevant properties should be included in the Voluntary Purchase list (Option PM14).

A search of listed property prices for the area through local real estate agents (LJ Hooker) reveals market values (as at June 2002) of various types of residential property in the area ranging from $120,000 - $600,000.

A conservative assumption of the cost of approximately $400,000 per property has been adopted. A breakdown of the numbers of properties and associated costs are listed in Table 9.3.

Table 9.3 Breakdown of Properties for Voluntary Purchase

Street	Number of Properties Identified	Likely Total Cost
Arrow Avenue	5	$2,000,000
Cypress Avenue	1	$400,000
Koloona Avenue	7	$2,800,000
Princes Highway	1	$400,000
The Avenue	3	$1,200,000
Uralba Street	1	$400,000
Total	**18**	**$7,200,000**

Table 9.3 indicates that the total cost of a voluntary purchase program would be of the order of $7.2 million (assuming all purchases are undertaken at once, i.e. no discounting applied). Should this option be considered appropriate, as assessed within the options analysis in Section 11, a programmed means of undertaking voluntary purchase, either on a ranked list by depth of above floor flooding or on a locality basis (similarly to the house raising program) could be developed. This will need to be based on appropriate agreements being reached with individual property owners.

Details of individual properties identified for voluntary purchase have been provided to Council in a 'Commercial in Confidence' Appendix to this report. Identified property owners will be contacted by Council for discussions regarding their interest in being involved in a Voluntary Purchase Program. The success of such a program is contingent on joint funding from the Department of Natural Resources and the meeting of the relevant subsidy criteria as applied by the Department.

An assessment of the reduction of the annual average damage was made by entirely removing the properties identified. The reduction in Average Annual Damage as a result of voluntary purchase was found to be from $13.5 million under the existing case to $13.2 million. Thus, over a period of 50 years and at a discount rate of 7%, the net present value of the reduction in damages achieved by voluntary purchase would be $4.1 million.

Thus the cost benefit ratio is 0.57 which is comparable with some of the structural options outlined in Table 8.13.

The procedure by which voluntary purchase could be undertaken could generally include two alternate approaches:

- The owner of land affected by flood hazard may in writing request Council to acquire that land. The owner would thus, relinquish all responsibility of their land to Council. The economic and social (including psychological) effects of flooding would therefore generally be averted in the future, or
- Zone 9 (Reservation Zone) and Clause 35 of the existing LEP sets out a procedure for the identification and acquisition of land and could be applied to land within a flood prone area by Council or another public authority. This is considered to be an unfavourable approach as it does not really allow for the

process to be 'Voluntary' in the truest sense of the word. As such it is not recommended as an option.

After voluntary purchase, Council would then arrange for demolition of the building and have the land rezoned to open space.

In addition to those lots which currently have a dwelling located on them that qualify for voluntary purchase, there are a few lots which are currently in private ownership but have not yet been developed in accordance with the land use zoning under the LEP (1990). These lots have been included in Table 9.3.

An alternative to the voluntary acquisition is the potential for a land swap with suitable parcels of land owned by Council. A detailed assessment of the number of parcels of land that are potentially within this category has not been carried out and would need to be the subject of further investigation. These investigations could be included as a line item in the Floodplain Risk Management Plan.

9.5 Flood Refuges

The State Emergency Service reports that in the 1998 flood, the access bridge to the Figtree Gardens Caravan Park was inundated by about 2.0m and the SES has highlighted that there is currently no safe egress from the site under these types of conditions. The Allans Creek Flood Study (Lawson and Treloar, 2006) indicates that the Princes Highway at American Creek will be overtopped by ~1.7m in a 100 year ARI event for ~8 hours and ~3.2 m in a PMF for ~ 6 hours.

Given the flood prone nature of the Figtree Gardens Caravan Park and the limited egress opportunities, it is proposed that a flood refuge be considered for construction within the Caravan Park grounds (Option PM5).

This facility could take the form of a facilities hall that would require refuge at a high level necessitating an elevated second level above the PMF and suitable access for a range of persons. The size and location of the facility would need to be such that it does not exacerbate flood risk in the area and is accessible to all residents of the Park. The structure would need to be designed to withstand flood and debris forces up to and including those experienced in the PMF.

9.6 Zoning Modifications

Whilst the rezoning of land to Zone 9 has been ruled out as part of the Voluntary purchase process (Section 9.4), the rezoning of other areas is a potential solution to the issue of managing flood prone land (Option PM6).

Section 117(2) of the Environmental Planning and Assessment Act (1979) provides for directions to be updated from time to time. General direction G25 (now repealed) refers to flood liable land. The instrument previously provided a legal mechanism to ensure that high hazard areas and floodways are suitably zoned. Consequently Council cannot:

- rezone flood liable land from a zone described as special uses - flood liable, rural, open space, scenic protection, conservation, environment protection, water catchment or coastal lands protection, or by a similar description, to a zone described as residential, business, industrial, special use, village or by a similar description; or
- enact provisions within the LEP which apply to flood liable land which:
  (a) permit a significant increase in the development of that land
  (b) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, on infrastructure or on services or
  (c) permit development to be carried out without development consent, except development for the purposes of agriculture (not including dams, drainage canals, levees, building or structures in floodways, high hazard flood storage areas) minor development and additions as defined in the Floodplain Development Manual (now the Floodplain Development Manual, 2005)

The onus of the former directive is that land defined substantially in accordance with the principles contained in the Floodplain Development Manual (2005) as high hazard flood liable land or as floodway shall be zoned in draft LEPs as special uses - high hazard flood liable or special uses floodway, rural, open space, scenic protection, conservation, environment protection, water catchment, or coastal land protection, or as a zone having a similar description.

It is understood that following the repeal of all Section 117 directions in September 2005, a new direction is currently being prepared to address matters identified above. Consideration of the new directive will be required as part of the ongoing planning requirements for flood risk management.

Table 9.4 provides a guide to the number of lots and their land use currently located within the High Risk Precinct (as defined in Section 4.5).

Table 9.4 Breakdown of Lots by Zone Located in the High Risk Precinct

Zone	Definition	Details	Number of lots affected by high risk flood precinct
1	Non Urban	May be rezoned or developed in the future	10
2(a)	Low Density Residential	Detached housing, dual occupancy, educational establishments, residential flats	558
2(b)	Medium Density Residential	Boarding housing, camp or caravan sites, community facilities, educational establishments, health consulting, hospitals, motels, places of worship, residential flats, utility installations	99
3(b)	Neighbourhood Business	Not Cottage industries, hospitals, institutions, light industry, transport terminals	6
3(d)	Commercial Services	Not Boarding housing, hospitals, heavy industry, institutions, places of worship, shops	16
4(a)	Light Industrial	Camp or caravan sites, commercial premises, dwellings, shops	43

Zone	Definition	Details	Number of lots affected by high risk flood precinct
4(b)	Heavy Industrial	Educational establishments, light industrial retail outlets, recreation areas, restaurants, turf farming	66
5(b)	Special Uses	Not Brothels	7
5(c)	Special Uses	Not Brothels	83
6(a)	Public Recreation	Camp or caravan sites, some dwellings, intensive agriculture, leisure areas, registered clubs, utility installations	65
6(b)	Private Recreation	Camp or caravan sites, some dwellings, intensive agriculture, leisure areas, registered clubs, utility installations	7
6(c)	Tourism	Boarding housing, camp or caravan sites, car parking, cottage industries, educational establishments, home employment, licensed premises, motels, passenger transport terminals, recreational areas, registered clubs, restaurants, serviced apartments, utility installations	10
7(b)	Environmental Protection Conservation	Dwelling houses, granny flats, home employment, utility installations	3
7(c)	Environmental Protection - Residential	Cottage industries, dwelling houses, granny flats, educational establishments, home employment, utility installations	2
9(b)	Reservation	Land required for future essential services, roads, open space and community purposes	5
Total			980

Based on the information in 9.4, it may be appropriate for consideration of the rezoning of land (99 lots) that is 2(b) in the high risk precinct to 2(a1) - Special Low Density Residential Zone. This approach would provide a stronger mechanism through the Local Environment Plan provisions for development control than those applied within a Development Control Plan would. The application of this approach could occur such that, where land is already developed, if redeveloped would be returned to a lesser density site coverage. Where land is not developed, this approach would prevent an increase in the likely density of site coverage and reduce the number of persons exposed to high risk. It is difficult to apply the principles of the repealed Directive G25 as the definition of the high risk precinct is a derivation of the definitions found in the Floodplain Development Manual (2005) and do not specifically identify 'floodway', 'flood fringe' or 'flood storage' areas. To overcome this matter it may be appropriate for Council to prepare separate 'floodway' mapping (potentially to include floodways as defined by the PMF) to identify those allotments which require specific rezoning under the provisions of Section 117 of the EP&A Act (1979).

Alternately, land zoned 2(b) within the medium risk precinct could be considered for rezoning. Given the limited coverage of the medium risk precinct in comparison to the high risk precinct, this may not cover a significant area.

It may also be appropriate for consideration of the rezoning of land (90 lots) that is 5(b) and 5(c) in the high risk precinct to a more compatible use (such as 6(a) or similar) or arranging for a land swap with land zoned 6(a) or non-urban outside of the floodplain.

There are a number of implications for the rezoning process for both Council and landholders and it is recommended that rezoning, whilst preferable on a broad scale, be undertaken on a case by case basis. This option may involve some financial compensation and it is recommended that further investigation of this matter be undertaken.

Given the proposed development controls outlined in Section 9.1, the rezoning process may well be made redundant given the proposed requirements for development for different land use types.

Note that the Local Government Act (1993) indicates that vacant land that is identified to be at risk from flooding such that it can no longer be developed should be earmarked for a level of financial relief from water and sewerage rates.

9.7 Section 149 Certificates

Section 149 Certificates are issued under the Environmental Planning and Assessment Act (1979) and provide information to land holders and prospective purchasers on the hazards that affect the land.

With respect to flooding, there are two types of certificates issued:

- Section 149(2) Certificates - these certificates identify relevant planning instruments pertinent to the land such as the Development Control Plan *Managing Our Flood Risks* DCP (DCP 54).
- Section 149(5) Certificates - these certificates identify whether the land is flood prone.

Council has a standard format for these certificates. The current wording is outlined below along with proposed wording to better define the matter of flood risk.

In addition to Section 149 certificates, a ‘flood certificate’ has also been proposed for the Towradgi Creek Floodplain (Section 9.7.3).

9.7.1 Current Wording

The current wording and format of the Section 149 certificates consists of information on a number of matters (e.g. flooding, land stability, bushfire risk etc). Section 149(2) certificates deal with planning issues only. Section 149(5) certificates contain the flood hazard notation adopted for a property and are therefore reviewed in detail. The existing wording for the various flood hazard notations on Section 149(5) certificates is shown in Table 9.5.

Table 9.5 Section 149(5) Certificate Wording

Condition	Current Wording
Flood Hazard **– Affected**	Council's flood hazard/flood assessment maps show that the land is located in an area where flooding has occurred or is suspected. The services of a suitably qualified engineer should be sought to ascertain the likely effect, if any, on the land. **Note:** Advice given by Council relating to the likelihood of land being flooded or the nature or extent of such flooding is based on information contained in Council's flood hazard maps. The maps are compiled from data received by Council and considered by Council to be reasonably reliable. Council does not warrant that its flood hazard maps contain all information ever received by Council relating to the likelihood of land being flooded or the nature or extent of any such flooding.
Flood Hazard **– Not Affected**	Council's flood hazard/flood assessment maps do not show that the land is located in an area where flooding has occurred or is suspected. If you have any doubt as to whether the land is affected by flooding the services of a suitably qualified engineer should be obtained. **Note 1:** Some land may experience water inundation as a result of the creation of stormwater detention basins or channels or flow paths in the course of development of the land. **Note 2:** Advice given by Council relating to the likelihood of land being flooded or the nature or extent of such flooding is based on information contained in Council's flood hazard maps. The maps are compiled from data received by Council and considered by Council to be reasonably reliable. Council does not warrant that its flood hazard maps contain all information ever received by Council relating to the likelihood of land being flooded or the nature or extent of any such flooding.
Ponding	Council has become aware that there may be potential for short term localised ponding on part of this lot, however, drainage connections are available to alleviate this problem during the course of dwelling construction.
Piped Watercourse	Council's records indicate that the land may be affected by a piped watercourse, the exact location of which is unknown to Council.
Flood Hazard **– Affected** **– Voluntary Purchase**	Council's flood hazard/flood assessment maps show that the land is located in an area where significant flooding has occurred. The subject property is currently included in Council's voluntary purchase scheme. Further information regarding the voluntary purchase scheme is available from Council.
Stormwater – Detention/Storage	The development consent for this subdivision required the developer to provide on site detention storage for stormwater runoff in accordance with Council's requirement at the subdivision stage. Due to the unknown size and location of a future dwelling, Council has agreed to defer the requirement for detention storage. Accordingly details of the detention storage as required in the development consent for the subdivision must be submitted with the application for dwelling construction on this lot.

9.7.2 Proposed Wording

Given the extensive nature of the flood investigations undertaken for Allans Creek for flood behaviour up to the PMF and the issue of culvert blockages, it is recommended the following wording be considered for adoption for Section 149(5) certificates (Option PM7). It is also important to ensure that Section 149(5) certificate wording is consistent across all catchments in the local government area.

It is recommended that advice be provided on all 149(5) Certificates for properties affected by flooding of Allans Creek and its tributaries up to the PMF.

Overall, the advice should be clear and unambiguous and include:

- required statutory information
- reference to the fact that 'flood-prone' does not necessarily mean the floor areas of dwellings will be inundated, instead it relates to some portion of the site being identified as being flood-prone and that any development on the land is therefore to adhere to Council's flood-related development controls
- reference to adopted flood planning levels for the site with particular reference to the PMF, the rare nature of this kind of event and the need for evacuation during rare events.

It should be noted that the wording of advice on certificates is one aspect of the flood education process but this education generally only occurs when a property is sold. The following recommendations have been adapted from guiding information provided in the Floodplain Development Manual (2005).

Different wording scenarios are recommended for adoption in the following cases:

- properties located wholly within the low risk precinct (Case 1)
- properties located wholly or partly within the medium risk precinct (Case 2)
- properties located wholly or partly within the high risk precinct (Case 3).

Suggested wording for Case 1 (Land wholly within the Low Risk Precinct):

"Council considers the land in question to be above the flood planning level within the Low Risk Precinct. Information relating to this flood risk may be obtained from Council.

However, the land could be flooded in quite rare events. The property is included in flood preparedness related education campaigns and emergency management considerations. The property may need to be evacuated during a rare event. Restrictions on development in relation to flooding apply to this land and are set out in Council's Flood Policy and Development Control Plan - Managing Our Flood Risks that are available for inspection at Council. "

Suggested wording for Case 2 (Land wholly or partly within the Medium Risk Precinct, but with no part in the High Risk Precinct):

"Council considers the land in question to be below the Flood Planning Level and within the Medium Risk Precinct and therefore subject to flood-related development controls. Information relating to this flood risk may be obtained from Council.

Restrictions on development in relation to flooding apply to this land and are set out in Council's Flood Policy and Development Control Plan - Managing Our Flood Risks that are available for inspection at Council.

Floods larger than the event used in determining the Flood Planning Level can occur and as such Council has a policy on flood preparedness, related education campaigns and emergency management considerations for these rare floods. The property may need to be evacuated during flood events".

Suggested wording for Case 3 (Land wholly or partly within the High Risk Precinct):

"Council considers the land in question to be below the Flood Planning Level and within the High Risk Precinct and therefore subject to flood-related development controls. Information relating to this flood risk may be obtained from Council.

Restrictions on development in relation to flooding apply to this land and are set out in Council's Flood Policy and Development Control Plan - Managing Our Flood Risks that are available for inspection at Council.

Floods larger than the event used in determining the Flood Planning Level can occur and as such Council has a policy on flood preparedness, related education campaigns and emergency management considerations for these rare floods. The property may need to be evacuated during flood events".

Due to the way in which the flood risk precincts were developed (i.e. using 1D cross sections and 2m topographic contours) and since only one spot ground level is available for those properties which have been surveyed, it is recommended that the following words also be included on the certificate for all scenarios.

"Council does not have sufficient accurate ground level information to indicate the extent of the land that may be affected. This information may be obtained by the applicant/owner through the commission of a Registered Surveyor to determine ground levels on the site and a Chartered Professional Engineer to determine flood extents on the site and acceptable habitable floor levels ".

The process by which the revision of Section 149 certificate wording should be undertaken involves:

- internal review of proposed rewording of certificates by Council
- legal review of the proposed rewording
- adoption of the reworded advice by Council.

9.7.3 Flood Certificates

It is recommended that the Flood Certificate developed as part of the Towradgi Creek Floodplain Risk Management Study (Bewsher Consulting, 2002) be adapted for Allans Creek (Option PM8). The wording for the Section 149 certificates proposed above may alternately be incorporated in the flood certificates rather than in the 149 certificates.

9.8 Policy Preparation and Revisions

There are two main areas of policy that have been identified as a potential issue with regard to flooding. These are:

- no specific policy for Caravan Parks/Manufactured Home Estates
- managing additional impervious areas and associated additional runoff for infill development and greenfield and brownfield type subdivisions.

Proposed options to address these matters are described below.

9.8.1 Caravan Park/Manufactured Home Estate Policy

Given the location of a large scale caravan park in the lower parts of the American Creek floodplain (Figtree Gardens) and future potential for the development of caravan or relocatable home parks, it is recommended that Council identify appropriate flood risk management strategies for this special type of residential development. A number of other Caravan Parks/Manufactured Home Estates are also located within the LGA, some of which lie within the floodplains of other areas (e.g. Lake Illawarra).

An inspection of the Figtree Gardens Caravan Park indicates that a number of caravans are likely to be immovable in the time of a flood and also the critical duration for flooding would prohibit an appropriate warning time to allow for the preparation for evacuation. The nature of the access to and from the park is a high hazard area and refuge would generally be required to be taken within the site. This is an issue for extreme events since available information indicates that the entire site is flood-affected. Section 9.5 provides an option for redressing this issue.

The development consent for the Figtree Gardens Caravan Park was issued by Council in 1975. At this time there were limited development controls imposed on developments of this type with regard to flooding and there was also limited information on the nature and extent of design flood behaviour.

Currently the main means by which flood risks are managed for Caravan parks in flood-prone areas is via Council's LEP (Clause 120) which states that *'Caravan Parks should not be established on flood liable land unless the application for development consent has demonstrated that adequate safeguards to life and property have been incorporated into the proposed development*'.

An option is to develop a specific policy for Caravan Parks/Manufactured Home Estates (Option PM9). In the development of such a policy, it is recommended that the findings of Yeo (2001) be considered carefully for their implications including:

- a concern for flood liable caravan parks in that those that cater for permanent residents usually attract an over-representation of potentially at-risk groups such as pensioners, retirees and those on low incomes, for which the social implications of flooding are significant with regard to the loss of property and insurance issues.

- short stay visitors may have no awareness of flood risk
- even where parks were allowed to be developed in flood-prone areas on the proviso that assets could be moved to avoid exposure to a flood, very few (<10%) of cabins and resident vans could actually be moved before a flood
- vans can float at water depths of over 2 m and subsequently cause damage by floating into other items.

Investigations by Yeo (2001) report that state legislation and policies cover the operation of caravan parks and manufactured home estates:

- including the Environmental Planning and Assessment Act (1979)
- Local Government (Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation (1995)
- SEPP 21 (Caravan Parks)
- SEPP36 (Manufactured Home Estates).

It is recommended that Council ensure that an appropriate environmental planning instrument (such as within Council's *Managing Our Flood Risks* DCP) includes controls to only allow caravan/relocatable home or manufactured home estate type developments in areas outside of the high risk precinct. Should these types of developments be allowed in the medium or low risk precincts, particular development controls will need to be applied in order to ensure that life and property risks are minimised with respect to flooding.

9.8.2 Management of Runoff from Future Development

Land development almost always involves the creation of additional impervious surfaces on a site. The amount and the rate of the runoff from the site commonly increases when impervious surfaces increase.

On site detention (OSD) for new or redeveloped areas is a means of managing the rate of runoff from the site that is created as a result of the development. A variety of different approaches have been formulated and adopted across New South Wales as a means of attempting 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 created as a result of additional impervious surfaces within a new development.

In the Allans Creek floodplain, due to the flooding mechanism in different areas, changes in peak flows, the timing of the peak flow and changes in runoff volume have potential consequences for flood behaviour. There are potentially both local effects due to individual development and the cumulative effect of all potential areas being developed. Given uncertainty associated with local effects from individual developments and the strategic floodplain scale nature of this study, these are not assessed here. The broad scale nature of the cumulative effects of land development have not been assessed as part of this investigation and it is recommended that a detailed cumulative impact assessment be undertaken to

consider new development areas and identify and assess means of managing the impacts over the full range of flows (Option PM10). This may include the development of a regional detention basin strategy.

As a guide to the potential impacts, the sensitivity analysis reported in the Allans Creek Flood Study (Lawson and Treloar, 2006) indicate that for an increase in flows of 20% at the 100 year ARI, the average change in water depth across the catchment is +0.20m. The peak variation in water level was found to be +1.54 m (Unanderra Industrial area).

However, the sensitivity analysis reported in the Allans Creek Flood Study (Lawson and Treloar, 2006) did not consider changes to the timing of the arrival of hydrographs, it merely considers additional flows with the same timing. Further detailed assessments of the impact of hydrograph timing changes are required.

Within the Allans Creek catchment, Council currently manages new development and redevelopment via an existing OSD policy (1988). Council is currently in the process of reviewing this OSD policy. In the absence of a comprehensive database, it is presumed that, except in unusual circumstances, all development within the catchment that has been approved by Council since the adoption of the OSD policy in 1988 included a requirement for OSD compliance with the policy.

Council's draft policy (2005) has recently been reviewed and incorporates a range of requirements.

In general the current policy includes:

- the definition of storage – 'the provision of depressed areas in paved or landscaped areas which are provided with relatively small stormwater outlets, so as to detain a pond of water for a short duration, during more intense storms'.
- the requirements apply to developments for which there is an increase in impervious area over the existing usage or the impervious area.
- calculation procedures for sites smaller than 2 ha.
- Sites with OSD will have the details transferred to their land title certificates (as a positive covenant) to indicate to owners that the system exists
- OSD facilities are not to be inundated by any flood events up to and including the 100 year ARI
- maximum ponding depths are listed for the four types of areas, parking/paving, landscaping, covered/fenced storage and roof area
- open storage areas are not to be located in privately controlled areas for multiple occupancy sites (e.g. villa housing).

The overall objective is to 'prevent or mitigate any increase in stormwater runoff resulting from development'.

Given the severity of the flood issue for existing development in the Allans Creek catchment, recommendations for the draft policy with regard to the Allans Creek Floodplain include:

- use of a catchment based approach for calculating peak discharges as opposed to a site or lot based approach and the consideration of a full range of return intervals frequencies and a full range of storm durations (the Allans Creek Flood Study could be used as a guide to appropriate return intervals and appropriate storm durations)
- assessment of the cumulative impacts of storage facilities and associated effectiveness
- zero net increase in peak discharges from natural conditions (i.e. Pre-European conditions) for all greenfield and brownfield subdivisions
- consideration of the effects of release timings in the lower portions of the catchment
- on-site reuse to be mandatory for greenfield and brownfield subdivisions to maintain water balance of site to natural conditions (i.e. Pre-European conditions)
- infill development to have zero net increase in peak discharges from existing conditions (i.e. predevelopment) and a credit in Section 94 contributions (or similar type of economic incentive) for reducing peak discharges to below the existing conditions
- use of regional detention systems for greenfield and brownfield subdivisions in preference to lot-based detention systems, use of lot-based and regional reuse systems.

It is recommended that, where a large scale development is proposed in the catchment; the developer should be required to submit a flood study to ensure that the proposed development will not have adverse impact on downstream properties. The extent of the modelling should be governed by the hydraulic controls within the floodplain and therefore should extend sufficiently downstream to evaluate all possible impacts on flood levels. This may necessitate an extensive floodplain area to achieve this objective. A range of design events should be considered, along with a range of event durations.

9.9 Data Collection Strategies

Whilst not specifically a property modification option, the collection of data as a strategy is an important part of the ongoing assessment of the impacts of flooding and the ongoing development of understanding of the nature of the catchment.

A series of data is currently collected including:

- peak flood height levels – maximum height indicators at various locations
- observed peak flood height levels – by resident report and interview (post-flood)
- continuous water level recorders – operated by Sydney Water Corporation (SWC) and Department of Commerce (DoC) at locations F6 Freeway Culverts on Byarong Creek and American Creek just upstream of the Princes Highway.

The current locations of stand-alone data collection systems are shown in Figure 9.1.

It is proposed that a series of additional maximum height indicators and rainfall gauges be considered as part of the implementation of the floodplain risk

management plan (Option PM11). Proposed locations for these systems are shown in Figure 9.1.

The Flood Study (Lawson and Treloar, 2006) found that the current locations of the continuous water level recorder resulted in reported stage hydrographs being compromised by the blockage of culverts. As a result, it is recommended that the water level recorder be relocated to a location away from the culverts (commensurate with their locality for other purposes, perhaps such as in association with water quality monitoring). However, given the considerable potential for blockage and backwater effects through the majority of the floodplain, it is unlikely that there will be locations that are suitable except in the lower portion of the floodplain. As such, it is recommended that an additional water level recording station be placed in the lower parts of the floodplain in order to quantify the total catchment volume from flood events. The proposed location for this is also shown in Figure 9.1.

It is also recommended that, following significant flood events, a similar approach to the data collection post-flood be undertaken by Council as was undertaken for the 1998 and 1999 events as reported in Henshaw (1999). This involved the systematic collection of flood levels from residents using standardised forms and the entry of this data into Council's GIS (Option PM12).

9.10 Public Awareness and Education for Property Issues

Given the issues of private ownership and maintenance requirements for a large portion of the creek system, it is considered appropriate that where Council is unable to access private property to maintain the creek system, residents need to be provided with guidance on appropriate techniques to use to manage the creek within their property (Option PM13).

It is recommended that these guidelines be prepared and distributed to all affected residents on an annual basis with their rates notice.

9.11 Summary of Costs

Overall, a summary of the likely costs of the proposed property modification options is provided in Table 9.6.

Table 9.6 Summary of Property Modification Options

Option	Likely Implementation Capital/Recurrent Cost*
PM1 Updating of DCP54 with Development Control Matrix for Allans Creek	$5,000 (C, I)
PM2 Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure	$5,000 (C, I)
PM3 House Raising Program	$1.92 million (C)
PM4 Voluntary Purchase Program	$7.2 million (C)
PM5 Provision of a Flood Refuge within the Figtree Gardens Caravan Park	$300,000 (C)
PM6 Detailed Investigation of Possible Zoning Modifications	$30,000 (C, I)
PM7 Revision of Section 149(5) Certificate Wording	$5,000 (C, I)
PM8 Adapt Towradgi Creek Flood Certificate for Allans Creek	$5,000 (C, I)
PM9 Caravan Park/Manufactured Home Estate Policy	$5,000 (C, I)
PM10 Cumulative Impact Study and Review of On-Site Detention Policy	$40,000 (C)
PM11 Data Collection Strategies – Installation of Maximum Height Indicators, Rainfall Gauge(s), Relocation of Byarong Creek Water Level Recorder and Installation of Additional Water Level Recorders	$40,000 (C), $5,000 (R)
PM12 Collection of Data Following Flood Events	$10,000 (O)
PM13 Public Awareness and Education for Property Matters (Creek Maintenance in Private Property)	$10,000 (C, I)
PM14 Additional Property Survey	$10,000 (C)

*where C Capital Cost
I Internal Council Cost
R Recurrent Cost
O Infrequent One-off Costs (Following Flood Events, Assume recurrent cost of $2,000 for life cycle costs).

10. EMERGENCY RESPONSE MODIFICATION OPTION ASSESSMENT

The development and implementation of flood emergency response plans are important and the only means of reducing the damage and hazard associated with the residual risk of flooding. Flood emergency measures include:

- education about flood preparedness
- flood forecasting and warning
- plans for the defence and evacuation of the area (if required)
- relief of evacuees, and
- recovery of the area once the flood subsides.

Implementing flood emergency measures is an effective means of reducing the costs of flooding and managing the continuing and residual risk to the area.

10.1 Recent Past Experience - The 1998 and 1999 Flood Events

Detailed discussions were held with the SES officers (including the South Coast Division Executive Officer, Reconnaissance/Intelligence Officer and State Headquarters Planning and Research Officer) as part of the preparation of this study. The SES report that a number of issues arose during the 1998 and 1999 events that were of particular concern:

- given the flood affected nature of the majority of the Wollongong area, some crews had to be mobilised from the Albion Park area. In the case of the 1998 event, it took approximately five hours to mobilise crews from Albion Park due to traffic congestion induced by flood inundation of roads and approximately 12 hours to provide significant assistance. Given the rapid nature of the flooding and the timing (at night) their role was largely to assist with the recovery process which took of the order of weeks.
- the Wollongong Local Unit Headquarters is located in Montague Street, North Wollongong (next to the Council works depot) which lies within a flood affected area. There are plans to relocate these Headquarters to a more appropriate site. This site is where SES vehicles and equipment is located. In general teams have three vehicles to utilise. It should be noted that the Local Flood Plan (SES, 2004) makes reference to the potential for this area to be inaccessible or inundated and if this does occur then operations are to be controlled from the Bulli Bush Fire Brigade Headquarters, Dumbrell Road, Bulli.
- As a guide, the 1998 event required the mobilisation of 46 teams as well as the Rural Fire Service.
- Prime concern is the use of their resources to ensure risk to life is minimised as a first priority with risk to property being a second priority.
- a recommendation of the Floodplain Risk Management Plan should be the prioritisation of localities to attend to that are most likely to be flood affected and the order in which these areas should be attended to with regard to the timing of the flood peak.

- SES are currently working on the need for improved interpretation of severe weather warnings from the Bureau of Meteorology to make these warnings more meaningful to their target audience.
- updating of flood intelligence cards with the findings of the flood study would be useful.
- SES has an awareness week in November each year where displays are held in the local shopping districts.
- SES is concerned for the potential risks and additional burden likely to be placed on their officers and volunteers as a result of the approval of additional residential dwellings in the floodplain without self-managed evacuation (e.g. vertical evacuation).

Further details of the SES response to the wider Wollongong area floods of 1998 can be found in Pfister (1998).

The SES indicated that they would prefer the following actions to occur:

- a copy of the Flood Study (Lawson and Treloar, 2006) in both hard copy and electronic format to be supplied to the SES for reference
- a copy of all relevant flood extent and flood risk precinct mapping to be made available to SES in digital format for emergency planning purposes and hard copy format (laminated A1 plans would be ideal for use in the Operations Room)
- a copy of the Floodplain Risk Management Study and Plan to be made available to the SES for reference when adopted by Council
- given the issues with mobilisation of crews to a single location, where travel to a location may be compromised by flooding, it may be useful to advise crews of three to four people to attend to locations for a reconnaissance directly from their homes or workplaces and to advise of requirements to Headquarters
- consideration of a trial SMS service (would require a database for registrations for those interested local residents)
- Updating of the FloodSafe brochures for localities (e.g. one for Byarong Creek, one for American Creek and one for the Charcoal Creek area). A review of the means of distribution or the content since limited feedback from the distribution of the last FloodSafe brochure with Council rate notices following the 1998 and 1999 floods (a copy is shown in Figure 10.1a and 10.1b) was found to be not as effective as expected. Other SES information brochures with a fridge magnet may be a more effective means of ensuring people retain information. Note that the distribution of this brochure was sponsored by Council, the NRMA and the SES.
- potential relocation of water level recorders currently in existence in Byarong and American Creek and linkages to a real time system to be used for flood warning and/or to assist with remote evaluation of conditions during the course of a flood
- installation of additional rainfall gauges to be hooked to an ALERT system via the BoM.
- continued use of media (e.g. The Illawarra Mercury, The Advertiser and Win TV).

The SES currently operates a paging service for each duty crew. However, more experienced crews know when to mobilise based on their understanding of the local area.

10.2 DISPLAN Status and Recommendations

Flood emergency management for the Wollongong area is organised under the *Wollongong City Local Flood Plan* (SES, 2004). This plan is a sub-plan of the Wollongong Local Disaster Plan (DISPLAN) and has been prepared under the State Emergency and Rescue Management Act, 1989. The plan is consistent with similar plans prepared for areas across NSW and covers the following aspects:

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

The plan also consists of a series of annexures, which include details of the flood threat, a description of the effects of flooding on the community, details of gauges monitored by the SES, details of the dissemination of flood bulletins. Arrangements for caravan parks are provided, but the Figtree Gardens Caravan Park is not included in the details.

One option to be considered is for the following amendments to be made to this document as a result of the findings of both the flood study and this study:

- prepare for the closing of roads, in association with the RTA and Council at the crossing of major creek systems (as outlined in Section 10.5)
- mobilise crews to known hot spot locations within the Allans Creek catchment
- add a reference to the Proprietors of the Figtree Gardens Caravan Park to the plan to also prepare a Flood Hazard Management Plan. Annex F of the DISPLAN should also make reference to the Figtree Gardens Caravan Park
- Section 3.20 of the DISPLAN refers to Stranded Travellers being referred to temporary accommodation in hotels and motels. The list of appropriate temporary accommodation prepared should exclude those sites listed in Table 10.3 that are flood prone.
- Numbers of properties inundated are detailed in this report (Section 4.4) and as such Annex B of the DISPLAN can be updated with this information. Details for higher risk areas (such as Nursing Homes and the like) can also be updated in Annex B with information contained in Table 10.3.
- Revision of the F6 Freeway being flood-free is required in the Transport Disruption section in Annex B. Other transport disruption details from Table 10.2 could be translated to Annex B.
- Warnings recommendations such as those included in Handmer (2000) be included in the revision of flood warning alerts.

10.3 Flood Forecasting and Warning Systems

The Bureau of Meteorology issues two types of flood warning, 'flood watches' and 'flood warnings'. The current forecasting and warning mechanisms for the Wollongong area are based on predictions of severe rainfall, primarily from rainfall radar systems.

Systems to detect rainfall amounts for intense rainfall events (referred to as an ALERT system) are currently in place in both Wollongong and the wider Illawarra area. This system draws upon the Bureau of Meteorology's rainfall gauge network and includes those gauges located as part of the network of Automatic Weather Stations (AWS) that report on a regular basis. Data from this network is available on real time at the Bureau of Meteorology Flood Forecasting Page for the 'Central NSW Coast' at www.bom.gov.au/hydro/flood/nsw/greatersyd.shtml. Details available include 24 hour rainfall totals and rainfall from the last hour in graphical format. Details of depths of rainfall recorded at specific gauges are also available.

The value of the system in enhancing the issue of flood warnings and timely actions by residents themselves or combat agencies remains an issue due to the very short times to flood peak from the onset of rainfall in some parts of the catchment.

Advice from the Bureau of Meteorology (Gordon McKay, *pers comm*) indicates that the weather-based warnings (Severe Thunderstorm Warnings, Severe Weather Advices, Gale Warnings etc) are 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 disseminate the information to the local media. Specific flood warnings for flash flood catchments such as Allans Creek are not issued by the Bureau.

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
- Large industrial operations (such as Bluescope Steel)
- Rail operations
- RTA
- Registered Clubs in the area (e.g. Western Suburbs Leagues Club, Bowling Clubs etc)
- Figtree Gardens Caravan Park
- Other areas as appropriate.

Given the significant spatial variation in the catchment and the existing coverage of the Bureau of Meteorology rainfall gauge network, it is recommended that additional gauges be installed within the Allans Creek catchment. These are shown in Figure 9.1. Further and related discussion of this issue can be found in Section 9.8. The instrumentation could be used for emergency response purposes. The connection of the additional instruments into the Bureau of Meteorology's system is outlined as an option in Section 10.8.

10.4 Combat Agencies in the Floodplain

It is important to note that there are combat agency buildings affected by flooding up to the PMF. Combat agency buildings in the area that are not affected by flooding are listed in Table 10.1.

Table 10.1 Combat Agency Sites in and Around the Allans Creek Floodplain

Not Flood Affected (up to PMF)
Unanderra Fire Station
Mt Kembla RFS
Unanderra Police

SES Divisional Headquarters for the Illawarra/South Coast region are located in Auburn Street, Wollongong. However, the Local Unit Headquarters are located to the north of the Allans Creek catchment in the Cabbage Tree Creek Floodplain and have been known to flood in some circumstances. It is understood that the SES are currently reviewing alternate locations for this unit.

10.5 Road and Rail Transport Issues

Generally the Princes Highway is the first major hydraulic control for waters from the upper catchment on all branches. Specifically, when the capacity of the Princes Highway culverts is exceeded (via blockage or excess flow) floodwaters in Byarong Creek can be diverted via Arrow Avenue and onto the Princes Highway towards Figtree Westfield and ultimately towards Lysaght Oval. Similarly, the culverts under The Avenue, once blocked divert water towards Figtree Westfield and Lysaght Oval. The combination of these two flood waves worsens flooding in the lower Figtree area. Blockage of the culverts under the F6 Freeway also exacerbates flooding in this region.

Blockage of the Princes Highway bridges on American, Charcoal and Allans Creeks has a measurable effect upstream, with the resulting backwater exacerbating peak flood levels. For example, the backwater drowns out the Tallegalla Street footbridge on Charcoal Creek.

Blockage of both the Byarong Creek and American Creek culverts under the F6 Freeway leads to the worst possible flooding combination for the region between the Princes Highway and the F6 Freeway. Flood flows are detained behind the Freeway, and are forced to flow downstream by overtopping the Freeway via the low point on the Freeway, near Lysaght Oval. The American Creek and Byarong Creek catchments form a large portion of Allans Creek catchment and with the F6 Freeway culverts blocked, a significant flow is forced over the Freeway leading to the likely closing of the Freeway during rare and extreme events.

Blockage of the culverts under the Illawarra Rail Line has an impact on flood levels in Byarong Creek, Charcoal Creek, Allans Creek and Cummins Creek and once blocked results in floodwaters overtopping the railway line. In the north of the catchment the combined flow of American Creek and Byarong Creek overtop the railway line, even though the railway bridge in its current configuration is likely to only be blocked 25% under the design blockage criteria for spans greater than 6 m. This is due to the large flow passing the bridge. In the south the railway is situated in both a cutting and at the natural surface level and as such is exposed to overtopping by the creeks. Experience indicates that it is likely that the majority of culverts in the catchment will be blocked up to 100% and as such will be overtopped.

A list of the overtopping durations and depths for the Princes Highway, Illawarra Rail line and the F6 Freeway is provided in Table 10.2.

Table 10.2 Major Transport Link Flooding*

	Duration Overtopped at PMF (hrs)	Depth of flood over road/rail at PMF (m)	Duration Overtopped at 100 year ARI (hrs)	Depth of flood over road/rail at 100 year ARI (m)
Princes Highway				
Allans Creek	2	0.65	*	*
American Creek	9.5	3.17	8	1.69
Byarong Creek	5.5	1.19	4	0.88
Charcoal Creek	9	1.61	8	1.02
Jenkins Creek	7	1.13	4	0.89
Unanderra Drain	8	1.04	8	0.41
Illawarra Railway				
Jenkins Creek	7.5	1.20	4.5	0.97
Charcoal Creek	7.5	3.04	4.5	1.76
Allans Creek	3	0.81	*	*
Unanderra Drain	7	2.27	4.5	0.55
American Creek	2	0.38	-	-
F6 Freeway				
American/Byarong Creeks	8.5	3.43	8	2.17
Allans Creek/ Unanderra Drain	5.5	1.20	*	*
Freeway Trib Branch	5	0.67	3	0.36

* These roads are not overtopped immediately above the creek, however they are overtopped in the immediate area as shown in the flood extent mapping (Figures 7.15 and 7.20).
Note: The times provided are for the peak overtopping duration which may not coincide with the storm duration that yielded the peak overtopping depth.
* These roads are not overtopped immediately above the creek, however they are overtopped in the immediate area.
Note: The times provided are for the peak overtopping duration which may not coincide with the storm duration that yielded the peak overtopping depth.

In the upper reaches of the catchment the effect of culvert blockage is generally local and storage is small, i.e., if a culvert is blocked, the increase in water levels are localised. There is no significant impact on water level downstream of a blocked culvert, and the steep slopes and low decks of bridges prevent the drowning out of structures upstream of a blocked culvert.

10.6 Evacuation Centres

Where evacuation is required, evacuees are directed to centres for temporary refuge and accommodation. These centres are identified in the Wollongong City DISPLAN. However, a number of locations that would generally be utilised as flood evacuation centres have been identified to lie within the Allans Creek floodplain. Locations such as Primary and High Schools, Clubs, Churches, Retirement Villages have been identified throughout the floodplain.

Those areas both affected by flooding (up to the PMF) and not affected by flooding are listed in Table 10.3.

Table 10.3 Flood Assessment of Potential Evacuation Centres in the Vicinity of the Allans Creek Catchment

Flood Affected (up to PMF)	Not Flood Affected (up to PMF)
Primary Schools	
Farmborough Road Primary School	Cringila Primary School
St Pius X Primary School	Figtree Heights Public School
Figtree Primary School	Nareena Hills Primary School
Lindsay Park Primary School	Unanderra Primary School
	West Wollongong Primary School
	St Therese Catholic Primary School
	Coniston Primary School
	Mt St Thomas Primary School
	Mt Kembla Primary School
	Mt Keira Primary School
High Schools	
Figtree High School	Illawarra Grammar School
	Edmund Rice College
Churches	
Immaculate Conception Church	Cringila Mosque
All Saints Church (Anglican)	Fokuangshan Nan Tien Temple
Figtree Church of Christ	Unanderra Presbyterian Church
Figtree Christian Science Church	Unanderra Orthodox Church
	Soldiers and Miners Memorial Church
	Figtree Uniting Church
	Mt St Thomas Church
	St Therese Church
	Wollongong Church of Jesus Christ
Clubs (Sporting and Other)	
Kembla Heights Bowling Club	Kembla Heights Bowling Club
Western Suburbs Leagues Club	Cringila Sportsground
Wollongong RSL Club	
BHP Sports Stadium	
The John Lysaght Recreation Centre	
Hellenic Club	
Slovenian-Australian Club	
Hotels/Motels/Caravan Parks	
Figtree Sovereign Motel	Cringila Village Inn
Figtree Hotel	
Unanderra Hotel	
Figtree Gardens Caravan Park	
Hospitals/Nursing Homes/Retirement Villages	
Figtree Nursing Home	Coniston Nursing Home
The Illawarra Hospital	Nareena Homes Retirement Village
Farmborough Heights Retirement Village	
Major Shopping Centres	
Figtree Westfield Shopping Centre	

10.7 Public Awareness And Education

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.

Flood awareness is an ongoing issue and requires continuous effort of related organisations (e.g. Council and SES). The major factor determining the degree of awareness within the community is the frequency of moderate to large floods in recent history of the area. The more recent and frequent the flooding, the greater the awareness.

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

It is recommended that the following awareness campaigns be considered for the Allans Creek floodplain (some identified from Section 10.1):

- Updating of the FloodSafe brochures for localities (e.g. one for Byarong Creek, one for American Creek and one for the Charcoal Creek area).
- Issue of other SES information brochures with a fridge magnet may be a more effective means of ensuring people retain information
- Annual Remembrance Day (possibly the 17th August)
- Continued use of media (e.g. The Illawarra Mercury, The Advertiser and Win TV)
- Development of a Schools Package
- Information dissemination to be undertaken via information in Council rates notices for all affected properties on a regular basis.

10.8 Summary of Costs

Overall, a summary of the likely costs of the proposed emergency response modification options is provided in Table 10.4.

Table 10.4 Summary of Emergency Response Modification Options

Option	Likely Implementation Capital/Recurrent Cost
EM 1 Periodic Revision Of Displan/Flood Sub Plan	$5,000 (SES/Council, C, I)
EM 2 Preliminary Assessments for the establishment of a Trial SMS Service	$30,000 (SES/Council, C)
EM 3 Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system)	$30,000 (BoM, I) $10,000 (R)
EM 4 Relocation Of Combat Agency Headquarters (Police)	$500,000 (C, NSW Police)
EM 5 Electronic Information Transfer Agreement For Council Held Information To SES	$1,000 (C, I)
EM 6 Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES	$2,000 (C, I)
EM 7 Public Awareness and Education - Locality Based Floodsafe Brochure	$10,000 (C, SES/Council), $1,000 (R)
EM 8 Public Awareness And Education - Fridge Magnets	$5,000 (C, SES/Council)
EM 9 Public Awareness And Education - Annual Remembrance Day (17th August)	$5,000 (Council/SES, R)
EM 10 Public Awareness And Education - Schools Package	$5,000 (C, Council/SES)

*where C Capital Cost
I Internal Council or identified organisation cost
R Recurrent Cost.

11. COMPARATIVE ASSESSMENT OF OPTIONS

11.1 Overview

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

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criteria as shown in Table 11.1.

11.2 Scoring System

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

The criteria adopted include:

• Technical	Likely Overall Hydraulic Improvement
• Economic	Capital and Operating Costs
	Reduction in Risk to Property
• Social	Reduction in Social Disruption
	Reduction in Risk to Life
• Environmental	Meeting of River Flow and Water Quality Objectives
	Fauna/Flora
• Community	Community Support
• Authority	Council/Agency/SES Support
• Policy/Legislation	Compatible with Policies and Plans.

The scoring system is shown in Table 11.1 for the above criteria apart from the community support, which is described in Table 11.2.

Table 11.1 Details of Scoring System Adopted

CRITERIA	SCORE				
	-2	-1	0	1	2
Likely Overall Hydraulic Improvement	Negative impact (> 0.2 m increase in peak flood level at any location)	Negative impact (> 0.1 m increase in average peak flood level at any location)	Negligible Improvement or only local improvement	Flood Level Decrease (0.1 - 0.5 m decrease in peak average flood level across the floodplain)	Flood Level Decrease (>0.5 m decrease in peak average flood level across the floodplain)
Capital and Operating Costs	Extreme (eg >$2 million)	High $500,000 - $2 million	Medium $200,000 - $500,000	Low $50,000 - $200,000	Low $10,000 - $50,000
Reduction in Risk to Property*/**	Major increase in AAD	Slight increase in AAD	No Improvement	Slight decrease in AAD	Major decrease in AAD
Reduction in Risk to Life	Major increase in risk to life	Slight increase in risk to life	No change in risk to life	Slight reduction of risk to life	Major reduction of risk to life
Reduction in Social Disruption	Major increase in social disruption	Slight increase in social disruption	No change to social disruption	Slight reduction of social disruption	Major reduction of social disruption
Compatible with Water Quality and River Flow Objectives	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible
Fauna/Flora Impact	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
Council/State Agency Attitude	Strong disagreement	Disagreement	Neutral/No response	Support	Strong support
Compatible with Policies and Plans	Completely incompatible	Slightly incompatible	Neutral	Compatible	Completely Compatible

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

** Combined assessment of some options undertaken for AAD (e.g. Option 2, Option 4, Option 5, Option 8 and Option 11 considered multiple options

Table 11.2 Details of Weighted Community Scoring System Adopted

CRITERIA	SCORE								
	-4	-3	-2	-1	0	1	2	3	4
Community Attitude	S >-5 Strong Disagreement	-	-1> S >-5 Disagreement	-	0 Neutral/ No response	1<S<18 Support	19<S<36 Support	37<S<55 Strong support	56<S<75 Strong support

Likely Overall Hydraulic Improvement

In general the likely overall hydraulic improvement was restricted to a reduction in peak flood level of around 0.5 m or less. Issues related to the reduction of flood hazard and related social disruption and risk to life are considered as separate criteria. Where an option was not modelled, engineering judgement as to the likely overall improvement was applied by experienced floodplain hydraulic specialists.

Economic Assessment Overview

The economic assessment involved an appreciation of both:

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

Capital and operating costs for major structural options were assessed as described in Section 8, whilst a judgement of the likely capital and recurrent costs was made by experienced engineers.

Social Impact Assessment

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

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

In general, recent flood events within the area have led to a general awareness of flooding in the area. The nature of the population in the area is such that the population is fairly stable with some growth expected. However, regardless of the awareness in the area, the social disruption of flooding (via the effects of property inundation, loss of access and traffic disruption) remain. Similarly, whilst there is an understanding of the potential for flooding, the reduction in the risk to life is an important criteria. However, this criteria is highly subjective as it is difficult to assess the behaviour of persons under extreme conditions such as flooding.

Environmental Assessment

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

- Compatibility of the Option with Water Quality and River Flow Objectives
- Fauna/Flora Impact.

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

The management goal reported by the ICMC (1994) is to ensure the long term management of urban watercourse corridors maintains and enhances:

- the safe conveyance of runoff
- channel stability
- biological diversity
- good water quality, and
- an aesthetic and recreative urban landscape.

For example, the environmental impacts of an option such as an online detention basin on Brandy and Water Creek will involve a reduction of the limited riparian zone that currently exists in the area. The construction of such a structure will involve the disturbance of the area during construction and will also result in a major discontinuity in the creek system in an already disturbed wildlife corridor. The construction of a detention basin in this area is not consistent with the findings of the Commission of Inquiry for *The Long Term Planning and Management of the Illawarra Escarpment, Wollongong Local Government Area* (Office of the Commissioners of Inquiry or Environment and Planning, 1999).

Other options may not have a direct impact, but it will be important to ensure that appropriate scour protection in the form of ecologically and geomorphologically compatible bed and bank stabilisation is provided downstream of any structure or works proposed.

The environmental impacts of works such as creek modification are likely to be all positive since the system is currently degraded in terms of flora and fauna due to erosion resulting in bank slumping, sedimentation, weed growth and associated loss of habitat. The modification process will result in bank stabilisation and associated reduction of erosion and sedimentation, weed removal and replacement with local indigenous vegetation and associated habitat. This modification will seek to result in improved habitat corridor linkages as well as provide a small buffer zone for water quality purposes to improve the quality of runoff reaching the creek in dry weather/low flow conditions.

Community

The community support for an option scores were derived by converting the community responses received in the February 2002 consultation period discussed in Section 3 to a numerical score. Initially, each response counted on a range of -2 to +2 based on the support. Thus, total scores were a function of the number of responses received (up to 75 for some options). The higher the number of responses indicated a strong community support and in one case (Koloona Avenue), a petition of resident signatures in support of the option was submitted. These scores were then normalised to a range of -4 to +4 to give a higher weighting to the community attitude (i.e. 18% of the total score, whereas each other criteria was worth 9% of the total score).

Authority

The attitude of different organisations such as Council, State Agencies and the SES to different options were subjectively assessed based on discussions with representatives over the course of the study.

Policy/Legislation

A single Policy/Legislation criteria was applied such that the option should be compatible with current Policies and Plans. This was based on an assessment of related policies and plans outlined in Section 2.

11.3 Multi-Criteria Matrix Assessment

The assignment of each option with a score for each criteria is shown in its entirety in Appendix G. The total score for each option was calculated by equally weighting each consideration and summing the total.

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

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

11.4 Summary of Outcomes

Table 11.3 summarises the overall findings of the ranking of all of the options by score alone with a listing of those options ranked 1 - 15.

Table 11.3 Ranked Options List for Highest 15 Options by Score Alone

Rank	ID	Category of Measure	Creek	Locality	Type of Measure	Score
1	FM21	*Flood Modification*	Byarong	Entire system	Corridor Management and Maintenance	13
2	FM41	*Flood Modification*	American	Entire system	Corridor Management and Maintenance	12
3	FM3	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Creek modification works	12
4	FM2	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Debris Control Structure(s)	11
5	FM56	*Flood Modification*	Allans	Upstream of Princes Highway Bridge	Debris Control Structure	11
6	FM57	*Flood Modification*	Freeway/ Industrial Area	Unanderra Industrial area – Upstream of Berkeley Road (two crossings)	Debris Control Structure(s)	11
7	FM58	*Flood Modification*	Byarong	Upstream of The Avenue	Debris Control Structure(s)	11
9	FM4	*Flood Modification*	Byarong	Park on left bank Upstream of Koloona Avenue, Mt Keira	Detention Basin	11
10	FM46	*Flood Modification*	Charcoal	Between d/s of Lindsay Maynes Park and Upstream of Railway, Unanderra	Creek modification works	10
11	FM48	*Flood Modification*	Charcoal	Between Tallegalla Street and Princes Highway, Unanderra	Creek modification works and flood detention area	10
12	FM55	*Flood Modification*	American	Culverts under F6 Freeway	Bridge Construction	10
13	FM1	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Pipe outlet realignment	9
14	FM24	*Flood Modification*	American	Along length in Upper Reaches	Creek modification works	9
15	FM16	*Flood Modification*	Byarong	Arrow Avenue/Bellevue Road	Stormwater Drainage and Overland flow path modifications	9

Table 11.3 indicates that the highest priority type of works for implementation based on score alone favours flood modification works such as:

- maintenance of the existing system
- modification/rehabilitation of the creek systems
- debris control, and
- culvert/bridge modifications.

Table 11.4 summarises the overall findings of the ranking of all of the options by cost benefit index (net present value/total score) with a listing of those options ranked 1 - 15. The lower the index, the greater the overall benefit.

Table 11.4 Ranked Options List for Highest 15 Options by Benefit:Cost Index

Rank	ID	Category of Measure	Creek	Locality	Type of Measure	Index
1	EM5	*Emergency Response Modification*	Entire Floodplain	NA	Electronic Information Transfer Agreement For Council Held Information To SES	200
2	EM6	*Emergency Response Modification*	Entire Floodplain	NA	Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES	400
4	EM1	*Emergency Response Modification*	Entire Floodplain	NA	Periodic Revision Of Displan/Flood Sub Plan	833
5	PM9	*Property Modification*	Entire Floodplain	NA	Caravan Park/Manufactured Home Estate Policy	1000
6	PM7	*Property Modification*	Entire Floodplain	NA	Revision of Section 149(5) Certificate Wording	1000
7	PM2	*Property Modification*	Entire Floodplain	NA	Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure	1000
8	PM8	*Property Modification*	Entire Floodplain	NA	Adapt Towradgi Creek Flood Certificate for Allans Creek	1000
9	EM8	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Fridge Magnets	1000
10	FM1	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Pipe outlet realignment	1111
11	PM13	*Property Modification*	Entire Floodplain	NA	Public Awareness and Education for Property matters (Creek Maintenance in Private Property)	1667
12	FM26	*Flood Modification*	American	Govett Crescent, Figtree	Tide flaps on stormwater outlets.	2380
13	PM14	*Property Modification*	Entire Floodplain	Identified Areas	Collection of addition property survey	2500
14	EM7	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Locality Based Floodsafe Brochure	5760
15	EM10	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Schools Package	6000

Table 11.4 indicates the highest priority type of works for implementation based on capital cost: benefit index (capital cost/score ratio) gives a more balanced series of measures including:

- Electronic Information Transfer Agreement
- Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES
- Updating of DCP54 with Development Control Matrix for Allans Creek
- Periodic Revision Of Displan/Flood Sub Plan
- Caravan Park/Manufactured Home Estate Policy
- Revision of Section 149(5) Certificate Wording/Adapting Towradgi Creek Flood Certificate for Allans Creek

- Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure
- Public Awareness and Education Packages.

As outlined above, the complete ranked list can be found in Appendix G.

Overall, some of the less hydraulically efficient measures, such as tide flaps on stormwater outlets at Govett Crescent, ranked higher via the benefit:cost index approach due to their low cost. However, a critical review of any of the options that ranked highly through this process will need to be undertaken before the final list of options is identified through the process of the preparation of the Floodplain Risk Management Plan.

12. RECOMMENDATIONS AND CONCLUSIONS

The approach utilised within the multi-criteria matrix analysis (Section 11) does not specifically address the consideration of the overall effect of the combination of options. For example, those options considered in combination, such as the flood modification options outlined in Section 8.2 (identified as Options 1 – 11) have not been assessed for the combined benefit of the individual options.

Therefore interpretation of the results of the cost:benefit analysis alone (for Options 1 – 11) and the multi-criteria matrix has been undertaken to draw out a list of proposed options for inclusion in the floodplain risk management plan.

The flood modification options assessed using modelling that have the greatest cost:benefit ratio (greater than 0.5) and benefit a large number of properties are:

- Construction of a bridge to replace the culverts at the American Creek Crossing of the F6 Freeway, C:B of 0.96, 74 properties with over-floor flooding eliminated at the 100 year ARI (Option 1, details in Section 8.2.1, Identifier FM55)
- Construction of a range of bridges and works in the lower floodplain near the F6 Freeway, C:B of 0.69, 121 properties with over-floor flooding eliminated at the 100 year ARI (Option 11, details in Section 8.2.11, Identifiers FM18, FM20, FM37, FM38, FM 55, FM59).

It is important to note that the bridge at the American Creek crossing of the F6 Freeway (Option 1, FM55) forms part of the works associated with the works in the lower floodplain (Option 11). Thus, it is recommended that the American Creek bridge is constructed first, followed by the other works associated with Option 11. The lower floodplain works have significant social benefits, resulting in the reduction of over-floor flooding for over 120 properties.

In addition to these works, a range of properties are eligible for house raising. A total of 47 properties were specifically identified for house raising, with the benefit:cost ratio being the most substantial of any option considered, at 5.19.

The results of multi-criteria matrix assessment indicates that there is substantial benefit to be gained by implementing a range of cost-effective measures. The matrix approach indicates that there are essentially two approaches that can occur concurrently:

- those that require major capital investment with associated major or minor recurrent expenditure (generally major capital works)
- those that require minor capital investment with associated major or minor recurrent expenditure (generally minor works or planning).

Both approaches are required to manage the floodplain in a holistic sense. As a consequence, a mixture of the two approaches are recommended. The two types of activities can run concurrently through the life of the implementation of the Floodplain Risk Management Plan.

Recommended options to be included in the plan are derived from Section 8.2, Tables 11.3, 11.4 and Appendix G. Due to the very large nature of the Allans Creek floodplain, these options have been selected to ensure a good spatial coverage of works and measures to provide benefit to the most severely affected areas of the floodplain.

Major Works	Minor/Planning Works
• Modification of the American Creek culverts under the F6 Freeway • Riparian corridor management for the entire creek system • Debris control structures for a range of locations • Improvements at the Princes Highway Bridge crossing of Byarong Creek and Associated Upstream Creek Works • Creek works on Byarong Creek between the Princes Highway and The Avenue • Amplification of The Avenue culverts (Byarong Creek) • Creek modification works and flood detention area between Lindsay Maynes Park and Upstream of Railway, Unanderra • Creek works for American Creek between Gibsons Road and Princes Highway • Creek works on Charcoal Creek between Blackman Pde and Tallegalla Street • Lowering of the west bank of Brandy and Water Creek to reduce overfloor flooding in the properties along Darrah Drive. • Removal of F6 median strip • Bund on western side of Govett Crescent • Stormwater Drainage and Overland flow path modifications – Arrow Avenue/Bellevue Road • Program of house raising and voluntary purchase (depending on construction type and level of risk) for the limited number of properties not benefited by proposed works.	• Electronic Information Transfer Agreements between Council and the SES • Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES • Updating of DCP54 with Development Control Matrix for Allans Creek • Periodic Revision Of Displan/Flood Sub Plan • Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure • Revision of Section 149(5) Certificate Wording • Provision of a Flood Refuge within the Figtree Gardens Caravan Park • Caravan Park/Manufactured Home Estate Policy • Development and Issue of Fridge Magnets for Public Awareness And Education • Realignment of the pipe outlet upstream of Koloona Avenue • Public Awareness and Education for Property matters (Creek Maintenance in Private Property) • Detailed Investigation of Possible Zoning Modifications • Cumulative Impact Study and Review of On-Site Detention Policy • Development of a Schools Package for Public Awareness And Education • Development of a Locality Based Floodsafe Brochure • Further investigations into a scheme for the Upper Byarong Creek locality.

A detailed review of the findings of the multi-criteria matrix assessment is recommended to be undertaken as part of the Floodplain Risk Management Plan. The plan should identify for each option:

- a priority
- a likely timeframe for implementation
- details of the likely capital and operational costs
- details of the responsible authorities to implement the option
- details of the means of measuring the performance of that option
- details of what additional investigations may be required.

For example, for a particular option it may include a recommendation like:

- further investigations be made of the flood bypass and riparian buffer option which is likely to be of significant benefit in both the reduction of flood levels but also the improvement in habitat and water quality in the creek. The viability of the option is dependent on the sustainability of the floodway. Detailed design of the floodway will need to incorporate controlled intake and outlet of water such that the accretion of sediment can be managed. This option will require ongoing monitoring and maintenance through the preparation and implementation of a creek management plan. This plan should include aspects such as a schedule of regular inspections and means of identifying and rectifying issues. Detailed design should make reference to appropriate guidelines and manuals such as *A Rehabilitation Manual for Australian Streams* (CRC for Catchment Hydrology, 1999) and the *Natural Channel Design Guidelines* (Brisbane City Council, 2000). This option should be considered in conjunction with the creation of a bund/embankment at the upstream end of Govett Crescent to prevent ingress of flow to the street at the upstream end from mainstream flooding

- further investigations be made of the creek modification option which is also likely to be of significant benefit and will also assist with the stabilisation of the banks of the existing creek resulting in a reduction in the sediment source to the area. This should also be considered in conjunction with ongoing maintenance of the creek system and the preparation of a creek management plan. The aspects of the plan should be similar to those outlined above.

- Additional investigations are also recommended for inclusion in the Floodplain Risk Management Plan for those lots within the high risk precinct that are currently in private ownership but have not yet been developed in accordance with the land use zoning under the LEP (1990). It is recommended that this land could also be voluntarily acquired by Council. A detailed assessment of the number of parcels of land that are potentially within this category would need to be the subject of further investigation.

A key finding of the assessment of all of the options is that there is no complete set of options that can be economically implemented to remove the risk of flooding entirely from the floodplain. A large range of options were evaluated and many are identified as being suitable for implementation, yet the need for ongoing management of the residual or continuing risks in the floodplain will require management. This management, through appropriate emergency preparation and response, will aid in reducing future flood damages in the catchment.

13. REFERENCES

Bewsher Consulting (2002) *Towradgi Creek Floodplain Risk Management Study*, Prepared for Wollongong City Council.

Blong, R. (2000) Internal flood damage to residential buildings, *Proceedings, 40th Annual Conference*, NSW Floodplain Management Authorities, Parramatta.

Brisbane City Council (2000) *Natural Channel Design Guidelines.*

Bureau of Meteorology (1994): *The Estimation of Probable Maximum Precipitation in Australia; Generalised Short Duration Method*, Australian Government Publishing Service, Canberra.

CRC for Catchment Hydrology (1999) *A Rehabilitation Manual for Australian Streams.*

Danish Hydraulic Institute (2003) *MIKE-11 2003 User Guide and Technical Reference*, Agern Alle 5, Horsholm Denmark.

DIPNR (2004) *Riparian Corridor Management Study - Covering All Of The, Wollongong Local Government Area And Calderwood Valley In The Shellharbour Local Government Area*, Prepared for Wollongong City Council, March.

DLWC (1997) *Wollongong 1:25,000 Acid Sulfate Soils Risk Map*.

Evans, J. and Bewick, B. (1999), The Wollongong Flash Flood Event - 17 August 1998*, Proceedings IEAust Water Panel Workshop*.

Forbes Rigby (1999), *Compendium of Data - Storm Event of 17th August 1998 in the Northern Suburbs of Wollongong for Wollongong City Council.*

Forbes Rigby (2000) *Stormwater Management Plan Wollongong Coastal Catchment*, Prepared for Wollongong City Council, March.

Forbes Rigby (2000) *A Review of Flooding on the Flood Plan of American Creek above the Princes Highway at Figtree*, Prepared for Edenvell Pty Ltd, July.

Forbes Rigby (2001) *Addendum to Report on Flooding on the Flood Plan of American Creek above the Princes Highway at Figtree*, Prepared for Edenvell Pty Ltd, April.

Forbes Rigby (2002) *Erosion and Sedimentation Study and Riparian Lands Assessment of Allans Creek Catchment*, Report prepared for Port Kembla Harbour Environment Group, December.

Franks, S. W. and Kuczera, G. (2002) Flood frequency analysis and multi-decadal climate variability, *Proceedings*, 24th Hydrology and Water Resources Symposium, IEAust, Melbourne, 19-24 May, 2002.

Frost, S. and Rice, M. (2003) Voluntary House Raising Program: The Fairfield Experience, *Proceedings*, 43rd Annual Conference of the Floodplain Management Authorities of NSW, Forbes, February.

Handmer, J. (2000) Are Flood Warnings Futile? Risk Communication in emergencies, *The Australasian Journal of Disaster and Trauma Studies*, Volume 2000-2, http://ww.massey.ac.nz/~trauma/.

Hazelton, P. A., Bannerman, S. M. and Tillie, P. J. (1990) *Wollongong - Port Hacking 1:100,000 Soil Landscape Series Sheet 9029-9129*, Soil Conservation Service.

Henshaw, S. (1999) Managing in the Aftermath of the Storm, *GIS User*, August - September, No 35, pp43-44.

Hunt, I. and Kofod, P. (2000) Wollongong Floods, *Proceedings*, 40th Annual Floodplain Management Conference, Parramatta, 9th - 12th May, pp259-265.

Illawarra Catchment Management Committee (1994) *Management of Urban Watercourse Corridors*, Wollongong.

Ingal Civil Products (2002) *SUPERCOR Box Culvert Product Details*.

Lawson and Treloar (2006) *Allans Creek Flood Study*, Prepared for Wollongong City Council, Rep1986v4, September.

Little, S & Babister, M (1999) The Influence of the Illawarra Escarpment on Long Duration Design Rainfalls and the Implications for Floodplain Management, *Proceedings IEAust Water Panel Workshop*.

Mary Dallas Consulting Archaeologists (1995) *Wollongong City Aboriginal Heritage Planning Study*, Prepared for Wollongong City Council.

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

Office of the Commissioners of Inquiry or Environment and Planning (1999) *The Long Term Planning and Management of the Illawarra Escarpment, Wollongong Local Government Area*.

Pfister, N. (1998) Emergency Response to the Wollongong Floods, August 1998 – An SES Perspective, *Proceedings*, The Institution of Engineers, Australia Sydney Division Water Panel Workshop (http://www.ses.nsw.gov.au/papers/opper_1999.pdf).

PWD (1991) *Allans Creek Flood Study*, Prepared by Kinhill Engineers for the Public Works Department, Coast and Rivers Branch.

Reinfelds, I. and Nanson, G. C. (2001) 'Torrents of Terror': the August 1998 Storm and the Magnitude, Frequency and Impact of Major Floods in the Illawarra Region of New South Wales, *Australian Geographical Studies*, 39(3):335-352, November.

Rigby, E. and Silveri, P. (2001), The Impact of Blockages on Flood Behaviour in the Wollongong Storm of August 1998*, Proceedings of the 6th Conference on Hydraulics in Civil Engineering,* Hobart.

SCARM (2000) *Floodplain Management in Australia - Best Management Principles and Guidelines*, SCARM Report No 73, CSIRO Publishing, Victoria.

Southern Catchment Management Board (2003) *Southern Catchment Blueprint - An Integrated Catchment Management Plan for the Southern Catchment 2002*, NSW Department of Land and Water Conservation.

State Emergency Service (2004) *Wollongong City Local Flood Plan - A Sub-Plan Of The Wollongong Local Disaster Plan, (Displan)*, March.

The Institution of Engineers, Australia (Revised Edition 1999) *Australian Rainfall and Runoff - A Guide to Flood Estimation*.

Wollongong City Council (1994) *Allans Creek Unanderra Industrial Area Flood Study*, Report PW94082, October.

Wollongong City Council (2002) *Requirements for On Site Detention Storage*, Adopted - 1988, Amended 2002.

Wollongong City Council (2002) *Conduit Blockage Policy.*

Wollongong City Council (2005) *Requirements for On Site Detention Storage* - Draft.

Wollongong City Council (2004) *Development Control Plan No 54 - Managing Our Flood Risks*, December.

Wollongong City Council (*1994*) *Urban Drainage Design Manual.*

Wollongong City Council (*in preparation*) *Drainage Design Code* - Draft.

Water Studies (1992) *FLDAMAGE User Manual*, March.

WP Software (1992). *RAFTS-XP - Runoff Analysis & Flow Training Simulation with XP Graphical Interface - User Manual*, Belconnen ACT.

14. ACKNOWLEDGEMENTS

This study has been undertaken and report prepared with the assistance of:

- Allans Creek Floodplain Risk Management Committee
- Wollongong City Council - Design Division
- Department of Natural Resources
- Roads and Traffic Authority
- State Emergency Service
- Various resident groups and the community of the Allans Creek area
- Industrial proprietors who assisted with the development of flood damage curves
- Port Kembla Port Corporation.

This study was funded under the State Government's Floodplain Management Program through the Department of Natural Resources on a 2:1 (State:Council) ratio.

15. QUALIFICATIONS

This report has been prepared by Lawson and Treloar (now Cardno Lawson Treloar) for Wollongong City Council and as such should not be used by a third party without proper reference.

The report relies on the accuracy of the following information:

- Utility service locations provided by others
- Ground survey and Land Information provided by Council and the Department of Commerce (formerly Department of Public Works and Services).

Cost estimates provided for options in this report are preliminary only and more detailed cost estimates should be prepared during the detailed design phase.

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

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

The results of the study are based on the following assumptions/conditions:

- Design flood extents and risk precincts are approximate between cross sections of the model. Where surveyed levels are not available, flood extents are based on the 2m LIC contour data provided by Council and the interpolation of model results.
- The local pit and pipe stormwater drainage system is not modelled.

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

APPENDIX A

COMMUNITY CONSULTATION MATERIALS

APPENDIX B

SUMMARY OF COMMUNITY RESPONSES

APPENDIX C

DETAILS OF ALL OPTIONS

APPENDIX D

ADOPTED FLOOD DAMAGE CURVES

APPENDIX E

PRELIMINARY LEVEE DETAILS

APPENDIX F

OPTION CAPITAL COSTS

APPENDIX G

OPTIONS ASSESSMENT MATRIX

APPENDIX H

PROPERTIES FOR VOLUNTARY PURCHASE (COMMERCIAL IN CONFIDENCE)

APPENDIX I

PROPERTIES FOR VOLUNTARY HOUSE RAISING (COMMERCIAL IN CONFIDENCE)

Report Prepared For
Wollongong City Council

Allans Creek Floodplain Risk Management Study

Report J1946/R1946
September, 2006

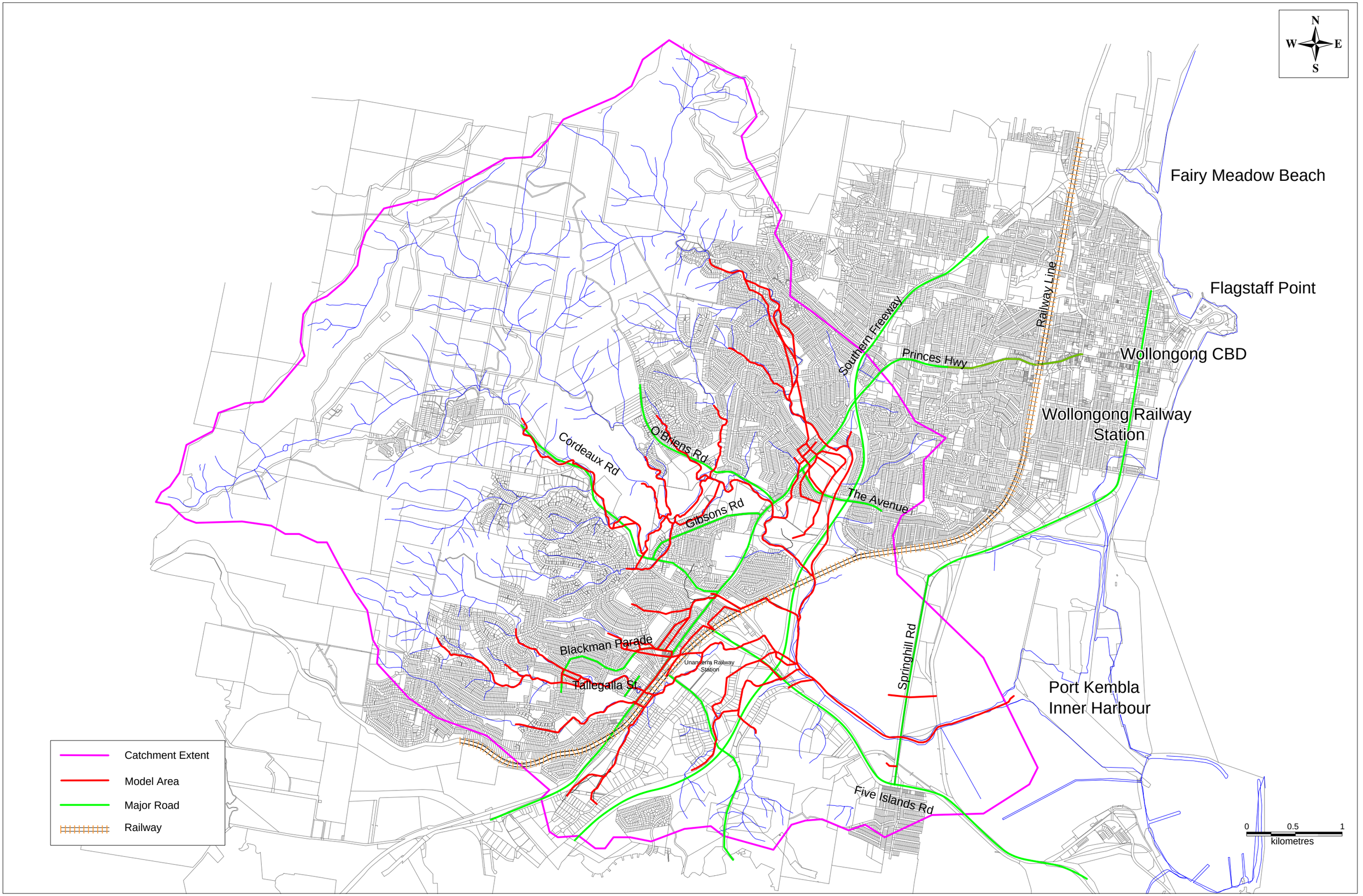

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FIGURE 1.1
Catchment Study Area
J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 1.1 Catchment.Wor

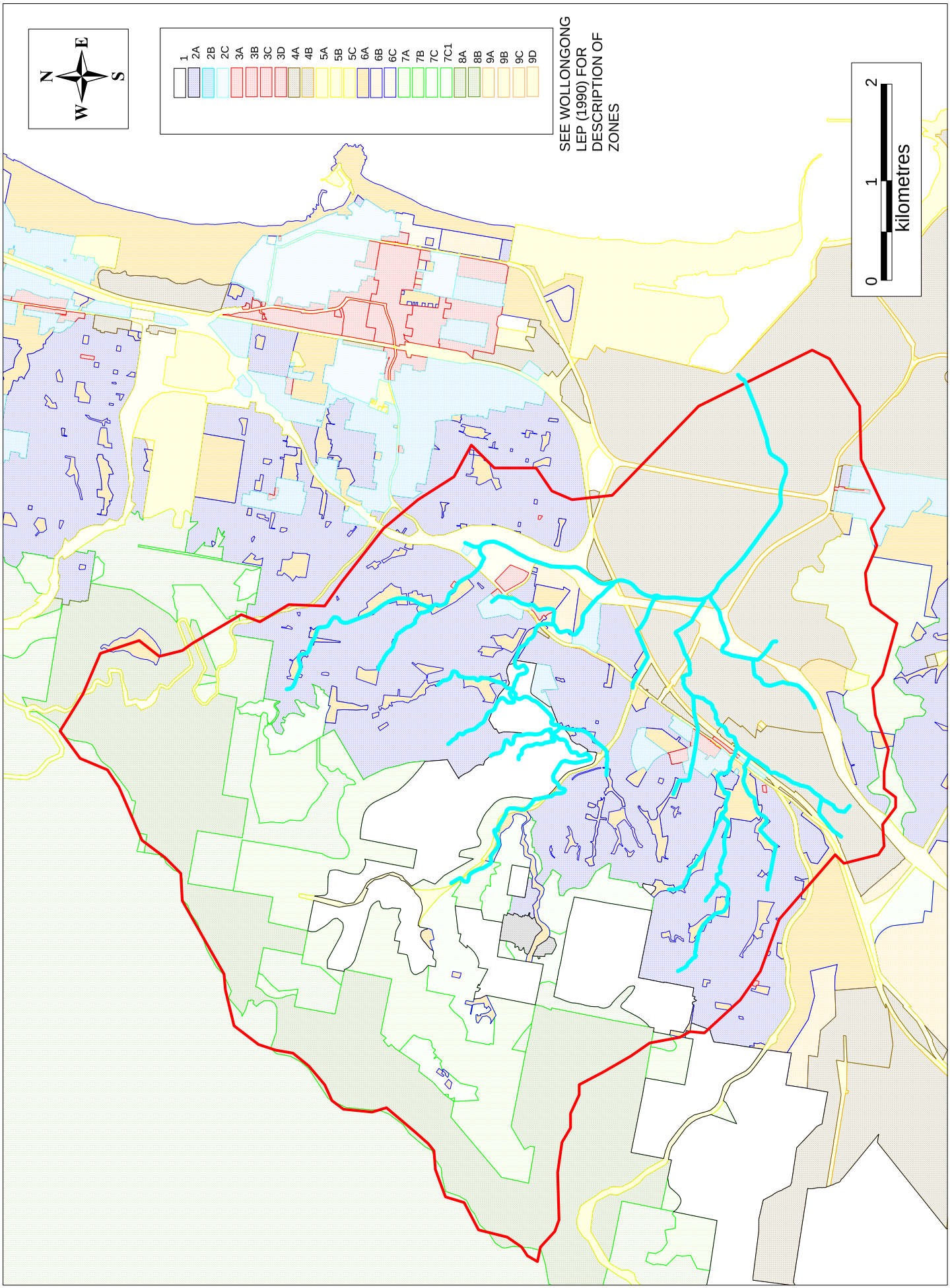

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FIGURE 2.1
CATCHMENT LAND USE

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 2.1 Land Use.wor

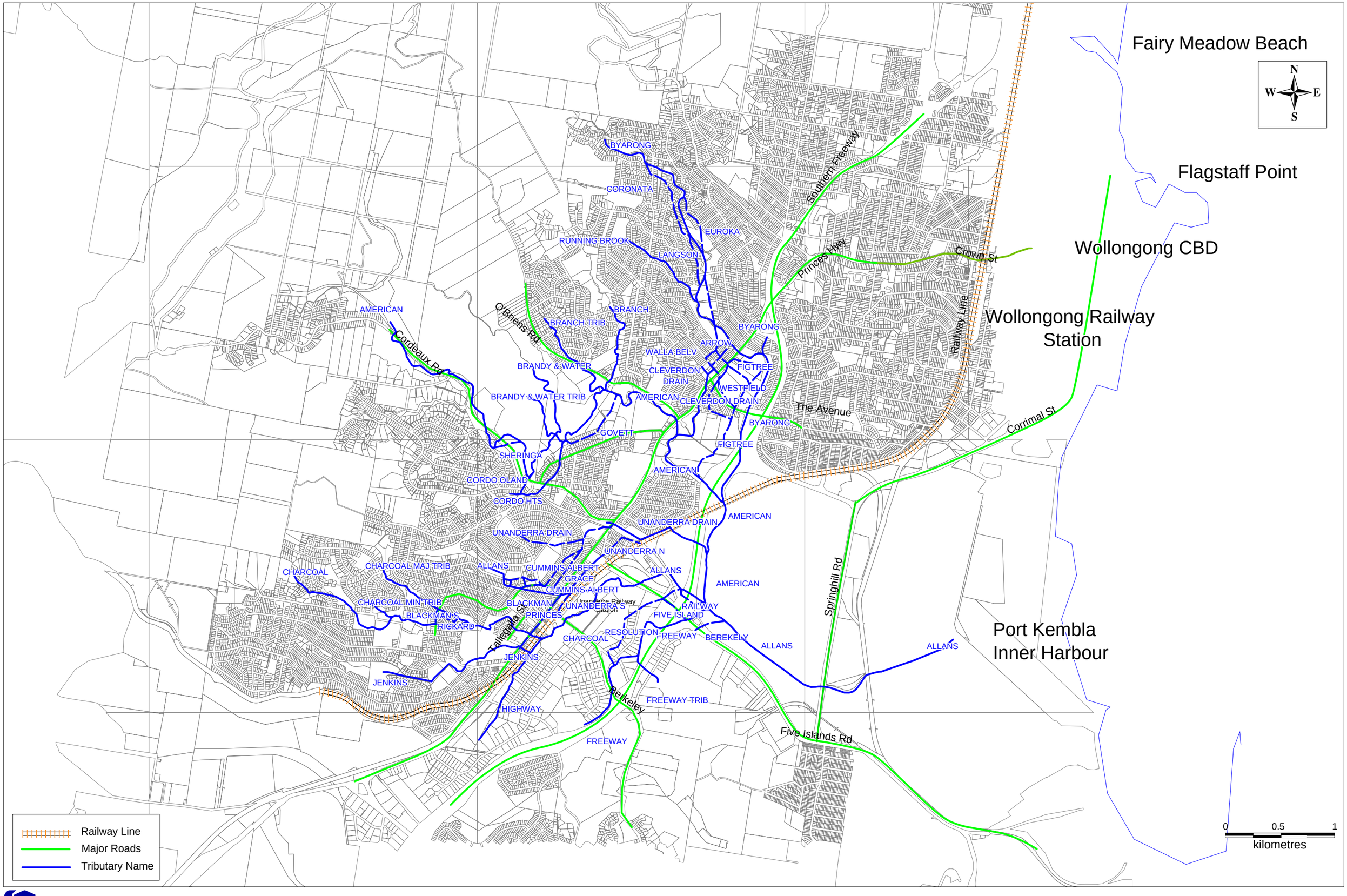

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FIGURE 2.2
Tributary Systems

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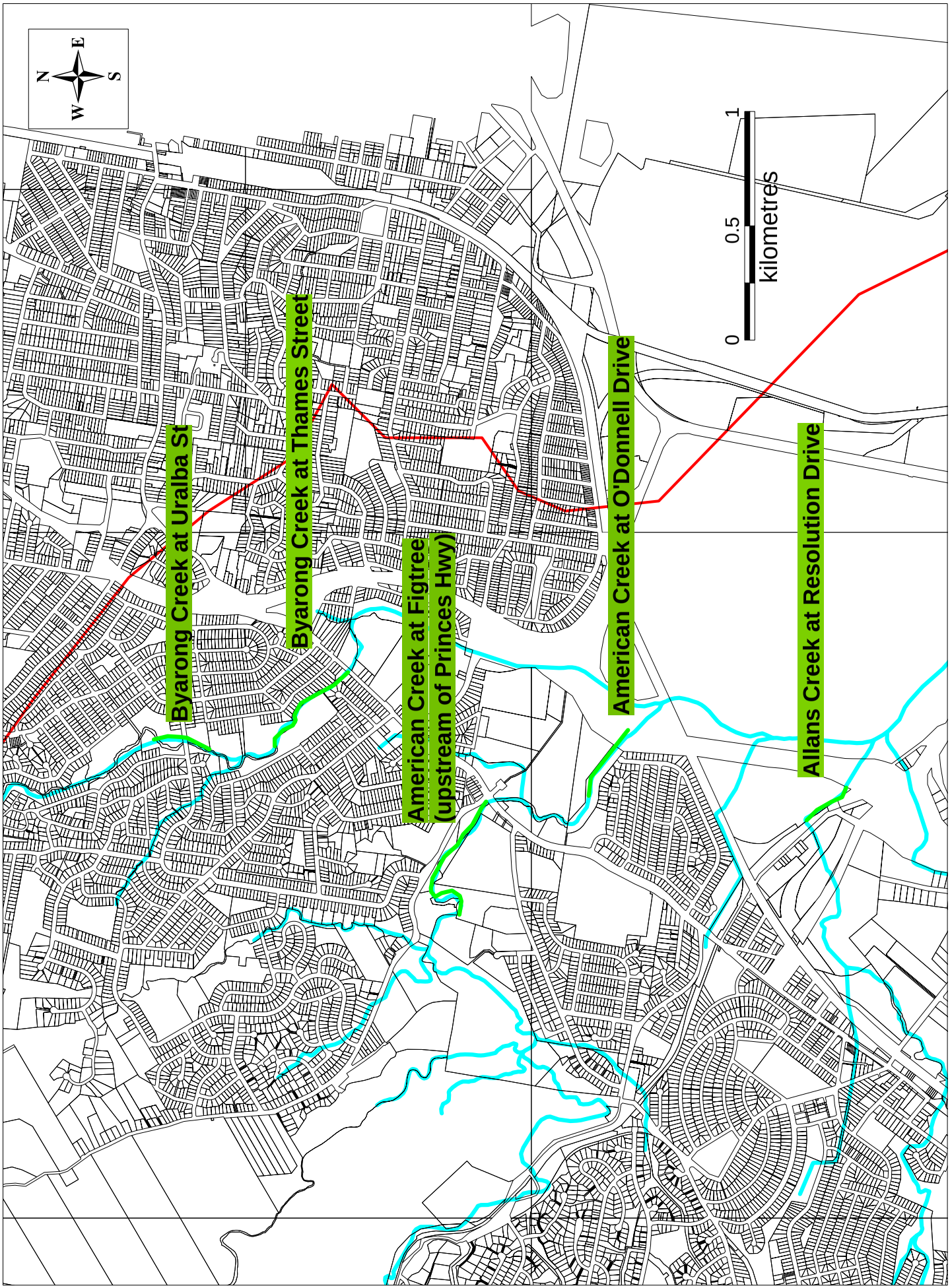

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FIGURE 2.3
FLORA AND FAUNA SURVEY SITES

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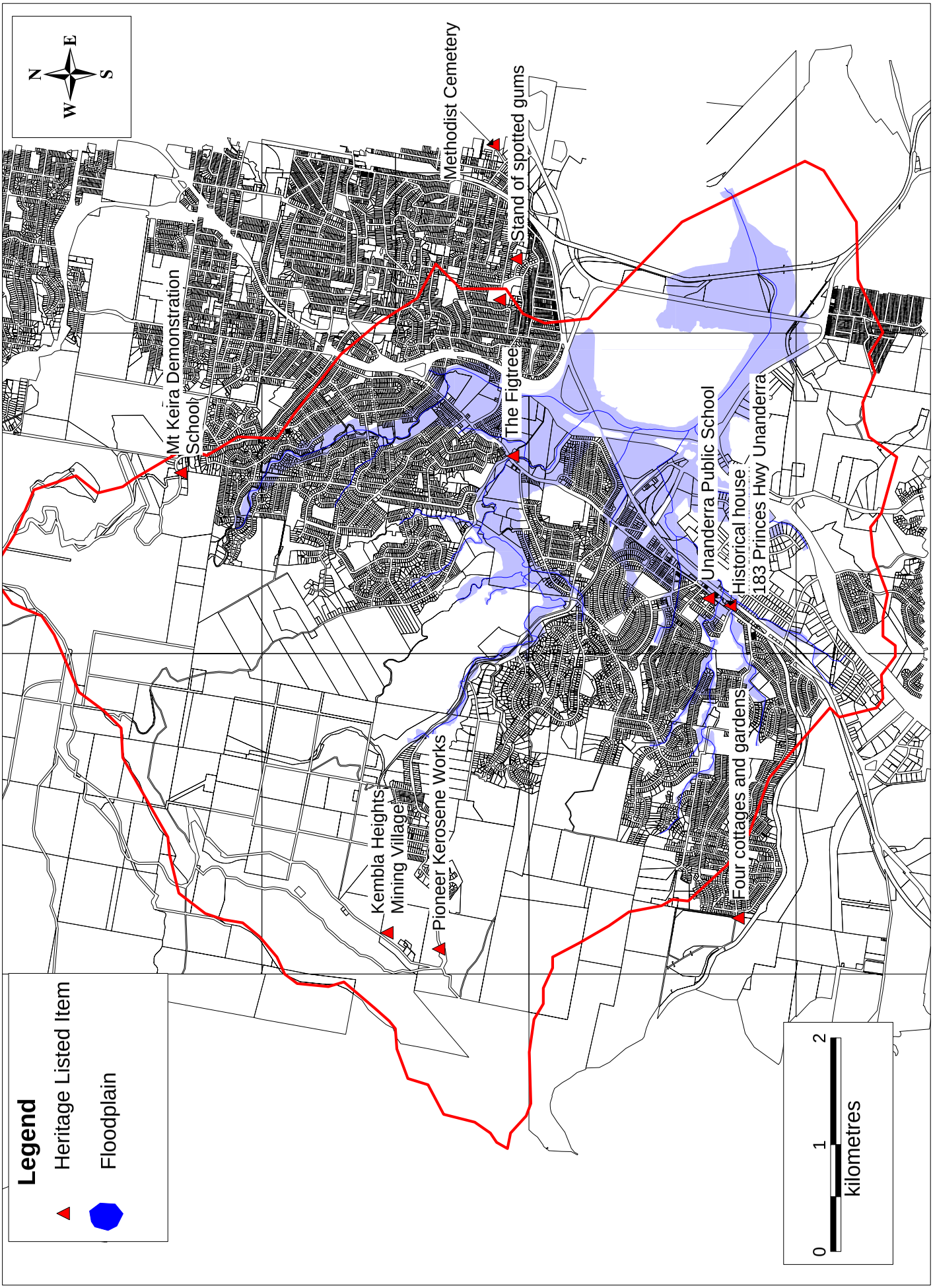

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FIGURE 2.4
EUROPEAN HERITAGE ITEMS WITHIN & ADJACENT TO THE FLOODPLAIN

J1946\Figures 2006\Floodplain Management Study V6\Figure 2.4 Euro Heritage.wor

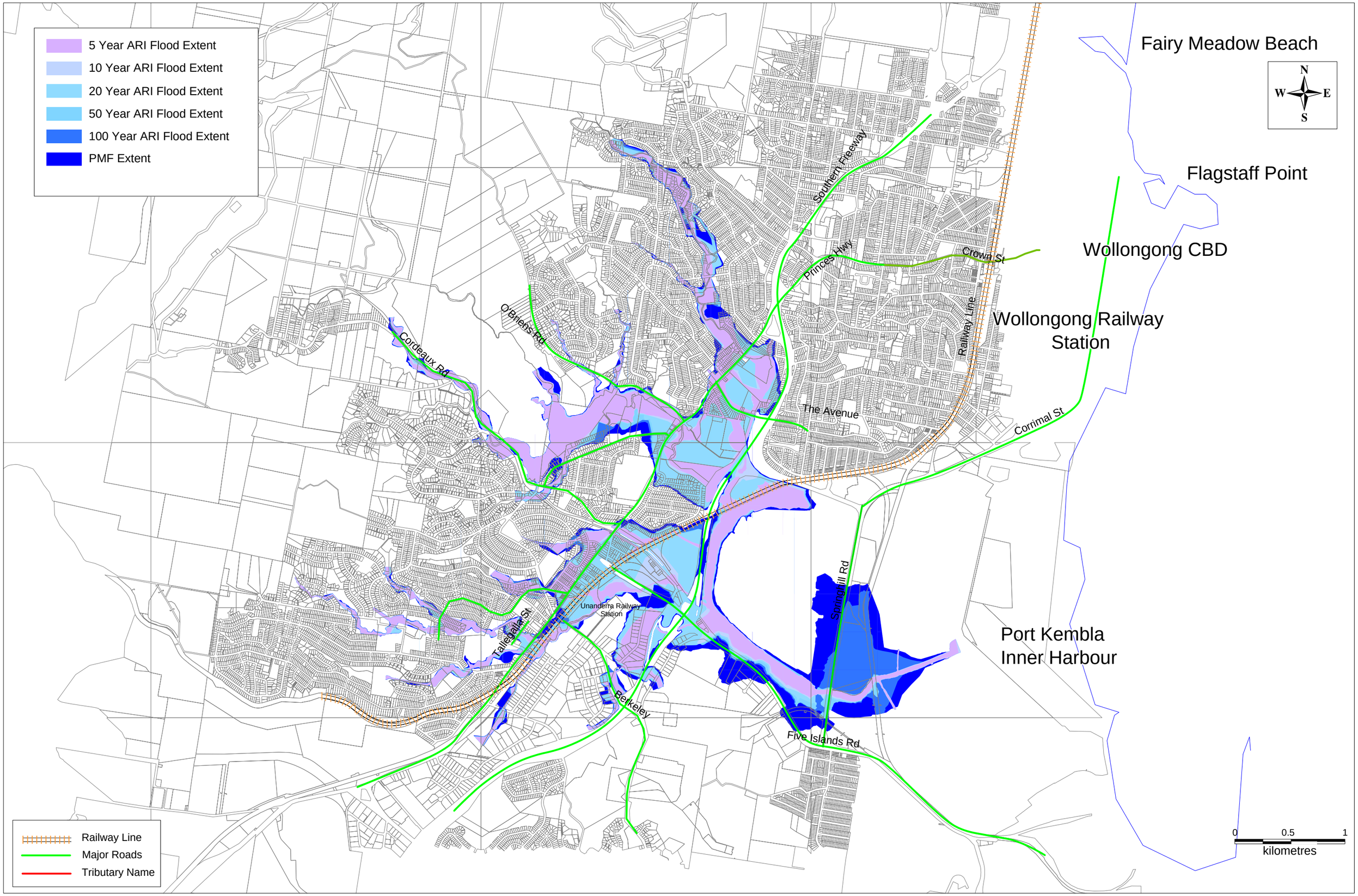

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FIGURE 4.1
FLOOD EXTENT MAPS

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 4.1 Extents.Wor

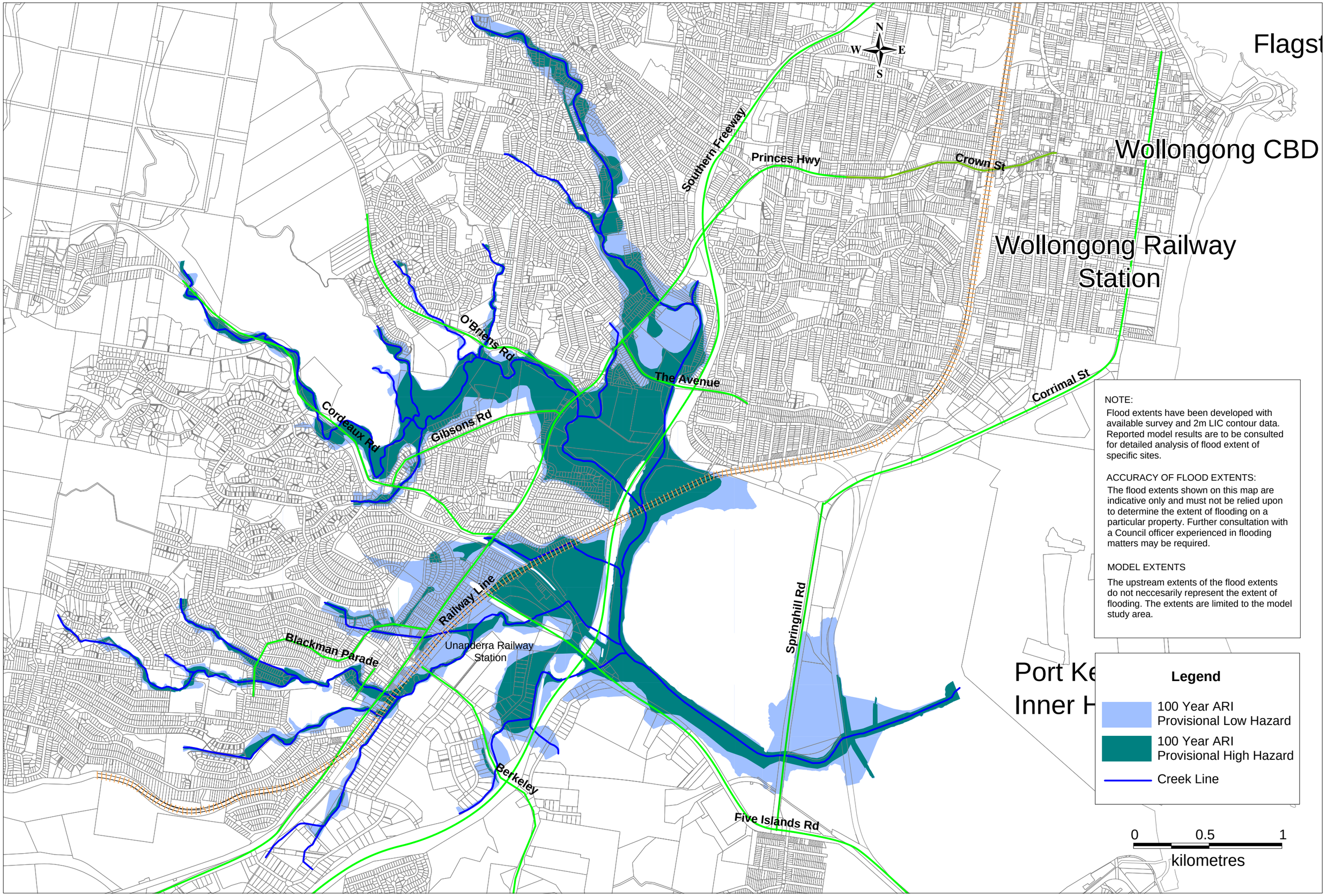

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FIGURE 4.2
100 YEAR ARI PROVISIONAL FLOOD HAZARD

J1946/Figures 2006/Floodplain Risk Management Study Figures V6\Figure 4.2 100yr Provisional Hazard.Wor

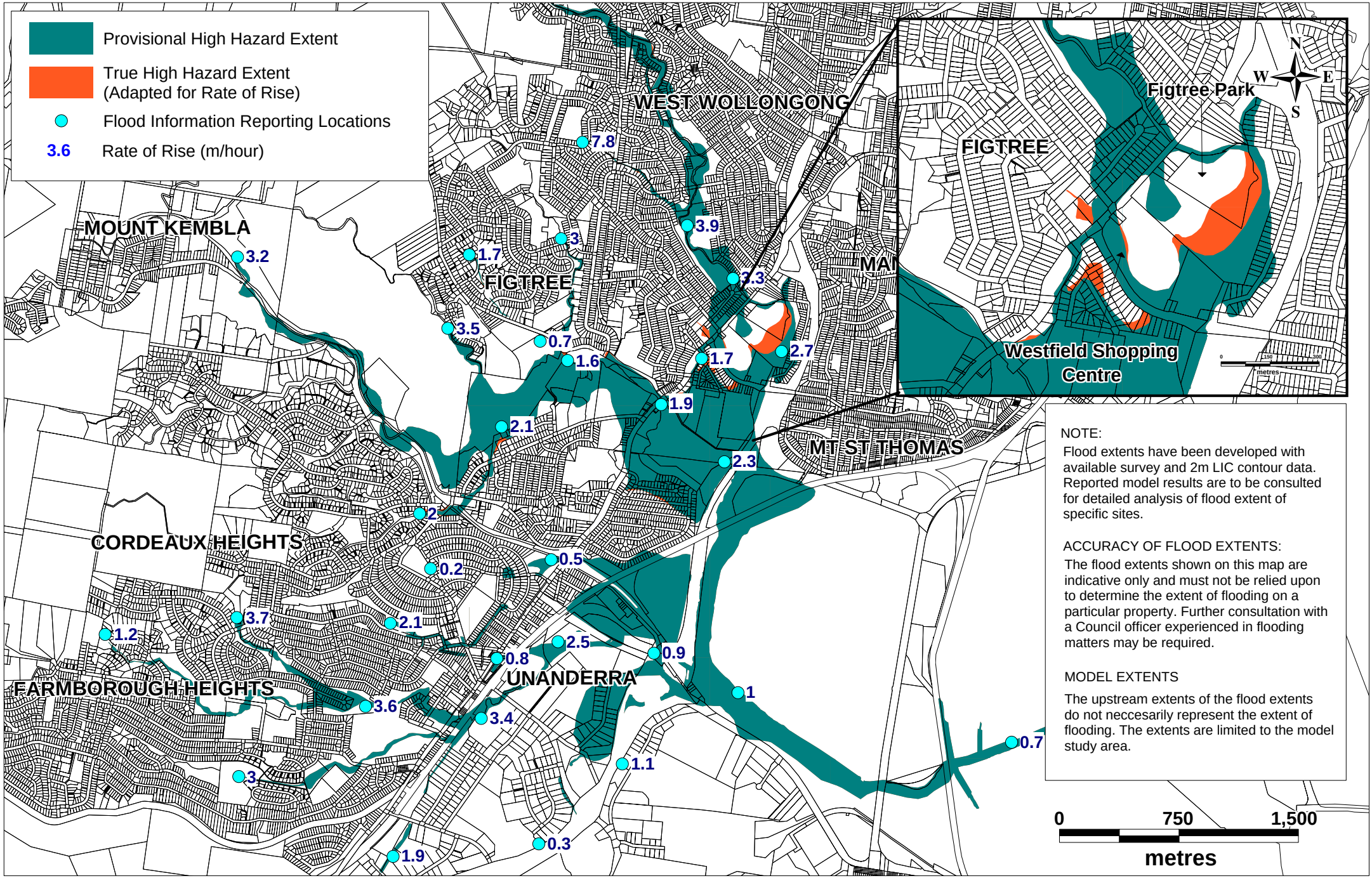

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FIGURE 4.3
RATE OF RISE ADDITIONAL HIGH HAZARD AREAS

J1946/Figures 2006/Floodplain Risk Management Study Figures V6\Figure 4.3 Rate of Rise.Wor

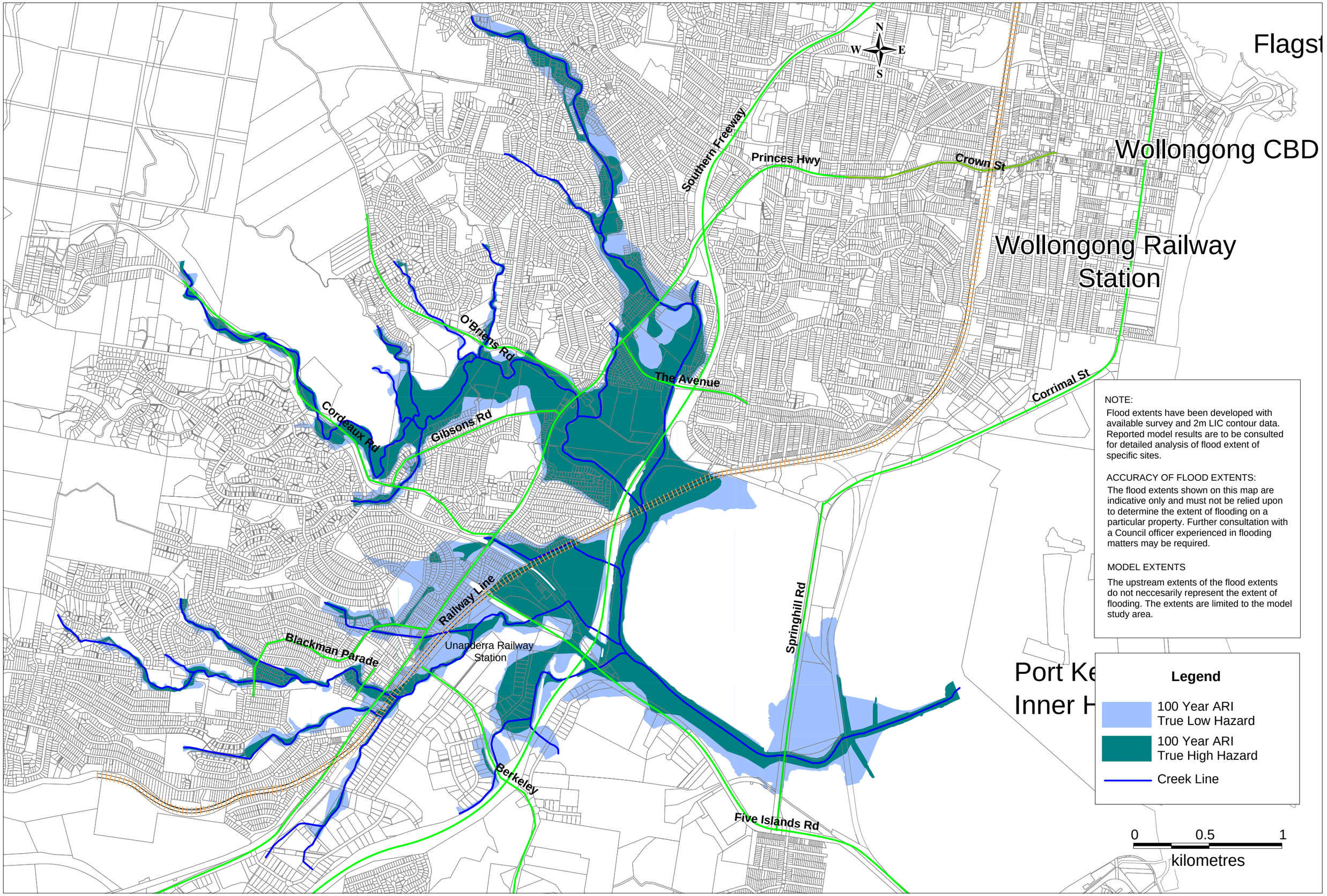

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FIGURE 4.4
100 YEAR ARI TRUE FLOOD HAZARD

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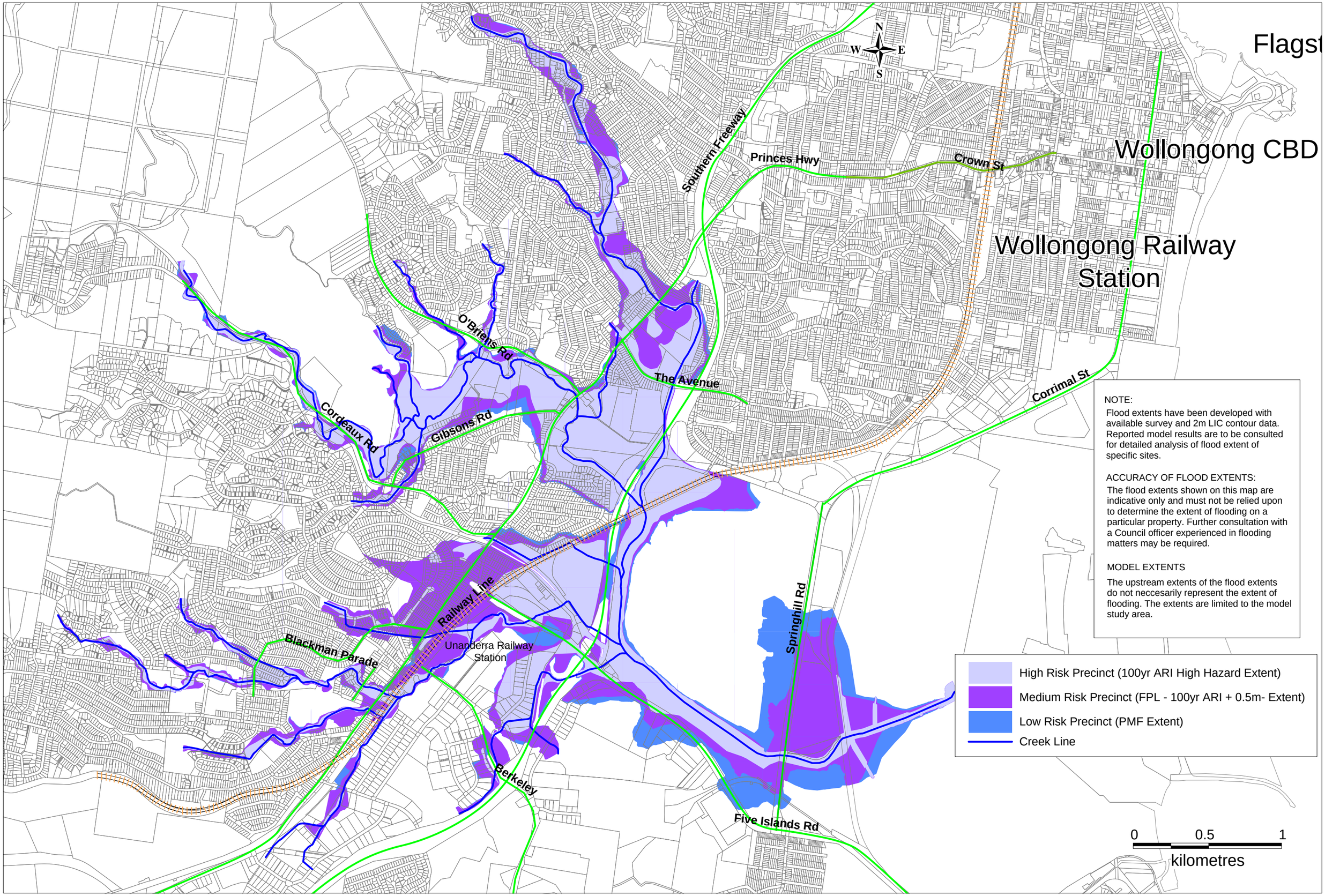
N
W
E
S
Flagst
Wollongong CBD
Wollongong Railway Station
Southern Freeway
Princes Hwy
Crown St
Corrimal St
The Avenue
O'Briens Rd
Cordeaux Rd
Gibsons Rd
Railway Line
Blackman Parade
Unanderra Railway Station
Berkeley
Springhill Rd
Five Islands Rd
NOTE:
Flood extents have been developed with available survey and 2m LIC contour data. Reported model results are to be consulted for detailed analysis of flood extent of specific sites.
ACCURACY OF FLOOD EXTENTS:
The flood extents shown on this map are indicative only and must not be relied upon to determine the extent of flooding on a particular property. Further consultation with a Council officer experienced in flooding matters may be required.
MODEL EXTENTS
The upstream extents of the flood extents do not neccesarily represent the extent of flooding. The extents are limited to the model study area.
High Risk Precinct (100yr ARI High Hazard Extent)
Medium Risk Precinct (FPL - 100yr ARI + 0.5m- Extent)
Low Risk Precinct (PMF Extent)
Creek Line
0
0.5
1
kilometres

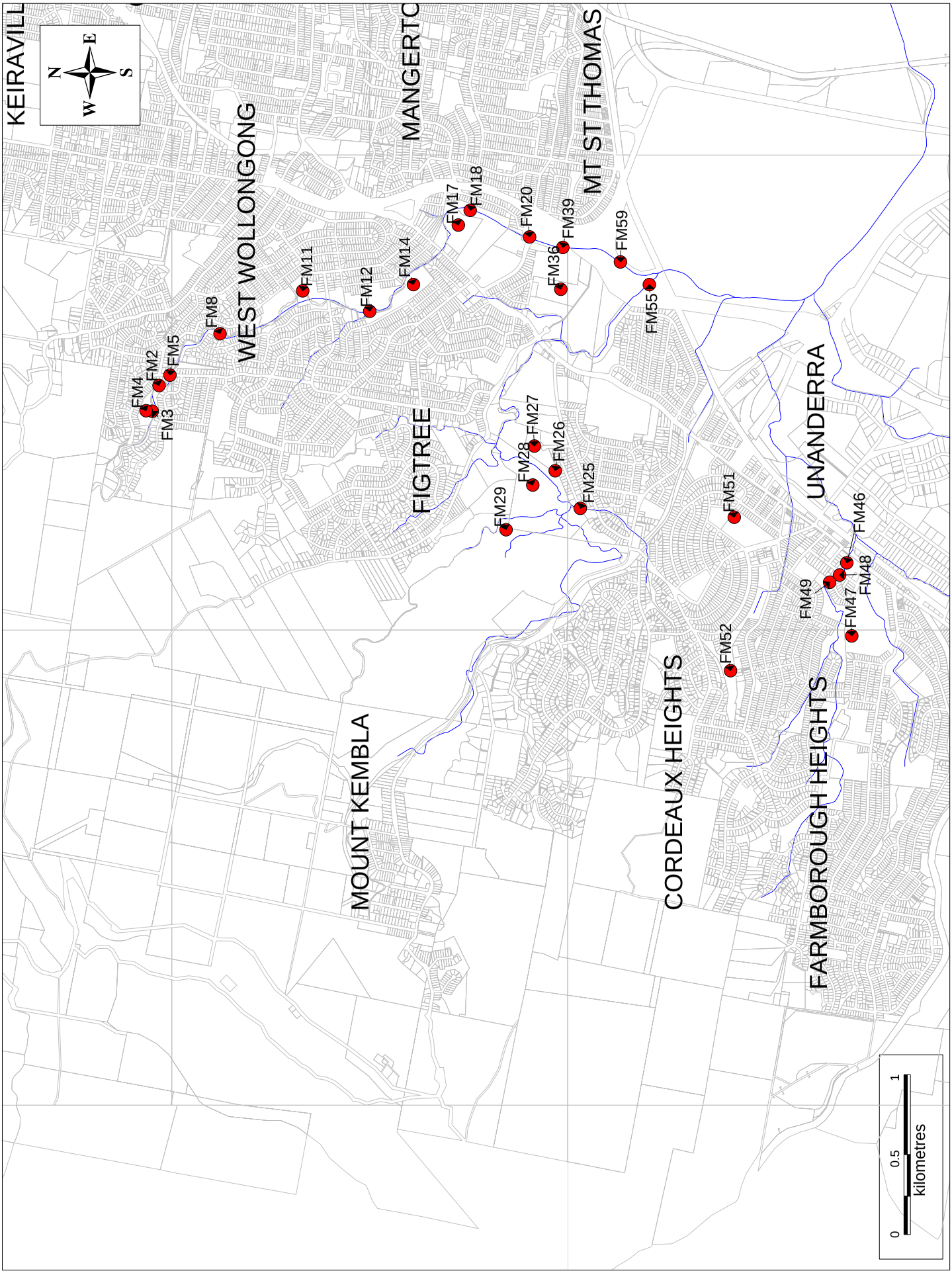

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FIGURE 7.1
LOCATION OF FLOOD MODIFICATION OPTIONS ASSESSED USING MODELLING

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 7.1 Options Loc.wor

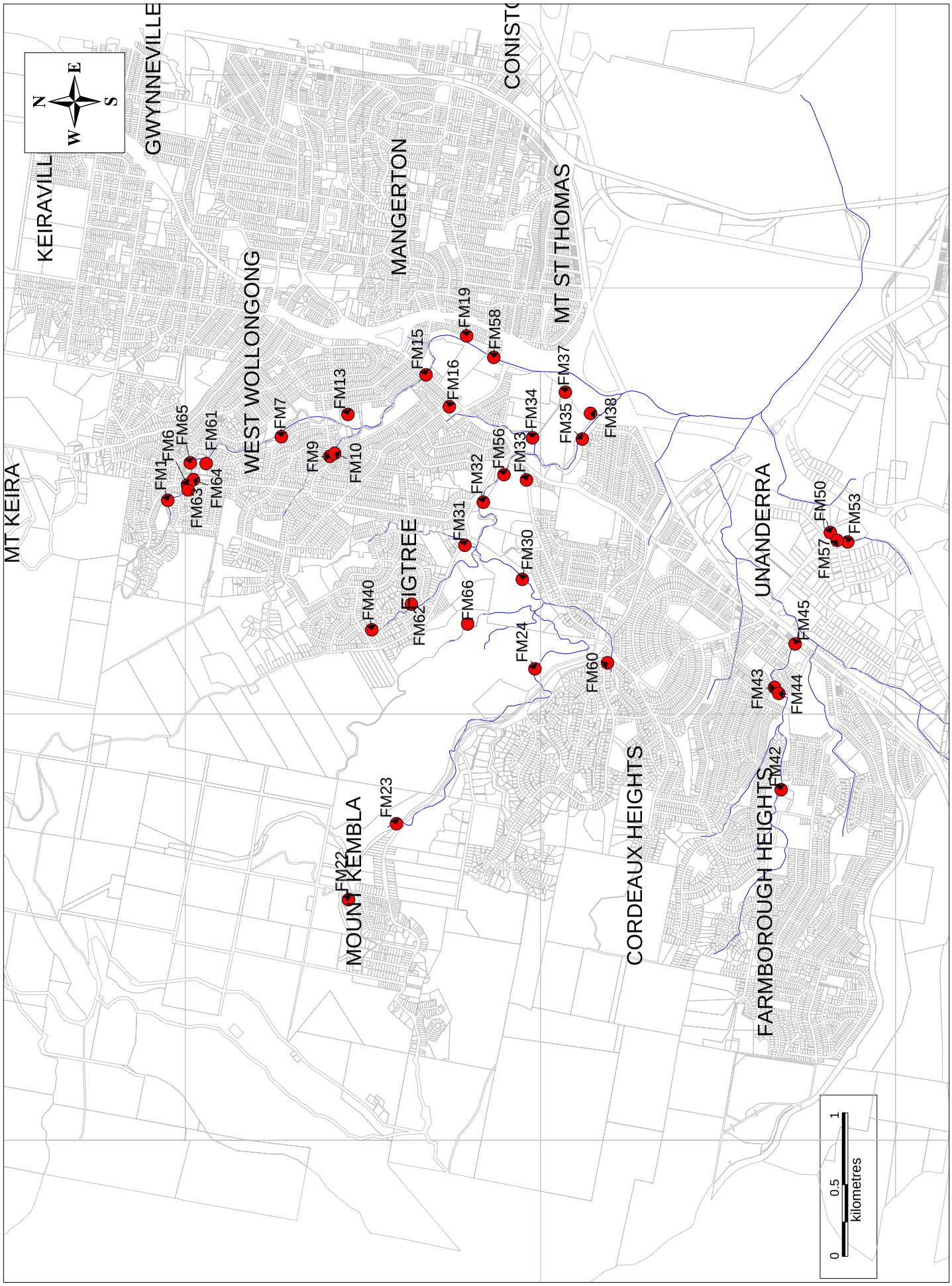

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FIGURE 7.2
LOCATION OF FLOOD MODIFICATION OPTIONS ASSESSED QUALITATIVELY

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 7.2 Options Loc.wor

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FIGURE 8.1
DETAILS OF FLOOD MODIFICATION OPTION 1

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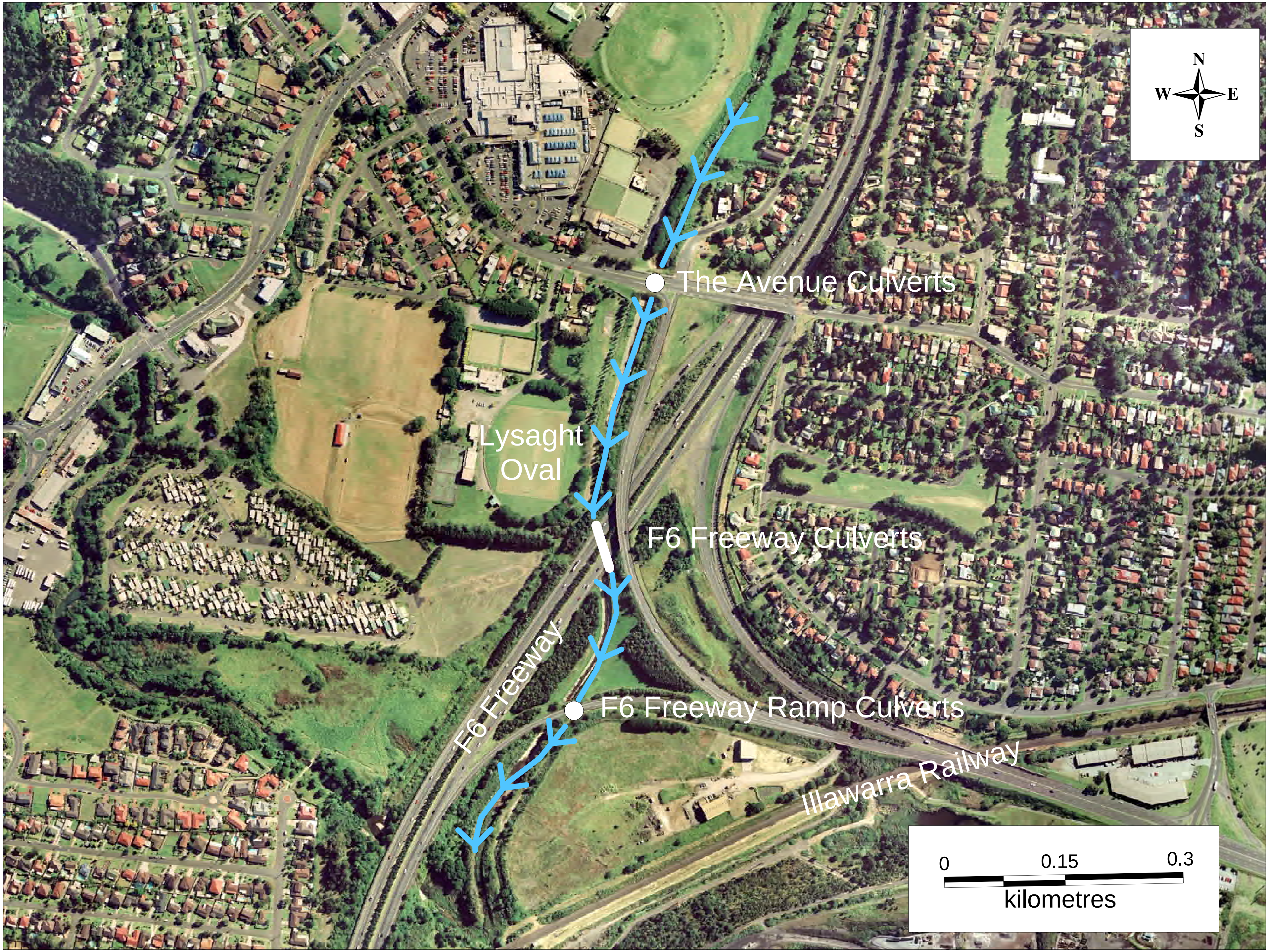

FIGURE 8.2
DETAILS OF FLOOD MODIFICATION OPTION 2

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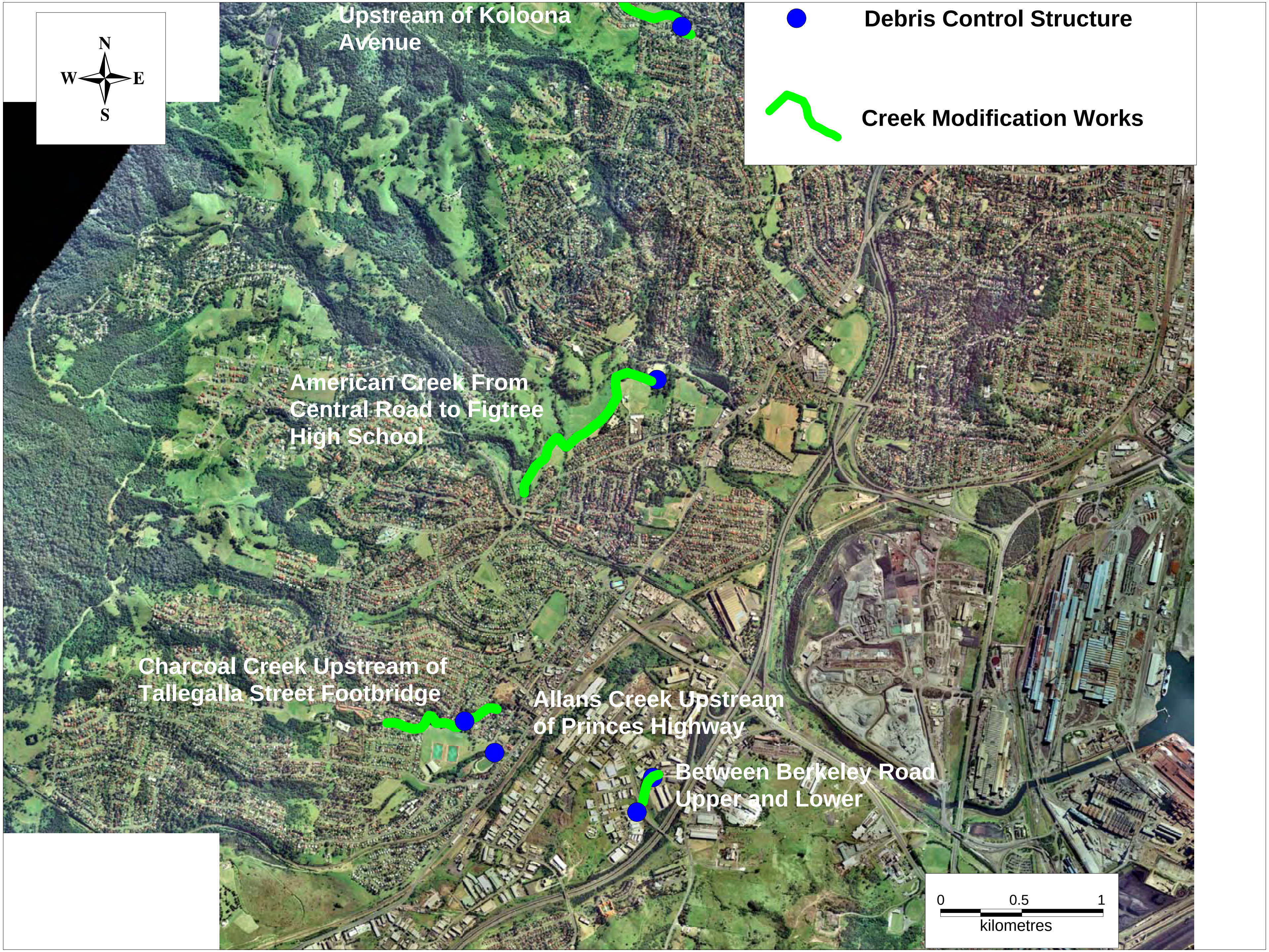

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FIGURE 8.3
DETAILS OF FLOOD MODIFICATION OPTION 3

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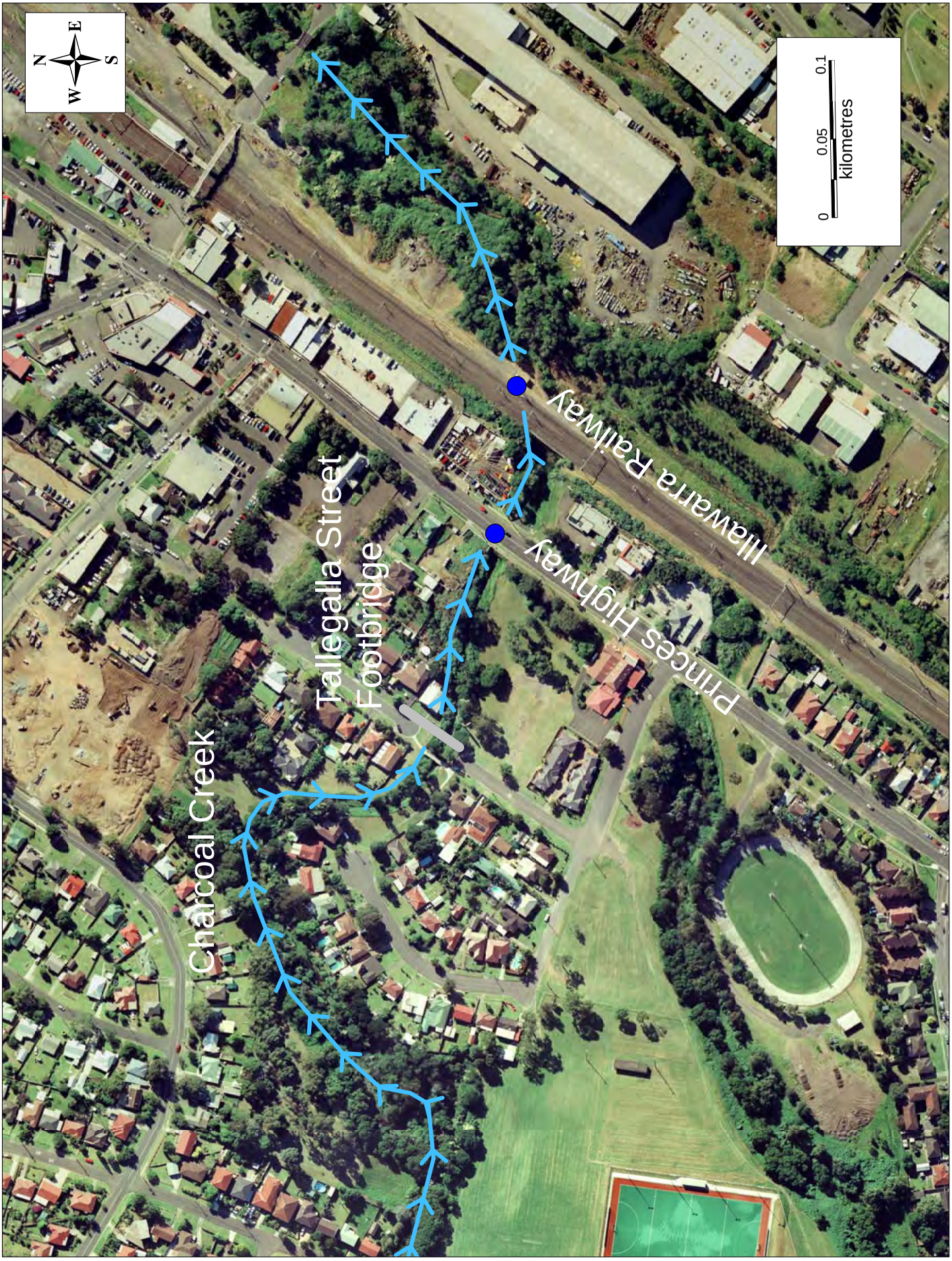

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FIGURE 8.4
DETAILS OF FLOOD
MOFIFICATION OPTION 4

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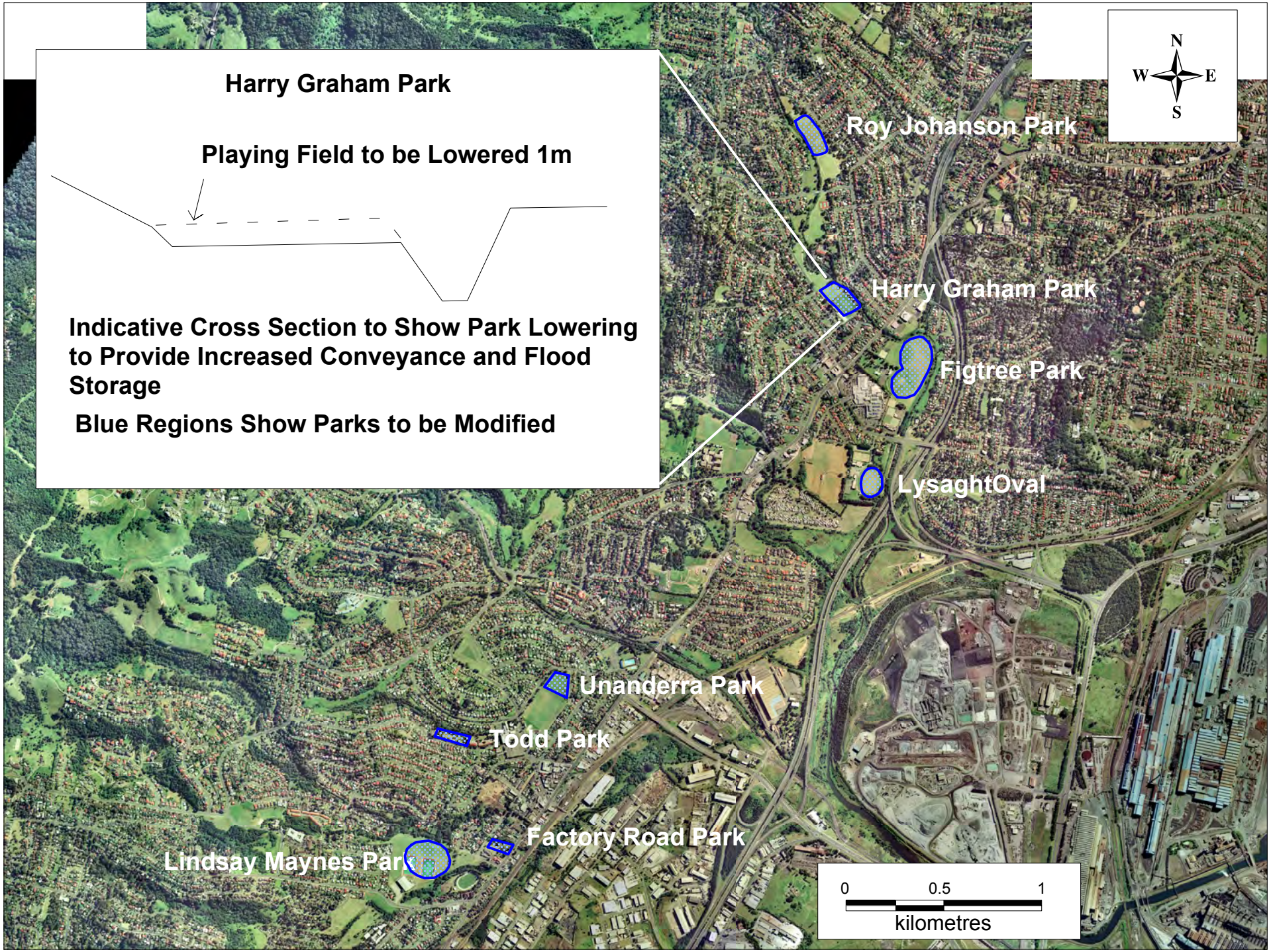

FIGURE 8.5
DETAILS OF FLOOD MODIFICATION OPTION 5

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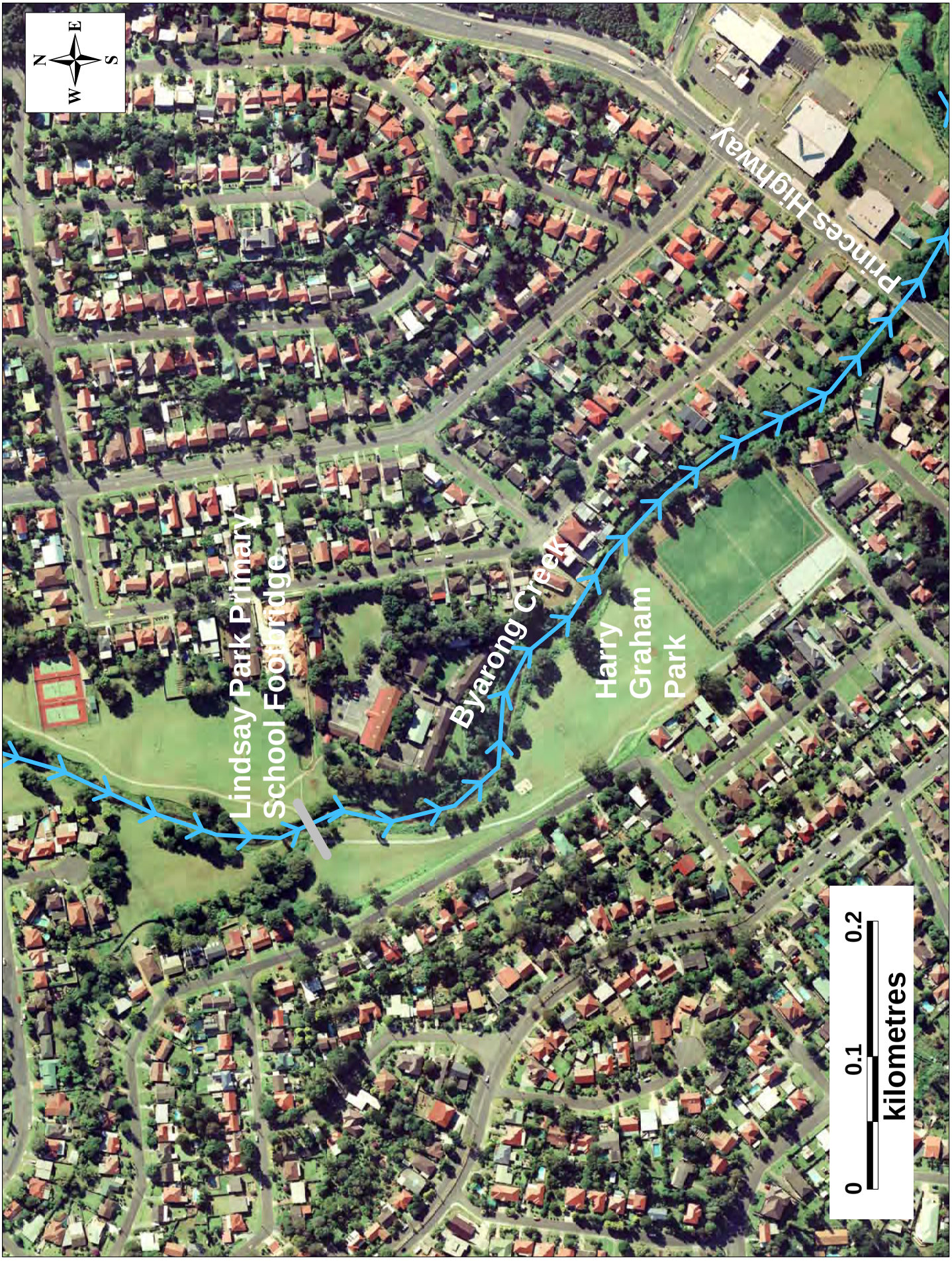

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FIGURE 8.6
DETAILS OF FLOOD MODIFICATION OPTION 6

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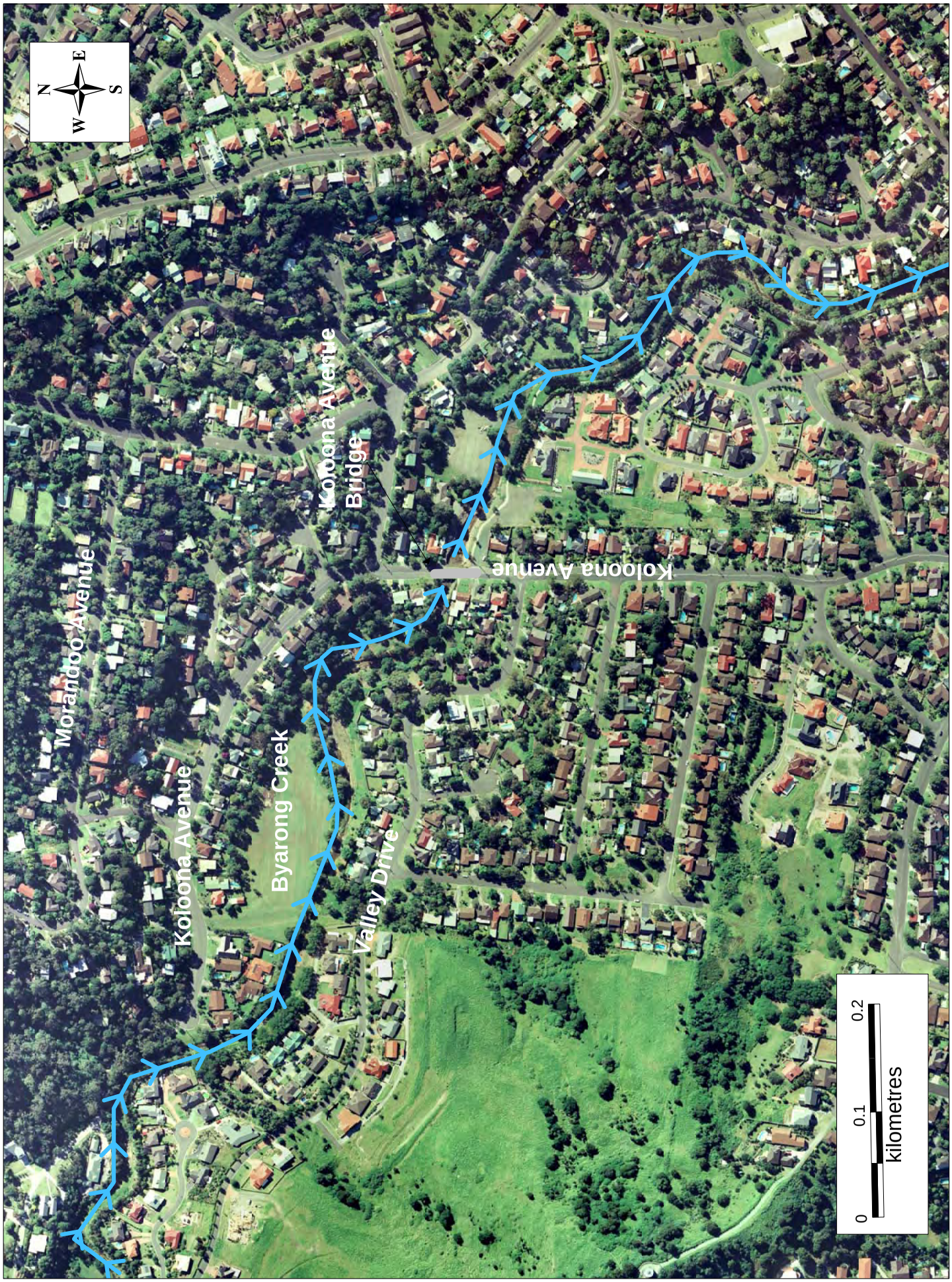

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FIGURE 8.7
DETAILS OF FLOOD
MODIFICATION OPTION 7

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FIGURE 8.8
DETAILS OF FLOOD MODIFICATION OPTION 8

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FIGURE 8.9
DETAILS OF FLOOD
MODIFICATION OPTION 9

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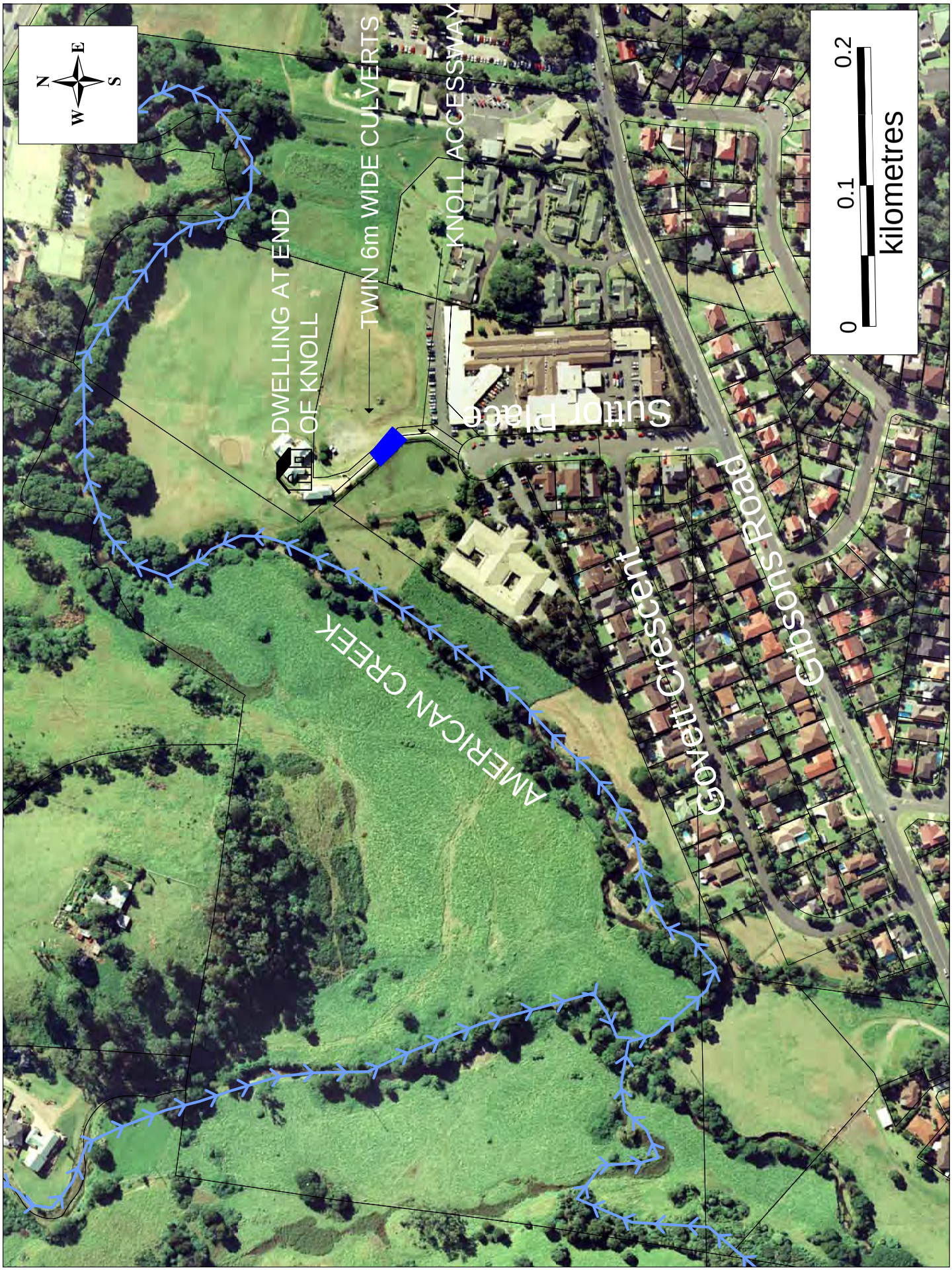

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FIGURE 8.10
DETAILS OF FLOOD
MODIFICATION OPTION 10

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FIGURE 8.11
DETAILS OF FLOOD MODIFICATION OPTION 11

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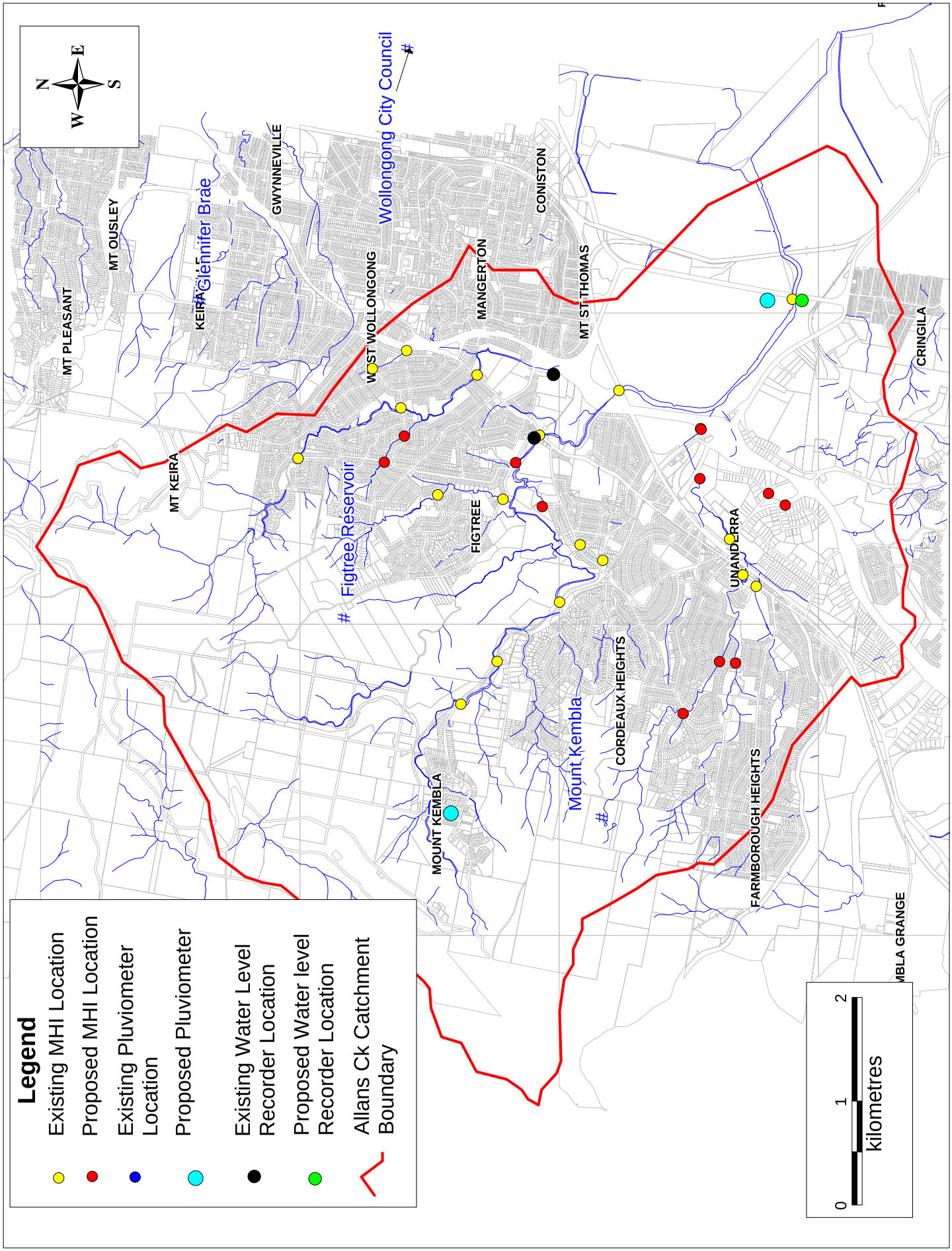

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FIGURE 9.1
CURRENT AND POTENTIAL MONITORING LOCATIONS

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If you need or are told to evacuate

- Listen to your radio for information.
- Turn off the electricity, gas and water.
- Collect your valuables, mementos and medications and take them with you.

When you leave

Tell the Police, the SES or your neighbours as soon as you can.

How will I know when a flood is coming?

The SES will broadcast flood advice on all local radio stations including ABC Illawarra, Wave FM and i98FM.

Listen to one of these stations for information. It is wise to have a battery powered radio and fresh batteries in case the power fails.

When flash flooding occurs there may not be time to warn everyone.

How the SES can help you

In partnership with the Wollongong City Council the SES is responsible for flood planning in Wollongong. During a flood, SES volunteers are responsible for flood safety advice, evacuation and rescue.

If you would like to know more about how to protect yourself and your belongings before a flood, or would like more information about joining the SES, please ring 1800 201 200.

FOR FLOOD EMERGENCIES CALL THE SES ON

132 500

www.ses.nsw.gov.au

NRMA INSURANCE

NRMA Insurance Limited ABN 11 000 016 722
www.nrma.com.au

WOLLONGONG *City of Innovation*

www.wollongong.nsw.gov.au

X2911 06/01

FloodSafe in the Wollongong Area

SES STATE EMERGENCY SERVICE

NRMA INSURANCE

WOLLONGONG *City of Innovation*

FIGURE 10.1A
CURRENT FLOOD AWARENESS BROCHURES FOR WOLLONGONG

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FIGURE 10.1B
CURRENT FLOOD AWARENESS BROCHURES FOR WOLLONGONG

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 10.1B SES.Wor

A message from your Mayor

Are you at risk from floods?

Wollongong City Council has begun a campaign to heighten the awareness posed by floods and landslips.

These hazards destroy public facilities and homes, threaten and disrupt lives and cause enormous loss to business and services. As the Mayor of Wollongong City, I want to help alleviate this suffering that causes financial, social and psychological harm.

This brochure is the first in a series of initiatives undertaken by your council to mitigate against future flooding and landslips. Jointly sponsored by Wollongong City Council, the State Emergency Service and NRMA Insurance Limited, it is designed to provide advice on how the community can reduce the risk to property and life.

George Harrison
Lord Mayor, City of Wollongong

Does it flood in Wollongong?

Yes, it does. Although we live on a beautiful part of the coast, Wollongong has a history of flash flooding on the many creeks that cross the coastal plain, and landslips along the escarpment.

Flash flooding

Flash flooding occurs when creeks rise quickly after heavy rainfall. This usually means that there is little warning before water begins to enter properties, houses and businesses. The fast-flowing water carries a large amount of debris.

Landslips

Landslips may occur on the escarpment during and after periods of heavy rain and can cause serious damage to buildings.

Flood information

You may be able to obtain specific information on your property by contacting Wollongong City Council on 4227 7213.

What can do to be ready?

Now

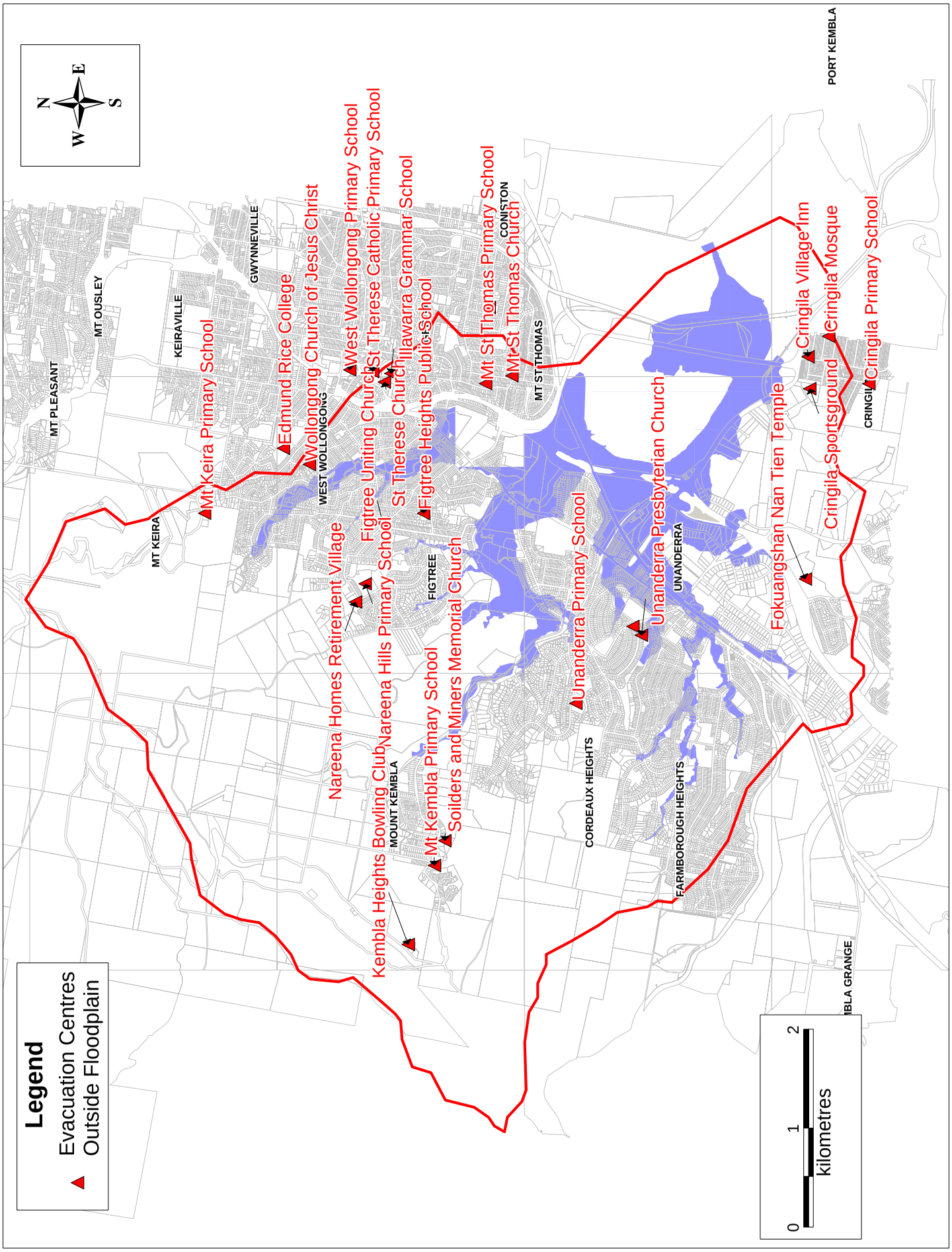
- Find out if your house or business could be affected by flooding or landslips.
- In case you have to evacuate, work out a safe route.
- Keep your local emergency numbers handy (for example, on your fridge).

When it's raining heavily in your area

- Listen to your local radio station for warnings and advice.
- Check that your neighbours have heard the warnings.
- If water might enter your house, secure your valuables. Raise anything you can onto tables and benches.

After flooding has begun

- Avoid driving or walking through flood water. Don't drive on roads that have been closed.
- If you are at home, stay there until advised otherwise.
- If you are away from your home, don't try to return home until you are sure it is safe.
- Keep listening to your local radio station.
- Avoid using electrical or gas appliances.
- Never eat or drink food that has been in contact with flood water.
- Keep in touch with your neighbours in case they need help.
- Wear shoes and gloves while cleaning up, and use a strong disinfectant.



LAWSON & TRELOAR

J1946/R1946/V6
1 September 2006

Allans Creek Floodplain Risk Management Study

FIGURE 10.2
EVACUATION CENTRES
OUTSIDE THE FLOODPLAIN

J1946\Figures 2006\Floodplain Management Study Figures V6\Figure 9.1 Evac.wor

TO THE RESIDENTS OF ALLANS CREEK CATCHMENT

AMERICAN CREEK

Allans Creek Floodplain Risk Management Study and Plan

Draft Floodplain Management Options - Feedback Form

Please fill out and return to: Lawson & Treloar Pty Ltd
PO Box 852
Pymble NSW 2073

OR Fax (02) 9983 1055
OR Email comments to: nsw@lat.com.au
OR Hand to representatives at Westfield Figtree on either 16th or 23rd February.

Name:.....
Address:.....
Telephone:.....

Comments on Proposed Options:

Mt Kembla Park.....
.....
Cordeaux Road.....
.....
Govett Crescent.....
.....
Between Cordeaux Road And Suttor Place.....
.....
Princes Highway.....
.....
Figtree Gardens Caravan Park.....
.....
O'Donnell Drive.....
.....
Sid Parrish Park.....
.....
F6 Freeway.....
.....
General comments or other options (please attach sheet if there is insufficient space)
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Allans Creek Floodplain Newsletter

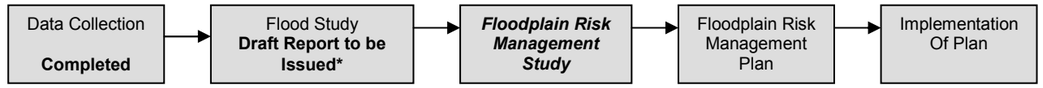
January 2002 - American Creek Catchment

As part of the Allans Creek Floodplain Risk Management Process, Wollongong City Council has engaged Lawson & Treloar Pty Ltd to conduct a Floodplain Risk Management Study and prepare a Floodplain Risk Management Plan for the Allans Creek catchment area (see over for a map of the catchment).

These studies are being prepared under the guidance of the **Allans Creek Floodplain Management Committee** which is convened by Wollongong City Council and consists of community representatives, Councillors and Council technical staff as well as the Department of Land and Water Conservation, the State Emergency Service and other state agencies concerned with flood-related matters.

The Floodplain Risk Management Study aims to identify options for reducing the risk of flooding. However, flooding cannot be eliminated altogether. For more information about flooding refer to the "Facts about Flooding" brochure available from Wollongong City Council.

The Floodplain Risk Management Plan will determine preferred management options to reduce flooding based on an assessment of social, economic, and ecological impacts. This fits into the overall floodplain management process, under the State Government's Flood Prone Land Policy, which follows the stages:



* Flood levels are now available on request from Council

Allans Creek drains three major areas; American Creek, Byarong Creek, and the southern areas of Charcoal Creek, Jenkins Creek and the main arm of Allans Creek through the Port Kembla Industrial Area. Residents in each of these catchment areas have been sent newsletters for their specific catchment. **This newsletter is for residents in the American Creek catchment.**

Possible options being considered for **American Creek** are listed over the page. Options include flood modification options, property modification options and emergency response modification options.

Flood modification options can include structural works such as detention basins, creek rehabilitation, levee banks, culvert amplification, debris control structures.

Property modification options can include modifications to individual properties such as house raising, flood proofing, voluntary purchase (applies only to residents subject to high hazard flooding), the adoption of development control policies and building codes or the rezoning of land.

Emergency response modification options can include modifications to the way in which emergency response is currently handled (by emergency management organisations such as the State Emergency Service, Police, Fire and Ambulance).

Comments received from the feedback forms will be included in a draft report to be issued in the coming months which will be made available for public review.

PUBLIC CONSULTATION: A public display will be available at Westfield Figtree on both Saturday 16 February and Saturday 23 February 2002 between 9am - 4pm. All interested persons are welcome to view the display and discuss issues with the team.

This newsletter also contains an opportunity for you to comment on these options via our tear-off feedback form. Your response is confidential.

Some Options Identified

MT KEMBLA PARK - Options include contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas.

CORDEAUX ROAD - Options include a proposed debris control structure to reduce risk of blockage of culverts and bridges downstream.

GOVETT CRESCENT- Options include placing a small embankment at the western end of Govett Crescent to prevent flood flow from American Creek flowing into Govett Crescent and/or placing tidal flaps on the three stormwater pipes adjacent to Govett Crescent also to prevent flood flows in American Creek entering the local drainage system and surcharging into the street and/or replacing accessway across the floodplain (Suttor Place) with bridge/culverts.

BETWEEN CORDEAUX ROAD AND SUTTOR PLACE - Options include works upstream of the junction of American Creek and Brandy and Water Creek to improve the riparian zone and/or a flood bypass channel and/or a detention basin on Brandy and Water Creek and/or the rehabilitation of the creek with bank regrading, stabilisation and weed removal.

PRINCES HIGHWAY - Options include elevating the footbridge near the school to reduce the chance of blockage and/or installation of an earth levee wall on the Figtree High School Oval. The earth wall may act as a spectator mound for the sports field.

FIGTREE GARDENS CARAVAN PARK - Options include a proposed increase in culvert size under the entrance to the park and the most important aspect of education about flood risks to residents and visitors.

O'DONNELL DRIVE - Flow capacity of the F6 Freeway Bridge can be exceeded forcing floodwaters to rise behind the Freeway, which has been constructed at a level above the adjacent land. A backwater effect occurs via the table drain leading to the Freeway. Options include the installation of a flood wall involving the construction of a combined earth wall and reinforced block fence on the rear property alignment.

SID PARRISH PARK - Options include the proposed contouring of the park to form a detention basin to attenuate flow and/or creek rehabilitation works between Lysaght Oval and the Freeway.

F6 FREEWAY - Culverts under the F6 Freeway can block and cause backwater flooding. Options include duplicating the existing culverts in association with a debris control structure to reduce the risk of blockage.

BRANCH AVENUE - Options include creek rehabilitation such as weed removal, bank regrading and stabilisation to increase conveyance and reduce peak flood levels.

GENERAL - Creek rehabilitation in all areas will reduce the risk of flooding, this includes removal of Coral trees and weeding of the creek banks. It is important that after these are removed that the bank is restabilised to prevent erosion.

Frequently Asked Questions

What areas lie within the Allans Creek Catchment? The land area draining to Allans Creek, as well as tributary streams, to Port Kembla. (See the map on the opposite page).

What is a Floodplain? The area of land subject to inundation by floods up to the probable maximum flood event. (ie. Flood-prone land).

What are rare and extreme design flood events? Rare and extreme design flood events are referred to in terms of their chance of occurrence. For example, the 1% Annual Exceedence Probability (AEP) flood has a 1% chance (ie. a chance of 1 in 100) of occurring in any one year whilst the Probable Maximum Flood (PMF) is the largest flood that could conceivably occur at a particular location.

What will the Draft Flood Study show? The Study (Draft to be issued) considers the flooding behaviour of the whole creek system for various 'design' flood events such as the 1% AEP and PMF. Maps of indicative flood extent have been prepared and will shortly be available for viewing at Council.

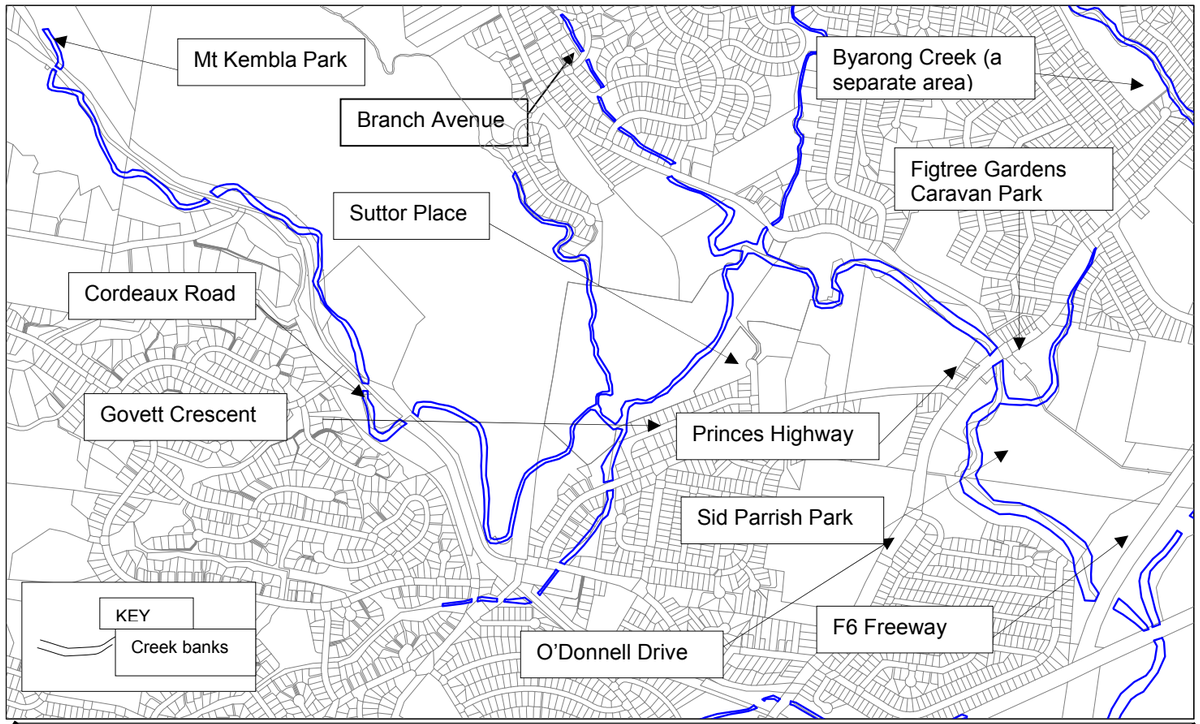
What are Floodplain Management Options? The feasible measures to manage or reduce the risk of flooding for a particular area of the floodplain. Options include flood modification, property modification or emergency response modification measures.

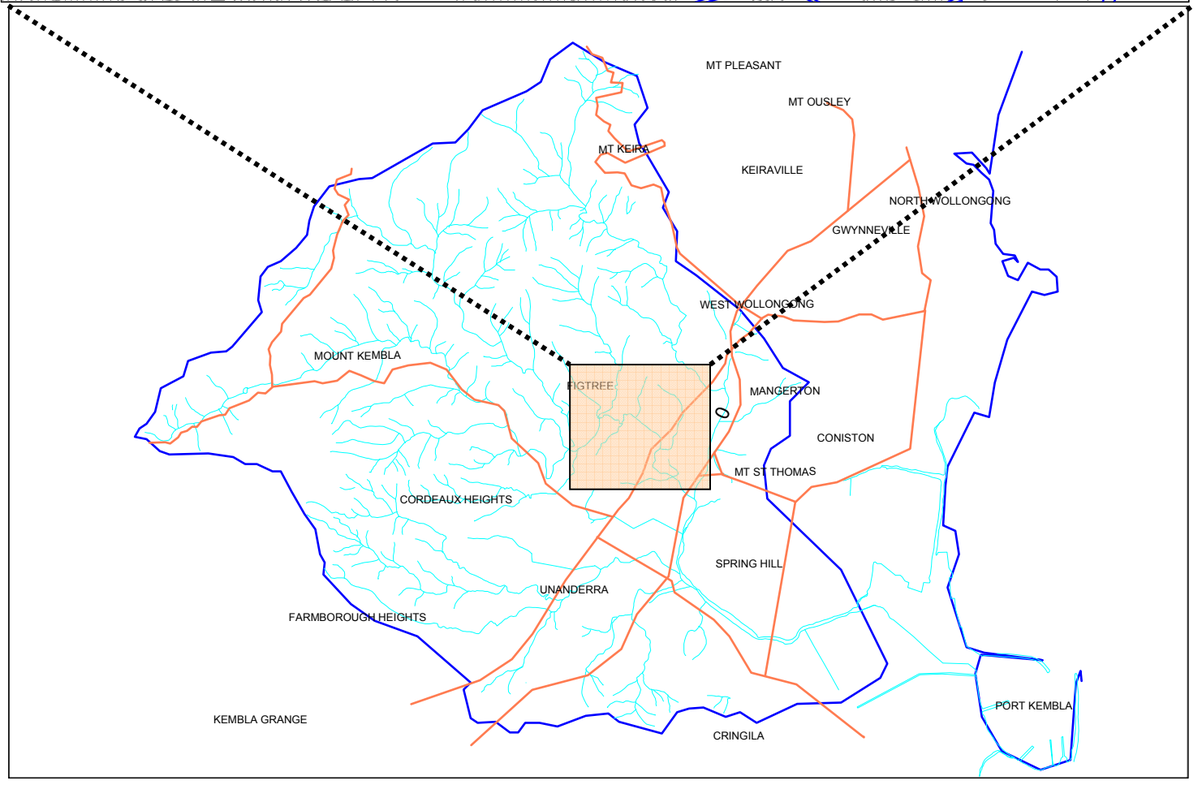
Why does Flooding Occur? Flooding is a natural process that occurs periodically as a result of rainfall events in a catchment. The effects of flooding in Wollongong (and many other urban areas in New South Wales) are magnified by the proximity of urban development to natural and modified creeks and channels. The banks of creeks and channels are exceeded in flood events with flow being conveyed through properties, via streets or ponding.

What is Flash Flooding? Flash flooding occurs following intense rainfall with resulting flood levels rising to their peak within a very short duration, ie 30min – 2hrs. This tends to occur in steep urbanised catchments such as Allans Creek and gives residents a very short time to prepare.

More Details? Contact Ms Yelia Perera at Wollongong Council on 4227 7111 or Ms Louise Howells, Project Manager, Allans Creek Floodplain Risk Management Study at Lawson and Treloar on 9983 1000.

Option Locations





TO THE RESIDENTS OF ALLANS CREEK CATCHMENT

BYARONG CREEK

Allans Creek Floodplain Risk Management Study and Plan

Draft Floodplain Management Options - Feedback Form

Please fill out and return to: Lawson & Treloar Pty Ltd
PO Box 852
Pymble NSW 2073

OR Fax (02) 9983-1055
OR Email comments to: nsw@lat.com.au
OR Hand to representatives at Westfield Figtree on 16th or 23rd February.

Name:.....
Address:.....
Telephone:.....

Comments on Proposed Options

Koloona Ave.....
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Euroka St.....
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Whelan Avenue.....
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Langson Ave.....
.....
Roy Johanson Park.....
.....
Uralba Street.....
.....
Thames Street.....
.....
Thames Street Downstream.....
.....
Harry Graham Park.....
.....
Arrow Avenue (Near Princes Highway).....
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Figtree Park.....
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Preston St.....
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The Avenue.....
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General comments or other options (please attach sheet if there is insufficient space)

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Allans Creek Floodplain Newsletter

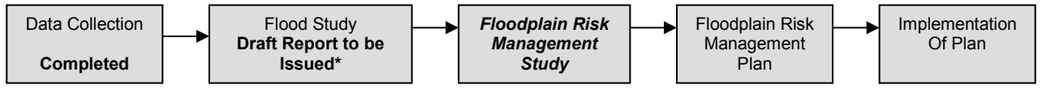
January 2002 - Byarong Creek Catchment

As part of the Allans Creek Floodplain Risk Management Process, Wollongong City Council has engaged **Lawson & Treloar Pty Ltd** to conduct a Floodplain Risk Management Study and prepare a Floodplain Risk Management Plan for the Allans Creek catchment area (see over for a map of the catchment).

These studies are being prepared under the guidance of the **Allans Creek Floodplain Management Committee** which is convened by Wollongong City Council and consists of community representatives, Councillors and Council technical staff as well as the Department of Land and Water Conservation, the State Emergency Service and other state agencies concerned with flood-related matters.

The Floodplain Risk Management Study aims to identify options for reducing the risk of flooding. However, flooding cannot be eliminated altogether. For more information about flooding refer to the "Facts about Flooding" brochure available from Wollongong City Council.

The Floodplain Risk Management Plan will determine preferred management options to reduce flooding based on an assessment of social, economic, and ecological impacts. This fits into the overall floodplain management process, under the State Government's Flood Prone Land Policy, which follows the stages:



* Flood levels are now available on request from Council

Allans Creek drains three major areas; American Creek, Byarong Creek, and the southern areas of Charcoal Creek, Jenkins Creek and the main arm of Allans Creek through the Port Kembla Industrial Area. Residents in each of these catchment areas have been sent newsletters for their specific catchment. **This newsletter is for residents in the Byarong Creek catchment.**

Over the page possible options being considered for **Byarong Creek** are listed. Options include flood modification options, property modification options and emergency response modification options.

Flood modification options can include structural works such as detention basins, creek rehabilitation, levee banks, culvert amplification, debris control structures.

Property modification options can include modifications to individual properties such as house raising, flood proofing, voluntary purchase (applies only to residents subject to high hazard flooding), the adoption of development control policies and building codes or the rezoning of land.

Emergency response modification options can include modifications to the way in which emergency response is currently handled (by emergency management organisations such as the State Emergency Service, Police, Fire and Ambulance).

Comments received from the feedback forms will be included in a draft report to be issued in the coming months which will be made available for public review.

PUBLIC CONSULTATION: A public display will be available at Westfield Figtree on both Saturday 16 February and Saturday 23 February 2002 between 9am - 4pm. All interested persons are welcome to view the display and discuss issues with the team.

This newsletter also contains an opportunity for you to comment on these options via our tear-off feedback form. Your response is confidential.

Some Options Identified

KOLOONA AVE - Byarong Creek flows under Koloona Ave in quadruple box culverts. Flooding occurs in this area as the culvert capacity is reduced by debris from the upper catchment. Options include stormwater inflow pipe realignment, replacing the culverts with a clear span bridge and/or placing debris control structures upstream to reduce blockages in conjunction with creek rehabilitation works and/or an offline dry detention area in the reserve upstream.

EUROKA ST - Flood flows can exceed the Byarong Creek banks and flood some properties on Euroka Street. There are no feasible structural management options specifically recommended for this area (some options upstream may reduce flooding in this area), development controls are the most likely means of managing the flood risk.

WHELAN AVENUE - Option considered is a debris control structure to reduce the risk of blockage of culverts and bridges downstream.

LANGSON AVE - Flood flows can exceed the Byarong Creek banks and flood some properties on Langson Avenue. An option is to replace the rear fences of properties in this area with a bund wall extending down to Uralba Street. However this option could potentially increase local flood hazard.

ROY JOHANSON PARK - Proposed contouring of park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas.

URALBA STREET - A tributary of Byarong Creek approaches Uralba St in a small lined open channel which is piped under Uralba St to outlet into an open channel in the rear of properties in Risley Road. Floodwaters in channel can exceed the capacity of culverts under Uralba Street and flow overland through properties to downstream creek channel. An option to improve the inflow to the culvert system is adding additional inlets and pits to reduce flooding in this area.

THAMES STREET - Byarong Creek is restricted near Lindsay Park Public School which can result in local flooding as well as blockage of the footbridge with debris. Options include elevating the footbridge near the school to reduce the chance of blockage and/or installation of an earth levee wall in the park behind affected properties. The earth wall may protect private residences as well as acting as a spectator mound for the sports field.

THAMES STREET DOWNSTREAM - Flood flows can exceed the Byarong Creek banks and flood some properties on Thames Street near the intersection with The Mall. There are no structural management options specifically identified for this area and development controls are the most likely means of managing the flood risk along with education about flood risks.

HARRY GRAHAM PARK - Proposed contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas.

ARROW AVENUE (NEAR PRINCES HIGHWAY) - Byarong Creek flood flows back up behind the Princes Highway that has been constructed above the adjacent ground levels. Flood flows can exceed the banks and flow parallel to Arrow Avenue towards the shops on Bellevue Road and onwards towards Sid Parrish Park. The local stormwater system is also exceeded in regular rainfall events resulting in a separate flooding mechanism. Options include widening of the Princes Highway bridge and placing a debris control structure upstream in Harry Graham Park. Additional stormwater system amplification in the area and creek rehabilitation works including widening and reforming of the banks is also an option to reduce frequent flooding.

FIGTREE PARK - Options include contouring of the park between Princes Hwy and The Avenue to form a detention basin to attenuate flows and/or creek rehabilitation (removal of weeds and creek bank widening and stabilisation) (see also Options below which link to these options).

PRESTON ST - Byarong Creek flood flows can build up behind The Avenue culverts and road embankment which has been constructed above the adjacent ground levels. Floodwaters rise behind The Avenue (see below) with consequent flow into some properties. Options include building a reinforced block wall along the rear of Preston Street property boundaries along with installing drainage behind the wall for local catchment runoff and/or flood proofing of affected properties.

THE AVENUE - Floodwaters rise on the northern side of The Avenue until they overtop the road at its lowest point. Options include installation of additional culverts at a higher level for bypass flows which will reduce the amount of water overflowing the road. Increasing the width of the channel and widening and regrading the banks between the Princes Hwy and The Avenue will reduce peak flood levels.

Frequently Asked Questions

What areas lie within the Allans Creek Catchment? The land area draining to Allans Creek, as well as tributary streams, to Port Kembla. (See the map on the opposite page).

What is a Floodplain? The area of land subject to inundation by floods up to the probable maximum flood event. (ie. Flood-prone land).

What are rare and extreme design flood events? Rare and extreme design flood events are referred to in terms of their chance of occurrence. For example, the 1% Annual Exceedence Probability (AEP) flood has a 1% chance (ie. a chance of 1 in 100) of occurring in any one year whilst the Probable Maximum Flood (PMF) is the largest flood that could conceivably occur at a particular location.

What will the Draft Flood Study show? The Study (Draft to be issued) considers the flooding behaviour of the whole creek system for various 'design' flood events such as the 1% AEP and PMF. Maps of indicative flood extent have been prepared and will shortly be available for viewing at Council.

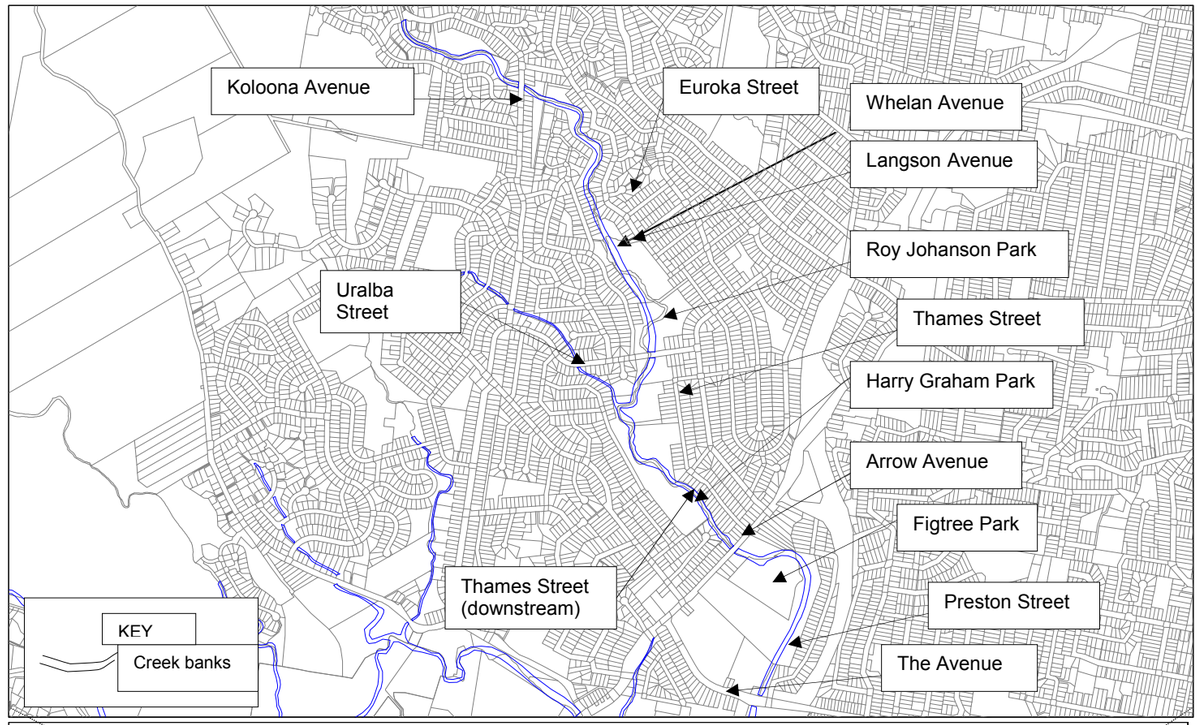
What are Floodplain Management Options? The feasible measures to manage or reduce the risk of flooding for a particular area of the floodplain. Options include flood modification, property modification or emergency response modification measures.

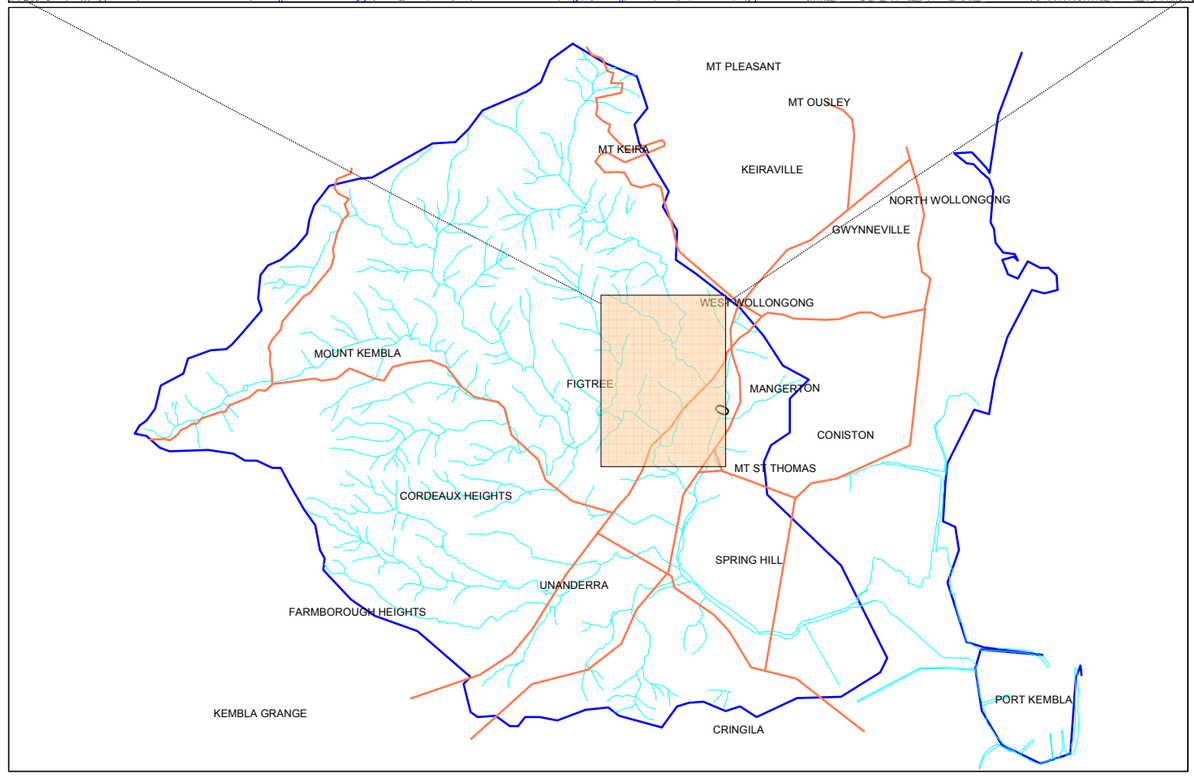
Why does Flooding Occur? Flooding is a natural process that occurs periodically as a result of rainfall events in a catchment. The effects of flooding in Wollongong (and many other urban areas in New South Wales) are magnified by the proximity of urban development to natural and modified creeks and channels. The banks of creeks and channels are exceeded in flood events with flow being conveyed through properties, via streets or ponding.

What is Flash Flooding? Flash flooding occurs following intense rainfall with resulting flood levels rising to their peak within a very short duration, ie 30min – 2hrs. This tends to occur in steep urbanised catchments such as Allans Creek and gives residents a very short time to prepare.

More Details? Contact Ms Yelia Perera at Wollongong Council on 4227 7111 or Ms Louise Howells, Project Manager, Allans Creek Floodplain Risk Management Study at Lawson and Treloar on 9983 1000.

Option Locations





TO THE RESIDENTS OF ALLANS CREEK CATCHMENT

JENKINS CREEK, CHARCOAL CREEK AND PORT KEMBLA INDUSTRIAL AREA

Allans Creek Floodplain Risk Management Study and Plan

Draft Floodplain Management Options - Feedback Form

Please fill out and return to: Lawson & Treloar Pty Ltd
PO Box 852
Pymble NSW 2073

OR Fax (02) 9983-1055
OR Email comments to: nsw@lat.com.au
OR Hand to representatives at Westfield Figtree on 16th or 23rd February.

Name:.....
Address:.....
Telephone:.....

Comments on Proposed Options:

Old Five Islands Road.....
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Princes Highway (Two Creek Crossings).....
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Rickard Road .....
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Normandie Place.....
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Lindsay Maynes Park.....
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Tallegalla Street.....
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Prince of Wales Avenue.....
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Resolution Drive.....
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Marley Place .....
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Unanderra Park.....
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Todd Park.....
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Berkeley Road.....
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General comments or other options (please attach sheet if there is insufficient space)
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Allans Creek Floodplain Newsletter

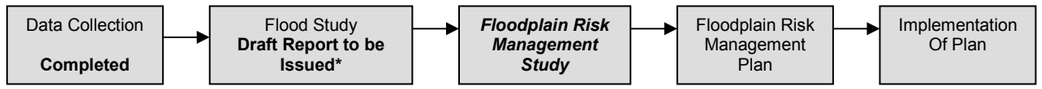
January 2002 – Jenkins Creek, Charcoal Creek and Port Kembla Industrial Area Catchments

As part of the Allans Creek Floodplain Risk Management Process, Wollongong City Council has engaged **Lawson & Treloar Pty Ltd** to conduct a Floodplain Risk Management Study and prepare a Floodplain Risk Management Plan for the Allans Creek catchment area (see over for a map of the catchment).

These studies are being prepared under the guidance of the **Allans Creek Floodplain Management Committee** which is convened by Wollongong City Council and consists of community representatives, Councillors and Council technical staff as well as the Department of Land and Water Conservation, the State Emergency Service and other state agencies concerned with flood-related matters.

The Floodplain Risk Management Study aims to identify options for reducing the risk of flooding. However, flooding cannot be eliminated altogether. For more information about flooding refer to the "Facts about Flooding" brochure available from Wollongong City Council.

The Floodplain Risk Management Plan will determine preferred management options to reduce flooding based on an assessment of social, economic, and ecological impacts. This fits into the overall floodplain management process, under the State Government's Flood Prone Land Policy, which follows the stages:



* Flood levels are now available on request from Council.

Allans Creek drains three major areas; American Creek, Byarong Creek, and the southern areas of Charcoal Creek, Jenkins Creek and the main arm of Allans Creek through the Port Kembla Industrial Area. Residents in each of these catchment areas have been sent newsletters for their specific catchment. **This newsletter is for residents in the Jenkins Creek, Charcoal Creek and the Port Kembla Industrial Area.**

Possible options being considered for the **Jenkins Creek, Charcoal Creek and the Port Kembla Industrial Area** are listed over the page. Options include flood modification options, property modification options and emergency response modification options.

Flood modification options can include structural works such as detention basins, creek rehabilitation, levee banks, culvert amplification, debris control structures.

Property modification options can include modifications to individual properties such as house raising, flood proofing, voluntary purchase (applies only to residents subject to high hazard flooding), the adoption of development control policies and building codes or the rezoning of land.

Emergency response modification options can include modifications to the way in which emergency response is currently handled (by emergency management organisations such as the State Emergency Service, Police, Fire and Ambulance).

Comments received from the feedback forms will be included in a draft report to be issued in the coming months which will be made available for public review.

PUBLIC CONSULTATION: A public display will be available at Westfield Figtree on both Saturday 16 February and Saturday 23 February 2002 between 9am - 4pm. All interested persons are welcome to view the display and discuss issues with the team.

This newsletter also contains an opportunity for you to comment on these options via our tear-off feedback form. Your response is confidential.

Some Options Identified

OLD FIVE ISLANDS ROAD - Floodwaters can overwhelm the local stormwater system in the catchment draining to the channel behind the Western Suburbs swimming pool. There are no structural management options for this area and development controls are the most likely means of managing the flood risk along with education about flood risks and/or flood proofing of some properties.

PRINCES HIGHWAY (Two creek crossings) - Floodwaters overwhelm the local drainage system in the catchment draining to the Western Suburbs swimming pool and there is general overland flow flooding in the area. There are no structural management options for this area due to concentrated development in the area and development controls are the most likely means of managing the flood risk and/or education about flood risks and/or flood proofing of some properties.

RICKARD ROAD - Options include a flood detention basin sited at a reserve running through the Farmborough Grove retirement village. A road bridge across the gully already has earthworks constricting the existing gully, and presents as a suitable site for a detention basin wall. Removal of an earth mound left after maintenance further downstream of the area and upgrading of the existing stormwater system would improve creek conveyance and reduce flood levels.

NORMANDIE PLACE - Option considered is the construction of a flood bypass channel redirecting flow between Blackman Pde and Normandie Place to Lindsay Maynes park and/or upgrading the Princes Highway Bridge.

LINDSAY MAYNES PARK - Options include creek rehabilitation works between the park and Unanderra Railway Station and/or proposed contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas.

TALLEGALLA STREET - Options include creek rehabilitation works and/or contouring park areas to create a flood detention area and/or elevating the footbridge to improve conveyance and reduce the risk of blockage.

PRINCE OF WALES AVENUE- Floodwaters rise behind the culverts at Berkeley Road which can block with debris. There are no structural management options for this area and development controls are the most likely means of managing the flood risk along with education about flood risks and/or flood proofing of affected properties.

RESOLUTION DRIVE - An unnamed creek flows through pipe culverts under Berkeley Road. Downstream of the culverts, a concrete lined trapezoidal channel carries the flow along the line of the freeway and behind industrial sites on Resolution Drive. The channel then turns abruptly to pass beneath the F6 Freeway. An additional large flow enters the lined channel from the other side of the freeway downstream of the culverts from upstream of Glastonbury Avenue. Options include upgrading the Berkeley road culverts and improving inlet works.

MARLEY PLACE - Floodwaters back up behind the culverts at the F6 freeway. There are no structural management options for this area and development controls are the most likely means of managing the flood risk along with education about flood risks.

UNANDERRA PARK - Option considered is the lowering of the playing fields to form an offline detention basin to attenuate flood flows and reduce flooding in downstream areas.

TODD PARK - Option considered is the lowering of the playing fields to form an offline detention basin to attenuate flood flows and reduce flooding in downstream areas.

BERKELEY ROAD - An existing flood detention area lies within the industrial area. Options include ensuring the function of this area is not compromised by placement of goods by industrial property occupants within the area to reduce the storage area along with regular general maintenance of the flood detention area.

GENERAL – Creek rehabilitation in all areas will reduce the risk of flooding, this includes removal of Coral trees and weeding of the creek banks. It is important that after these are removed that the bank is restabilised to prevent erosion. Culvert amplification in suitable locations (eg railway culverts).

Frequently Asked Questions

What areas lie within the Allans Creek Catchment? The land area draining to Allans Creek, as well as tributary streams, to Port Kembla. (See the map on the opposite page).

What is a Floodplain? The area of land subject to inundation by floods up to the probable maximum flood event. (ie. Flood-prone land).

What are rare and extreme design flood events? Rare and extreme design flood events are referred to in terms of their chance of occurrence. For example, the 1% Annual Exceedence Probability (AEP) flood has a 1% chance (ie. a chance of 1 in 100) of occurring in any one year whilst the Probable Maximum Flood (PMF) is the largest flood that could conceivably occur at a particular location.

What will the Draft Flood Study show? The Study (Draft to be issued) considers the flooding behaviour of the whole creek system for various 'design' flood events such as the 1% AEP and PMF. Maps of indicative flood extent have been prepared and will shortly be available for viewing at Council.

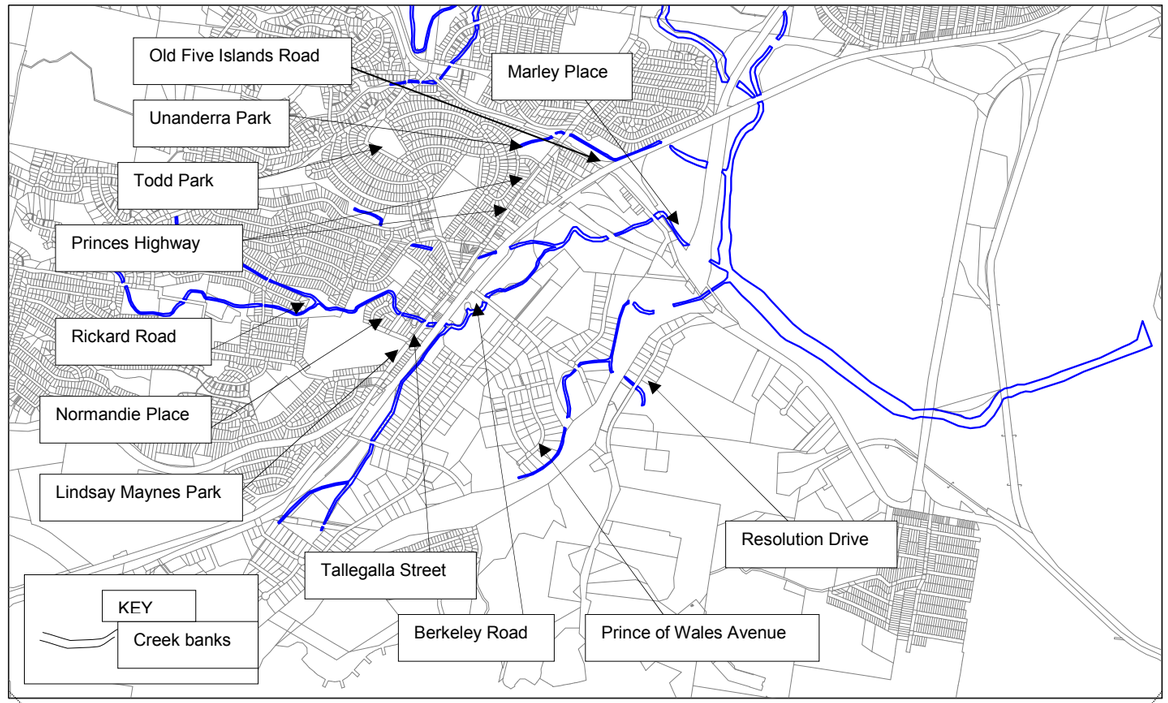
What are Floodplain Management Options? The feasible measures to manage or reduce the risk of flooding for a particular area of the floodplain. Options include flood modification, property modification or emergency response modification measures.

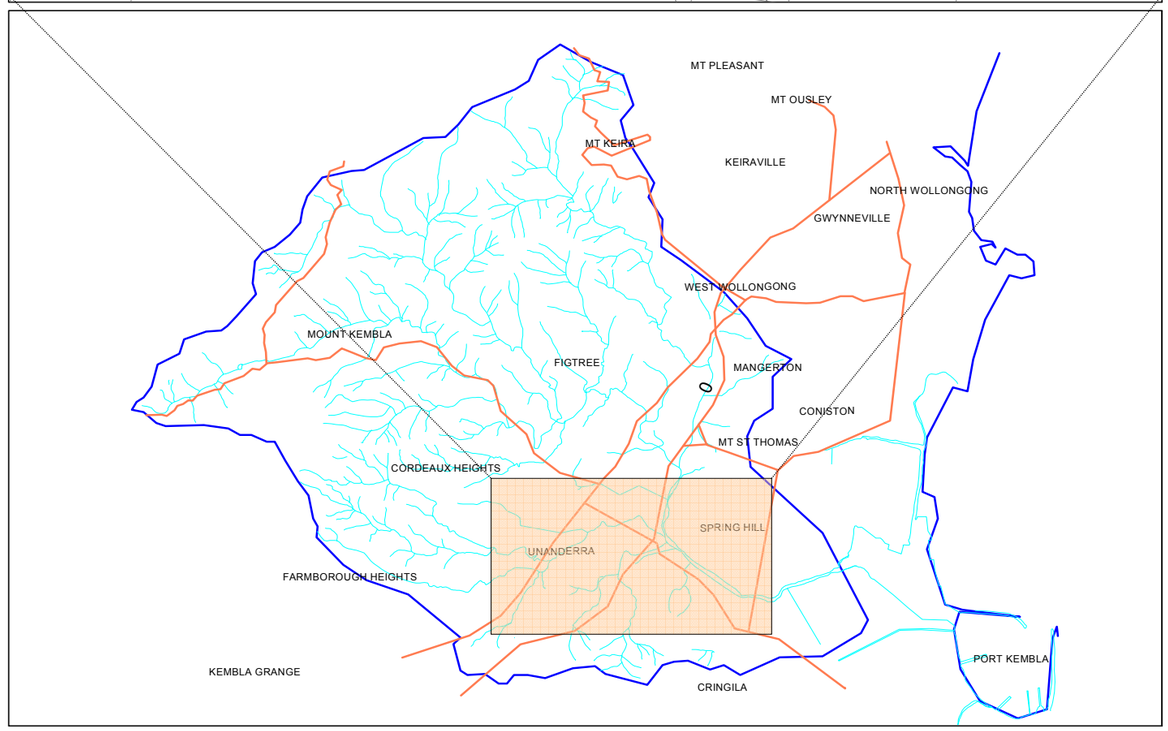
Why does Flooding Occur? Flooding is a natural process that occurs periodically as a result of rainfall events in a catchment. The effects of flooding in Wollongong (and many other urban areas in New South Wales) are magnified by the proximity of urban development to natural and modified creeks and channels. The banks of creeks and channels are exceeded in flood events with flow being conveyed through properties, via streets or ponding.

What is Flash Flooding? Flash flooding occurs following intense rainfall with resulting flood levels rising to their peak within a very short duration, ie 30min – 2hrs. This tends to occur in steep urbanised catchments such as Allans Creek and gives residents a very short time to prepare.

More Details? Contact Ms Yelia Perera at Wollongong Council on 4227 7111 or Ms Louise Howells, Project Manager, Allans Creek Floodplain Risk Management Study at Lawson and Treloar on 9983 1000.

Option Locations





Community Responses - American Creek - see Appendix A for Questionnaire Details

RESPONDANT STREET	RESPONDANT SUBURB	OPTION AT MT KEMBLA PARK	OPTION AT CORDEAUX RD	OPTION AT GOVETT CRESCENT	OPTION AT BETW'N CORDEAUX RD & SUTTOR PLACE	OPTION AT PRINCES HIGHWAY	OPTION AT FIGTREE GARDENS CARAVAN PARK	OPTION AT O'DONNELL DRIVE	OPTION AT SID PARRISH PARK	OPTION AT F6 FREEWAY	OPTION AT BRANCH AVE	GENERAL COMMENTS
Gibsons Rd	Figtree											The creek crossing Gibsons Rd is restricted by build up of growth of reeds and grass causing back up to Cordeaux Hts feeders. When water leaves this area it is impossible for Allans Creek to handle flow of water from all feeders due to silting of creek at top end near feeway to Spring Hill Road. Also Figtree Bridge was raised app 2 mts to allow flow of water from C/Heights area before houses were built (the law of averages is clear no natural soakage (?)) so more runoff of water to creeks (?).
Govett Cres	Figtree	Good proposal and should be adopted.	Makes good sense.	Wholeheartedly support proposal. Speed of water down Govett Cres is real safety problem. Both options necessary for long term effect.	A must do. (Current arrangement causes damming effect.)	No comment. Not clear on details.	Sounds reasonable.	What happens up-stream.	Sounds OK.	Duplicate existing culverts.		Proposals are at least an attempt to solve the problems which are getting worse because of over development of escarpment. Let us see some action before the next disaster.
Darragh Dr	Figtree	Agree with this approach however, as flood waters recede, silt buildup will need to be removed otherwise over time we will have a dam.	This all needs to be combined with a vegetation control plan.			This needs to be done, the creek banks especially require retention work.						The control of flooding in these areas needs to also include a clear vegetation control plan. Brandy and water Creek have Coral trees and Lantana infestation which during severe rain will block any drainage culverts. American Creek, at the Princes Hwy Figtree blocks the bridge drainage in the same manner.
Govett Cres	Figtree	Good ideas!!	Good ideas!!	The levy bank at the end of the street is a good idea.	The proposed new flood bypass channel is an excellent idea and should proceed with the "Wests" development. [see general comments]	Good ideas!!	Good ideas!!	Good ideas!!	Good ideas!!	Of LITTLE real value & far too expensive.		[Cordeaux Rd continued...] The provision of 6m wide box culverts under the accessway to the knoll is well over due. I am sure that there is also far more fill towards the creek than allowed for on the owners plans.
O'Briens Rd	Figtree					The bridge is not likely to cause blockage until the water level is above the bank, after which blockage will not make much difference to flooding (may cause damage to bridge though).						POSITIVES: Retention basins; cleaning refuse; clearing blockages. NEGATIVES: Levee banks/embankments/retaining walls must go all the way upstream, or floodwater wil go behind them (eg. Govett Cres proposal); assumption that increasing flow upstream will not cause increased flooding downstream; levee banks may help one area, but must make flood deeper elsewhere; "natural" appearance and character of the area may be lost by "upgrading" creek channels. Put a hold on any further development, at least until prevention measures are completed and proven to be effective. Should not apply to existing building blocks in areas already sub-divided, but would prevent new sub-divisions.
Gibsons Rd	Figtree	Keep the creeks beautiful. Not to look like drains please.		Must get rid of the access road across the floodplain!!! Now!	These ideas sound good as long as banks are revegetated to prevent erosion & that new development is accounted for.	Any levy banks or walls must not force water into other areas. Obvious yes but necessary definitely.						Will Council own the floodplain or leave it in private hands?... Council needs to keep the creeks clean & free of debris & weeds… This [American Creek due to new development] is eroding the already steep banks & threatening property. This must be addressed before any new development is allowed which will only worsen the problem. Any changes must enhance the appearance of the creeks, not detract from the natural beauty of the area. Also must be friendly to the native birds and animals.
Arrow Ave	Figtree						Redesign of the junction between tributary and American creek to prevent backflow during storm events		A detention area is an excellent idea			
Cleverdon Cres	Figtree								Detention basin is a good idea			This location also has local drainage problems that cause flooding, would like local trib running between Princess Hwy and Cleverdon Cres to be excavated and cleared to be able to cope with storm flows
Garden Ave	Figtree										The creek needs to be cleaned out. Some property development maybe encroaching on the creek which may cause flooding problems in the future.	

Community Responses - American Creek - see Appendix A for Questionnaire Details

RESPONDANT STREET	RESPONDANT SUBURB	OPTION AT MT KEMBLA PARK	OPTION AT CORDEAUX RD	OPTION AT GOVETT CRESCENT	OPTION AT BETW'N CORDEAUX RD & SUTTOR PLACE	OPTION AT PRINCES HIGHWAY	OPTION AT FIGTREE GARDENS CARAVAN PARK	OPTION AT O'DONNELL DRIVE	OPTION AT SID PARRISH PARK	OPTION AT F6 FREEWAY	OPTION AT BRANCH AVE	GENERAL COMMENTS
-	-										Key concerns are a large meander around the Scout hall and culverts near the Pony Club grounds	Key issues with flooding are the amount of vegetation and weeds growing in the creek. Further development is also an important issue
-	-											There has been a lot of dumping of material along the creek banks in the Branch Creek area, this will result in increased flooding. Weed removal and stabilisation of the banks is a good option

Community Responses - Byarong Creek - see Appendix A for Questionnaire Details

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
Seddon St	Wollongong												Seddon Street: Culvert drain under the Avenue is not wide enough at one point. Restricted by intermediate supports.		I believe that the Preston-Seddon street flooding is caused by the culvert drain under the Avenue at the end of Preston street. On each occasion flooding occurred debris had bridged across the narrow openings of the culvert with subsequent build up of rubbish causing extreme restriction to water flow. A complete bridging of the culvert ie. no intermediate supports would assist in maintaining a complete opening for the creek and therefore assist in maintaining maximum flow at all times.
Preston St	Mangerton					Detention basins in Johanson Park, Harry Graham & Figtree Park will assist in retarding flash flooding - the main problem for most areas in the Byarong catchment in August '98 & October '99.				As for Roy Johanson Park.		As for Roy Johanson Park.	Upstream detention basins are required - in addition, the embankment and culvert under the Avenue can be improved to assist in reducing water backing up.		In recent years flash flooding has been the major problem - upstream development has increased volume of runoff at times of heavy rainfall this can only be reduced by retardation basins wherever possible - plus preventing/reducing the current damming effects produced by the Avenue embankment and inadequate culvert.
Karbo St	Figtree														In the backyard the water (flood) came as high as 1 metre and 10cm.
Langson Ave	Figtree				The last big floods caused serious bank erosion in the area from the asthma pool to midway down Langson Av. [see general comments]										[Langson Ave cont...] However, the affect of cleaning after the flood widens and deepens the creek in this area and water now drains away more quickly. However recently willows, rushes, morning glory and other weeds are choking the creek and reducing flows. Therefore, it is essential to regularly bulldoze this section & keep the channel clear. If this was done there would be no need for any engineering works in this section. Further, if regular cleaning was done further downstream a lot of the problems would be solved.
Seddon St	Mangerton											Seddon Street runs parralel with Ghost Creek			You have not mentioned Ghost Creek at the back of our home! The last two big floods we had 5 ft of water in our back yard. But did not reach our home. Heavy rain fell in February this month '02 at times was four feet but did not reach our yard.
Northcliffe Dr	Berkeley														The proposal is a good start but why no widen and deepen the creek down stream to assist in the run off. Also could I get the Allans Creek Floodplain Newsletter if there are any in the future.
Valley Drive	Figtree	Best option is clear span bridge. Upstream rehabilitation should include: [see general comments]													[Koloona Ave cont...] (a) Storm water drain from Morandoo Ave to be redirected to discharge downstream in direction of water flow (it now discharges across Byarong Creek). (b) Build up of silt on north side of Byarong Creek at this point should be removed and deposited on south side (as it used to be). (c) Gabion or solid stone wall should be built on stream side of this deposit on south side to prevent further erosion.
Wallawa St										You should have added Wallawa St.					The creek came to Karbo St water down it Bellevue Rd meet with no where to go. The creek is a mess all the time when full breaks banks all way down on both sides.
Arrow Ave	Figtree										Widening of the banks & regular removal of debris. Regular clearing of drains of debris (top of the street).				Suggestion: To create more depth in the banks as currently it is filled with sand, rubble after and during floods.
Arrow Ave	Figtree										Please refer to our attached sheer in reference to this matter. [General Comments]				[Arrow Ave cont...] The proposal outlined in your Manifesto for controlling the flooding of Byarong Creek is exciting and very welcome news for the residents of Arrow Avenue, particularly for the residents living alongside the Creek in question. This will also address the problems of creek bank subsidence and erosion in the Byarong Creek Catchment area. The widening of the Princes Highway Bridge and placing a debris control structure upstream in Harry Graham Park in accordance with the Floodplain Newsletter will be of inestimable value in solving many problems experienced in the past. Furthermore, we fully support the proposal for Arrow Ave (near the Pacific Highway) and Harry Graham Park. We also recommend the installation of Gabion Baskets along the creek banks adjacent to the properties in Arrow Avenue living alongside the Byarong Creek, as we do. When these frequent floods occur the flow exceeds the creek bank exactly at the point where our house and land is located at the cul-de-sac in Arrow Avenue.

Community Responses - Byarong Creek - see Appendix A for Questionnaire Details

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
															The flood waters, after inundating our land and extensively damaging our property and often destroying house contents, flow up Arrow Avenue parallel to the Princes Highway into Bellevue Road, spreading out in various directions. We desperately need help as we have experienced years of these floods from Byarong Creek as we are located alongside the main flow of Byarong Creek. One year we actually lost over half of our yard area as it was washed away by the flood waters into the creek. Many truckloads of soil and rocks had to be purchased by me to restore our yard, and many times over the 35 years we have lived here we have been inundated by flood water from Byarong Creek. We still have a huge amount of silt and soil left under our house from the last major flood in August 1998. We also experienced in this last flood, structural damage to parts of our house and property, as well as car damage. All the residents of Arrow Ave suffered financially and personally when we were evacuated during the night. We live in constant fear and trepidation during heavy rains and storms similar to that experienced this week in Wollongong. Vast amounts of debris and rubbish have accumulated along the creekbank this week after the heavy rainfall. We always have filled sandbags ready to safeguard certain areas of our property. The recent rains have again resulted in extensive erosion of the creek bank alongside our backyard further encroaching on and and narrowing this strip of land. The creek bank has been eroded to now fall sharply away to the creek. We appreciate that action is now being taken through the implementation of the creek flood plan and to also include Arrow Ave to overcome all the problems endured over the years.
Wallawa St															Bend downstream from green footbridge (green footbridge could be raised) could be straightened. Outflow from Small Creek above footbridge and new buildings off Thames St exacerbate situation if pushes water off mainstream across Memorial Park there. Right bank low. One other vital spot bridge pylons by RSL Bowling Club. Drains from 1 Wallawa St appear to run towards creek uphill. Outflow into creeks to be angled with flow.
Grafton Av	Figtree														When we bought this land in 1965, the council + water board + solicitor told us there could not be any flooding. It is plenty of drainage. This is not so. Later the council made it a flood area and never told the residents. [map attached]
Walla Place [Coral Cres]	Unanderra														What about flooding across Harry Grahams Park soccer oval which floods Wallawa Place lower end?
-	-									Wallawa St 4 houses flooded worse than Arrow Ave.					Nothing about Wallawa St yet 1 house was 5ft. Water came down Wallawa off Bellevue Rd. Also down drive into Karno into then into Wallawa St. Hence into Park which was flooded. Creek needs cleaning out as it is all silted up. Lifting bridge at school sounds good but last flood was up to Risley which was about 100 yds wide from creek.
Cleverdon Cres		Most blockages are caused by build up of branches and litter leaves etc. A periodic clean up of these should stop blockage at culverts.	Remedy as above should alleviate problems here.	Debris control is exactly that. If there is little or no debris then there is no need to control it.	Flood here is caused by water being choked at uralbast culverts increase the capacity of culverts.	Sound proposal.	Improve the inflow by all means but an increase in the capacity under uralbast is a must.	Installation of earth levee as proposed is a sound option. Debris should be handled ithe same as Koloona Ave.	If possible a small widening of the creek at this point with maybe some gabion walls and all of the above.	Sound proposal.	The flooding here in 1998 was caused by water backing up because the culverts under The Avenue were blocked.	All options are sound.	All options are sound.	All options are sound.	The creek at the back of Cleverdon Cres (name not known) is a huge problem because it is choked with trees and weeds between Figtree Hotel and the caravan park. The water cannot get away and ultimately floods the properties in Cleverdon Crs. It must be attended to. I understand this area is a council problem.

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
Preston St	Mangerton												Dear Sir, I had a discussion with Council representatives on the 16th Feb regarding the flooding situation in my street. I was told that the open drain flowing through my property will not be piped during the preferred for Preston Street. I cannot see how this option can possibly relieve the flooding situation on my property. [see general comments]		[Preston St cont...] The bank of the north side of the drain on my property is about 1 metre higher than the south bank. When there is a heavy downpour even when the level of Byarong creek is low the water in the drain escapes and floods my yard. This occurs on a regular basis. I can only imagine how quickly the water will enter the house if, duringa severe and prolonged storm occurs and the level of water in Byarong Creek rises to a level above the flow of water from the drain. If this concrete wall / levee bank goes ahead and the drain on 50 Preston St is not piped then this can only mean (to me) that my property is giong to be used as a relief point for the build up of water pressure with only result being another inundation through the house. Again if this is the option to be implemented then I would strongly urge Council to consider voluntary purchase of my property. I would like to remind Council that two houses in my street have already been resumed and my houses is in a lower position that were these two.
Preston St	Mangerton												With regard to the options for the management of the flooding pf PRESTON STREET that you have put forward. There is only one way to reduce the flooding in PRESTON STREET, the AVENUE and WESTFIELD SHOPPING CENTRE that is remove the daming effect of the culvert. [see general comments]		[Preston St cont...] The original culvert (which is still there) was a low level culvert and when the flood waters exceeded the capacity of the culvert the waters rose approx 1/2 metre and flowed over the top thus causing very little flooding. There is no problem after the Avenue as the floodwaters can pass along the side of the expressway to Allen's Creek. The problem was created when they constructed the overpass bridge over the expressway instead of taking into account the amount of water that flows down Byron Creek when it is in flood and building a bridge that would handle it they just built the road up above the existing culvert so that in flood time the water level has to rise from 2 to 3 metres higher before there is relief. Also Byron Creek is choked with straight Willow trees (which are noxious weeds) and catch debree and block the culvert. This problem could be helped by forming a cement canal between the PRINCES HIGHWAY and the AVENUE as it is below the AVENUE. Now for the other option of a levee wall I cannot see how this would work as it would have to be at least 3 metres tall behind the houses to keep Byron Creek back. In the last flood there was 2 metres of water in PRESTON STREET. The water actually carried a car down the footpath and then what do you do with all the water coming down from the very large catchment area of MT THOMAS MANGERTON McCARTHUR HEIGHTS.
Thames St	West Wollongong								I am owner/occupier of 11 Thames St [Thames St Downstream] since April 1969. We have witnessed several floods, none as severe as August, 1989. (Perhaps the occurrence of the 300 yr flood). Council has been requested regularly - with few results - to remove natural debris-						[Thames St downtown cont...] When the channel is too small to accommodate the volume of water, nature does the widening by erosion etc, of the banks. Both of these problems could be solved by installing a box culvert the size of the current channel [bank to bank], and stabilising the bank behind the culvert wall. The result would be a wide, CLEAR channel accommodating a very large volume of water with a clear passage from headwaters to Allans Creek and the Pt Kembla Harbour creating a "flood" in the harbour rather than upstream where massive damage occurs. A concrete culvert no doubt would be costly to construct. The preferred option at Koloona ave and the upper end of the Johanson Park was the use of gabions which have proved to be as effective, and of aesthetic appearance. I would recommend that: - Creek banks be cut vertically and spoil be retained; - Gabions be placed up to existing land levels; - Spoil be replaced behind gabion wall to consolidate the banks.

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
									causing growth in the creek banks so that water can readily flow away. [see general comments]						In order that the flow is clear and open to the Harbour this work should begin at the confluence Byarong Creek and Allans Creek and continue upstream to the existing work near Koloona Ave. One must expect that this work would be long term and necessarily having been costed would require fixed planning over a number of years. There are many, many "pluses" with this plan eg., - vast reduction of natural growth which generates debris for the length of the creek; - open free flow of a much larger volume of water following heavy rains and reduction of inundation of land; - when flooding does occur (and it will) flood levels will fall at a faster rate; - elimination of complaints from ratepayers who want creeks cleaned out; - elimination of disputes between Council and property owners as to responsibility for maintenance of creek banks/bed; - permanent change to property descriptions on title deeds: "Rear boundary is top of bank of creek". Maintenance of creek bank then is the indisputable responsibility of individual property owners; - Council expenditure for clearing of debris from time to time would be reduced as only the supports under crossings, bridges would be require attention. Having experienced a lack of action in the past to clearing natural growth, I do not favour the use of "trash racks" now ephemistically called debris control structures. They are seldom cleared. Retention ponds are effective in reducing the speed of the flow and have limited use. During dry periods they become breeding grounds for mosquitoes, rats and other pests. I invite your inspection of the highly costly work done in Nerang Park at rear of Akuna Street Gwynneville and the state of the "jungle" now obscuring the work, and tending to choke the flow of that creek. Some cleaning has been done - very recently - and the trash racks have been cleared; the spoil is in evidence. But other growth is plain to see and will become debris over time. I would appreciate your comments on the above in due course.
Valley Drive	Figtree	The only viable option is to replace the culverts with a clear span bridge. If this had been done after the floods in 1974 and 75, the 1999 flooding would not have been as bad.	In 1999, the wall of water that resulted when the dam behind Kaloona Ave culverts broke, cause much of the flooding in these two streets [Euroka St & Whelan Ave].												In March 74, poplar trees fell into the creek above the Kaloon Avenue culverts. They turned the bridge into a dam. The water rose until it brokoe through the fences on the Valley Drive corner. The resulting wall of water flooded houses on both sides of Kaloona Avenue and spread out across Hill Brook Park. Having room to spread slowed the flow and reduced the impact downstream. In 1999, a similar dam formed and broke. The mound along the western side of the Mill Brook Park sub-division forced the wall of water back into Byarong Creek, causing much of the flooding in Europka and Arrow Avenue. After the 1974 flood, council ran a bulldozer up the bed of the creek through Kaloona Park, but didn't batter the banks. Subsequent floods severely eroded these banks.
Thames St	Wollongong														As we understand the Newsletter you have sent out, there seems to be no sultion to alleviating the flooding problem in the Thames Street Downstream area except for "Development Controls" whatever this may entail. Clearly the area ia already fully developed and so it is unclear what development controls would be appropriate. It seems clear to us that as further development occurs up stream the rate of runoff during a heavy storm will increase and so the likelihood of 'flash' flooding is likely to increase. This seems to be a fact of life and so the problem resolves itself into: 'How do we get this large volume of water safely and quickly into the ocean via Allans Creek'. We do not assume to be experts in the area of flood mitigation and so have no arguments with what you propose but it does seem obvious that the cross-sectional area of the creek needs to be progressively increased the closer it gets to discharging into Allans Creek and hence into the ocean. Our specific concern is that by contouring Harry Graham park (presumably by increasing the height of the creek bank on the North side of the Park) the overall level of the creek will rise in the vicinity of Thames Street thus making the problem worse for the Thames Street downstream areas. For Langson Avenue you have proposed that the rear fences could be replaced by a bund wall extending down to Uralba Street. Is this a suitable option for the properties along Langson Avenue, why cannot the same approach be taken for the properties from, say, Lindsay Park school to the highway? We know that the problem is a difficult and costly one to fix but our concern is that in fixing the problem for some people that you don't make it worse for others.

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
Seddon St	Mangerton											Problems: Park at higher level than Seddon St, no weed prevention except unstable mechanical deforestation, soil erosion, creek direction. Recommendation: change the direction of the Creek and re-landscaping of Figtree Park.	Makes sense, but conjecture on the height of the barriers. Will access or views be a problem? May not be practical for Seddon St since there is only a small distance between the Byarong creek edge and rear of properties. Another option: piping of the creek.		Summary of Recommendations: - Make sure Seddon Street is included in the flood management plan; - Understand Ghost Creeks role in the flooding; - Conduct a proper study of the developments of thos Princes Highway businesses and their contribution if any to the Ghost Creek flooding; - Investigate the possibility of piping the Ghost Creek; - Investigate the possibility of resolving the Ghost Creek / Byarong Creek intersection; - Establish proper strategies to improve stabilisation of the banks; - Ensuring Council has a program to maintain the banks and that debris is removed on a more regular basis and this to include Ghost Creek, which is part of a Council easement.
Arrow Ave	Figtree	-						Elevation of footbridge not likely to make any difference - flooded before footbridge put in.		Only in MINOR floods would this be of any improvement.	Can't see how widening P/Hwy Bridge would help. Widening creek + NOT adequately reinforcing banks wouldn't help.				
Koloona Ave	Figtree	We would prefer to see the bridge removed, having been flooded the freestanding bridge is preferable to the present one; [see general comments]													[Koloona Ave cont...] with a retaining basin installed in Koloona Park. Our immediate worry is the heavy duty rail across the bridge. The old rail at least was knocked down by the debris, allowing the water to get away. This barrier will become a solid all so your home has a greater chance of being flooded again. The water comes at such a speed that we wouldn't get away.
Koloona Ave	Figtree	Remove the bridge spanning Byarong Creek at Koloona Avenue. [see general comments]													[Koloona Ave cont...] The single span bridge proposed for Koloona Avenue will take decades to be constructed and will cost between 3 to 4 million dollars. Very unlikely for any Govt. local, state or federal to fund this project. By cutting Koloona Avenue at Byarong creek there are a number of alternative roads for access by traffic. A regular program of creek cleaning + maintenance be commenced as S.A.P. Currently gutter runoff pipes & the creek are only cleaned after a crisis. This lack of cleaning only adds to the problem of flooding. The Authority policing and reviewing the Flood Mgt. Plan should be independent of Council. Councils plans are usually short term due to restrictions of yearly budgets.
Preston St	Mangerton	Clear span bridges AND debris control. The more control and reducing debris lessens flood damage downstream.	Again keeping debris out of system helps prevent flooding here if water is backed up or slowed futher down.	Enlarge the culverts to increase water flow. Debris control structures along the length of system.	Bund wall seems a ridiculous option if has the POTENTIAL to increase flooding. Clear flow of water downstream will help here.	No comment.	If the existing culverts are inadequate then redesign them to cope, reduce development in runoff catchment area.	Again debris control upstream and here AND raise the footbridge. Why muck about!	All creek systems are virtual drains of over-developed run-off. Enlarge the systems and keep them clear.	No comment.	It's always the same roadways are elevated so that cars stay dry, and inadequate drainage is used without regard for future dev.	Enlarge and line the system free of obstructions.	A levee faced with concrete or caged stone would help but the problem remains at the Avenue embankments.	Extra culverts as a bypass for the bridge. A small one under Preston St is in place but it was rendered useless when RTA built the noise barriers on expressway.	[The Avenue cont...]These are backfilled - no one seems to notice this. Again it is a matter of keeping roads dry at the expense of homes. Council must except that creeks are now virtual drains for developed areas and more has to be done to ensure that these DRAINS are enlarged to cope with excess capacity AND KEPT CLEAN by controlling debris allowing free flow of water.
Koloona Ave	Figtree	Living alongside the Byarong Creek I am constantly aware of how quickly debris collects under the culvert and I am very much in favour of a clear span bridge.													
Euroka St	Figtree		Widen bend in creek behind 48. Look at rise in road - Lexburh corner to allow flow to go into park.												

Community Responses - Byarong Creek - see Appendix A for Questionnaire Details

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
Koloona Ave	Mt Keira	We support the clear span bridge option combined with upstream debris control measures.													Even though this construction work would be inconvenient to us, the clear span bridge option seems to be the most effective way of protecting our home in the longer term. As engineers we well understand the concept of a bottleneck and that bridge is certainly it! Maintenance around the Byarong Creek area needs to be ongoing as well. eg. clearing of fallen trees, etc.
Naples Rd	Farmborough Hts												Past resident (no. 44) of this street - house flooded badly in 1972 + worse recently - need to make culverts much larger.		
Thames St	West Wollongong							Keep the creek clean of trees.							
Arrow Ave	Figtree										A retention dam/basin should be considered. Other options noted are necessary for residents safety (duty of care by Council).				
-	-					The bed of Byarong Creek has risen at least 1 mtre more in places. The creek needs cleaning out at present it is full of reeds.		The stormwater drain is going up the creek instead of going with the flow of the creek.							We don't need retaining walls in Arrow Ave. That will only cause more back up for us and we will be worse off. We need a Public meeting and we need Council to listen to the residents who have lived on the creek for 30 to 40 years.
Koloona Ave	Mt Keira	The bridge MUST be made a single span bridge. The culverts block passage very easily. [see general comments]													[Koloona Ave cont…] A retension basin at the reserve would greatly help. Also, a continuous cleaning of the creek should be implemented. I have contacted Council many times in regards to this with no response. Also - can the course of Byarong Creek be returned to its natural course. It was altered many times with thinking being that this would alleviate future flooding. This has made it worse for me.
Thames St	West Wollongong								Stormwater pipe needs realigning & increasing in size.						It is hard to envisage details as set out in this proposal & I feel that a Public meeting with greater explanation of how all proposals outlined interconect & WORK is necessary. Care must be taken so that one persons flood problem is not solved to the detriment of someone else.
-	-												We are against the construction of a wall behind our properties.		Either rasing of the most effected properties and/or redesigning the culverts & cleaning out the creek banks.
The Avenue	Figtree													On 17/8/98, water came out of Westfield centre through the vehicular access opp. Nos 153 & 155 The Avenue.	Coming up against water travelling down The Avenue from the Princes Highway end causing a considerable turbulence at this point. A considerable flow of water entered the grounds of the residences on the southern side of The Avenue and pushed over the fences between the residential properties until the road of the sporting oval beyond no.149 & then flowed on to Byarong Creek.
Uralba st	Figtree	CLEAR SPAN BRIDGE + debris control upstream.	Definitely development controls.	Debris control.	LEVEE BANK down to Uralba St Figtree and beyond as West W'gong side of creek is higher than Figtree side.	Proposed scheme for johnson Pk would be detrimental to to those in Uralba St near bridge.	Add additional pits + inlets to help flow problems.	One option raise the bridge behind Lyndsay Park school or dig out debris + silt that has accumulated last 3 years.	Development controls.	Proposed detension basin may help downstream, but what about upstream.	A one span bridge across Pacific Hwy + debris control upstream.	Retension basin in park. The main problem here is… [see Preston st]	The bridge over The Avenue at RSL. This needs to be a one span bridge ONLY.	As above BRIDGE PROBLEM.	After all is said + done, development above Byarong Creek should cease, as this increases the flood risk + all dead trees + other noxious weeds + rubbish should be cleaned out regularly, not leave it to every time the area floods. How many more surveys are to be done before WE FINALLY GET SOME ACTION on all of your proposals.
Thames St	West Wollongong	Replace culverts with clear span bridge at a higher level.	As with Koloona Ave.	Debris control.	Widen creek to take more volume.	Contour park.	Add additional pits.	Elevate footbridge and add levee wall.	Byarong Creek widening downstream of Princes Hwy could reduce water buildup Mithanes St.	Contour park to form retention area.	Princes Hwy forms a "dam wall" effect and causes water to be retained in the street. Widen bridge.	Widen creek and remove weeds along eastern edge of park.	Any widening of creek downstream of park should reduce flood level but not eliminate.	Install additional culverts.	the Princes Hwy is a major restriction to water. Runoff from west of Hwy and a significant increase in drain capacity is required to make a big difference in lowering flood levels [downstream of Thames St]. Flood attenuation upstream could aggravate the position downstream.

Community Responses - Byarong Creek - see Appendix A for Questionnaire Details

STREET	RESPONDANT SUBURB	OPTION AT KOLOONA AVE	OPTION AT EUROKA ST	OPTION AT WHELAN AVE	OPTION AT LANGSON AVE	OPTION AT ROY JOHANSON PARK	OPTION AT URALBA ST	OPTION AT THAMES ST	OPTION AT THAMES ST DOWNSTREAM	OPTION AT HARRY GRAHAM PK	OPTION AT ARROW AVE	OPTION AT FIGTREE PK	OPTION AT PRESTON ST	OPTION AT THE AVENUE	GENERAL COMMENTS
Langson Ave	Figtree	Note all development upstream of Koloona Ave must include adequate control of runoff.			The eastern side of creek Roy Johanson Park is higher than the W. side towards Langson Uralba junction.	The creek jumps its banks into the park. It DOES NOT bank up from the Uralba bridge, it jumps its bank 200m upstream!	Need to: (1) Lower E bank of Roy Johanson Park for flood retention; (2) Put levee along W bank above Uralba.								The work on Koloona to the Asthma pool has probably increased flow rates above Uralba. This means we will experience flood heights but for shorther periods. [Attached letter and colour photos]
Arrow Ave	Figtree									Levee bank on Harry Graham Park.	Remove the rubber tree.		Levee bank.	Levee bank.	Maintain the creek in a clean condition. [Summary of letter + photos attached]
Koloona Ave	Figtree	No mention of area near Cottonwood Ave. - See general comments.													...The pipe [under Koloona Ave] could not cope and any improvements downstream with culverts and drains could make the problem here worse than it was. We would like to see the creek alongside our house cleaned out & the bush & scrubs cut back to allow water to flow & not back up as it did. The current drainage system around Cottonwood Ave & Koloona Ave just could not cope with the amount of water that was present.
Koloona Ave	Mt Keira	Remove the bridge, or replace with a single span bridge													Have not seen much work being done since the floods and the grant, only one driveway modified and the creek cleared once.
Seddon St	Mangerton												Concern about water being redirected from Preston st causing flooding in "Ghost Creek"		"Ghost Creek" has not been included in the report
Arrow Ave	Figtree					excellent idea				detention basin is an excellent idea. For the short term leave walls should be erected to protect people in Arrow ave and Wallawa St	Upgade pipes, realign creek to increase flow into culverts			Good options, additional culverts are also required where Byrong ck goes under expressway	
Uralba st	Figtree	Replace culverts with clear span bridge.	Development controls	Control structure may be of some help d/s	bund wall is a good idea	May be a help, but would be a bit of a worry if living opposite	Main issues are flooding from Byarong creek coming up Langson Ave. Also problems with channel in Uralba St	Clean and deepen creek. Eductation about not throwing rubbish into creek		Contouring of park may help but it may make things worse	Clear span bridge over Princess Hwy	Removal of weeds, deepening and widening	Reinforced wall may be helpful, but may make things worse	Clear span bridge over creek near RSL	Byarong and American creek need weeding and maintenance
Preston St	Mangerton												Block wall defies logic and common sense	Existing culverts are undersized and not maintained, they silt up and are not cleaned out	Need to maintain the creek, the RTA should have to maintain their culverts. Increased development upstream will affect flood levels
Preston St	Mangerton											Retention basin and maintenance are both good ideas	Block wall is NOT an option, this will not help with flooding from Mt St Thomas	Create single span culvert	Any improvement further up in the system will only increase flooding around the Avenue culverts. The only option is to lift my house to a level above the floodwaters
Balook St	Mt Keira	Redesign bridge and include a detention basin.				Retention basin is a good idea				Agree with retention basin		Agree with retention basin			Realigning of the culverts at Balook St would help local flooding. Any debri control structures must be strong to account for boulders from u/s
Koloona Ave	Mt Keira	Replace culverts with a clear span bridge	Suggest detention basin		Build up west side of creek bank	Retention basin is a good idea									
The Avenue	Figtree													These culvets are undersized and need enlarging	
Koloona Ave	-	Replace culverts with a clear span bridge													This is a petition supporting all suggestions for Byarong creek with special emphasis on replacing the bridge at Koloona Ave (57 people signed the petition)

Community Responses - Charcoal Creek - see Appendix A for Questionnaire Details

RESPONDENT STREET	RESPONDENT SUBURB	OPTION AT OLD FIVE ISLANDS RD	OPTION AT PRINCES HIGHWAY	OPTION AT RICKARD RD	OPTION AT NORMANDIE PLACE	OPTION AT LINDSAY MAYNES PARK	OPTION AT TALLEGALLA ST	OPTION AT PRINCE OF WALES AVE	OPTION AT RESOLUTION DRIVE	OPTION AT MARLEY PLACE	OPTION AT UNANDERRA PARK	OPTION AT TODD PARK	OPTION AT BERKELEY RD	GENERAL COMMENTS
-	-		With all the rain we had there's been no problem with flooding since they cleaned the drains.											Council workers should clean up grass cuttings, think about how much goes down the drain and into our waterways!
Princes Hwy	Unanderra		South Creek crossing doesn't appear to be the problem. Water appears to be due to inadequate size of storm water pipes under Central Road south west of Unanderra Hotel. [see general comments]											[Princes Hwy cont...] Water builds up here the flows down Albert St, Nudjia Rd into Grace & Frazer St. If local storm water drains are already full this leads to inundation of yards and possibly homes. Ie. The water affecting homes along the highway and side streets comes from stormwater drains S\W of Central Road not from the creek crossing at the Princes Hwy.
Rickard Rd	Unanderra			Suggested options appear positive - Details needed - Improving crk conveyance at restrictive locations (widening).										Estimate fence bank reduced from 3 meters to 2 meters in past years.
O'Donnell Drive	Figtree	O'Donnell Drive + Marley Place.												My house has flooded twice. It has been proved that the drainage in the estate we live in is undersized and we now collect more water in our creek because of development up stream. To fix this problem as well as for other residents put up a retension basin in the vacant ground that BHP has and is not using and it is right next to Allans Creek which by the way BHP has neglected and is in bad need of drenching.
Albert St	Unanderra													Anything that is done, hopefully will improve the situation. Creeks and drains must be kept clean at all times. Maybe deepening of creeks would help in some circumstances.
Albert St	Unanderra										What a pathetic plan. Lower the playing fields and create a swamp. What sort of option would this be?			Sure Albert St runs a "banker" at odd times but the whole flooding problem could be minimised, if a proper effort was made to keep all waterways free from weed + shrub growth + bottle necks such as culverts modified as outline in "General Option" in newsletter. Solution to many of the problems is commitment of authorities. Money is a problem, but Councils efforts are also a problem.Eg. lack of street cleaning, condition of underground pipes, etc.
Rickard Rd	Unanderra			We have lived here for 26 years. The road has flooded on a few occasions before, but now with all the development on the escarpment it has become more frequent.										The creek has only been cleaned twice in 26 years. The opening to the street drainage pipe over our back fence is always overgrown. There are piles of cut trees on the opposite back that have been there for 2 years... There is a walkway which crosses the creek and is impassable after rain...
Hurt Pde	Unanderra	I think a lot more could be done wuth the drainage system.												During heavy downpours the water runs down Hurt Pde but before it can reach the drain, it enters our property down the driveway. I feel that if more drains could be located south of our property, less water would enter our property. (Suggest house raising)
Rickard Rd	Unanderra			Requires regular cleaning out, bank stabilisation/gabling required due to increase erosion of bank.		See Rickard Rd.	See Rickard Rd.							Due to urbanisation of Coachwood Park the amount of water running through the creek has increased with one problem noted above and the second is that the road way (bridges) over Blackman Pde are constructed of pipes reducing the flow of water and should it become blocked flooding Rickard Road is the end result. A single span roadway (bridge) would reduce the problem along with gabling of the banks and bed of the creek, also pipe work are exposed.
-	-													

Community Responses - Charcoal Creek - see Appendix A for Questionnaire Details

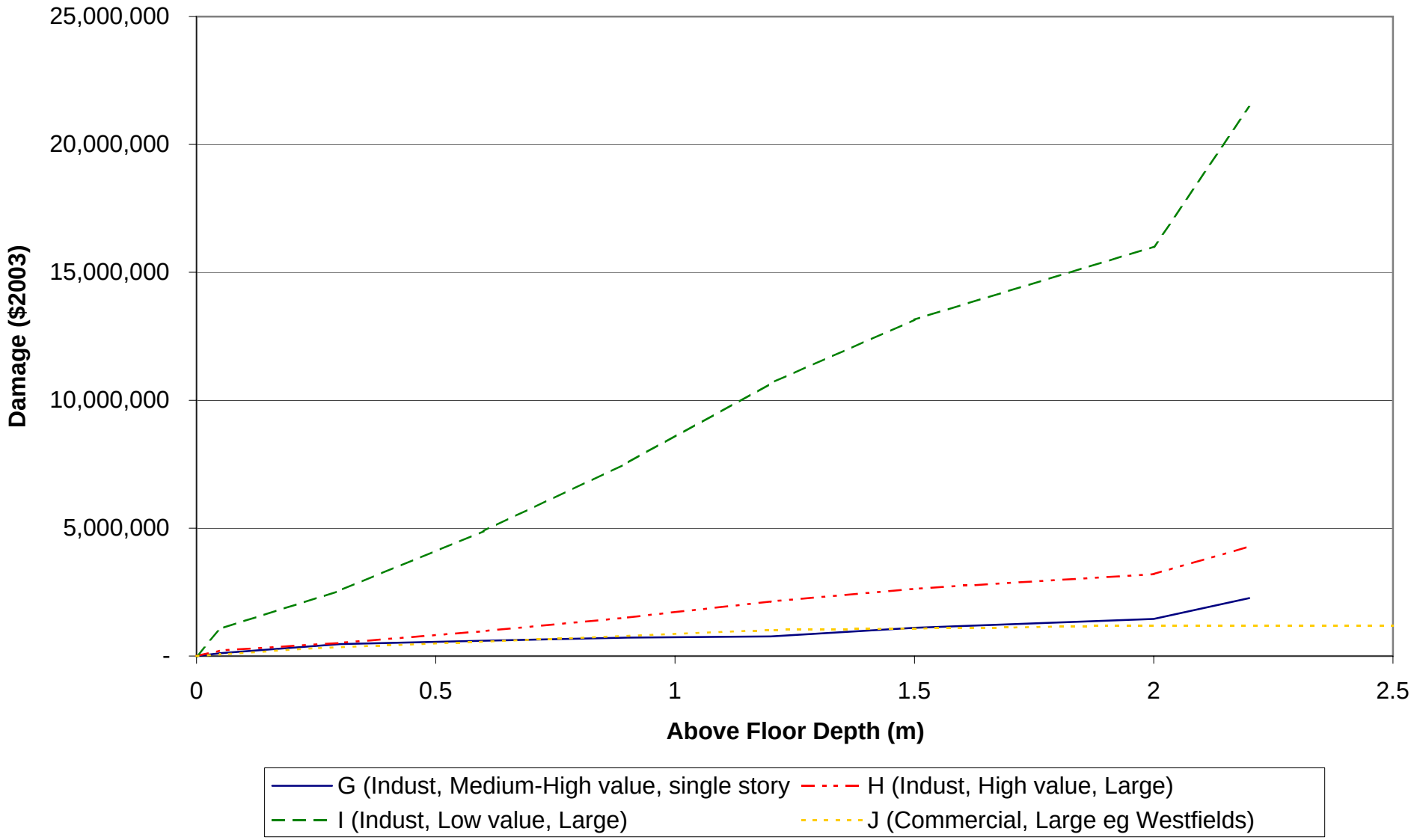
RESPONDENT STREET	RESPONDENT SUBURB	OPTION AT OLD FIVE ISLANDS RD	OPTION AT PRINCES HIGHWAY	OPTION AT RICKARD RD	OPTION AT NORMANDIE PLACE	OPTION AT LINDSAY MAYNES PARK	OPTION AT TALLEGALLA ST	OPTION AT PRINCE OF WALES AVE	OPTION AT RESOLUTION DRIVE	OPTION AT MARLEY PLACE	OPTION AT UNANDERRA PARK	OPTION AT TODD PARK	OPTION AT BERKELEY RD	GENERAL COMMENTS
Normandie Pl	Unanderra		Provide more culverts at Princes Hwy.				Elevate footbridge.							Street culverts are too low at creek bed. Charcoal Creek is more important than Allan's Creek. Clean and remove debris that blocks Charcoal Creek and culverts. [summary of attached letter]
Normandie Pl	Unanderra				Clean all shrubs and rubbish out of creek.									
Tannery St	Unanderra													The creek needs to be maintained, the weeds removed and planted with natives. Includes suggested methods and species for planting
Normandie Pl	Unanderra				Upgrade the culverts under the Princess Hwy. The local drain from Normandie Pl is too low and restricts the flow of water, resulting in localised flooding		Evauation of footbridge is necessary							

All Floodplain Risk Management Options for Allans Creek Floodplain Risk Management Study					
Identifier	**Category of Measure**	**Creek**	**Locality**	**Type of Measure**	**Details**
FM1	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Pipe outlet realignment	Stormwater inflow pipe realignment on left bank upstream of Koloona Avenue
FM2	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment
FM3	*Flood Modification*	Byarong	Upstream of Koloona Avenue, Mt Keira	Creek Works	Bank regrading and stabilisation, removal of exotic tree species and general weed removal and control
FM4	*Flood Modification*	Byarong	Park on left bank Upstream of Koloona Avenue, Mt Keira	Detention Basin	Contouring park to form an offline dry detention area
FM5	*Flood Modification*	Byarong	Koloona Avenue, Mt Keira	Bridge Alteration	Replacement of piered bridge with clear span bridge
FM6	*Flood Modification*	Byarong	Koloona Avenue, Mt Keira	Creation of a cul-de-sac	Removal of bridge altogether
FM7	*Flood Modification*	Byarong	Langson Avenue, West Wollongong	Levee Embankment	Remove rear fences along flood affected properties and construct a flood wall through Roy Johanson Park down to Uralba Street
FM8	*Flood Modification*	Byarong	Upstream of Whelan Avenue	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment
FM9	*Flood Modification*	Byarong	Uralba Street, West Wollongong	Culvert Enhancement	Twin box culvert to replace existing single pipe. A tributary of Byarong Creek approaches Uralba Street in a lined open channel which is piped underground beneath Uralba Street to an outlet at the rear of properties in Risley Street.
FM10	*Flood Modification*	Byarong	Uralba Street, West Wollongong	Easement Creation	Voluntary purchase or creation of an easement to provide an overland flow path that does not pass through properties.
FM11	*Flood Modification*	Byarong	Roy Johanson Park	Detention Basin	Contouring park to form a dry detention area
FM12	*Flood Modification*	Byarong	Footbridge near rear of Lindsay Park Public School, Thames Street, West Wollongong	Replacement of bridge with new clear span footbridge with higher obvert elevation	Footbridge causes backwater flooding
FM13	*Flood Modification*	Byarong	Rear of Properties just upstream of Lindsay Park Public School, Thames Street, West Wollongong	Levee Embankment	Byarong Creek is restricted near the rear of the public school and flooding of properties upstream could be reduced by the placement of a levee bank along the rear of those properties.
FM14	*Flood Modification*	Byarong	Harry Graham Park	Lowering of playing fields to form a detention area	Contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas
FM15	*Flood Modification*	Byarong	Princes Highway Bridge, Byarong Creek	Bridge Improvements and Upstream Creek Modification works	Improvements of flow entry to bridge, placing a debris control structure upstream in Harry Graham Park, modification of creek system at rear of Arrow Avenue Properties
FM16	*Flood Modification*	Byarong	Arrow Avenue/Bellevue Road	Stormwater Drainage and Overland flow path modifications	Additional stormwater system amplification in the area (Bellevue Street and downstream)
FM17	*Flood Modification*	Byarong	Figtree Park	Detention Basin	Contouring park to form a detention area
FM18	*Flood Modification*	Byarong	Channel Between Princes Hwy and The Avenue	Channel Widening	Increasing the width of the channel and regrading and rehabilitating the banks to increase conveyance
FM19	*Flood Modification*	Byarong/Ghost Creek	Preston Avenue, Mangerton, Seddon Street, Mangerton	Levee Embankment with stormwater relief	Construction of a Reinforced block wall along the rear of properties adjacent to the creek with stormwater drainage through the wall with tidal flaps for local catchment runoff.
FM20	*Flood Modification*	Byarong	The Avenue, Figtree	Bridge Construction	Replacement of culverts with a clear span bridge
FM21	*Flood Modification*	Byarong	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis
FM22	*Flood Modification*	American	Mt Kembla Park (u/s of Stones Road), Mt Kembla	Retarding Basin	Lowering of playing fields to form retarding basin offline of main creek
FM23	*Flood Modification*	American	Upstream of Cordeaux Road	Debris Control Structure(s)	Pole structures to control debris before it arrives at Railway , which when overtopped results in ballast being washed away
FM24	*Flood Modification*	American	Along length in Upper Reaches	Creek rehabilitation works	Weed removal, bank regrading and stabilisation
FM25	*Flood Modification*	American	Govett Crescent, Figtree	Levee Embankment	Levee to prevent flow from creek entering Govett Crescent via upstream (western) end
FM26	*Flood Modification*	American	Govett Crescent, Figtree	Tide flaps on stormwater outlets.	Placing tidal flaps on the three stormwater pipes adjacent to Govett Crescent also to prevent flood flows in American Creek entering the local drainage system and surcharging into the street
FM27	*Flood Modification*	American	Suttor Place, Figtree	Access alteration	Replacing accessway across the floodplain (Suttor Place) with bridge/culverts
FM28	*Flood Modification*	American	Between Gibsons Road and Suttor Place, Figtree	Flood bypass channel	Riparian Corridor Creation and Flood Bypass Channel via lowering the left bank of American Creek by approximately 1 m over a creek line distance of 260 m
FM29	*Flood Modification*	American/Brandy and Water	Between O'Briens Road and Creek, Figtree	Retarding Basin	Retarding basin on Brandy and Water Creek, upstream of confluence with American Creek
FM30	*Flood Modification*	American	Between Gibsons Road and Princes Highway	Creek rehabilitation works	Works upstream of the junction of American Creek and Brandy and Water Creek to improve the riparian zone, Bank regrading and stabilisation, removal of exotic tree species and general weed removal and control
FM31	*Flood Modification*	American	O'Briens Road, Figtree	Culvert Amplification	Amplification of the culvert under O'Briens Road to American Creek (Near No 40)
FM32	*Flood Modification*	American	Footbridge from O'Briens Road to Figtree High School Oval	Elevation of clear span footbridge	Elevating the footbridge near the school to reduce the chance of blockage
FM33	*Flood Modification*	American	Properties on Princes Highway adjacent to Figtree High School Oval	Levee Embankment	Earth mound levee to prevent backwater flooding from Princes Highway culvert entering rear of properties adjacent to High School oval
FM34	*Flood Modification*	American	Figtree Caravan Park	Access Road Culvert Amplification	Increase size of culvert under entrance to Figtree Caravan Park

Identifier	Category of Measure	Creek	Locality	Type of Measure	Details
FM35	*Flood Modification*	Allans	O'Donnell Drive/Cobblers Park	Ring levee	A combined earth wall and/or reinforced block fence around all properties in this area
FM36	*Flood Modification*	American/Byarong	Sid Parrish Park/Lysaght Oval	Retarding Basin	Contouring of park area to form a detention area
FM37	*Flood Modification*	American	Between Lysaght Oval and Freeway Bypass	Formalise channel for flow	Currently there is no formal channel and the flow passes overland
FM38	*Flood Modification*	American/Byarong	Between The Avenue and Freeway	Creek rehabilitation works	Creek works between Lysaght Oval and the Freeway
FM39	*Flood Modification*	Byarong	Freeway	Culverts under Freeway and Freeway On-Ramp	Duplication of existing culverts in association with a debris control structure to reduce the risk of blockage
FM40	*Flood Modification*	Branch	Branch Avenue	Creek rehabilitation works	Weed removal, bank regrading and stabilisation, replanting with native trees
FM41	*Flood Modification*	American	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis
FM42	*Flood Modification*	Charcoal	Charcoal Creek near Waples Road	Flood detention basin	Detention basin within reserve running through Farmborough Grove Retirement Village
FM43	*Flood Modification*	Charcoal	Between Blackman Pde and Tallegalla Street	Creek rehabilitation works	Bank regrading, removal of weeds and landscaping
FM44	*Flood Modification*	Charcoal	Between Blackman Pde and Normandie Place	Flood bypass channel	Construction of a flood bypass channel redirecting flow between Blackman Pde and Normandie Place to Lindsay Maynes park. Redirection of flow across Lindsay Maynes Park to Jenkins Creek
FM45	*Flood Modification*	Charcoal	Princes Highway rear Factory Road Intersection	Bridge modifications	Upgrading the Princes Highway Bridge
FM46	*Flood Modification*	Charcoal	Between d/s of Lindsay Maynes Park and Upstream of Railway, Unanderra	Creek rehabilitation works	Reduction of roughness will assist in reducing flood levels in this area
FM47	*Flood Modification*	Charcoal	Lindsay Maynes Park	Flood detention basin	Contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas
FM48	*Flood Modification*	Charcoal	Between Tallegalla Street and Princes Highway, Unanderra	Creek rehabilitation works, flood detention area and debris control structure.	Reduction of roughness and lowering of ground levels in this natural detention area will increase storage. Will require some form of levee on the upstream side near Tallegalla Road
FM49	*Flood Modification*	Charcoal	Tallegalla Street Footbridge, Unanderra	Elevation of clear span footbridge	Footbridge blocks with debris causing backwater flooding
FM50	*Flood Modification*	Freeway	Berkeley Road	Culvert Amplification	Upgrading the Berkeley road culverts and improving inlet works
FM51	*Flood Modification*	Unanderra	Unanderra Park	Detention Basin	Lowering of playing fields to form retarding basin offline of main creek
FM52	*Flood Modification*	Cummins	Todd Park	Detention Basin	Lowering of playing fields to form retarding basin offline of main creek
FM53	*Flood Modification*	Freeway/Industrial Area	Just upstream of Berkeley Road	Maintenance of flood detention area	An existing flood detention area lies within the industrial area - the function of this area should not be compromised by placement of goods by industrial property occupants within the area to reduce the storage area along with regular general maintenance of the flood detention area
FM54	*Flood Modification*	Charcoal	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis
FM55	*Flood Modification*	American	Culverts under F6 Freeway	Bridge Construction	Construction of a bridge in association with a debris control structure to reduce the risk of blockage
FM56	*Flood Modification*	American	Upstream of Princes Highway Bridge	Debris Control Structure	Poles across creek to catch large debris washed from upper catchment
FM57	*Flood Modification*	Freeway/Industrial Area	Unanderra Industrial area – Upstream of Berkeley Road (two crossings)	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment
FM58	*Flood Modification*	Byarong	Upstream of The Avenue	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment
FM59	*Flood Modification*	Byarong	Freeway	Median Strip Removal	Removal of median mound to allow flow passage over Freeway
FM60	*Flood Modification*	American Creek	Upstream of Alukea Road Culverts	Debris Control Structure(s)	Poles across flowpath to catch large debris washed from upper catchment
FM61	*Flood Modification*	Byarong Creek	Vicinity of Casuarina Place and Whelan/Coronata Intersection	Ring levee	A combined earth wall and reinforced block fence around properties in this area
FM62	*Flood Modification*	American Creek	Baker Crescent	Levee	A small levee to prevent flow ingress to properties just upstream of culvert
FM63	*Flood Modification*	Byarong Creek	Immediately Upstream of Koloona Avenue	Flood storage area	Lowering of land following voluntary purchase of property
FM64	*Flood Modification*	Byarong Creek	Immediately Downstream of Koloona Avenue	Flood storage area	Lowering of land following voluntary purchase of property
FM65	*Flood Modification*	Byarong Creek	Left bank of Creek in Vicinity of Casuarina Place and Euroka Street	Flood storage area	Lowering of land to allow for additional flood storage
FM66	*Flood Modification*	Brandy and Water	West Bank	Floodplain Lowering	Lowering of the west bank of Brandy and Water Creek to reduce overfloor flooding in the properties along Darrah Drive

Identifier	Category of Measure	Creek	Locality	Type of Measure	Details
PM1	*Property Modification*	Entire Floodplain	NA	Updating of Draft DCP54 with Development Control Matrix for Allans Creek	See Report
PM2	*Property Modification*	Entire Floodplain	NA	Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure	See Report
PM3	*Property Modification*	Entire Floodplain	NA	House Raising Program	See Report
PM4	*Property Modification*	Entire Floodplain	NA	Voluntary Purchase Program	See Report
PM5	*Property Modification*	Entire Floodplain	NA	Provision of a Flood Refuge within the Figtree Gardens Caravan Park	See Report
PM6	*Property Modification*	Entire Floodplain	NA	Detailed Investigation of Possible Zoning Modifications	See Report
PM7	*Property Modification*	Entire Floodplain	NA	Revision of Section 149(5) Certificate Wording	See Report
PM8	*Property Modification*	Entire Floodplain	NA	Adapt Towradgi Creek Flood Certificate for Allans Creek	See Report
PM9	*Property Modification*	Entire Floodplain	NA	Caravan Park/Manufactured Home Estate Policy	See Report
PM10	*Property Modification*	Entire Floodplain	NA	Cumulative Impact Study and Review of On-Site Detention Policy	See Report
PM11	*Property Modification*	Entire Floodplain	NA	Data Collection Strategies – Installation of Maximum Height Indicators, Rainfall Gauge(s), Relocation of Byarong Creek Water Level Recorder and Installation of Additional Water Level Recorders	See Report
PM12	*Property Modification*	Entire Floodplain	NA	Collection of Data Following Flood Events	See Report
PM13	*Property Modification*	Entire Floodplain	NA	Public Awareness and Education for Property matters (Creek Maintenance in Private Property)	See Report
PM14	*Property Modification*	Entire Floodplain	Darragh Drive, Stockwell Place, Booreea Road, Gibsons Roa	Collection of addition property survey	See Report
EM1	*Emergency Response Modification*	Entire Floodplain	NA	Periodic Revision Of Displan/Flood Sub Plan	See Report
EM2	*Emergency Response Modification*	Entire Floodplain	NA	Preliminary Assessments for the establishment of a Trial SMS Service	See Report
EM3	*Emergency Response Modification*	Entire Floodplain	NA	Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system)	See Report
EM4	*Emergency Response Modification*	Entire Floodplain	NA	Relocation Of Combat Agency Headquarters (Police)	See Report
EM5	*Emergency Response Modification*	Entire Floodplain	NA	Electronic Information Transfer Agreement For Council Held Information To SES	See Report
EM6	*Emergency Response Modification*	Entire Floodplain	NA	Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES	See Report
EM7	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness and Education - Locality Based Floodsafe Brochure	See Report
EM8	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Fridge Magnets	See Report
EM9	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Annual Remembrance Day (17th August)	See Report
EM10	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Schools Package	See Report

Industrial Damage Curves - Unprepared



LAWSON TRELOAR
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1 September 2006

Allans Creek Floodplain Risk Management Study

FIGURE D2
Adopted Industrial Damage Curves
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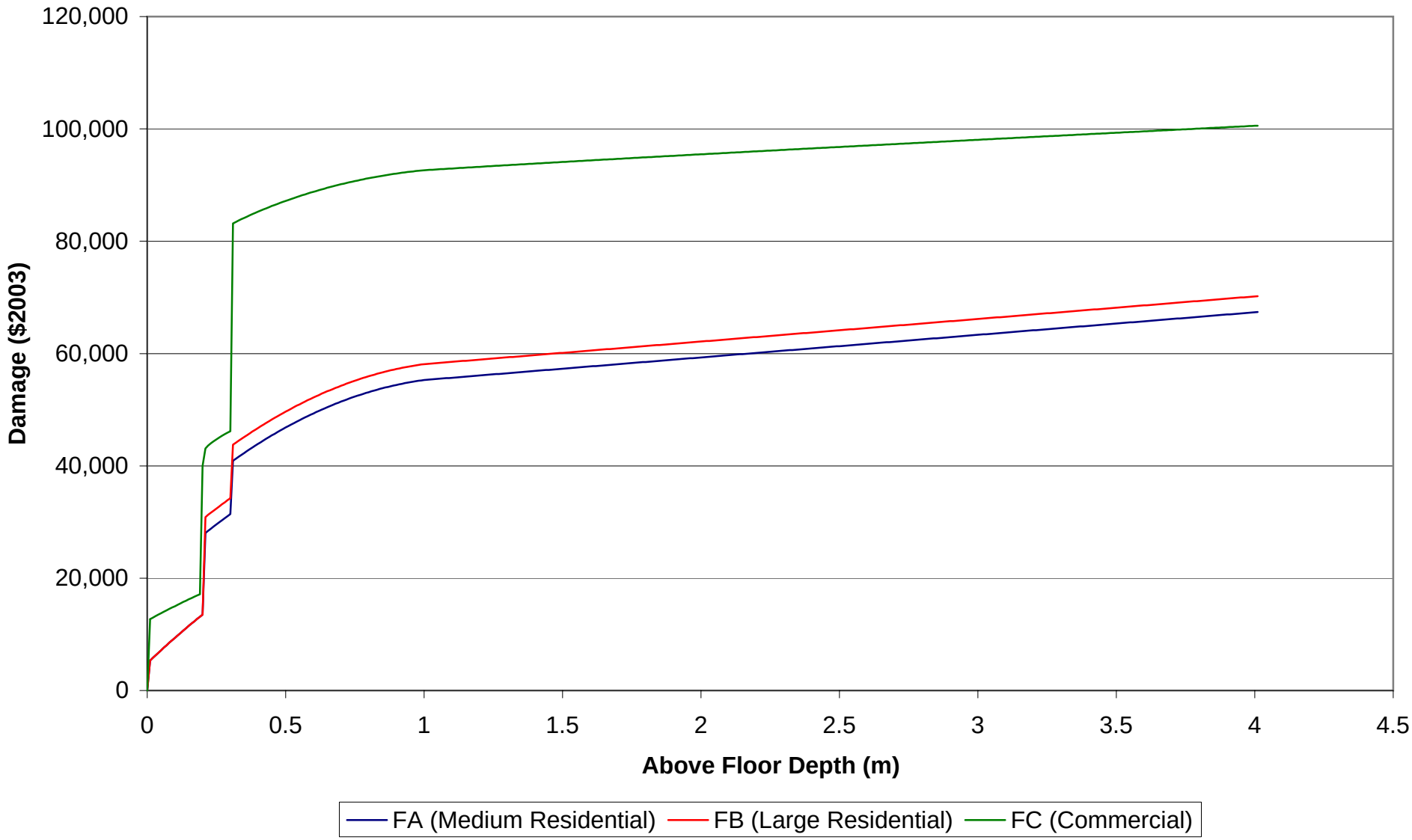
Residential and Commercial Damage Curves - Unprepared



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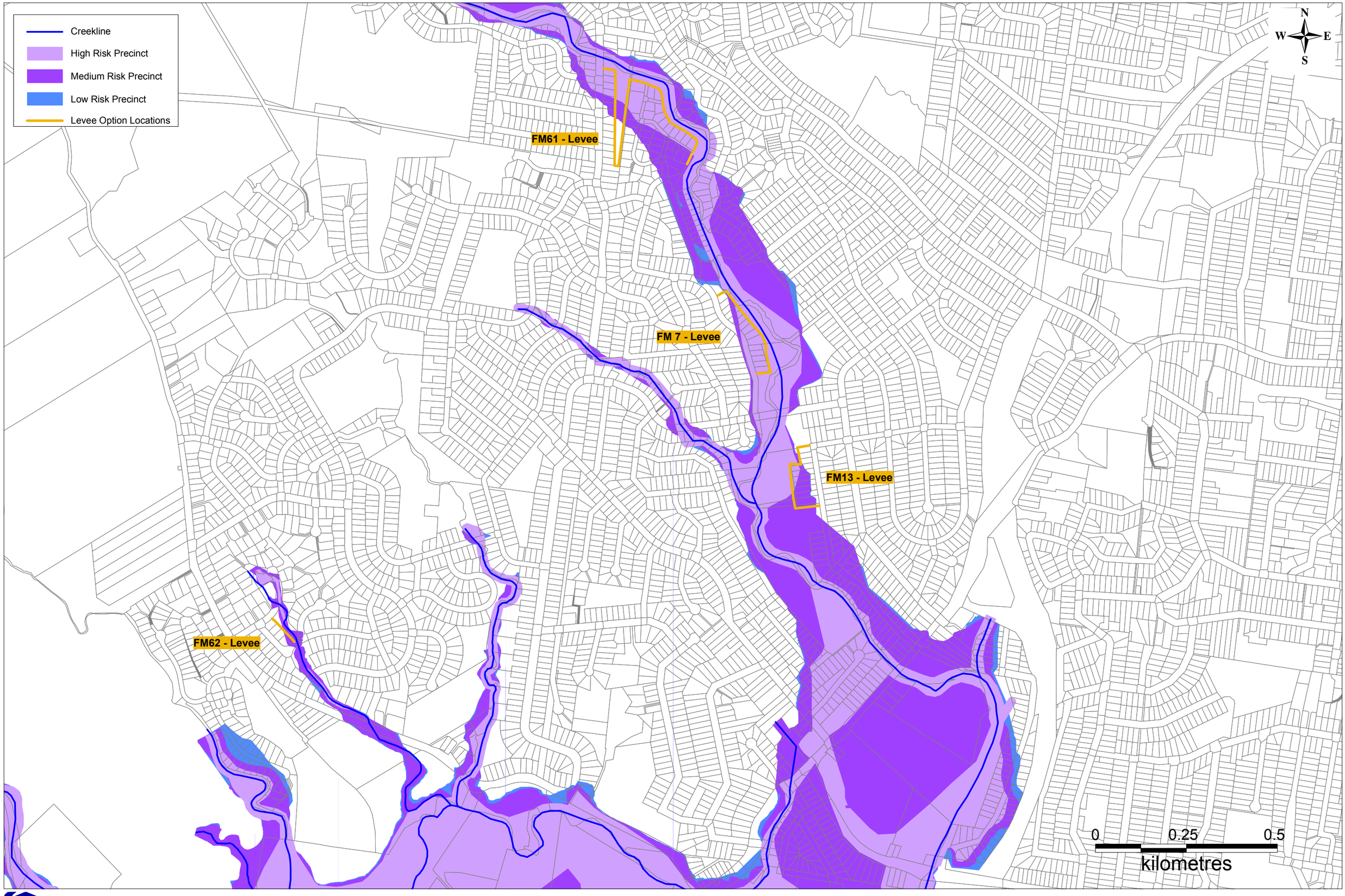
1 September 2006

Allans Creek Floodplain Risk Management Study

FIGURE D1
Adopted Residential and Commercial Damage Curves
J:\WR\J1946\Figures 2006\Floodplain Risk Management Study Figures V6\Appendix D Damage Curves.xls



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1 September 2006

Allans Creek Floodplain Risk Management Study

APPENDIX E - General Outline of Levee Options - North

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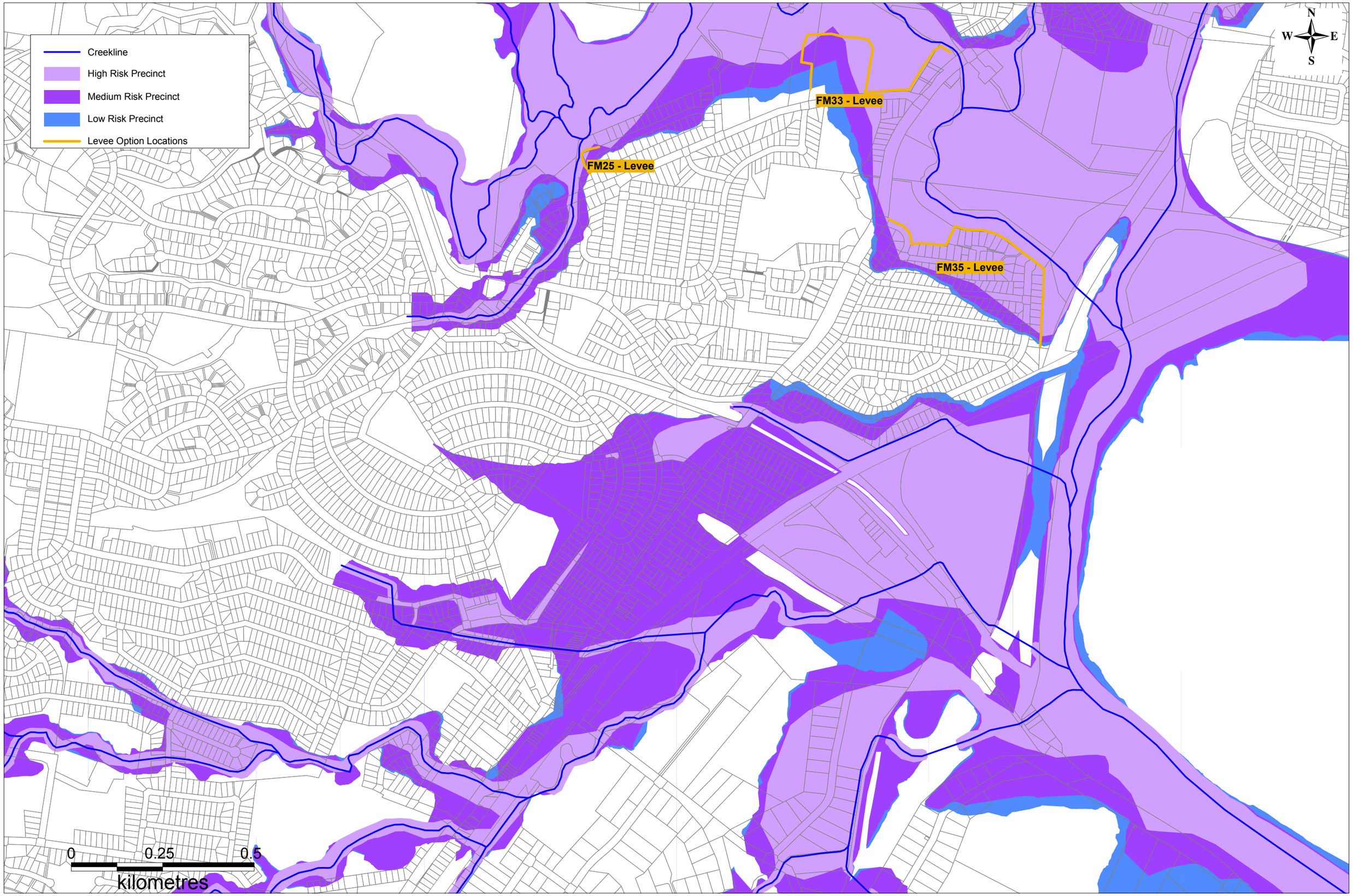

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1 September 2006

Allans Creek Floodplain Risk Management Study

APPENDIX E - General Outline of Levee Options - South

J:\WR\J1946\Figures 2006\Floodplain Risk Management Study Figures V6\Appendix E Southern Levee Options.Wor

Preliminary Costing of Floodplain Management Option

OPTION 1 American Creek F6 Bridge Construction

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	200,000	1	$ 200,000
2	Survey, Geotech Investigations etc	Item	50,000	1	$ 50,000
3	Detailed Design	Item	150,000	1	$ 150,000
4	Review of Environmental Factors	Item	50,000	1	$ 50,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	5,000	1	$ 5,000
7	Erosion and Sediment Control Works	Item	20,000	1	$ 20,000
8	Site Clearing	m^2	9	6,000	$ 51,000
9	Flow diversions/coffer dams	Item	10000	1	$ 10,000
10	Traffic Management	Item	300,000	1	$ 300,000
11	Excavation	m^3	70	30,000	$ 2,100,000
12	Demolition of existing culvert	Item	400000	1	$ 400,000
13	Bridge Construction	m^2	2250	2000	$ 4,500,000
14	Pavement (including contra-flow and drainage)	m^2	400	2000	$ 800,000
15	Kerb and gutter	m	40	240	$ 9,600
16	Handrails	m	66	120	$ 7,920
17	Revegetate/Landscape	m^2	20	3,000	$ 60,000
18	Disestablish Site	Item	2,000	1	$ 2,000
	GST (10%)				**$ 872,052**
	Contingency (20%)				**$ 1,918,514**
	Total				**$ 11,511,086**
				Say	**$ 11,550,000**

Preliminary Costing of Floodplain Management Option

OPTION 2 Amplification of Structures - Byarong Creek - The Avenue to the F6 On-Ramp

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	200,000	1	$ 200,000
2	Survey, Geotech Investigations etc	Item	50,000	1	$ 50,000
3	Detailed Design	Item	200,000	1	$ 200,000
4	Review of Environmental Factors	Item	75,000	1	$ 75,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	3	$ 6,000
7	Erosion and Sediment Control Works	Item	5,000	3	$ 15,000
8	Revegetate/Landscape	m^2	20	5,000	$ 100,000
9	Disestablish Sites	unit	2,000	3	$ 6,000
The Avenue					
10.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
10.2	Traffic Management	Item	30,000	1	$ 30,000
10.3	Excavation	m^3	70	300	$ 21,000
10.4	Bridge Construction	m^2	2,250	1000	$ 2,250,000
10.5	Temporary works for support	Item	10,000	1	$ 10,000
10.6	Surfacing and line marking	m^2	24	900	$ 21,600
10.7	Kerb and gutter	m	36	100	$ 3,637
10.8	Footpath	m^2	40	150	$ 6,000
10.9	Handrails	m	66	100	$ 6,600
				Subtotal	$ 2,353,837
F6 Freeway (Byarong Creek)					
11.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
11.2	Traffic Management	Item	300,000	1	$ 300,000
11.3	Excavation	m^3	70	7,000	$ 490,000
11.4	Bridge Construction	m^2	2,250	3500	$ 7,875,000
11.5	Temporary works for support	Item	10,000	1	$ 10,000
11.6	Laying of pavement on road	m^2	24	1200	$ 28,800
11.7	Kerb and gutter	m	36	100	$ 3,637
11.8	Handrails	m	66	100	$ 6,600
					$ 8,719,037
F6 Offramp (Byarong Creek)					
12.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
12.2	Traffic Management	Item	50,000	1	$ 50,000
12.3	Excavation	m^3	55	300	$ 16,500
12.4	Bridge Construction	m^2	2,250	900	$ 2,025,000
12.5	Temporary works for support	Item	10,000	1	$ 10,000
12.6	Laying of pavement on road	m^2	24	900	$ 21,600
12.7	Kerb and gutter	m	36	100	$ 3,637
12.8	Handrails	m	66	100	$ 6,600
					$ 2,138,337
	GST				$ 1,386,821
	Contingency 20%				$ 2,773,642
	Total				**$ 18,028,674**
				Say	**$ 18,050,000**

Preliminary Costing of Floodplain Management Option

OPTION 3 Creek Modification and Debris Control Construction

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	100,000	1	$ 100,000
2	Survey, Geotech Investigations etc	Item	100,000	1	$ 100,000
3	Detailed Design	Item	100,000	1	$ 100,000
4	Review of Environmental Factors	Item	50,000	1	$ 50,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	10,000	3	$ 30,000
7	Erosion and Sediment Control Works	Item	200,000	1	$ 200,000
8	Site Clearing	m^2	9	145,800	$ 1,312,200
9	Excavation	m^3	70	500	$ 35,000
10	Excavate Berkeley Road culverts	m^3	70	500	$ 35,000
11	Remove existing culverts	m^3	140	200	$ 28,000
12	Install culverts greater than 1.5m Diagonal	Item	20,000	8	$ 160,000
14	Revegetate/Landscape	m^2	20	145,800	$ 2,916,000
15	Construct Debris Control Structure	per pole	300	50	$ 15,000
16	Disestablish Site	Item	5,000	1	$ 5,000
	GST (10%)				$ 509,120
	Contingency (20%)				$ 1,018,240
	Total				**$ 6,618,560**
				Say	**$ 6,650,000**

Preliminary Costing of Floodplain Management Option

OPTION 4 Elevation of Lindsay Park Footbridge

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	15,000	1	$ 15,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Detailed Design	Item	10,000	1	$ 10,000
4	Review of Environmental Factors	Item	5,000	1	$ 5,000
5	Permits	Item	2,000	1	$ 2,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	1	$ 2,000
7	Erosion and Sediment Control Works	Item	5,000	1	$ 5,000
8	Vegetation Clearing	m^2	9	500	$ 4,500
9	Existing Bridge Demolition/Disposal	m^3	200	10	$ 2,000
10	Excavation	m^3	70	100	$ 7,000
11	End Support Construction	Item	20,000	2	$ 40,000
12	Raising of Bridge	Item	100,000	1	$ 100,000
13	Revegetate/Landscape	m^2	20	500	$ 10,000
14	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 21,450
	Contingency (20%)				$ 42,900
					$ 278,850
				Say	**$ 300,000**

Preliminary Costing of Floodplain Management Option

OPTION 6 Elevation of Tallegalla Street Footbridge

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	15,000	1	$ 15,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Detailed Design	Item	10,000	1	$ 10,000
4	Review of Environmental Factors	Item	5,000	1	$ 5,000
5	Permits	Item	2,000	1	$ 2,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	1	$ 2,000
7	Erosion and Sediment Control Works	Item	5,000	1	$ 5,000
8	Vegetation Clearing	m^2	9	500	$ 4,500
9	Existing Bridge Demolition/Disposal	Item	50,000	1	$ 50,000
10	Excavation	m^3	70	20	$ 1,400
11	End Support Construction	Item	20,000	1	$ 20,000
12	Construction of Bridge	m^2	2,000	150	$ 300,000
13	Revegetate/Landscape	m^2	20	500	$ 10,000
14	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 43,690
	Contingency (20%)				$ 87,380
	Total				**$ 567,970**
				Say	**$ 600,000**

Preliminary Costing of Floodplain Management Option

OPTION 5 Park Excavation to Form Detention Basins

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	20,000	8	$ 160,000
2	Survey, Geotech Investigations etc	Item	10,000	8	$ 80,000
3	Detailed Design	Item	12,000	8	$ 96,000
4	Review of Environmental Factors	Item	5,000	8	$ 40,000
5	Permits	Item	2,000	8	$ 16,000
6	Site Establishment (Fencing/Office/amenities)	Item	3,000	3	$ 9,000
7	Erosion and Sediment Control Works	Item	5,000	8	$ 40,000
8	Excavation/ Disposal	m^3	70	160,000	$ 11,200,000
9	Revegetate/Landscape	m^2	10	125000	$ 1,250,000
10	Disestablish Site	unit	2,000	3	$ 6,000
	GST (10%)				$ 1,289,700
	Contingency (20%)				$ 2,579,400
	Total				**$ 16,766,100**
			Say		**$ 16,800,000**
			Approx/site		**$ 2,100,000**

Preliminary Costing of Floodplain Management Option

OPTION 7 Koloona Avenue Culvert Enhancement

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	30,000	1	$ 30,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Detailed Design	Item	40,000	1	$ 40,000
4	Review of Environmental Factors	Item	10,000	1	$ 10,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	3,000	1	$ 3,000
7	Erosion and Sediment Control Works	Item	5,000	1	$ 5,000
8	Demolition existing culverts	m^3	140	50	$ 7,000
9	Excavation	m^3	70	20	$ 1,400
10	Bridge Construction	m^2	2,000	375	$ 750,000
11	Temporary Road Diversions	Unit	5,000	1	$ 5,000
12	Laying of pavement on road	m^2	24	180	$ 4,320
13	Kerb and gutters	m	36	90	$ 3,273
14	Handrail	m	66	60	$ 3,960
15	Temporary works for support	Unit	5,000	1	$ 5,000
16	Revegetate/Landscape	m^2	20	100	$ 2,000
17	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 88,695
	Contingency (20%)				$ 177,391
	Total				**$ 1,153,039**
				Say	**$ 1,200,000**

Preliminary Costing of Floodplain Management Option

OPTION 8 Amplification of Culverts from the Princes Highway to the F6 On-Ramp incorporating Creek Modification and Median Removal

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	200,000	1	$ 200,000
2	Survey, Geotech Investigations etc	Item	50,000	1	$ 50,000
3	Detailed Design	Item	200,000	1	$ 200,000
4	Review of Environmental Factors	Item	75,000	1	$ 75,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	3	$ 6,000
7	Erosion and Sediment Control Works	Item	5,000	3	$ 15,000
8	Disestablish Sites	unit	2,000	3	$ 6,000
9	Creek Excavation	m^3	70	40,000	$ 2,800,000
10	Turf	m^2	10	25,000	$ 250,000
Princes Highway					
11.1	Excavation	m^3	70	300	$ 21,000
11.2	Stabilisation of Entry and Exit	Item	50,000	1	$ 50,000
11.3	Revegetation	Item	10,000	1	$ 10,000
					$ 81,000
The Avenue					
12.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
12.2	Traffic Management	Item	30,000	1	$ 30,000
12.3	Excavation	m^3	70	300	$ 21,000
12.4	Bridge Construction	m^2	2,250	1000	$ 2,250,000
12.5	Temporary works for support	Item	10,000	1	$ 10,000
12.6	Surfacing and line marking	m^2	24	900	$ 21,600
12.7	Kerb and gutter	m	36	100	$ 3,637
12.8	Footpath	m^2	40	150	$ 6,000
12.9	Handrails	m	66	100	$ 6,600
					$ 2,353,837
F6 Freeway (Byarong Creek)					
13.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
13.2	Traffic Management	Item	300,000	1	$ 300,000
13.3	Excavation	m^3	70	7,000	$ 490,000
13.4	Bridge Construction	m^2	2,250	3500	$ 7,875,000
13.5	Temporary works for support	Item	10,000	1	$ 10,000
13.6	Laying of pavement on road	m^2	24	1200	$ 28,800
13.7	Kerb and gutter	m	36	100	$ 3,637
13.8	Handrails	m	66	100	$ 6,600
					$ 8,719,037
F6 Offramp (Byarong Creek)					
14.1	Flow diversions/coffer dams	Item	5,000	1	$ 5,000
14.2	Traffic Management	Item	50,000	1	$ 50,000
14.3	Excavation	m^3	70	300	$ 21,000
14.4	Bridge Construction	m^2	2,250	900	$ 2,025,000
14.5	Temporary works for support	Item	10,000	1	$ 10,000
14.6	Laying of pavement on road	m^2	24	900	$ 21,600
14.7	Kerb and gutter	m	36	100	$ 3,637
14.8	Handrails	m	66	100	$ 6,600
					$ 2,209,265
American Creek F6 Culvert Enhancement					
15.1	Flow diversions/coffer dams	Item	10000	1	$ 10,000
15.2	Traffic Management	Item	300,000	1	$ 300,000
15.3	Excavation	m^3	70	30,000	$ 2,100,000
15.4	Demolition of existing culvert	Item	400000	1	$ 400,000
15.5	Bridge Construction	m^2	2250	2000	$ 4,500,000
15.6	Pavement (including contra-flow and drainage)	m^2	400	2000	$ 800,000
15.7	Kerb and gutter	m	40	240	$ 9,600
15.8	Handrails	m	66	120	$ 7,920
					$ 8,127,520
Removal of Median Strip F6 Freeway					
16.1	Traffic Management	Item	50,000	1	$ 50,000
16.2	Excavation	m^3	70	1,000	$ 70,000
16.3	Turf	m^2	10	500	$ 5,000
					$ 125,000
	GST				$ 2,522,266
	Contingency 20%				$ 5,044,532
	Total				**$ 32,723,029**
				Say	**$ 33,750,000**

Preliminary Costing of Floodplain Management Options for Allans Creek Flood Study

Option 9 Flood Bypass Channel Construction - American Creek

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	10,000	1	$ 10,000
2	Survey, Geotech Investigations etc	Item	10,000	1	$ 10,000
3	Detailed Design	Item	30,000	1	$ 30,000
4	Review of Environmental Factors	Item	10,000	1	$ 10,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	3	$ 6,000
7	Erosion and Sediment Control Works	Item	10,000	1	$ 10,000
8	Site Clearing	m^2	9	19,000	$ 171,000
9	Excavation	m^3	70	19,000	$ 1,330,000
10	Revegetate/Landscape	m^2	20	19,000	$ 380,000
12	Disestablish Site	Item	5,000	1	$ 5,000
	GST (10%)				$ 196,700
	Contingency (20%)				$ 393,400
					$ 2,557,100
				Say	**$ 2,600,000**

Preliminary Costing of Floodplain Management Option

Option 10 Suttor Place Accessway Modifications

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT ($2003)
1	Project Management	Item	10,000	1	$ 10,000
2	Survey, Geotech Investigations etc	Item	5,000	1	$ 5,000
3	Detailed Design	Item	10,000	1	$ 10,000
4	Review of Environmental Factors	Item	2,000	1	$ 2,000
5	Permits	Item	2,000	1	$ 2,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	1	$ 2,000
7	Erosion and Sediment Control Works	Item	5,000	1	$ 5,000
8	Temporary Flow Diversions	m	180	20	$ 3,600
9	Excavation	m^3	70	120	$ 8,400
10	Supply and Deliver Humedeck	Item	100,000	1	$ 100,000
11	Associated foundations and supports	Item	20,000	1	$ 20,000
12	Energy dissipation works	Item	10,000	1	$ 10,000
13	Revegetate/Landscape	m^2	20	200	$ 4,000
14	Disestablish Site	unit	2,000	1	$ 2,000
	GST (10%)				$ 18,400
	Contingency (20%)				$ 36,800
	Total				**$ 239,200**
				Say	**$ 300,000**

Preliminary Costing of Floodplain Management Option

OPTION 11 **Lower Byarong and American Creek Floodplain Scheme**

ITEM	DESCRIPTION	UNIT	RATE $	QUANTITY	AMOUNT
1	Project Management	Item	200,000	1	$ 200,000
2	Survey, Geotech Investigations etc	Item	50,000	1	$ 50,000
3	Detailed Design	Item	200,000	1	$ 200,000
4	Review of Environmental Factors	Item	75,000	1	$ 75,000
5	Permits	Item	5,000	1	$ 5,000
6	Site Establishment (Fencing/Office/amenities)	Item	2,000	3	$ 6,000
7	Erosion and Sediment Control Works	Item	20,000	2	$ 40,000
8	Disestablish Sites	unit	2,000	3	$ 6,000
9	Creek Widening	m^3	50	20,000	$ 1,000,000
10	Overland Flowpath excavation	m^3	50	20,000	$ 1,000,000
11	Revegetate/Landscape (Turf only)	m^2	10	25,000	$ 250,000
12	Debris control American Creek	Item	10,000	1	$ 10,000
13	Debris control Byarong Creek	Item	10,000	1	$ 10,000
The Avenue					
14.1	Flow diversions/coffer dams	Item	5000	1	$ 5,000
14.2	Traffic Management	Item	120,000	1	$ 120,000
14.3	Excavation	m^3	70	300	$ 21,000
14.4	Bridge Construction	m^2	2250	1000	$ 2,250,000
14.5	Temporary works for support	Item	10,000	1	$ 10,000
14.6	Surfacing and line marking	m^2	24	900	$ 21,600
14.7	Kerb and gutter	m	36.37	100	$ 3,637
14.8	Footpath	m^2	40	150	$ 6,000
14.9	Handrails	m	66	100	$ 6,600
				Subtotal	$ 2,443,837
F6 Freeway					
15.1	Flow diversions/coffer dams	Item	10000	1	$ 10,000
15.2	Traffic Management	Item	300,000	1	$ 300,000
15.3	Excavation	m^3	70	30,000	$ 2,100,000
15.4	Demolition of existing culvert	Item	400000	1	$ 400,000
15.5	Bridge Construction	m^2	2250	2000	$ 4,500,000
15.6	Pavement (including contra-flow and drainage)	m^2	400	2000	$ 800,000
15.7	Kerb and gutter	m	40	240	$ 9,600
15.8	Handrails	m	66	120	$ 7,920
				Subtotal	$ 8,127,520
Voluntary Purchase					
16.1	Properties near Arrow Avenue cul-de-sac and The Avenue	house	350,000	9	$ 3,150,000
16.2	Legal and related negotiations	Item	20,000	9	$ 180,000
16.3	Demolition Costs	Item	30,000	9	$ 270,000
16.4	Vegetation/Landscaping	Item	2000	9	$ 18,000
				Subtotal	$ 3,618,000
	GST				$ 1,704,136
	Contingency 20%				$ 3,408,271
	Total				**$ 22,153,764**
				SAY	**$ 22,200,000**

Notes: *Creek rehabilitation, incoperating creek widening is applied over 1100 meters*

Multi Criteria Ranking Matrix - Options Ranked on COST:BENEFIT INDEX

										Technical Peformance	Economic Criteria	Economic Criteria	Social Criteria	Social Criteria	Environmental Criteria		Community Criteria		Authority Criteria	Authority Criteria				
Identifier	Category of Measure	Creek	Locality	Type of Measure	Details	Model Assessment or Desktop Assessment ?	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 years)	Likely Overall Hydraulic Improvement	Capital and Operating Costs	Reduction in Risk to Property	Reduction in Risk to Life	Reduction in Social Disruption	Water Quality and River Flow Objectives	Fauna/Flora	Raw Community Response	Normalised Community Attitude	Council/Agency/SES/etc	Compatible with Policies and Plans	TOTAL SCORE	RANK on TOTAL SCORE	Cost Benefit Ind	RANK on Cost Benefit Index (Lowest number indicates most inefficient option)
EM5	*Emergency Response Modification*	Entire Floodplain	NA	Electronic Information Transfer Agreement For Council Held Information To SES	See Report	Desktop Assessment	$1,000	$0	$1,000	0	2	0	1	0	0	0	*	0	1	1	5	53	200	87
EM6	*Emergency Response Modification*	Entire Floodplain	NA	Issue Of Flood Study, Floodplain Risk Management Study and Plan Reports and Laminated Flood Extent Plans To SES	See Report	Desktop Assessment	$2,000	$0	$2,000	0	2	0	1	0	0	0	*	0	1	1	5	53	400	86
PM1	*Property Modification*	Entire Floodplain	NA	Updating of DCP54 with Development Control Matrix for Allans Creek	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	1	0	0	0	0	*	0	2	1	6	37	833	84
EM1	*Emergency Response Modification*	Entire Floodplain	NA	Periodic Revision Of Displan/Flood Sub Plan	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	1	0	0	0	*	0	2	1	6	37	833	84
PM9	*Property Modification*	Entire Floodplain	NA	Caravan Park/Manufactured Home Estate Policy	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	1	1	0	0	*	0	1	0	5	53	1000	79
PM7	*Property Modification*	Entire Floodplain	NA	Revision of Section 149(5) Certificate Wording	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	1	0	0	0	*	0	1	1	5	53	1000	79
PM2	*Property Modification*	Entire Floodplain	NA	Updating Relevant Council documents to include Guidelines for Public Domain Infrastructure	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	0	0	0	0		0	2	1	5	53	1000	79
PM8	*Property Modification*	Entire Floodplain	NA	Adapt Towradgi Creek Flood Certificate for Allans Creek	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	1	0	0	0	*	0	1	1	5	53	1000	79
EM8	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Fridge Magnets	See Report	Desktop Assessment	$5,000	$0	$5,000	0	2	0	1	0	0	0	*	0	1	1	5	53	1000	79
FM1	*Flood Modification*	Byarong	Upstream of Kooloona Avenue, Mt Keira	Pipe outlet realignment	Stormwater inflow pipe realignment on left bank upstream of Koloona Avenue	Desktop Assessment	$10,000	$0	$10,000	0	2	0	0	0	1	0	75	4	1	1	9	13	1111	78
PM13	*Property Modification*	Entire Floodplain	NA	Public Awareness and Education for Property matters (Creek Maintenance in Private Property)	See Report	Desktop Assessment	$10,000	$0	$10,000	0	2	0	0	0	1	0	*	0	2	1	6	37	1667	77
FM26	*Flood Modification*	American	Govett Crescent, Figtree	Tide flaps on stormwater outlets.	stormwater pipes adjacent to Govett Crescent also to prevent flood flows in American Creek entering the local	Desktop Assessment	$5,000	$500	$11,900	0	2	0	0	0	0	0	3	1	1	1	5	53	2380	76
PM14	*Property Modification*	Entire Floodplain	Darragh Drive, Stockwell Place, Bo	Collection of addition property survey	See Report	Desktop Assessment	$10,000	$0	$10,000	0	2	0	0	0	0	0	*	0	1	1	4	72	2500	75
EM7	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Locality Based Floodsafe Brochure	See Report	Desktop Assessment	$10,000	$1,000	$23,801	0	2	0	1	0	0	0	*	0	2	1	6	37	3967	74
EM10	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Schools Package	See Report	Desktop Assessment	$15,000	$1,000	$28,801	0	2	0	1	0	0	0	*	0	1	1	5	53	5760	73
PM6	*Property Modification*	Entire Floodplain	NA	Detailed Investigation of Possible Zoning Modifications	See Report	Desktop Assessment	$30,000	$0	$30,000	0	2	1	1	1	0	0	*	0	0	0	5	53	6000	72
PM12	*Property Modification*	Entire Floodplain	NA	Collection of Data Following Flood Events	See Report	Desktop Assessment	$0	$2,000	$27,601	0	2	0	0	0	0	0	*	0	1	1	4	72	6900	71
FM62	*Flood Modification*	American Creek	Baker Crescent	Levee	A small levee to prevent flow ingress to properties just upstream of culvert	Desktop Assessment	$50,000	$500	$56,900	0	2	1	1	1	1	0	*	0	1	1	8	21	7113	70
PM10	*Property Modification*	Entire Floodplain	NA	Cumulative Impact Study and Review of On-Site Detention Policy	See Report	Desktop Assessment	$40,000	$0	$40,000	0	2	0	0	0	0	0	*	0	1	1	4	72	10000	69
FM25	*Flood Modification*	American	Govett Crescent, Figtree	Levee Embankment	Levee to prevent flow from creek entering Govett Cresecent via upstream (western) end	Desktop Assessment	$75,000	$1,000	$88,801	1	1	1	0	1	1	0	3	1	1	1	8	21	11100	68
FM53	*Flood Modification*	Freeway/Industrial Area	Just upstream of Berekely Road	Maintenance of flood detention area	An existing flood detention area lies within the industrial area - the function of this area should not be compromised by placement of goods by industrial property occupants within the area to reduce the storage area along with regular general maintenance of the flood detention area	Desktop Assessment	$0	$5,000	$69,004	0	2	1	0	0	1	0	0	0	1	1	6	37	11501	67
FM54	*Flood Modification*	Charcoal	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis	Desktop Assessment	$0	$10,000	$138,007	1	2	1	0	1	2	1	15	1	1	1	11	4	12546	66
FM2	*Flood Modification*	Byarong	Upstream of Kooloona Avenue, Mt Keira	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment	Model Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	75	4	1	1	10	6	12760	62
FM58	*Flood Modification*	Byarong	Upstream of The Avenue	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment	Desktop Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	75	4	1	1	10	6	12760	62
FM56	*Flood Modification*	American	Upstream of Princes Highway Bridge	Debris Control Structure	Poles across creek to catch large debris washed from upper catchment	Desktop Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	75	4	1	1	10	6	12760	62
FM57	*Flood Modification*	Freeway/Industrial Area	Unanderra Industrial area – Upstream of Berkeley Road (two crossings)	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment	Desktop Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	75	4	1	1	10	6	12760	62
EM9	*Emergency Response Modification*	Entire Floodplain	NA	Public Awareness And Education - Annual Remembrance Day (17th August)	See Report	Desktop Assessment	$0	$5,000	$69,004	0	2	0	1	0	0	0	*	0	1	1	5	53	13801	61
FM13	*Flood Modification*	Byarong	Rear of Properties just upstream of Lindsay Park Public School, Thames Street, West Wollongong	Levee Embankment	Byarong Creek is restricted near the rear of the public school and flooding of properties upstream could be reduced by the placement of a levee bank along the rear of those properties.	Desktop Assessment	$100,000	$1,000	$113,801	0	1	1	0	1	1	0	5	1	1	1	7	26	16257	60
FM63	*Flood Modification*	Byarong Creek	Immediately Upstream of Koloona Avenue	Flood storage area	Lowering of land following voluntary purchase of property	Desktop Assessment	$100,000	$2,000	$127,601	0	1	1	1	1	1	0	0	0	1	1	7	26	18229	59
FM23	*Flood Modification*	American	Upstream of Cordeaux Road	Debris Control Structure(s)	Pole structures to control debris before it arrives at Railway , which when overtopped results in ballast being washed away	Desktop Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	*	0	1	1	6	37	21267	57
FM60	*Flood Modification*	American Creek	Upstream of Alukea Road Culverts	Debris Control Structure(s)	Poles across flowpath to catch large debris washed from upper catchment	Desktop Assessment	$100,000	$2,000	$127,601	1	1	0	0	1	1	0	*	0	1	1	6	37	21267	57
FM33	*Flood Modification*	American	Properties on Princes Highway adjacent to Figtree High School Oval	Levee Embankment	Earth mound levee to prevent backwater flooding from Princes Highway culvert entering rear of properties adjacent to High School oval	Desktop Assessment	$100,000	$1,000	$113,801	0	1	1	0	1	1	-2	5	1	1	1	5	53	22760	56
FM59	*Flood Modification*	Byarong	Freeway	Median Strip Removal	Removal of median mound to allow flow passage over Freeway	Desktop Assessment	$125,000	$0	$125,000	1	1	1	0	0	0	0	*	0	1	1	5	53	25000	55
FM8	*Flood Modification*	Byarong	Upstream of Whelan Avenue	Debris Control Structure(s)	Poles across creek to catch large debris washed from upper catchment	Desktop Assessment	$100,000	$2,000	$127,601	-1	1	0	0	1	1	0	4	1	1	1	5	53	25520	54
PM11	*Property Modification*	Entire Floodplain	NA	Data Collection Strategies – Installation of Maximum Height Indicators, Rainfall Gauge(s), Relocation of Byarong Creek Water Level Recorder and Installation of Additional Water Level Recorders	See Report	Desktop Assessment	$40,000	$5,000	$109,004	0	2	0	0	0	0	0	*	0	1	1	4	72	27251	53
FM40	*Flood Modification*	Branch	Branch Avenue	Creek Modification works	Weed removal, bank regrading and stabilisation, replanting with native trees	Model Assessment	$200,000	$2,000	$227,601	1	1	1	0	1	2	2	-2	-2	1	1	8	21	28450	51
FM37	*Flood Modification*	American	Between Lysaght Oval and Freeway Bypass	Formalise channel for flow	Currently there is no formal channel and the flow passes overland	Desktop Assessment	$100,000	$1,000	$113,801	0	1	0	0	0	1	0	*	0	1	1	4	72	28450	51
FM24	*Flood Modification*	American	Along length in Upper Reaches	Creek Modification works	Weed removal, bank regrading and stabilisation	Model Assessment	$250,000	$2,000	$277,601	1	0	1	0	1	2	2		0	1	1	9	13	30845	50
EM3	*Emergency Response Modification*	Entire Floodplain	NA	Enhancing Existing Flood Warning Systems (using additional rainfall gauges within the ALERT system)	See Report	Desktop Assessment	$30,000	$10,000	$168,007	0	2	0	1	0	0	0	*	0	1	1	5	53	33601	48
EM2	*Emergency Response Modification*	Entire Floodplain	NA	Preliminary Assessments for the establishment of a Trial SMS Service	See Report	Desktop Assessment	$30,000	$10,000	$168,007	0	2	0	1	0	0	0	*	0	1	1	5	53	33601	48
FM7	*Flood Modification*	Byarong	Langson Avenue, West Wollongong	Levee Embankment	Remove rear fences along flood affected properties and construct a flood wall through Roy Johanson Park down to Uralba Street	Desktop Assessment	$200,000	$1,000	$213,801	0	1	1	0	1	1	0	0	0	1	1	6	37	35633	47
FM32	*Flood Modification*	American	Footbridge from O'Briens Road to Figtree High School Oval	Elevation of clear span footbridge	Elevating the footbridge near the school to reduce the chance of blockage	Desktop Assessment	$250,000	$2,000	$277,601	1	0	1	0	1	1	0	5	1	1	1	7	26	39657	46
FM46	*Flood Modification*	Charcoal	Between d/s of Lindsay Maynes Park and Upstream of Railway, Unanderra	Creek Modification works	Reduction of roughness will assist in reducing flood levels in this area	Model Assessment	$350,000	$5,000	$419,004	1	0	1	0	1	2	2	1	1	1	1	10	6	41900	45
FM12	*Flood Modification*	Byarong	Footbridge near rear of Lindsay Park Public School, Thames Street, West Wollongong	Replacement of bridge with new clear span footbridge with higher obvert elevation	Footbridge causes backwater flooding	Model Assessment	$300,000	$500	$306,900	1	0	1	0	1	1	0	5	1	1	1	7	26	43843	44
FM50	*Flood Modification*	Freeway	Berkeley Road	Culvert Amplification	Upgrading the Berkeley road culverts and improving inlet works	Desktop Assessment	$250,000	$1,000	$263,801	1	0	1	0	1	1	0	0	0	1	1	6	37	43967	43
FM4	*Flood Modification*	Byarong	Park on left bank Upstream of Kooloona Avenue, Mt Keira	Detention Basin	Contouring park to form an offline dry detention area	Model Assessment	$500,000	$2,000	$527,601	1	0	2	0	1	1	0	75	4	1	1	11	4	47964	42

Identifier	Category of Measure	Creek	Locality	Type of Measure	Details	Model Assessment or Desktop Assessment ?	Estimate of Capital Cost	Estimate of Recurrent Cost	Net Present Value (7%, 50 years)	Likely Overall Hydraulic Improvement	Capital and Operating Costs	Reduction in Risk to Property	Reduction in Risk to Life	Reduction in Social Disruption	Water Quality and River Flow Objectives	Fauna/Flora	Raw Community Response	Normalised Community Attitude	Council/Agency/SES/etc	Compatible with Policies and Plans	TOTAL SCORE	RANK on TOTAL SCORE	Cost Benefit Ind	RANK on Cost Benefit Index (Lowest number indicates most inefficient option)
FM16	*Flood Modification*	Byarong	Arrow Avenue/Bellevue Road	Stormwater Drainage and Overland flow path modifications	Additional stormwater system amplification in the area (Bellevue Street and downstream)	Desktop Assessment	$450,000	$2,000	$477,601	1	0	2	1	2	0	0	5	1	1	1	9	13	53067	41
FM21	*Flood Modification*	Byarong	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis	Desktop Assessment	$0	$50,000	$690,037	1	2	1	0	1	2	2	29	2	1	1	13	1	53080	40
FM41	*Flood Modification*	American	Entire system	Maintenance	Removal of weeds and debris from the creek on a regular basis	Desktop Assessment	$0	$50,000	$690,037	1	2	1	0	1	2	2	4	1	1	1	12	2	57503	39
FM34	*Flood Modification*	American	Figtree Caravan Park	Access Road Culvert Amplification	Increase size of culvert under entrance to Figtree Caravan Park	Desktop Assessment	$400,000	$2,000	$427,601	0	0	0	2	1	1	0	2	1	1	1	7	26	61086	38
FM10	*Flood Modification*	Byarong	Uralba Street, West Wollongong	Easement Creation	Voluntary purchase or creation of an easement to provide an overland flow path that does not pass through properties.	Desktop Assessment	$250,000	$0	$250,000	1	0	0	0	1	1	0	*	0	1	0	4	72	62500	37
FM64	*Flood Modification*	Byarong Creek	Immediately Downstream of Koloona Avenue	Flood storage area	Lowering of land following voluntary purchase of property	Desktop Assessment	$350,000	$2,000	$377,601	0	0	1	1	1	1	0	0	0	1	1	6	37	62934	36
FM27	*Flood Modification*	American	Suttor Place, Figtree	Access alteration	Replacing accessway across the floodplain (Suttor Place) with bridge/culverts	Model Assessment	$300,000	$1,000	$313,801	0	0	0	0	0	1	0	3	1	1	1	4	72	78450	35
FM3	*Flood Modification*	Byarong	Upstream of Kooloona Avenue, Mt Keira	Creek works	Bank regrading and stabilisation, removal of exotic tree species and general weed removal and control	Model Assessment	$900,000	$5,000	$969,004	1	-1	1	0	1	2	2	75	4	1	1	12	2	80750	34
FM22	*Flood Modification*	American	Mt Kembla Park (u/s of Stones Road), Mt Kembla	Retarding Basin	Lowering of playing fields to form retarding basin offline of main creek	Desktop Assessment	$500,000	$2,000	$527,601	1	0	2	0	1	1	-1	*	0	1	1	6	37	87934	33
FM5	*Property Modification*	Entire Floodplain	NA	Provision of a Flood Refuge within the Figtree Gardens Caravan Park	See Report	Desktop Assessment	$300,000	$5,000	$369,004	0	0	0	2	0	0	0	*	0	1	1	4	72	92251	32
FM48	*Flood Modification*	Charcoal	Between Tallegalla Street and Princes Highway, Unanderra	Creek Modification works and flood detention area	Reduction of roughness and lowering of ground levels in this natural detention area will increase storage. Will require some form of levee on the upstream side near Tallegalla Road	Model Assessment	$1,000,000	$2,000	$1,027,601	1	-1	2	0	1	2	2	3	1	1	1	10	6	102760	31
FM9	*Flood Modification*	Byarong	Uralba Street, West Wollongong	Culvert Enhancement	Twin box culvert to replace existing single pipe. A tributary of Byarong Creek approaches Uralba Street in a lined open channel which is piped underground beneath Uralba Street to an outlet at the rear of properties in Risley Street.	Desktop Assessment	$400,000	$1,000	$413,801	0	0	0	0	0	1	0	5	1	1	1	4	72	103450	30
FM38	*Flood Modification*	American/Byarong	Between The Avenue and Freeway	Creek Modification works	Creek works between Lysaght Oval and the Freeway	Model Assessment	$450,000	$5,000	$519,004	-1	0	-1	0	0	2	2	1	1	1	1	5	53	103801	29
FM49	*Flood Modification*	Charcoal	Tallegalla Street Footbridge, Unanderra	Elevation of clear span footbridge	Footbridge blocks with debris causing backwater flooding	Model Assessment	$600,000	$2,000	$627,601	1	-1	1	0	1	1	0	3	1	1	1	6	37	104600	28
FM45	*Flood Modification*	Charcoal	Princes Highway rear Factory Road Intersection	Bridge modifications	Upgrading the Princes Highway Bridge	Desktop Assessment	$750,000	$2,000	$777,601	1	-1	1	1	1	1	0	2	1	1	1	7	26	111086	27
FM65	*Flood Modification*	Byarong Creek	Left bank of Creek in Vicinity of Casuarina Place and Euroka Street	Flood storage area	Lowering of land to allow for additional flood storage	Desktop Assessment	$600,000	$2,000	$627,601	0	-1	1	1	1	1	0	0	0	1	1	5	53	125520	26
FM44	*Flood Modification*	Charcoal	Between Blackman Pde and Normandie Place	Flood bypass channel	Construction of a flood bypass channel redirecting flow between Blackman Pde and Normandie Place to Lindsay Maynes park , Redirection of flow across Lindsay Maynes Park to Jenkins Creek	Desktop Assessment	$500,000	$2,000	$527,601	1	0	1	0	-1	0	0	2	1	1	1	4	72	131900	24
FM31	*Flood Modification*	American	O'Briens Road, Figtree	Culvert Amplification	Amplification of the culvert under O'Briens Road to American Creek (Near No.40)	Desktop Assessment	$500,000	$2,000	$527,601	1	0	0	0	1	0	0	*	0	1	1	4	72	131900	24
FM5	*Flood Modification*	Byarong	Koloona Avenue, Mt Keira	Bridge Alteration	Replacement of piered bridge with clear span bridge	Model Assessment	$1,200,000	$3,000	$1,241,402	1	-1	1	1	1	0	0	75	4	1	1	9	13	137934	23
FM18	*Flood Modification*	Byarong	Channel Between Princes Hwy and The Avenue	Channel Widening	Increasing the width of the channel and regrading and rehabilitating the banks to increase conveyance	Model Assessment	$1,200,000	$5,000	$1,269,004	1	-1	2	0	1	1	2	9	1	1	1	9	13	141000	22
FM36	*Flood Modification*	American/Byarong	Sid Parrish Park/Lysaght Oval	Retarding Basin	Contouring of park area to form a detention area	Model Assessment	$1,000,000	$1,000	$1,013,801	1	-1	2	0	1	1	0	1	1	1	1	7	26	144829	21
FM14	*Flood Modification*	Byarong	Harry Graham Park	Lowering of playing fields to form a detention area	Contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas	Model Assessment	$1,000,000	$2,000	$1,027,601	1	-1	2	0	1	1	0	3	1	1	1	7	26	146800	19
FM11	*Flood Modification*	Byarong	Roy Johanson Park	Detention Basin	Contouring park to form a dry detention area	Model Assessment	$1,000,000	$2,000	$1,027,601	1	-1	2	0	1	1	0	6	1	1	1	7	26	146800	19
EM4	*Emergency Response Modification*	Entire Floodplain	NA	Relocation Of Combat Agency Headquarters (Police)	See Report	Desktop Assessment	$500,000	$0	$500,000	0	0	1	1	0	0	0	*	0	0	1	3	86	166667	18
FM52	*Flood Modification*	Cummins	Todd Park	Detention Basin	Lowering of playing fields to form retarding basin offline of main creek	Model Assessment	$1,000,000	$1,000	$1,013,801	1	-1	2	0	1	1	0	0	0	1	1	6	37	168967	16
FM35	*Flood Modification*	Allans	O'Donnell Drive	Ring levee	A combined earth wall and reinforced block fence around all properties in this area	Desktop Assessment	$1,000,000	$1,000	$1,013,801	0	-1	1	1	1	1	0	4	1	1	1	6	37	168967	16
FM61	*Flood Modification*	Byarong Creek	Vicinity of Casuarina Place and Whelan/Coronata Intersection	Ring levee and overland flow path definition	A combined earth wall and reinforced block fence around properties in this area	Desktop Assessment	$1,000,000	$1,000	$1,013,801	0	-1	1	1	1	1	0	*	0	1	1	5	53	202760	15
FM66	*Flood Modification*	Brandy and Water	West Bank	Floodplain Lowering	Lowering of the west bank of Brandy and Water Creek to reduce overfloor flooding in the properties along Darragh Drive	Desktop Assessment	$1,600,000	$2,000	$1,627,601	2	-1	1	1	1	0	-1	9	1	2	2	8	21	203450	14
FM43	*Flood Modification*	Charcoal	Between Blackman Pde and Tallegalla Street	Creek Modification works	Bank regrading, removal of weeds and landscaping	Model Assessment	$2,000,000	$2,000	$2,027,601	1	-1	1	0	1	2	2	1	1	1	1	9	13	225289	13
FM42	*Flood Modification*	Charcoal	Charcoal Creek near Waples Road	Flood detention basin	Detention basin within reserve running through Farmborough Grove Retirement Village	Desktop Assessment	$200,000	$2,000	$227,601	1	1	1	0	1	-1	-2	1	1	1	-2	1	87	227601	12
FM51	*Flood Modification*	Unanderra	Unanderra Park	Detention Basin	Lowering of playing fields to form retarding basin offline of main creek	Model Assessment	$1,000,000	$1,000	$1,013,801	1	-1	2	0	1	1	0	-2	-2	1	1	4	72	253450	11
FM30	*Flood Modification*	American	Between Gibsons Road and Princes Highway	Creek Modification works	Works upstream of the junction of American Creek and Brandy and Water Creek to improve the riparian zone, Bank regrading and stabilisation, removal of exotic tree species and general weed removal and control	Model Assessment	$2,300,000	$5,000	$2,369,004	1	-2	2	0	1	2	2	3	1	1	1	9	13	263223	10
FM15	*Flood Modification*	Byarong	Princes Highway Bridge, Byarong Creek	Bridge Improvements and Upstream Creek Modification works	Improvements of flow entry to bridge, placing a debris control structure upstream in Harry Graham Park, modification of creek system at rear of Arrow Avenue Properties	Desktop Assessment	$2,500,000	$5,000	$2,569,004	1	-2	1	2	2	1	0	5	1	2	1	9	13	285445	9
FM17	*Flood Modification*	Byarong	Figtree Park	Detention Basin	Contouring park to form a detention area	Model Assessment	$2,000,000	$5,000	$2,069,004	1	-1	2	1	1	0	0	9	1	1	1	7	26	295572	8
FM20	*Flood Modification*	Byarong	The Avenue, Figtree	Bridge Construction	Replacement of culverts with a clear span bridge	Model Assessment	$2,500,000	$2,000	$2,527,601	1	-2	1	1	2	1	0	12	1	2	1	8	21	315950	7
FM28	*Flood Modification*	American	Between Gibsons Road and Suttor Place, Figtree	Flood bypass channel		Model Assessment	$2,250,000	$5,000	$2,319,004	2	-2	1	0	1	1	1	3	1	1	1	7	26	331286	6
FM47	*Flood Modification*	Charcoal	Lindsay Maynes Park	Flood detention basin	Contouring of the park to form a landscaped detention area to attenuate flood flows and reduce flooding in downstream areas	Desktop Assessment	$2,000,000	$2,000	$2,027,601	1	-1	2	0	1	0	0	1	1	1	1	6	37	337934	5
PM3	*Property Modification*	Entire Floodplain	NA	House Raising Program	See Report	Desktop Assessment	$1,920,000		$1,920,000	0	-1	2	0	2	0	0	*	0	0	1	4	72	480000	4
FM55	*Flood Modification*	American	Culverts under F6 Freeway	Bridge Construction	Construction of a bridge in association with a debris control structure to reduce the risk of blockage	Model Assessment	$11,550,000	$2,000	$11,550,000	2	-2	2	2	2	0	0	0	0	2	2	10	6	1155000	3
PM4	*Property Modification*	Entire Floodplain	NA	Voluntary Purchase Program	See Report	Desktop Assessment	$7,200,000	$0	$7,200,000	0	-2	2	1	2	0	0	*	0	0	1	4	72	1800000	2
FM39	*Flood Modification*	Byarong	Freeway	Culverts under Freeway and Freeway On-Ramp	Duplication of existing culverts in association with a debris control structure to reduce the risk of blockage	Model Assessment	$11,000,000	$2,000	$11,027,601	1	-2	1	1	1	1	0	6	1	1	1	6	37	1837934	1
FM19	*Flood Modification*	Byarong/Ghost Creek	Preston Avenue, Mangerton, Seddon Street, Mangerton	Levee Embankment with stormwater relief	Construction of a Reinforced block wall along the rear of properties adjacent to the creek with stormwater drainage through the wall with tidal flaps for local catcment runoff.	Desktop Assessment	$300,000	$2,000	$327,601	0	0	1	0	1	0	0	-9	-4	1	1	0	88		#N/A
FM6	*Flood Modification*	Byarong	Kooloona Avenue, Mt Keira	Creation of a cul-de-sac	Removal of bridge altogether	Desktop Assessment	$500,000	$0	$500,000	1	0	1	1	0	0	0	-2	-2	-1	-1	-1	#N/A	-500000	#N/A
FM29	*Flood Modification*	American/Brandy and Water	Between O'Briens Road and Creek, Figtree	Retarding Basin	Retarding basin on Brandy and Water Creek, upstream of confluence with American Creek	Model Assessment	$3,000,000	$5,000	$3,069,004	-2	-2	0	0	0	-2	-2	3	1	1	-2	-8	#N/A	-383625	#N/A