Bowral
Floodplain Risk Management Study and Plan

From the Mount Gibraltar Lookout, looking southwest across Bowral and Mittagong Creek

Final Report
June 2009

Report of Wingecarribee Shire Council's
Bowral Floodplain Management Committee

Bewsher

WINGECARRIBEE SHIRE COUNCIL

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FOREWORD

In New South Wales the prime responsibility for local planning and the management of flood liable land rests with local government. To assist local government with floodplain management, the NSW Government has adopted a Flood Prone land Policy in conjunction with the *Floodplain Development Manual*.

The Policy is directed at providing solutions to existing flood problems and to ensure that new development is compatible with the flood hazard and does not create additional flood problems.

The Policy sets out four sequential stages in the development of a floodplain management plan:

1	Flood Study	- Assessment to define the nature and extent of flooding.
2	Floodplain Risk Management Study	- Comprehensive evaluation of management options with respect to existing and proposed development.
3	Floodplain Risk Management Plan	- Formal adoption by Council of a management plan for floodplain risks
4	Implementation of the Plan	- Measures undertaken to reduce the impact of flooding on existing development, and implementing controls to ensure that new development is compatible with the flood hazard.

Wingecarribee Shire Council commissioned Bewsher Consulting Pty Ltd to prepare a Flood Study, Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Plan (FRMP) for two catchments in Bowral: the main Mittagong Creek catchment and the "Beavan Place" sub-catchment. Don Fox Planning Pty Ltd contributed to the planning aspects of the investigation.

The Flood Study was initially presented in October 2004 as Working Paper No. 1. It was subsequently amended in May 2005 to incorporate the new Bowral Street Bridge. Since that work was presented in Appendix D of the Bowral FRMS&P report dated August 2005, additional modelling was done in December 2008 using new modelling software, and sensitivity tests were undertaken to assess the impact of blockage factors and climate change. A revised addendum to the original Flood Study report is found preceding the original Flood Study report in Appendix D of this report.

The majority of this FRMS&P report has not been changed from the August 2005 version. Sections that have been updated to reflect recent developments are the Executive Summary, Chapter 3 (flood study summary), a few items in Chapter 4 (Figure 4.3), Chapter 6 (planning considerations), a few items in Chapter 8 (Figure 8.8, Table 8.2, Section 8.2.4), Glossary/FAQs, Appendix E (100 year flood profiles), Table F5, Appendix H (LEP) and Appendix I (DCP). The calculation of damages, the draft FRMP and the costing of options have not been updated since the August 2005 report.

The next stage of the floodplain risk management process is for Wingecarribee Shire Council to formally adopt the draft Floodplain Risk Management Plan.

This project was conducted under the Natural Disaster Mitigation Programme and has received Commonwealth and State Government financial and technical support.

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EXECUTIVE SUMMARY

Bewsher Consulting Pty Ltd was commissioned by Wingecarribee Shire Council, in conjunction with the Department of Environment and Climate Change (DECC), to prepare a Floodplain Risk Management Study and Plan for the Mittagong Creek floodplain and one of its tributaries (draining the "Beavan Place" sub-catchment), which flow through the town of Bowral. Don Fox Planning Ltd provided specialist town planning advice for the study.

The study was overseen by the Bowral Floodplain Management Committee, which comprises Councillors and staff from Wingecarribee Shire, officers from DECC and the State Emergency Services (SES), and several community representatives.

Local drainage and stormwater overland flow were not included in the scope of the study. Therefore it is recommended that Council now undertake investigations of the local drainage and stormwater overland flow issues in Bowral.

Principal Outcomes

The principal outcomes of this study include:

- a revision of the former Flood Study, including sensitivity tests to assess the potential influence of bridge and culvert blockage and climate change on flood behaviour, leading to improved estimates of flood behaviour and maps of the estimated extent of flood inundation, for the 5 year, 10 year, 50 year, 100 year and probable maximum floods, provided in a revised document (**Appendix D** of this report);
- a map that divides the floodplain into high, medium, fringe low and low flood risk precincts (**Figure 3.1**);
- definition of the flood problem by construction of a Flood Damages Database, which quantifies flood damages and records information on potentially flood affected properties within the study area up to the PMF, including estimated or surveyed ground and floor levels, and estimated flood levels for each property (*Working Paper No. 3*);
- a review of potential floodplain management measures to reduce the potential for flood damage (**Table 8.1**), incorporating results from extensive community consultation;
- the review of existing flood-related planning controls for Bowral and preparation of a revised development control plan (DCP) for flooding (**Appendix I**); and
- a recommended Floodplain Risk Management Plan for Bowral.

The Floodplain Risk Management Plan

The Bowral Floodplain Risk Management Plan is presented in **Table 9.1** and on **Figure 9.1**. The recommended measures have been selected from a range of available measures, after an assessment of the impacts on flooding, as well as environmental, social and economic considerations.

The recommended measures have been categorised into high, medium and low priority measures, as follows:

High Priority (within 2 years)

- revised planning controls, involving amendments to Wingecarribee LEP, DCP 34 and Section 149(2) Certificates;
- improved emergency management plans, especially revision by the SES of the Wingecarribee Local Flood Plan, to include flood information derived from this study;
- improved public awareness of flood risks, by producing a Bowral FloodSafe brochure and web-site, installing flood markers in a central location, revising and regularly issuing flood certificates, and holding hazard awareness days;
- improved management of the riparian corridor, by establishing a creek maintenance program and by preparing a Mittagong Creek Riparian Corridor Management Plan to guide rehabilitation of the creek corridor in a way compatible with hydraulic, environmental and recreational objectives;
- a scoping study to gauge the support and practicability of implementing two voluntary house raising/reconstruction schemes;
- a scoping study to further investigate the feasibility of constructing a detention basin in Retford Park, especially to provide detailed ground survey;
- a scoping study to further investigate the feasibility of constructing a detention basin in Bowral Golf Course;
- if other options for the benefit of Farmborough Close are not supported, a study to better model the interaction of creek flows and overland flow in this area, to assess the suitability of a levee.

Medium Priority (within 4 years)

- contingent upon the outcomes of the scoping study, implementation of voluntary house raising/reconstruction schemes to raise 7 weatherboard/fibro houses and 7 brick houses, which are currently inundated in the 10 year flood, to levels 0.5m above the 100 year flood;
- removal of the Victoria Street Bridge, and amplification of the railway culvert north of Nerang Street;
- contingent upon the outcomes of the scoping study, construction of a large detention basin in Retford Park, to mitigate flows in Mittagong Creek;
- contingent upon the outcomes of the scoping study, construction of a small detention basin in Bowral Golf Course, to mitigate flows in the "Beavan Place" sub-catchment;
- installation of a pluviograph and possibly a stream gauge for Mittagong Creek, particularly to permit the collection of more accurate data in the catchment.

Low Priority (within 7 years)

- continuation of Council's on-site detention (OSD) policy, and promotion of Water Sensitive Urban Design (WSUD);
- preparation of flood-proofing guidelines, to encourage innovation among proprietors and residents.

Timing and Funding

The total capital cost to implement measures recommended in the Plan is $5.7M. This would yield damage savings of $3.0M, resulting in a benefit-cost ratio (BCR) of 0.5. It would reduce the number of houses flooded above floor level in the 100 year event by 43, from 76 to 33. The capital cost of the Plan without the Retford Park basin is $1.7M, yielding damage savings of $1.4M – a BCR of 0.9. This would reduce the number of houses flooded above floor level in the 100 year event by 21, from 76 to 55. The capital cost of the Plan without both the Retford Park and Bowral Golf Course basins is $1.2M, yielding damage savings of $1.1M – a BCR of 0.9. This would reduce the number of houses flooded above floor level in the 100 year event by 18, from 76 to 58.

On-going maintenance costs are estimated at $31,500 per year.

The timing of the proposed works will depend on Council's overall budgetary commitments and the availability of funds. Funding will be available through a number of sources, as identified in **Table 9.1**.

1. INTRODUCTION

1.1 OBJECTIVES OF THIS STUDY

In October 2002, Wingecarribee Shire Council commissioned Bewsher Consulting to prepare a revised Flood Study and Floodplain Risk Management Study & Plan (FRMS&P) for the Mittagong Creek floodplain, which flows through the town of Bowral in the NSW Southern Highlands. The study area was extended in May 2004 to include the "Beavan Place" sub-catchment, a left bank tributary of Mittagong Creek. At that time, it was agreed to change the name of the Study from the "Mittagong Rivulet" FRMS&P to the "Bowral" FRMS&P, in order to reflect the broader scope of the study area. Further, it was agreed that in keeping with its official name (as documented by the Geographical Names Board of NSW), Mittagong Creek would be referred to as a creek and not as a rivulet.

The Bowral Floodplain Risk Management Study & Plan investigates what can be done to minimise the effects of flooding. Specific objectives of the study include:

- a revision of an earlier flood study;
- quantification of the flood problem in Bowral;
- assessment of potential floodplain management measures to address the problem; and
- the development of a recommended Floodplain Risk Management Plan for the Bowral area, outlining the best measures to reduce flood damage, based on consideration of environmental, social, economic and engineering issues.

1.2 THE STUDY AREA

The study area encompasses a substantial portion of the township of Bowral. Bowral township is located 5km off the Hume Highway, 115km south-west of Sydney. The town is situated within the Wingecarribee Local Government Area (LGA).

The study area includes the floodplain of Mittagong Creek between Old South Road and the Wingecarribee River. It also includes the floodplain of the tributary draining the "Beavan Place" sub-catchment, which flows through Bowral Golf Course and joins Mittagong Creek downstream of the built-up area. The floodplain includes all land potentially subject to flooding up to the probable maximum flood (PMF). A map of the study area is shown in **Figure 1.1**.

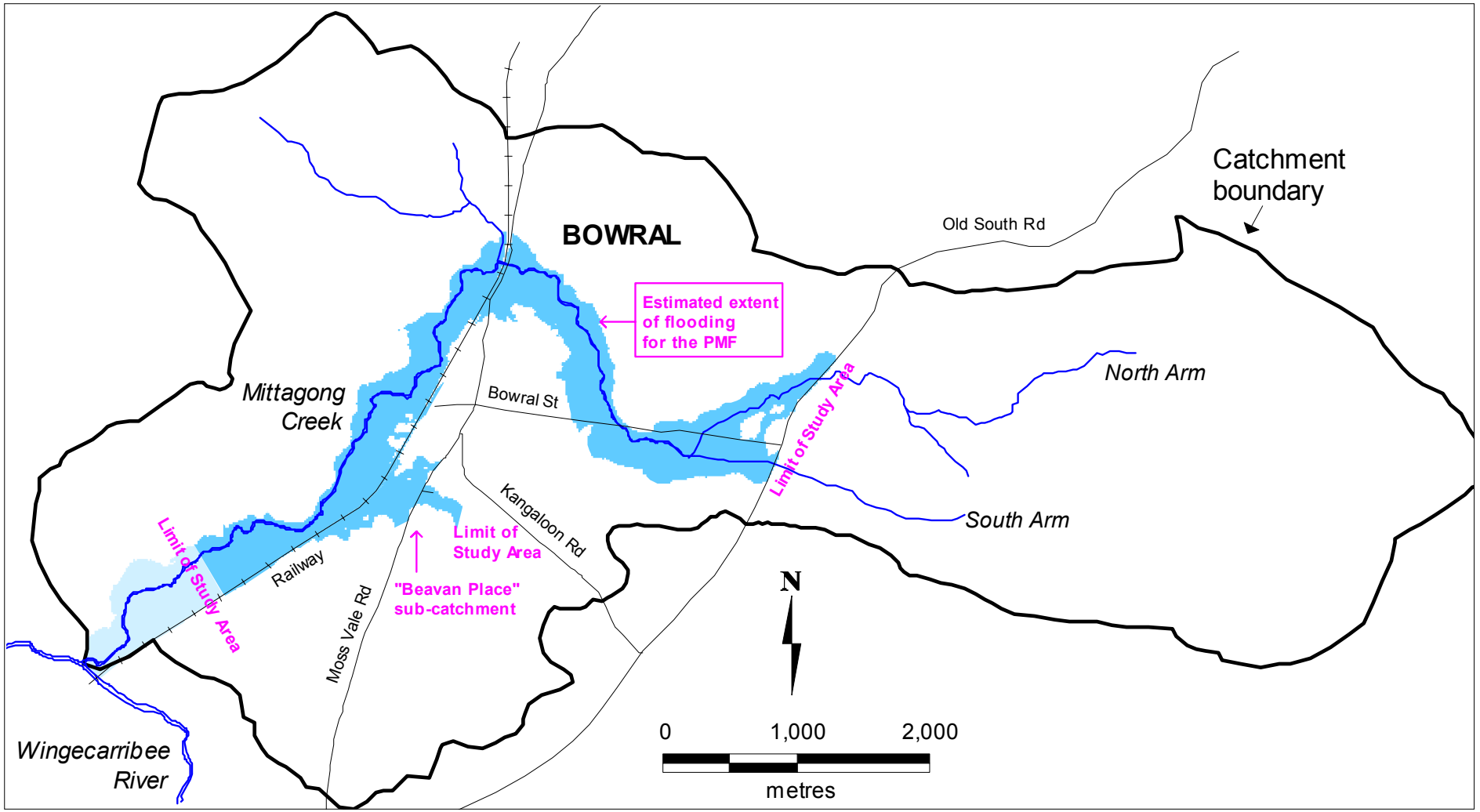


FIGURE 1.1
The Study Area

1.3 THE GOVERNMENT'S FLOODPLAIN MANAGEMENT PROCESS

The main responsibility for managing flood prone lands in NSW rests with local government. The NSW Government provides assistance on state-wide policy issues and technical support. Financial assistance is also provided to undertake flood and floodplain risk management studies, and for the implementation of works identified in these studies.

A Flood Prone Land Policy and a *Floodplain Development Manual* (NSW Government, 2005) form the basis of floodplain management in New South Wales.

The objectives of the Policy include:

< reducing the impact of flooding and flood liability on existing developed areas by flood mitigation works and measures, including ongoing emergency management measures, the raising of houses where appropriate, and by development controls; and

< reducing the potential for flood losses in all areas proposed for development or redevelopment by the application of ecologically sensitive planning and development controls.

The Policy, through Section 733 of the Local Government Act, 1993, provides some legal protection for councils and other public authorities and their staff against claims for damages resulting from their issuing advice or granting approvals on floodplains, providing they have acted substantially in accordance with the principles contained in the *Floodplain Development Manual*.

The implementation of the Flood Prone Lands Policy generally culminates in the preparation and implementation of a Floodplain Risk Management Plan, which is the ultimate objective of the current study.

The steps in the floodplain management process are summarised in **Figure 1.2**.

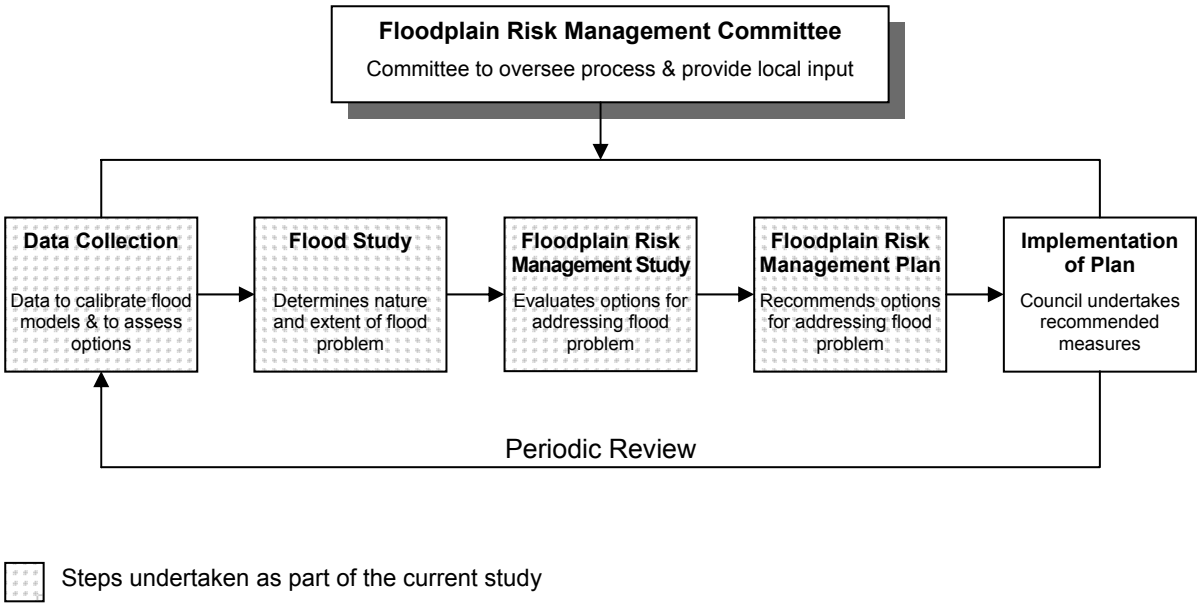


FIGURE 1.2
The Floodplain Risk Management Process

2. BACKGROUND INFORMATION

2.1 PHYSICAL DESCRIPTION

Mittagong Creek and its tributaries form the primary sources of flooding within the study area. Mittagong Creek drains a small catchment (29.8 km^2). The "Beavan Place" sub-catchment east of the railway line occupies only 1.2 km^2 of the total catchment.

A digital elevation model of the catchment is shown in **Figure 2.1**. This indicates that the catchment is moderately steep, with Bowral town situated 180 to 200 metres below the Mt Gibraltar lookout (863m). The catchment consequently responds rapidly to rainfall.

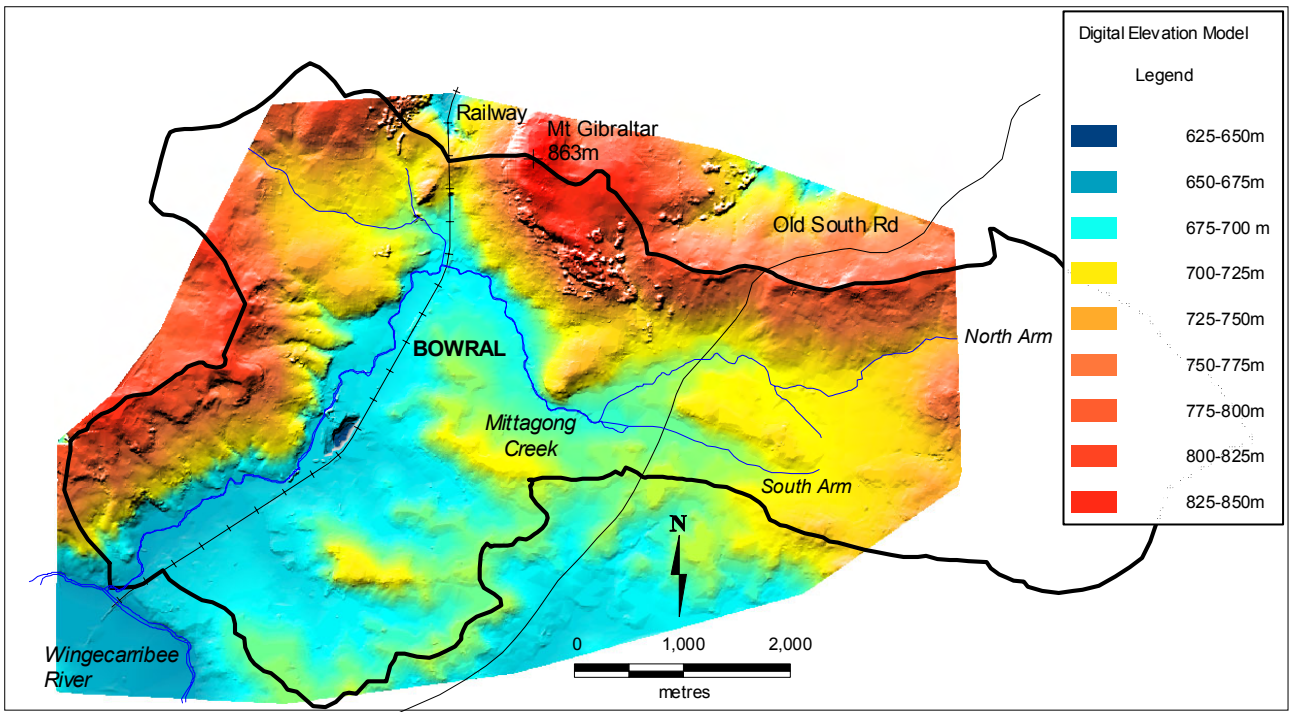


FIGURE 2.1
Digital Elevation Model, Mittagong Creek Catchment

For the most part, the topography, together with the street pattern, is favourable for evacuation purposes. The land rises consistently away from the creek banks and the orientation of properties and streets generally allow for evacuation simply by walking uphill away from the creek to land outside of the floodplain. Distances required to travel to evacuate from the floodplain are no more than about 300m, even in the largest possible flood. One area from which evacuation may be hazardous in a large flood is Farmborough Close, with residents first having to traverse lower-lying ground towards the eastern end of the street. Another potentially problematic area is Kiama Street, on the western side of the railway. In a probable maximum flood (PMF) event, residents at the southern end of the street would have to travel a distance of about a kilometre to reach dry ground near the railway bridge, since no other high ground is readily accessible.

2.2 SOCIAL ISSUES

An understanding of population characteristics is an important consideration of floodplain risk management studies. Characteristics of the population and development trends within the study area provide an understanding of the community's values in relation to the utilisation of the floodplain.

A summary of recent Census data for Bowral (Postcode 2576) and the Wingecarribee LGA is provided in **Appendix A**. Salient points are listed below:

At the 2001 Census:

- Bowral's population was almost 11,000;
- 22% of Bowral's population was aged 65 years and over compared to 13% for NSW as a whole;
- 79% of Bowral's population was Australian-born compared to 70% for NSW as a whole;
- 97% of Bowral's population spoke English only compared to 75% for NSW as a whole;
- 45% of Bowral's population used a computer at home, and 36% used the Internet shortly before the Census; and
- 8% of Bowral's dwellings (334) had no motor vehicles.

Between 1991 and 2001:

- Wingecarribee LGA recorded 23% growth in population over 10 years (or 2% compounded annually);
- In Wingecarribee LGA, the number of 0-4 year olds and 15-24 year olds decreased, while the number of residents aged 55-64 and 65+ increased substantially, presumably bolstered by an influx of retirees (55% and 53% growth over 10 years, respectively) (see **Figure 2.2**);
- Wingecarribee LGA's median age increased from 32 to 38, pointing to the aging population;
- In Wingecarribee LGA, the number of people not in the labour force increased by 27% over 10 years;
- The number of occupied private dwellings in Wingecarribee LGA increased by 32%, with most of the increase accommodated in separate houses; and
- The proportion of households owning or purchasing a dwelling in Wingecarribee LGA increased by 3% while the proportion renting decreased by 8%.

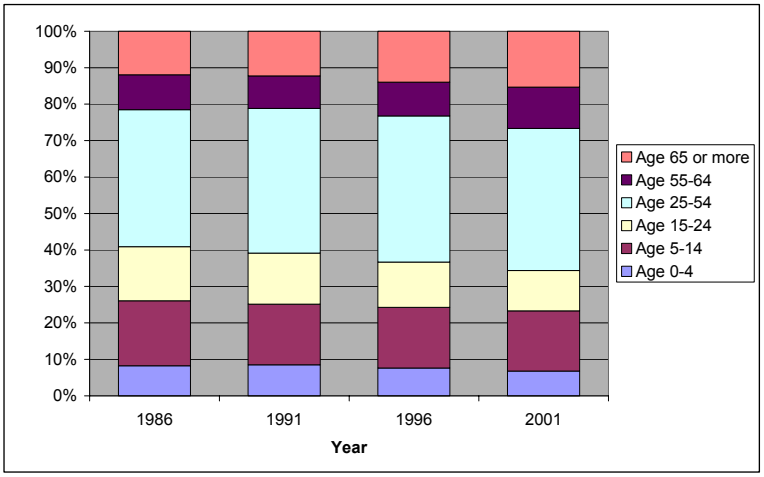
Bowral's social profile has a number of implications for this floodplain risk management study:

(a) A significant proportion of the growth being experienced in Wingecarribee LGA is believed to be occurring in and around the town of Bowral. This growth in housing has been occurring both on "greenfield" sites such as East Bowral as well as via the medium density redevelopment of large residential lots in "Old" Bowral. It is apparent that some flood-liable land has already been redeveloped with medium density housing, and it is understood that there is considerable pressure for more development in flood-liable locations. There is, then, a tension between the benefits of development and the risk to people and property situated in flood-liable locations. Care must be taken to avoid the unnecessary sterilisation of land in Bowral, land which is highly sought after for the betterment of the local community.

(b) Bowral has a high proportion of residents aged 65 and over, who are likely to be less capable of evacuating before severe flooding. Eight per cent of Bowral's residents have no motor vehicle. Clearly, the SES needs to be mindful of this high degree of dependency when formulating the Local Flood Plan, specifically when planning evacuation for rare but severe floods. Further, households with the main income earner in the older age group may be at a stage of life where the ability to financially recover from flood damages and losses would be more difficult.

(c) Bowral has a very high proportion of English speakers, suggesting that the use of English in any flood education initiatives such as brochures or signs would be adequate. The Internet is an easy means of reaching up to 36% of the community.

FIGURE 2.2
Changing Age Structure, Wingecarribee LGA, 1986-1991-1996-2001



2.3 CULTURAL AND HERITAGE ISSUES

An understanding of Bowral's culture and heritage is important for ensuring that any recommended floodplain management measures are sympathetic to sensitive sites.

The first land grant in the Bowral District was made to the explorer John Oxley in 1823. The land was subdivided in the late 1850s to take advantage of the proposed railway line. Bowral town was established in 1861, and a municipality was declared in 1886. Today, Bowral is the commercial centre of the Southern Highlands.

A search of the State Heritage Inventory in November 2004 yielded 84 records for Bowral and 20 for Burradoo. These addresses have been checked according to a map of the floodplain. The following heritage properties are situated on land liable to flooding, although in most cases the risk of flooding is low (rarer than the 100 year event):

- Bowral Fire Station, 16 Merrigang Street, Bowral
- Bradman Oval and Collection of Cricket Memorabilia, Glebe Street, Bowral
- Bradman's Cottage, 20 Glebe Street, Bowral
- Cottage, 52 Shepherd Street, Bowral (another Bradman residence)
- Retford Park, Old South Road, Bowral

Others addresses on the heritage inventory found to be just beyond the range of the PMF are:

- Bowral Railway Station Group (cottage, platform buildings, overbridge)
- Cottage, 23 Shepherd Street, Bowral
- Laurel House, 47 Merrigang Street, Bowral

Obviously, none of the houses on the heritage list would be suitable for voluntary house purchase or voluntary house raising schemes, even if other criteria such as flood risk were favourable for such schemes. The existence of heritage buildings may also affect the nature of infill development. For example, an insistence upon higher floor levels would make it difficult to integrate new buildings in a manner visually sympathetic with surrounding heritage buildings.

2.4 VEGETATION ISSUES

An analysis of the vegetation within the study area is important for the following three reasons:

- To provide an understanding of the ecological characteristics and value of vegetation within the study area in order that floodplain management decisions are sympathetic to conservation values and, where appropriate, take advantage of the opportunities provided by existing vegetation to form open space areas and linkages;
- To ensure that any flood mitigation measures, in particular structural measures, are not fundamentally unacceptable due to their potential impact upon important vegetation areas; and
- To provide a basis for the removal of exotic vegetation or weed species from the river corridor, to improve the river hydraulics (and provide other ecological benefits) which may reduce flood levels or prevent the redirection of the flow path of floodwaters.

A map of native vegetation communities in the Mittagong Creek catchment is provided in **Figure 2.3** (adapted from a GIS layer provided by Council, believed to be derived from Eco Logical Australia, 2003). This figure indicates that the floodplain downstream of Old South Road has been cleared of native vegetation, with the exception of a few patches of the "Southern Highlands Shale Woodland" community, which is listed as an Endangered Ecological Community under the *Threatened Species Conservation Act 1995*.

Instead of native vegetation communities, the creek corridor was until recently infested with exotic plants (especially willow). Recognising the need for rehabilitation, the Bowral community has embarked upon a program to remove exotic species and replant various native species. Mittagong Urban Landcare Group was formed in about 1996, and Bowral Urban Landcare Group in 2000, with the objective of rehabilitating Mittagong Creek from its then degraded state. The extensive activities undertaken by these groups are summarised well in **Appendix B**, which contains an excerpt from *Riparian Management Guidelines for the Wollondilly and Wingecarribee Rivers* (Crawford and Lewis, 2002). Funding has been received from Wingecarribee Shire Council, Wollondilly Catchment Management Committee, the Sydney Catchment Authority (SCA) and DECC. Much of the area upstream of the railway line has been rehabilitated (though weed control has been hampered in cases where private householders own land to the creek bank), but willow infestation is still problematic in some areas downstream of the railway (e.g., Willow Road to 83-85 Kirkham Road). Maintenance is also required to prevent willow regrowth.

It is beyond the scope of this study to provide a detailed vegetation management strategy, but it recommended that such a strategy be prepared to ensure that management of the riverine corridor satisfies the various hydraulic, ecological, recreational and aesthetic objectives. Close liaison is required between Council, DECC, SCA, local Landcare groups, and residents. The objectives of a vegetation management strategy should include the following:

(a) To remove exotic plant species from the creek corridor to improve the hydraulic function of the creek.

(b) To provide for the rehabilitation of the creek corridor with endemic plant species which are tolerant of riverine conditions.

(c) To create an environment which is sympathetic to the ecology of the creek and, in particular, fauna habitat.

(d) To create a rehabilitated creek corridor which allows for access by the general community for recreation and education.

(e) To ensure that the potential for soil erosion and destabilisation of the creek banks is addressed by providing for the managed and staged rehabilitation of the creek.

In addition to the above objectives, it will eventually be desirable for Council and other relevant authorities to consider the management of the overall catchment area as point source rehabilitation is difficult without changes in the whole catchment. That is, the problem associated with weed infestation will ultimately need to be addressed with respect to the upper and lower creek areas, as well as that section of the creek in the township precinct.

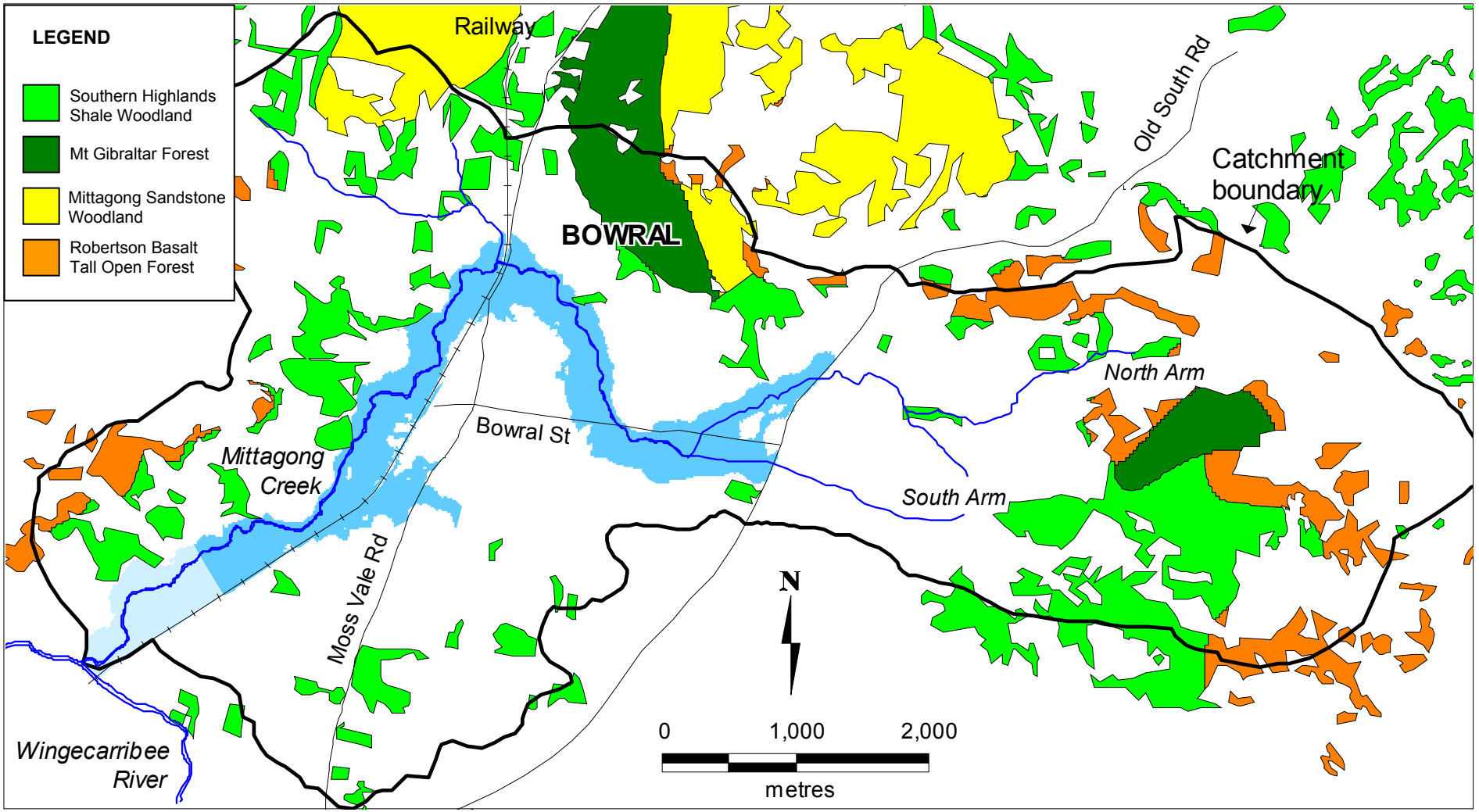


FIGURE 2.3
Vegetation Communities in the Mittagong Creek Catchment

3. EXISTING FLOOD BEHAVIOUR

The text in this chapter was revised in April 2009.

3.1 HISTORY OF FLOODING

Mittagong Creek has a history of flooding. Records of floods are sparse, but floods are known to have occurred in:

- March 1893 (a record daily rainfall for Bowral Post Office of 303mm was recorded on 6th March, with 182mm of this falling from 8.30 a.m. to 1 p.m. on Sunday 5th March, the great bulk of which fell in 2½ hours from 10.30 a.m. to 1 p.m.; this exceeds expected intensities for the 100 year ARI event; newspaper reports in **Appendix C** indicate that severe flooding was experienced, partly caused by the collapse of three private dams; several bridges and handrails were washed away; a good deal of debris was mobilised including willow trees, fences, tubs and furniture; several houses were flooded requiring rescues and there were a number of "narrow escapes");
- 1915 (an early photo shows flooding in Shepherd Street);
- March 1975;
- March 1978 (including Beavan Place);
- November 1985 (Beavan Place);
- August 1986;
- April 1988; and
- October 1999.

A photographic record of flooding has been compiled in **Appendix C**, based partly on material provided by the Berrima District Historical Society.

Interestingly, the revised Flood Study indicates that the 1988 and 1999 floods, with peak discharges at Mittagong Road of 66 and 63 m^3/s respectively, are more frequent than the 5 year ARI event, which has a discharge of 83 m^3/s.[1] This suggests that the residents of Bowral have not experienced genuinely serious flooding for many years.

3.2 REVISED FLOOD STUDY

Development of a flood model for the Mittagong Creek catchment is described in detail in **Appendix D**. This reproduces *Working Paper No. 1 – Revision of Flood Study* (October 2004) and contains a *Flood Study Addendum* (April 2009) describing modelling conducted in May 2005 to assess the influence on flood levels of the new Bowral Street Bridge (then under construction) and modelling conducted in December 2008 using a new version of software to assess the sensitivity of the flood regime to the blockage of structures and to climate change.

The flood model defines existing flood behaviour and provides a basis for assessing floodplain management measures. The flood model is comprised of a hydrologic model (RAFTS, Version 2000 6.12) and a hydraulic model (TUFLOW; the Mittagong Creek model originally used Build 2003-07-BA, which was revised in December 2008 to Build 2008-08-AD-ISP; the Beavan Place model used Build 2004-06-AC).

[1] Assessment based on October 2004 model run. Mittagong Road Bridge is represented by Node 1.14 – Tables 1 and 5, **Appendix D**.

The *hydrologic* model determines the runoff resulting from a particular rainfall event. The primary outputs from the model are hydrographs at various locations along the waterway to describe the quantity, rate and timing of stream flow that results from rainfall events. The model covers the entire catchment.

The *hydraulic* model simulates the movement of floodwaters through the waterway reaches, storage elements and hydraulic structures. The model calculates flood levels and flow patterns and also models the complex effects of backwater, roughness, overtopping of embankments, waterway confluences, bridge constructions and other hydraulic structures across the study area. Two hydraulic models were developed for this study: the first for Mittagong Creek from just upstream of its confluence with the Wingecarribee River to where the Main (North) Arm and the South Arm cross Old South Road; the second for the Beavan Place sub-catchment located east of the railway (see **Figure 3.1**).

The hydrologic and hydraulic models were calibrated to historical flood events to demonstrate the validity of the models. The April 1988 flood model yielded a very good fit with observed flood levels. The October 1999 flood model yielded a good fit with observed flood levels.

Following the successful reproduction of the April 1988 and October 1999 flood events, the design 5 year, 10 year, 50 year and 100 year average recurrence interval (ARI) events and the probable maximum flood (PMF) were modelled. (Only the 100 year ARI flood and PMF were remodelled in December 2008). Design floods are hypothetical floods used for floodplain management studies. They are modelled by applying design rainfall totals which are derived from *Australian Rainfall and Runoff* (2000). Critical durations (storm durations found to yield the highest flood levels) were 9 hours for the main Mittagong Creek catchment and 2 hours for the Beavan Place sub-catchment. Flood levels in the Wingecarribee River were estimated by extending the hydraulic model developed for the Berrima Flood Study – these function as the downstream boundary condition for the Mittagong Creek model. The design flood model reflects ultimate development conditions throughout the catchment based on full development in accordance with current landuse zonings.

In recent years, there has been growing recognition of the influence of bridge and culvert blockage on flood behaviour. The influence of blockage was assessed in the *Flood Study Addendum* (**Appendix D**). Given the potential for blockage along Mittagong Creek and the limited opportunities available to mitigate the blockage, the blockage assumptions used in both the 2005 and 2008 modelling, and which were the recommendation of Council's Floodplain Management Committee during the Bowral FRMS&P, were endorsed.

In recent years, there has also been growing recognition of the potential influence of climate change on flood behaviour. This was assessed for Mittagong Creek through a sensitivity test reported in the *Flood Study Addendum* (**Appendix D**). Increasing the rainfall intensity would naturally lead to an increase in flood levels. Nevertheless, in view of the forthcoming improvements to rainfall intensity-frequency-duration (IFD) data and to projections of changed rainfall intensities with climate change, it is recommended that a decision regarding the inclusion of a climate change flood risk allowance in setting Flood Planning Levels (FPLs) be deferred.

Appendix D includes inundation maps for the 1988 and 1999 floods, as well as the 5 year, 10 year, 50 year, 100 year and PMF design floods. Electronic copies of the detailed model outputs have been supplied to Council for incorporation into its Geographical Information System (GIS).

Appendix E shows long profiles of the 100 year ARI flood level, comparing the December 2008 model run to the previous 1990 Mittagong Rivulet Flood Study (WSC, 1990). On average, from Old South Road to Oxley Hill Road Bridge, the 100 year flood levels derived from the current study are about 0.3m higher than the levels derived from the HEC-RAS modelling used in the earlier study. However, the difference in 100 year flood levels in the creek adjacent to Farmborough Close is about 0.4-0.5m.

3.3 FLOOD RISK PRECINCTS

Different parts of the floodplain are subject to different degrees of hazard and flood risk. In keeping with the floodplain planning principles adopted for the Berrima Floodplain Risk Management Study & Plan (Bewsher Consulting, 2002), this study recognises that different development controls should apply to different flood risk areas, or precincts.

For Bowral, following release of the 2007 Flood Planning Guideline (**Section 6.6**), it was decided to add a fourth flood risk precinct to the previously proposed "High", "Medium" and "Low" – the "Fringe Low" flood risk precinct. The flood risk precincts are mapped in **Figure 3.1**. The flood risk precincts are:

High Flood Risk	Land below the 100 year ARI flood level that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties. In this precinct, there would be substantial risks of damage to property, which could not be feasibly or reasonably managed with flood related building and planning controls.
Medium Flood Risk	Land below the 100 year ARI flood level that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct, flood related building and planning controls can be reasonably and feasibly employed to minimise flood damage to property.
Fringe Low Flood Risk	Land above the 100 year ARI flood level but not more than 0.5m above it. In this precinct, properties are still within the freeboard of 0.5m which Council normally includes when setting minimum floor levels in order to minimise flood damage to property.
Low Flood Risk	Land with a low probability of flooding lying above a level 0.5m above the 100 year ARI flood and below the probable maximum flood (PMF). In this precinct, the risk of damages is low for most land uses.

The high flood risk precinct is where high flood damages, potential risk to life, or evacuation problems are anticipated. Most development should be restricted in this precinct.

The medium flood risk precinct is generally where there is still a significant risk of flood damage, but where these damages can be minimised by the application of appropriate development controls.

The fringe low flood risk precinct is the area just above the 100 year ARI flood level, where appropriate development controls would still be applied to minimise flood damages.

The low flood risk precinct is the area more than 0.5m in elevation above the 100 year flood, but below the level of the probable maximum flood (PMF), where the risk of damage is low. Most land uses would be permitted within this precinct.

FIGURE 3.1 - BOWRAL FLOOD RISK PRECINCTS

LEGEND

High Flood Risk Precinct
Land below the 100 year ARI flood that is either subject to a high hydraulic hazard or where there are significant evacuation difficulties

Medium Flood Risk Precinct
Land below the 100 year ARI flood that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties

Fringe Low Flood Risk Precinct
Land between the 100 year ARI flood extent and a level 0.5m in elevation above the 100 year ARI flood

Low Flood Risk Precinct
Land with a low probability of flooding lying above a level 0.5m above the 100 year ARI flood and below the probable maximum flood (PMF)

Limit of mapping

Mittagong Creek catchment boundary

Assumed boundary of mainstream flooding for the 100 year ARI flood. Inundation beyond this line may occur as a result of overland flows travelling towards Mittagong Creek.

Assumed boundary of mainstream flooding for the PMF. Inundation beyond this line may occur as a result of overland flows travelling towards Mittagong Creek.

NOTE
Flood risks from overland flow, stormwater inundation, most tributary flooding, or upstream of Old South Road, are not shown.

NOTE
Flood model results from the Mittagong Creek model are available for this area downstream of the limit of mapping, but these should be used with caution due to the influence of flows from the Wingecarribee River.

Mittagong Creek
Railway
Bowral St
Beavan Place model area
Kangaloon Rd
Old South Rd
Moss Vale Rd
Wingecarribee River

NORTH
0 400 800
metres

Bewsher Consulting Pty Ltd

Job No.: J1731
File: J1731_FRP_Bowral.WOR
Date: 2 Apr 2009

4. DEFINING THE FLOOD PROBLEM

4.1 FLOOD DAMAGES DATABASE

A flood damages database has been established to quantify the impacts of flooding in the Bowral study area, and to allow an economic appraisal of floodplain management options. A full explanation of methods used and results is provided in *Working Paper No. 3 – Flood Damages Database* (May 2005).

The flood damages database contains details of those properties that are potentially affected by flooding up to the probable maximum flood (PMF). Properties within the database were identified using flood level estimates for the PMF and contour mapping of the catchment to define the extent of potential flood inundation. Property details were then extracted for this region using Council's computerised Geographical Information System (GIS) and rates database.

Almost 900 properties are included in the database. These have been divided into four separate areas, as shown in **Figure 4.1** and **Table 4.1**.

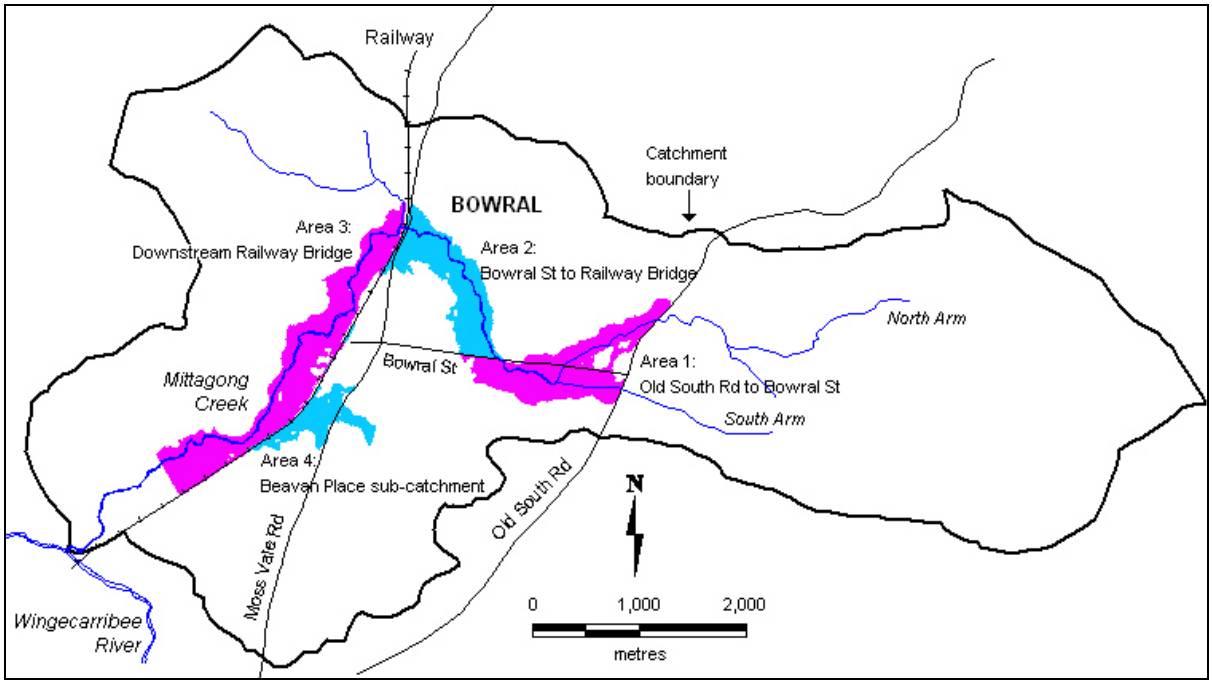


FIGURE 4.1
Damages Database Areas

TABLE 4.1
Damages Database Areas

Area Number	Area Name	Number of Properties in Database
1	Old South Road to Bowral Street Bridge	297
2	Bowral Street Bridge to Railway Bridge	328
3	Downstream Railway Bridge	134
4	Beavan Place sub-catchment	117
TOTAL		876

A list of attributes recorded for each property and an explanation of the derivation or source of those attributes are provided in **Table 4.2**.

TABLE 4.2
Attributes Recorded in Flood Damages Database

Attribute	Comment/Source
Area No.	From Figure 4.1
Res. or Comm./Ind.	Residential or commercial/industrial land use
Object ID	Council's unique identifier for each property
Address	Council
Legal Description (Lot, Section, Plan)	Council
Current Zoning	Council
No. of buildings	Estimated number of separate buildings/units at ground level, based on aerial photography and Council records including strata
Res. Code (low-set single storey or slab or ground; high-set single storey; double storey)	Refers to DIPNR's house categories for residential flood damage calculation (DIPNR, 2004a)
Comm./Ind. Code	Refers to Bewsher Consulting's categories for commercial and industrial damage
Building Description	Extracted from Mittagong Rivulet Property Database 1992 (MRPD92)
Comment	
Surveyed ground and floor level and source	Most surveyed ground and floor levels from the MRPD92
Estimated ground and floor level and source	Most estimated ground levels from a digital elevation model constructed in January 2004
Design flood levels for PMF, 100 year, 50 year, 10 year (unblocked) and 5 year (unblocked) ARI events	From the revised Flood Study (May 2005)
Flood Risk Precincts	From Figure 3.1

Council provided property details from their property database in May 2004 (with an additional 22 properties in November 2004). Where available, *surveyed* floor and ground levels were used. Floor survey data for about 300 properties was available from the Mittagong Rivulet Property Database of 1992. It should be recognised that some of this data will be outdated, given redevelopment that has occurred over the last 12 years. Floor survey data was extracted from development plans for 26 properties in the Beavan Place sub-catchment, an area not included in the 1992 survey. In all, floor level survey data was available for 295 properties, which corresponds to **63%** of the 471 properties that contain buildings expected to be flooded above floor level in the PMF. However, floor survey data is available for a greater proportion of the more frequently flooded buildings. Of the 76 houses expected to be flooded above floor level in the 100 year event, surveyed floor levels are available for 56, corresponding to **74%**.

For properties without surveyed levels, ground levels were estimated using digital elevation models (DEMs) developed by Bewsher Consulting. The Mittagong Creek DEM was developed from aerial photogrammetry undertaken by HATCH and checked against available survey (October 2003). A portion of the Beavan Place sub-catchment, east of Moss Vale Road, was beyond the range of the HATCH survey, so a less detailed terrain model was developed from a collage of ground survey plans. Where buildings are present, ground levels were extracted at a point coinciding with or adjacent to the building. Based on an assessment of the difference between surveyed ground and floor levels, building floor

levels were estimated by adding an average "height above ground" of 0.5m to each ground level estimate.

For the purposes of assessing flood damages and options, it was decided to use an "unblocked" model for the 5 year and 10 year design floods. This was justified on the grounds that debris is expected to mobilise at larger flood events with higher discharges and velocities. Blocked conditions were still assumed for the 50 year, 100 year and PMF events, in the manner described in **Section 3.2**.

4.2 TYPES OF FLOOD DAMAGE

The definitions and methodology used in estimating flood damage have been established by a number of previous investigations. The types of flood damage examined in this study are summarised in **Figure 4.2**. The two main categories are referred to as "tangible" or "intangible" flood damages. Tangible flood damages are those that can be more readily evaluated in monetary terms, while intangible damages relate to the social cost of flooding and therefore are more difficult to quantify.

Tangible flood damages are divided further into direct and indirect damages. Direct flood damages relate to the loss, or loss in value, of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation and living expenses, and any extra outlays that occur because of the flood.

4.3 BASIS OF FLOOD DAMAGES CALCULATIONS

Flood damages have been calculated by applying a number of stage-damage curves to every property included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular property type.

In June 2004, DIPNR issued draft guidelines for the preparation of site-specific residential stage-damage curves (DIPNR, 2004a). The guidelines are intended to ensure greater consistency in residential flood damage calculations, by detailing new stage-damage data, and by facilitating a process whereby various factors are used to automatically adjust the data according to location. For Bowral, it was not possible to survey or inspect each property to classify the dwelling in keeping with DIPNR's definitions. Information from the 1992 Mittagong Rivulet Property Database was used to identify two "high set" houses (floor heights > 1.50m) and ten double storey houses. Every other house was assumed to be of a "low set" single storey or "slab on ground" type. The new residential stage-damage curves incorporate direct damage to buildings and contents (but not building failure), direct damage to properties such as fencing and sheds (but not landscaping remediation costs) and indirect damage (clean-up costs and time in alternative accommodation), but exclude damage to motor vehicles and social (intangible) losses. It is also noted that the new curves estimate "actual" rather than "potential" losses, because they are based on actual flood damages from Brisbane (1974) and Katherine (1998), and make provision for damage reduction where community awareness is high and warning times are substantial. The interpolated damage reduction factor for Bowral is not much below 1.00 (0.96), since flood awareness is low and warning times are expected to be no longer than an hour or so.

No standard stage-damage curves have been issued by DIPNR for commercial and industrial damages. The stage-damage relationships used to estimate these damages in this study were based on a collation of information from investigations following floods in Sydney (1986), Bathurst (1986), Nyngan (1990), Forbes (1990), Inverell (1991) and Coffs Harbour (1996). Damages to buildings and contents were doubled at DIPNR's (then current) recommendation (DIPNR, 2004b). For consistency with the residential damages assessment, actual losses were estimated by applying a ratio of actual to potential damages of 0.96. Indirect commercial/industrial losses were estimated as 50% of direct actual commercial/industrial damages, based on an estimate that the indirect cost of flooding to businesses is 5% of the actual direct damage for every day that trading is lost (Water Studies, 1992).

Damages to infrastructure (including roads and bridges, water supply and sewerage, electricity and telephone supplies, and natural gas supplies) were estimated as 30% of total direct and indirect residential and business damage for floods up to and including the 100 year ARI event, and 20% for floods higher than the 100 year ARI event.

All damage estimates have been updated to reflect Year 2004 values.

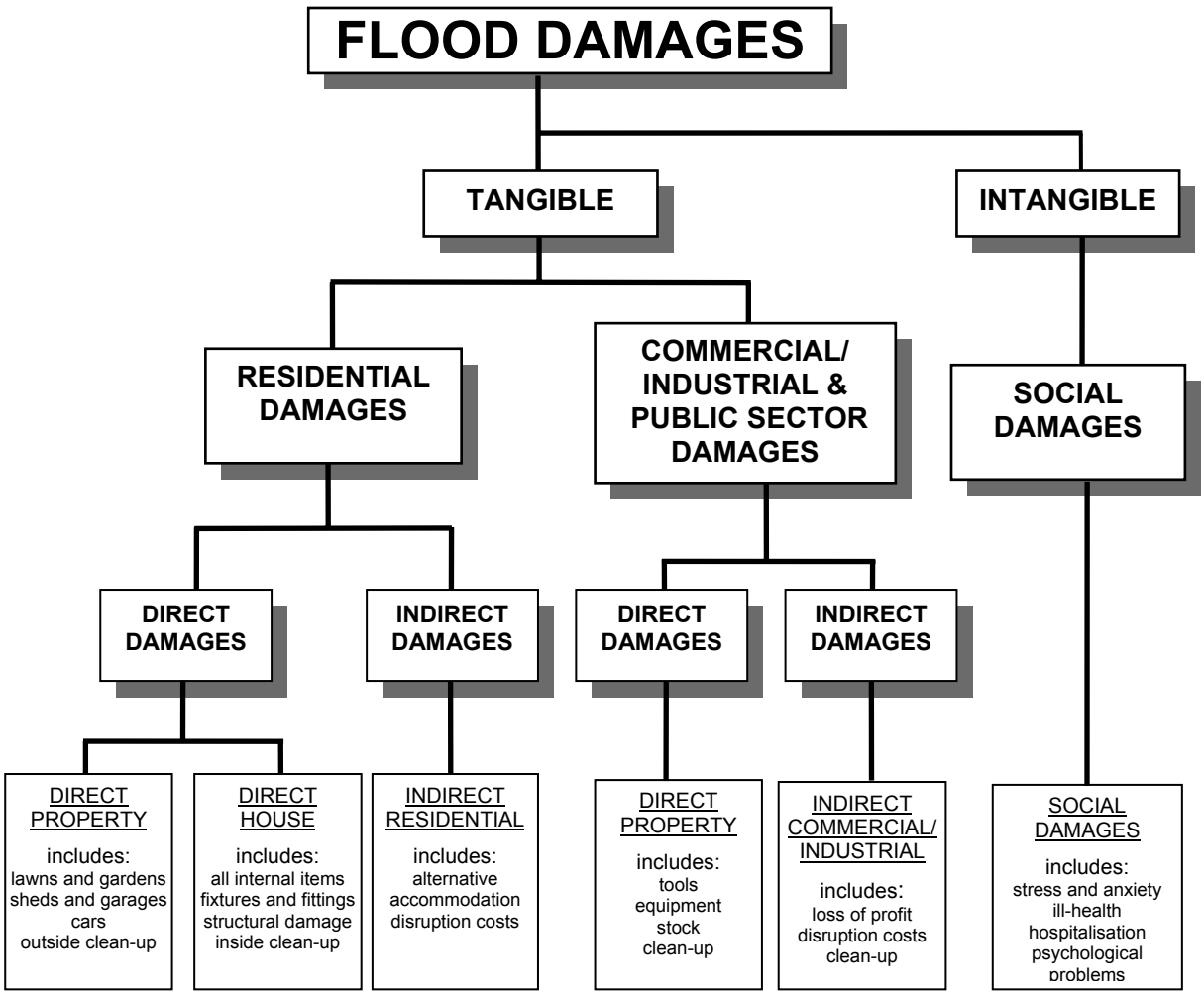


FIGURE 4.2
Types of Flood Damage

4.4 SUMMARY OF FLOOD DAMAGES

A summary of predicted flood damages for the Bowral study area is provided in **Table 4.3** and **Table 4.4**. More detailed results are provided in **Appendix F**. Key results are:

- A 100 year ARI flood is expected to cause tangible damages in the order of $10 million;
- The annual average damage within the study area is almost $1 million, which is a measure of the cost of flood damage that could be expected each year, on average, by the community;
- The present value of damages within the study area is about $10.3 million, representing the maximum amount of money that could be spent on flood mitigation measures if an economic benefit/cost ratio of 1.0 is required and all flood damages can be avoided;
- If all floods including and more frequent than the 100 year flood were completely mitigated, the present value would be about $3.3 million, which means that no more than $7 million should be spent on reducing risks of flood up to the 100 year event;
- 76 houses would be flooded above floor level in the 100 year flood;
- 23 businesses would be flooded above floor level in the 100 year flood;
- Most residential exposure is situated in Areas 1 and 2;
- There is a sizeable commercial/industrial exposure in Area 3, which contributes disproportionately to overall annual average damages, reflecting the greater concentration of value per property, and the use of a 2x multiplier for commercial/industrial damages.

TABLE 4.3
Summary of Flood Damages by Event

Flood Event	Predicted Actual Damage in Flood Event ($2004)	* Average Annual Damage ($2004)	* Present Value of Damage ($2004)
5 Year	$1.6M	$970,000	$10,320,000
10 Year	$2.4M		
50 Year	$7.2M		
100 year	$9.8M		
PMF	$62.9M		

* Based on treasury guidelines of a 7% discount rate and expected life of 20 years

TABLE 4.4
Summary of Flood Damages by Area

Area	Number of buildings flooded above floor in 100 year event		Annual Average Damage ($2004)
	Residential	Commercial/ Industrial	
1	30	0	$220,000
2	33	3	$260,000
3	5	15	$360,000
4	8	5	$140,000
TOTAL	76	23	$970,000

Figure 4.3 shows the distribution of houses and businesses expected to be flooded above floor level in the 100 year and 10 year floods. Several features are noteworthy:

- In general, the flood-affected houses and businesses are dispersed along the course of the creek. This has implications for the appropriateness of some flood mitigation options. For example, replacing a bridge or culvert typically brings only localised benefits, and for Bowral, each replacement would benefit only a handful of buildings;
- Nevertheless, some concentrations of exposure are apparent. The most outstanding is Farmborough Close, where several houses along the northern side of the street are expected to be inundated above floor level even in the 10 year flood. Several houses are also exposed near the Shepherd Street Bridge.

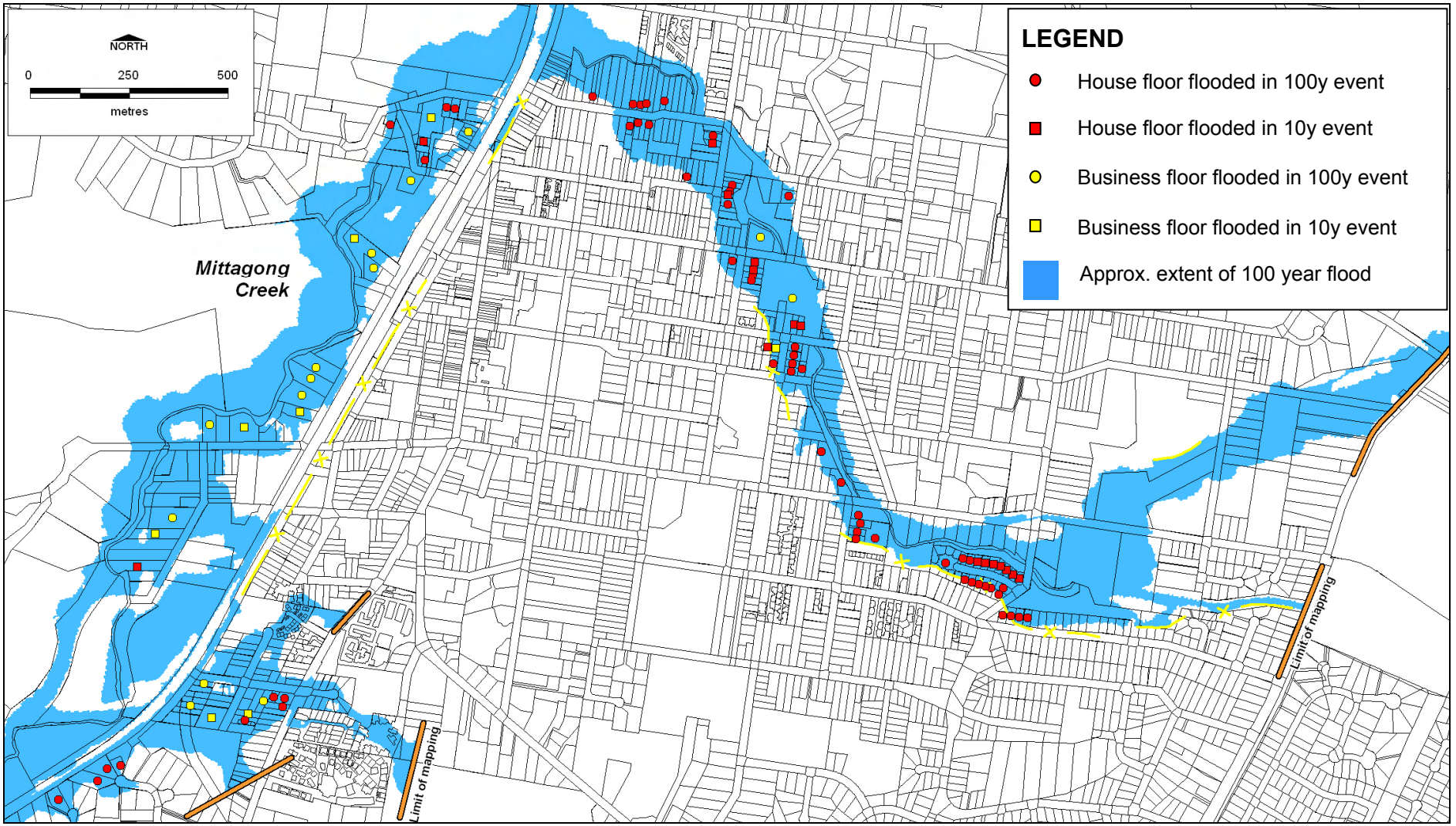


FIGURE 4.3

Houses and Businesses Subject to Above Floor Flooding in the 100 Year and 10 Year ARI Events

(Note: Distribution of buildings flooded in 100 year event based on revised flood modelling in December 2008)

5. COMMUNITY CONSULTATION

5.1 CONSULTATION PROCESS

The success of any floodplain management plan hinges on its acceptance by the local community and other stakeholders. This can only be achieved by involving the local community at all stages of the decision-making process. This includes collecting their ideas and knowledge on flood behaviour in the study area, and discussing the issues and outcomes of the study with them.

Community consultation has been an integral component of the current study. As well as improving the community's awareness of and readiness for flooding, the consultation has aimed to inform the community about the development of the floodplain management study and its likely outcomes. It has also provided an opportunity to collect feedback and ideas on potential floodplain management measures and other related issues.

The key elements of the consultation process have been as follows:

- Regular meetings of the Bowral Floodplain Management Committee;-
- Community newsletters;
- Community questionnaires;
- Poster display of flood model results;
- Agency and interest group questionnaire;
- Web site;
- Public exhibition of the recommended floodplain risk management plan.

These elements, with the exception of the last two, are discussed fully in *Working Paper No. 2 – Community Consultation* (June 2004) and in *Working Paper No. 2 – Community Consultation: Addendum - Beavan Place Extension* (November 2004). The salient findings are summarised below.

5.2 FLOODPLAIN MANAGEMENT COMMITTEE

The study has been overseen by the Bowral Floodplain Management Committee (previously the Mittagong Rivulet FMC). This committee comprises representatives from:

- Wingecarribee Shire Council;
- Department of Infrastructure, Planning and Natural Resources (DIPNR, now DECC);
- State Emergency Service; and
- The local community.

The Committee has met regularly to hear progress reports by the consultant, and to provide direction as the study progressed. The Committee has provided a valuable mechanism for the views of many interested parties to be represented. The main agenda items at each meeting are summarised in **Table 5.1**:

TABLE 5.1
Meetings of Bowral Floodplain Management Committee

DATE OF MEETING	MAIN AGENDA ITEMS
22 Nov 2002	Introduction to study, planning issues
4 Dec 2003	Status of flood study
4 Mar 2004	Community survey results, update on flood modelling
21 Jun 2004	Design flood modelling results, extension of study, flood problems and remedies
9 Dec 2004	Definition of flood problem from damages database, evaluation of floodplain management options, preparation of preliminary Plan
17 Feb 2005	Review of draft Floodplain Risk Management Study report
14 Jul 2005	Review of public exhibition and meeting, report revisions, final recommendations

5.3 COMMUNITY NEWSLETTERS

A community newsletter was prepared and sent to 1,356 property owners and tenants situated within a study area defined by an early estimate of the Mittagong Creek probable maximum flood (PMF), in January 2004. A modified community newsletter was prepared and sent to 53 property owners and tenants situated within the "Beavan Place" sub-catchment study area, in July 2004. **Appendix G** contains copies of the newsletters. The newsletters performed a variety of functions: introducing readers to the study; reminding them that floods could be more than "nuisance value"; flagging various kinds of potential management strategies; providing answers to some frequently asked questions about the "100 year flood" and "probable maximum flood"; and encouraging residents' participation in the study through completion of a survey. Answers to these questions were provided:

- Why do we need to be concerned about floods?
- Why do we need a study?
- Who is responsible for the study?
- What is the study about?
- How can you be involved?
- Who can you contact for more information?

5.4 COMMUNITY QUESTIONNAIRES

In January 2004, a community questionnaire was prepared and sent to the 1,356 property owners and tenants within the Mittagong Creek study area. In July 2004, a questionnaire was sent to 53 property owners and tenants within the "Beavan Place" sub-catchment study area. 286 responses were received to the first survey (yielding a response rate of 21%) and 21 responses were received to the second survey (yielding a response rate of 40%). A particular goal of the surveys was to canvass residents' ideas about how to solve the flood problem. Using mostly "open" questions, several very detailed responses were received. A copy of the questionnaires, and a selection of the responses, is included at **Appendix G**.

5.4.1 Floodplain management measures – Mittagong Creek survey

From the Mittagong Creek survey, common suggestions as to how to solve Bowral's flood problems were grouped, and are shown in descending order of frequency in **Figure 5.1**. A diverse range of measures was suggested, which are placed here into three categories: measures that modify flood behaviour (either decreasing flow inputs to the creek, enhancing flow capacity and flow rate through the creek, or using levees to protect property); measures that modify property; and measures that modify people's response to floods.

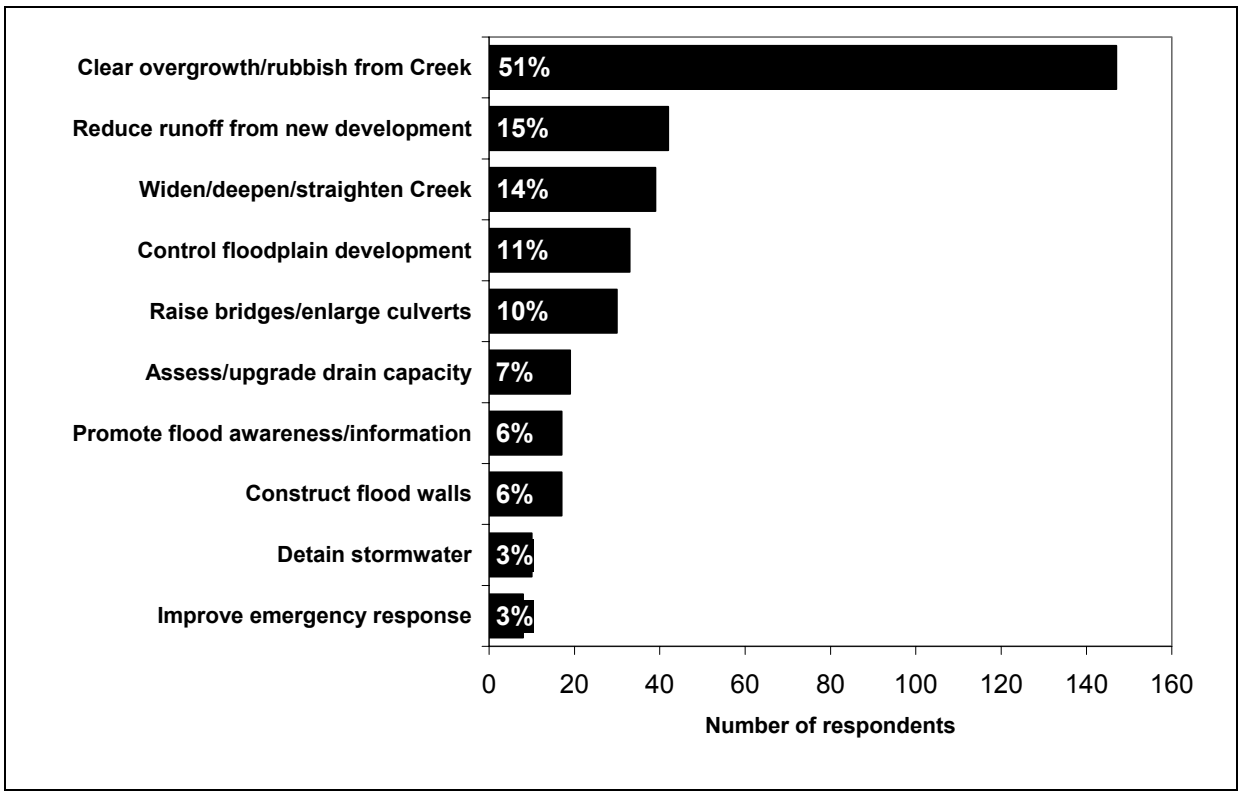


FIGURE 5.1
Community's Suggested Floodplain Management Measures
Based on results from Mittagong Creek community survey, January 2004

Measures to modify flood behaviour

Measures to decrease flow inputs to the creek

- 42 respondents (15%) expressed concern about the potential effect of new residential development in enhancing runoff via increased impervious surfaces. Much concern was directed towards East Bowral, situated on the eastern side of Old South Road. Another concern was a growing trend towards development of large lots by medium-density ("cluster") housing in "Old" Bowral (e.g., 117 Bowral St). Two respondents suggested the use of porous pavers.
- 10 respondents (3%) called for detention basins. One respondent noted that potential sites on the Northern arm should be investigated, since two basins were recently constructed on the Southern arm, adjacent to East Bowral housing. These sites are shown on **Figure 5.2**.
- 6 respondents (2%) called for improved catchment management and erosion prevention.
- 6 respondents (2%) suggested diverting flows to adjacent catchments.

- 4 respondents (1%) suggested that rainwater tanks be made compulsory for new dwellings, and subsidised for old dwellings.

Measures to enhance flow capacity/rates through the system

- 147 respondents (51%) – by far the most frequent response – called for a regular program (cf. what is seen as the current ad hoc approach) to clear the creek of overgrowth and rubbish which includes car tyres, shopping trolleys etc. There is a good deal of concern about the effect of prolific reed growth (e.g., see responses 95 and 190 in **Appendix G**). A number of respondents described specific areas that they thought were in need of clearance, which are shown in **Figure 5.2**. One respondent said better night lighting might discourage illegal dumping, and another said that more funding should be given to Landcare to maintain the creek.
- 39 respondents (14%) called for a deepening or widening or straightening of the creek.
- 30 respondents (10%) called for bridges to be raised or culverts to be enlarged. Some saw bridge-raising as a priority to allow for emergency access/egress during floods. Bridges that were explicitly mentioned are shown in **Figure 5.2**. There was also concern about unapproved bridges across the creek, west of the railway.
- 19 respondents (7%) called for the capacity of stormwater drains to be assessed and upgraded. The locus of these complaints was around Bowral-Bendooley-Sheffield Streets (**Figure 5.2**), some distance from the creek, and therefore not within the scope of this study.
- 7 respondents (2%) called for the creek to be partly or even wholly lined with concrete or rock. This "concrete" group was balanced by a "green" group who argued for a careful management of the creek environment, in order to promote ecological health.

Measures to control flooding by levees

- 17 respondents (6%) called for the construction of flood walls/levees. Two sites were mentioned: adjacent to Farmborough Close and along the creek between Merrigang St and Rose St (**Figure 5.2**). Others highlighted the need for caution in using flood walls, to avoid exacerbating flooding problems elsewhere.

<u>Measures to modify property</u>

- 33 respondents (11%) referred either to the need for better regulation of floodplain development, or the need to stop any further development of the floodplain.

<u>Measures to modify response</u>

- 17 respondents (6%) called for improved awareness and education of floods (including flood markers), as well as easy access to flood information.
- 8 respondents (3%) called for improvements in flood warning and evacuation systems.

In response to a separate "closed" question, most respondents indicated support for the disclosure of flood risk, whether by advising property buyers (72%), publishing flood maps on Council's web-site (69%), installing flood markers on telegraph poles as reminders of the heights of previous floods (67%), and issuing certificates to all residents stating whether their property is flood-affected (64%). Only seven (2%) respondents thought that Council should provide no advice about flood problems.

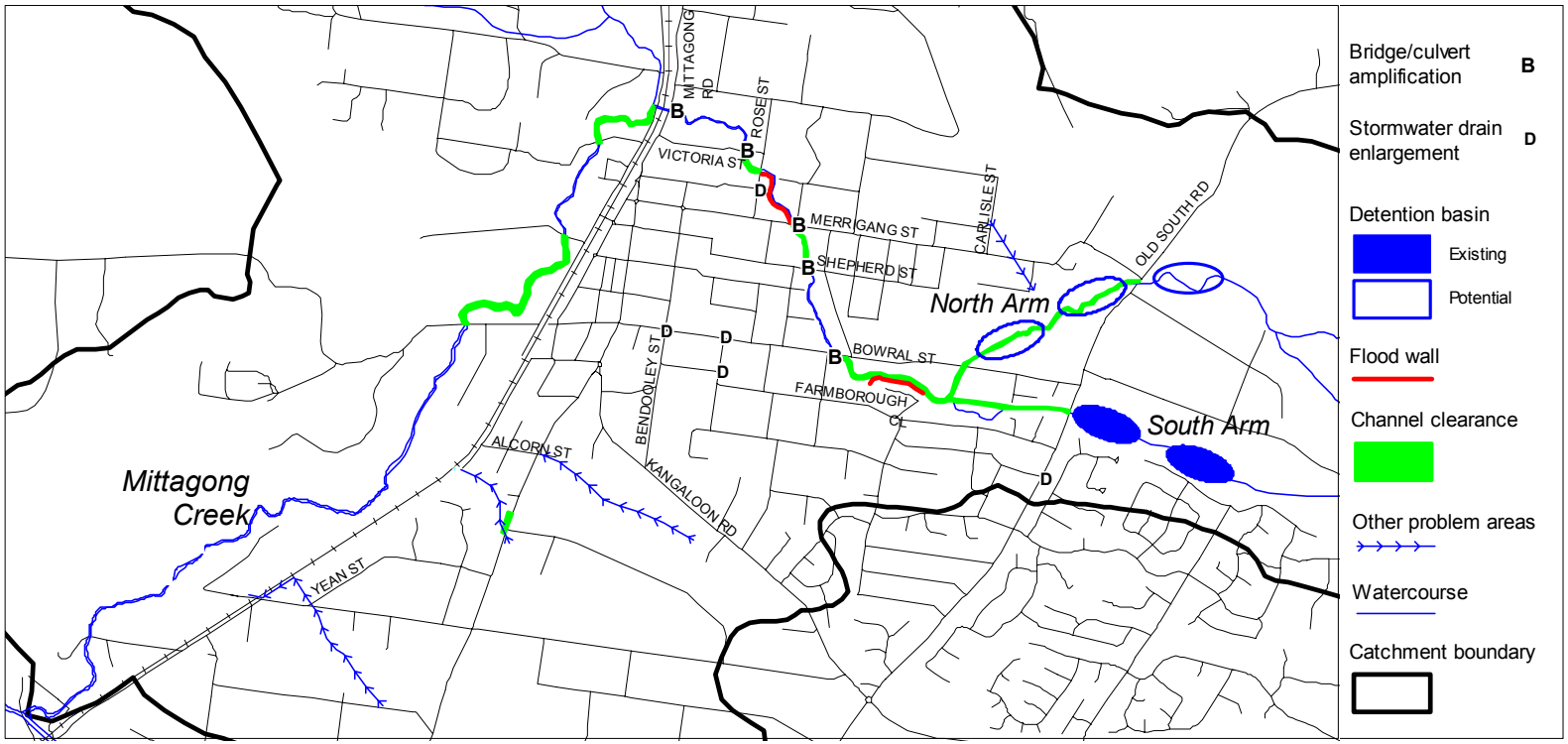


FIGURE 5.2
Location of Community's Suggested Floodplain Management Measures
Based on results from Mittagong Creek community survey, January 2004

5.4.2 Floodplain management measures – "Beavan Place" survey

As was found for the main Mittagong Creek survey, the most common suggestion for dealing with the flood problem in the "Beavan Place" sub-catchment was clearing drains of debris. Four respondents in the Beavan Place Sub-catchment expressed concern about the possible effect of new and often high-density developments in exacerbating runoff. Four also commented on the need to provide more drainage. Two respondents expressed a need to realign drains. Residents of Beavan Place whose houses back onto the new Mirvac development expressed concern about the effects of this raised development on local flooding. Two respondents recommended that further consideration be given to a detention basin in Bowral Golf Course, including an engineer who seemed to be speaking on behalf of Bowral Golf Club. Most submissions advocated structural solutions to the flood problem. The only non-structural measures that were recommended were the installation of flood markers to inform prospective buyers of the risk, and the limiting of development on flood-prone land.

5.4.3 Other issues

A number of respondents considered floodplain management within the broader context of environmental sustainability. Several respondents opposed the mooted clearing of reeds on the grounds of loss of valuable habitat (e.g., see response 246 in **Appendix G**). Comments were offered about the need to reduce creek nutrient levels and pollution. Several people flagged the illegal diversion of stormwater into the sewerage system, and sewage overflow during heavy rain, as important issues. A number of respondents saw synergies between improvements to the riverine corridor and the promotion of recreational and tourist pursuits such as cycling and 'eco-walks'. Three people raised the issue of a potential effect of changed flood ratings on property values. One respondent drew attention to the need to protect heritage buildings.

5.5 POSTER DISPLAY OF FLOOD MODEL RESULTS

Posters depicting the modelled 1988 and 1999 floods were displayed in Springett's Arcade, Bowral, in February 2004. Residents were invited to complete a "Flood Model Feedback Form". Only 16 responses were received, and some of these were not complete. The ten responses to a question about the accuracy of the flood model are summarised in **Figure 5.3**. One person who thought the model was "poor" was really complaining about the scope of the model – she questioned why (at that stage) flood-prone areas mooted for future development were not included, such as near Kangaloon Road. This is really no comment on the *accuracy* of the model at all, rather its scope. Only one person identified a serious discrepancy between their memory of the flood depth and the model's representation of the flood depth, by about a metre. This person, and others who indicated minor discrepancies, were contacted, and their comments subsequently taken into account for calibrating the flood model. Importantly, a good many people were satisfied with the model, including several who spoke to the Consultant but did not feel it necessary to complete a feedback form.

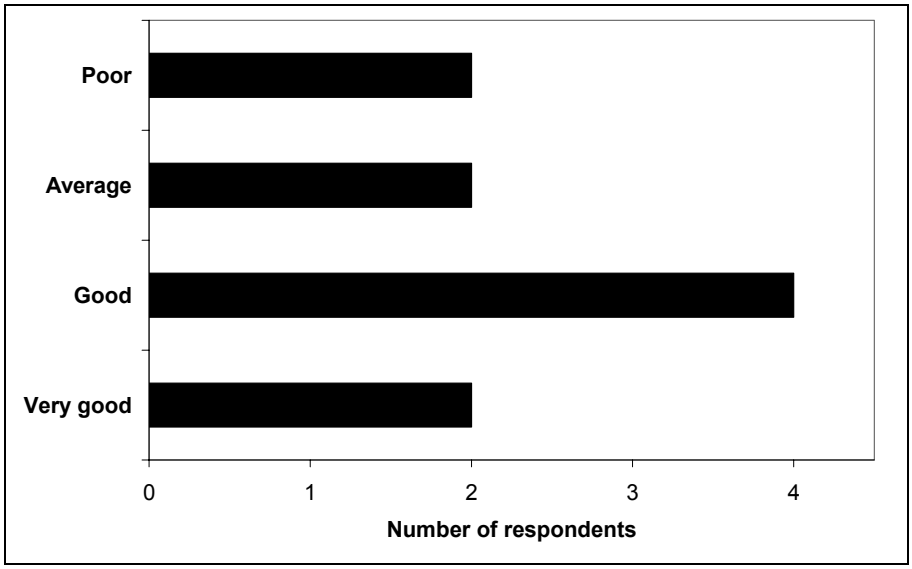


FIGURE 5.3
Community Feedback on Accuracy of Model's Calibration of 1988 and 1999 Events

5.6 AGENCY AND INTEREST GROUP QUESTIONNAIRE

Government agencies and interest groups were also sent an introductory letter and a separate questionnaire in March 2004. The agencies that were contacted, with a summary of responses received, is provided in **Table 5.2**. Full agency responses are recorded in **Appendix G**.

A common theme in responses received from agencies – as for the community survey – concerned the role of riparian vegetation. The Bowral Urban Landcare Group (BULG) provided a detailed submission detailing the group's activities within the riparian zone, especially removing weeds and planting native vegetation, with an emphasis on grasses and sedges, in order to avoid obstructions to flow. BULG does not support the removal of reeds from the river bed as a flood control measure, citing their important bed control and water quality functions, and noting the erosion of the river bed that was triggered by the removal of reeds at the Rose Street Bridge. To arrest bed erosion, BULG has arranged for the installation of six bed controls and two rock walls in the creek.[2]

In a similar vein, the DIPNR response drew attention to the habitat value achieved through the construction of log weirs, rock ramps and v-notch weirs, as well as the native vegetation re-introduced along the creek. It was recommended that Council consider adopting a similar process and study as the Illawarra Riparian Corridor Management Study.

The NSW Fisheries' response emphasised their opposition to any structure that would obstruct the free passage of fish and to any proposal that involves modification or destruction of fish habitat.

[2] In a letter tabled at the Bowral Floodplain Management Committee meeting of 17 February 2005, three community members of the Committee stated their objection to the inclusion of the BULG submission, being of the view that these were personal views and not necessarily those of BULG members overall. The main point of dissension appears to centre on the issue of the reeds – whether to remove or not.

TABLE 5.2
List of Agencies and Interest Groups Sent Questionnaires

AGENCY	CONTACT	RESPONSE
AGL	Officer in charge	
Berrima District Historical Society	Officer in charge	Sent copy of flood file
Bowral Chamber of Commerce and Industry	Officer in charge	
Bowral Urban Landcare group	Vice President Ms Jennifer Cox	Letter
Bushcare groups WSC	Bushland Facilitator	
DIPNR	Raj Upreti	
DIPNR (Moss Vale District Office)	Karen Elton	Survey
DIPNR (Transport and Infrastructure Planning)	Manager	
DIPNR (Illawarra and South Coast Planning Office)	Regional manager	
Integral Energy	Network planner	
Ministry of Transport	Strategic Planning Manager	Acknowledged
Mittagong Rivulet Landcare group	President Mrs Helen Chadwick	Acknowledged
National Trust of Australia (NSW)	Officer in charge	
NSW Aboriginal Land Council	Officer in charge	
NSW Agriculture, Goulburn District Office	Officer in charge	Survey
NSW Dept of Environment and Conservation (EPA)	Manager, Wollongong Regional Office	Acknowledged
NSW Fire Brigades	James Smith, Chief Superintendent	Acknowledged
NSW Fisheries	Michelle Perry	Survey
NSW Police	Officer in charge	
Office of Economic Development, Southern Highlands	Officer in charge	Return to sender
Railcorp NSW (South Area)	Darren Sloane	Return to sender
Railcorp NSW	Officer in charge, Bowral Railway Station	
Roads and Traffic Authority	Robyn Lyster, Area Maintenance Manager	Survey
Southern Highlands Cycle Club	Mr Ian Crick	
State Emergency Services - Wingecarribee Unit	Ms Lyn Ritchie	Phone call
Sydney Catchment Authority (Moss Vale Office)	Officer in charge	
Telstra	Mr Mark McKenzie, Southern Highlands General Manager	Email 01/09/04
Tourism Southern Highlands	Officer in charge	
Wingecarribee Indigenous Advisory Committee	Community Development Officer - Anne-Maree Dalziel	Letter

5.7 WEB SITE

An internet web site was developed as part of the community consultation strategy for this study. The site is located at www.bewsher.com.au/bowral.htm. It provides a link to the community newsletters, and also provides the opportunity for residents to forward any comments directly to the study team.

5.8 PUBLIC EXHIBITION AND MEETING

Posters summarising the recommended Bowral Floodplain Risk Management Plan were displayed in Springett's Arcade, Bowral, in May 2005. Residents were invited to inspect a copy of the draft Study report at Council offices. In addition, a public meeting was held on 26 May 2005. Residents were invited to make written submissions on the Plan.

A summary of the 39 responses received is contained in **Appendix G**. Of these responses, there was a good deal of support for the proposed Retford Park detention basin, while one submission objected to issuing flood certificates and three submissions objected to the proposed removal of Victoria Street Bridge, which forms an important walking route. A detailed submission on behalf of 10 residents of "Berida Park", David Street, objected to the proposed Bowral Golf Course detention basin due to its adverse effect on visual amenity, performance in maximum floods and risk of failure. Instead, the submission suggested that a series of detention basins be constructed upstream of the 1st fairway. It also argued the need for much larger culverts under Moss Vale Road at Beavan Place. Several responses reiterated the call for immediate clearing/widening/dredging of the creek. A number of responses called for improved drainage: in the area of Ascot Road and Albert Street, in Victoria Street, and in the area around Elm Street/Myrtle Street/Holly Street. One response drew attention to filtration traps as a means for preventing rubbish accumulating in the creek. Overall, there was good support for the proposed planning and development controls. Some of those who opposed these were under the misapprehension that they would be forced to demolish their houses (voluntary house raising is by definition *voluntary*, and could be publicly funded if recommended as part of an adopted Plan). A number of comments were also received, several expressing scepticism about the accuracy of the 2005 Flood Study, several arguing that property values would be adversely affected if Council adopted the proposed Flood Risk Precincts, and several pointing to the need to investigate stormwater flooding as well as creek flooding. A "question and answer" sheet prepared by Council addresses several of these comments, and is also shown here in **Appendix G**.

At its meeting on 14 July 2005, the Bowral Floodplain Management Committee discussed the community feedback and recommended that the final report add the following recommendations:

- Council should undertake further investigations of stormwater overland flow and local drainage issues in Bowral;
- A scoping study for the Bowral Golf Course detention basin is recommended, to investigate options and negotiate with relevant parties;
- Council should investigate the purchase of a pluviograph and/or stream gauge for Mittagong Creek to permit the collection of more accurate data in the catchment.

The first recommendation stands as a separate recommendation in **Section 9** while the second and third recommendations have been incorporated into the recommended Bowral Floodplain Risk Management Plan, summarised in **Table 9.1**.

6. REVIEW OF POTENTIAL PLANNING INSTRUMENTS AND MEASURES

The text in this chapter was revised in November 2008 and amended in June 2009

6.1 INTRODUCTION

This section of the report identifies and examines various forms of planning instruments and associated controls that apply to the study area and that may have potential for use for the purposes of implementing flood risk management planning controls. A similar review was undertaken as part of the *Berrima Floodplain Risk Management Study* (FRMS) (Bewsher Consulting, 2002) but this review includes a number of recent changes to relevant planning policies. Not all of these planning policies will be applicable, but are reviewed for the purposes of completeness and to provide a general overview of planning controls and the strategic planning direction for the area.

It is noted that the Plan making processes under the EPA Act (such as for LEPs and DCPs) operate independently to the preparation of FRMPs under the Floodplain Development Manual. While these two processes could be overlapped, it has been the usual practice to undertake the processes separately. This will provide for extended opportunities for public participation. Accordingly, once the FRMP has been adopted by the Council, it can subsequently implement the recommendations of the FRMP, which may include the preparation of an LEP and DCP under the EPA Act. During this later plan-making process further refinement and adjustment to the recommended LEP and DCP can be undertaken.

6.2 STATE ENVIRONMENTAL PLANNING POLICIES

A State Environmental Planning Policy (SEPP) is a planning document prepared in accordance with the Environmental Planning & Assessment Act (EPA Act) by the Department of Planning and eventually approved by the Minister, which deals with matters of significance for environmental planning for the State. No SEPP has been prepared dealing specifically with the issue of flooding, but some regulate development in response to potential flood risks.

State Environmental Planning Policy (Housing for Seniors or People with a Disability) 2004 (Seniors Living SEPP) applies to urban land or land adjoining urban land where dwellings, hospitals and similar uses are permissible. Seniors Living SEPP would apply to parts of the study area, and would effectively override Council's planning controls to permit residential development for older and disabled persons to a scale permitted by the SEPP. Notwithstanding, Clause 6(2)(a) of the SEPP restricts its application from land identified as "floodways" or "high flooding hazard" in another environment planning instrument such as a REP or LEP (as described below).

As the State Government's Floodplain Development Manual is aimed at encouraging a merit based approach to floodplain planning for individual areas, it is unlikely to be desirable to establish a global policy for floodplain development through the application of a SEPP. However, the categorisation of any areas as "floodways" or "high flooding hazard" in Council's LEP would have the effect of precluding development under the Seniors Living SEPP.

6.3 REGIONAL ENVIRONMENTAL PLANS (REPS)

A Regional Environmental Plan (REP) is prepared in accordance with the EPA Act by the Department of Planning (DoP) and eventually approved by the Minister. A REP provides objectives and controls for environmental planning for a region, or part of a region. The extent of a region will vary depending upon the issue to be addressed but normally refers to more than one LGA. Illawarra Regional Environmental Plan No. 1 is one such REP, and this has the following implications in regard to the Bowral FRMS:

(a) Clause 28 of the REP requires that any draft LEP proposed to control development on rural land which has a history of flooding, requires Council to obtain sufficient information to introduce appropriate controls to minimise the effect of flooding on any potential development. The Bowral FRMS, prepared in accordance with State Government policy, would provide an appropriate basis for addressing the provisions of Clause 28 in the study area, if ever required.

(b) Clause 65 of the REP stipulates that a draft LEP shall not rezone land from rural to urban unless Council has consulted with the DoP, prepared a plan of management and is satisfied that the potential for flood losses is "contained". Again, the ultimate outcome of the Bowral FRMS is to produce a Floodplain Risk Management Plan (FRMP) for the Mittagong Creek floodplain (and the "Beavan Place" sub-catchment), which effectively provides a management plan to minimise flood damages and risk to life. The Plan will, therefore, be an important consideration for any future urban rezonings in the study area. Compliance with the Plan will also be important for the purposes of maintaining Council's indemnity from liability pursuant to Section 733 of the Local Government Act, 1993.

(c) Clause 66 of the REP provides the following provisions in regard to the management of land subject to flooding:

> "*66.(1) A draft Local Environmental Plan to control development on land in existing urban areas which has a history of flooding shall be prepared only when the consent authority has identified the flood behaviour on that land and associated flood risk.*
>
> *66.(2) A plan of management for the land referred in subclause (1) shall indicate appropriate controls or development standards relating to floor height, building materials, access, infill, land clearing and the like to ensure the effects of any flooding on the development shall be minimal."*

As above, it is considered that a FRMP prepared in accordance with State Government flood policy and the Floodplain Development Manual would satisfy the provisions of Clause 66 in regard to the requirement for a plan of management. It is important to note that such a plan of management is a necessary prerequisite to any LEP on land covered by the REP, inclusive of the study area, which has the effect of controlling development in existing urban areas with a "history" of flooding.

The REP does not define terms such as "*flood liable land*", "*land subject of flooding*" and "*plan of management*". The traditional flood planning approach adopts as a designated flood (or flood planning level – FPL) the 100 year average recurrence interval (ARI) which would regulate development with only a defined section of the floodplain. Floods greater than the 100 year ARI can occur, with the ultimate upper limit being an extreme flood – normally the probable maximum flood (PMF). A more flexible approach to dealing with the issue of flooding across the full range of floods has been outlined and discussed previously.

A review of Illawarra REP No. 1 is an option that would need to be pursued by the DoP in consultation with relevant government authorities. Council could refer this FRMS to the Department to initiate consideration of a review to reframe its flood related provisions to accord with the principles of modern-day floodplain planning and to consistently define

terminology. The Department is in the process of reviewing and phasing out REPs as part of a broader organisational planning review and accordingly, such a referral would be timely.

6.4 REGIONAL PLANNING STRATEGIES

An outcome of the recent planning reforms was to phase out REPs and to establish a framework for regional planning through various other mechanisms, in particular Regional Planning Strategies prepared by the DoP in consultation with Councils and other government agencies. The Sydney-Canberra Corridor Regional Strategy (DoP 2008) applies to the local government areas of Wingecarribee, Goulburn Mulwaree, Upper Lachlan, Yass Valley, Palerang and Queanbeyan, and is one of a number of regional strategies prepared by the DoP.

The issue of flood risk is discussed in the Strategy, with the following key outcomes noted:

- *"Local environmental plans will zone areas subject to natural hazards appropriately to reflect the risks associated with the hazard and the limitations of the land"* (pg.44).
- *"Councils should ensure that their local strategies, local environmental plans and development control plans maximise the achievement of the principles and recommendations in these policies and plans, in particular: ……*
  - *Floodplain risk management plans, prepared in accordance with the NSW Floodplain Development Manual (NSW Government 2005)*
  - *Management of flood liable land under the Floodplain Development Manual*
  - *National Climate Change Adaptation Framework (Council of Australian Governments 2007)…"* (pg.43)

All FRMPs adopted by Council will therefore be important and necessary considerations for Council in the preparation of the new Shire wide LEP and DCPs, currently underway.

6.5 HISTORICAL ADVISORY CIRCULARS

The Department of Planning is responsible for providing advice to local councils to ensure that best practice is maintained in the planning process. A Planning and Environment Commission Circular was issued in 1977 advocating prescriptive floodplain planning controls and the adoption of the 100 year average recurrence interval (ARI) flood standard. Subsequently, a Departmental Circular (No. 122) was issued by the Department of Planning and more recently as Circular No. C9 to assist Councils to relate the flood policy of the State Government and the (then) Floodplain Development Manual to the requirements of the EPA Act and the Department's general approach to floodplain planning.

The original State Flood Policy (1984) disbanded the mandatory application of a singular 100 year ARI flood standard and required local Councils to implement floodplain management policies based on a merits based approach. The Circular states that in accordance with the Floodplain Development Manual, Councils should prepare single comprehensive local environmental plans to implement their FRMPs, and so avoid an ad hoc, piecemeal approach to planning within floodplains.

In recognition that the preparation of such LEPs may take some time, Councils were advised that in the interim, adequate supporting data for decision making should be obtained inclusive of:

- any relevant FRMP or interim policy;
- details of flooding in the area;
- social and economic impact of flooding;
- environmental impacts of development in the floodplain (e.g. on water quality, flood behaviour, etc);
- the availability of alternative flood free sites and reasonable alternative uses for the subject site;
- cumulative adverse impacts;
- matters of state and regional significance (e.g. the impact of development on a floodplain beyond local government boundaries); and
- increased risk of flood damage to regional infrastructure, reduction in flood storage capacity, etc.

These earlier directions have been refined by the more recent Flood Planning Guideline issued by the DoP.

6.6 2007 FLOOD PLANNING GUIDELINE

On January 31, 2007 the NSW Planning Minister announced a new guideline for development control on floodplains (the "2007 Flood Planning Guideline"). An overview of the new Guideline and associated changes to the EPA Act and Regulation was issued by the Department of Planning in a Circular dated January 31, 2007 (Reference PS 07-003). The new Guideline issued by the Minister in effect relates to a package of directions and changes to the EPA Act, Regulation and Floodplain Development Manual.

This Guideline provides an amendment to the Manual. The Guideline confirms that unless there are "exceptional circumstances", Councils are to adopt the 100 year flood as the flood planning level (FPL) for residential development, with the exception of some sensitive forms of residential development such as seniors living housing. The Guideline does provide that controls on residential development above the 100 year flood may be imposed subject to an "exceptional circumstances" justification being agreed to by the Department of Natural Resources (now DECC) and the Department of Planning (DoP) prior to the exhibition of a Draft LEP or Draft DCP.

The Guideline provides conflicting statements in regard to what is the Residential FPL for the purposes of applying the directions in the Guideline. Despite noting the FPL for typical residential development would generally be based around the 100 year flood plus a freeboard of typically 0.5 metres, the Guideline "*confirms*" that "*unless there are exceptional circumstances, Councils should adopt the 100 year flood as the FPL for residential development*". However, senior officers of the DoP have repeatedly advised that the FPL is inclusive of freeboard (typically 0.5 metres) and this has been included in a draft Q&A document issued to the Floodplain Management Authorities of NSW in a letter dated 28 March 2008 from the Director-General of the DoP.

The Guideline also provides directions in regard to Section 117 Directions, the content of the DCPs and the Section 149 Planning Certificates. These directions are discussed separately below.

6.7 SECTION 117 DIRECTIONS

Ministerial directions pursuant to Section 117(2) of the EPA Act specify matters which local councils must take into consideration in the preparation of LEPs. Section 117(2) Direction No G25 (in regard to 'flood liable land') had been in existence for sometime, prior to a recent review. This direction was aimed specifically at enforcing the principles contained within the Floodplain Development Manual.

A further review was undertaken as part of the NSW planning reforms and new Section 117 ministerial directions were issued by the DoP (30 September 2005) and recently re-issued in a similar form (19 July 2007).

6.8 2007 REVISIONS TO THE SECTION 117 DIRECTIONS

Section 117 Direction No. 15 – Flood Prone Land, was revised on January 31, 2007. The principal implication of the revision of the Direction was to introduce provisions to limit the imposition of LEP controls on residential development within that part of the floodplain above the 100 year flood level.

Direction 4.3, as currently applies, deals specifically with flood prone land and has the following two objectives:

> *"(a) To ensure that the development of flood prone land is consistent with the NSW Government's Flood Prone Land Policy and the principles of the Floodplain Development Manual, 2005.*
>
> *(b) To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land".*

The direction applies to all councils that contain flood prone land when an LEP proposes to "create, remove or alter a zone or provision that affects flood prone land". In such cases, the direction requires draft LEPs to ensure the following:

- consistency with the principles of the Floodplain Development Manual (including the Planning 2007 Flood Guideline);
- do not rezone flood prone zoned special use areas, recreation, rural or environmental protection to a residential, business, industrial or special use area zone;
- do not permit development in floodways that would result in significant flood impacts on others, permit a significant increase in development on the floodplain, require substantial government spending on flood mitigation, or allow development without consent except for agriculture or flood mitigation works;
- that flood related development controls are not imposed on residential development above the "residential flood planning level" unless adequate justification to the satisfaction of the DoP is provided;
- flood planning levels must be consistent with the Floodplain Development Manual and 2007 Flood Planning Guideline.

Clause (6) of the Direction specifies circumstances which must be satisfied in order for the Director-General or nominee to allow for a variation to the Direction, as follows:

> *"(6) A draft LEP may be inconsistent with this Direction only if council can satisfy the Director-General (or an officer of the Department nominated by the Director-General) that any particular provision or area should be varied or excluded having regard to the provisions of section 5 of the Environmental Planning and Assessment Act, and*
>
> *(a) the rezoning is in accordance with a floodplain risk management plan prepared in accordance with the principles and guidelines of the Floodplain Development Manual, 2005, or*
>
> *(b) the rezoning is, in the opinion of the Director-General (or an officer of the Department nominated by the Director-General), of a minor significance."*

In our view, the LEP recommendations provided later in this report (to be implemented as Council progresses its consolidated "template" LEP) could be considered to be of "minor significance". Further, the LEP recommendations could also be able to be considered consistent with the objects provided at Section 5 of the Act, and will be in accordance with a FRMP prepared in accordance with the Manual and adopted by Council.

While Section 117 Directions are not relevant in DCPs, the new Guideline does indicate the approval of the DoP is required prior to the exhibition of a draft DCP that varies from the Guideline. Accordingly, the following comments are relevant to both future draft LEPs and DCPs.

6.9 JUSTIFICATION FOR VARIATIONS TO THE 2007 GUIDELINE

We have liaised with the Department of Planning generally in regard to issues associated with the new flood planning Guideline. It is understood that the Department is in the process of preparing further clarification in regard to the Guideline. The Guideline, the specific exemption provisions of the Section 117 Direction, and our understanding of the further clarification to be provided by the Department of Planning, are all directed towards establishing a basis for councils to seek variations to the restrictions of the Guideline and the Direction on the basis of "exceptional circumstances".

The recommended DCP and LEP provisions (discussed below) are generally consistent with the new guideline. However, it could be interpreted that the following minor inconsistencies arise:

a. The LEP provisions do not differentiate between development generally and residential development,

b. The DCP provisions retain controls for residential development in the Berrima floodplain in the Low Flood Risk Precinct (between the 100 year flood and PMF extents).

It is questionable as to whether the new Guideline is infringed but so as to avoid doubt, grounds under the exceptional circumstances provisions are nonetheless considered applicable. The relevant grounds to justify "exceptional circumstances" in this case could be as summarised as follows:

- Preparation of the FRMP commenced before the introduction of the new Guideline, and substantial effort and involvement from government departments, Council and the community have provided for the ultimate adoption of the FRMP in a manner which now creates some limited inconsistency with the new Guideline. The recommended flood related controls were debated by the Floodplain Management Committee formed in accordance with the Manual, taking into account local factors, and endorsed the controls.
- There is a history of significant flooding in the area.
- Council's existing planning controls (DCP 34) currently place restrictions on development in the floodplain and require consideration of floods up to the Probable Maximum Flood (PMF) in certain circumstances.
- The intent of the FRMP is to facilitate further development subject to managing risk within a package of measures, not to unreasonably restrict development. The risk management measures include increasing awareness of all flood hazard and consequent risk to property and the safety of persons.
- Those controls to be imposed upon residential development in that portion of the floodplain between the 100 year extent and PMF primarily relate to the setting of floor levels at the 100 year plus freeboard level (0.5m), requiring flood compatible building components below that level, ensuring the structure is sound and impacts on other development in the floodplain are considered, and most importantly to address emergency evacuation issues. These controls are the same as what Council currently imposes in accordance with the provisions of DCP 34 to at least some floodplains.
- Not permitting a variation to the restrictions of the Guideline and the Direction would constrain consideration of evacuation issues for all residential development across the floodplain on an integrated and comprehensive basis.

As discussed later, it is recommended that the above grounds form the basis of a submission to the DoP and DECC seeking endorsement for the DCP and LEP controls on the basis of "exceptional circumstances". The endorsement of the recommended DCP and LEP controls by the Departments and the ultimate adoption would effectively allow for their notification on Section 149 Certificates, with certainty that there would not be contravention of the new Guideline.

6.10 CHANGES TO ENVIRONMENTAL PLAN MAKING IN NSW

The EPA Act has recently been amended to facilitate the reproduction of planning instruments into a standardised format, commonly referred to as the *"LEP template"*. Section 33A of the EPA Act deals with the prescribing of a "standard instrument" for LEPs and other environmental planning instruments (EPIs). Section 33B of the Act provides the Minister with the power to establish a program for the repeal of existing EPIs and their replacement with contemporary standard instruments.

The LEP template came into effect on 31 March, 2006 with the gazettal of the *Standard Instrument (Local Environmental Plans) Order*, last amended on 14 December 2007. The template contains no compulsory clauses or map requirements specifically relevant to addressing flood hazards. However, the Department of Planning Circular (Circular PF 06-008, dated 3 April 2006) and Department of Planning LEP Practice Notes (PN06-001 and PN06-003, both dated 12 April 2006 and PN06-002, dated 12 April 2006 and corrected 18 April 2006) issued in conjunction with the gazettal of the Order provides a number of relevant advices, including that Councils can:

- prepare additional local provisions that address local planning issues, such as flood planning provisions developed in accordance with the Floodplain Development Manual;
- add local objectives to the core zone objectives;
- define terms relevant to a local provision in certain circumstances;
- suggest new definitions to the Department of Planning that could be suitable for inclusion in the standard dictionary; and
- include hazard overlays maps that apply in addition to zones and may apply to land in several different zones.

Council is in the process of preparing its new "template" LEP. The draft Wingecarribee LEP 2007 was placed on public exhibition from November 28, 2007 to February 1, 2008. Submissions from the public exhibition period were collated by Council staff and reported to Council. Changes to the draft LEP 2007 have now been made and the revised draft Plan (to be renamed draft LEP 2008) has been forwarded to the Department of Planning requesting that a new Section 65 Certificate be issued permitting Council to place the revised draft on public exhibition for a further 28 days. The current draft LEP contains flood risk management provisions as outlined and discussed later.

6.11 LOCAL ENVIRONMENTAL PLANS (LEPS)

6.11.1 Background

A Local Environmental Plan (LEP) is a plan prepared in accordance with the EPA Act which defines zones, permissible uses within those zones and specific development standards and other special matters for consideration when developing land. Wingecarribee has an existing LEP and is advanced in preparing a new LEP in accordance with the NSW "template". While the current LEP provisions will be phased out soon it is helpful to review the provisions of the LEP to provide context.

The study area is currently affected by the provisions of Wingecarribee Local Environmental Plan 1989 (WLEP). The aims and objectives of WLEP (Clause 2) contain no particular objective with regard to minimising risks due to natural hazards such as flooding. There are objectives with regard to specific zonings (Rural 1(a) and Rural Small Holdings 1(c)) targeted at ensuring development minimises risks from natural hazards, in particular bushfire and flooding (refer to Objective (g)).

Clause 34 of WLEP deals with the control of development specifically with regard to the issue of flooding. This clause refers to *"land potentially affected by flooding"* as flooding from a 1% flood event, which is misleading to the extent that it suggests flooding above the 1% (or 100 year flood) level does not occur or there is no chance of flooding above this level, which is not correct. Subclause (g) refers to the availability of evacuation access up to the 1% flood level. Whereas this may not provide an appropriate or adequate level of safety in all cases throughout the LGA, notwithstanding, it is not a significant issue within the town. Subclause (k) requires consideration of *"Council's floodplain management policy"* and this importantly redirects emphasis to FRMPs prepared in accordance with the State Government's flood policy.

Clause 51 of WLEP requires development consent for landfill. This clause requires that consideration be given to various factors inclusive of impact on flood levels and extents, prior to granting consent.

Clause 68(4) of WLEP states that Council shall not consent to a building on any land subject to a 1% flood. This could be an onerous requirement as some *"buildings"* (as defined by the Act) may be able to be appropriately located within the 100 year flood extent (i.e. barbeques, cabanas, etc). Further, the hazards associated with building in any particular part of the floodplain cannot be appropriately gauged by reference to only the frequency of the flooding, as the depth of floodwater may be extremely shallow with no velocity to its flow, and there may be adequate warning time available to ensure damages are minimised. A reconsideration of this clause, and its integration with Council's exempt and complying development provisions would be appropriate.

Clause 6B(3)(d) provides provisions in regard to complying development. This clause states that development is not complying development if it is on land that is determined to be potentially affected by flooding in accordance with subclause (4). Subclause (4) provides that when determining whether land is potentially affected by inundation by flooding, an assessment must be made of whether the land:

"(a) has been identified by information, data and reports held by the Council as being likely to flood inundation, and

(b) is partly or wholly located within the banks of a watercourse, and

(c) is partly or wholly located within a floodplain, and

(d) is wholly or partly within 3 metres elevation of the bed of a watercourse, and

(e) has a written or oral history of being subject to flood inundation, and

(f) shows any evidence of previous flood inundation."

Council is in the process of preparing its new "template" LEP. The draft Wingecarribee LEP 2007 was placed on public exhibition from November 2007 to February 2008. Submissions from the public exhibition period were collated by Council staff and reported to Council. Some changes to the draft LEP 2007 were subsequently made and the revised draft Plan (renamed draft LEP 2009) was placed on exhibition in March, 2009. The draft LEP 2009 contains flood risk management provisions as described in **Table 6.1**.

The importance of the LEP to floodplain management can be summarised by the following objectives:

- To provide objectives for the application of floodplain management principles in the assessment of development applications.
- To appropriately identify areas subject to flooding in order that development applications in such areas may be specially considered and that Council has a basis for notifying the public of the potential for flooding on individual parcels of land in accordance with Section 149 Certificates issued under the EPA Act.
- To outline general matters for consideration with more detailed controls being the subject of a DCP in accordance with accepted practice.
- To clearly define terminology used in the LEP which relates to floodplain management.
- To ensure that the permissibility and prohibition of uses is consistent with the FRMP, in order that flood sensitive land uses are clearly prohibited within areas subject to significant and hazardous levels of flooding. In this regard we note that the prohibition of land uses is a matter which must be clearly outlined within the LEP as this function cannot legally be transferred to a DCP.

TABLE 6.1
Flood Risk Management Provisions in the Draft Wingecarribee LEP 2009

7.10 Flood Prone Land

(1). The objectives of this clause are:

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

(2). This clause applies to land subject to the discharge of a 1:100 ARI (average recurrent interval) flood event, which includes land identified as flood prone land on the Flood Planning Map.

Note. *Only land that is flood prone is shown on the Flood Planning Map.*

(3). Development consent is required for the following on land identified as flood prone on the Flood Planning Map:

- *earthworks;*
- *the erection of a building;*
- *the carrying out of a work;*
- *flood mitigation works (other than those carried out by or on behalf of a public authority).*

(4). Consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development:

- *will not adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties; and*
- *will not significantly alter flow distributions and velocities to the detriment of other properties or the environment; and*
- *will enable safe occupation and evacuation of the land; and*
- *will not significantly detrimentally affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the river bank/watercourse; and*
- *will not be likely to result in unsustainable social and economic costs to the flood affected community or general community as a consequence of flooding; and*
- *if located in a floodway,*

  (i) is compatible with the flow conveyance function of the flood prone land; and

  (ii) is compatible with the flood hazard within the flood prone land.

(5). In this clause, ***Flood Planning Map*** *means the Wingecarribee Local Environmental Plan 2009 Flood Planning Map.*

Our brief requires advising as to appropriate LEP provisions. Notwithstanding the progress Council has made with the incorporation of flood related provisions within its draft LEP, it is considered appropriate to discuss and evaluate all options having regard to the above objectives. The template LEP contains no mandatory provisions or guidance as to a flood risk management clause, and there has been considerable debate between flood risk management practitioners and government officials about this. The main issues considered in framing the recommendations for Council's LEP are discussed below.[3]

6.11.2 To Have Flood Related Provisions or Not?

A clause such as that contained in the current draft LEP is what we would normally recommend. Such a clause provides an appropriate balance between being overly restrictive and prohibiting development that upon detailed assessment is found acceptable and providing some recognition of flood risk as a relevant consideration. The omission of the clause would not mean that Council would be precluded from considering flood risk in the assessment of development applications but flags it as a possible issue and specifies the broad criteria for assessing the issue. This would simply encourage the consideration of flood risk issues and provide weight to the issue if ever the subject of review by the Courts.

Due to the significance of flooding as an environmental hazard within the LGA, it is considered appropriate that some recognition of the hazard be provided at the LEP level. The inclusion of such a clause will also provide continuity from council's existing LEP which includes references to flooding. The failure to replace flood related provisions would present to the public a perception of decreasing importance of floodplain management in the LGA, being a significant environmental hazard in the local planning context.

Flood related provisions can reinforce the significance of flooding in the assessment of development applications, identify key issues for consideration in development applications, provide definitions to establish parameters for dealing with development within the floodplain (e.g. specify what part of the floodplain might be exempt or complying development), establish a framework for Section 149 Certificates and provide consistency in regard to informing the public about flood hazards.

Such a clause can also be a mechanism to recognise and give effect to an FRMP prepared by Council in accordance with the Floodplain Development Manual, consistent with various government policies including higher order planning policies such as the "*Sydney-Canberra Corridor Regional Strategy*" (DoP 2008). FRMPs previously prepared for Berrima and Bowral require the inclusion of flood related provisions in Council's LEP.

The DECC have advised Council that they object to Council's Template LEP if it does not include a flood related clause. This is understandable having regard to the above.

Accordingly, it is our view that the Template LEP should include flood risk management related provisions.

[3] Comments are based on interim draft LEP wording provided to the Consultants in November 2008, predating the wording contained in the draft Wingecarribee LEP 2009 in **Table 6.1**.

6.11.3 How to Define Flood Liable Land?

A vast array of definitions of flood liable land and related terms exist in planning instruments. The important considerations are:

- Consistency with government policy.
- Avoid confusing the public by inadvertently implying that some areas are not subject to flood risk when they are in effect only not subject to flood related planning controls.
- Allow for flood risks associated with any development proposals to be considered when relevant.
- It must be simple – to avoid misinterpretation and unnecessarily burdening the development assessment process.
- Capable of supporting more appropriate detailed controls in a DCP.

It is recommended that the definition of flood liable land included within the LEP encompass the whole of the floodplain, that is, up to the PMF. This would be consistent with the provisions of the Floodplain Development Manual, would resolve issues of confusion with the public in regard to why there is land not deemed to be flood liable (i.e. above the FPL but still with a chance of flooding), and provide a more appropriate framework for more detailed planning controls to be embodied within a DCP.

It is considered that the DoP Planning Guideline should not be interpreted to prevent the definition of flood liable as above, only to restrain the introduction of provisions that contained restrictions on standard residential development. This interpretation would be consistent with the definition of "flood prone land" contained in the recently gazetted Liverpool 2008 LEP.

6.11.4 Whether to Incorporate Flood Maps into the LEP?

Our discussions with Council, DECC and DoP in regard to this project and others indicate that it is the opinion of the DoP and Parliamentary Counsel that there must be an LEP Map that depicts flood liable land, if the LEP refers to such in a specific flood related clause. Whilst this would be ideal it is not practical if to be done correctly and in a way that does not mislead the public for the following reasons:

- Council is unlikely to be able to identify all flood liable land inclusive of major overland flow paths as defined as flooding under the Floodplain Development Manual; and
- even if the above was possible, revised modelling, improved survey information, flood mitigation works, and new development can result in constant adjustments to the extent of flood liable land. This issue is made even more problematic with climate change flood risk considerations.

It is preferable in our view that the definition of flood liable land does not refer to a singular map at a point in time, but rather is determined by Council based on current best information. This is effectively the process that occurs now with most Councils and would continue to occur if a flood related clause was not included in the LEP.

While not preferred, alternatively the LEP definition could refer to a map held in the offices of Council that may be amended from time to time (but not formally part of the LEP) or adopted as part of Council foreshadowed comprehensive DCPs and regularly reviewed by Council and amended as required in accordance with the Regulations.

We recommend that DoP be asked to review their position in regard to the inclusion of flood liable land maps as part of the LEP for reasons inclusive of the above and the following:

- The need for maps is not considered critical as the only LEP controls proposed relate to basic matters for consideration and would not have implications in regard to the permissibility of development.
- The LEP clause is consistent with FRMPs adopted by Council and required to be implemented pursuant to state government policy including the Floodplain Development Manual and the "*Sydney-Canberra Corridor Regional Strategy*" (DoP 2008).
- Council's existing LEP makes reference to flood affected land with no maps.
- Experience shows that Council would consequently develop two flood maps systems – the gazetted LEP maps and the current flood maps. There may be years between LEP updates that will bring the two map sets into sync for a point in time. This will create an unnecessary administrative burden, cause difficulties when assessing DAs subject to conflicting maps, confuse the public and work against flood awareness objectives of flood risk management.

A typical example of problems that would arise with LEP flood maps will be Council receiving a DA which for a site not mapped as flood prone by the LEP but on assessment determined to be subject to a significant flood hazard. The applicant would argue that flood risk is not a relevant consideration because of the LEP while Council would argue it was nonetheless a relevant consideration under S79C of the EPA Act. This only works against the intent of having a flood related clause because in the end Council is better off having no LEP flood clause and relying on S79C of the EPA Act and its DCP. If the LEP flood clause broadly defined flooding (as recommended below) the considerations required would have the added weight of the LEP, and the applicant would be more likely to rely on current information.

This is an issue that is relevant to the majority of Councils in NSW. We understand that the Floodplain Management Authorities have made representations to the Planning Minister's Office in regard to this issue and it will be reviewed. It may not be resolved as part of this FRMP. Consequently, if the DoP and DECC positions do not change Council will need to make a decision to refuse to progress the LEP with flood overlay maps or accept the inclusion of flood overlay maps notwithstanding the above limitations. If the latter decision is made the information conveyed by the maps will need careful management both in regard to ensuring the public fully understands their limitations (by methods such as disclaimers and supplementary information) and providing on-going reviews and LEP amendments.

6.11.5 Whether to Prohibit Development Likely to be Subject to Unacceptable Flood Risk?

While consideration was given to introducing prohibitions on flood sensitive developments within certain parts of the floodplain (e.g. in the high flood risk precinct), this is not proposed. In this case it is considered that appropriate controls on the type and form of development can be imposed through the recommended DCP provisions. This will retain flexibility for Council in implementing its flood risk management objectives.

However, Council should consider the full risks of flooding when deciding upon appropriate land use zones for individual properties and if appropriate adopt restrictive zones available within the Template LEP.

6.11.6 What to do with Exempt and Complying Development?

In addition to the above, there will be a need to frame Council's exempt and complying development provisions in the Template LEP to avoid the need to consider formal development applications for minor and inconsequential development affected by flooding. We understand that the DoP has directed that exclusions for exempt and complying

development will need to be incorporated within the detail specification for each type of development as opposed to within an over arching clause. In undertaking this exercise, we would recommend the following principles:

- that no development in a high flood risk precinct be considered exempt development; and
- that no development on flood liable land (as proposed to be defined inclusive of land up to the PMF) be considered complying development.

6.11.7 Summary

Having regard to our views expressed above, it is recommended that Council's Template LEP should provide some reference to floodplain management, principally to satisfy the above potential functions of an LEP in the floodplain management process. This should simply include a definition of flood liable land, a clause requiring basic matters for consideration and no flood maps. Draft LEP provisions consistent with the above recommendations and in a format suitable for inclusion in the LEP Template, are outlined within **Appendix H**.

6.12 DEVELOPMENT CONTROL PLANS (DCPs)

6.12.1 Background

A Development Control Plan (DCP) is a plan prepared in accordance with Section 72 of the Environmental Planning & Assessment Act which provides detailed guidelines for the assessment of development applications. Various DCPs of some relevance apply in the study area.

In NSW a DCP is the appropriate mechanism for specifying detailed controls to be applied for new development. Such a DCP was recommended as part of the Berrima FRMP, incorporating a structure and controls applicable to the whole LGA. This DCP was adopted by Council as DCP 34 in February 2002. This DCP was reviewed as part of this study to update provisions and incorporate controls relevant to the Bowral floodplain.

Provisions provided specifically for Bowral (and residual parts of the LGA on an interim basis until a FRMP is prepared) may also be worthwhile additions to controls previously recommended and applied to the Berrima floodplain. Such additional controls include those in relation to car parking and site access. Since the Berrima controls were produced and endorsed under the direction of a Floodplain Management Committee representing that area, it is not proposed to provide any substantive alterations to those controls as part of this plan. Notwithstanding, some minor refinements to the Berrima controls are undertaken to allow for consistency with the updated draft DCP and Draft Template LEP. Further, it is recommended that the Bowral controls be taken into consideration as part of any future review of the Berrima FRMP.

Recent amendments to the EPA Act have been undertaken to encourage the preparation of consolidated DCPs, consistent with the reforms provided by the LEP template. The provisions of Section 74C (2) of the EPA Act would ultimately limit the creation of one DCP applying to a property. Council is in the process of preparing a new comprehensive DCP in a series of discrete but integrated parts. This new DCP will be precinct based and provide separate parts for different towns, villages and rural areas.

An outcome of this FRMP is the production of a specific flood risk management DCP section that can be included in the appropriate section of the Bowral DCP part of the new

comprehensive DCP. This new flood risk management DCP section can be modified for inclusion in relevant DCP parts applying to other areas. The recommended DCP section is a reviewed version of DCP No. 34 and is included as **Appendix I**. The DCP should be accompanied by a map which identifies all Flood Risk Precincts for Bowral.

6.12.2 General

Consistent with DCP 34, a matrix of recommended planning controls for the floodplain of the study area is provided. These controls vary dependent upon the relevant flood risk precinct and individual land use categories, consistent with the philosophical approach outlined previously. The matrix provides a singular consolidated list of controls appropriate for the purposes of this report.

We have also provided a structure which would allow for the outcomes of any future FRMP within the LGA to be incorporated into the document. Accordingly, it is recommended that Council adopts the model flood-related DCP provisions, provided at **Appendix I**, in principle for inclusion within each part of its new DCP. The DCP provisions will require a minor review to remove any inconsistency or overlap between each DCP part. The following subsections of this report outline the principles underlying the model flood-related DCP controls for the Bowral and other floodplains.

6.12.3 Specific DCP Considerations

There are seven areas of development control consideration relevant to floodplain planning in this case, which may be applied to development in the study area. The “car parking and driveway access controls” were not originally included in the Berrima prescriptive planning controls but can be considered in future reviews. The following provides a discussion of the controls that would be appropriately considered under each of these headings.

6.12.4 Floor Levels

In principle, all habitable floor levels of dwellings should be no lower than the 100 year ARI flood level plus freeboard unless there is good reason to depart from this standard. This will provide a level of protection to property that is generally expected by the community in the LGA with reference to the history of existing planning controls. This control would apply to residential development and therefore be consistent with the new Departmental Guideline. Additionally, where practical, extended floors associated with minor additions to existing development should be provided at the 100 year ARI flood level plus freeboard but should never be at a level lower than the existing floor level where that does not comply with the standard.

Critical utilities and sensitive uses should have levels above the PMF, as these will be essential to minimising danger and disruption to the community during major floods.

Similarly, the floor levels of retail and commercial development should be at the 100 year ARI flood level plus freeboard, where possible. An alternative floor level control is provided for commercial uses in order to allow for floor and street levels to relate in a manner consistent with existing development in a centre, subject to elevated storage space being provided.

Less “flood sensitive” land uses such as buildings associated with *recreation* or some *non-urban uses* could have buildings located with floor levels at a lower flood level (plus freeboard) sufficient to avoid nuisance flooding. (In some circumstances, it may be appropriate to vary this requirement and where a site specific analysis was carried out).

Where possible it is desirable to require new floor levels to be at the 100 year (plus 0.5m freeboard) height. However, for minor infill development in established areas such as a replacement dwelling or a single dwelling in an older street where the higher level would impose significant streetscape and amenity impacts with proportionally minor benefits to the broader community in regard to reduced flood damages, the above floor levels may be acceptable minimums. The DCP is to establish guidelines for the implementation of this principle.

6.12.5 Flood Compatible Building Components

All structures below the design flood level for individual land uses should be constructed of flood compatible materials. With regard to the identification of appropriate flood compatible materials, an appropriate general list of materials and fittings is provided within the recommended DCP. However, we note that the DECC commissioned a detailed study by the CSIRO and the University of Newcastle which identifies appropriate flood compatible materials (including methods of construction) applicable to Australian conditions (in particular, the Hawkesbury-Nepean Floodplain). This study is now published in the form of building guidelines for the Hawkesbury Nepean Floodplain. It was beyond the scope of this study to review and incorporate these guidelines as appropriate but it is recommended that this be undertaken as part of the next DCP review.

6.12.6 Structural Soundness

An engineer's report is considered to be appropriate to ensure structures located within high flood risk precincts are capable of withstanding the forces of floods including debris and buoyancy factors.

The issue of structural soundness should also be considered elsewhere within the floodplain, but it is not considered that an engineering report would be necessary in each case. The applicant would still need to demonstrate that the issue has nonetheless been addressed, by either explaining how such an issue is not relevant in any particular case, or that the design has minimised any impacts to the maximum practical extent. Council engineers may require an engineer's report once the matter is assessed or the applicant could elect to provide such a report in recognition of the issue.

The proposed DCP controls generally require buildings to be structurally sound in floods up to a 100 year event. Structural stability up to a PMF event is required where buildings are required to provide a refuge above the PMF, and for all "sensitive uses and facilities".

6.12.7 External Flood Effects

An important principle in floodplain management is to ensure that development within the floodplain does not increase the flood affectation or hazard upon other properties or persons. Hence, it is recommended that an engineer's report is provided for any development within the high flood risk precinct or for any subdivision works and filling in the medium flood risk precinct to prove that the development will not increase flood affectation elsewhere. This matter will also need to be considered with regard to other land uses in the floodplain but an engineering report may not be necessary in each case. As above, the applicant would be required to demonstrate that the issue has been addressed and Council engineers will assess the matter and determine whether an engineering report is nonetheless required in any particular case.

6.12.8 Evacuation

These controls are aimed at ensuring that human life is protected by maximising opportunities to safely evacuate people outside of or "above" the floodplain.

In principle, the direction of evacuation will be dependent on warning times, duration of floods and available evacuation routes. As warning times and flood duration are relatively short, and roads out of the floodplain can be blocked during a flood, it can be more appropriate to require a refuge on-site above the PMF as a suitable means of evacuation (often referred to as "vertical evacuation" or "refuge in place"). Flexibility is to be provided within the planning controls for evacuation to be achievable either out of the floodplain or to a suitable refuge on site above the PMF.

6.12.9 Car Parking and Driveway Access

Domestic car parking (including carports and garages) should be provided as high as practical and high enough to avoid nuisance flooding. Some flexibility is appropriate to allow for variations between ground level at the position of the parking and the level of the road. Driveways should be designed so as not to allow for motorists to need to travel down into rising floodwaters at depths able to cause a vehicle to float.

Larger parking structures, in particular enclosed parking such as basement parking, should be subject to more stringent flood risk management measures. These parking structures should be protected from inundation from a 100 year flood and provide internal warning mechanisms and evacuation routes should larger floods occur that would rapidly flood the structure.

6.12.10 Management and Design

Special consideration of the design and management of individual proposals can also reduce the flood risk and potential damage to property and persons. These measures may involve the provision of a flood plan for individual sites which ensures that individuals consider and plan a means to minimise the likelihood of flood damage, including providing for the movement of goods above the flood level within the likely available flood warning time. Other specific considerations are for the storage of certain goods above the design flood level and requiring the implementation of mitigating measures to prevent pollution of the waterway and floodplain potentially occurring during floods.

6.13 COUNCIL POLICIES

In addition to formal regulations such as a DCP or an LEP, Councils may from time to time adopt specific policies with regard to their long term vision for development within the floodplain or to deal with specific matters such as flooding. Normally, such policies are translated into DCPs or other planning instruments such as an LEP.

The State Government Flood Policy introduced in 1984 specifically abandoned the mandatory application of the 100 year ARI flood standard as the designated flood standard for the State of New South Wales, and required each LGA to determine their flood standard or standards based on merit. The Floodplain Development Manual introduced in 1986, and the more recent Floodplain Development Manual released in 2005, provide guidelines to assist councils in determining the relevant standards and policies, through the preparation of Floodplain Risk Management Studies and Plans.

Until the adoption of a FRMP, Councils under the 1986 Floodplain Development Manual were required to produce an interim flood policy. The ability to rely on interim policies was removed in 2001 (with the introduction of the Floodplain Management Manual at that time) which increases the urgency to prepare FRMPs for flood affected areas in the LGA.

The procedures now outlined within the 2005 Floodplain Development Manual provide Council with indemnity pursuant to the limitations provided by Section 733 of the Local Government Act 1993, and accordingly are very important to Council's overall risk management procedures. The eventual outcome of all FRMPs, including this FRMP will be to translate relevant planning recommendations of these documents into the instruments available through the EPA Act, principally LEPs and DCPs.

6.14 DEVELOPMENT APPLICATION ASSESSMENT

Development applications for proposals which are permissible with consent must have regard to the relevant 'Matters for Consideration' contained in Section 79C of the EPA Act.

Section 79C(1)(a)(i) of the Act requires the consent authority to take into consideration, when determining a development application, the provisions of any environmental planning instrument. Accordingly, Council is required to have regard to the provisions of the applicable LEPs which specify various matters to consider with respect to flood liable land. Section 79C(1)(a)(iii) requires that Council also consider any DCP in force.

The EPA Act and accompanying Regulations 2000 also identify certain developments which are deemed to be "designated development". Designated developments are generally large scale developments which have been identified as potentially causing greater impacts on the environment. Hence, designated development proposals require the preparation of an Environmental Impact Statement (EIS) and more specialised assessment procedures including statutory notification of the development application with third party rights of appeal for any objector.

Schedule 3 of the Environmental Planning and Assessment Regulation 2000 identifies those developments which are designated development by virtue of their processing capacity, site requirements or location near environmentally sensitive features. Developments such as certain industries, local works, extractive industries, mines and the like are permissible in the zoning of the study area and adjoining land. Some of these developments may be regarded as designated development when located within a certain distance of a natural water body or wetlands or on flood prone land or a floodplain.

Schedule 3 of the EPA Regulation 1994 defines floodplain as follows:

> *"Floodplain means the floodplain level nominated in a Local Environmental Plan or those areas inundated as a result of a 100 year flood event if no level has been nominated."*

Accordingly, there are a number of potential outcomes of the FRMP process which may have implications in regard to the manner in which Development Applications are dealt with.

6.15 SECTION 149 PLANNING CERTIFICATES

6.15.1 General

A Section 149 Planning Certificate is basically a zoning certificate issued under the provisions of the EPA Act, and must be attached to a contract prepared for the sale of

property. The matters to be contained within the Section 149(2) Certificate are prescribed within Schedule 4 of the Environmental Planning and Assessment Regulation, 1994.

The wording of the Regulation is such that inconsistencies arise between local councils in regard to the extent of information they provide on flooding. It has been argued that on literal interpretation, councils are only required to provide a 'yes' or 'no' answer as to whether such a policy exists. Further, there is potential equivocation in regard to the obligation of council to advise persons when a council is aware of a flood risk, (e.g. that a property is known to be located between the 100 year ARI and PMF extents), and there are no policies restricting development subject to the risk. A principal issue which arises is whether there is a legal requirement or duty for council to advise of the risk (Mawson J, Prior N, and Bewsher D, 1994).

A Section 149(5) Certificate, being a more complete but more expensive certificate, requires councils to advise of *"other relevant matters affecting the land of which it may be aware"*. These more complete certificates are not mandatory for inclusion with property sale contracts – a Section 149(2) Certificate being the minimum required. Where a Section 149(5) Certificate is obtained, this would more clearly require a council to notify of flood risks of which it is aware.

It is recognised that S149 certificates should not be solely relied upon as broad community education tools as they have only limited circulation. The majority of flood-affected properties would not be reached in a given year. However, with the existing system of notifications on S149 (2) certificates, if no notification appears, then it is often misunderstood to mean that property is "flood-free" rather than there are no development controls. S149 certificates should not confuse or mislead those people who have access to them, with regard to understanding whether there are any risks of floods affecting a particular property.

6.15.2 2007 Amendments to the Regulation

Schedule 4 of the Regulation was amended, commencing on February 16, 2007, to specify flood related information that can be shown on Section 149(2) Certificates. The amendment will require councils to distinguish between the situation where there are flood related development controls on nominated types of "residential development" and all other development. More sensitive land uses such as group homes or seniors living are excluded from the limitation of notations for residential development.

The new Clause 7(A)(1) of the Regulation means that Council should not include a notation for residential development on Section 149(2) Certificates in "low risk areas" if no flood related development controls apply to the land. Under Clause 7(A)(2) Council can include a notation for critical infrastructure or more flood sensitive development on Section 149(2) Certificates in low flood risk areas if flood related development controls apply. Low flood risk areas are undefined, but in the context of the Circular dated 31 January 2007 it is assumed to be a reference to that part of the floodplain between the 100 year flood (plus freeboard) and the PMF extents.

6.15.3 Practical Difficulties in Compiling Notations

Council may (now and in the future), have flood information and policies for different properties at various standards, including:

(a) no flood studies or preliminary assessment by an engineer;

(b) no flood studies but a preliminary assessment by an engineer indicating the property is likely to be affected by flooding but the extent of flooding will need to be determined;

(c) a flood study that has been completed but has not yet been adopted by the Floodplain Risk Management Committee and/or Council;

(d) a flood study that has been completed and has been adopted by the Floodplain Risk Management Committee and/or Council;

(e) a floodplain risk management study and plan that has been completed but has not yet been adopted by the Floodplain Risk Management Committee and/or Council; and

(f) a floodplain risk management study and plan that has been completed and has been adopted by the Floodplain Risk Management Committee and/or Council.

The Floodplain Development Manual defines flood prone land as all land potentially affected by inundation during a flood, up to the PMF. This includes both riverine flooding and flooding from major overland flow paths.
Flood mapping will identify the areas subject to major flooding in the study area. However this typically does not extend to the top end of contributing local catchments where water courses and overland flow paths are located within pipes or narrowly formed channels or are not evident except during major storms.

In our experience of current practice in NSW, Councils may have additional detailed flood mapping for the main catchment areas, some have maps or local knowledge of potentially affected areas (e.g. through a history of complaints) and some have no specific documented knowledge of potentially affected areas. Whilst it is desirable, we would expect that Council will never be able to unequivocally confirm that they have mapped all areas subject to potential flooding (mainly due to the unreasonable resources that would be required to map all overland flow paths), although Council may be able to say that they confidently believe they have identified the majority of properties affected by significant flooding.

6.15.4 Conclusion

It is desirable that all properties in the floodplain (i.e. up to the probable maximum flood where known of by available mapping) be notified on both S149(2) and S149(5) certificates. The proposed LEP clause and definitions and DCP provisions would establish a consistent basis for this. Section 149 Certificates have a limited circulation and purpose but are one important component of information which contributes to the public's overall knowledge of flood risks and should not be conflicting or misinforming (by omission). Should Council limit notifications on S149(2) certificates in any way, it is recommended that a notation be included that indicates further information about flood risks may be available upon enquiry with Council or in a Section 149(5) Certificate.

While there may be some concern about property owners having such a notation, there is an expectation by prospective purchasers that it would be provided, as indicated by the 2005 Manual. Further, it should be recognised that this revised approach for notifications on Section 149 Certificates, inclusive of the definitional change in LEPs, DCPs and Policies is not intended to lead to any significant alteration to the permissibility of development but is more directed towards providing factual information (important due to liability issues) and increasing awareness of the potential flood risk and the relative degree of such risk known to Council.

Suggested Section 149 (2) and (5) Certificate notations for consideration by Council are provided separate to this report. The various options for notations will need to take into consideration flooding from both riverine and overland flow situations. Such notations should be ultimately determined by Council having regard to the particular circumstances of individual floodplains and be the subject of separate legal advice. Further if necessary to avoid any doubt, the approval of the DECC and DoP could be sought under the exceptional circumstances provisions of the new Guideline.

6.16 SECTION 94 CONTRIBUTIONS PLANS

Section 94 Contributions Plans under the EPA Act provide a basis for the levying of development contributions to construct drainage and flood mitigation works required as a result of future development. Standard Section 94 contributions can only be applied to fund works with a direct nexus to the new development and cannot be applied for the purposes of rectifying past inadequacies. Section 94A Contributions Plans are an alternative where no nexus is required but the quantum of the contribution is capped at 1% of development costs.

Future Section 94 schemes will also require consideration of the Department of Planning Circular (PS 07-018) issued on 6 November 2007, and recent statutory changes mooted within the Circular and now partly contained the EPA Act amendments and awaiting further legislation prior to commencement. These changes are intended to limit costs to development imposed through development levies but retain drainage in the category of "key community infrastructure".

Plans could be established within the Bowral study area, where it is necessary or appropriate to fund flood mitigation works through such plans. However, given the extensive existing development within the Mittagong Creek catchment (including the "Beavan Place" sub-catchment), the area of future development would represent only a small proportion of the beneficiaries of any structural flood mitigation option. This, along with the substantial effort required to establish a Section 94 Contributions Plan, suggests that such a Plan may be unwarranted unless appropriately incorporated into a S94A Plan.

7. FLOODPLAIN MANAGEMENT PRINCIPLES

7.1 TYPES OF MEASURES AVAILABLE

Floodplain management measures can be divided into three general groups:

1) those that modify flood behaviour;
2) those that modify property in order to minimise flood damage; and
3) those that modify people's response to flooding.

Measures that modify flood behaviour usually include structural or engineering works that attempt to lower flood levels, or to divert floodwaters away from areas that would otherwise flood. Several types of measures were suggested by the community. A number of people advocated reducing flow inputs to the creek, whether by detention basins, flow diversions, catchment management or the use of on-site detention (OSD) and rainwater tanks for new development. Several people suggested that bridges and culverts be replaced or removed, or the creek be cleared of overgrowth, or structural in-channel works be conducted, to enhance the capacity of the creek to convey floodwaters. Another structural measure suggested by the community is the construction of levees, to protect property from flooding.

Measures that modify property in order to minimise flood damage include voluntary house purchase, voluntary house raising or house reconstruction, "flood-proofing" and controls on new development.

Measures that modify people's response to flooding include measures that provide additional warning of flooding, improved emergency management planning and improved public awareness of the flood risk.

Specific floodplain management measures for Bowral are considered in **Section 8**.

7.2 SELECTION OF THE FLOOD PLANNING LEVEL

The flood planning level (FPL) is the flood level selected for planning purposes, and directly determines the area of land subject to flood-related building and development controls.

Selection of the FPL is one of the most critical decisions in floodplain management, and is not an easy one. It should be based on an understanding of the flood behaviour, together with the balancing of social, economic and environmental consequences of flooding, including the potential for property damage and the risk to human life. Traditionally, only one FPL has been selected for a particular area, but current thinking is to consider more than one FPL for different types of developments or locations within the floodplain.

The adoption of a single FPL may be unduly restrictive for some types of land uses. For example, whilst it may be appropriate for some land uses, such as a hospital, to be located above the extreme flood, it could be argued that residential, industrial or recreational land uses do not require such restrictive control.

The adoption of a single FPL also tends to generate misconceptions regarding flood risk. Residents situated within the floodplain (i.e. the area below the probable maximum flood) but above the FPL, often mistakenly believe that they are not at risk from flooding.

To overcome the shortcomings of a single FPL, a "graded" set of controls which allow for the variation of damage risk with flood frequency and land use, was adopted for the *Berrima Floodplain Risk Management Study & Plan* (Bewsher Consulting, 2002).

The selection of controls and the conditions at which the controls apply, was based on:

- the procedures and philosophy espoused in the Government's *Floodplain Development Manual*;
- consideration of the social, economic and environmental impacts of flooding and the proposed controls;
- minimising Council's exposure to legal actions in relation to flooding;
- Council's previous development policies;
- views expressed by the community, the Berrima Floodplain Risk Management Committee, and various senior officers within Council and DECC;
- experience gained from the development of planning controls and flood policies for various communities across NSW in recent years.

It was decided during the Berrima Study that the 100 year flood level would be retained as the principal floor level control for residential land uses in the study area. The decision was based on a consideration of:

- the unacceptable increase in flood risks and damages, should a lower level be adopted;
- an unacceptable burden on future development, if a higher level was adopted;
- inconsistencies with recent development approvals if a level different from the 100 year flood was adopted; and
- recognition that the community views the residential floor level control as the principal component of the Council floodplain controls, and that changes to this control should not be made unless very strong arguments exist.

Given this precedent, it is recommended that for this study too, the 100 year flood level be retained as the principal floor level control for residential land uses within the Bowral study area.

7.3 CRITERIA FOR ASSESSING FLOODPLAIN MANAGEMENT MEASURES

A range of assessment criteria have been used for evaluating potential floodplain management measures within the study area. These are described below. A qualitative assessment has been undertaken for each floodplain risk management option according to these criteria. **Table 7.1** provides the scores used for each criterion for this qualitative assessment.

- *Number of buildings protected in the 100 year flood*

  A prime indicator of the effectiveness of a measure in reducing the potential for flood damage and the risk to life is the reduction in the number of buildings that are affected by significant floods.

- *Financial feasibility*

  Measures proposed within the floodplain risk management plan must be capable of being funded. There are various sources of funding that may be utilised, including funding

related to the development of new release areas (Section 94 Contributions), and funding from Wingecarribee Council, with assistance from DECC, for the alleviation of existing flood problems.

- *Economic merit*

  The ratio of the benefit divided by the cost (i.e. the benefit/cost ratio) is a common measure of assessing economic feasibility. Theoretically, no investment should be made on a measure if the benefit/cost ratio does not exceed unity (i.e. if the benefits do not exceed the costs). However, traditionally many floodplain management measures have been undertaken where this is not the case because the intangible benefits (i.e. those not able to be quantified) are considerable. Benefit/cost ratios can also be useful in ranking competing options.

- *Community acceptance*

  An understanding of community attitudes towards any proposed floodplain management measures is essential. Strongly negative community attitudes often would be enough to deter the implementation of a proposal which otherwise had merit. Community views on potential floodplain management measures were assessed early in the study through distribution of the community questionnaire. These results were discussed in **Section 5.4**. Further opportunity for comment was provided during public exhibition of the Bowral Floodplain Risk Management Plan (**Section 5.8**).

- *Environmental impact*

  Floodplain management measures involving structural works may often have significant environmental impacts. Impacts on vegetation, visual amenity and soil erosion/ sedimentation must be considered when evaluating works within floodplains.

- *Impact on flood behaviour*

  The impact on flood behaviour caused by any measure needs to be considered for upstream and downstream locations. These impacts can include such things as changes in flood levels, changes in velocities or alteration of flow directions.

- *Performance during large floods*

  All measures must be assessed in the knowledge that large floods, i.e. larger than the 100 year flood, or larger than any known historical flood, will happen at some time in the future. It is therefore imperative that the options do not expose the community to unacceptable risks by providing a false sense of security.

- *Technical feasibility*

  If the proposed measures involve structural works, these works must be able to be constructed and be free from major technical constraints.

- *Political/administrative feasibility*

  Any recommended measure will have more chance of success if it involves little if any disruption to current political and administrative structures, attitudes and responsibilities.

  Council and other authorities also have various strategic objectives concerning development within the study area.

TABLE 7.1
Explanation of Assessment Scores for Qualitative Assessment Matrix

CRITERIA	RANKING SCORE				
	– –	–	O	+	+ +
REDUCTION IN NUMBER OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD	number of houses flooded above floor in 100 year flood would increase	number of houses flooded above floor in 100 year flood could increase	no existing houses protected from over-floor flooding in 100 year flood	1 or 2 existing houses protected from over-floor flooding in 100 year flood	more than 2 existing houses protected from over-floor flooding in 100 year flood
FINANCIAL FEASIBILITY	Very unlikely to receive funding	May not receive funding	Neutral	Would possibly receive funding	Very likely to receive funding
ECONOMIC MERIT	Benefit–Cost Ratio less than 0.1	Benefit–Cost Ratio = 0.1–0.3	Benefit–Cost Ratio = 0.3–0.7	Benefit–Cost Ratio = 0.7–1.0	Benefit–Cost Ratio greater than 1.0
COMMUNITY ACCEPTANCE	Strongly against in community survey and community workshop	Not supported in community survey and community workshop	Neutral	Supported in community survey and community workshop	Strongly supported in community survey and community workshop
ENVIRONMENTAL IMPACT AND ECOLOGICAL ENHANCEMENT	Significant negative environmental impact	Some negative environmental impact	No environmental impact and no opportunity for ecological enhancement	Some opportunity for ecological enhancement	Significant opportunity for ecological enhancement
IMPACT ON FLOOD BEHAVIOUR	Significantly increase flood levels and/or velocities	Some increase in flood levels and/or velocities	No change	Some reduction in flood levels and/or velocities	Significantly reduces flood levels and/or velocities
CONSEQUENCES IN EXTREME FLOODS	Significantly increases risk	Some increase in risk	No change in risk	Some reduction in risk	Significant reduction in risk
TECHNICAL FEASIBILITY	Very difficult	Difficult	Neutral	Easy	Very easy and straight forward
POLITICAL/ ADMINISTRATIVE / LEGAL IMPACT	Significant changes required which are very unlikely to be supported	Some changes required which may not be supported	No changes or impact	Some changes required are likely to be supported	Significant changes required which are likely to be strongly supported

8. EVALUATION OF FLOODPLAIN MANAGEMENT MEASURES

Potential floodplain management measures for Bowral are discussed below. These include the measures suggested by the community. Each measure is included in a qualitative assessment matrix (**Table 8.1**) to assess its relative merits, thereby determining whether it should be included in Bowral's Floodplain Risk Management Plan.

TABLE 8.1
Qualitative Matrix Assessment of Floodplain Risk Management Options

MEASURE NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION		REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
					NO. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
1	**FLOOD MODIFICATION MEASURES**															
1.1	**Detention Basins**	Retford Park Detention Basin	Scoping study	O	0	++	$25K	+	Not assessed	+	O	O	O	++	O	Yes
			Implementation	++	21	+	~$4M	O	0.5	+	–	++	+	–	–	Yes*
		Bowral Street Detention Basin		+	2	–	~$2M	–	0.2	+	O	+	O	–	– –	No
		Combined (Retford Park and Bowral Street) Detention Basins		++	21	–	~$6M	O	0.4	+	O	++	O	–	– –	No
		Bowral Golf Course Detention Basin	Scoping study	O	0	++	$25K	+	Not assessed	+	O	O	O	++	O	Yes
			Implementation	++	5	+	~$0.5M	O	0.7	O	O	+	O	–	–	Yes*
1.2	**Divert flows to adjacent catchments**			Not assessed	Not assessed	– –	$30-50M	– –	<0.1	+	–	+	O	– –	– –	No
1.3	**Catchment management**			Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	+	++	+	O	+	O	Not applicable
1.4	**Control runoff from new development**	Continue OSD policy and incorporate into WSUD program		O	0	Not applic	Council staff costs	+	Not assessed	++	+	+	O	+	+	Yes
1.5	**Modify bridges and culverts**	Replace bridges and culverts (Bowral Street Bridge as example)		+	2	–	$700K	– –	<0.1	++	O	+	O	–	O	No
		Remove Victoria Street Bridge		O	0	+	$20K	++	2.5	+	O	+	O	+	–	Yes
		Amplify railway culvert north of Nerang Street		++	4	+	$60K+	+	0.8	+	O	+	O	+	–	Yes
1.6	**Manage riparian corridor**	Establish creek maintenance program to remove urban waste		Not assessed	Not assessed	+	$40K plus $20K pa maintenance	Not assessed	Not assessed	++	++	+	O	O	O	Yes
		Prepare Mittagong Creek Riparian Corridor Management Plan		O	0	++	$20K plus Council staff costs	+	Not assessed	++	++	O	O	++	O	Yes

MEASURE NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
1.7	**Structural works in channel**	Line channel with concrete	++	76	– –	$50M	–	0.1	O	– –	++	O	–	– –	No
		Large-scale dredging, widening, straightening	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	++	– –	+	O	–	– –	No
1.8	**Flood walls**	Scoping study	O	0	++	$20K	+	Not assessed	+	O	O	O	++	O	Yes
		Farmborough Close levee to protect to 10y flood	O	0	+	$300K+	++	1.7	+	O	–	– –	– –	–	No
		Farmborough Close levee to protect to 100y flood	++	17	+	$400K+	++	3.0	+	O	–	– –	– –	–	No**
2	**PROPERTY MODIFICATION MEASURES**														
2.1	**Voluntary house purchase**	9 houses northern side Farmborough Close	++	9	– –	$3.6M	–	0.3	?	+	O	++	++	– –	No
		10 houses flooded above floor in 5y	++	10	– –	$4.8M	–	0.3	?	+	O	++	++	– –	No
		17 houses flooded above floor in 10y	++	17	– –	$8.2M	–	0.2	?	+	O	++	++	– –	No
2.2	**Voluntary house raising/ reconstruction**	Scoping study	O	0	++	$20K	+	Not assessed	?	O	O	O	++	O	Yes
		7 weatherboard/fibro houses (Rose/ Shepherd/Una/Kiama/Sherwood) raised 0.5m above 100y level	++	7	++	$350K	++	1.5	?	O	O	–	–	O	Yes*
		7 brick houses (Farmborough) demolished and rebuilt 0.5m above 100y level	++	7	+	$560K	+	0.9	?	O	O	–	–	O	Yes*
2.3	**Flood-proofing**	Development of Flood Proofing Guidelines for the study area	O	0	+	$5K plus Council staff costs	Not assessed	Not assessed	O	O	O	+	+	O	Yes
2.4	**Revise planning and development controls**	Amend Wingecarribee LEP; Amend DCP 34; Amend Section 149(2) Certificates	O	0	Not applic	Council staff costs	+	Not assessed	++	O	O	++	++	–	Yes

MEASURE NO.	FLOODPLAIN RISK MANAGEMENT MEASURE	DESCRIPTION OF OPTION	REDUCTION OF HOUSES FLOODED ABOVE FLOOR LEVEL IN 100 YEAR FLOOD		FINANCIAL FEASIBILITY		ECONOMIC MERIT		COMMUNITY ACCEPTANCE	ENVIRON-MENTAL IMPACTS AND ECOLOGICAL ENHANCE-MENTS	IMPACTS ON FLOOD BEHAVIOUR	CONSE-QUENCES IN EXTREME FLOODS	TECHNICAL FEASIB-ILITY OR DIFFICULTY	ADMINIS-TRATIVE / POLITICAL / LEGAL IMPACTS	RECOMMENDED FOR FURTHER CONSIDERATION
				NO. HOUSES		CAPITAL COST		BENEFIT–COST RATIO							
3	**RESPONSE MODIFICATION MEASURES**														
3.1	**Improve flood warning system**	E.g. Install rain-gauge	O	0	+	$6K plus $500 pa maintenance	–	Not assessed	+	O	O	O	+	O	Yes
3.2	**Improve emergency management**	Revise Local Flood Plan	O	0	Not applic	SES staff costs	+	Not applic	+	O	O	+	++	O	Yes
3.3	**Improve public awareness**	Develop/distribute Bowral FloodSafe brochure and web-site	O	0	++	$1K (1,000 brochures)	+	Not applic	++	O	O	+	++	O	Yes
		Install flood marker/ sign	O	0	++	$6K	+	Not applic	++	O	O	+	++	–	Yes
		Update/ distribute flood certificates	O	0	+	Council staff costs	+	Not applic	++	O	O	+	++	O	Yes
		Institute hazard awareness days	O	0	+	Council staff costs	+	Not applic	?	O	O	+	++	O	Yes

Note: Refer to **Table 7.1** for an explanation of the symbols used.

* Contingent upon results of scoping studies.

** Actual construction of the Farmborough Close levee is not recommended at this stage, but could be pursued if other options for Farmborough Close (voluntary house reconstruction; the Retford Park Detention Basin) are not supported, and if the scoping study yields favourable results.

8.1 MEASURES THAT MODIFY FLOOD BEHAVIOUR

8.1.1 Detention Basins

Detention basins act to temporarily store floodwater from upper catchment areas during floods, releasing the water at a controlled rate. This tends to reduce peak flows and levels downstream of the basin sites. Council has constructed detention basins on the South Arm of Mittagong Creek, adjacent to East Bowral, immediately upstream of Old South Road (see **Figure 8.1a**). The East Bowral project cost about $2.8M, with substantial cost savings because all fill material was obtained on site, and being a Council reserve, there were no land acquisition costs. A further three potential detention basin sites have been identified, as indicated on **Figure 8.2**: the Retford Park and Bowral Street sites, situated on the Main (North) Arm of Mittagong Creek; and the Bowral Golf Course site, situated on the tributary draining the "Beavan Place" sub-catchment. Another potential site on the Main Arm was identified, immediately downstream of Old South Road, but was so small that it made negligible difference to flows, and was consequently not further investigated.[4]

a: Existing detention basin, South Arm

b: Retford Park detention basin site

c: Bowral Street detention basin site

d: Bowral Golf Course detention basin site

FIGURE 8.1
Existing and Potential Detention Basin Sites

[4] At their junction, the Main (North) Arm drains ~10.8 km^2 and the South Arm drains ~1.9 km^2 of the total basin.

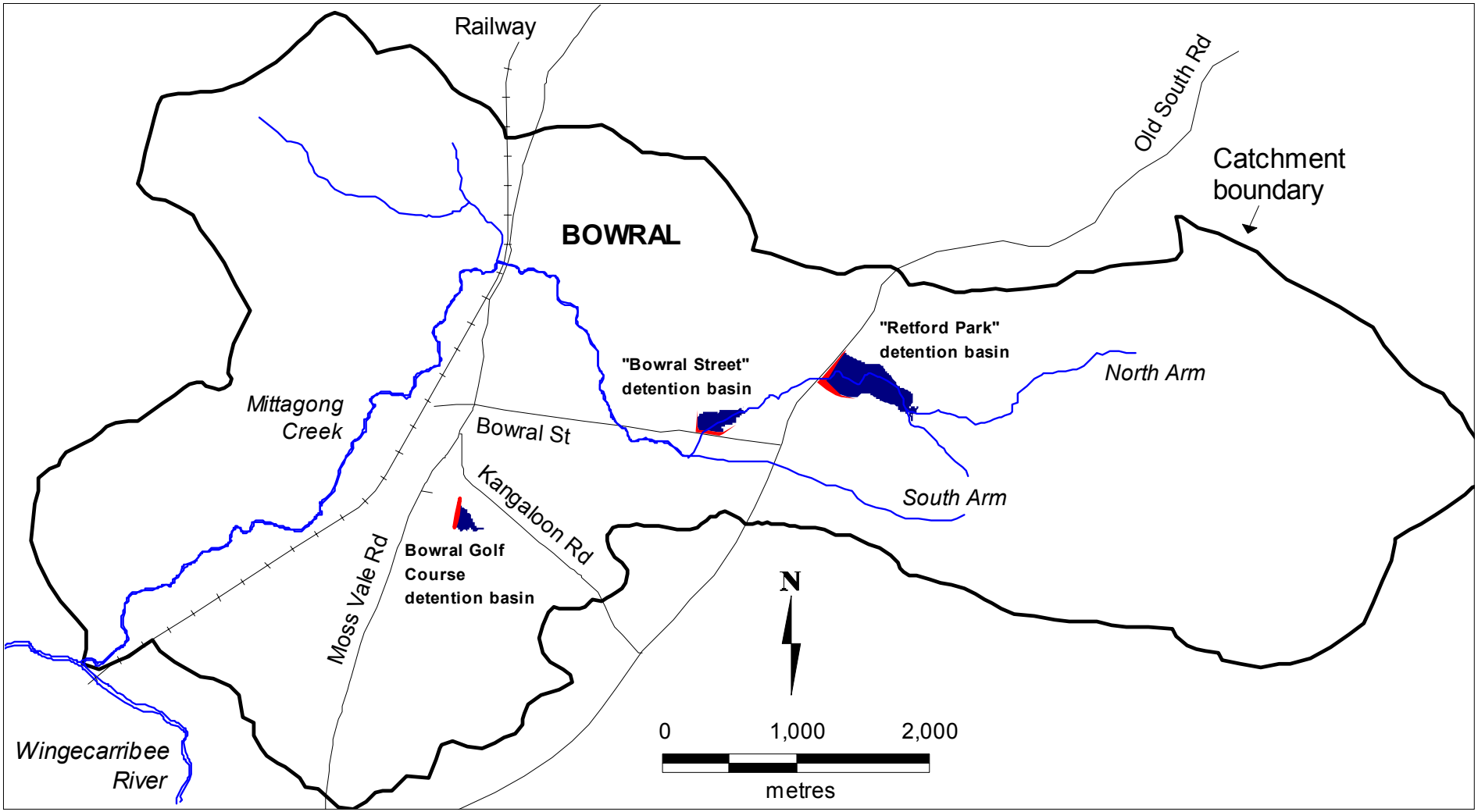


FIGURE 8.2
Location of Potential Detention Basin Sites

Preliminary basin details were determined using the RAFTS hydrologic model, which was developed as part of the Bowral Flood Study. Storage volume inputs for the Retford Park and Bowral Golf Course basins were imprecise, as these areas are beyond the range of the aerial photogrammetry, necessitating a reliance on 2m contours. Indicative flood level reductions were determined by estimating the ARI of the post-basin outflow, then interpolating between design flood levels based on a logarithmic scale.

8.1.1a Retford Park Detention Basin

Scoping study recommended, then implementation if feasible

A site on the Main Arm of Mittagong Creek, immediately upstream of Old South Road, was identified as a potential site for a large detention basin. **Figure 8.3** indicates that a 6m high earth embankment (at the deepest point) would provide a storage volume of about 355,000 m^3. A basin of this size would reduce 100 year flows to about 20 year flows at the Bowral Street Bridge (Node 1.09), to about 40 year flows at the Railway Bridge (Node 1.14), and to about 70 year flows near the Oxley Hill Road Bridge (Node 1.20). The corresponding reduction in 100 year flood levels would be about 0.4m, 0.2m and 0.1m, respectively. The number of houses expected to flood above floor level in the 100 year flood would decrease by 21, from 76 to 55, and the number of businesses expected to flood would decrease by 4, from 23 to 19. The total damage savings would amount to about $2.1M. This compares to a capital cost in the order of $4M, which takes account of detailed design and survey, earthworks (by far the largest component), drainage and remediation, and also incorporates a 20% contingency (but makes no explicit allowance for any costs of land acquisition). This yields a benefit-cost ratio (BCR) of approximately 0.5, which is "neutral" in the qualitative assessment matrix (**Table 7.1**). Cost savings could be had if the fill material was obtained on-site, which could also enhance storage volumes through excavation.

In its favour is the fact that the basin "footprint" is situated entirely on one property – smoothing the process of negotiation – and the property is zoned 7(B), Environmental Protection. The basin footprint slightly intersects with an Endangered Ecological Community (**Section 2.4**), but this is not considered prohibitive given the rarity with which the basin would fill. Retford Park is listed as a heritage property (**Section 2.3**), but this too is not considered prohibitive since the buildings are situated some distance beyond the footprint. The visual impact of a 6m embankment requires consideration, though only adjacent to the creek would the embankment reach such a height, and the vista beyond is modest (**Figure 8.1b**). Another factor that would need to be considered is dam safety, requiring referral to the Dams Safety Committee of NSW.

Although the most significant item of capital expenditure in the Plan, the Retford Park Detention Basin would have more effect than any other single (feasible) measure in reducing the number of houses flooded above floor level in the 100 year event. For this reason, it is recommended that further consideration be given to this option. A first step would be to commission a study to further assess its feasibility. In particular, a detailed ground survey is required to facilitate initial design, since only 2m contours were available for this study. Negotiations with the landowner should begin, including the potential for securing fill on-site. Other potential obstacles would need to be resolved via liaison with the NSW Department of Environment and Conservation, the NSW Heritage Office and the Dams Safety Committee. A scoping study of this nature is expected to cost about $25K.

8.1.1b Bowral Street Detention Basin

Not recommended for further consideration

A site on the Main Arm of Mittagong Creek, immediately upstream of the Bowral Street culvert, was also identified as a potential site for a detention basin. In order to allow

controlled passage of the PMF, the basin spillway could be no higher than 681.5 mAHD, which provides a storage volume of only about 50,000 m^3 (**Figure 8.4**). A basin of this size would mitigate the 100 year flood only slightly, reducing flows to about 80 year flows up to the Railway Bridge, and reducing levels by 0.04m. The number of houses expected to flood above floor level in the 100 year flood would decrease by 2, from 76 to 74, and the number of businesses expected to flood would decrease by 2, from 23 to 21. The total tangible damage savings would amount to less than $0.5M. This compares to a capital cost in the order of $2M, yielding a benefit-cost ratio (BCR) of approximately 0.2.

A significant impediment to constructing a basin on this site is the cost of acquiring private property within the basin "footprint", property that is zoned for residential use. The cost of land acquisition was not accounted for in the above estimate. Given this, and the limited hydrological benefits, the Bowral Street basin is not recommended for further consideration.

8.1.1c Combined Basins

Not recommended for further consideration

Construction of both the large Retford Park basin and the small Bowral Street basin would reduce 100 year flows to about 20 year flows at the Bowral Street Bridge, to about 40 year flows at the Railway Bridge, and to about 60 year flows near Oxley Hill Road, corresponding to reduced 100 year levels of 0.4m, 0.2m and 0.1m respectively. 21 houses and 4 businesses would be saved from flooding in the 100 year event. Damage savings would approximate $2.2M. The capital cost of about $6M yields a BCR of approximately 0.4. It is apparent that most of the benefits would be derived from the large Retford Park basin, with negligible benefits from the smaller basin. Therefore, the combined basin option is not recommended for further consideration.

8.1.1d Bowral Golf Course Detention Basin

Scoping study recommended, then implementation if feasible

A basin site located entirely within Bowral Golf Course was identified as an option for mitigating flood damages in the "Beavan Place" sub-catchment. **Figure 8.5** shows the footprint of the largest basin possible for the site, given the proximity of residential property to the north-east, and the requirement for 0.5m freeboard. In order to allow controlled passage of the PMF, the basin spillway is longer than desirable given the proximity of houses downstream, but any shortening would require a compensatory reduction in spillway level, which would compromise the performance of the basin. The 2m high earth embankment would provide a storage volume of about 10,000 m^3, reducing 100 year flows to about 20 year flows, and levels by up to 0.3m. The number of houses flooded above floor level in the 100 year event would decrease from 8 to 3, and the number of businesses from 5 to 2. The total tangible damage savings would amount to about $330K, which compares to a capital cost in the order of $0.5M, yielding a BCR of approximately 0.7.

In its favour is the fact that the basin "footprint" is situated entirely on one property zoned 6(B), Open Space (Recreation). The impact on the golf course would need to be considered. As much as half the width of the fairway would be subject to works, though this could be lessened if it were feasible to construct a concrete wall rather than an earthen embankment. Once complete, the fairway would be somewhat narrower. Adverse effects on the golf course possibly could be offset by improvements, such as sub-soil drainage works (though this would increase the cost). Another consideration is the loss of visual amenity – residents of "Berida Park" could possibly lose their views of the golf course. Another factor that would need to be considered is dam safety, possibly requiring referral to the Dams Safety Committee of NSW.

In view of its hydrological impact, and relatively favourable BCR, it is recommended that further consideration be given to the Bowral Golf Course basin. A first step would be to commission a study to further assess its feasibility. The community has expressed a desire for alternative sites to be investigated (**Section 5.8**). Negotiations with the landowner and surrounding residents should begin. More detailed ground survey should be carried out to facilitate design. A scoping study of this nature is expected to cost about $25K.

8.1.2 Divert Flows to Adjacent Catchments

Not recommended for further consideration

A few members of the community suggested diverting flows to adjacent catchments as a means of reducing peak flows in Mittagong Creek. No specific details were provided, but this would likely require major construction work at a cost of $30–50M, far in excess of the total present value of damages (about $10.3M – **Section 4.4**). Given an unfavourable BCR, and the likelihood of worsening flooding in receiving catchments, it is recommended that no further consideration be given to this measure.

8.1.3 Catchment Management

Consideration of this measure is beyond the scope of this study

A few members of the community suggested improving catchment management as a means of reducing runoff and the deposition of sediment in Mittagong Creek. Afforestation of the upper catchment area, and sustainable farming practices, would be expected to bring about some minor, though unquantifiable, benefits in terms of flood mitigation. However, it is typically the case that the more intense the rain (such as a 100 year event), the less the attenuating benefits of vegetation. Improved catchment management is regarded as more of an environmental measure than a flood mitigation measure, and for that reason, is not considered further in this study.

8.1.4 Control Runoff from New Development

Continuation of OSD policy and promotion of WSUD recommended

A good deal of concern was expressed in the community survey about the potential effect of new residential development in enhancing runoff via increased impervious surfaces. Detention basins are one means of ensuring no increase in runoff as a result of development – the basins adjacent to the East Bowral development already perform this function, and the Retford Park and Bowral Golf Course basins would also detain any additional runoff from catchment development. Council has existing policies requiring on-site detention (OSD) for up to 100 year events (unless waived) and rainwater tanks for new houses (4000 L) and new medium density development (2000 L). One survey respondent suggested that Council should subsidise rainwater tanks for old dwellings. Council could incorporate these policies within an overall program of Water Sensitive Urban Design (WSUD), which can be defined as “the integration of urban planning development with the management, protection and conservation of the water cycle as a whole”. Types of WSUD techniques include grass or vegetated swales, infiltration trenches, bio-retention systems, wetlands, porous pavers, rainwater tanks and grey water reuse (see www.wsud.org).

However, it needs to be remembered that it is not possible to anticipate whether rainwater tanks will be empty, half-full or full during a major flood event. Their primary purpose is for efficient use of rainwater, and any benefits for flood mitigation are incidental. Similarly, WSUD structures typically are designed to function at smaller rainfall events.

Nevertheless, it is recommended that Council continue to implement its OSD policy, and to incorporate this into an overall program of WSUD.

8.1.5 Modify Bridges and Culverts

a) Replacing bridges and culverts not recommended for further consideration
b) Removing Victoria Street Bridge recommended for further consideration
c) Amplifying railway culvert north of Nerang Street recommended for further consideration

Bridges and culverts can sometimes act as a restriction to flood flows, leading to an increase in upstream flood levels. This effect is captured on the long profile of the 100 year flood along Mittagong Creek (**Appendix E**). **Figure 8.6** illustrates the 18 bridges and culverts across Mittagong Creek from Old South Road to Oxley Hill Road (some of which may be illegal), as well as two culverts under the railway line that drain water from the "Beavan Place" sub-catchment. The afflux associated with each structure in the 100 year event is recorded. It is apparent that some structures have negligible effect (<0.2m) while others have a substantial effect, such as the Victoria Street Bridge (about 0.6m). The effect of a bridge or culvert on flood behaviour is a function of the area of the waterway opening, the extent of blockage across that opening (discussed in **Section 3.2** and **Appendix D**), and the proportion of flood flow that is naturally routed across the floodplain. An inspection at the Shepherd Street Bridge indicates that only about 10% of the 100 year flow travels in the channel, and only about 20% of the 5 year flow travels in the channel. That is, the bulk of the flow is routed across the floodplain.

A substantial number of survey respondents called for bridges to be replaced or culverts to be enlarged. To test the economic merit of this option, the (old) Bowral Street Bridge (**Figure 8.6d**) was used as a case study.[5] Improving the hydraulic conveyance of floodwater, both under the bridge and over the road approaches, could reduce 100 year flood levels at 6 houses immediately upstream (within 100m) by up to 0.4m, but could slightly increase flood depths at 1 house downstream. This may require a very much larger bridge that might be impractical given the constraints of the adjacent road approaches. Such a bridge could cost at least $700K. The total damage savings from this measure approximate $50K, yielding a BCR of less than 0.1. Consequently, replacement of the Bowral Street Bridge would not be economic on the grounds of flood mitigation alone (it could have other intangible benefits such as flood-free access). This example suggests that bridge replacement is not a cost effective flood mitigation measure for Bowral – typically only small areas would benefit for each structure, with modest benefits for significant costs. For this reason, this measure is not recommended for further consideration.

Bridge removal, however, is a different matter, since removal is much more affordable (in the order of $20K). It is noted that the Victoria Street Bridge (**Figure 8.6i**) is used only by pedestrians at present. If the bridge was closed, alternative access to the town centre via the Rose Street Bridge is readily available. Preliminary calculations suggest that removal of the bridge could provide damage savings of up to $50K. Given a favourable BCR, it is recommended that further consideration be given to removal of the Victoria Street Bridge.

Although bridge and culvert replacement may not be economic, small-scale amplification of culvert openings may be worthwhile. The large afflux associated with the culvert situated north of Nerang Street (**Figure 8.6t**) could be reduced by conducting works similar to those recently carried out by Council on the culvert situated south of Alcorn Street at a cost of about $60K (**Figure 8.6s**). A reduction in levels of even 0.2m immediately upstream of the culvert could save 4 houses from inundation in the 100 year event. While negotiations with the Railways would be required to deepen the culvert opening, the favourable BCR suggests that further consideration be given to this measure.

[5] At the time of writing in May 2005, a new Bowral Street Bridge was under construction.

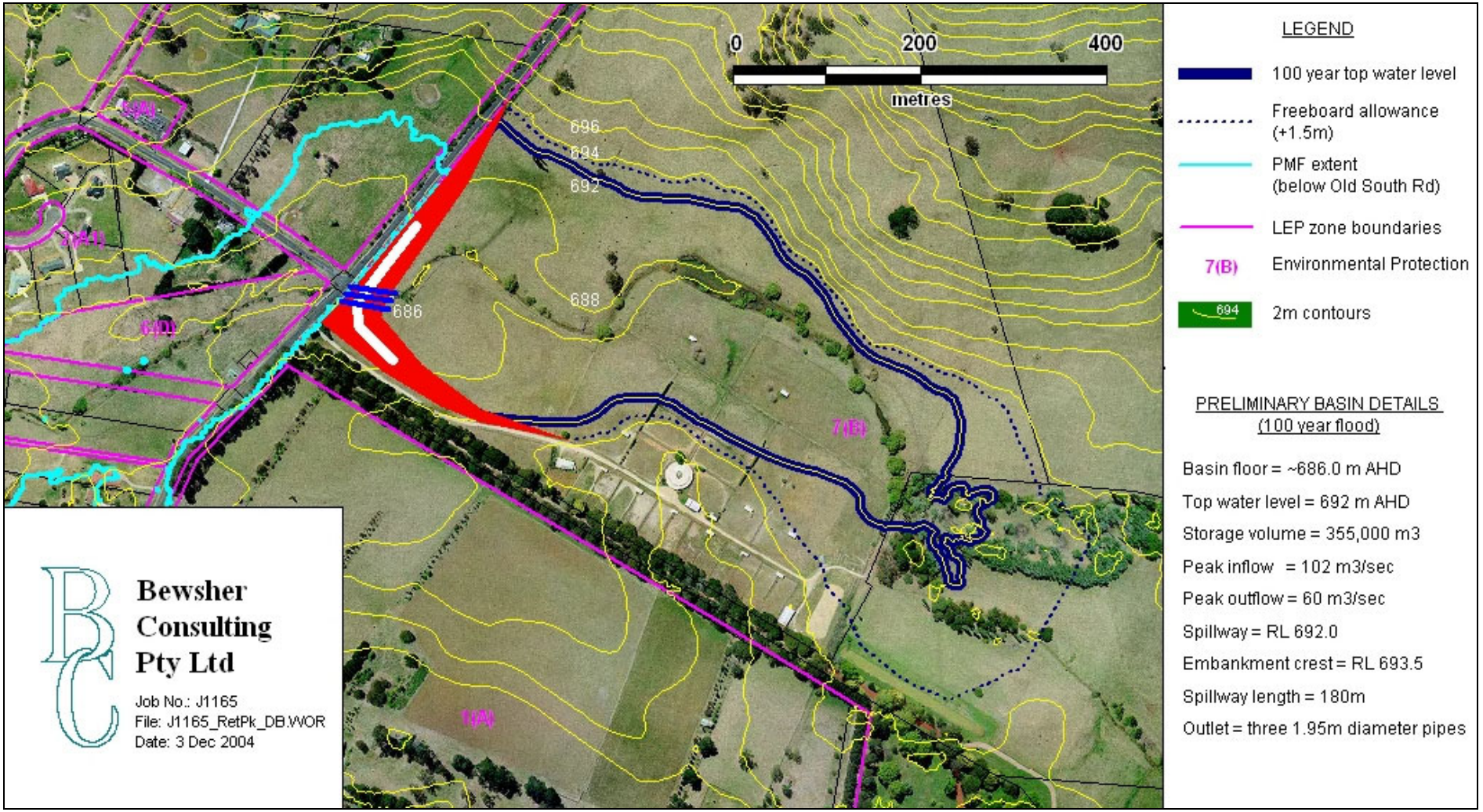


FIGURE 8.3
Retford Park Detention Basin

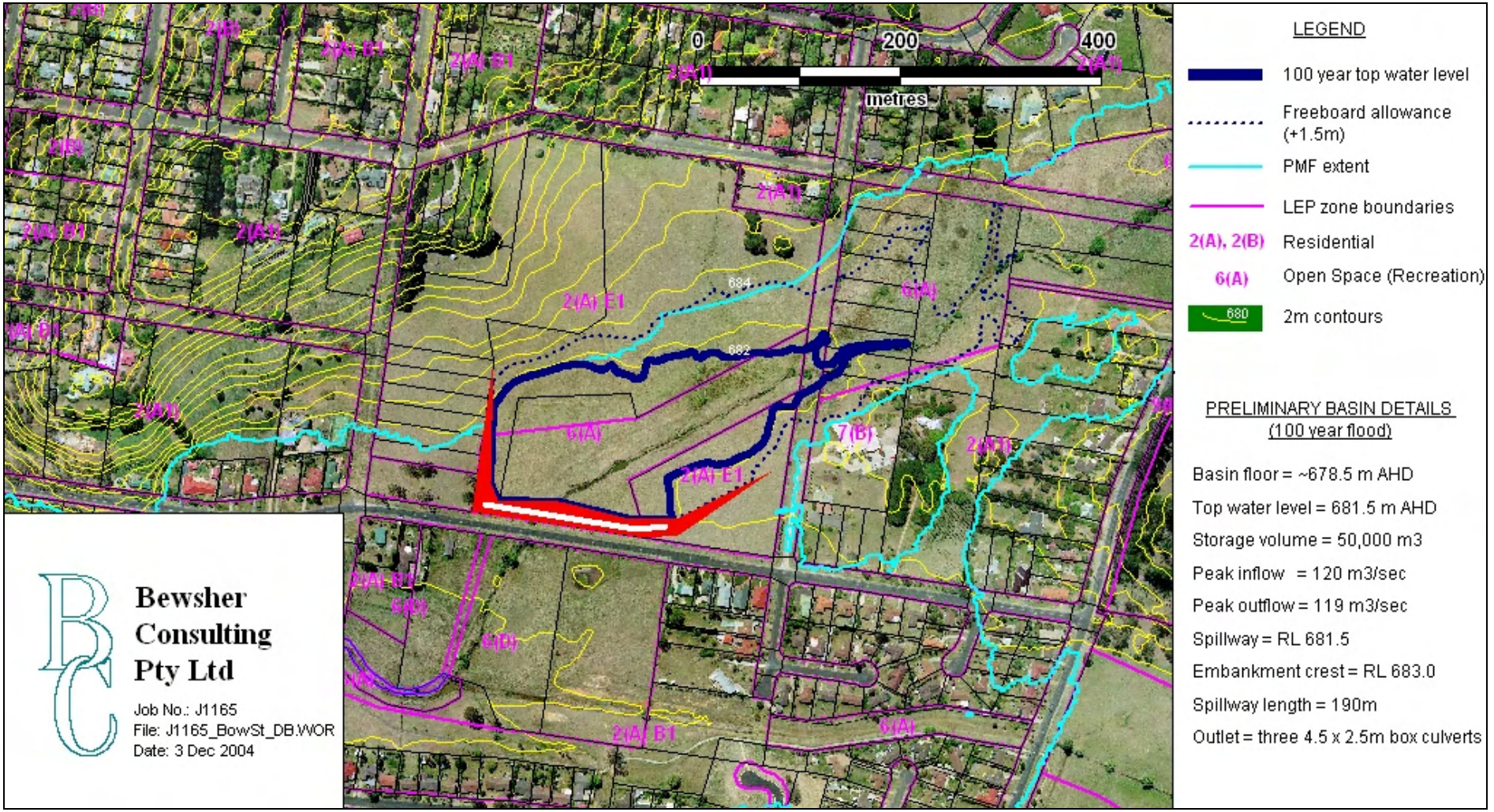


FIGURE 8.4
Bowral Street Detention Basin

FIGURE 8.5
Bowral Golf Course Detention Basin

FIGURE 8.6
Bridges and Culverts on Main Watercourses within Study Area

Photograph (2003–2004)	Location	100y Afflux *
	a: Old South Road culvert (Main Arm)	~0.9m
	b: Bowral Street culvert (Main Arm)	~0.4m
	c: Footbridge adjacent to Farmborough Close	<0.2m
	d: Bowral Street Bridges [replaced in 2005]	~0.6m

FIGURE 8.6
Bridges and Culverts on Main Watercourses within Study Area

Photograph (2003–2004)	Location	100y Afflux *
	e: Shepherd Street Bridge	<0.2m
	f: Footbridge upstream Merrigang Street	<0.2m
	g: Merrigang Street Bridge	~0.7m
	h: Rose Street Bridge	<0.2m

FIGURE 8.6
Bridges and Culverts on Main Watercourses within Study Area

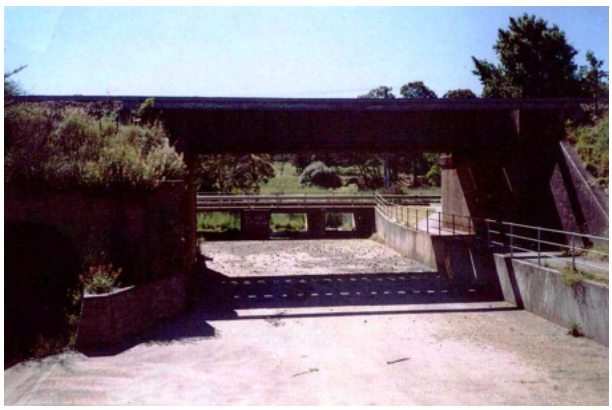
Photograph (2003–2004)	Location	100y Afflux *
	i: Victoria Street Bridge	~0.6m
	j: Footbridge upstream Mittagong Road	<0.2m
	k: Mittagong Road Bridge	<0.2m
	l: Railway Bridge	<0.2m

FIGURE 8.6
Bridges and Culverts on Main Watercourses within Study Area

Photograph (2003–2004)	Location	100y Afflux *
	m: Kirkham Road Bridge	~1.0m
	n: Mount Road Bridge	<0.2m
	o: Footbridge downstream Sherwood Avenue (unapproved?)	<0.2m
	p: Bridge at rear of Dean Trailers (unapproved?)	<0.2m

FIGURE 8.6
Bridges and Culverts on Main Watercourses within Study Area

Photograph (2003–2004)	Location	100y Afflux *
	q: Willow Road Bridge	~0.4m
	r: Oxley Hill Road Bridge	~0.6m
	s: Railway culvert south of Alcorn Street (Beavan Place sub-catchment)	~0.5m (post-works)
	t: Railway culvert north of Nerang Street (Beavan Place sub-catchment)	~1.8m

* 100 year afflux is approximate, and assumes various blockage factors (see **Appendix D**).

8.1.6 Manage Riparian Corridor

Establishment of creek maintenance program recommended
Preparation of Mittagong Creek Riparian Corridor Management Plan recommended

A good deal of concern was expressed in the community survey about the potential effect of rubbish and vegetation (including prolific reed growth – **Figure 8.7a**) in clogging up the channel, thereby potentially exacerbating flood levels (e.g., see responses 95, 147, 182, 184, 190 in **Appendix G**). Further, a member of the Floodplain Management Committee has pointed out several areas along the creek, where gravel from local roads appears to have accumulated in the creek bed (**Figure 8.7b,c**). The most frequently mentioned solution to dealing with the flood problem was to clear the channel of overgrowth and rubbish (**Figure 5.1**). To ease the passage of floodwater and reduce the potential for blockage, and to improve the waterway's health, it is recommended that Council institute a maintenance program to inspect the creek for urban waste, and to remove objects that have no place in the creek environs, such as car tyres, shopping trolleys and obvious accumulations of road gravel. An initial clean-up could cost $40K, with $20K annual maintenance costs.

However, managing riparian vegetation is a more complex task. This is because of the geomorphic and ecological functions of vegetation, to which several agencies have drawn attention (**Appendix G** – see also response 246). Simply removing vegetation could trigger erosion of the creek bed and banks, and result in loss of water quality, habitat and a valuable wildlife corridor. Thus any recommendation for a "quick-fix" clearing of riparian vegetation would be most unlikely to gain the necessary support of DECC.

In the first place, we recommend that a Mittagong Creek Riparian Corridor Management Plan should be prepared (this was recommended by the Bowral Urban Landcare Group and DECC). No such Plan was underway in March 2005. Close liaison between Council, DECC, the Sydney Catchment Authority, local Landcare groups and residents will be required. In this way, the diverse and often strongly-held views on appropriate management of the riparian corridor can be considered, and necessary information collected (e.g., the geomorphic and ecological value of the reeds), to plan a course of action that best satisfies the various environmental, floodplain management and urban planning concerns. A number of objectives of such a plan were proposed in **Section 2.4**. The plan should establish what the "ideal" Mittagong Creek should look like, and how this ideal could be achieved and maintained. As well as establishing a framework for managing riparian vegetation, this plan should establish guidelines (and a program) relating to minor channel works. The cost of developing such a plan is estimated to cost $20K, plus Council staff costs. Implementation of the plan would be ongoing.

8.1.7 Large-Scale Structural Works in Channel

Not recommended for further consideration

A handful of community members called for the channel of Mittagong Creek to be lined with concrete in order to enhance the capacity of the creek. If a concrete channel was built to contain the 100 year flow from Old South Road to Oxley Hill Road, 76 houses would no longer flood in the 100 year event (and lesser events), with damage savings of $7M. But the cost of such a structure is estimated to cost $50M, so the scheme is not economic (BCR 0.1). Just as significant an impediment to a concrete channel are the environmental impacts – such a structure would be very unlikely to gain the approval of DECC or NSW Fisheries on geomorphologic and ecological grounds. Another objection is the loss of visual amenity. Several community members have spoken of the value of the *natural* riparian corridor as a community asset and tourist attraction, and some have pointed out the ugliness of that section of the creek near the Mittagong Road Bridge which has been concrete-lined (e.g., see response 282 in **Appendix G**).

a: Mittagong Creek downstream of Rose Street, Mar 2004

b: Mittagong Creek at foot of Banksia Street, Feb 2005 (Source: Dorothy Weber)

c: Mittagong Creek downstream of Rose Street Bridge, Feb 2005 (Source: Dorothy Weber)

FIGURE 8.7
Views of Mittagong Creek

Similar issues apply for large-scale structural works aimed at deepening, widening or straightening the creek. The cost of these measures would be more modest, but the environmental impacts would be prohibitive. Dredging or widening a river may initiate increased erosion, water turbidity, downstream siltation, and loss of aquatic habitat. NSW Fisheries would require a permit for such works under the Fisheries Management Act, 1994, and it is likely that such a permit would not be granted. DECC is also likely to object on environmental grounds.

Given an unfavourable BCR and substantial environmental impacts, in-channel structural works are not recommended for inclusion in the floodplain risk management plan. However, some localised, minor works may be warranted from time to time. Extraction of urban waste such as road base was addressed under the first recommendation in the previous section, and the proposed Mittagong Creek Riparian Corridor Management Plan would establish guidelines relating to minor channel works.

8.1.8 Flood Walls/Levees

Construction of Farmborough Close flood wall not recommended at this stage.
If other options for this area not supported, scoping study recommended.

A concentration of flood-liable houses in Farmborough Close was noted in **Section 4.4**. A number of respondents to the community survey suggested building a levee to protect these houses from flooding. A preliminary plan of such a levee, and profiles of flood and ground surfaces along the length of the levee, is shown in **Figure 8.8**. An alternative plan would be to extend the levee along the rear of houses situated on the northern side of Ascot Road. **Figure 8.8** shows that to protect against the 10 year flood, a wall would need to be 0.9m high at the lowest point, and to protect against the 100 year flood, a wall would need to be 1.6m high at the lowest point. Given the standard requirement for 0.5m freeboard, the levees would need to be up to 1.4m and 2.1m high to contain the 10 year and 100 year floods, respectively. Damage savings of $500K are expected for a levee protecting against the 10 year flood, and $1,190K for a levee protecting against the 100 year flood. These calculations point to the prominence of the Farmborough Close area flood damages in the study area. Given a distance of only about 10m between the creek and the property line (**Figure 8.9a**), a graded earth embankment would not be feasible, so that the levees would need to be in the form of a concrete wall. The cost of the levees would be in the order of $300K and $400K respectively, yielding very favourable BCRs. A levee, particularly the higher one, would also alleviate the anxiety felt by residents during heavy rain, and avert health problems currently experienced following frequent floods.

However, a number of other factors need to be considered, which point to the limitations of a flood wall:

- Internal drainage. As indicated on **Figure 8.8**, a significant overland flow path drains towards Farmborough Close. The ponding of local stormwater runoff behind the levee would be problematic. A related issue is uncertainty about the extent of flooding in this area. **Figure 8.8** shows a "100 year cut-off line", which indicates the consultant's estimate of the extent of flooding from Mittagong Creek. If the Farmborough Close levee was pursued as a realistic option, an investigation would need to be conducted to better model the interaction of flows from the creek with local stormwater runoff. This would facilitate refinement of the design. Addressing the issue of internal drainage – initially by a detailed study then by various works such as installation of pumps and realignment of drainage lines – would undoubtedly increase costs significantly.

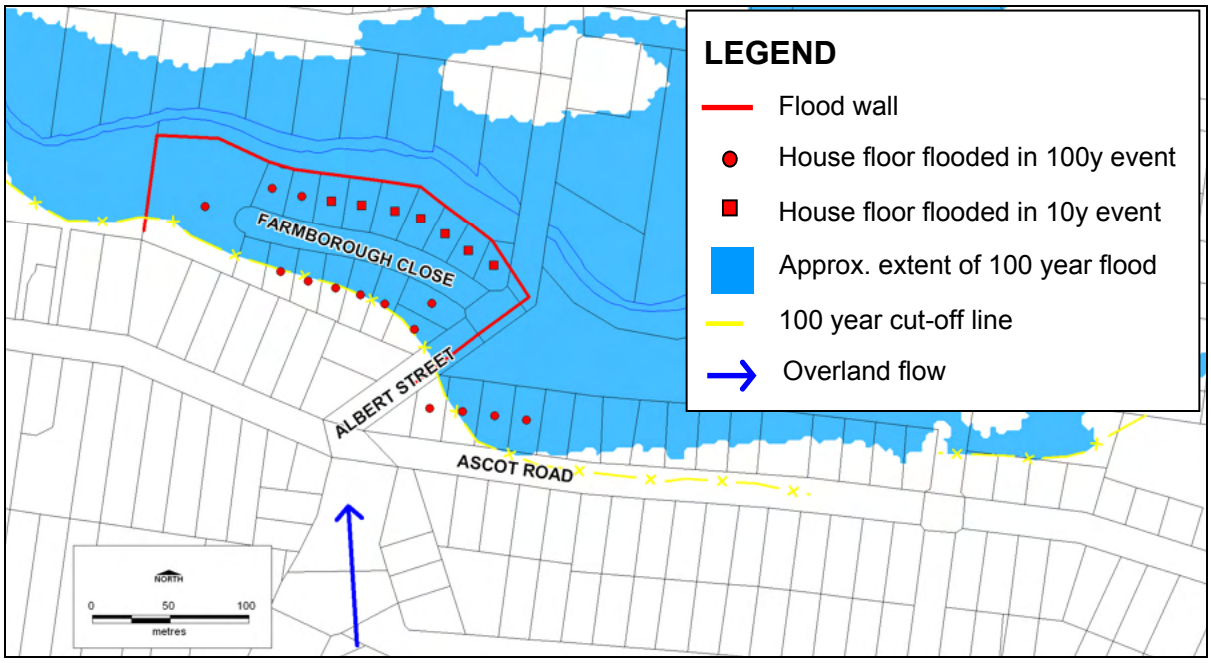
- Loss of flood conveyance and storage. Flood levels elsewhere could increase due to the loss of flood storage in the Farmborough Close area.

- Loss of amenity and visual impact. Construction of a flood wall would establish a barrier between the residents of Farmborough Close and the natural environs of Mittagong Creek that they so appreciate. No longer would they enjoy such easy access to the cycleway. (However, it is noted that most properties have high fences on their border with the creek – **Figure 8.9a**. Residents would need to be consulted to determine whether the benefits of reduced flood risk outweighed any loss of amenity.)

- False sense of security. Levee banks tend to induce a false sense of security among the people they "protect". The common misperception that a levee solves all flood problems can result in catastrophic losses in the event of overtopping, since people are unlikely to be prepared for these rarer events.

Although a levee to protect houses in Farmborough Close (and Albert Street) against either the 10 year or 100 year flood has economic merit and offers other benefits such as reduced anxiety, there are a number of shortcomings – especially the issue of internal drainage – that mitigate against including this measure in the floodplain risk management plan. However, if

other options to alleviate flood problems in Farmborough Close are not supported, then further consideration could be given to the Farmborough Close levee. A first step would be to commission a study to better model the interaction of Mittagong Creek flooding and overland flows in this area, at a cost of about $20K.



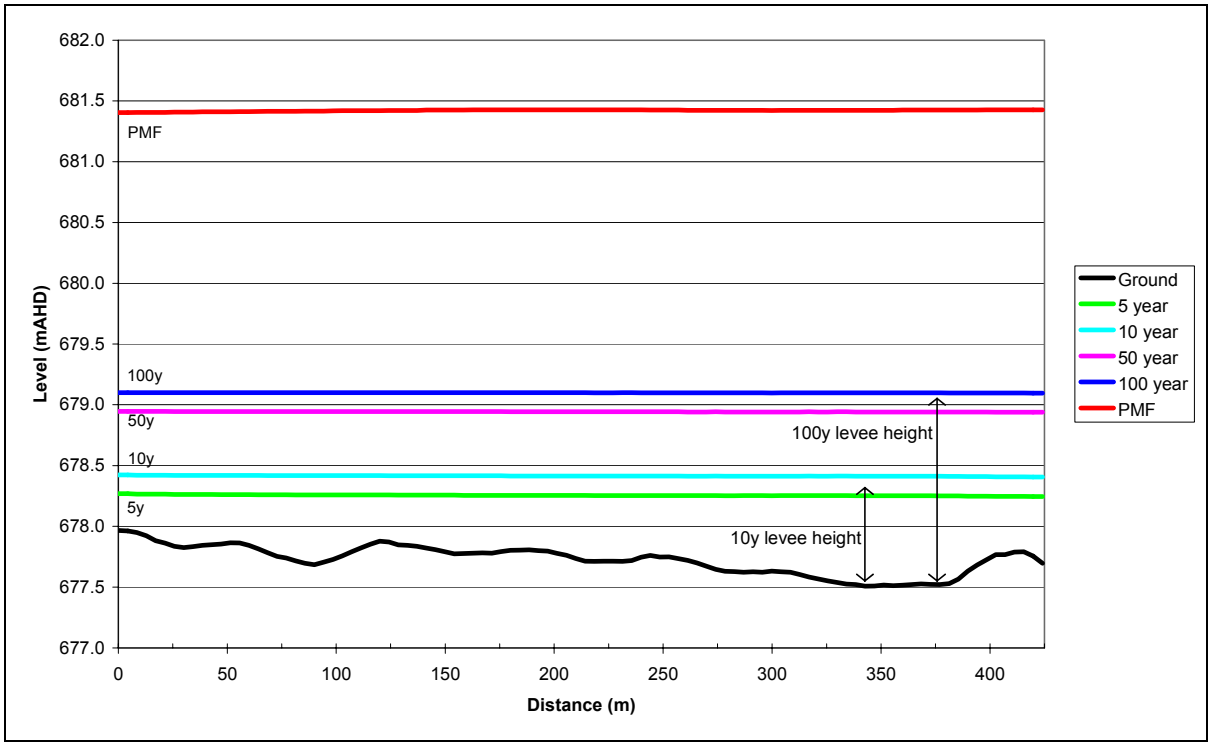


FIGURE 8.8
Farmborough Close Levee: Plan View (top) and Long Profile from Upstream to Downstream (bottom)
(Note: Distribution of buildings flooded in 100 year event based on revised flood modelling in December 2008)

a: Rear of properties on northern side of Farmborough Close, looking downstream

b: Flood-proofing at 50 Shepherd Street

FIGURE 8.9
Views of Farmborough Close and Shepherd Street

8.2 MEASURES THAT MODIFY PROPERTY

8.2.1 Voluntary House Purchase

Not recommended for further consideration

Under a voluntary purchase (VP) scheme, Council would offer to purchase flood liable properties if and when they became available for purchase, subject to the availability of funds at the time. VP is not compulsory acquisition and affected property owners can expect to receive market values, or higher than market values, since valuations assume no VP scheme is in place and disregard development constraints that may apply on that land due to its flood prone nature. Land purchased under a VP scheme would revert to parkland.

Large scale VP schemes are expensive and difficult to justify on economic grounds alone. The current study tested three scenarios: purchasing the 9 houses situated on the northern side of Farmborough Close; purchasing the 10 houses flooded above floor level in the 5 year flood; and purchasing the 17 houses flooded above floor level in the 10 year flood. Damage savings of $1.0M, $1.3M and $1.9M are expected for each scenario, respectively. Real estate agents and residents were questioned to estimate indicative property values for the affected houses, which ranged from $400K for houses in Farmborough Close to $600K for houses in older parts of Bowral. The estimated cost for each VP scenario is $3.6M, $4.8M and $8.2M, respectively. This yielded BCRs of less than 0.3. During the course of a scheme, property values are expected to rise, which can further exacerbate the costs.

Despite unfavourable BCRs, VP schemes may still gain funding if the houses are subject to very high flood hazard. This is not the case in Bowral, where the worst-affected house would be flooded above floor level to a depth of 1.2m in the 100 year flood, with a velocity of only about 0.5m/s.

Given the expense, the low economic merit and the relatively low flood hazard relative to other sites in the State, which means that voluntary purchase in Bowral is very unlikely to secure State funding, it is recommended that no further consideration be given to this measure.

8.2.2 Voluntary House Raising/Reconstruction

Scoping study recommended, then implementation if supported

The raising of timber and fibro houses has proved to be an effective floodplain management measure for various locations throughout NSW. Fairfield City Council has been implementing a successful house raising program in the Prospect Creek catchment for many years.

Various forms of house raising schemes can be considered. The easiest form of house raising occurs where houses are of either timber or fibro construction. Fairfield Council's experience in Prospect Creek has shown that such houses can be raised by 1–2m for a cost of about $50K.

Physically raising houses of brick veneer or full brick construction is more costly, and in most cases impractical. One solution for these dwellings is to completely rebuild the house at a higher level, which may or may not be accompanied by a change in home ownership. With a change in home ownership, Council could acquire the property, demolish the existing house, and sell the vacant building lot with appropriate floor level controls. Based on the experience of Fairfield Council, the typical net cost for this option is about $80K per house.

The State and Commonwealth Governments provide financial subsidies for house raising schemes. The standard approach involves a subsidy based on the full cost of house raising, where this can be economically justified. This is generally the case for timber or fibro houses that are located below the 20 year flood level. In marginal cases, subsidies have been provided for the first $10K cost to raise a particular house, with the homeowner required to pay the difference.

Four options are available to home owners subject to frequent flooding at Bowral:

- Raise house privately without subsidy;
- Raise house with government subsidy;
- Reconstruct house privately (i.e. without subsidy) with floor level set as per Council's Flood Planning Level (FPL);
- Voluntary purchase of house by Council followed by redevelopment consistent with FPL. This may be especially warranted in special circumstance (e.g., hardship).

Of the 17 houses in the study area flooded above floor level in the 10 year flood, 7 are weatherboard or fibro houses which appear to be suitable for raising. These are listed in **Table 8.2**. A house at 50 Shepherd Street (with a depth over floor of 1.2m in the 100 year flood) was withdrawn from the list as it is already afforded some protection from a flood wall. Another four houses that upon visual inspection appeared to be at significant risk (2A Glebe St; 1,3,5 Sherwood Ave) were found to be exposed to insufficient flood hazard to merit inclusion. Damage savings of $530K would be expected if these 7 houses were raised 0.5m above the 100 year flood, at a cost of $350K, yielding a BCR of 1.5.

Farmborough Close contains 7 brick houses flooded above floor level in the 10 year flood (**see Figure 8.8** and **Table 8.2**), which if demolished and rebuilt with floor levels raised 0.5m above the 100 year level, would result in damage savings of $500K, at a cost of $560K, yielding a BCR of 0.9. This would be something of a compromise solution to the problem at Farmborough Close, since properties situated in a high flood risk precinct are not regarded as suitable for residential development. However, this case would be one of a *re*development that would substantially reduce the extent of flood affectation to the existing dwellings, which is permitted under the proposed revisions to DCP 34 as "concessional development". If residential use was deemed inappropriate, there may be potential to change the zoning to a more flood compatible use.

Off-setting the benefits of house-raising schemes are a number of disadvantages:

- Steps to gain access to the house may not be suitable for older people or those with disabilities;
- Other property damage within the property, e.g., damage to parked cars and equipment, may still occur;
- Indeed, after raising, residents may enclose the downstairs area to create further habitable areas (without Council approval) and thus increase future damage potential (this increase in damage potential has been accounted for by changing the DIPNR house category to "high set single storey" for this option, which allows for more damage *below* floor level);
- Aesthetic and town planning constraints may apply: e.g., isolated raising of individual properties in a street may be less desirable than schemes that include a group of properties in a street; and
- People living in raised houses will be less likely to evacuate, which increases the threat to life in the rare event that a flood reaches the (now raised) floor level.

TABLE 8.2
Houses Flooded Above Floor Level in the 10 Year ARI Event, Recommended for Consideration in Voluntary House Raising/Reconstruction Schemes

ADDRESS	CONSTRUCTION TYPE	FLOOR LEVEL RECORDS	EXISTING 10 YEAR FLOOD DEPTH OVER FLOOR*	EXISTING 100 YEAR FLOOD DEPTH OVER FLOOR**
23 Rose Street	Weatherboard	Surveyed	0.2m	0.6m
45 Shepherd Street	Weatherboard	Surveyed	0.02m	0.5m
48 Shepherd Street	Weatherboard	Surveyed	0.6m	1.0m
2 Una Street	Fibro	Surveyed	0.3m	0.8m
4 Una Street	Weatherboard	Surveyed	0.03m	0.5m
27 Kiama Street	Fibro	Estimated	0.03m	0.7m
7 Sherwood Avenue	Weatherboard	Surveyed	0.4m	0.9m
2 Farmborough Close	Brick	Estimated	0.2m	0.8m
4 Farmborough Close	Brick	Surveyed	0.2m	0.7m
6 Farmborough Close	Brick	Estimated	0.2m	0.7m
8 Farmborough Close	Brick	Surveyed	0.2m	0.7m
10 Farmborough Close	Brick	Estimated	0.2m	0.7m
12 Farmborough Close	Brick	Estimated	0.2m	0.7m
14 Farmborough Close	Brick	Estimated	0.01m	0.6m

* Based on May 2005 flood model.

** Based on December 2008 flood model, maximum envelope of blocked and unblocked model runs.

Nevertheless, in view of the economic merit of both suggested voluntary house raising schemes, it is recommended that further investigation be carried out, particularly to assess the level of support among affected householders, and to conduct detailed house inspections in order to determine the practicability of implementing these options. The estimated cost of further investigation is $20K. If supported, then implementation of the two house raising/reconstruction schemes is recommended.

8.2.3 Flood-proofing

Development of "Flood-proofing Guidelines" for the study area recommended

Individual properties can be modified to reduce the impacts of flooding by the construction of flood retaining walls outside the house (similar to levees in function), waterproofing walls of houses and by placing shutters across doors and other openings. Such flood-proofing techniques usually are applied only to commercial properties, though **Figure 8.9b** shows an example of a flood retaining wall constructed around a house at 50 Shepherd Street. A limitation of flood-proofing techniques is the requirement to have someone to close the flood gates or to install the flood shutters at short notice. If this can be done then much property can be saved (until the gate or shutter is overtopped). Flood-proofing can be implemented at no cost to Council, or with some nominal contribution (such as production of a brochure outlining techniques at a cost of $5K), to encourage such works.

8.2.4 Revise Planning and Development Controls

Revision of Wingecarribee LEP, DCP 34 and Section 149(2) Certificates recommended

A significant proportion of survey respondents called for better regulation of development on floodplains. Land use planning and development controls are key mechanisms by which Council can manage flood affected areas. Such mechanisms will influence future development (and redevelopment) so that benefits will accrue gradually over time. Without comprehensive floodplain planning, existing problems may be exacerbated and opportunities to reduce flood risks may be lost.

Flood related planning controls for Bowral were reviewed in **Section 6**. The main recommendations are:

- Amend Wingecarribee Local Environmental Plan in the manner indicated in **Section 6** and **Appendix H**;
- Amend Development Control Plan (DCP) 34 in the manner indicated in **Section 6** and **Appendix I**; and
- Include notations upon Section 149(2) Certificates to indicate affectation by DCP 34 (this includes all properties affected by the PMF).

It is noted that a climate change sensitivity test was conducted in December 2008. While increasing rainfall intensities increases flood levels, it is recommended that a decision about including a climate change flood risk allowance in Flood Planning Levels (FPLs) be deferred until improved information about rainfall intensity-frequency-duration (IFD) data and improved projections of changed rainfall intensities with climate change become available (expected in the next 1-2 years).

8.3 MEASURES THAT MODIFY PEOPLE'S RESPONSE TO FLOODING

Actual flood damages can be reduced if an effective flood warning system is in place, if appropriate and up-to-date emergency plans have been constructed, and if the flood-prone community is aware of the risk and prepared to respond. Measures to improve the Bowral community's response to flooding were considered in detail in *Working Paper No. 4 – Flood Warning, Emergency Management and Flood Awareness* (July 2004). The salient findings are summarised below.

8.3.1 Improve Flood Warning System

Installation of rain gauge and/or stream gauge recommended for further consideration

Mittagong Creek occupies a small, steep catchment (**Section 2.1**) that responds rapidly to heavy rain. Model hydrographs indicate that flood peaks can be reached only one hour after rainfall peaks, offering scant opportunity for effective flood warnings. Indeed, the Commonwealth Bureau of Meteorology (BoM), the organisation responsible for issuing flood warnings in Australia, does not issue specific predictions for catchments in which the time between the flood-producing rain and the flood is less than 6 hours. Nevertheless, the Bureau does offer four services that may be of some benefit in alerting the emergency services and community to the threat of flooding (McKay, 2004, p.3):

General Weather forecast
General weather forecasts may indicate the likelihood of heavy rain from synoptic scale events, typically with more than 24 hours notice.

Flood Watch
A "Flood Watch" is issued by the NSW Flood Warning Centre, typically providing 24 to 48 hours notice that flooding is possible based upon current catchment conditions and future rainfall, which is predicted by computer models of the atmosphere.

Severe Weather Warning
A "Severe Weather Warning" is issued for synoptic scale events when one or more of the following hazardous phenomena are forecast:

- Gale force winds (average 10-minute wind speed exceeding 62 km/h)
- Damaging winds (peak wind gusts exceeding 89 km/h)
- Destructive winds (peak wind gusts exceeding 124 km/h)
- Torrential rain and/or flash flooding

Severe Thunderstorm Warning
A "Severe Thunderstorm Warning" is issued by the Severe Weather Team, typically providing 0.5 to 2 hours' notice of impending severe storms. These forecasts are based upon radar and, if available, data from field stations, reports from storm spotters, as well as an analysis of the synoptic situation.

Unfortunately, none of these services provides much precision in terms of the likely spatial and temporal distribution of flooding (let alone the magnitude of flooding).

Gordon McKay, manager of the Bureau's NSW Flood Warning Centre, acknowledges that there may be some potential to develop a "now-casting" service (i.e., providing a lead time of 1–3 hours) using radar and rainfall data. However, there are doubts as to the effectiveness of such a system. Firstly, it is difficult to estimate rainfall from radar with confidence. Secondly, there are questions as to what benefit an hour or so forewarning of a flood would provide, and particularly whether that benefit warrants the significant cost.

Another potential tool, albeit less sophisticated, would be a rainfall-based intelligence system. This idea involves analysing rainfall duration–intensity associated with previous floods, to gain an appreciation for likely flood severities and consequences, if the Bureau were to issue a prediction of X mm of rainfall over the next Y hours. For Bowral, however, little quantitative data is available for previous floods – either rainfall or creek levels (**Section 3.1**) – to facilitate the development of such a system.

Another means of strengthening local capacity to anticipate flood emergencies would be to install a radio telemetered rain gauge, at a cost of about $6K for equipment and installation, with $500 for annual maintenance. This would provide the SES with access to real-time rainfall data, which would enable them to conduct "what-if" scenarios, such as assuming that the rainfall rate for the past hour will continue for another hour. However, the spatial variability of rainfall means that even real-time data needs to be interpreted with caution. Other tools for evaluating the threat of flooding are the observation of local radar images and the simple assessment of local weather conditions (McKay, 2004, p.4).

The provision of an effective, formal flood warning system for a catchment that responds so quickly to rainfall will always be problematic. Time is the primary constraint – if a flood follows rainfall by less than a few hours, it is very difficult to predict a flood and communicate a flood warning to the community-at-risk, while still allowing time for people to do something about it. Nevertheless, the Bowral Floodplain Management Committee recommended that Council investigate the purchase of a pluviograph and/or stream gauge (**Section 5.8**). Significantly, the reason for this was not as a tool for flood warning but to permit the collection of more accurate data in the catchment, which would benefit future hydrological investigations. It is noted that the Bureau of Meteorology currently operates a rain gauge in Bowral at Orchard Street, towards the western margin of the Mittagong Creek catchment.[6] This suggests that a second rain gauge should be located in the eastern section of the catchment, perhaps near the Retford Park property. The Bureau offers technical assistance such as ordering equipment and siting gauges. Typically, gauges are located on private property to minimise the risk of theft and vandalism.

Although opportunities to improve prediction of flooding in Bowral are limited, there is scope for stream-lining the communication stage of the flood warning system. The SES needs to have systems in place to warn residents of the likelihood of flooding. Devising warning messages before flooding occurs is critical for flash flood environments (EMA, 1999, p.38). Recently the SES devised pre-written warning messages for the Illawarra. Bowral would also benefit from pre-written warning messages. Then, if the Bureau issued a Flood Watch or a Severe Weather Warning, or if radar indicated heavy rain in progress, the SES would be ready to issue a media release, or to conduct radio interviews, using carefully selected language (e.g., "could", "perhaps", "possibly", "if the weather worsens"), tailored to the level of threat. A key element of these warnings should be the grave danger of attempting to drive or walk through water, which accounts for most flood deaths in Australia. If flooding was imminent, the SES could also undertake *specific* warning to targeted clients (e.g., Farmborough Close), via telephone, mobile public address systems (e.g. loud-hailer from Police vehicle), and possibly door-knocking. It is recommended that the SES reviews and updates its procedures for communicating flood warnings in Bowral. This recommendation is subsumed under the next section, to revise the Local Flood Plan.

[6] The Bowral (Orchard Street) gauge (No. 68255) is an ALERT radio telemetered station which reports each 1mm increment of rain directly to the various base stations (BoM, SCA, SES). The data is updated hourly on the BoM web site.

8.3.2 Revise Local Flood Plan

Revision of Local Flood Plan recommended

The latest revision of the Wingecarribee Local Flood Sub-Plan was released in November 1997. This document outlines the nature of the flood threat, responsibilities for flood warnings, and arrangements for flood response. A few salient extracts are reproduced below:

The Flood Threat

- Flood-producing rains can occur … at any time of year, and can be caused by severe thunderstorm activity or by the passage of frontal systems.
- Much of the flooding … is 'flash' flooding.
- Floods are relatively infrequent and usually cause little concern.
- Bowral is drained by Mittagong Creek. Up to 100 blocks could experience inundation in a 1% flood on this stream and about a quarter of these could have water over the floorboards of dwellings.
- Closure of roads is mainly confined to local minor roads, usually for periods of only a few hours and in most cases alternative routes or access is available.

Flood Warnings

- The SES Local Controller monitors developing floods by: a. Receiving information from the Illawarra-South Coast Division HQ about heavy rain…; b. Ensuring that known flood liable locations in the towns are checked after every heavy rain.
- When flooding is expected or is occurring, the SES Local Controller will: a. Provide the Illawarra-South Coast Division HQ with information which is relayed to radio stations…; b. Inform the Wingecarribee Council Engineering Department and police stations in or near the affected areas…

Response

- Response activities are usually limited to: a. Provision of flood information to the Illawarra-South Coast HQ for broadcast…; b. Barricading by the Wingecarribee Shire Council of roads which are dangerous to travel on…
- On rare occasions, the following additional actions may be necessary: a. Furniture raising, removal and storage… This will be restricted largely to Bowral; b. Sandbagging of shopfront doors and vents…; c. Evacuation from houses…

The *NSW State Flood Plan* (2002) stipulates that Local Flood Plans should be reviewed when new information from flood studies becomes available. It is recommended that the SES now revise the Wingecarribee Local Flood Plan, using information from both the *Berrima FRMS&P* and the *Bowral FRMS&P*. The revision should:

- Incorporate the latest flood intelligence. The current study has generated a good deal of information of value for planning response: flood depths and extents for both historic floods and "design" floods up to the extreme flood (PMF); mapping of flood risk precincts (**Figure 3.1**); and estimated or surveyed ground and floor levels for every property situated in the floodplain (see *Working Paper No. 3 – Flood Damages Database*). **Appendix F** indicates that 76 houses would be flooded above floor level in the 100 year flood (including those in the "Beavan Place" sub-catchment). **Figure 4.3** shows the distribution of houses and businesses flooded above floor level in the 10 year and 100 year floods. **Table 8.2** lists some of the houses which would be flooded above floor level in the 10 year flood. This kind of information is valuable for prioritising responses such as evacuations and road closures. Clearly, one "hot-spot" that emergency planners need to be aware of is Farmborough Close.
- Review and update the section on communicating flood warnings as discussed in **Section 8.3.1**.

- Develop a strategy for managing extreme flooding. The revised flood study indicates that the PMF could be more than 2m higher than the 100 year flood. Although flooding of this magnitude would be very unlikely indeed, its catastrophic consequences demand some thought be given to its management. Clearly, many residents would need to evacuate their houses in such circumstances, with very little time in which to do so safely.
- Take account of the high proportion of residents aged 65 years and over, which could provide challenges for evacuation and recovery, as discussed in **Section 2.2**.
- Develop contingencies in case of isolation. During severe flooding, road closures could cut access between Bowral and Mittagong, where the SES Local Headquarters are situated. Inter-agency arrangements with other emergency services organisations such as the Fire Brigade need to be formalised.

8.3.3 Improve Public Awareness

Actual flood damages can be reduced, and safety increased, where communities are "flood-ready":

> *"People who understand the environmental threats they face and have considered how they will manage them when they arise will cope better than people who lack such comprehension… Many people who live and work in flood liable areas have little idea of what flooding could mean to them – especially in the case of large floods of severities well beyond their experience or if a long period has elapsed since flooding last occurred. It falls to the combat agency, with assistance from councils and other agencies, to raise the level of flood consciousness and to ensure that people are made ready for flooding. In other words, flood-ready communities must be purposefully created. Once created, their flood-readiness must be purposefully maintained and enhanced."*
> (Keys, 2002, p.52)

Members of the Bowral Floodplain Management Committee cannot recall seeing a flood approaching the 100 year flood in their lifetimes. Consequently, the community is not familiar with the rare floods that they will one day experience. Education strategies in Bowral need to address the problem of apathy and disinterest. Also, the community needs to be alerted to the danger of extreme flooding (PMF), which could be more than 2m higher than the 100 year flood.

Community flood awareness and readiness can be generated and maintained by a range of techniques, discussed below.

8.3.3a Develop/distribute Bowral FloodSafe Brochure and Web-site

Recommended

A FloodSafe brochure is a product developed by the SES, outlining the history of flooding at a particular location, showing the area subject to flooding on a map, and providing advice about what to do before, during and after a flood. A FloodSafe guide for Picton is attached at **Appendix J**. In order to take advantage of the Bowral Floodplain Management Study, it is recommended that a FloodSafe brochure be developed for Bowral. The SES would produce the brochure in consultation with Council. A brochure in English would be adequate given its widespread use in Bowral (**Section 2.2**). Printing would cost $1K for the first 1,000 brochures. Brochures should be distributed to all property owners and tenants within the floodplain. Experience from an education campaign along the Woronora River shows that the mode of delivery has a bearing on how it is received – education material personally

delivered by the SES tends to be better received by the community than material mailed out (Molino & Huybrechs, 2004).

FloodSafe information should also be mounted on Wingecarribee Shire Council's web-site. There was strong community support (69%) for publishing flood maps on the Internet.

8.3.3b Install Flood Marker/Sign

Recommended

Another method of raising flood awareness is the construction of flood markers in the Mittagong Creek floodplain. Flood signs have the advantage of reaching a large proportion of the community. A majority of respondents (69%) supported the idea of installing flood markers. Placement of markers in relation to travel routes is critical to their effectiveness in delivering messages, so the most appropriate locations may be next to some of the main bridges across the creek (e.g., Mittagong Road near the Swimming Pool – **Figure 8.10**).

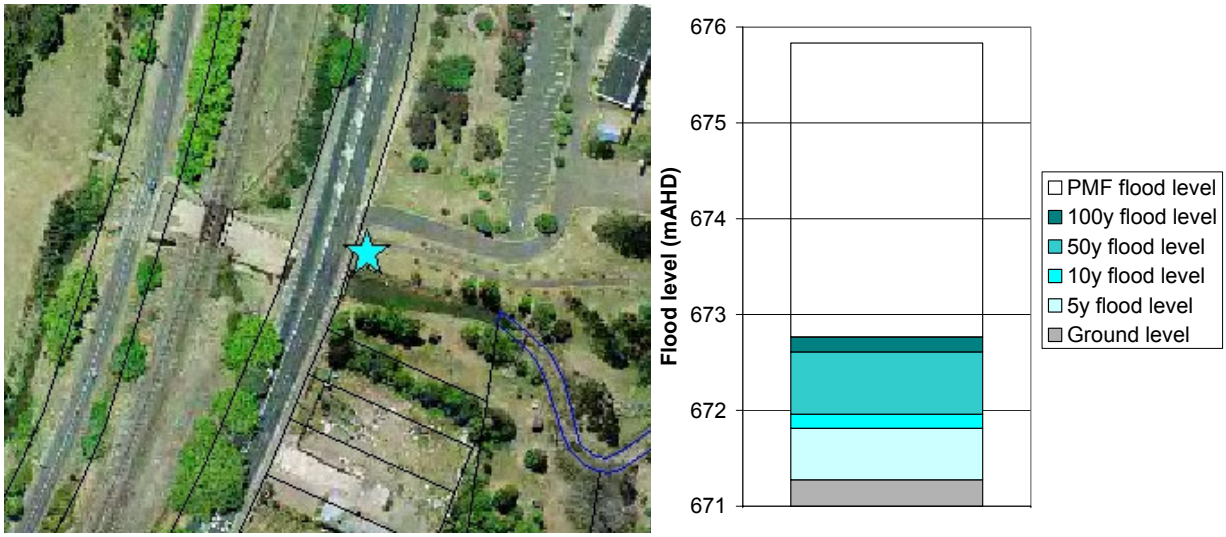


FIGURE 8.10
Suggested Site for Flood Marker, and Design Flood Levels at Site

A variety of styles of flood markers are available. **Figure 8.11** shows the flood stage markers that have been installed along the Wingecarribee River in Berrima. At a cost of $6K, these provide a readily recognised message that "this river is subject to flooding". Flood stage markers may also perform a safety function if situated near the low-points on the approaches to bridges (e.g., Merrigang St Bridge), since drivers may be dissuaded from driving through floodwater. Markers could also act as valuable reference points.

Another possibility is the installation of a flood sign, which could indicate the levels of design floods, as well as containing a simple message (e.g., "Are you ready for the next flood?") **Figure 8.12** shows such a sign along the Woronora River, which has proved to be an effective element in raising community awareness (Molino & Huybrechs, 2004).

It is recommended that flood markers or flood signs be installed on the Mittagong Creek floodplain. This is expected to cost about $6K, based on the cost of the Berrima markers.

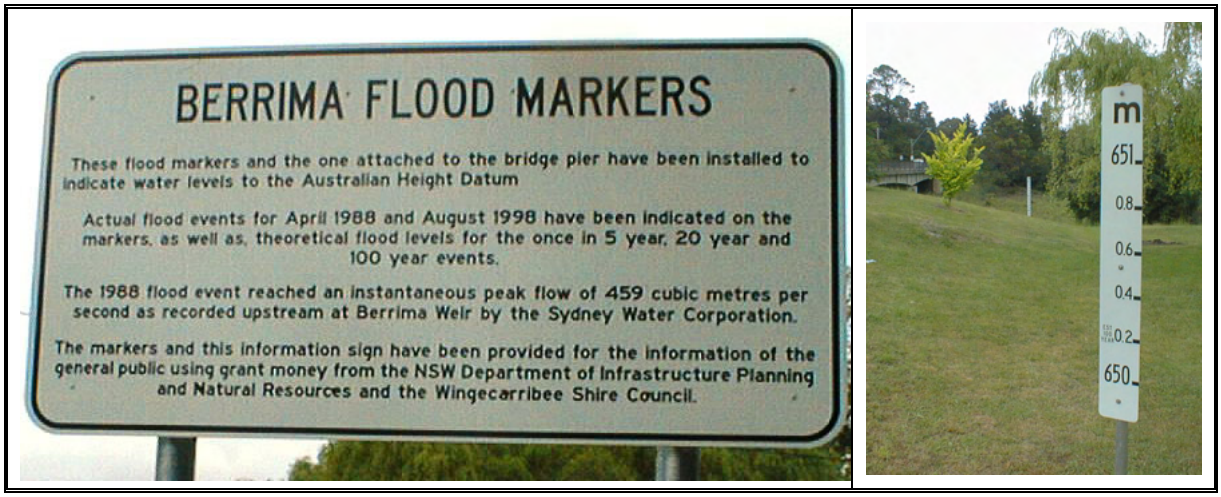


FIGURE 8.11
Berrima Flood Markers

FIGURE 8.12
Woronora River Flood Sign

8.3.3c Update/distribute Flood Certificates

Recommended

An effective means of raising community awareness about flooding is the regular issuing of 'flood certificates' to all occupiers of the floodplain. From the community survey, 64% of respondents indicated support for the issuing of flood notification certificates. Council already issues flood certificates, though typically only when interested parties inquire and where information is available, for a fee of $40. The format of these certificates is illustrated in **Figure 8.13**. Certificates record a property's flood risk potential, floor and ground levels, estimated design flood levels, and the depths of flooding over the lowest floor and ground levels. These certificates need to be updated with the latest information.

As well as being made available upon the payment of a fee, the certificate should be posted out with Council's rates notices every 2 years. This would be one means of keeping flood awareness on the agenda.

Wingecarribee Shire Council

Flood Certificate

Certificate Issued for Property at: 25 Creekview Crescent, Bowral
Lot E, DP 25252

Requested by: Mr F. & Mrs L. Smith

1. Classification of Flood Risk

Council records indicate that the above property is located within a High Flood Risk area.

Land that is potentially subject to inundation is classified as low, medium or high flood risk. Council has prepared a development control plan known as "Managing our Flood Risk" that provides details of flood related development controls that may be applicable.

2. Known Floor and Ground Levels

The lowest floor level of the main building on this property is : 678.2m AHD
Source of information : Survey Database 1992

The lowest ground level on this property is : Not known
Source of information :

If the floor level and/or ground level are currently unknown and you would like to know what the levels are; this can be surveyed by a registered surveyor.

3. Estimated Flood Levels

Flood levels in the vicinity of the above property have been extracted from the Bowral Floodplain Risk Management Study (Bewsher Consulting, 2005).

Size of Flood*	Flood Level	Depth over Lowest Floor Level	Depth over Lowest Ground Level
Extreme Flood	**681.4m AHD**	**3.2m**	**not known**
100 Year Flood	**679.1m AHD**	**0.9m**	**not known**
50 Year Flood	**678.9m AHD**	**0.7m**	**not known**
10 Year Flood	**678.4m AHD**	**0.2m**	**not known**
5 Year Flood	**678.2m AHD**	**0.0m**	**not known**

****The Extreme Flood is an estimate of the Probable Maximum Flood (or PMF), which is extremely rare.***
A 100 year flood is a large flood. It has a 1 in 100 (ie 1%) chance of occurring in any year.
A 50 year flood has a 1 in 50 (ie 2%) chance of occurring in any year.
A 10 year flood has a 1 in 10 (ie 10%) chance of occurring in any year.
A 5 year flood is more frequent. It has a 1 in 5 (i.e. 20%) chance of occurring in any year.

Issued by: Mark Scotland
Surveyor/Designer
Wingecarribee Shire Council
29 February 2005

Flood Certificate - Bowral 25 Creekview Cresent.doc

FIGURE 8.13
Sample Flood Certificate

8.3.3d Institute Hazard Awareness Days

Recommended

Another way of maintaining a culture of flood preparedness would be to designate hazard awareness days, with integrated programs involving emergency services and the community at large. As part of this day, articles could be submitted to local newspapers, response agency personnel could be interviewed on radio, displays could be prepared, guided tours could be conducted to explain local flood mitigation systems (taking care to debunk the myth that any particular system "solves" the problem!), school projects could be prepared, and street parades featuring response agency personnel could be held. Key aims of a hazard awareness day should be to heighten people's awareness of selected hazards and to persuade them to do what they can to minimise the risk at their property. The focus of the day could rotate from one year to the next, with a bushfire theme, flood theme, drought theme, water safety theme etc.

9. FLOODPLAIN RISK MANAGEMENT PLAN

9.1 RECOMMENDED MEASURES

A Floodplain Risk Management Plan showing the preferred floodplain risk management measures for Bowral is presented in this chapter. The recommended measures have been selected from the range of measures discussed in **Section 8**, after an assessment of each measure's impact on flood risk, as well as consideration of environmental, social, and economic factors. The Floodplain Risk Management Plan is presented in **Table 9.1** and on **Figure 9.1**. The principal components of the Plan are discussed below.

The recommended measures have been categorised according to priority, based on how easily (quickly) each measure can be implemented and on value for money. The timing of the proposed works will depend on Council's overall budgetary commitments, and the availability of funds from other sources.

It is important to recognise that the scope of this study was limited to the Mittagong Creek floodplain and one of its tributaries draining the "Beavan Place" sub-catchment. It is recommended that Council now undertake further investigations to identify and manage local drainage and stormwater overland flow problems in Bowral (see **Section 5.8**).

9.2 HIGH PRIORITY MEASURES (within 2 years)

9.2.1 Revise Planning and Development Controls

The application of effective landuse planning and development controls will ensure that the potential for flood damage does not increase, and is reduced over time as flood compatible redevelopment gradually occurs. As discussed in **Section 6** and **Section 8.2.4**, three planning instruments require amendment: Wingecarribee Local Environmental Plan (**Appendix H**), Development Control Plan 34 (**Appendix I**) and Section 149(2) Certificates. This measure can be implemented immediately, at very little cost.

9.2.2 Improve Emergency Management

It is recommended that the SES revise the Wingecarribee Local Flood Plan by incorporating the detailed "flood intelligence" prepared during the Bowral Floodplain Risk Management Study. Other factors such as the response to extreme flooding should also be addressed (see **Section 8.3.2**). This measure can be implemented now for minimal cost.

9.2.3 Improve Public Awareness

Actual flood damages can be reduced, and safety increased, where communities are "flood-ready". As discussed in **Section 8.3.3**, recommended ways of promoting readiness are:

- Produce a Bowral FloodSafe brochure and web-site;
- Install flood markers at a prominent location;
- Update flood certificates with data from the *Flood Damages Database*, and issue to all occupiers of the floodplain on a regular basis; and
- Institute hazard awareness days, including days devoted to a flood theme, with integrated community activities.

All the measures listed above can be implemented at a low cost. Some maintenance will be required to ensure the flood markers remain free of graffiti, and to keep the flood database up to date and for on-going issue of certificates. This could be incorporated in the duties of Council officers.

9.2.4 Manage Riparian Corridor

Dominant among the community's concerns about flooding was the state of Mittagong Creek (**Section 5.4.1**). The establishment of a creek maintenance program, with regular inspections of the creek and removal of obvious urban waste, is recommended (**Section 8.1.6**). An initial clearance is expected to cost in the order of $40,000. Annual maintenance could cost $20,000. Also recommended is preparation of a Mittagong Creek Riparian Corridor Management Plan, especially as a basis for managing vegetation (**Section 8.1.6**). The Plan would ensure that management of the riverine corridor satisfies the various hydraulic, environmental and recreational objectives. Close liaison between Council, DECC, SCA, local Landcare groups and residents is required. Some suggested objectives of the Plan are outlined in **Section 2.4**. Outcomes would include additional information, detailed specifications and a timetable/work program for the implementation of works within definable sections of the creek corridor. The Plan should incorporate ongoing maintenance as part of an overall long-term strategy. The cost of preparing the management plan is estimated to be $20,000.

9.2.5 Voluntary House Raising/Reconstruction Scoping Study

The assessment of potential floodplain risk management measures indicated that voluntary house raising/reconstruction would be one of the most cost-effective measures for reducing the flood problem at Bowral (**Section 8.2.2**). The recommended first stage in this strategy would be to conduct a scoping study, at a cost of about $20,000, to assess the affected residents' willingness to participate in such schemes, and to conduct house inspections to clarify the ease with which the affected houses could be raised or reconstructed.

9.2.6 Retford Park Detention Basin Scoping Study

Although the most significant item of capital expenditure in the Plan, the Retford Park Detention Basin would produce flood mitigating benefits for much of the study area, especially along Mittagong Creek from Old South Road to the railway line. It would have more effect than any other single measure in reducing the number of houses flooded above floor level in the 100 year event. For this reason, it is recommended that further investigation be carried out. In particular, a detailed ground survey is required, since only 2m contours were available for this study. This would facilitate initial design. Negotiations with the landowner should begin, including the potential for securing fill on-site, which would reduce costs. Other potential obstacles would need to be resolved, too, via liaison with the Dams Safety Committee, the NSW Department of Environment and Conservation and the NSW Heritage Office. A scoping study of this nature is expected to cost about $25,000.

9.2.7 Bowral Golf Course Detention Basin Scoping Study

A detention basin situated in Bowral Golf Course would make a significant contribution towards alleviating flooding in the "Beavan Place" sub-catchment. While it is one of the larger cost items recommended for inclusion in the Plan – at about $0.5M, third behind the Retford Park Basin and the Voluntary House Reconstruction scheme for Farmborough Close – it is expected to reduce the number of houses flooded above floor level in the 100 year event by five. It could also off-set any increases in runoff from new development. It is recommended that a scoping study be conducted to assess options for the exact location of a basin, to negotiate with the landowner and local residents who may be affected by a basin, and to carry out a detailed ground survey.

9.2.8 Farmborough Close Levee Scoping Study

If it becomes apparent that other options to alleviate flood problems in the Farmborough Close area – voluntary house reconstruction and the Retford Park Basin – are not supported, then further consideration could be given to the Farmborough Close levee. The first step would be to commission a study to better model the interaction of Mittagong Creek flooding and overland flows in this area, at a cost of about $20,000. It would also be important to gauge the residents' support for a flood wall (this could be combined with the consultation described under **Section 9.2.5**).

9.3 MEDIUM PRIORITY MEASURES (within 4 years)

9.3.1 Voluntary House Raising/Reconstruction Works

Contingent upon the results of the scoping study (**Section 9.2.5**), particularly whether the affected residents are likely to support this measure, it is recommended that two voluntary house raising/reconstruction schemes be implemented. The first involves raising 7 weatherboard and fibro houses – situated in Rose, Shepherd, Una, Kiama and Sherwood Streets – currently subject to above floor flooding in the 10 year flood, to a level 0.5m higher than the 100 year flood. This is expected to cost about $350,000, with a highly favourable BCR. The second involves demolishing 7 brick houses – situated in Farmborough Close – subject to above floor flooding in the 10 year flood, then rebuilding those houses at a level 0.5m higher than the 100 year flood. This is expected to cost about $560,000, with a favourable BCR and other intangible benefits to residents of Farmborough Close.

9.3.2 Modify Bridges and Culverts

Section 8.1.5 shows that while replacing bridges and culverts to increase flow capacities is generally not economic, removing the Victoria Street Bridge would be affordable (about $20,000) and economic and cause only minor inconvenience in terms of pedestrian access. Similarly, amplifying the railway culvert north of Nerang Street, at a cost of about $60,000, is expected to reduce the afflux and consequently reduce the number of houses flooded above floor level in the 100 year flood by four, in Nerang Street and Romney Place.

9.3.3 Retford Park Detention Basin

Contingent upon the results of the scoping study (**Section 9.2.6**), construction of a large detention basin on the Retford Park property is recommended, at an estimated cost of $4M.

9.3.4 Bowral Golf Course Detention Basin

Contingent upon the results of the scoping study (**Section 9.2.7**), construction of a small detention basin at Bowral Golf Course is recommended, at an estimated cost of $0.5M.

9.3.5 Install Rain and/or Stream Gauge

Primarily to permit the collection of more accurate data, it is recommended that Council install a pluviograph and/or stream gauge in the Mittagong Creek catchment. This could also be of limited value for improving flood predictions, perhaps by facilitating preparation of a rainfall-based intelligence system (**Section 8.3.1**).

9.4 LOW PRIORITY MEASURES (within 7 years)

9.4.1 Prepare Flood-proofing Guidelines

Flood-proofing measures to reduce the potential for flood damage have already been implemented by some residents. It is recommended that Council encourage this kind of self-driven innovation by preparing flood-proofing guidelines. This is expected to cost about $5,000.

9.4.2 Control Runoff from New Development

In order to ensure no increase in runoff from new developments or redevelopments, it is recommended that Council continue its policy for on-site detention (OSD), as discussed in **Section 8.1.4**. It is also recommended that this policy be integrated within an overall program of Water Sensitive Urban Design (WSUD).

9.5 FUNDING AND IMPLEMENTATION

Detailed costings of the recommended measures are recorded in **Appendix K**. The total capital cost of implementing the Plan is $5.7M. This would yield damage savings of $3.0M, resulting in a benefit-cost ratio (BCR) of 0.5. It would reduce the number of houses flooded above floor level in the 100 year event by 43, from 76 to 33. The capital cost of the Plan without the Retford Park basin is $1.7M, yielding damage savings of $1.4M – a BCR of 0.9. This would reduce the number of houses flooded above floor level in the 100 year event by 21, from 76 to 55. The capital cost of the Plan without both basins is $1.2M, yielding damage savings of $1.1M – a BCR of 0.9. This would reduce the number of houses flooded above floor level in the 100 year event by 18, from 76 to 58.

If the Retford Park basin is already built, the *additional* damage savings expected to accrue from the voluntary house raising/reconstruction (VHR) schemes are reduced somewhat, to a total of $520K, which at a cost of $910K yields a BCR of 0.6. On the other hand, if the VHR schemes are implemented first, the *additional* damage savings expected to accrue from the Retford Park basin are also reduced, to a total of $1.54M, which at a cost of $4M yields the more marginal BCR of 0.4.

A variety of sources of funding may be drawn upon to implement the Bowral Floodplain Risk Management Plan. These include:

- State and Commonwealth funding for flood mitigation measures through DECC;
- Council funds;
- Section 94 Contributions from future development where flooding may be exacerbated by such development (but this was not recommended in **Section 6.7**);
- Commonwealth funds through the National Landcare Program, and Sydney Catchment Authority funds, to assist in rehabilitating the creek corridor; and
- Volunteer labour from community groups.

Council can expect to receive the majority of financial assistance through DECC. These funds are available to implement measures that contribute to reducing existing flood problems. Funding assistance is usually provided on a 2:1 basis (State:Council) or a 1:1:1 basis (Commonwealth:State:Council).

Although much of the Plan may be eligible for Government assistance, funding can not be guaranteed, since Government funds are allocated on an annual basis to competing projects throughout the State. Options that receive Government funding must be of significant benefit to the community. Funding of investigation and design activities as well as any

works and ongoing programs, is normally available. Maintenance, however, is usually the responsibility of Council.

9.6 ON-GOING REVIEW OF PLAN

The Plan should be regarded as a dynamic instrument requiring review and modification over time. The catalyst for change could include flood events, legislative change, alterations in the availability of funding, or changes to the area's planning strategies. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

TABLE 9.1
Recommended Floodplain Management Measures

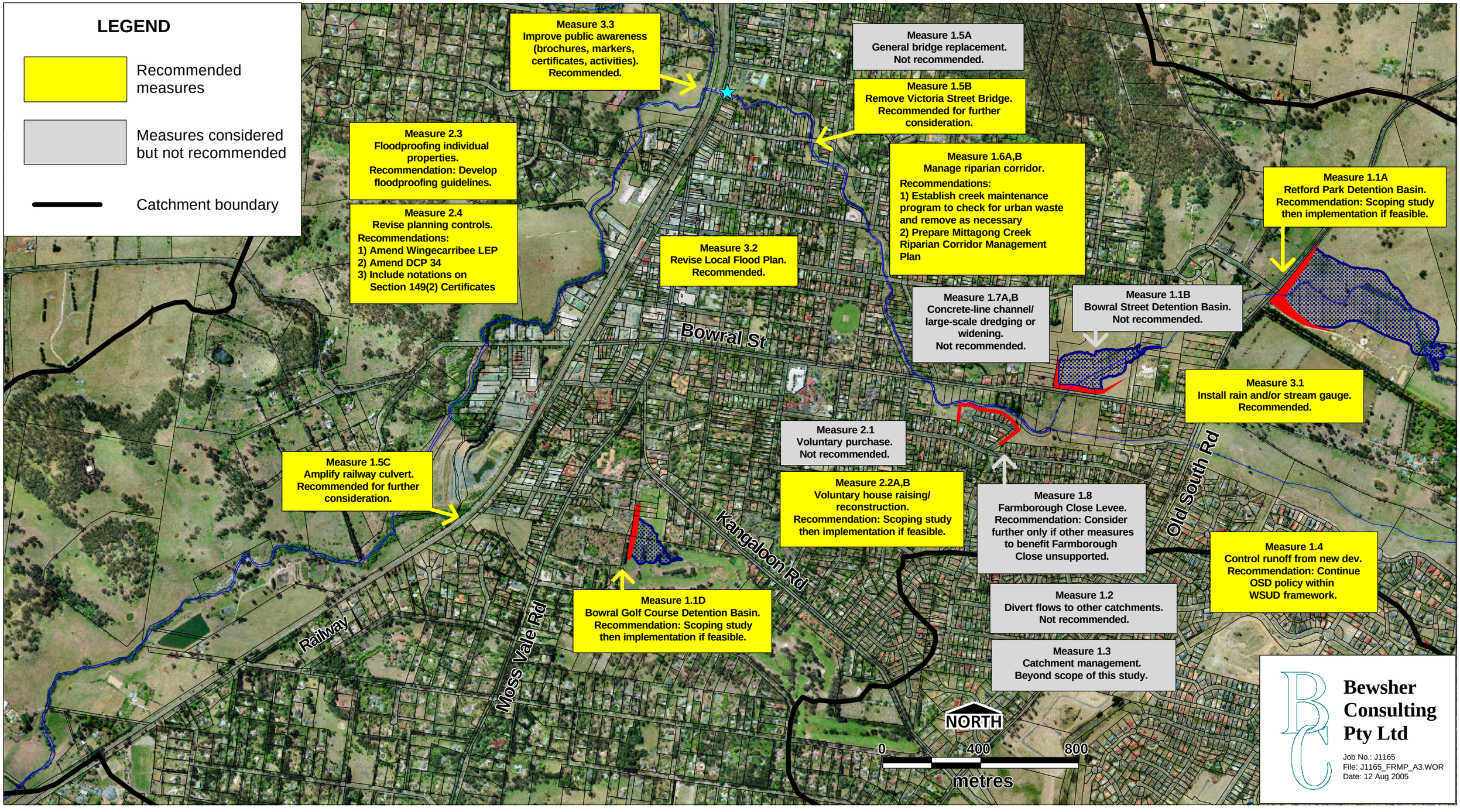
Measure No.	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
2.4	Revise planning and development controls (Amend Wingecarribee LEP, DCP 34, Section 149(2) Certificates)	Nil	Council	Nil	Council	High
3.2	Improve emergency management (revise Local Flood Plan)	Nil	SES	Nil	SES	High
3.3	Improve public awareness ► Bowral FloodSafe brochure and web-site ► Install flood marker/sign ► Update/distribute flood certificates ► Institute hazard awareness days	 1,000 6,000 Nil Nil	 DECC, Council, SES DECC, Council Council Council	 Nil 1,000 5,000 5,000	 Council Council Council Council + others	High
1.6	Manage riparian corridor ► Establish creek maintenance program ► Prepare Riparian Corridor Management Plan ► Implement Plan	 40,000 20,000 To be determined	 Council DECC, Council Various	 20,000 N/A To be determined	 Council N/A Various	High
2.2	Voluntary house raising/reconstruction ► Scoping study	20,000	DECC, Council	N/A	N/A	High
1.1A	Retford Park Detention Basin ► Scoping study	25,000	DECC, Council	N/A	N/A	High
1.1D	Bowral Golf Course Detention Basin ► Scoping study	25,000	DECC, Council	N/A	N/A	High
1.8	Farmborough Close levee ► Scoping study**	20,000	DECC, Council	N/A	N/A	High**

Measure No.	Description	Capital Expenditure		Maintenance		Priority
		Est. Cost ($)	Funding Sources	Est. Cost ($ pa)	Funding Sources	
2.2	Voluntary house raising/reconstruction* ► 7 weatherboard/fibro houses ► 7 brick houses	 350,000 560,000	 DECC, Council DECC, Council	 N/A N/A	 N/A N/A	Medium*
1.5	Modify bridges and culverts ► Remove Victoria Street Bridge ► Amplify railway culvert north of Nerang Street	 20,000 60,000+	 DECC, Council DECC, Council	 Nil Nil	 Council Council	Medium
1.1A	Retford Park Detention Basin*	4M	DECC, Council	Nil	Council	Medium*
1.1D	Bowral Golf Course Detention Basin*	0.5M	DECC, Council	Nil	Council	Medium*
3.1	Install rain gauge	6,000	DECC, Council	500	Council	Medium
1.4	Control runoff from new development ► Continue OSD policy ► Devise WSUD program	 Nil ?	 Developers Council	 Nil ?	 Developers Council	Low
2.3	Flood-proofing guidelines	5,000	DECC, Council	Nil	Council	Low
	TOTAL	**5,658,000**		**31,500**		

* Contingent upon results of scoping studies.

** Actual construction of the Farmborough Close levee is not recommended at this stage, but could be pursued if other options for Farmborough Close (voluntary house reconstruction; the Retford Park Detention Basin) are not supported, and if the scoping study yields favourable results.

FIGURE 9.1:
RECOMMENDED BOWRAL FLOODPLAIN RISK MANAGEMENT PLAN



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11. FREQUENTLY ASKED QUESTIONS

Why do flood levels change over time?

There is a chance that floods of various magnitudes will occur in the future. As the size of a flood increases, the chance that it will occur becomes rarer. Because some of these rare floods have never been experienced or accurately recorded since European settlement, the height of future floodwaters is normally predicted using computer models. These computer models simulate flood levels and velocities for a range of flood sizes and flood probabilities. Given the importance of estimating flood levels accurately, councils and the NSW Department of Environment and Climate Change (DECC) engage experts to establish and operate the computer models.

From time to time the computer models are revised and predicted flood levels can change. The resultant change in flood levels however is normally very small. The reasons why the computer models are revised can include:

- new rainfall or ground topography information becomes available;
- new floods occur which provide additional data from which to fine-tune the models;
- better computer models become available as the science of flood modelling improves and computer capabilities increase; or
- flood mitigation works may have been carried out, or development within the catchment may have occurred, that was not previously simulated in the models.

How are these studies funded?

Flood studies and floodplain risk management studies are often carried out under State Government guidelines and are funded on a 1:1:1 basis among the Federal and State Governments, and councils. This funding arrangement is also available for the construction of flood mitigation works.

My property is in a Low Flood Risk Precinct. What does this mean?

The classification of a 'Low Flood Risk Precinct' can differ slightly between councils. For Bowral it means that your property is higher than the 100 year flood plus 0.5m freeboard but still has a very slight chance of inundation from larger (i.e. rarer) floods.

If you are a residential property owner, there will be no change to how you may develop your property. However, there may be controls on the location of essential services such as hospitals, evacuation centres, nursing homes and emergency services.

My property is in a Fringe Low Flood Risk Precinct. What does this mean?

The 'Fringe Low Flood Risk Precinct' refers to land that is above the height of the 100 year flood but not more than 0.5m above it. In this area your property is just above the reach of the 100 year flood but still within the freeboard of 0.5m which Council normally includes when setting minimum floor levels for flood prone properties.

My property is in a Medium Flood Risk Precinct. What does this mean?

The classification of a 'Medium Flood Risk Precinct' can differ slightly between councils. Often it means that your property is inundated in a 100 year flood, however conditions are not likely to be hazardous during such a flood. If you are a residential property owner development controls will probably be similar to those that currently exist.

My property is in a High Flood Risk Precinct. What does this mean?

The classification of a 'High Flood Risk Precinct' can differ slightly between councils. Often it means that your property will be inundated in a 100 year flood and that hazardous conditions may occur. This could mean that there would be a possible danger to personal safety, able bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult, or there may be a potential for significant structural damage to buildings. This is an area of higher hazard where stricter controls may be applied.

Will my property value be altered if I am in a Flood Risk Precinct?

Any change in a council's classification of properties can have some impact on property values. Nevertheless, councils normally give due consideration to such impacts before introducing a system of flood risk classifications or any other classification system (e.g. bushfire risks, acid sulphate soil risk, etc). If your property is now classified as being in a Flood Risk Precinct, the real flood risks on your property have not changed, only its classification has altered. A prospective purchaser of your property could have previously discovered this risk if they had made enquiries themselves.

If you are in a Low Flood Risk Precinct, generally there will be no controls on normal residential type development. Previous valuation studies have shown that under these circumstances, your property values will not alter significantly over the long term. Certainly, when a new system of classifying flood risks is introduced, there may be some short-term effect, particularly if the development implications of the precinct classification are not understood properly. This should only be a short-term effect however until the property market understands that over the long-term, the Low Flood Risk Precinct classification will not change the way you use or develop your property.

Ultimately, however, the market determines the value of any residential property. Individual owners should seek their own valuation advice if they are concerned that the flood risk precinct categorisation may influence their property value.

My property was never classified as 'flood prone' or 'flood liable' before. Now it is in a Low Flood Risk Precinct. Why?

The State Government changed the meaning of the terms 'flood prone', 'flood liable' and 'floodplain' in 2001. Prior to this time, these terms generally related to land below the 100 year flood level. Now it is different. These terms now relate to all land that could possibly be inundated, up to an extreme flood known as the probable maximum flood (PMF). This is a very rare flood.

The reason the Government changed the definition of these terms was because there was always some land above the 100 year flood level that was at risk of being inundated in rarer and more extreme flood events. History has shown that these rarer flood events can and do happen (e.g. the 1990 flood in Nyngan, the November 1996 flood in Coffs Harbour, the January 1998 flood in Katherine, the August 1998 flood in the northern suburbs of Wollongong, the 2002 floods in Europe, Hurricane Katrina in 2005, etc).

Will I be able to get house and contents insurance if my house is in a Flood Risk Precinct?

In contrast to the USA and many European countries, flood insurance has generally not been available in Australia for residential property. Following the disastrous floods in Coffs Harbour in November 1996 and in Wollongong in August 1998, very limited flood cover began to be offered by some insurance companies. From 2008, many insurance companies started offering wider cover although the extent of the cover particularly for very flood prone properties is still not well known and may differ between insurers. The most likely situation is that your insurer will now offer you some flood cover although this will be dependent on the flood level information that the insurer has for your property. (This may not necessarily be the same as that available from Council). If flood cover is offered, the classification of your property within a Flood Risk Precinct per se, is unlikely to alter the availability of cover. Obviously insurance policies and conditions may change over time or between insurance companies, and you should confirm the specific details of your situation with your insurer.

Will I be able to get a home loan if my land is in a Flood Risk Precinct?

Most banks and lending institutions do not account for flood risks when assessing home loan applications unless there is a very significant risk of flooding at your property. The system of Flood Risk Precinct classification will make it clear to all concerned, the nature of the flood risks. Under the previous system, if a prospective lending authority made appropriate enquiries, they could have identified the nature of the flood risk during assessment of home loan applications. As a result, it is not likely that the classification of your property within a Flood Risk Precinct will alter your ability to obtain a home loan. Nevertheless, property owners who are concerned about their ability to obtain a loan should clarify the situation with their own lending authority.

How have the flood risk maps been prepared?

Because some large and rare floods have often not been experienced or accurately recorded since European settlement commenced, computer models are used to simulate the depths and velocities of major floods. These computer models are normally established and operated by flooding experts employed by local and state government authorities. Because of the critical importance of the flood level estimates produced by the models, such modelling is subjected to very close scrutiny before flood information is formally adopted by a council. Maps of flood risks (e.g. 'low', 'medium' and 'high') are prepared after consideration of such issues as:

- flood levels and velocities for a range of possible floods;
- ground levels;
- flood warning time and duration of flooding;
- suitability of evacuation and access routes; and
- emergency management during major floods.

What is the probable maximum flood (PMF)?

The PMF is the largest flood that could possibly occur. It is a very rare and improbable flood. Despite this, a number of historical floods in Australia have approached the magnitude of a PMF. Every property potentially inundated by a PMF will have some flood risk, even if it is very small. Under the State Government's Floodplain Development Manual (2005), councils must consider all flood risks, even these potentially small ones, when managing floodplains. As part of the State Government's Manual, the definitions of the terms 'flood liable', flood prone' and 'floodplain' refer to land inundated by the PMF.

What is the 100 year flood?

A 100 year flood is the flood that will occur or be exceeded on average once every 100 years. It has a probability of 1% of occurring in any given year. If your area has had a 100 year flood, it is a fallacy to think you will need to wait another 99 years before the next flood arrives. Floods do not happen like that. Some parts of Australia have received a couple of 100 year floods in one decade. On average, if you live to be 70 years old, you have a better than even chance of experiencing a 100 year flood.

Why do councils prepare floodplain management studies and plans?

Under NSW legislation, councils have the primary responsibility for management of development within floodplains. To appropriately manage development, councils need a strategic plan which considers the potential flood risks and balances these against the beneficial use of the floodplain by development. To do this, councils have to consider a range of environmental, social, economic, financial and engineering issues. This is what happens in a floodplain risk management study. The outcome of the study is the floodplain risk management plan, which details how best to manage flood risks in the floodplain for the foreseeable future.

Floodplain risk management plans normally comprise a range of works and measures such as:

- improvements to flood warning and emergency management;
- works (e.g. levees or detention basins) to protect existing development;
- voluntary purchase or house raising of severely flood-affected houses;
- planning and building controls to ensure future development is compatible with the flood risks; and
- measures to raise the community's awareness of flooding so that they are better able to deal with the flood risks they face.

Will the Flood Risk Precinct maps be changed?

Yes. All mapping undertaken by council is subjected to ongoing review. As these reviews take place, it is conceivable that changes to the mapping will occur, particularly if new flood level information or ground topography information becomes available. However, this is not expected to occur very often and the intervals between revisions to the maps would normally be many years. Many councils have a policy of reviewing and updating floodplain management studies and plans about every five to ten years. This is the likely frequency at which the maps may be amended.

12. GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

100 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
10 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 10 years. Also known as a 10% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
5 year ARI flood	A **flood** that occurs (or is exceeded) on average once every 5 years. Also known as a 20% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
acid sulphate soils	Sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid. More detailed explanation and definition can be found in the NSW Government Acid Sulfate Soil Manual published by the Acid Sulfate Soil Management Advisory Committee.
afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.
annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 1% AEP flood occurs (or is exceeded) on average once every 100 years. It is also referred to as the '100 year flood' or the '1 in 100 year flood'.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All flood levels, floor levels and ground levels are normally provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in an area over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe the frequency or probability of floods occurring. Large floods occur rarely, whereas small floods occur more frequently. For example, a 100 year ARI flood is a flood that occurs (or is exceeded) on average once every 100 years. See also **annual exceedance probability (AEP)**.
BoM	The Australian Bureau of Meteorology.
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site.

DECC	NSW Department of Environment and Climate Change. Previously the State Government's Flooding Unit was part of the **Department of Natural Resources (DNR)**, and prior to that was part of the **Department of Infrastructure, Planning and Natural Resources (DIPNR)**.
design flood	A theoretical **flood** likely to occur, on average, every "x" years, eg a 100 year ARI flood is a design flood likely to occur, on average, every 100 years. See **average recurrence interval (ARI)** and **annual exceedance probability (AEP)**. The height of the design flood is called the 'design flood level'.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
DIPNR	The former NSW Department of Infrastructure, Planning and Natural Resources. This department contained the State Government's Flooding Unit from April 2003 to August 2005.
discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (**m^3/s**). Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
DNR	The former NSW Department of Natural Resources. This department contained the State Government's Flooding Unit from August 2005 to April 2007.
DoP	NSW Department of Planning.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.
effective warning time	The time available after receiving advice of an impending **flood** and before the floodwaters prevent appropriate flood response actions being undertaken. The **effective warning time** is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding. In NSW, the State Emergency Service (SES) is the principal agency involved in emergency management during floods.
extreme flood	An estimate of the **probable maximum flood (PMF)**, which is the largest flood likely to occur.
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam. It includes local overland flooding associated with major drainage before entering a watercourse. In addition, it includes coastal inundation resulting from raised sea levels, or waves overtopping the coastline.
flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.

flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use. **Flood risk** and flood hazard are not interchangeable terms.
flood level	The height of the **flood** described either as a depth of water above a particular location (e.g. 1m above a floor, yard or road) or as a depth of water related to a standard level such as **Australian Height Datum** (e.g. the flood level was 7.8 mAHD). Terms also used include flood stage and water level.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term 'flood liable land' now covers the whole of the **floodplain**, not just that part below the 100 year flood level.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain risk management studies** and incorporated in **floodplain risk management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
flood risk precinct	An area of land with similar flood risks and where similar development controls may be applied by a council to manage the flood **risk**. (The flood risk is determined based on the existing development in the precinct or assuming the precinct is developed with normal residential uses). The Bowral study area has four flood risk precincts: 'high risk' (generally **high hazard** land below the **100 year flood**), 'medium risk' (generally **low hazard** land below **the 100 year flood**), 'fringe low risk' (generally land above the **100 year flood** but not more than 0.5m above it) and 'low risk' (generally land above the level of the **100 year flood** plus 0.5m but below the level of the **PMF**). Flood risk and **flood hazard** are not interchangeable terms. (See also **risk**).
Flood Study	A study that investigates flood behaviour, including identification of flood extents, flood levels and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the **probable maximum flood** (PMF) event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**. (Note that the term 'risk' is often dropped in common usage and 'Floodplain Risk Management Studies or Plans' are referred to as 'Floodplain Management Studies and Plans'.)
Floodplain Risk Management Study	These studies are carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) and assess options for minimising the danger to life and property during **floods**. These options aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.

floodway	Floodways are those parts of a floodplain where a significant discharge of water occurs during **floods**. They are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
flow	See **discharge**.
freeboard	A factor of safety expressed as the height above the flood level. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as 'greenhouse' and climate change.
geographical information system (GIS)	A system of software designed to support the management, manipulation, analysis and display of spatially referenced data.
geomorphology	The study of landforms.
high flood hazard	For a particular size **flood**, there may be a possible danger to personal safety, able-bodied adults may have difficulty wading to safety, evacuation by trucks may be difficult and/or there may be a potential for significant structural damage to buildings.
hydraulics	Term given to the study of water flow; in particular, the assessment of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the estimation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge at any particular location varies with time during a flood).
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
local overland flooding	Inundation by local **runoff** rather than overbank discharge from a stream, river, estuary, lake or dam.
low flood hazard	For a particular size **flood**, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	Metres **Australian Height Datum (AHD)**.
m/s	Metres per second. Unit used to describe the **velocity** of floodwaters. 10km/h ≈ 2.8m/s.
m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for flows or **discharges**. It is the rate of flow of water measured in terms of volume per unit time.

merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well being of the State's rivers and **floodplains**.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest **flood** likely to ever occur. It has a very rare chance of occurring. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**.
RAFTS	The software program used to develop a computer model that analyses the **hydrology** (rainfall-**runoff** processes) of the **catchment** and calculates hydrographs and **peak discharges**. Known as a hydrological model.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within the **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route and other relevant factors.
risk	Risk is measured in terms of consequences and likelihood. In the context of floodplain management, it is the likelihood and consequences arising from the interaction of floods, communities and the environment. For example, the potential inundation of an aged person's facility presents a greater flood risk than the potential inundation of a sportsground amenities block (if both buildings were to experience the same type and probability of flooding). Reducing the probability of flooding reduces the risk, increasing the consequences increases risk. (See also **flood risk precinct**).
risk management	The process of identifying, analysing, evaluating, treating, monitoring and communicating risks. A generic framework for risk management in Australia is provided in the joint Australian and New Zealand Standard AS/NZS 4360;1999.
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
Section 149 Certificates	In NSW, councils issue these certificates to potential property purchasers under Section 149 of the NSW Environmental Planning and Assessment Act. It is compulsory to attach S149(2) certificates to contracts for sale of land and these certificates generally identify policies affecting development of the land. Other information and risks concerning the property are generally provided on S149(5) certificates (which are not compulsory in contracts for sale of land).
stage–damage curve	A relationship between different water depths and the predicted flood damage at that depth.

TUFLOW	The software program used to develop a computer model that analyses the two-dimensional **hydraulics** of the waterways within a **catchment** and calculates water levels (flood levels) and flow velocities. Known as a hydraulic model.
velocity	The term used to describe the speed of floodwaters, usually in **m/s** (metres per second). 10km/h = 2.8m/s.

APPENDIX A

CENSUS DATA FOR BOWRAL AND WINECARRIBEE LGA

Census Data, 2001, Postal Area 2576 (Bowral)

Source: Table B01 unless otherwise stated; NSW data from www.abs.gov.au/

AREA: Postal Area 2576 (NSW)	Males	Females	Persons	Prop %	NSW Prop %
Total persons	5042	5747	10789	100.0	
Aged 15 years and over	3941	4663	8604	79.7	79.3
Aged 65 years and over	938	1415	2353	21.8	13.1
Aboriginal	27	19	46	0.4	1.8
Torres Strait Islander	0	0	0	0.0	0.1
Both Aboriginal/Torres Strait Islander(b)	3	3	6	0.1	0.1
Total Aboriginal/Torres Strait Islander	30	22	52	0.5	1.9
Australian born	3951	4585	8536	79.1	69.9
Born overseas:					
Canada, Ireland, NZ, South Africa, UK(c) and USA	539	570	1109	10.3	
Other country(d)	280	296	576	5.3	
Total Born Overseas	819	866	1685	15.6	23.1
Speaks English only	4611	5268	9879	97.4	75.0
Speaks language other than English(e)	207	214	421	4.2	18.7
Australian citizen	4543	5205	9748	90.4	86.4
Australian citizens aged 18 years and over	3261	3991	7252	67.2	64.3
Unemployed(f)	106	89	195		
Employed(f)	2350	2035	4385		
In the labour force(f)	2456	2124	4580		
Not in the labour force(f)	1298	2259	3557		
Unemployment rate(f)	4.3	4.2	4.3		
Participation Rate(f)	62.9	46.0	53.7		
Enumerated in private dwelling	4703	5335	10038	93.0	97.0
Enumerated in non-private dwelling	339	412	751	7.0	
Persons enumerated same address 1 years ago(f)	3740	4302	8042		
Persons enumerated same address 5 years ago(f)	2032	2345	4377		
Overseas visitor	39	40	79	0.7	
Population Density (Persons per Square km)			21.69		
Use a computer at home [B15]	2463	2303	4766	44.5	40.8
Used the Internet [B16]	2105	1873	3978	36.9	36.1
Dwellings with zero motor vehicles [B29]	–	–	334 dwellings	8.1	12.0

(a) Overseas visitors included in categories: 'Total persons', 'Aged 15 years and over' and 'Overseas visitor'. All other categories exclude overseas visitors.
(b) Applicable to persons who are of both Aboriginal and Torres Strait Islander origin.
(c) Comprises England, Scotland, Wales, Northern Ireland, Channel Islands, Isle of Man and UK n.f.d.
(d) Includes 'inadequately described', 'at sea', 'not elsewhere classified' and 'not stated'
(e) Includes 'non-verbal so described' and 'inadequately described'
(f) see table 22 for further notes

Census Data, 1986-1991-1996-2001, Wingecarribee LGA

AREA: Wingecarribee LGA	1986	1991	1996	2001	Change 1991-01	%Change 1991-01	Compound Rate of Change 1991-96	1996-01
DEMOGRAPHIC SUMMARY								
Total persons								
Males	13871	16404	18016	19812	3408	20.8	2%	2%
Females	14316	16836	18761	21028	4192	24.9	2%	2%
Persons	28187	33240	36777	40840	7600	22.9	2%	2%
Aged 15 years and over								
Males	10117	12069	13452	14960	2891	24.0	2%	2%
Females	10725	12749	14413	16386	3637	28.5	2%	3%
Persons	20842	24818	27865	31346	6528	26.3	2%	2%
Aboriginal & Torres Strait Is.								
Males	67	115	185	261	146	127.0	10%	7%
Females	71	83	177	236	153	184.3	16%	6%
Persons	138	198	362	497	299	151.0	13%	7%
AGE SUMMARY								
Age 0-4	2330	2822	2795	2760	-62	-2.2	0%	0%
Age 5-14	5015	5532	6071	6697	1165	21.1	2%	2%
Age 15-24	4184	4665	4556	4502	-163	-3.5	0%	0%
Age 25-54	10599	13184	14657	15847	2663	20.2	2%	2%
Age 55-64	2693	2971	3405	4600	1629	54.8	3%	6%
Age 65 or more	3366	4067	5102	6230	2163	53.2	5%	4%
Age Group as a Percentage of the Population								
Age 0-4	8.3	8.5	7.6	6.8	-1.7	-20.4	-2%	-2%
Age 5-14	17.8	16.6	16.5	16.4	-0.2	-1.5	0%	0%
Age 15-24	14.8	14.0	12.4	11.0	-3.0	-21.5	-2%	-2%
Age 25-54	37.6	39.7	39.9	38.8	-0.9	-2.2	0%	-1%
Age 55-64	9.6	8.9	9.3	11.3	2.3	26.0	1%	4%
Age 65 or more	11.9	12.2	13.9	15.3	3.0	24.7	3%	2%
Median Age								
Males	30	31	34	37	6	19.4		
Females	32	34	36	39	5	14.7		
Persons	31	32	35	38	6	18.8		
ETHNICITY SUMMARY								
Australian Born	23604	27529	29780	32552	5023	18.2	2%	2%
Overseas Born: ESC	2523	3239	3427	3749	510	15.7	1%	2%
Overseas Born: NESC	1532	1813	1948	2203	390	21.5	1%	2%
Total Overseas Born	4055	5052	5375	5952	900	17.8	1%	2%
Birthplace Group as a Percentage of the Population								
Australian Born	83.7	82.8	81.0	79.7	-3.1	-3.8	0%	0%
Overseas Born: ESC	9.0	9.7	9.3	9.2	-0.6	-5.8	-1%	0%
Overseas Born: NESC	5.4	5.5	5.3	5.4	-0.1	-1.1	-1%	0%
Total Overseas Born	14.4	15.2	14.6	14.6	-0.6	-4.1	-1%	0%
OSB Poor English speakers	92	195	176	185	-10	-5.1	-2%	1%
OSB Poor Eng % of pop	0.3	0.6	0.5	0.5	-0.1	-22.8	-4%	-1%
OSB Poor Eng % of 5+ pop	0.4	0.6	0.5	0.5	-0.2	-24.2	-4%	-1%
LABOUR FORCE SUMMARY								
Employed	10822	13324	14764	16874	3550	26.6		
Unemployed	909	1330	1197	885	-445	-33.5		
Not in the Labour Force	8541	9535	11037	12119	2584	27.1		
Unemployment Rate	7.7	9.1	7.5	5.0	-4.1	-45.1		
Participation Rate	56.3	59.0	57.6	56.7	-2.4	-4.0		

AREA: Wingecarribee LGA	1986	1991	1996	2001	Change 1991-01	%Change 1991-01	Compound Rate of Change 1991-96	1996-01
INCOME SUMMARY								
Median Individual Income	$8,700	$13,900	$15,000	$19,700	$5,800	41.7		
Median Family Income	$22,200	$33,900	$35,700	$48,000	$14,100	41.6		
Median Household Income	$20,100	$28,400	$31,400	$39,800	$11,400	40.1		
Standardised Medians (CPI)								
Median Individual Income	$15,300	$17,500	$16,700	$19,700	$2,200	12.6		
Median Family Income	$39,300	$42,800	$39,800	$48,000	$5,200	12.1		
Median Household Income	$35,500	$35,800	$35,000	$39,800	$4,000	11.2		
DWELLINGS SUMMARY								
Occupied Private Dwellings (OPD)	9243	11448	13228	15121	3673	32.1		
Occupancy Ratio	2.86	2.73	2.63	2.56	-0.16	-6.0		
H'holds Owned/purchasing	6340	8098	9391	11048	2950	36.4		
H'holds Renting	2225	2452	2874	2970	518	21.1		
Per cent Hlds Owned/purchasing	68.6	70.7	71.0	73.1	2.3	3.3		
Per cent Hlds Renting	24.1	21.4	21.7	19.6	-1.8	-8.3		
Average Number bedrooms	2.9	3.2	n/av	n/av	n/av	n/av		
Average Number vehicles	1.59	1.63	1.59	1.70	n/av	n/av		
Separate Houses (OPD)	8136	10362	11804	13727	3365	32.5		
Other Dwelling Structures (OPD)	1107	1086	1424	1394	308	28.4		
Per cent Separate Houses	88.0	90.5	89.2	90.8	0.3	0.3		
Per cent Other Dwell Structures	12.0	9.5	10.8	9.2	-0.3	-2.8		
Median Mortgage	$387	$639	$876	$1,013	$374	58.5		
Median Rent	$72	$120	$132	$163	$43	35.8		
Standardised Medians (CPI)								
Median Mortgage	$685	$807	$978	$1,013	$206	25.6		
Median Rent	$127	$151	$147	$163	$12	7.6		

EXPLANATORY NOTES
OSB: ESC = Overseas born: Main English Speaking Countries. This is an approximation only, as Canada is not included for 1986.
OSB: NESC = Overseas born: Other than Main English Speaking Countries
OSB Poor English speakers = Overseas born people who speak English "Not well" or " Not at All" - Note 1986 measures OSB NESC only.

APPENDIX B

CASE STUDY OF RIPARIAN MANAGEMENT
MITTAGONG CREEK EASTERN SECTION – BOWRAL

Source: Crawford, C. and Lewis, B., 2002, *Riparian Management Guidelines for the Wollondilly and Wingecarribee Rivers*, Wollondilly Catchment Management Committee, Goulburn, pp.5-7 to 5-9.

Mittagong Creek eastern section - Bowral

Background information

The Bowral Urban Landcare Group (BULG) was set up in April 2000 with the objective of rehabilitating from its degraded state the eastern section of Mittagong Creek that runs from Settlers Park to Old South Road.

BULG started with 12 members and it now has 84. Its project has received recognition in the form of environmental grants totally $45 000 so far, from Wingecarribee Shire Council, Wollondilly Catchment Management Committee, Sydney Catchment Authority and the Department of Land and Water Conservation.

The project

The aim for this section of the Mittagong Creek is to improve water quality and restore the areas as a natural habitat for aquatic bird and animal life. The result will be a scenically attractive place for walking and other passive recreational activities to be enjoyed by local residents and tourists alike. Importantly also, higher quality water will be going into the Wingecarribee-Wollondilly river system that feeds into Warragamba Dam and Sydney's water supply.

Issues present along the riparian zone

Along this section of the Mittagong Creek many issues were present. The creek was badly degraded, suffering from willow infestation, heavy siltation, significant erosion, including creek bed lowering, minimal riparian vegetation and sewage pollution. See **Figure 5-3a and b**.

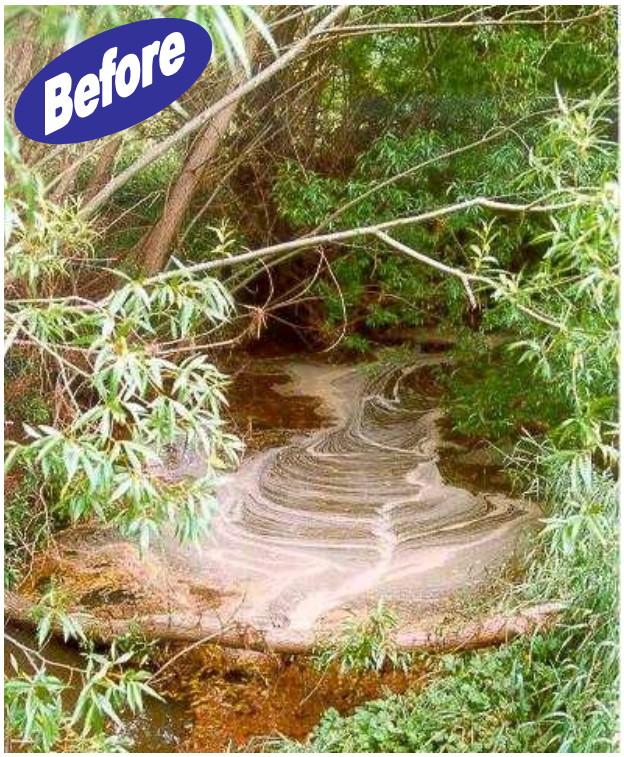


***Figure 5-3a and b**: These before and after photographs of a completed rock sill along the Mittagong Creek reveal the dramatic changes that can result from restorative riparian works.*

Actions taken to address these issues

Restoration of stream health and water quality has been achieved by:

- Removal of environmental weeds, especially willows. This work is still ongoing, however all possible willows not on private land have been removed.
- Removal of rubbish and debris. This is also ongoing.
- Erosion control through:
    - Planting native trees, shrubs and grasses. See **Table 5-1** for the list of species planted along the Mittagong Creek.
    - Installation of log and rock sills, rock ramps, rock toes and erosion matting to prevent further streambed and bank erosion.

  These works are still being carried out as further funding becomes available.
- Recreation of aquatic habitat through native plantings, provision of log and rock sills and the increased oxygenation of the water generated by rock ramps and sills. The rock ramps mimic a natural pool and riffle sequence habitat required by instream fauna. See **Figure 5-4a, b and c**.
- Lobbying Wingecarribee Shire Council and other authorities thus getting the antiquated sewer line along the creek, which regularly spilled raw sewerage into it, replaced.

Table 5-1*: The recommended varieties of native plant species for the Mittagong creek, Bowral.*

	Common name	**Botanical name**
Toe of bank	Spiny-headed Mat-rush	*Lomandra longifolia*
	Rush	*Juncas usitatus*
	Microlaena	*Microlaena stipoides*
	Wallaby Grass	*Danthonia* spp.
	Sedge	*Carex* spp.
	Sedge	*Cyperus* spp.
	Kangaroo Grass	*Themeda australis*
	River Tussock	*Poa labillardieri*
Middle of bank	Hop Goodenia	*Goodenia ovata*
	River Tea-Tree	*Leptospermum obovatum*
	Tea-Tree	*Leptospermum polygalifolium*
	Bursaria	*Bursaria spinosa*
	River Bottlebrush	*Callistemon sieberi*
	Late Black Wattle	*Acacia mearnsii*
	Silver Wattle	*Acacia dealbata*
	Prickly-leaved Paperbark	*Melaleuca stypheloides*
	Paperbark	*Melaleuca linariifolia*
	Silver Banksia	*Banksia marginata*
Top of bank	Swamp Gum	*Eucalyptus ovata*
	Paddy's River Box	*Eucalyptus macarthurii*
	Forest Red Gum	*Eucalyptus tereticornis*
	Ribbon Gum	*Eucalyptus viminalis*
	Candlebark	*Eucalyptus rubida*
	River Peppermint	*Eucalyptus elata*
	Hakea	*Hakea salicifolia*
	Forest oak	*Casuarina torulosa*
	Blackwood	*Acacia melanoxylon*

For more information please contact Bowral Urban Landcare Group on (02) 4861 5520.

***Figure 5-4a, b and c**: The staging of the construction of a V-Notch Weir at the end of Boolwey Street Bowral, on the Mittagong creek. Works were carried out in October 2001*

APPENDIX C

HISTORIC RECORD OF BOWRAL FLOODS

The Bowral Free Press, Wednesday, March 8, 1893, p.2 (Source: State Library of NSW)

Floods in Bowral.

Unprecedented Rainfall.

Narrow Escapes.

Heavy Damages to Property.

Nearly £500 Damages to Streets and other Council Property.

Also Heavy Losses to Owners.

ALTHOUGH the weather during last week was beautifully fine, a change took place on Saturday evening. From an early hour clouds began to rise, preceded by the old folks complaining of aching corns, while the singing cricket and croaking frog predicted rain in the near future. Before twilight waned the distant rumbling of thunder could be heard, while the storm seemed to be backing up from all points of the compass. When darkness set in, the lightning flashes were vivid and appalling, and were followed by loud grumblings overhead like the prolonged sound of booming cannons. With the exception of a slight storm between eight and nine not over-much rain fell during the rest of the night, while the next morning broke with promise of a wet Sabbath. Slight showers were in full play till about 10.30, when the pent up warnings of nature broke forth with a blinding, drenching, and streaming downpour of rain. It seemed as if all the water-spouts of the heavens were let loose; at times the rain was carried in sheets by occasional gusts of wind, while at others the drops fell thick and fast. Thunder rumbled at different parts, while the unabating appearance of the storm began to be alarming. Fires were doubted, dinners were spoilt, houses leaked, while other supernumeraries are too various to mention. All the low-lying country in the vicinity was nothing but sheets of water, while the watertables and gutters in many of the streets were not sufficient to carry the overflow away, consequently it became stationary in some places, and at others swamped the street and made free entrance into residences. Torrents of water could be seen streaming off the hills and high adjacent land; dams bursted and landslips took place, while everything presented the appearance of being a second edition of the Queensland flood. In the meanwhile the creek rose as if on pinions, and it is some 23 years ago since it was seen so high—if it was then is a moot question. It played havoc with everything it came in contact with; bridges were slaughtered and fences swept away. Ducks and fowls were shown no mercy; furniture, boxes, tubs, casks, and other sundry articles were tossed and tumbled like "ocean greyhounds" in its whirling, gushing, and leaping torrent. Willow trees on the banks of the once gurgling stream were torn up by the roots and carried in its course. Rescue parties were out willing to help those sufferers who were in distress; in many places their services were needed, as various narrow escapes took place. At times intense excitement prevailed; along the sides of the creek could be seen numerous pedestrians, amongst whom were ladies who did not seem in the least afraid of melting. Such was the flood that took place on the Sunday in question, it will be long remembered and is a fitting event to be recorded in the annals of Bowral history.

THE NURSERY.

At Messrs. Cope and Sons' nursery in Merrigang-street the greatest damage appears to have been done and the biggest loss sustained. It was indeed a pitiable sight to see the once pretty and attractive grounds wholly submerged in the surging flood waters. Flowers were washed up by the roots, and plants, shrubs, and fruit trees were swept away. In the house the water rose to about 14 or 15 inches, and considerable difficulty was experienced in getting the lady members of the family on to *terra firma*. Men had to wade through water chin-high, and had to return with members of the fair sex shoulder-high, battling slowly but bravely with the torrent. It is believed that a horse belonging to this homestead was drowned, as it was carried off its legs and last seen plunging in the stream.

THE GAS WORKS.

At the Municipal Gas Works great havoc was played. A corrugated iron fence was broken down in a number of places, the fires put out, and the mains filled, a number of bags of coke were washed away, and three retorts broken. The water flowed through the residence very freely, although as sale was effected there the pay before there was a very little to spoil. A large log came with a terrific crash against the iron fence, bursting it open, but the log was blocked. The town was in darkness during the night as far as gas was concerned.

The Merrigang-street bridge bore up bravely against the brunt of the flood. Very little damage was done to it, only a portion of the hand-rails being carried away.

Proceeding down the creek, one was able to judge with what force the current was rushing. Fences were clean swept away, fowl-houses damaged, and bark huts fared very badly. On Willis' Estate the water covered a deal of ground, and a few families in that vicinity were forced to leave their home and seek shelter elsewhere. Nothing more of much consequence meets the eye until in

BONG BONG-STREET.

Here a wide expanse of water of over 100 yards could be seen extending along the street. A couple of houses were completely surrounded. At the house occupied by Mr. Crieman the water was up to thewindow-sill, while it also paid homage to the inside of the place. Mr. Smith's residence next door also received a fair share of patronage. The bridge was not very much damaged, although the gas lamp under the red bridge was broken. Further up the street was a large sheet of water and it paid a visit to the shops of Messrs. Mandelson, Lansdowne, Frost, Butter, Allerdice, and the Co-operative store, but with the exception of a couple of chairs, some boots, and other articles having a free bath no loss was sustained.

A large dam in Mr. B. M. Osborne's Hopewood estate gave away, and the rush of the large body of water, combined with debris and large logs, compelled the dam in Mr. Holle's property to burst asunder. This terrific rush of water carried away a bridge crossing to Mr. W. Neich's residence on the Fairmount Estate, while the Centennial Road bridge was clean uplifted.

Some houses in the vicinity of Railway Crescent were also swamped, and the families had to be removed.

THE LAWN TENNIS COURT.

The court belonging to the Bowral Lawn Tennis Club was not passed by the flood without having a share of damages meted out to it. It is a complete wreck. Great havoc has been played with the wire netting, and in many places it is laid low. Debris and other stuff is piled up all round; the crockery used for afternoon tea was also washed away.

IN BOWRAL-STREET.

In this street the water approached the road some two hundred yards above the bridge. At the latter great mischief was done. The handrails were slaughtered and knocked about greatly, although the flooring was not very much hurt. A young gentleman from the Brahan Bank School had a very narrow escape in trying to cross the bridge on horseback. Messrs. Baird and Herrington went to his rescue, andlanded him safely by the aid of a rope. The fences below the bridge received the same fate as those higher up the creek.

IN SHEPHERD-STREET.

Mr. W. P. Barnes gives us the following particulars concerning the adventures of a number of families in the lower part of the street. About 1 o'clock Mr. Barnes (who occupies the fifth house from the bridge) looked out of his house and saw the water was running along in front of his garden over a foot deep. Thinking that his neighbours must be in need of help he went to Mr. Dunwoodie's residence, and found two women and five children in the house, Mr. Dunwoodie being at church. The water in the place was over a foot deep. He first removed the three children, and at once returned for Mrs. Dunwoodie and her lady friend, and the two babies, removing all to his own residence. Messrs. Gash, Harper, and Wylie then appeared on the scene and the four went to Mr. Taylor's. Here there was Mrs. Taylor, a gentleman, and a child. These were taken to Mr. Reddall's empty house, where they were treated very kindly. The four rescuers then returned to Mr. and Mrs. Seamen's residence on the Glebe, and succeeded in getting Miss Seamen after difficulty to Mr. Perkins's residence; but Seamen preferred to remain, although his garden was completely submerged. Furniture from Mrs. Taylor's residence came out of the door and lodged in front of the fence. The Shepherd street bridge was not damaged.

THE GARDENS.

The Chinamen's gardens up the creek were in many parts swamped,and the loss sustained was not so much as anticipated. It was rumoured that the Celestial gardeners had to seek refuge on the top of their "humpies," but we believe the report was only a sham. "Floodee comee in five minee; very gladee got all tatee up loofee," was the reply of a native of the Flowery Land when questioned on the flood question.

MR. STANGER LEATHES.

A dam in Mr. Stanger Leathes property broke away, besides the damage done to his place was very considerable. A large number of trees and logs lodged on Merrigang-street, the other side Jamieson Hill, to clear which a number of hands were put on last Monday.

SMALLER ITEMS.

All bridges on Centennial Road to Cutaway Hill have been washed away; temporary thoroughfares have been made through the properties of Messrs. Fowler and B. M. Osborne by kind permission of the owners.

A landslip took place on the Wingecarribbee Estate, while another one took place on Mr. B. M. Osborne's property.

A couple of pigs belonging to Mr. W. Moore were drowned in a stye, besides which a number of ducks and fowls got a free carriage down the creek.

Mr. Pain's cottages in Wingecarribbee street were under water.

A second heavy storm took place between eight and nine on Sunday evening: several families had again to seek refuge elsewhere.

SUGGESTION.

To relieve the flood water going round the town in a circle, a suggestion has been made to cut a canal at the corner of Holly and Bowral streets; run the canal along Bowral-street past the hospital through Station-street under the railway to creek.

RAINFALL.

Through Mr. Sherriff's kindness we are enabled to publish the total rainfall for 3 days, the great bulk of which fell between 10.30 to 1 o'clock on Sunday morning:—

Saturday 8.30 a.m. to Sunday 8.30 a.m.	21	points
From 8.30 a.m. Sunday to 1 p.m. ..	717	,,
1 p.m. to 5.30 p.m.	259	,,
5.30 p.m. to 9.15 p.m.	124	,,
9.15 p.m. Sunday to 8.30 a.m. Monday	95	,,
8.30 a.m. Monday to 8.30 a.m. Tuesday	48	,,
Total	1263	,,

The Bowral Free Press, Saturday, March 11, 1893, p.2 (Source: State Library of NSW)

The Floods in Bowral.

Mr. Farrow's Official Report.

The following report, dated Thursday last, March 9th, was read at the Council meeting that evening by Mr. W. R. Farrow, Clerk of Works :—

The heavy storm of Sunday last combined with the collapsing of three private dams made great havoc with the thoroughfares. The greatest damage done was to the Centennial Road and Park, one bridge being swept away; the other, on Hollo's property, remains intact, but the debris from the dam completely blocked the water-way, consequently the torrent made two large breaches in the approaches. The metal road for about 300 yards has been greatly torn about. I have had the road fenced off at the washaways, and made arrangements with Colonel Roberts and Mr. Fowler for a temporary thoroughfare through their property. I have also made arrangements for getting the repairs done, but the continued bad weather has prevented the men from working. Logs for a new temporary bridge are being procured from Mr. Ben. Osborne's paddock, that gentleman having kindly given me permission. With the men engaged, and fine weather, I hope to have the road open for traffic in about 7 days.

In the Centennial Park about 30 rod of two rail fencing has been carried away, and about 10 rod displaced. The little foot bridge across the creek is also gone. The contractors, Horrington and Bauer, expected to have completed their earthwork in about 3 days, and I regret to say that all but about a dozen yards has been swept away.

Oxley st. has been greatly torn about and traffic all but suspended. Men have started to do necessary repairs. The log foot bridge in Rose-street has been swept away. Some of the logs are now lying in person's gardens, but I consider the cost of removal would be of far more expense than their worth.

Shepherd-street bridge had a portion of the approach washed away—this has been repaired. Slight damage was done to the handrail of this bridge, also to the Merrigang one—repairs will be effected as soon as possible.

At the north-end of Merrigang-street, near Cutler's, the street was completely blocked with logs and rubbish—these have been cleared away. The culvert at this spot will, when weather permits, want raising at least a foot to allow of the water passing under. At present it is completely silted up.

In Carlisle-street, the newly-made water-table and footpath have suffered considerably.

In the main portion of the town the damage done has not been of any great extent, further than silting up water channels and pipe drains; the latter will have to be lifted and cleaned.

Altogether 12 extra men and 3 horses and carts have been employed up to Tuesday night.

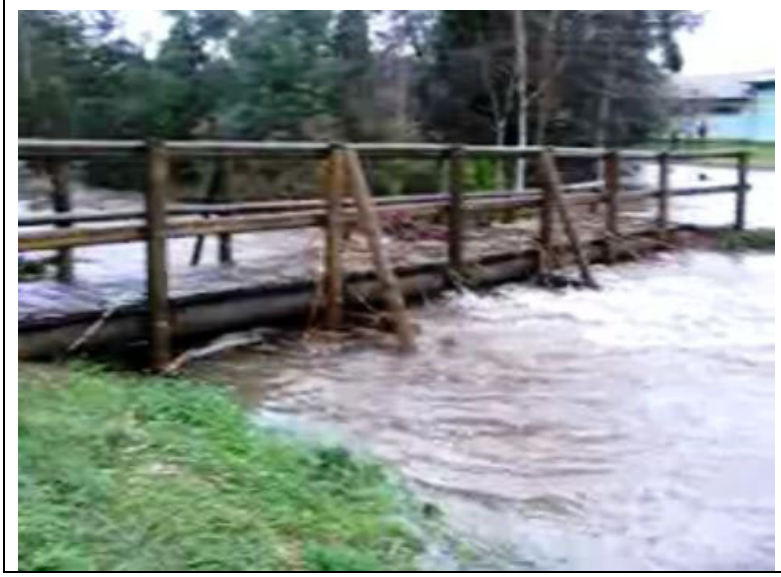
James Ralston, the accepted tenderer for spauls, has, not up to the present signed the necessary papers of contract. As we shall require some at an early date, will the council please to direct what is to be done in the matter. [Fresh tenders to be advertised for.]

As there is every appearance of continued wet weather, there will be a necessity of getting some ashes, our present stock being nearly run out. [5 trucks to be obtained.]

	**1915**: Flooding near Shepherd Street, with PL Travers (author of *Mary Poppins*) standing on bank. Source: Unknown
	**1975** March: Looking north along Mittagong Road. Source: WSC, 1990
	**1978** March. Source: Southern Highlands News, 22 March 1978 (Berrima District Historical Society)

	**1985** November: Beavan Place. Source: Southern Highlands News?, 13 November 1985 (Berrima District Historical Society)
	**1986** August: Rivulet Park. Source: Highlands Post, 8 August 1986 (Berrima District Historical Society)
	**1988** April: Looking south along Mittagong Road. Source: WSC, 1990

	**1999** October: Backyard of residence in Farmborough Close. Source: Mr Ted Westwood
	**1999** October: Bowral Golf Course. Source: Mr Charles Carey
	**2005** February: Beavan Place. Source: Mr Phil Campbell, SES

	**2007** June: Farmborough Close footbridge over Mittagong Creek. Source: YouTube

APPENDIX D

REVISION OF FLOOD STUDY, OCT 2004

This Appendix reproduces Working Paper No. 1 (Revision of Flood Study, October 2004) of the Bowral Floodplain Risk Management Study and Plan. This Working Paper was endorsed by the Bowral Floodplain Management Committee. Prior to its reproduction in this document, minor edits were made including replacing "Mittagong Rivulet" with "Mittagong Creek", removing Appendix A (since this has been replaced by Appendix C in this final report), and renaming Appendix B as Appendix D1 and Appendix C as Appendix D2.

FLOOD STUDY ADDENDUM, APR 2009

A Flood Study Addendum was prepared in April 2009. This reports the results of additional flood modelling conducted in May 2005 to assess the impact of the new Bowral Street Bridge and substantial flood modelling conducted in December 2008 using a new version of modelling software to assess the sensitivity of the flood regime to blockage of structures and to climate change.

WINGECARRIBEE SHIRE COUNCIL

BOWRAL
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

FLOOD STUDY ADDENDUM

April 2009

Report of Wingecarribee Shire Council's
Bowral Floodplain Management Committee, prepared by:

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1. INTRODUCTION

1.1 MAY 2005 UPDATE

At the February 2005 meeting of the Bowral Floodplain Management Committee, the Committee requested that the Flood Study which had been undertaken in 2004 be modified to take account of the new Bowral Street Bridge, for which construction was then imminent. Council officers provided the Consultant with design plans of the proposed structure and the computer flood model of Mittagong Creek was modified accordingly. Various options for road levels were also tested in the model.

As documented in Section 4.3.2 of the original Flood Study Working Paper, a blockage factor of 50% had previously been adopted as part of the design flood modelling of all bridge and culvert waterway openings, with the single exception of the very large railway opening downstream of the Mittagong Road Bridge. As part of the consideration of the new Bowral Street Bridge, a further review of blockage factors was undertaken in conjunction with Council. It was determined that in addition to the new Bowral Street Bridge, three other bridge structures which had relatively large waterway openings should be modelled with a design blockage factor of 25%. These three bridges were those at Mittagong Road, Mount Road and Oxley Hill Road. In addition, given the long length of the hand rail/crash barriers proposed at the new Bowral Street Bridge, it was decided that these structures should also be modelled with a 50% blockage factor.

In May 2005, revised computer modelling was undertaken including the new Bowral Street Bridge and the changes to blockage factors discussed above. This indicated that there would be no significant changes to the Mittagong Creek flood levels during the design 100 year event, as shown in the attached **Figure 18A** (cf. Figure 18 in the original Flood Study Working Paper). Full details of the model results for all design events were provided electronically to Council.

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

Bewsher Consulting Pty Ltd

J1165
Adm_MRBP_100y_500_Blk_01.WOR
03 May 2005

FIGURE 18A
100 YEAR DESIGN FLOOD

1.2 DECEMBER 2008 UPDATE

In August 2008, Wingecarribee Shire Council commissioned Bewsher Consulting for a number of additional tasks related to the Bowral Flood Study:

(a) Remodel the 100 year ARI flood for the Mittagong Creek floodplain using the 2008 version of TUFLOW (Build 2008-08-AD-ISP). This first involved verifying the calibration of the April 1988 and October 1999 floods with the new TUFLOW model. (Note that remodelling of the Beavan Place subcatchment was not included in this commission. That modelling utilised TUFLOW Build 2004-06-AC, which was more recent than the Build 2003_07_BA version originally used for Mittagong Creek).

(b) Test the sensitivity of the model to *blockage assumptions* by running a 100 year ARI model without blockage at structures crossing the creek;

(c) Assess the propensity for blockage at potential source locations, and assess the potential to address blockage; and

(d) Test the sensitivity of the model to *climate change* by running a 100 year ARI model run with a 20% increase in rainfall intensities.

The modelling tasks were undertaken in December 2008. The results of this work are presented below.

2. NEW TUFLOW MODEL

2.1 VERIFICATION OF MODEL CALIBRATION

2.1.1 Introduction

Following modelling of the April 1988 and October 1999 flood events utilising the 2008 version of TUFLOW, we report on the results obtained.

Table 2A and **Table 3A** represent revised versions of the original Table 2 and Table 3 (in the Bowral FRMS&P, Working Paper No. 1 – Revision of Flood Study, October 2004). The Tables report the latest TUFLOW modelled levels, the revised "difference" values between the historic levels and modelled levels, associated revised "remarks" and an additional column heading of "Change" which offers a comment on the quality of the "fit" relative to the previous model version.

TABLE 2a: APRIL 1988 FLOOD LEVELS

	Location	Recorded Level	HEC-RAS level in Council Study	Diff between Councl Study & recorded level	TUFLOW Flood Level	Diff between TUFLOW level & recorded level	Change	Remarks
1	Upstream face of railway underpass	671.24	671.96	0.72	671.30	0.06	significant improvement	
2	H.D.E. Office	671.60	672.10	0.50	671.68	0.08	significant improvement	
3	Swimming pool carpark	671.80	672.23	0.43	671.73	-0.07	significant improvement	
4	Footbridge	671.35	672.23	0.88	671.73	0.38	significant improvement	Reliability of recorded level is questionable given that difference is inconsistent with upstream and downstream reasonable fits.
5	100m Downstream of Victoria St	672.46	672.44	-0.02	672.45	-0.01	improved	
6	Just downstream of Victoria St	672.87	672.54	-0.33	672.71	-0.16	slightly worse	
7	Victoria St Bridge	672.73	673.01	0.28	672.83	0.10	improved	
8	100m upstream of Victoria St	673.05	673.17	0.12	672.98	-0.07	improved	
9	Sunroom Floor (23 Rose St)	673.22	673.22	0.00	673.10	-0.12	slightly worse	
10	Front gate (23 Rose St)	673.53	673.35	-0.18	673.20	-0.33	worse	
11	Rear of house upstream of Rose Stree	673.52	673.47	-0.05	673.53	0.01	improved	
12	Gas Co. Merrigang St	674.57	674.54	-0.03	674.51	-0.06	little change	
13	Just Upstream of Merrigang St	674.90	674.85	-0.05	674.89	-0.01	significant improvement	
14	50m upstream of Merrigang St	674.85	674.85	0.00	674.93	0.08	significant improvement	
15	Shepherd St - Springetts	675.11	675.56	0.45	675.39	0.28	significant improvement	Exact location of recorded flood level is uncertain.
16	Shepherd St. Bridge	675.69	675.62	-0.07	675.54	-0.15	worse	
17	Upstream of Shepherd St	675.40	675.68	0.28	675.58	0.18	significant improvement	
18	Bradman Close	676.14	676.21	0.07	676.63	0.49	worse	
19	Bowral St Bridge	677.35	677.62	0.27	677.16	-0.19	slightly worse	
20	Farmborough Close	677.94	677.75	-0.19	677.79	-0.15	worse	
21	Confluence with South Arm	678.00	678.05	0.05	677.98	-0.02	improved	
22	Bowral St Culvert	679.16	679.53	0.37	679.26	0.10	improved	
23	Bowral St Culvert (upstream)	679.33	679.77	0.44	679.51	0.18	improved	
24	Old South Rd Causeway	686.60	686.51	-0.09	686.59	-0.01	improved	
25	Behind Tynedale Crescent	679.30	679.34	0.04	679.76	0.46	worse	Exact location of recorded flood level is uncertain.
26	Upstream of Old South Road Culvert	680.30	680.28	-0.02	680.09	-0.21	worse	
27	Rear of Lot 3 Kiama St	663.37	663.20	-0.17	663.02	-0.35	little change	
28	Oxley Hill Rd	664.57	664.63	0.06	664.63	0.06	little change	
29	Willow Rd	668.59	668.31	-0.28	667.94	-0.65	worse	Reliability of recorded level is questionable given that difference is inconsistent with upstream and downstream reasonable fits.
30	Deans Factory	668.36	668.66	0.30	668.28	-0.08	improved	
31	Scout Hall (Small)	669.08	668.81	-0.27	668.97	-0.11	little change	
32	Scout Hall (Main)	669.18	668.92	-0.26	668.97	-0.21	little change	
33	Sherwood Ave	669.13	669.10	-0.03	669.05	-0.08	little change	
34	Oxley Timber (Channel)	669.23	669.19	-0.04	669.16	-0.08	little change	
35	Oxley Timber Gate	669.59	669.23	-0.36	669.43	-0.16	slightly worse	
36	Downstream Mount Rd	669.41	669.29	-0.12	669.29	-0.12	little change	
37	Oxley Timber (Factory)	669.72	669.44	-0.28	669.38	-0.35	slightly worse	
38	Kirkham Rd Downstream Underpass	671.46	671.18	-0.28	671.25	-0.21	worse	

TABLE 3a: OCTOBER 1999 FLOOD LEVELS

	Locations	Recorded Level	TUFLOW Flood Level	Difference	Change	Remarks
1	Willow Rd Footbridge - Surveyed by Council on 4/11/99	667.72	667.98	0.26	significant improvement	
2	Mount St - Surveyed by Council on 4/11/99	669.71	669.43	-0.28	slightly worse	
3	Mittagong Rd - Surveyed by Council on 4/11/99	671.11	671.20	0.09	significant improvement	
4	Rose St - Surveyed by Council on 4/11/99	673.02	673.36	0.34	improved	Recorded flood level may be unreliable. Hydrological analysis suggests that the peak flow for 1999 storm is very similar to the 1988 peak flow but the recorded flood level is significantly lower than the 1988 recorded level at a similar location. Also as noted for flood marks 5, 6 and 8 in this table, their values are also slightly higher than the comparative 1988 levels.
5	Merrigang St Bridge - Surveyed by Council on 4/11/99	674.98	674.96	-0.02	significant improvement	Excellent fit. (Recorded flood level higher than that of April 1988 storm at similar location by 80mm.)
6	Bowral St Bridge - Surveyed by Council on 4/11/99	677.50	677.27	-0.24	worse	Reasonable fit. (Recorded flood level higher than that of April 1988 storm at similar location by 150mm.)
7	Stanley Park Footbridge - Surveyed by Council on 4/11/99	677.84	677.59	-0.25	worse	
8	Bowral St Culvert - Surveyed by Council on 4/11/99	679.29	679.34	0.05	improved	Very good fit. (Recorded flood level higher than that of April 1988 storm at similar location by 130mm.)
9	Bowral St Bridge - local resident's observation documented in letter dated 25/11/02	678.23	677.27	-0.96	significantly worse	Considered to be a localised effect whereby flood flows are locally elevated due to pedestrian rail blockage effect - this localised regime cannot be reproduced with TUFLOW model.

2.1.2 April 1988 Flood Re-calibration Results

Adopting both the previous hydrologic input files and TUFLOW hydraulic parameters, it was found that TUFLOW was calculating slightly lower flood levels – typically between 0.05 and 0.20 metres. Overall a slightly better overall fit has been obtained.

2.1.3 October 1999 Re-calibration Results

Adopting the previous hydrologic input files and TUFLOW hydraulic parameters, it was found that TUFLOW was calculating slightly lower flood levels – typically between 0.10 and 0.25 metres. Again a slightly better overall fit has been obtained.

2.1.4 Commentary

Although the latest modelling typically provides a better fit to flood levels in the vicinity of various bridge structures, it is somewhat under-predicting levels relative to historic flood levels reported at and just upstream of the old Bowral Street bridge. This is attributed to the potential for some blockage of the bridge handrail to have occurred during the historic floods. However, in the design flood event scenarios, blockage factors are applied to the new bridge and its accompanying handrail, so issues associated with *historic* blockage are not of particular importance.

It is concluded that the latest runs have overall achieved a very similar or slightly improved calibration to the two historic flood events. Consequently, the design flood modelling proceeded without adjustment of the model.

2.2 100 YEAR FLOOD MODELLING

A revised map showing 100 year flood depths and levels for the new version of TUFLOW is shown in **Figure 18B** (cf. Figure 18 in the original Flood Study Working Paper). This map is based upon the *maximum envelope* (blocked and unblocked scenarios) of 100 year flood levels for Mittagong Creek. The same cut-off lines as used in the original report have been applied, to delineate the assumed boundary of mainstream flooding.

Figure 1 plots the difference in the 100 year ARI flood levels for the new version of TUFLOW compared to the earlier (May 2005) version.[1] **Table 1** provides a further measure of differences between the two model outputs. It compares the above-floor 100 year depths of inundation for the 14 houses previously recommended for inclusion in a VHR scheme (cf. **Table 8.2** in the Bowral FRMS&P report).

Figure 1 indicates that in the reach between the Bowral Street culvert on the north (main) arm and the new Bowral Street Bridge, including Farmborough Close (cf. **Table 1**), peak flood levels are reduced by 0.1 to 0.25m with the new modelling. In the reach between the Bowral Street Bridge and the Victoria Street Bridge, some areas record increases – of up to 0.12m for a few areas along Merrigang Street. From Victoria Street to the railway, decreases are recorded, in some areas of about 0.3m. Levels from the railway to Oxley Hill Road are mostly unchanged or reduced. At Bowral Brickworks, the 100 year flood levels are increased by about 0.5m, which is due to the new version defining additional inflows into the quarry.

[1] Only *blocked* model runs were compared, since a maximum envelope was not available for the earlier model run.

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This flgure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

Limit of Mapping

Beavan Place model area

Limit of Mapping

Limit of Mapping

Limit of Mapping

NORTH

0 400 800
metres

NOTES

Flood model results from the Mittagong Creek model are available for this area downstream of the limit of mapping, but these should be used with caution due to the influence of flows from the Wingecarribee river

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13 May 2009

FIGURE 18B
100 YEAR DESIGN FLOOD

LEGEND
Change in flood level from 2005 blocked conditions (m)

- Less than -0.5
- -0.5 to -0.25
- -0.25 to -0.1
- -0.1 to -0.05
- -0.05 to -0.02
- -0.02 to 0.02
- 0.02 to 0.05
- 0.05 to 0.10
- 0.10 to 0.25
- 0.25 to 0.50
- Greater than 0.5

Assumed boundary of mainstream flooding for this event.

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Date: 12 Dec 08

Figure 1:
2008 Blocked vs 2005 Blocked Structure Runs
100 Year ARI Flood Conditions

TABLE 1 – 100 Year ARI Flood Depths for Various Model Runs

Address			Construction type	Floor level source	100 year ARI flood depths over floor (m)			
					2005 TUFLOW model (blocked)	2008 TUFLOW model (blocked)	2008 TUFLOW model (unblocked)	2008 TUFLOW model (climate change unblocked)
23	ROSE STREET	BOWRAL	W'board Cottage	Surveyed	0.7	0.6	0.5	0.7
45	SHEPHERD STREET	BOWRAL	W'board Cottage	Surveyed	0.5	0.5	0.4	0.6
48	SHEPHERD STREET	BOWRAL	W'board Cottage	Surveyed	1.0	1.0	0.9	1.1
2	UNA STREET	BOWRAL	Fibro Cottage	Surveyed	0.7	0.8	0.6	0.7
4	UNA STREET	BOWRAL	W'board Cottage	Surveyed	0.4	0.5	0.3	0.5
27	KIAMA STREET	BOWRAL	Fibro Cottage	Estimated	0.7	0.6	0.7	1.0
7	SHERWOOD AVENUE	BOWRAL	W'board & Fibro Cttg	Surveyed	0.9	0.9	0.9	1.1
2	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Estimated	0.9	0.8	0.7	0.9
4	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Surveyed	0.9	0.7	0.6	0.9
6	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Estimated	0.9	0.7	0.6	0.9
8	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Surveyed	0.9	0.7	0.6	0.9
10	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Estimated	0.9	0.7	0.6	0.9
12	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Estimated	0.9	0.7	0.6	0.9
14	FARMBOROUGH CLOSE	BOWRAL	Brick Cottage	Estimated	0.7	0.6	0.5	0.7
				Average	0.78	0.71	0.61	0.83

Given the improved calibration and the internal modelling improvement incorporated in the 2008 TUFLOW software, the December 2008 modelling provides a superior definition of flood levels throughout Bowral to that reported earlier.

3. SENSITIVITY TO BLOCKAGE

3.1 100 YEAR FLOOD MODELLING

The baseline December 2008 100 year ARI model run adopted the same blockage conditions that had been adopted for the May 2005 model run that included modelling of the new Bowral Street Bridge. These assumptions were:

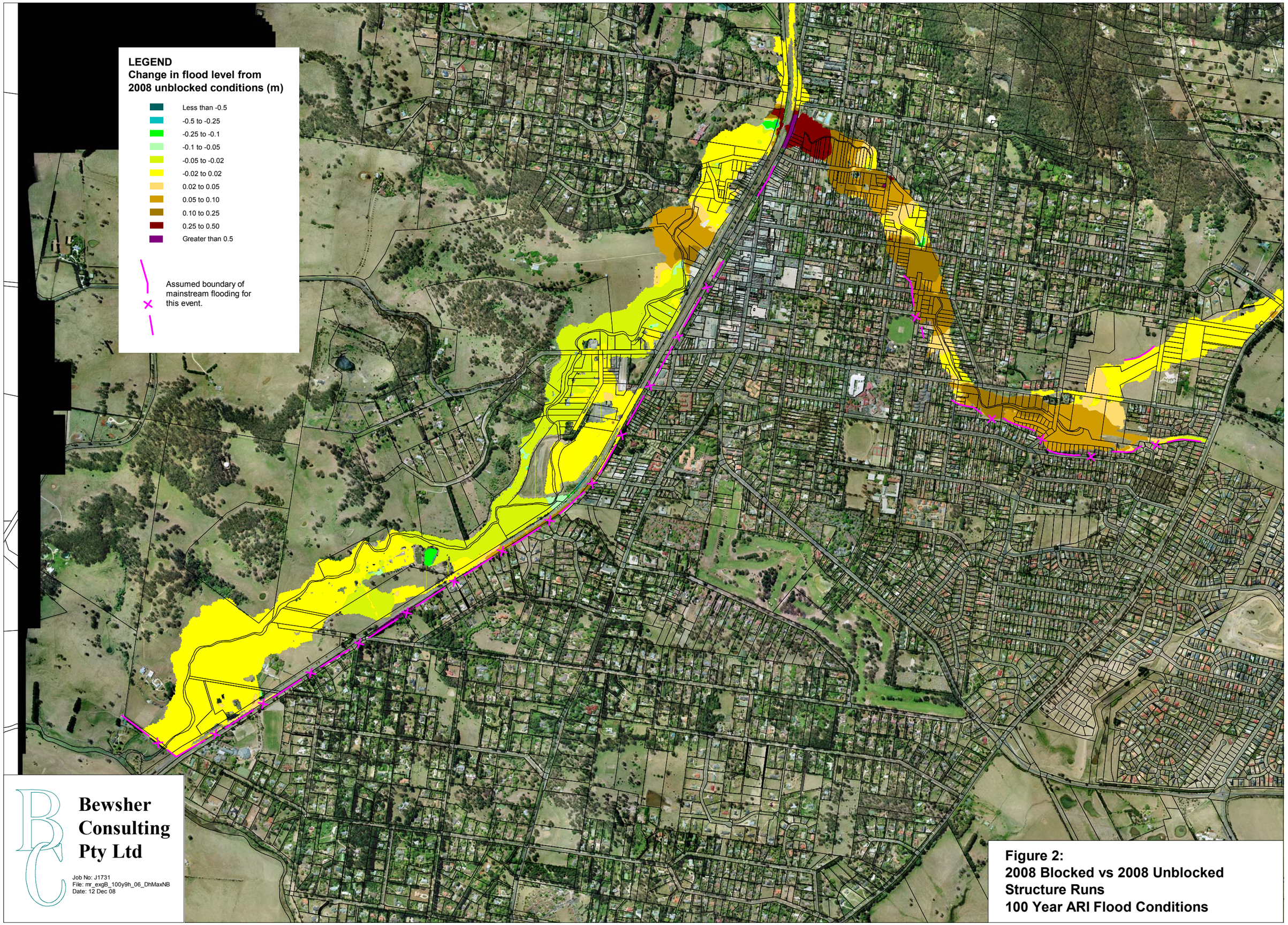
- 25% blockage of the waterway openings at the new Bowral Street Bridge, Mittagong Road Bridge, Mount Road Bridge and Oxley Hill Road Bridge;
- 0% blockage of the waterway opening at the railway bridge;
- 50% blockage of all other bridge and culvert waterway openings;
- 50% blockage of the hand rail and vehicular crash barriers at the new Bowral Street Bridge; and
- 100% blockage of the full height and width of the hand rail and vehicular crash barriers at all other structures.

Figure 2 compare the 100 year ARI flood levels for the latest "blocked" run and an unblocked run where all blockages of the waterway openings, hand rails and vehicular crash barriers were removed. Given the inundation of many structures crossing Mittagong Creek, it is not surprising that flood levels are increased when an allowance is made for blockage (cf. **Table 1**). **Figure 2** shows that east of the railway, there are several areas where blockage has the effect of increasing flood levels by 0.1 to 0.25m, with an area immediately upstream of the Kirkham Road Bridge where levels are increased by 0.25 to 0.5m (decreasing upstream). On the western side of the railway, blockage at the Willow Road Bridge appears to be influential in raising flood levels upstream, though downstream of that site there are some slight decreases.

3.2 POTENTIAL FOR BLOCKAGE

Objects that could block waterway structures come in all sorts of shapes and sizes. Some of the types of blockage documented in flooding in Wollongong and Newcastle are shown in **Figure 3**. Boulders, vegetation, fencing, outdoors furniture, vehicles and even shipping containers were implicated in the blockage of structures.

Material that could potentially block structures is found both within creek channels and on the floodplain. The community consultation conducted as part of the Bowral FRMS&P revealed a good deal of concern about the potential effect of the rubbish and weeds already in the channel. Car tyres, supermarket trolleys, lounges and other forms of urban waste were explicitly mentioned. This material and natural debris such as tree stumps already in the channel could readily be mobilised during a flood and transported towards bridges.



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Date: 12 Dec 08

Figure 2:
2008 Blocked vs 2008 Unblocked Structure Runs
100 Year ARI Flood Conditions

FIGURE 3 – Examples of Blockage from Australian Floods

Fencing and other debris blocking culvert, Wollongong 1998

Vegetation blocking vehicular crash barrier, Wollongong 1998

Vehicle blocking canal, Newcastle 2007

A good test of the potential for items on the floodplain to be mobilised during a flood, potentially leading to blockage of structures, is the motor vehicle. According to Figure L1 of the Floodplain Development Manual, vehicles become unstable (initially due to buoyancy) at depths of only 0.3m, even when velocities are minimal.

Based on the latest unblocked 100 year ARI flood model run, and the latest digital elevation model (DEM), flood depths above road surfaces at or near the many creek crossings in Bowral were estimated. The results are shown in **Figure 4**. In the 100 year flood, with the exception of the Oxley Hill Road Bridge, depths over the roads are expected to exceed 0.5m, and in eight cases, to exceed 1.0m, meaning that vehicles could become unstable. Whether those vehicles would be washed into the creek and cause blockage depends in part on the ability of the safety barriers to resist the force of the floodwater, vehicles and other debris borne by the flood.

3.3 POTENTIAL FOR MITIGATING AGAINST BLOCKAGE

3.3.1 Remove or Modify the Structures

One option to mitigate against blockage of the structures is to *remove* any structures surplus to requirements. The draft Bowral FRMP recommended consideration be given to removal of the Victoria Street Bridge, though it was noted that three submissions to the exhibited plan objected to this proposal on the grounds the bridge formed an important pedestrian route.

Another option is to *modify* the structures. The Bowral FRMS&P considered enlargement of the bridges and culverts, but found this was not economic. Designing handrails with larger openings, or allowing them to collapse in a downstream direction under flood loading, would mitigate against blockage of these structures. However, when Wollongong City Council considered this approach they found that the optimal design from a flood mitigation perspective was often in direct conflict with requirements for vehicle impact and public safety. The latter concerns outweighed those relating to handrail blockage, requiring larger and more rigid structures with vertical balustrades.

3.3.2 Prevent Sources of Blockage from Entering and Accumulating in the Channel

Section 8.1.6 of the Bowral FRMS&P report contained two recommendations that if implemented would go some way towards reducing the potential for blockage of structures along Mittagong Creek when the next flood comes. The first was for Council to institute a creek maintenance program in which a council ranger would regularly inspect the creek for urban waste and arrange its removal. Second, the preparation of a Mittagong Creek Riparian Corridor Management Plan was recommended as a basis for managing riparian vegetation. The proposed revision to Council's Flood Risk Management DCP (No. 34) also contained controls on new fencing to ensure it didn't become moving debris during flooding.

Other means of reducing the potential for objects to get washed into the creek during flooding are described below.

- Install vehicle and debris collection barriers along the length of Mittagong Creek and its major tributaries. These would need to be substantial structures and of sufficient structural integrity to resist the water borne debris loads. These structures would be expensive to construct and would have adverse visual and access/amenity impacts. Further, they themselves would likely exacerbate flooding in upstream areas due to blockage. Nevertheless they would reduce the potential for in-stream blockage to occur, although blockage resulting from in-stream vegetation and dumped debris, etc, would remain.

FIGURE 4 – Vehicular Bridges and Culverts on Mittagong Creek, Bowral

Photograph	Location (arranged upstream to downstream)	Approx. maximum 100y (unblocked) depth over road surface near bridge/culvert
	Old South Road culvert (Main Arm)	0.4m? (low reliability – edge of model)
	Bowral Street culvert (Main Arm)	0.5m
	Old South Road culvert (South Arm)	N/a (beyond hydraulic model)
	Bowral Street Bridge (new)	1.1m

Photograph	Location (arranged upstream to downstream)	Approx. maximum 100y (unblocked) depth over road surface near bridge/culvert
	Shepherd Street Bridge	1.4m
	Merrigang Street Bridge	1.3m (about 70m west of bridge)
	Rose Street Bridge	1.25m
	Victoria Street Bridge (note: now non-vehicular)	1.1m

Photograph	Location (arranged upstream to downstream)	Approx. maximum 100y (unblocked) depth over road surface near bridge/culvert
	Mittagong Road Bridge	0.6m
	Kirkham Road Bridge	0.9m
	Mount Road Bridge	1.9m (about 40m east of bridge)
	Bridge at rear of Dean Trailers (unapproved?)	2.5m

Photograph	Location (arranged upstream to downstream)	Approx. maximum 100y (unblocked) depth over road surface near bridge/culvert
	Willow Road Bridge	1.4m
	Oxley Hill Road Bridge	0.35m

- Ensure that the vehicular crash barriers in the vicinity of the waterway crossings are long enough to prevent vehicles from entering the channel (but this may require additional flood modelling to finalise design flood levels) and strong enough to resist flood and vehicular loading. This recognises the priority of safety concerns over blockage of the vehicular barriers, but does reduce the likelihood of blockage of the main waterway opening.
- Educate people about the dangers of driving through floodwater, and ensure roads are closed when flooded by clearly demarcating responsibilities in the Local Flood Plan (again, this is mainly a safety issue, but has a secondary benefit of reducing the potential for vehicles entering the creek).
- Install additional gross pollution traps where appropriate.
- Discourage dumping of debris in the creek corridors via signage and heavy penalties.

3.4 SHOULD FLOOD PLANNING LEVELS INCORPORATE AN ALLOWANCE FOR BLOCKAGE?

An email sent from the Consultant to Council on 16 June 2008 which addresses this topic is repeated below:

"In most urban catchments, allowance for blockage needs to be made as it is highly probable that water borne debris will reduce the effective waterway area at bridge and culvert openings.

The propensity for blockage increases as the severity of a flood increases. (The lack of observed blockage in small floods doesn't necessarily imply that blockage will not occur in bigger floods).

The propensity for blockage increases as the size of the waterway opening reduces.

In general, there is insufficient science/data to allow a prediction of the amount of blockage for a given size flood and opening.

It is usually impractical and inappropriate within one LGA to have blockage allowances varying between or within catchments, except based on structure opening sizes.

Blockage has to be considered during the flood study.

Usually blocked and unblocked conditions need to be evaluated and worst case conditions identified.

When considering multiple creek systems with multiple structures, it becomes impractical to consider individual blockage of each structure in isolation from other structures. (In one recent catchment study this would have necessitated over 10,000 model runs for one flood!). Commonsense has to prevail and a realistic set of likely blockage combination scenarios needs to be developed which will encapsulate all realistic blockage possibilities. (In the current Fairy and Cabbage Tree Creeks Flood Study at Wollongong, which has one of the most braided and blockage prone urban creek systems in NSW, including potential for various catchment diversions, we settled on a total of six blockage scenarios after discussions with Council and the Department).

In the absence of further research or government direction, the emerging consensus is that around 50% blockage be used for structures with openings small enough to trap vehicles. Where very special catchment conditions exist (Wollongong?), some deviation from this should be considered.

Council will leave itself exposed legally if it does not specifically allow for blockage and relies only on the 0.5m freeboard, in circumstances where the differences between the blocked and unblocked levels are significant."

Given the potential for blockage along Mittagong Creek and the limited opportunities available to mitigate the blockage, this current review endorses the blockage assumptions used in both the 2005 and 2008 modelling, and which were the recommendation of Council's Floodplain Management Committee during the Bowral FRMS&P.

4. SENSITIVITY TO CLIMATE CHANGE

4.1 BACKGROUND

There is increasing evidence that the temperature of the earth's atmosphere and oceans has increased over the last century, and that the accumulation of greenhouse gases in the earth's environment will accelerate this process in future years. Current estimates indicate that the annual average temperature for Australia could increase by about 1.0°C by 2030 (relative to 1990) and by between 1.8°C to 3.4°C by 2070 (*Climate Change in Australia*, CSIRO/BOM, 2007).

At Bowral, climate change could potentially affect flood behaviour by increasing the severity of flood producing storms or other weather systems.

The impact of climate change on rainfall is a topic of significant uncertainty. Evidence to date suggests that whilst mean annual rainfall over much of Australia is likely to decrease, the intensity of extreme daily rainfall could increase. Of interest for flooding is that the La Niña events often associated with flooding in eastern Australia may tend to become wetter (CSIRO/BOM, 2007). A study of rainfall intensity in the Hawkesbury-Nepean Catchment projected changes of -7% to +10% (for the 40 year ARI 24 hour rainfall event) by 2070 (CSIRO, 2007). In keeping with the mid-range sensitivity test recommended by DECC (2007), the climate change sensitivity test reported here adopted a figure of +20%.

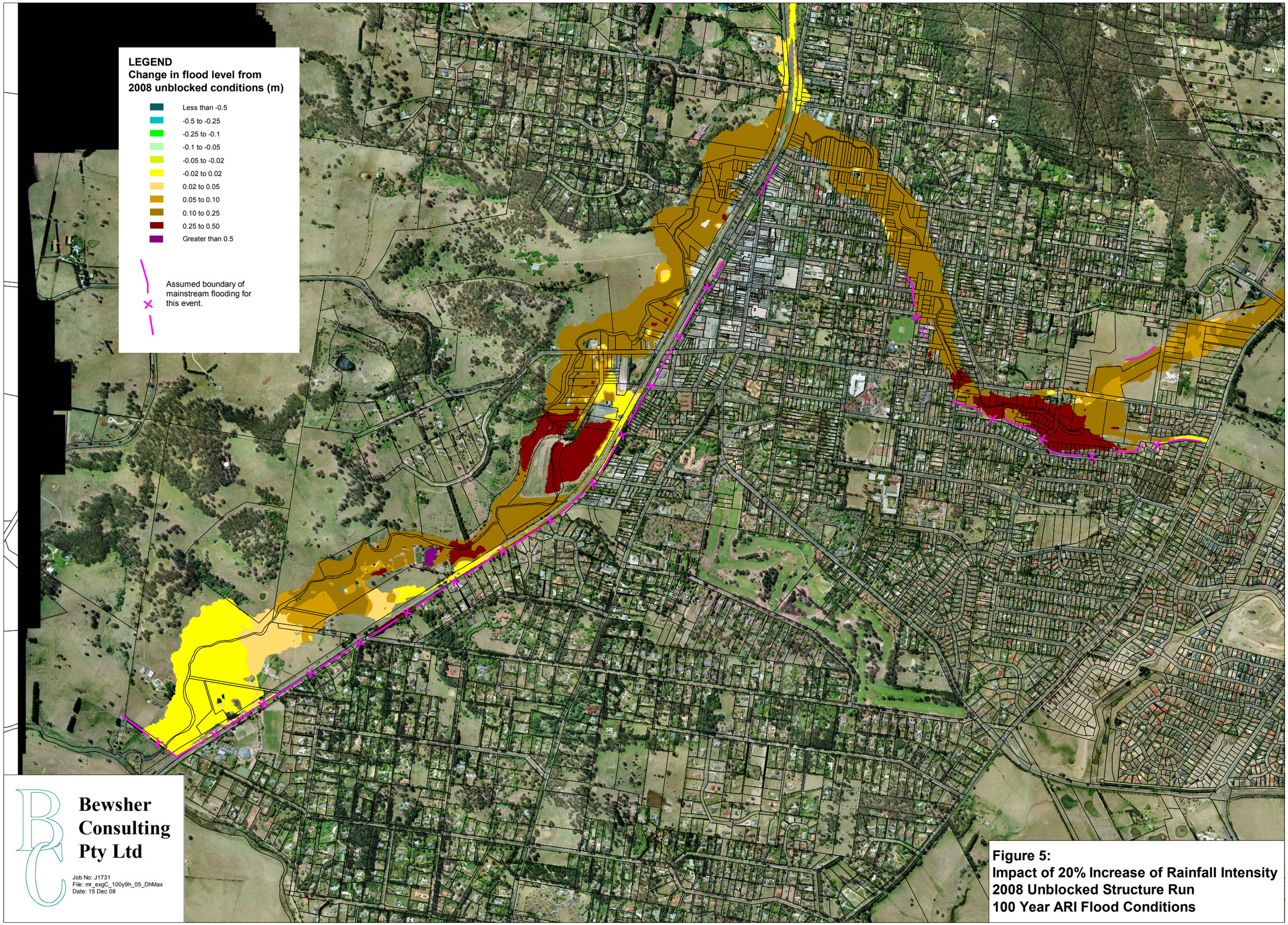
4.2 100 YEAR FLOOD MODELLING

Figure 5 compares the 100 year ARI flood levels for the "climate change" unblocked run with the latest unblocked run. It shows that increasing the 9 hour 100 year rainfalls by 20% increases the flows (often by a little more than 20%) leading to a general increase in flood levels of 0.1 to 0.25m, and an increase in some areas such as the eastern end of Farmborough Close slightly exceeding 0.25m (cf. **Table 1**). No changes were made to the Wingecarribee River tailwater level, which accounts for the lack of changes at the lower end of the model.

4.3 SHOULD FLOOD PLANNING LEVELS INCORPORATE AN ALLOWANCE FOR CLIMATE CHANGE?

It is anticipated that over the next 1-2 years, improved rainfall intensity-frequency-duration (IFD) data as well as improved projections of changed rainfall intensities with climate change will become available. These should allow some assessment of the probability (and timeframe) of increased rainfall intensities to be determined.

Once this data becomes available, it is recommended that Council assess the potential changes and determine whether revisions to the flood planning levels (FPLs) are required.



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Date: 15 Dec 08

Figure 5:
Impact of 20% Increase of Rainfall Intensity
2008 Unblocked Structure Run
100 Year ARI Flood Conditions

5. CONCLUSION

It is recommended that the December 2008 flood model results be adopted for applying Council's flood risk management provisions in its DCP to properties within the Mittagong Creek floodplain. The applicable flood levels would be the "maximum envelope", that is, the highest of "blocked" and "unblocked" model runs at a particular site. In relation to climate change, it is recommended that a decision regarding the inclusion of a climate change flood risk allowance in setting Flood Planning Levels (FPLs) be deferred until the anticipated improved rainfall intensity-frequency-duration (IFD) data and improved projections of changed rainfall intensities with climate change become available.

6. REFERENCES

CSIRO, 2007, *Climate Change in the Hawkesbury-Nepean Catchment*, report prepared for the NSW Government.

CSIRO/BOM, 2007, *Climate Change in Australia: Observed Changes and Projections*, prepared for the Australian Climate Change Science Programme.

DECC (Department of Environment and Climate Change), October 2007, *Practical Consideration of Climate Change, Floodplain Risk Management Guideline*.

IPCC, 2007, *Climate Change 2007: The Physical Science Basis, Summary for Policymakers*, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 5 February 2007.

WINGECARRIBEE SHIRE COUNCIL

BOWRAL
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

WORKING PAPER NO. 1
REVISION OF FLOOD STUDY

October 2004

Report of Wingecarribee Shire Council's
Bowral Floodplain Management Committee, prepared by:

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APPENDICES

1. INTRODUCTION

This working paper documents the methodology and results of modelling:

< the two relatively recent flood events in the Mittagong Creek catchment (see **Figure 1**) for which there are both rainfall and flood level data. Those two significant events were April 1988 and October 1999, and

< the design 5 year, 10 year, 50 year and 100 year average recurrence interval and probable maximum flood (PMF) events.

The hydraulic modelling extends from just upstream of the confluence with the Wingecarribee River to where the Main Arm and the South Arm cross the Old South Road and also covers a significant tributary (centred on Beavan Place) located east of the railway.

2. EARLIER FLOOD STUDIES

2.1 COUNCIL FLOOD STUDY

In 1990 Council completed an assessment of 20 year and 100 year ARI flood levels along the Creek (**Reference 1**). The extent of the flood modelling was from just upstream of the Sewage Treatment Plant (STP) to the confluence with the South Arm plus along the Main Arm and the South Arm as far upstream as the Old South Road.

The study involved the use of RAFTS hydrologic software to assess the catchment flows and HEC-2 hydraulic software to calculate the flood profiles. The models were calibrated using rainfall and flood level data from the April 1988 event (since there was very little information available regarding earlier flood events in 1975 and 1978). The models were then used to calculate the design event flood profiles.

The HEC-2 modelling was based on the use of over 170 field surveyed cross sections plus additional survey of a number of bridge structures.

2.2 DPWS FLOOD STUDY

In 2002 the NSW Department of Public Works and Services (DPWS) completed an assessment of 20 year and 100 year ARI flood levels along the Creek between the confluence with the Wingecarribee River and upstream of the Sewage Treatment Plant (**Reference 2**). This study — which was specifically undertaken to assess the potential

impact of various STP augmentation options — also included a preliminary assessment of Probable Maximum Flood levels.

The study utilised the 20 year and 100 year ARI flows from the Council flood study and project-specific field surveyed data was used to define cross sections for the HEC-RAS hydraulic software.

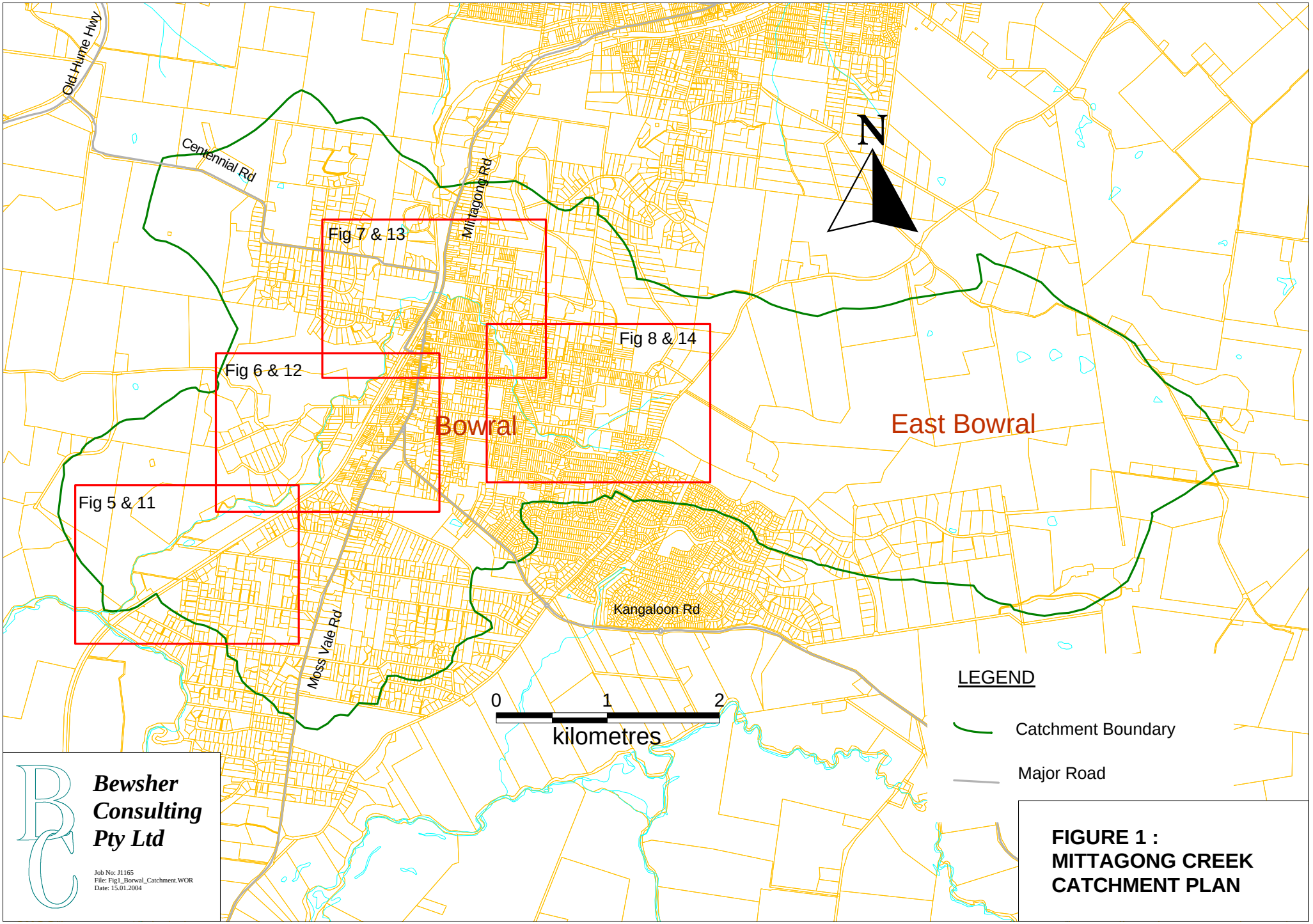
Old Hume Hwy
Centennial Rd
Mittagong Rd
Moss Vale Rd
Kangaloon Rd
Fig 7 & 13
Fig 8 & 14
Fig 6 & 12
Fig 5 & 11
Bowral
East Bowral
N
0
1
2
kilometres
LEGEND
Catchment Boundary
Major Road
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FIGURE 1 :
MITTAGONG CREEK
CATCHMENT PLAN

3. FLOOD CALIBRATIONS

3.1 CHOICE OF MODELS

Council's 1990 RAFTS model formed the basis of the new hydrologic model which was run in Version 2000 6.12 of the RAFTS software. The following additions and changes were made for the current study:

- as the Council model did not include the portion of the catchment downstream of the STP, it was extended to the confluence with the Wingecarribee River (which involved the incorporation of an additional ten sub-catchments into the original model);

- since a number of the original subcatchments had PERN values set at zero and the current RAFTS software will not accept zero values, those PERN values were changed to the value (0.015) recommended in the RAFTS manual.

Figure 2 defines the network of sub-catchments and nodes in the new RAFTS model.

As detailed later in this working paper, research was undertaken to compile the best available official rainfall information for the two storm events.

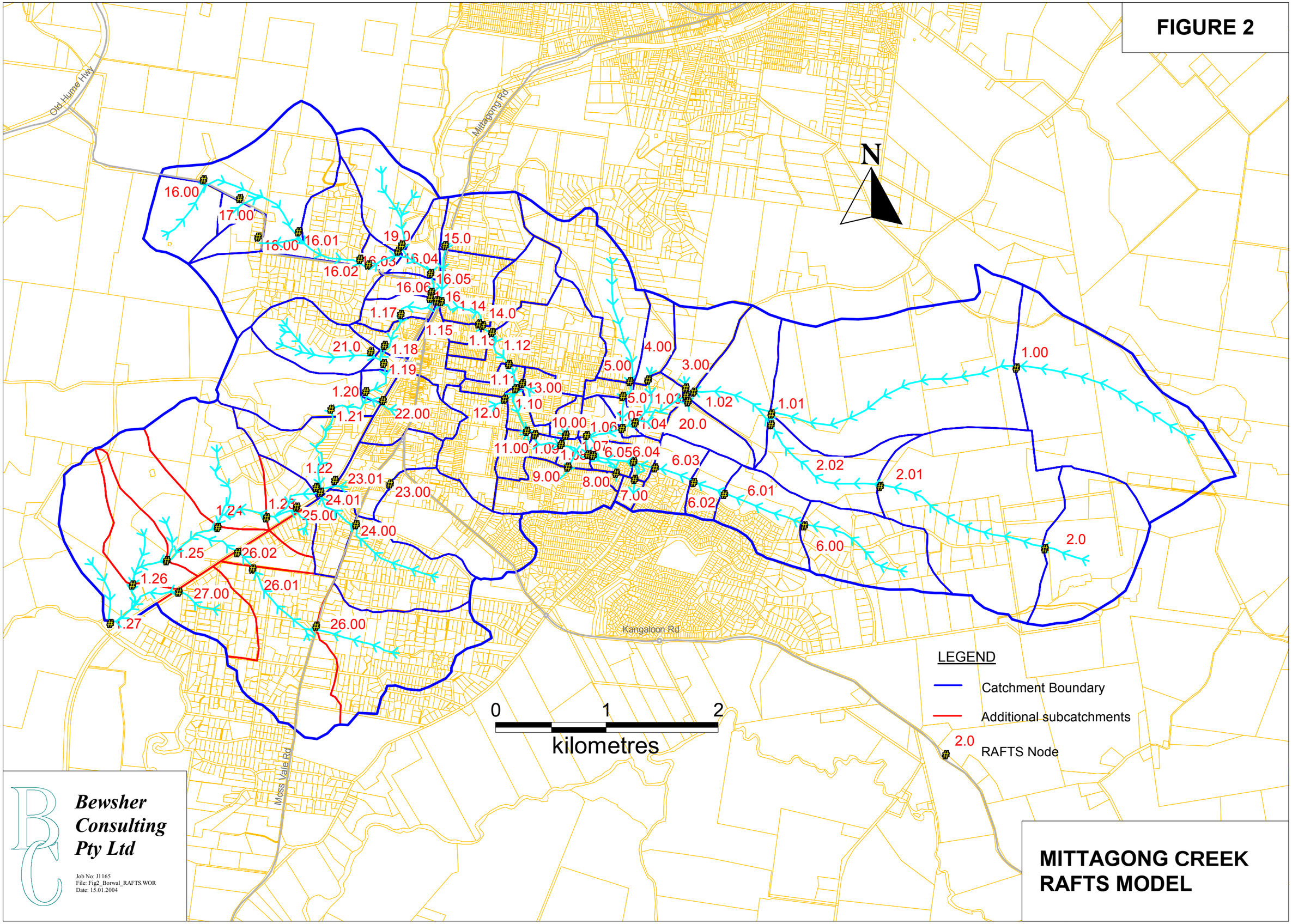
The latest hydraulic modelling software (which is more powerful in capability than HEC-RAS) was selected for modelling the flood behaviour along the Mittagong Creek floodplain. The type of model chosen was a combined 2D/1D hydraulic model known as TUFLOW. This type of model has the advantage that it is able to accurately define the main creek channel as a one-dimensional section while the overbank/overland flowpaths are modelled using a fine scale two dimensional grid. In TUFLOW the 2D solution algorithm solves the full two dimensional, depth averaged, momentum and continuity equations for free-surface flow while ESTRY (a 1D or quasi-2D modelling system which is based on the full one-dimensional free surface flow equations) is used for modelling the 1D elements.

The flow inputs for the TUFLOW model are the flow hydrographs imported directly from the RAFTS model results.

The survey data inputs for the TUFLOW model consist of a combination of:

- the field surveyed cross sections used in the Council and DPWS flood studies (**References 1** and **2**);

FIGURE 2



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MITTAGONG CREEK RAFTS MODEL

- a Digital Elevation Model (DEM) developed from project-specific aerial mapping; and

- details of additional floodplain structures based on either Council-supplied design plans or supplementary Council field survey.

Roughness parameters for the TUFLOW model are based on a combination of:

- floodplain inspections;

- review of 1992 aerial photography provided by Council and present day aerial photography supplied as part of the project aerial mapping; and

- review of parameters used in the Council and DPWS flood studies.

As detailed later in this working paper, Council provided a number of surveyed flood levels and these were supplemented by additional research undertaken by the Consultant.

3.2 APRIL 1988 FLOOD CALIBRATION

3.2.1 Rainfall Data

As previously determined during the Council flood study, it was confirmed that there was no recording rain gauge located within the catchment at the time of the flood which means that there is no accurate picture of the 1988 rainfall pattern within the study catchment.

It was confirmed that the nearest recording rain gauge data is from Maguires Crossing, a station which is located some three kilometres east of the catchment as shown in **Figure 3**.

The Maguires Crossing gauge data was supplied by Council and **Figure 4** plots the hourly pattern.

Similarly there were no official daily rain gauges within the catchment at the time of the flood. Additional nearby daily station data was obtained to supplement the data used in Council flood study and the spread of stations (and their corresponding rainfall totals) are also shown in **Figure 3**.

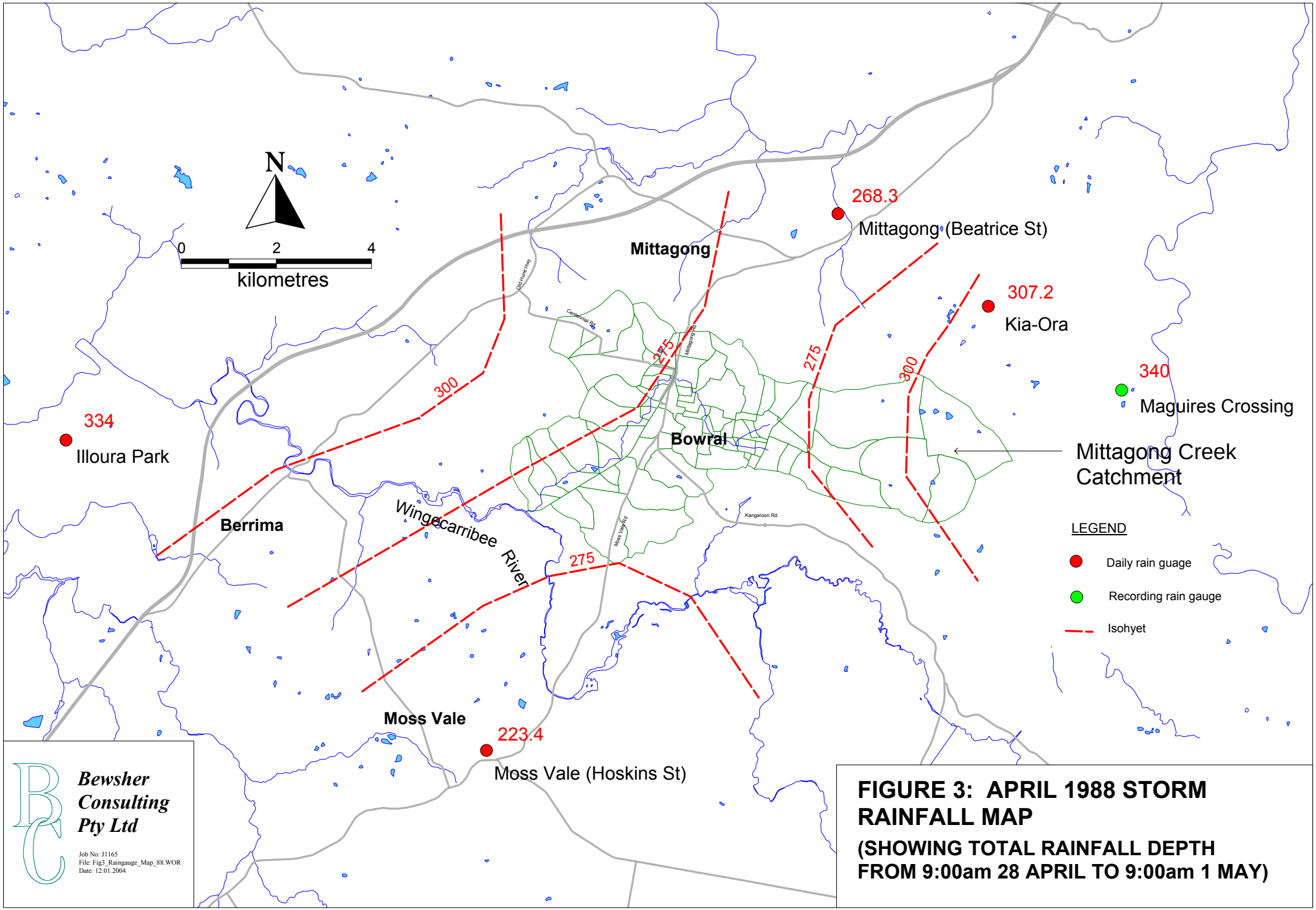

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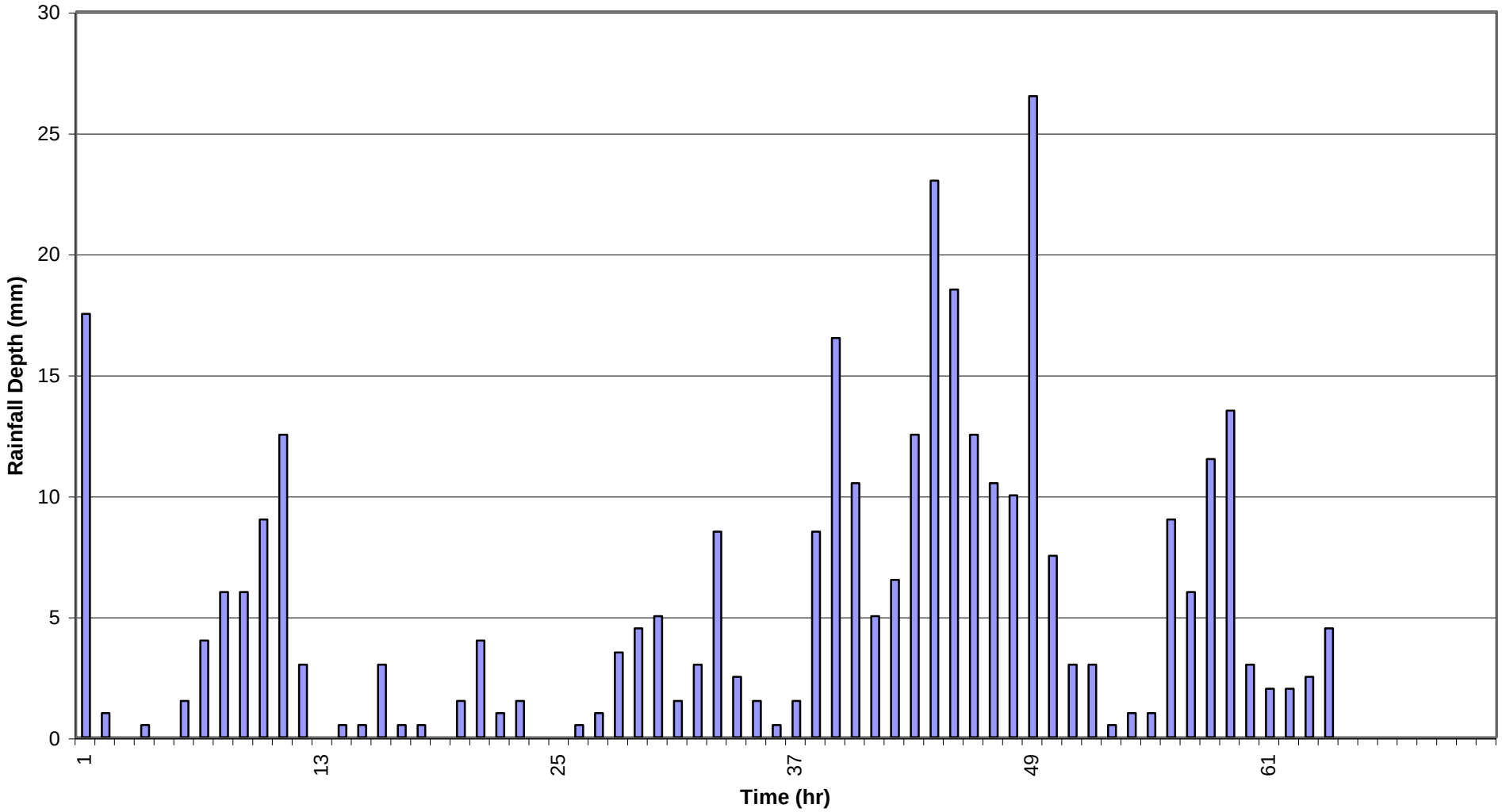
FIGURE 3: APRIL 1988 STORM RAINFALL MAP

(SHOWING TOTAL RAINFALL DEPTH FROM 9:00am 28 APRIL TO 9:00am 1 MAY)

Figure 4: Maguires Crossing April 1988 Storm Pattern (Starting at 9:00am 28 April)



3.2.2 RAFTS Modelling

The rainfall data imported into the newly extended RAFTS model consisted of:

- adoption of the Maguires Crossing temporal pattern throughout the model;
- variation of total storm rainfall throughout the model based on the isohyet pattern defined in **Figure 3;** and
- losses based on initial loss of 15 mm and continuing loss of 2.5 mm/h for pervious areas and initial loss of 0 mm and zero continuing loss for impervious areas (which are the same as those adopted previously by Council).

The calculated peak flood flows for each of the RAFTS nodes are listed in **Table 1** which also provides a comparison with several peak flows listed in the Council flood study report.

3.2.3 Flood Level Data

The Council flood study includes some flood time photographs and documents thirty eight flood levels and these are listed in **Table 2**. While this represents a substantial number of levels the list includes multiple surveyed levels at several locations so the amount of information for calibration is not as comprehensive as might be first thought.

Also, unfortunately the Council flood study report did not include precise location details for many of the surveyed flood levels.

3.2.4 TUFLOW Modelling

Since there have been a number of changes in floodplain conditions since the 1988 flood, the TUFLOW model was set up to reflect the circa 1988 conditions. That is, the 1988 flood model includes the following floodplain features which do not appear in the October 1999 flood model:

- the ‘original’ Creek channel alignment adjacent to and east of the brick quarry (that is, downstream of Kiama Street);
- the original roadway under the railway opening immediately downstream of Mittagong Road and the original Mittagong Road bridge;
- the original Kirkham Road bridge; and
- the Main Arm causeway at Old South Road.

TABLE 1: RAFTS DISCHARGES FOR 1988 AND 1999 STORMS

RAFTS Node (see Figure 1)	Peak Discharges (m^3/s)		
	1988 Storm (Council Study)[1]	1988 Storm [2]	1999 Storm [3]
1.00		8.8	8.4
2.00		6.4	5.8
2.01		15.3	14.6
2.02		17.6	16.7
1.01		35.9	34.9
20.00		2.7	2.8
1.02		38.4	37.5
3.00		2.5	2.7
1.03		39.6	38.8
4.00		1.6	1.7
1.04		40.9	40.0
5.00		5.6	5.7
5.01		6.1	6.1
1.05		45.1	44.3
1.06		45.5	44.6
6.00		3.3	5.1
6.01		6.2	7.9
6.02		7.2	9.1
6.03		8.5	10.4
7.00		0.5	0.5
6.04		9.2	10.9
8.00		0.2	0.2
6.05		9.7	11.5
1.07		53.4	54.7
9.00		3.2	3.3
10.00		1.0	0.9
1.08		54.8	56.8
1.09	57.3	55.0	57.0
11.00		1.2	1.2
12.00		3.3	3.5
1.10		57.9	58.6
13.00		1.8	1.7
1.11		59.2	59.1
1.12		62.5	61.2
1.13		63.9	62.2
14.00		0.5	0.5

RAFTS Node (see Figure 1)	Peak Discharges (m^3/s)		
	1988 Storm (Council Study)[1]	1988 Storm [2]	1999 Storm [3]
1.14		65.6	62.8
15.00		4.4	4.2
1.15	69.0	67.2	63.8
16.00		2.2	2.0
17.00		0.8	0.8
18.00		1.6	1.5
16.01		9.1	8.4
16.02		12.0	11.4
16.03		17.6	17.3
19.00		4.4	4.6
16.04		22.7	22.8
16.05		24.0	24.3
16.06		24.7	24.9
1.16		80.9	79.8
1.17		81.5	80.3
1.18		82.1	80.7
21.00		3.8	3.6
1.19		85.2	82.7
1.20		85.5	83.0
22.00		3.7	3.5
1.21		89.2	85.4
23.00		6.5	6.0
23.01		9.0	8.3
24.00		4.3	4.1
24.01		5.8	5.4
1.22	103.3	99.8	96.2
25.00		1.0	0.9
1.23		100.5	97.6
1.24		103.1	101.3
26.00		6.2	5.7
26.01		12.4	11.4
26.02		13.5	12.4
1.25		113.2	115.0
1.26		114.6	116.6
27.00		3.8	3.6
1.27		120.5	120.9

Notes

[1] 24hr duration-storm derived from 1988 storm data. Initial loss = 0mm; Continuing losses = 2.5mm/hr.

[2] Rainfall distribution over catchment estimated from a number of gauges, see Figure 3. Temporal pattern corresponds to Maguires crossing gauge data.

[3] Rainfall distribution over catchment estimated from a number of gauges, see Figure 10. Temporal pattern corresponds to Maguires crossing gauge data.

TABLE 2: APRIL 1988 FLOOD LEVELS

	Location	Recorded Level	HEC-RAS level in Council Study	Diff between Councl Study & recorded level	TUFLOW Flood Level	Diff between TUFLOW level & recorded level	Remarks
1	Upstream face of railway underpass	671.24	671.96	0.72	671.59	0.35	Reasonable fit (In Council Flood Study it was mentioned that scour ocurred at the underpass - ie a 1.5m deep and 30m scour trench formed in what was previously bitumen sealed pavement. This scour which was not reflected in the TUFLOW model may partly explain the magnitude of the difference.)
2	H.D.E. Office	671.60	672.10	0.50	671.89	0.28	Exact location of recorded flood level is uncertain.
3	Swimming pool carpark	671.80	672.23	0.43	671.92	0.12	
4	Footbridge	671.35	672.23	0.88	671.94	0.59	Reliability of recorded level is questionable given that difference is inconsistent with upstream and downstream reasonable fits.
5	100m Downstream of Victoria St	672.46	672.44	-0.02	672.53	0.07	
6	Just downstream of Victoria St	672.87	672.54	-0.33	672.76	-0.11	
7	Victoria St Bridge	672.73	673.01	0.28	672.87	0.14	
8	100m upstream of Victoria St	673.05	673.17	0.12	673.13	0.08	
9	Sunroom Floor (23 Rose St)	673.22	673.22	0.00	673.23	0.01	
10	Front gate (23 Rose St)	673.53	673.35	-0.18	673.35	-0.18	
11	Rear of house upstream of Rose Stre	673.52	673.47	-0.05	673.62	0.10	
12	Gas Co. Merrigang St	674.57	674.54	-0.03	674.53	-0.04	
13	Just Upstream of Merrigang St	674.90	674.85	-0.05	675.12	0.22	
14	50m upstream of Merrigang St	674.85	674.85	0.00	675.23	0.38	
15	Shepherd St - Springetts	675.11	675.56	0.45	675.56	0.45	Exact location of recorded flood level is uncertain.
16	Shepherd St. Bridge	675.69	675.62	-0.07	675.68	-0.01	
17	Upstream of Shepherd St	675.40	675.68	0.28	675.71	0.31	Reliability of recorded level is questionable given that difference is inconsistent with upstream and downstream reasonable fits.
18	Bradman Close	676.14	676.21	0.07	676.33	0.19	
19	Bowral St Bridge	677.35	677.62	0.27	677.50	0.15	
20	Farmborough Close	677.94	677.75	-0.19	677.99	0.05	
21	Confluence with South Arm	678.00	678.05	0.05	678.07	0.07	
22	Bowral St Culvert	679.16	679.53	0.37	679.29	0.13	
23	Bowral St Culvert (upstream)	679.33	679.77	0.44	679.54	0.21	
24	Old South Rd Causeway	686.60	686.51	-0.09	686.63	0.03	
25	Behind Tynedale Crescent	679.30	679.34	0.04	679.62	0.32	Exact location of recorded flood level is uncertain.
26	Upstream of Old South Road Culvert	680.30	680.28	-0.02	680.18	-0.12	
27	Rear of Lot 3 Kiama St	663.37	663.20	-0.17	663.02	-0.36	
28	Oxley Hill Rd	664.57	664.63	0.06	664.66	0.09	
29	Willow Rd	668.59	668.31	-0.28	668.12	-0.48	Reliability of recorded level is questionable given that difference is inconsistent with upstream and downstream reasonable fits.
30	Deans Factory	668.36	668.66	0.30	668.45	0.09	
31	Scout Hall (Small)	669.08	668.81	-0.27	669.02	-0.06	
32	Scout Hall (Main)	669.18	668.92	-0.26	669.02	-0.16	
33	Sherwood Ave	669.13	669.10	-0.03	669.10	-0.03	
34	Oxley Timber (Channel)	669.23	669.19	-0.04	669.20	-0.03	
35	Oxley Timber Gate	669.59	669.23	-0.36	669.53	-0.06	
36	Downstream Mount Rd	669.41	669.29	-0.12	669.32	-0.09	
37	Oxley Timber (Factory)	669.72	669.44	-0.28	669.50	-0.22	
38	Kirkham Rd Downstream Underpass	671.46	671.18	-0.28	671.49	0.03	

There being no reported flood level observations at the confluence with the Wingecarribee River, a simplified 1D element approach was used to approximate the Wingecarribee River flood regime at the confluence.

After choosing initial representative roughness parameters, a preliminary TUFLOW model was run and the results were compared with the surveyed flood levels. The comparison showed that there was generally good agreement with no major differences. The fact also that the model was not consistently either over-estimating or under-estimating flood levels was an indication that the hydrologic model had been satisfactory in calculating the flood flow.

A number of adjustments were subsequently made to the model — such as modifying some roughness parameters — to achieve a better fit while in some cases professional judgement was used to adjust the location of some of those surveyed flood levels whose exact locations were unknown.

Table 2 compares the revised TUFLOW levels with the historic flood levels and it can be seen that for most of the locations the difference is less than 150mm. For a number of the flood levels where the 'fit' is considered to be unsatisfactory it was determined that either the surveyed level was erroneous (based on inconsistency with nearby levels) or the location was quite uncertain and these are identified in the 'Remarks' column of the table. It is considered that overall a very good fit has been obtained.

Figures 5 to **8** define the modelled extent of inundation for the 1988 flood.

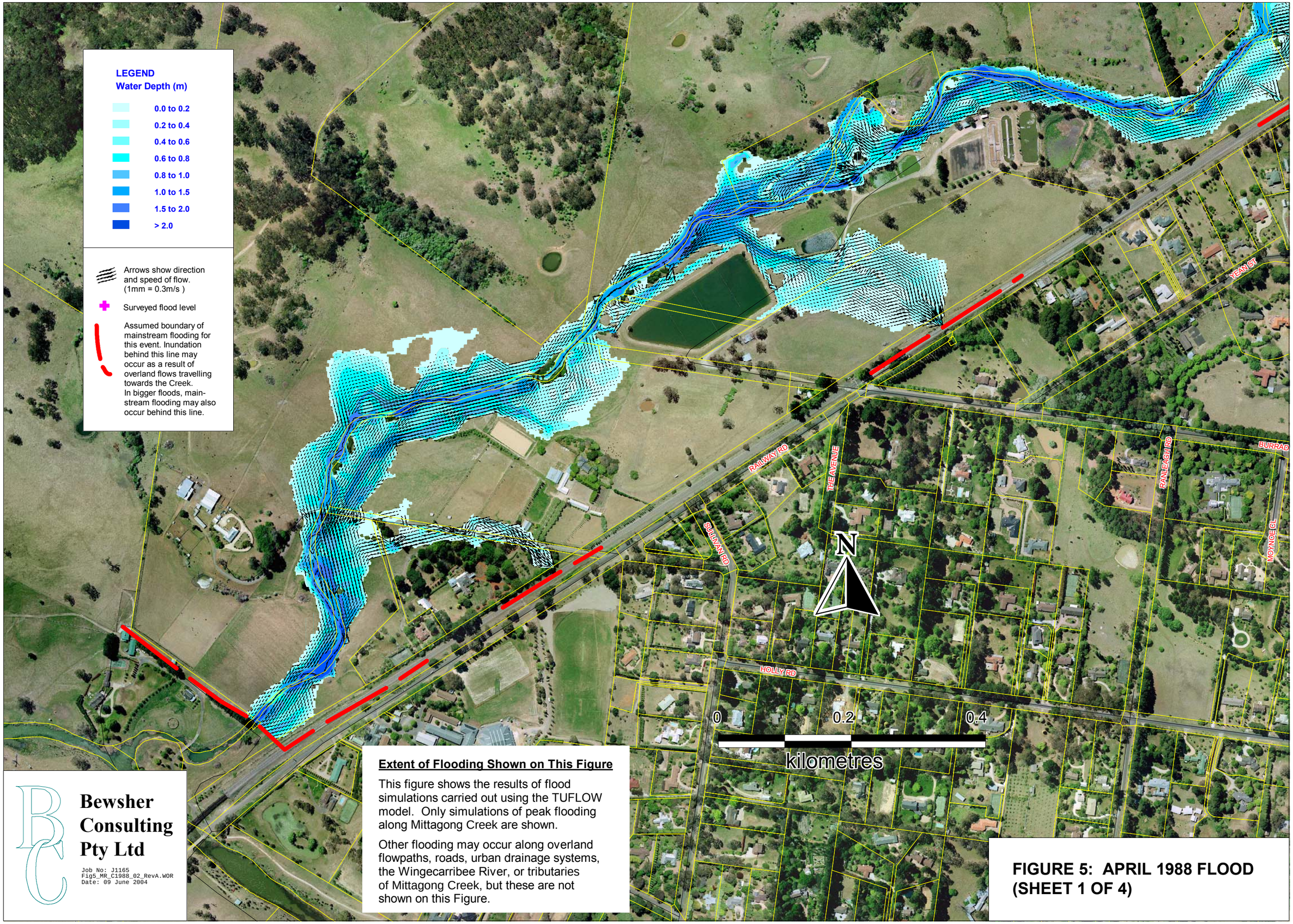
3.3 OCTOBER 1999 FLOOD CALIBRATION

3.3.1 Rainfall Data

As for the 1988 flood assessment, research was undertaken to obtain the best-available rainfall data. The research revealed that there was a recording rain gauge in the middle of the study catchment (Parry Drive), but unfortunately it did not operate during the storm. This meant that the Maguires Crossing data (which was supplied by Council) provided the closest temporal pattern.

Figure 9 plots the hourly pattern for the Maguires Crossing gauge.

Similarly there were no official daily rain gauges within the catchment at the time of the flood and the spread of stations (and their corresponding rainfall totals) are also shown in **Figure 10**.



Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along Mittagong Creek are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or tributaries of Mittagong Creek, but these are not shown on this Figure.

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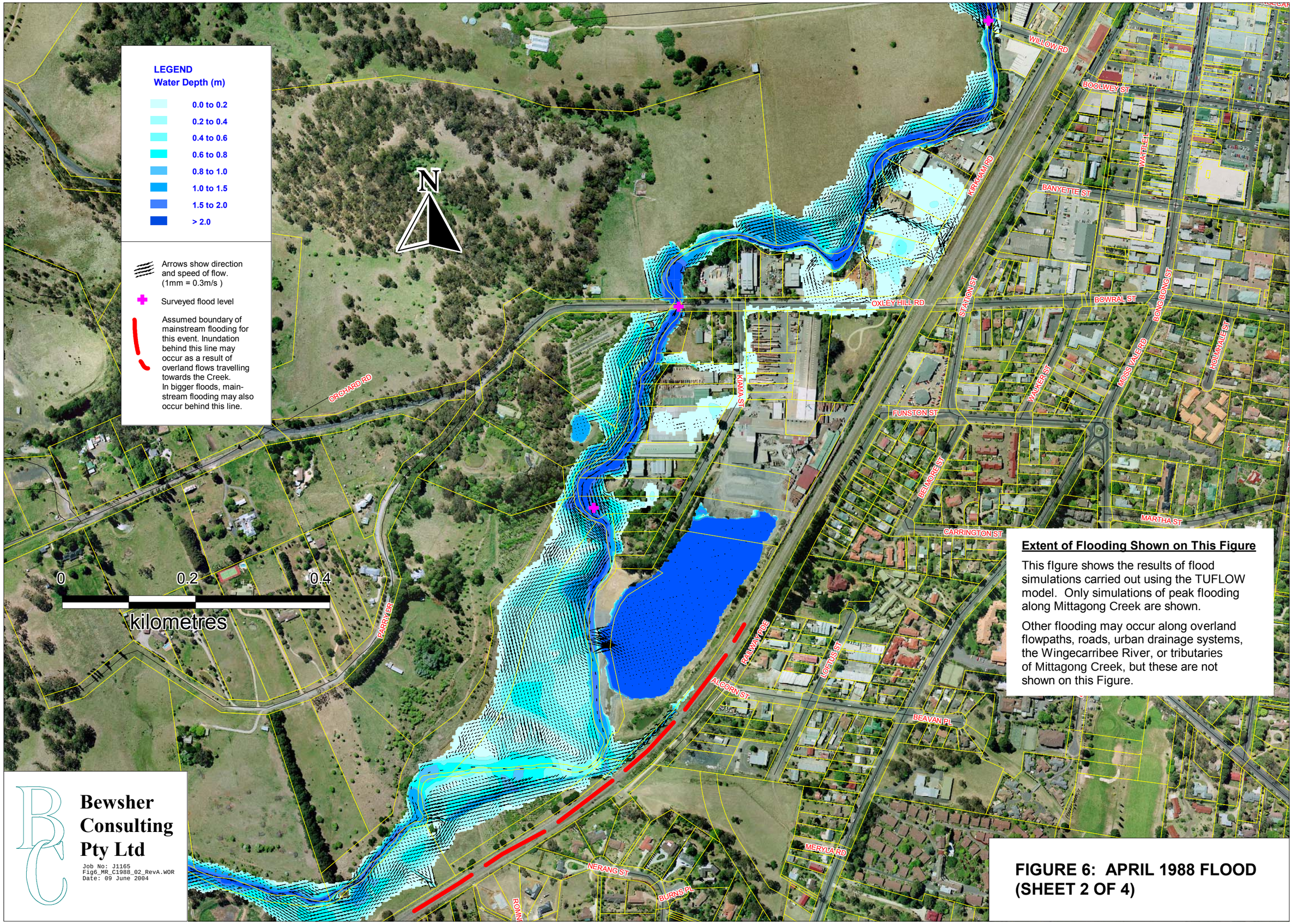
Fig5_MR_C1988_02_RevA.WOR
Date: 09 June 2004

FIGURE 5: APRIL 1988 FLOOD (SHEET 1 OF 4)



Extent of Flooding Shown on This Figure

This fIgure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along Mittagong Creek are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or tributaries of Mittagong Creek, but these are not shown on this Figure.

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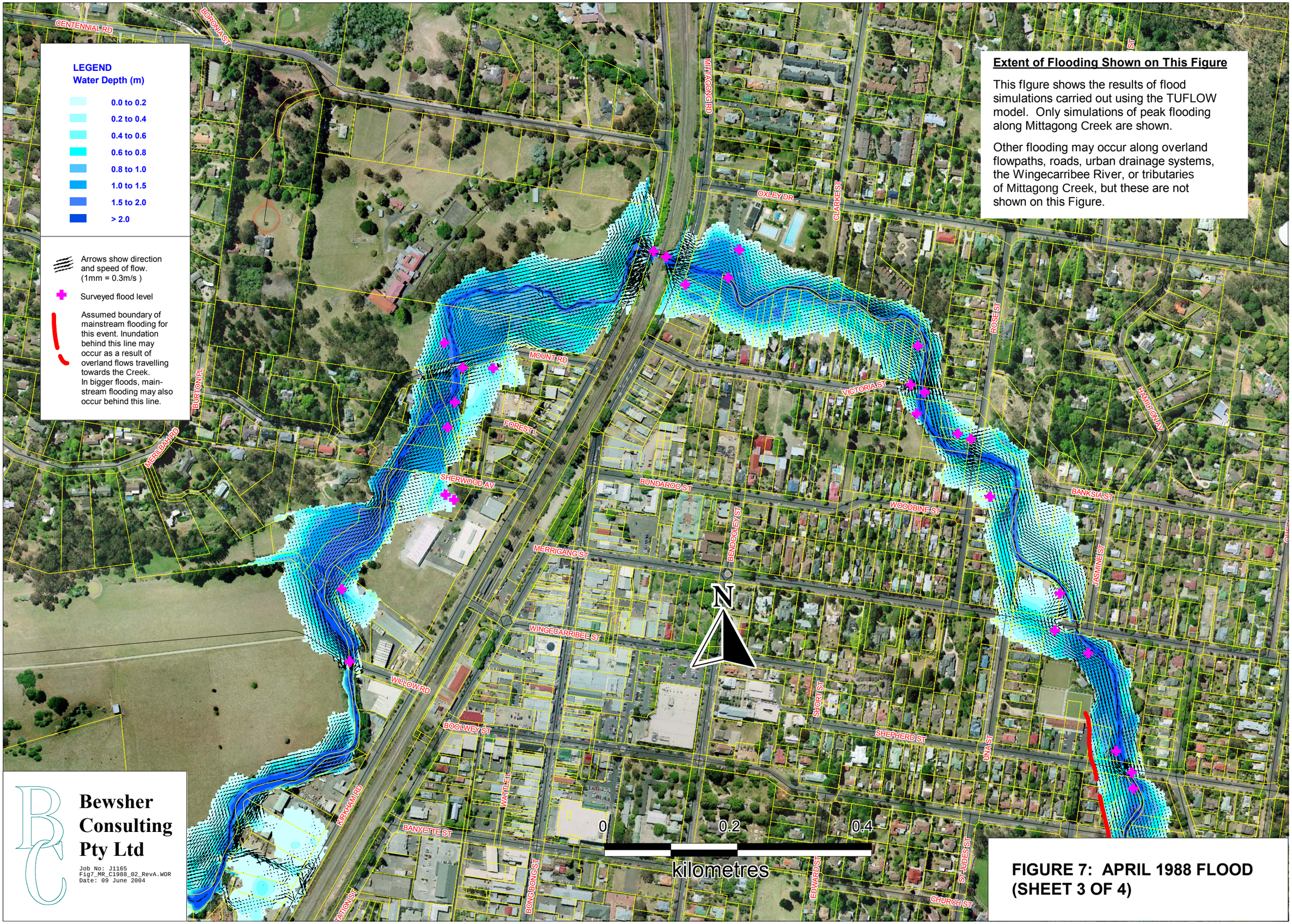
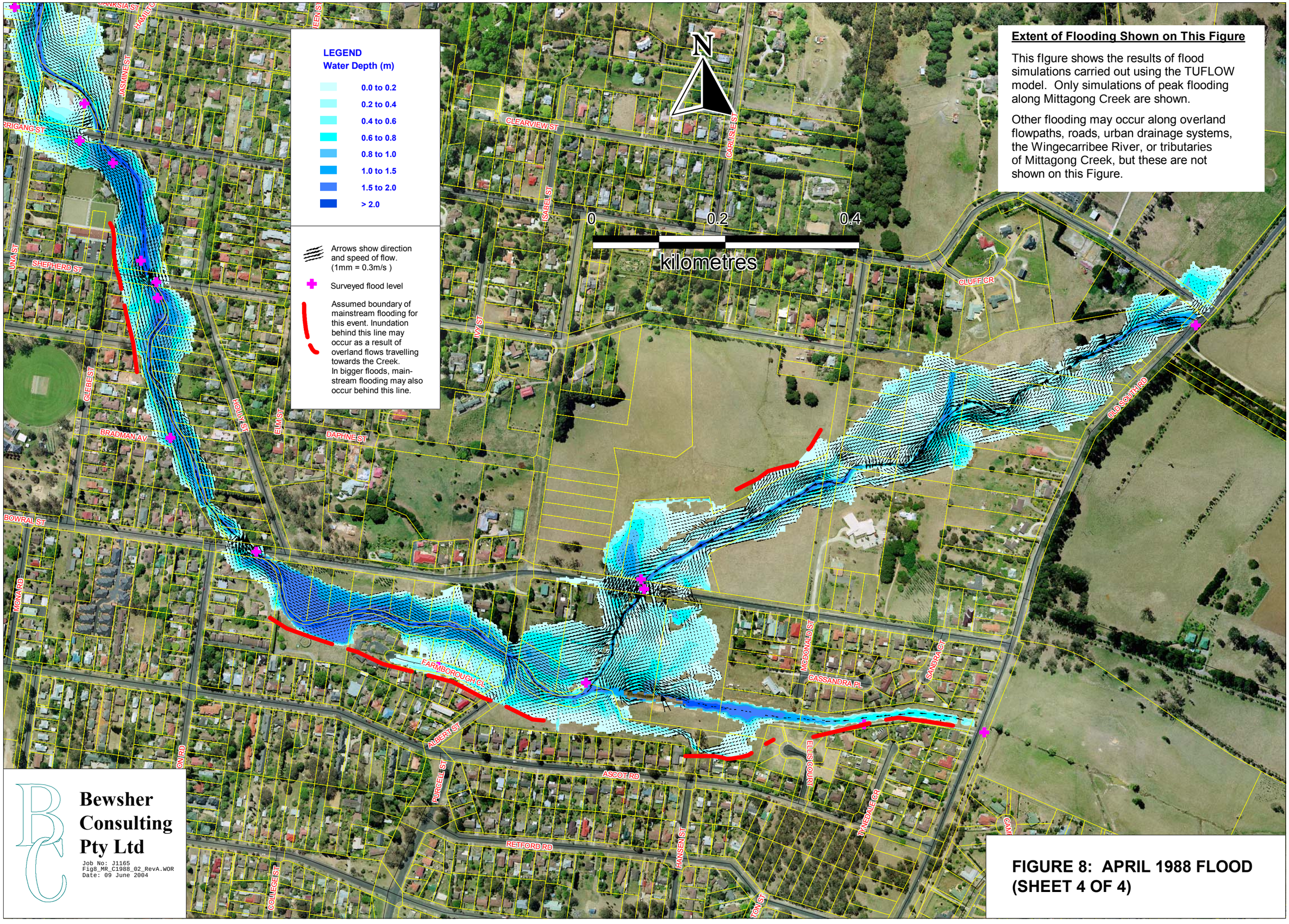
Job No: J1165
Fig6_MR_C1988_02_RevA.WOR
Date: 09 June 2004

FIGURE 6: APRIL 1988 FLOOD (SHEET 2 OF 4)


LEGEND
Water Depth (m)
0.0 to 0.2
0.2 to 0.4
0.4 to 0.6
0.6 to 0.8
0.8 to 1.0
1.0 to 1.5
1.5 to 2.0
> 2.0
Arrows show direction and speed of flow. (1mm = 0.3m/s)
Surveyed flood level
Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.
Extent of Flooding Shown on This Figure
This flgure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along Mittagong Creek are shown.
Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or tributaries of Mittagong Creek, but these are not shown on this Figure.
CENTENNIAL RD
BORONIA ST
MITTAGONG RD
OXLEY DR
CLARKE ST
ROSE ST
VICTORIA ST
HAMILTON AV
MOUNT RD
FOREST LL
BURTON PL
MERILBAH RD
SHERWOOD AV
BUNDAROO ST
WOODBINE ST
BANKSIA ST
JASMINE ST
BENDOOLEY ST
MERRICANG ST
WINGECARRIBEE ST
WILLOW RD
BOOLWEY ST
SHORT ST
SHEPHERD ST
UNA ST
WATTLE
BONGBONG ST
BANYETTE ST
KIRKHAM RD
EDWARD ST
ST JUDES ST
CHURCH ST
N
0
0.2
0.4
kilometres
Bewsher Consulting Pty Ltd
Job No: J1165
Fig7_MR_C1988_02_RevA.WOR
Date: 09 June 2004
FIGURE 7: APRIL 1988 FLOOD
(SHEET 3 OF 4)

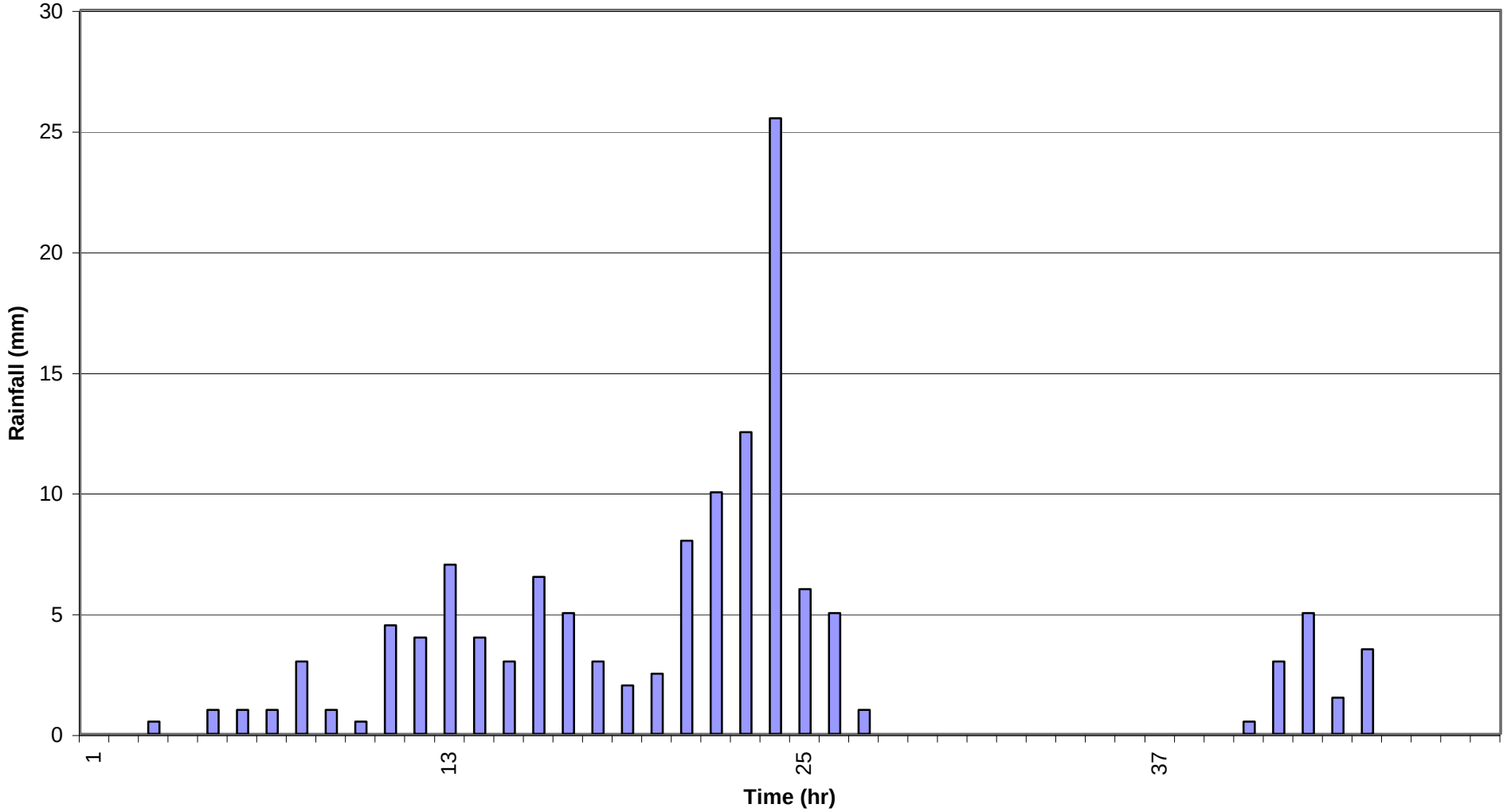


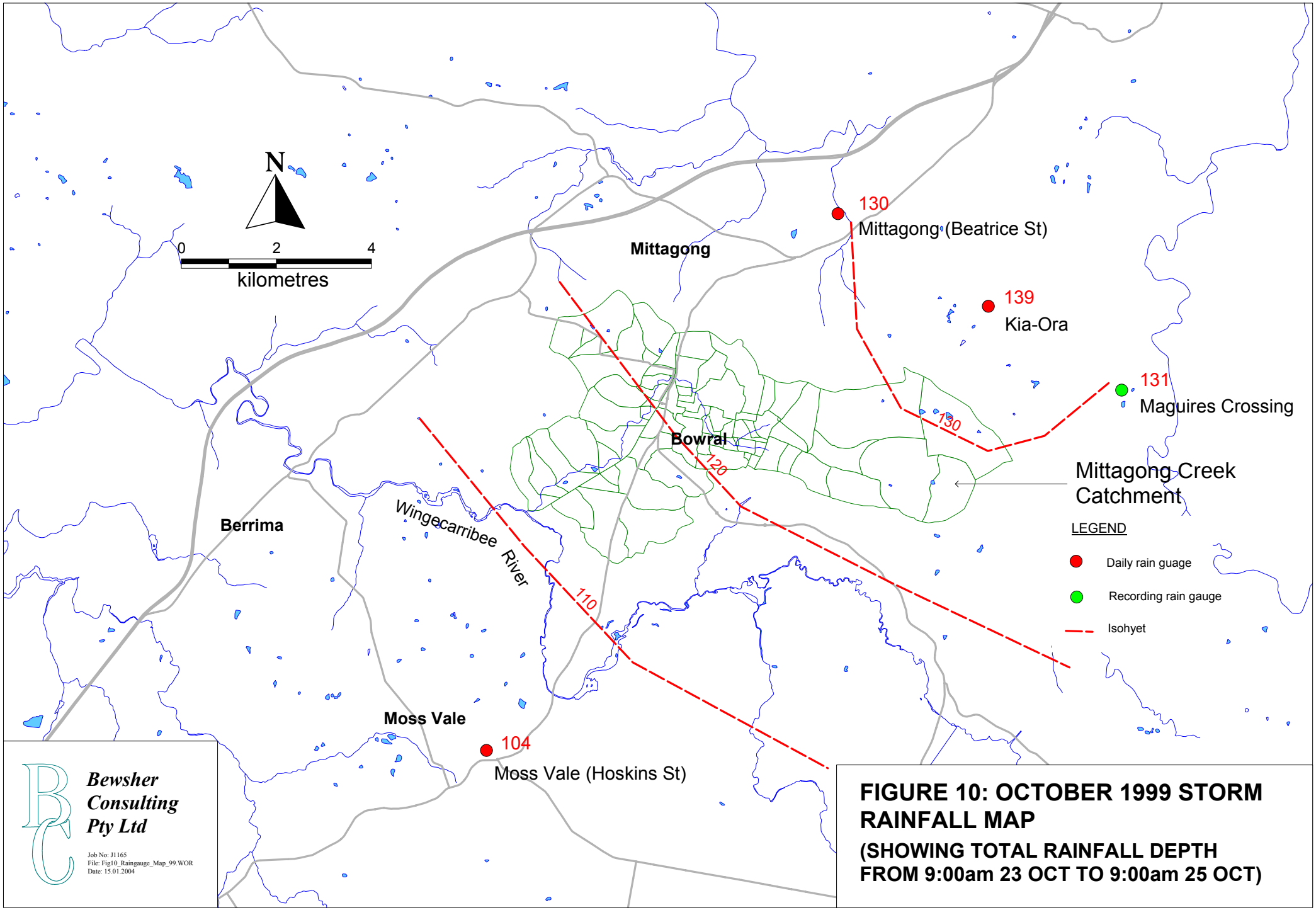
Bewsher Consulting Pty Ltd

Job No: J1165
Fig8_MR_C1988_02_RevA.WOR
Date: 09 June 2004

FIGURE 8: APRIL 1988 FLOOD (SHEET 4 OF 4)

Figure 9: Maguires Crossing October 1999 Storm Pattern (Starting at 9:00am 23 Oct)




N
0
2
4
kilometres
Mittagong
130
Mittagong (Beatrice St)
139
Kia-Ora
131
Maguires Crossing
Bowral
130
120
110
Mittagong Creek Catchment
Berrima
Wingecarribee River
Moss Vale
104
Moss Vale (Hoskins St)
LEGEND
Daily rain guage
Recording rain gauge
Isohyet
Bewsher Consulting Pty Ltd
Job No: J1165
File: Fig10_Raingauge_Map_99.WOR
Date: 15.01.2004
FIGURE 10: OCTOBER 1999 STORM RAINFALL MAP
(SHOWING TOTAL RAINFALL DEPTH FROM 9:00am 23 OCT TO 9:00am 25 OCT)

3.3.2 RAFTS Modelling

The 1999 RAFTS model was essentially the same as that developed for the 1988 event. The one change was the reflection of the amount of new development in East Bowral (that is, east of Old South Road) which was in place at the time of the flood. This adjustment, which consisted of an increase in the impervious percentages in the relevant RAFTS sub-catchments, was based on data supplied by Council.

The rainfall data imported into the RAFTS model consisted of:

- adoption of the Maguires Crossing temporal pattern throughout the model;
- variation of total storm rainfall throughout the model based on the isohyet pattern defined in **Figure 10;** and
- the same losses used in the 1988 storm model; that is, initial loss of 15 mm and continuing loss of 2.5 mm/h for pervious areas and initial loss of 0 mm and zero continuing loss for impervious areas.

The calculated peak flood flows for each of the RAFTS nodes are listed in **Table 1**.

3.3.3 Flood Level Data

Council provided a copy of the 1990 flood study's flood profile figures with the location and surveyed values of eight 1999 flood levels added. A series of flood photographs were also supplied by Council but these proved to be of less value since it was unclear whether or not they reflected conditions at the peak of the flood. An additional flood level was obtained from a resident's observation of the flood flow regime at the Bowral Street bridge.

The set of flood levels are listed in **Table 3**.

Telephone interviewing of a number of residents also provided further information about the nature of the flood flow at a number of locations.

3.3.4 TUFLOW Modelling

The October 1999 TUFLOW model includes the following floodplain features which do not appear in the April 1988 flood model:

- the realigned Creek channel west of the old brick quarry (that is, downstream of Kiama Street);
- the enlarged channel under the railway opening immediately downstream of Mittagong Road plus the new Mittagong Road bridge;

TABLE 3: OCTOBER 1999 FLOOD LEVELS

	Locations	Recorded Level	TUFLOW Flood Level	Difference	Remarks
1	Willow Rd Footbridge - Surveyed by Council on 4/11/99	667.72	668.12	0.40	Poor Fit
2	Mount St - Surveyed by Council on 4/11/99	669.71	669.50	-0.21	
3	Mittagong Rd - Surveyed by Council on 4/11/99	671.11	671.44	0.33	
4	Rose St - Surveyed by Council on 4/11/99	673.02	673.45	0.43	Recorded flood level may be unreliable. Hydrological analysis suggests that the peak flow for 1999 storm is very similar to the 1988 peak flow but the recorded flood level is significantly lower than the 1988 recorded level at a similar location. Also as noted for flood marks 5, 6 and 8 in this table, their values are also slightly higher than the comparative 1988 levels.
5	Merrigang St Bridge - Surveyed by Council on 4/11/99	674.98	675.18	0.20	Good fit. (Recorded flood level higher than that of April 1988 storm at similar location by 80mm.)
6	Bowral St Bridge - Surveyed by Council on 4/11/99	677.50	677.52	0.02	Good fit. (Recorded flood level higher than that of April 1988 storm at similar location by 150mm.)
7	Stanley Park Footbridge - Surveyed by Council on 4/11/99	677.84	677.87	0.03	
8	Bowral St Culvert - Surveyed by Council on 4/11/99	679.29	679.38	0.09	Good fit. (Recorded flood level higher than that of April 1988 storm at similar location by 130mm.)
9	Bowral St Bridge - local resident's observation documented in letter dated 25/11/02	678.23	677.93	-0.31	Considered to be a localised effect whereby flood flows are locally elevated due to pedestrian rail blockage effect - this localised regime cannot be reproduced with TUFLOW model. Noted good fit with flood mark 8 which is nearby.

- the enlarged Kirkham Road bridge;
- the Old South Road bridge on the Main Arm; and
- an illegal footbridge structure south-west of Sherwood Avenue.

There being no reported flood level observations at the confluence with the Wingecarribee River, the same simplified 1D element approach which was used to assess the 1988 flood was adopted to approximate the Wingecarribee River flood regime at the confluence.

After adjusting the circa 1988 roughness parameters to reflect mid 1990s stream clearing and associated near overbank works undertaken by Council, the TUFLOW model was run and the results were compared with the surveyed flood levels.

As with the 1988 flood modelling, the comparison showed:

- there was generally good agreement or no major difference; and
- the fact that the model was not consistently either over-estimating or under-estimating flood levels was an indication that the hydrologic model had been satisfactory in calculating the flood flow.

A number of adjustments were subsequently made to the model – such as modifying some roughness parameters and adjusting roadway crossing levels where the DEM values were found to differ from the field surveyed roadway levels – to achieve a better fit at the surveyed flood level locations.

Table 3 compares the revised TUFLOW levels with the historic flood levels and it can be seen that at six of the nine locations the difference is within +/- 250mm. For the other three locations possible explanations for the differences are provided in the 'Remarks' column of the table. It is considered that overall a good fit has been obtained.

Figures 11 to **14** define the modelled extent of inundation for the 1999 flood.

4.3 CONCLUSIONS AND COMMENTS

- As documented earlier, the combination of the RAFTS and TUFLOW models have achieved overall good fits to the surveyed April 1988 and October 1999 flood levels.
- Hydrologic modelling based on the best available rainfall data shows that the flood flows for both events are very similar. This is consistent with the data at locations where there are surveyed flood levels for both events – that is, the level differences are typically less than 200mm.

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0

Arrows show direction and speed of flow. (1mm = 0.3m/s)

Surveyed flood level

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

RAILWAY RD
THE AVENUE
YEAN ST
RANLEIGH RD
BURRAD
SULLIVAN RD
MOYNOE CL
HOLLY RD

N

0 0.2 0.4
kilometres

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along Mittagong Creek are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or tributaries of Mittagong Creek, but these are not shown on this Figure.

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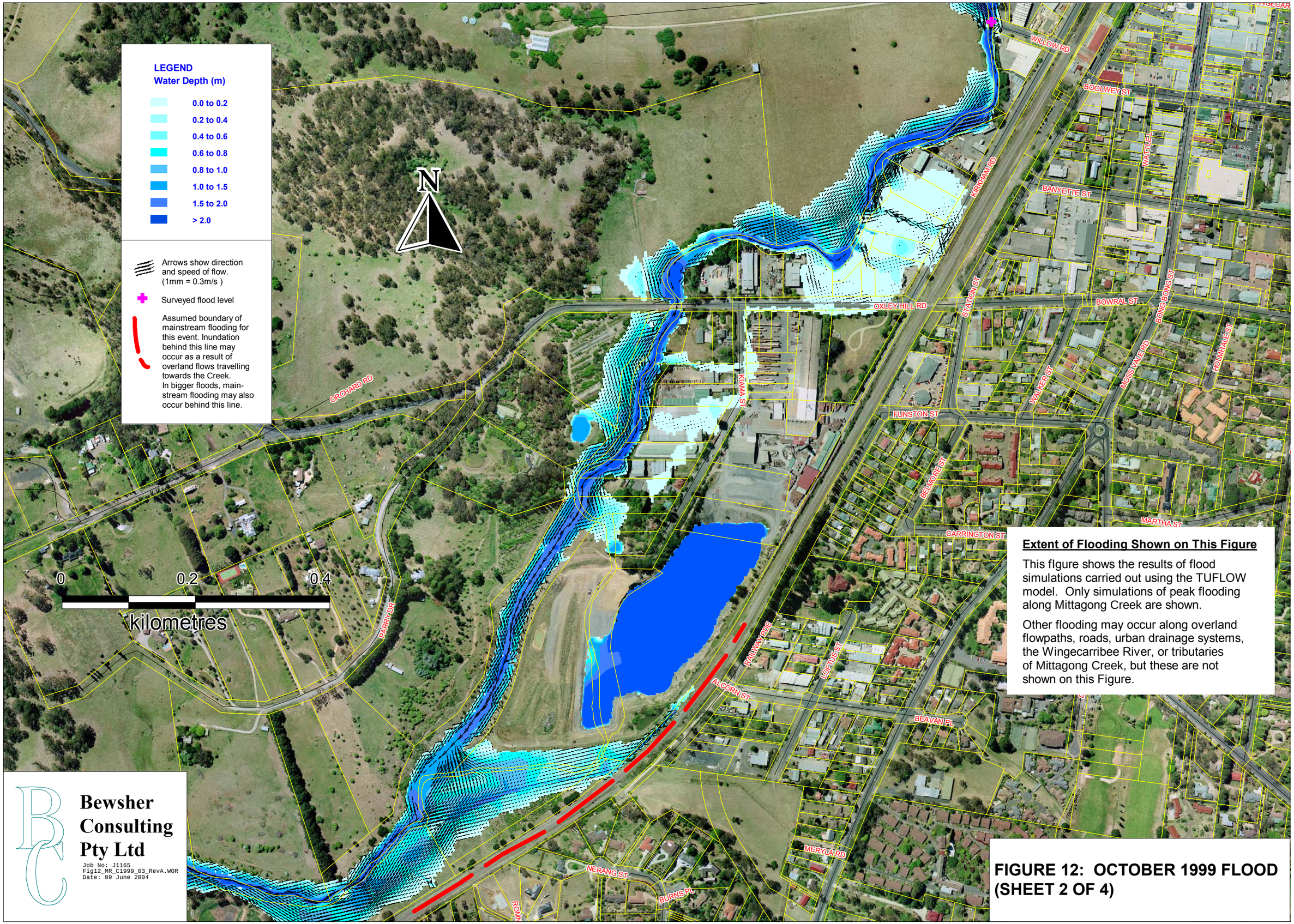
Job No: J1165
Fig11_MR_C1999_03_RevA.WOR
Date: 09 June 2004

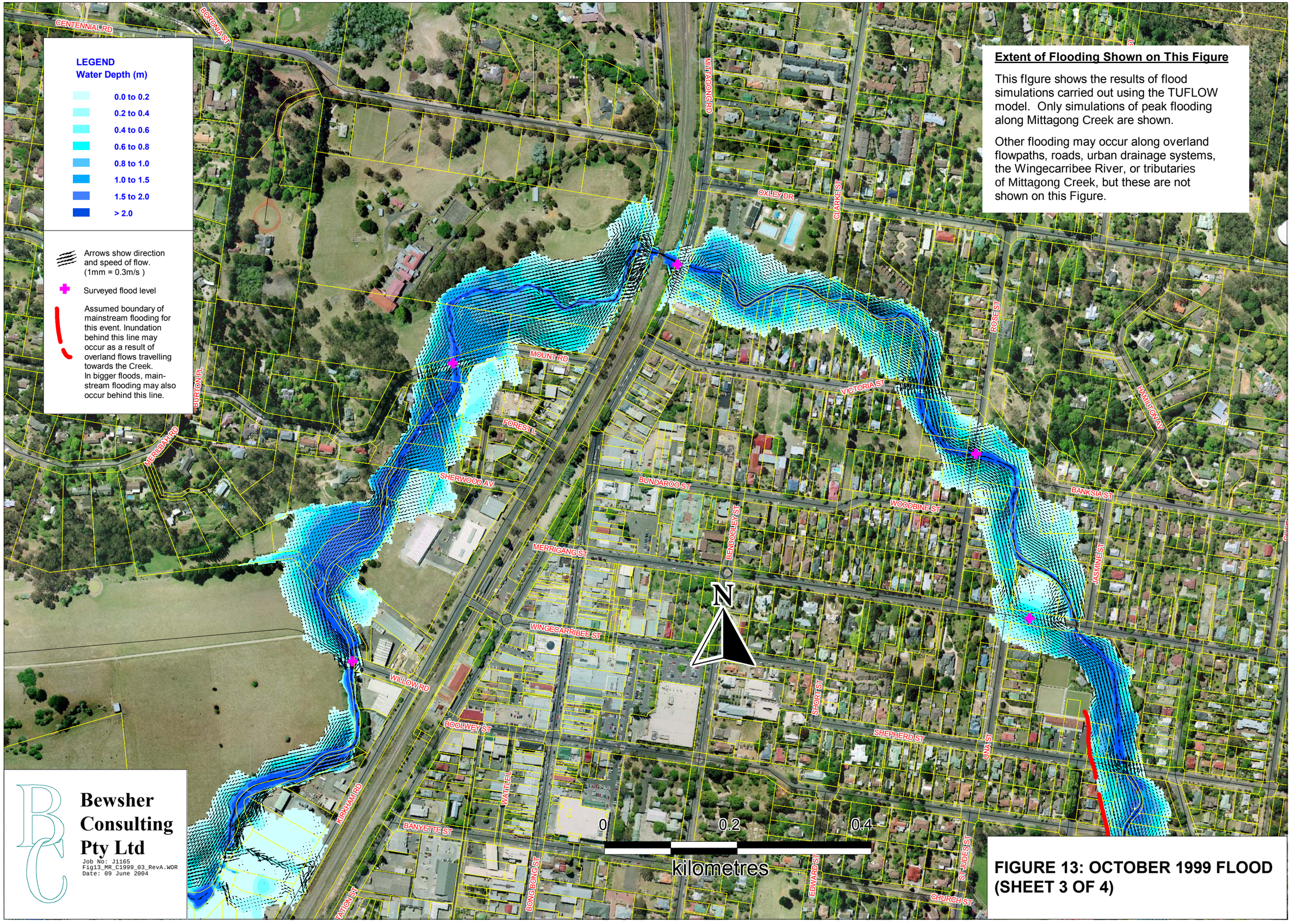
FIGURE 11: OCTOBER 1999 FLOOD (SHEET 1 OF 4)

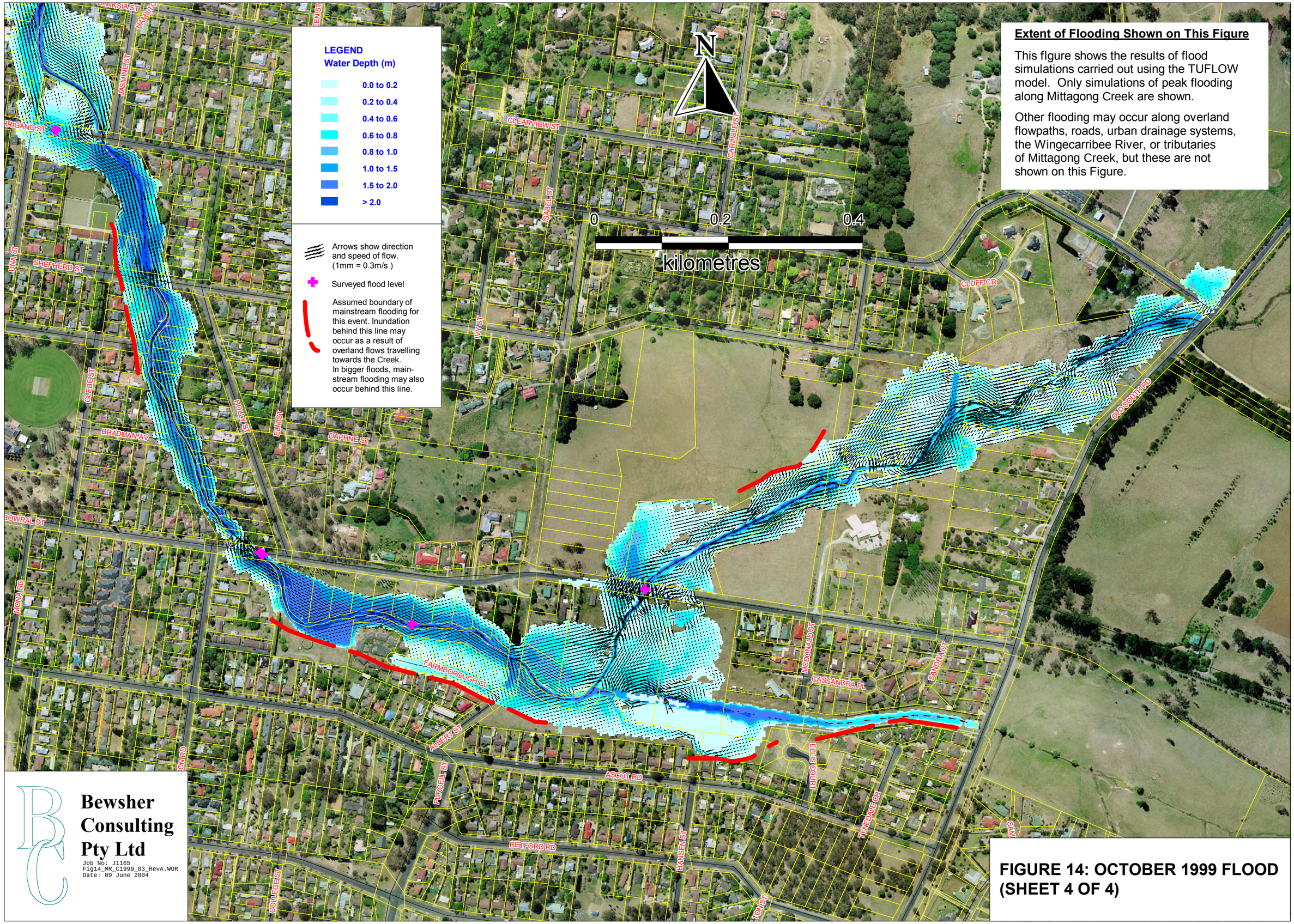


Bewsher Consulting Pty Ltd

Job No: J1165
Fig12_MR_C1999_03_RevA.WOR
Date: 09 June 2004

FIGURE 12: OCTOBER 1999 FLOOD (SHEET 2 OF 4)


LEGEND
Water Depth (m)
0.0 to 0.2
0.2 to 0.4
0.4 to 0.6
0.6 to 0.8
0.8 to 1.0
1.0 to 1.5
1.5 to 2.0
> 2.0
Arrows show direction and speed of flow. (1mm = 0.3m/s)
Surveyed flood level
Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.
Extent of Flooding Shown on This Figure
This flgure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along Mittagong Creek are shown.
Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or tributaries of Mittagong Creek, but these are not shown on this Figure.
CENTENNIAL RD
BORONIA ST
MITTAGONG RD
OXLEY DR
CLARKE ST
ROSE ST
HAMILTON AV
VICTORIA ST
MOUNT RD
FOREST L
SHERWOOD AV
BUNDAROO ST
WOODBINE ST
BANKSIA ST
JASMINE ST
BENDOOLEY ST
MERRIGANG ST
WINGECARRIBEE ST
WILLOW RD
BOOLWEY ST
SHEPHERD ST
UNA ST
SHORT ST
WATTLE L
BANYETTE ST
BONG BONG ST
EDWARD ST
ST JUDES ST
CHURCH ST
KIRKHAM RD
BURTON PL
MERILBAH RD
N
0
0.2
0.4
kilometres
Bewsher Consulting Pty Ltd
Job No: J1165
Fig13_MR_C1999_03_RevA.WOR
Date: 09 June 2004
FIGURE 13: OCTOBER 1999 FLOOD (SHEET 3 OF 4)



Bewsher Consulting Pty Ltd

Job No: J1165
Fig14_MR_C1999_03_RevA.WOR
Date: 09 June 2004

FIGURE 14: OCTOBER 1999 FLOOD (SHEET 4 OF 4)

4. DESIGN FLOOD SIMULATIONS

4.1 MAIN RAFTS MODEL

4.1.1 Update Of Model

While the RAFTS model used for modelling the calibration events had reflected existing catchment development, the design flood simulation model reflects ultimate development conditions throughout the catchment based on full development in accordance with current landuse zonings.

Table 4 lists the corresponding adopted RAFTS parameters.

4.1.2 East Bowral Flow Contributions

Development in the East Bowral release area (that is, upstream of Old South Road) is being accompanied by water quality and water quantity control basins which have been modelled using a SWMM model developed by Council.

For the best simulation of Mittagong Creek design flood events, SWMM hydrographs at Old South Road, as supplied by Council, were used to replace the corresponding RAFTS total hydrograph at the same location (which is the combination of flows from RAFTS catchments 6.0, 6.01, 6.02 & 6.03, see **Figure 2**). That is, the SWMM hydrographs were directly imported into the RAFTS model in order to develop the one catchment-wide hydrological design event model.

4.1.3 Design Storm Details

The series of design storms were developed using local area design intensity-frequency-duration data (see **Appendix D1**) and standard design storm patterns as recommended in *Australian Rainfall and Runoff*.

4.1.4 Design Flood Flows

A range of storm durations for each ARI design event were tested in the RAFTS model to establish the critical storm duration events. **Table 5** summarises the critical duration peak flows throughout the model and it shows that the Creek itself typically has a 9 hour (540 minute) critical duration while the various tributaries typically have a 90 minute or 120 minute critical storm duration.

TABLE 4: RAFTS DESIGN FLOOD MODEL PARAMETER

RAFTS	Catchment Area		Slope %		% Impervious		Pern		B		Link	Init. Loss		Cont. Loss	
Node	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.	#1	#2	#1	#2
1	206.0	0.0	2.4	0	1.8	0	0.06	0	0.478	0	1	15	0	2.5	0
2	100.0	0.0	8	0	1.8	0	0.06	0	0.18	0	2	15	0	2.5	0
2.01	183.8	11.2	3.9	3.9	5	100	0.06	0.015	0.3084	0.0027	2.001	15	0	2.5	0
2.02	56.0	0.0	1.3	0	0.3	0	0.06	0	0.3527	0	2.002	15	0	2.5	0
1.01	256.0	0.0	2.5	0	1.8	0	0.06	0	0.5244	0	1.001	15	0	2.5	0
20	23.0	0.0	3.6	0	1.8	0	0.025	0	0.0646	0	3	15	0	2.5	0
1.02	55.3	0.0	2	0	1.8	0	0.06	0	0.2642	0	1.002	15	0	2.5	0
3	31.7	3.9	7.2	7.2	5	100	0.025	0.015	0.0471	0.0011	4	15	0	2.5	0
1.03	0.3	0.1	1	1	5	100	0.025	0.015	0.0111	0.0005	1.003	15	0	2.5	0
4	17.2	1.7	11.1	11.1	5	100	0.045	0.015	0.0423	0.0006	5	15	0	2.5	0
1.04	15.0	3.6	1.2	1.2	5	100	0.025	0.015	0.0779	0.0027	1.004	15	0	2.5	0
5	76.6	15.0	7.5	7.5	5	100	0.045	0.015	0.112	0.0022	6	15	0	2.5	0
5.01	4.2	2.0	9.6	9.6	5	100	0.025	0.015	0.0143	0.0007	6.001	15	0	2.5	0
1.05	4.5	1.8	3.9	3.9	5	100	0.025	0.015	0.0231	0.001	1.005	15	0	2.5	0
1.06	10.7	4.2	3.8	3.8	5	100	0.025	0.015	0.0369	0.0016	1.006	15	0	2.5	0
6	57.2	3.5	3.4	3.4	5	100	0.025	0.015	0.0931	0.0015	7	15	0	2.5	0
6.01	41.9	6.8	1.3	1.3	5	100	0.025	0.015	0.1279	0.0035	7.001	15	0	2.5	0
6.02	13.5	3.0	1.3	1.3	5	100	0.025	0.015	0.0711	0.0023	7.002	15	0	2.5	0
6.03	20.3	4.9	1.2	1.2	5	100	0.025	0.015	0.0914	0.0031	7.003	15	0	2.5	0
7	3.4	1.6	1.8	1.8	5	100	0.025	0.015	0.0294	0.0014	8	15	0	2.5	0
6.04	3.3	2.5	0.8	0.8	5	100	0.025	0.015	0.0433	0.0027	7.004	15	0	2.5	0
8	1.4	0.7	6	6	5	100	0.025	0.015	0.0102	0.0005	9	15	0	2.5	0
6.05	6.7	3.0	0.8	0.8	5	100	0.025	0.015	0.0628	0.003	7.005	15	0	2.5	0
1.07	1.0	0.2	0.8	0.8	5	100	0.025	0.015	0.0237	0.0007	1.007	15	0	2.5	0
9	22.0	16.3	2	2	5	100	0.025	0.015	0.0739	0.0045	10	15	0	2.5	0
10	5.1	3.2	10.4	10.4	5	100	0.025	0.015	0.0151	0.0009	11	15	0	2.5	0
1.08	3.8	2.1	1	1	5	100	0.025	0.015	0.0419	0.0022	1.008	15	0	2.5	0
1.09	4.6	2.5	0.5	0.5	5	100	0.025	0.015	0.0654	0.0034	1.009	15	0	2.5	0
11	2.4	7.8	2.1	2.1	5	100	0.025	0.015	0.0227	0.003	12	15	0	2.5	0
12	28.4	15.5	1.7	1.7	5	100	0.025	0.015	0.0914	0.0048	13	15	0	2.5	0
1.1	6.5	2.4	1	1	5	100	0.025	0.015	0.0553	0.0023	1.01	15	0	2.5	0
13	6.3	8.0	6.7	6.7	5	100	0.025	0.015	0.0211	0.0017	14	15	0	2.5	0
1.11	4.7	3.9	1.2	1.2	5	100	0.025	0.015	0.0428	0.0027	1.011	15	0	2.5	0
1.12	44.7	25.6	4.2	4.2	5	100	0.025	0.015	0.0737	0.0039	1.012	15	0	2.5	0
1.13	27.2	9.3	10	10	5	100	0.025	0.015	0.0369	0.0015	1.013	15	0	2.5	0
14	2.9	2.2	1	1	5	100	0.025	0.015	0.0361	0.0023	15	15	0	2.5	0
1.14	17.2	12.4	6.4	6.4	5	100	0.025	0.015	0.0364	0.0022	1.014	15	0	2.5	0
15	33.0	8.0	14.1	14.1	5	100	0.025	0.015	0.0344	0.0012	16	15	0	2.5	0
1.15	3.4	18.4	1.3	1.3	5	100	0.025	0.015	0.0347	0.0059	1.015	15	0	2.5	0
16	35.6	0.0	5.8	0	2	0	0.06	0	0.1224	0	17	15	0	2.5	0
17	9.4	0.0	11.5	0	2	0	0.06	0	0.0435	0	18	15	0	2.5	0
18	15.1	0.9	14.3	14.3	5	100	0.045	0.015	0.0348	0.0004	19	15	0	2.5	0
16.01	72.1	9.2	5	5	5	100	0.045	0.015	0.1328	0.0021	17	15	0	2.5	0
16.02	36.5	10.0	4.7	4.7	5	100	0.025	0.015	0.0627	0.0023	17	15	0	2.5	0
16.03	61.1	12.9	5.7	5.7	5	100	0.025	0.015	0.0745	0.0024	17	15	0	2.5	0
19	52.5	0.0	5.9	0	2.3	0	0.045	0	0.1163	0	20	15	0	2.5	0
16.04	10.1	0.0	4.3	0	2	0	0.045	0	0.0586	0	17	15	0	2.5	0
16.05	13.1	2.6	4.2	4.2	5	100	0.025	0.015	0.0389	0.0012	17	15	0	2.5	0
16.06	8.7	2.6	4	4	5	100	0.025	0.015	0.0322	0.0012	17.01	15	0	2.5	0
1.16	0.1	0.0	1	1	5	100	0.025	0.015	0.0048	0.0003	1.016	15	0	2.5	0
1.17	12.7	2.1	7.4	7.4	5	100	0.025	0.015	0.0289	0.0008	1.017	15	0	2.5	0
1.18	9.4	5.9	4.7	4.7	5	100	0.025	0.015	0.031	0.0017	1.018	15	0	2.5	0
21	49.4	5.9	3.9	3.9	5	100	0.045	0.015	0.1236	0.0019	21	15	0	2.5	0
1.19	2.2	1.4	1	1	5	100	0.025	0.015	0.0316	0.0018	1.019	15	0	2.5	0
1.2	5.9	2.4	2	2	5	100	0.045	0.015	0.0569	0.0017	1.02	15	0	2.5	0
22	8.2	26.4	2.4	2.4	5	100	0.025	0.015	0.0403	0.0053	22	15	0	2.5	0
1.21	59.3	6.0	6.9	6.9	5	100	0.045	0.015	0.1022	0.0014	1.021	15	0	2.5	0
23	63.7	25.6	1.8	1.8	5	100	0.025	0.015	0.1352	0.006	23	15	0	2.5	0
23.01	11.0	22.5	1.3	1.3	5	100	0.025	0.015	0.0637	0.0066	23	15	0	2.5	0
24	50.1	17.4	2	2	5	100	0.025	0.015	0.1132	0.0047	24	15	0	2.5	0
24.01	14.5	8.6	2.6	2.6	5	100	0.025	0.015	0.0522	0.0028	24	15	0	2.5	0
1.22	35.7	16.6	6.2	6.2	5	100	0.025	0.015	0.054	0.0026	1.022	15	0	2.5	0
25	7.1	3.3	3.7	3.7	5	100	0.025	0.015	0.0301	0.0015	25	15	0	2.5	0
1.23	17.1	1.5	10	10	5	100	0.05	0.015	0.0483	0.0006	1.023	15	0	2.5	0
1.24	79.1	6.0	10	10	5	100	0.05	0.015	0.1072	0.0012	1.024	15	0	2.5	0
26	77.3	23.1	1.1	1.1	5	100	0.025	0.015	0.1912	0.0073	26	15	0	2.5	0
26.01	85.5	21.5	1.2	1.2	5	100	0.025	0.015	0.1929	0.0067	26	15	0	2.5	0
26.02	10.9	5.3	1	1	5	100	0.025	0.015	0.0723	0.0036	26	15	0	2.5	0
1.25	61.4	4.5	10	10	5	100	0.05	0.015	0.094	0.001	1.025	15	0	2.5	0
1.26	42.3	0.0	10	0	5	0	0.05	0	0.0775	0	1.026	15	0	2.5	0
27	42.0	11.9	1.7	1.7	5	100	0.025	0.015	0.1121	0.0041	27	15	0	2.5	0
1.27	57.5	0.0	8	0	5	0	0.05	0	0.1016	0	1.027	15	0	2.5	0

Note:

1 For impervious percentage less than 5%, assumed mostly rural, non-split catchment used.

2 For impervious percentage above 5%. Split-catchment is used.
For split catchment, a nominal minimum 5% impervious for pervious sub-catchment and 100% impervious for the impervious sub-catchment.

3 PERN for pervious subcatchment is 0.025 and PERN for impervious subcatchment is 0.015.
Exception is when the catchment is mostly rural and the percentage of impervious is small (say 10%), then
PERN values for pervious areas vary between 0.045 and 0.06 (as per Council RAFTS model).

TABLE 5: RAFTS DESIGN FLOOD FLOW SUMMARY

RAFTS NODES (See FIGURE 2)	ARI (Year) 5 Flow (m3/s)	5 Critical Storm Duration (min)	10 Flow (m3/s)	10 Critical Storm Duration (min)	50 Flow (m3/s)	50 Critical Storm Duration (min)	100 Flow (m3/s)	100 Critical Storm Duration (min)	PMF Flow (m3/s)	PMF Critical Storm Duration (min)
1	10.9	540	13.4	540	19.8	540	22.9	540	133.4	90
2	8.0	360	9.6	270	15.4	270	18.2	270	96.0	45
2.01	20.8	540	24.8	360	37.3	360	43.9	120	239.2	90
2.02	23.6	540	28.2	540	41.7	360	48.7	120	273.1	90
1.01	47.1	540	56.8	540	82.4	540	95.3	540	543.4	90
20	2.8	120	3.5	120	5.8	120	6.8	120	27.6	30
1.02	51.2	540	61.7	540	89.6	540	103.5	540	585.2	90
3	6.2	120	7.9	120	11.8	90	13.9	90	52.2	15
1.03	52.6	540	63.3	540	91.8	540	106.0	540	597.3	90
4	3.0	120	3.8	120	6.0	120	7.0	120	26.6	15
1.04	54.2	540	65.2	540	94.4	540	109.1	540	612.6	120
5	10.1	270	12.2	90	19.2	90	23.1	90	101.4	45
5.01	11.6	90	14.3	90	22.0	90	26.3	90	108.2	45
1.05	59.1	540	71.1	540	102.9	540	118.8	540	670.1	120
1.06	59.7	540	71.7	540	103.9	540	120.0	540	676.4	120
6.03	11.3	540	20.5	90	20.6	540	23.3	540	70.2	90
7	0.9	90	1.2	90	1.7	90	2.0	90	6.5	15
6.04	12.0	540	21.2	90	21.9	540	24.8	540	79.0	60
8	0.6	90	0.7	90	1.0	90	1.1	90	3.9	15
6.05	12.6	540	22.0	90	23.3	540	26.4	540	87.9	90
1.07	71.7	540	86.7	540	125.2	540	144.1	540	752.1	120
9	7.1	90	8.5	90	11.7	90	13.6	90	44.1	45
10	2.5	90	2.9	90	3.8	90	4.3	90	15.2	15
1.08	74.0	540	89.6	540	129.2	540	148.5	540	773.2	120
1.09	74.3	540	90.0	540	129.7	540	149.1	540	775.7	120
11	3.1	90	3.6	90	4.7	90	5.4	120	18.3	15
12	6.9	90	8.3	90	11.6	90	13.5	90	47.1	45
1.1	76.9	540	93.1	540	134.0	540	154.0	540	794.7	120
13	4.2	90	4.9	90	6.5	90	7.4	90	24.2	15
1.11	77.8	540	94.1	540	135.4	540	155.6	540	800.7	120
1.12	80.5	540	97.3	540	139.9	540	160.7	540	820.7	120
1.13	81.7	540	98.7	540	142.0	540	163.0	540	834.5	150
14	1.0	90	1.2	90	1.7	90	2.0	90	6.1	45
1.14	82.8	540	100.1	540	144.0	540	165.3	540	846.9	150
15	9.6	90	12.0	90	16.7	90	19.0	90	69.4	15
1.15	84.6	540	102.2	540	147.0	540	168.8	540	864.8	150
16	2.9	360	3.7	270	5.8	270	6.8	270	35.7	45
17	1.3	120	1.7	120	2.6	120	3.1	120	11.8	30
18	3.0	120	3.7	120	5.6	120	6.4	120	24.8	15
16.01	12.9	270	16.1	270	24.7	120	29.5	120	138.1	45
16.02	17.0	270	21.0	270	32.2	120	38.3	120	177.2	45
16.03	25.9	270	31.6	120	47.7	120	56.2	120	252.3	45
19	5.1	270	6.3	270	9.6	120	11.5	120	55.7	45
16.04	32.2	270	39.1	270	59.2	120	70.1	120	318.7	45
16.05	34.0	270	41.3	270	63.2	120	74.6	120	334.4	45
16.06	34.9	270	42.6	120	64.9	120	76.5	120	343.1	45
1.16	102.3	540	122.2	540	176.9	540	202.7	540	1010.2	150
1.17	102.9	540	122.9	540	177.8	540	203.8	540	1014.9	150
1.18	103.5	540	123.6	540	178.7	540	204.8	540	1019.1	150
21	5.0	270	6.3	270	9.6	270	11.0	270	56.7	45
1.19	106.7	540	127.2	540	183.6	540	210.3	540	1039.2	150
1.2	107.1	540	127.7	540	184.2	540	210.9	540	1041.5	150
22	10.1	90	11.7	90	15.5	90	17.5	90	61.8	15
1.21	111.2	540	132.4	540	190.6	540	218.1	540	1066.6	150
23	11.6	90	13.8	90	19.8	90	23.2	90	89.7	45
23.01	16.5	120	19.4	120	26.9	120	31.2	120	121.9	45
24	8.5	90	10.2	90	15.0	90	17.7	90	70.9	45
24.01	10.9	90	13.3	120	19.8	90	23.2	90	94.2	45
1.22	123.0	540	146.1	540	209.4	540	239.8	540	1141.0	150
25	2.2	90	2.7	90	4.0	90	4.5	90	15.3	15
1.23	124.1	540	147.7	540	211.6	540	243.4	540	1148.1	150
1.24	128.8	540	153.6	540	219.7	540	252.6	540	1168.9	150
26	10.4	90	12.1	90	17.3	90	20.0	90	87.4	45
26.01	20.5	90	24.0	90	34.5	90	40.2	90	181.7	45
26.02	21.9	90	25.8	90	37.2	90	43.3	90	196.9	45
1.25	146.1	540	173.6	540	247.2	540	283.7	540	1250.3	150
1.26	148.4	540	176.3	540	251.0	540	288.2	540	1261.4	150
27	6.1	90	7.3	90	11.0	90	12.9	90	55.7	45
1.27	154.5	540	183.3	540	261.2	540	300.2	540	1311.8	150

Note: Flow at Node 6.03 is from East Bowral SWMM Model

4.2 'BEAVAN PLACE' RAFTS MODEL

An additional RAFTS model was developed to provide a more detailed picture of flood flows in one of the tributary catchments that lies east of the railway line. The catchment is known as the Beavan Place catchment and details of the RAFTS model are presented in **Appendix D2**. As documented in **Appendix D2**, model inputs such as the rainfall intensities, rainfall losses and RAFTS model parameters are consistent with the overall Mittagong Creek catchment model.

4.3 TUFLOW MODELLING

4.3.1 Overall Floodplain and Tributary Models

Since significant flooding had been experienced in the Beavan Place tributary catchment, an additional TUFLOW model was developed to specifically examine that catchment's flood regime.

Therefore there are two TUFLOW models; the overall Mittagong Creek floodplain model which is based on the calibration models described in **Section 3** and the 'Beavan Place' tributary model.

4.3.2 Blockage of Floodplain Structures

The models include a number of culvert and bridge structures which either provide for roads crossing the floodplain or the passage of both Creek and tributary flows under the railway line. Except for the very large main railway opening which caters for Creek flows downstream of the Mittagong Road bridge, a 50% 'blockage factor' was applied to all structures. (In the TUFLOW model the blockages were modelled as follows: for bridge structures, the channel bed level was raised to a level such that the waterway area was reduced by half; for culvert structures, the width was halved for rectangular culverts and for circular culverts the modelled diameter size was reduced to 71% of actual size.)

Blockage associated with flood-borne debris collecting against bridge and culvert hand rails and vehicular crash barriers was also reflected in the design flood runs. 100% blockage was assumed for the full height and width of all such structures.

The Beavan Place model explicitly modelled the trunk stormwater pipe between Beavan Place and the railway and this was also modelled with the pipe system having a 50% blockage factor.

4.3.3 Wingecarribee River Flood Levels

The hydraulic model developed for the Berrima Flood Study was extended upstream using several approximated cross sections to provide an estimate of Wingecarribee River flood levels at the confluence with Mittagong Creek. **Table 6** tabulates the resultant Wingecarribee River flood levels which formed the downstream boundary condition for the Mittagong Creek TUFLOW model.

TABLE 6: Estimated Wingecarribee River Flood Levels

ARI	Flood Level (m AHD)
5	651.6
10	652.7
50	655.0
100	656.0
PMF	662.5

4.3.4 Design Flood Levels

Initial 100 year TUFLOW modelling of the overall floodplain was undertaken using the 2 hour and 9 hour storm RAFTS hydrographs. These runs confirmed that while the 9 hour model produced the highest flood levels along the Creek floodplain, the same duration flood levels along the lower reaches of the various tributaries were very similar to the 2 hour flood levels. That is, the 9 hour storm model effectively represented the critical duration storm throughout the overall floodplain.

For the Beavan Place catchment the critical storm duration was confirmed to be 2 hours and therefore its design flood regime is based on coincident 2 hour events in both the overall catchment and the tributary catchment.

The 5 year, 10 year, 50 year and 100 year design flood extents of inundation are presented in **Figures 15** to **18** and the probable maximum flood (PMF) extent of inundation is presented in **Figure 19**.

Electronic copies of the detailed model outputs were also supplied to Council for incorporation into its GIS system.

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

Bewsher Consulting Pty Ltd

J1165
Fig15_MRBP_5y_50B_01.WOR
1 Nov 2004

FIGURE 15:
5 YEAR DESIGN FLOOD

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

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J1165
Fig16_MRBP_10y_50B_01.WOR
1 Nov 2004

FIGURE 16:
10 YEAR DESIGN FLOOD

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

Bewsher Consulting Pty Ltd

J1165
Fig17_MRBP_50y_50B_01.WOR
1 Nov 2004

FIGURE 17:
50 YEAR DESIGN FLOOD

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

Bewsher Consulting Pty Ltd

J1165
Fig18_MRBP_100y_50B_01.WOR
1 Nov 2004

FIGURE 18:
100 YEAR DESIGN FLOOD

LEGEND
Water Depth (m)

- 0.0 to 0.2
- 0.2 to 0.4
- 0.4 to 0.6
- 0.6 to 0.8
- 0.8 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- > 2.0
- 16.2 Flood Contour (mAHD)

Assumed boundary of mainstream flooding for this event. Inundation behind this line may occur as a result of overland flows travelling towards the Creek. In bigger floods, main-stream flooding may also occur behind this line.

Extent of Flooding Shown on This Figure

This figure shows the results of flood simulations carried out using the TUFLOW model. Only simulations of peak flooding along the Mittagong Creek and Beavan Place catchment are shown.

Other flooding may occur along overland flowpaths, roads, urban drainage systems, the Wingecarribee River, or other tributaries of Mittagong Creek, but these are not shown on this Figure.

NORTH

0 400 800
metres

Bewsher Consulting Pty Ltd

J1165
MR_PMF_50B_01_A3.WOR
1 Nov 2004

FIGURE 19:
PMF DESIGN FLOOD

5. REFERENCES

1. Wingecarribee Shire Council Engineering Department. (1990). *Mittagong Rivulet Flood Study*.

2. NSW Department of Public Works and Services, Dams and Civil Section. (2002). *Mittagong Rivulet (Creek) Flood Study Extended Model covering Sewage Treatment Plant Site*. Commissioned by Wingecarribee Shire Council and the Department of Land and Water Conservation. Report No. DC 01187(Revision A). February.

3. Bewsher Consulting Pty. Ltd. (November 2000). *Berrima Flood Study (Revised)*. Report prepared for Wingecarribee Shire Council.

4. Bewsher Consulting Pty. Ltd. (February 2002). *Berrima Floodplain Risk Management Study and Plan.* Final Report. Report prepared for Wingecarribee Shire Council.

APPENDIX D1

DESIGN RAINFALL INTENSITY–FREQUENCY–DURATION DATA

" RARE " - Rainfall & Runoff Estimation Program

INTENSITY - FREQUENCY - DURATION TABLE

(Results in mm/hour)

FILE REFERENCE: wbt31

Values Used:

2 year I 1 hr : 33.20
I 12 hr : 7.00
I 72 hr : 2.60

50 year I 1 hr : 66.00
I 12 hr : 15.50
I 72 hr : 4.70

Co-efficient G : 0.03
F2 : 4.28
F50 : 15.75

	AVERAGE RECURRENCE INTERVAL (ARI) years								
TIME	1	2	5	10	20	50	100	200	500
5 mins	82.8	107	137	154	178	209	232	256	288
6 mins	77.6	99.9	128	145	167	196	218	240	270
7 mins	73.3	94.4	121	137	158	185	206	227	256
8 mins	69.6	89.6	115	130	150	176	196	216	243
9 mins	66.3	85.5	110	124	143	168	187	206	232
10 mins	63.5	81.8	105	119	137	161	179	198	223
12 mins	58.7	75.7	97.4	110	127	149	166	183	207
14 mins	54.8	70.7	91.0	103	119	139	155	171	193
15 mins	53.1	68.5	88.2	99.8	115	135	151	166	187
16 mins	51.5	66.4	85.6	96.9	112	131	146	161	182
18 mins	48.7	62.8	81.0	91.7	106	124	138	153	172
20 mins	46.3	59.7	77.0	87.1	101	118	132	145	164
25 mins	41.4	53.4	68.9	78.0	90.1	106	118	130	147
30 mins	37.6	48.6	62.8	71.1	82.1	96.6	108	119	134
40 mins	32.2	41.6	53.8	61.0	70.5	83.0	92.6	102	116
50 mins	28.4	36.7	47.6	54.0	62.4	73.5	82.0	90.7	102
1 hour	25.6	33.1	43.0	48.7	56.4	66.4	74.1	82.0	92.6
1.5 hours	20.0	25.9	33.8	38.5	44.6	52.8	59.0	65.4	74.1
2 hours	16.7	21.6	28.4	32.4	37.7	44.7	50.0	55.6	63.1
3 hours	12.9	16.8	22.1	25.4	29.6	35.2	39.6	44.0	50.1
4.5 hours	9.9	13.0	17.3	19.9	23.2	27.7	31.2	34.8	39.7
6 hours	8.3	10.8	14.5	16.7	19.6	23.4	26.4	29.5	33.7
9 hours	6.4	8.4	11.3	13.1	15.4	18.5	20.9	23.4	26.8
12 hours	5.3	7.0	9.5	11.0	13.0	15.6	17.7	19.8	22.8
15 hours	4.8	6.2	8.4	9.7	11.3	13.6	15.3	17.1	19.6
18 hours	4.3	5.7	7.5	8.7	10.1	12.1	13.6	15.2	17.3
24 hours	3.7	4.9	6.4	7.3	8.5	10.1	11.3	12.6	14.3
30 hours	3.3	4.3	5.6	6.4	7.4	8.7	9.8	10.8	12.2
36 hours	3.0	3.9	5.0	5.7	6.6	7.7	8.6	9.5	10.8
48 hours	2.6	3.3	4.2	4.7	5.4	6.4	7.1	7.8	8.7
72 hours	2.0	2.6	3.2	3.6	4.1	4.7	5.2	5.7	6.3

APPENDIX D2

‘BEAVAN PLACE’ CATCHMENT MODELLING

'BEAVAN PLACE' CATCHMENT MODELLING

D2-1. RAFTS MODEL

Figure D2-1 defines the sub-catchments of the separate RAFTS model generated for the 'Beavan Place' tributary of the Mittagong Creek catchment. (It represents a refinement of subcatchments 23.00 and 23.01 in the overall RAFTS model, see **Figure 2**).

The model reflects 'ultimate conditions' in the catchment and the adopted RAFTS parameters (as listed in **Table D2-1**), design rainfall intensities and initial and continuing losses are consistent with those adopted for the overall catchment.

Table D2-2 which lists the flows for the tested range of storm durations for each design event also shows that the critical storm duration is mostly two hours (and 45 minutes for the PMF event).

The RAFTS model was then adjusted to assess the potential impacts associated with an increasing trend to develop 'SEPP5' projects throughout the tributary. This was done by making an adjustment to the imperviousness percentage of those sub-catchments where SEPP5 projects were currently being contemplated – that is, an arbitrary increase of 300% of 'current' SEPP5 projects was assumed and the overall sub-catchment percentages were adjusted to suit (based on 80% imperviousness for the SEPP5 sites), see **Table D2-1**. **Table D2-3** documents the resultant 'SEPP5' 100 year peak flows and the corresponding percentage increases relative to the base case design model (ref **Table D2-2**).

D2-2. COMPARISON WITH EARLIER FLOW ESTIMATES

The design model produces a peak 100 year flow at Moss Vale Road of 30.9 m^3/s which is somewhat larger than an earlier Patterson Britton (2003) RAFTS model's value of 22.6m^3/s. Also compared with others estimates (Council's & GF Murphy & Associates') of 100 year peak flow at the golf course western boundary, the peak flow is slightly larger while the Paterson Britton flow is slightly smaller.

It is unclear as to why the two RAFTS models produce a relatively large difference in peak flow but it is probably a combination of the following factors:

1. the Bewsher Consulting total catchment area of 94.3ha is larger (but by only 0.3ha),
2. the Bewsher Consulting impervious area is 29.7ha (which is larger by 2.5ha),
3. the Bewsher Consulting design rainfall intensities are slightly larger,
4. the rainfall loss rates vary slightly,
5. the Bewsher Consulting 'PERN" values are slightly smaller,
6. while both models have adopted a 'split subcatchment' approach, Patterson Britton adopted a different approach in defining the characteristics for each split subcatchment.

D2-3. TUFLOW MODEL

This TUFLOW model incorporates a portion of the Mittagong Creek floodplain and also extends east from the railway embankment across Moss Vale Road, through Beavan Place, to the western boundary of the Bowral Golf Course. It also covers the two tributary depressions to the north and south of the main tributary depression, as shown in **Figures 15** to **19**. The only stormwater pipe system included in the model is the trunk system between Beavan Place and the Railway.

The survey data inputs for the TUFLOW model consist of a combination of:

< the same Digital Elevation Model (DEM) that was used for the Mittagong Creek floodplain model (but with the 'grid' reduced from 5 metres to 2.5 metres)

< Council-supplied details of the trunk stormwater pipe system between Beavan Place and the Railway,

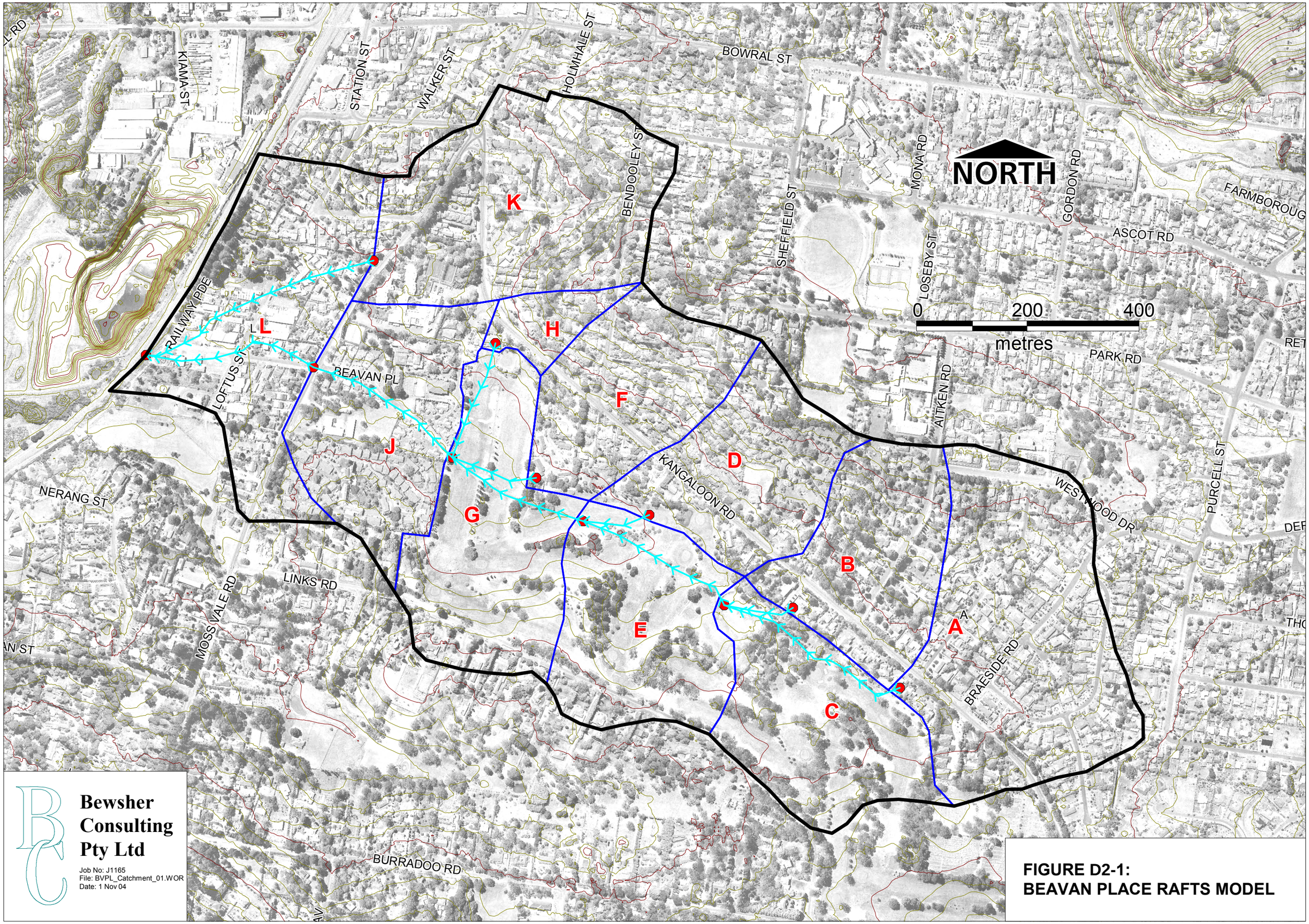
< design plan ground levels for the re-development of No. 500 Moss Vale Road (which lies just south of Beavan Place), and

< as-available miscellaneous ground level data and contour mapping.

The model was tested with a range of local catchment storm durations and the results confirmed that the two hour storm event was the 'critical' storm duration. The extents of inundation presented in **Figures 15** to **18** for the Beavan Place catchment correspond to the local catchment TUFLOW results for the condition of coincident two hour design storms over the local and overall catchments (and coincident 45 minute PMF design storms in **Figure 19**).

D2-4. REFERENCES

Patterson Britton & Partners (March 2003) *Mirvac Homes Residential Development Bowral Flood Impact Assessment.* Issue No. 2 (No. 500 Moss Vale Road).



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File: BVPL_Catchment_01.WOR
Date: 1 Nov 04

FIGURE D2-1:
BEAVAN PLACE RAFTS MODEL

TABLE D2-1: BEAVAN PLACE RAFTS MODEL PARAMETERS

ULTIMATE CATCHMENT

RAFTS	Catchment Area (ha)		Slope (%)		% Impervious		Pern		B Value		Initial Loss (mm)		Continuous Loss (mm/h)		Link
Node	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	Lag Time
A	10.9	7.7	2.4	2.4	5	100	0.025	0.015	0.0469	0.0028	15	0	2.5	0	3
B	6.1	3.5	4.8	4.8	5	100	0.025	0.015	0.0245	0.0013	15	0	2.5	0	1
C	10.6	0.0	1.7	0.0	3.3	0	0.025	0.000	0.0588	0.0000	15	0	2.5	0	2.5
D	6.7	2.8	5.6	5.6	5	100	0.025	0.015	0.0238	0.0011	15	0	2.5	0	1
E	10.8	0.0	2.2	0.0	5	0	0.025	0.000	0.0486	0.0000	15	0	2.5	0	2
F	6.0	3.3	4.3	4.3	6.5	100	0.025	0.015	0.0241	0.0013	15	0	2.5	0	1.5
H	1.1	1.1	8.8	8.8	5	100	0.025	0.015	0.0074	0.0005	15	0	2.5	0	2
G	12.3	0.0	2.6	0.0	7.4	0	0.025	0.000	0.0436	0.0000	15	0	2.5	0	2.5
J	3.7	7.7	3.1	3.1	5	100	0.025	0.015	0.0235	0.0024	15	0	2.5	0	2.5
K	5.0	11.1	2.6	2.6	5	100	0.025	0.015	0.0300	0.0032	15	0	2.5	0	3.5
L	3.3	12.0	1.0	1.0	5	100	0.025	0.015	0.0385	0.0054	15	0	2.5	0	0

'SEPP5' CONDITIONS

RAFTS	Catchment Area (ha)		Slope (%)		% Impervious		Pern		B Value		Initial Loss (mm)		Continuous Loss (mm/h)		Link
Node	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	Lag Time
A	9.0	9.6	2.4	2.4	5	100	0.025	0.015	0.0424	0.0031	15	0	2.5	0	3
B	4.7	4.9	4.8	4.8	5	100	0.025	0.015	0.0214	0.0016	15	0	2.5	0	1
C	10.6	0.0	1.7	0.0	3.3	0	0.025	0.000	0.0588	0.0000	15	0	2.5	0	2.5
D	5.3	4.2	5.6	5.6	5	100	0.025	0.015	0.0211	0.0013	15	0	2.5	0	1
E	10.8	0.0	2.2	0.0	5	0	0.025	0.000	0.0486	0.0000	15	0	2.5	0	2
F	3.9	5.4	4.3	4.3	6.5	100	0.025	0.015	0.0193	0.0017	15	0	2.5	0	1.5
H	0.5	1.7	8.8	8.8	5	100	0.025	0.015	0.0049	0.0007	15	0	2.5	0	2
G	12.3	0.0	2.6	0.0	7.4	0	0.025	0.000	0.0436	0.0000	15	0	2.5	0	2.5
J	3.7	7.7	3.1	3.1	5	100	0.025	0.015	0.0235	0.0024	15	0	2.5	0	2.5
K	4.8	11.3	2.6	2.6	5	100	0.025	0.015	0.0293	0.0033	15	0	2.5	0	3.5
L	3.3	12.0	1.0	1.0	5	100	0.025	0.015	0.0385	0.0054	15	0	2.5	0	0

TABLE D2-2: BEAVAN PLACE RAFTS DESIGN FLOOD FLOWS (m^3/s)

ARI = 100

RAFTS	Duration (min)										Max
Node	30	60	90	120	180	270	360	540	720	1080	
A	5.6	6.3	**7.4**	6.6	4.9	4.3	3.7	3.3	3.3	2.3	7.4
B	3.4	4.1	**4.4**	3.9	2.9	2.5	1.9	1.7	1.8	1.2	4.4
C	9.6	11.5	**13.3**	12.7	9.2	8.9	7.5	6.7	6.8	4.8	13.3
D	3.4	4.0	**4.3**	3.9	2.9	2.5	1.9	1.7	1.7	1.2	4.3
E	14.1	17.4	19.7	**19.8**	13.8	13.5	11.3	10.0	10.4	7.2	19.8
F	3.3	4.0	**4.3**	3.8	2.8	2.4	1.9	1.7	1.7	1.2	4.3
H	1.1	1.1	**1.2**	1.1	0.7	0.6	0.5	0.4	0.4	0.3	1.2
G	19.8	24.6	26.4	**28.5**	19.3	19.2	16.1	14.2	14.7	10.1	28.5
J	22.4	27.4	28.7	**30.9**	21.3	21.4	17.9	16.0	16.8	11.5	30.9
K	6.9	7.3	**8.2**	8.0	4.7	4.3	3.3	2.9	3.0	2.0	8.2
L	28.7	34.3	34.8	**38.5**	26.1	27.8	23.5	20.9	22.4	15.6	38.5

ARI = 50

RAFTS	Duration (min)										Max
Node	30	60	90	120	180	270	360	540	720	1080	
A	4.8	5.4	**6.4**	5.6	4.2	3.8	3.3	2.9	2.9	2.1	6.4
B	2.9	3.5	**3.9**	3.4	2.5	2.2	1.7	1.5	1.5	1.1	3.9
C	8.1	9.7	**11.5**	10.9	7.9	7.8	6.6	5.8	6.0	4.2	11.5
D	2.8	3.5	**3.8**	3.4	2.6	2.2	1.7	1.5	1.5	1.0	3.8
E	11.7	14.7	16.9	**17.1**	11.7	11.7	9.9	8.8	9.1	6.4	17.1
F	2.8	3.4	**3.8**	3.3	2.5	2.1	1.7	1.5	1.5	1.0	3.8
H	1.0	1.0	**1.1**	1.0	0.6	0.5	0.4	0.4	0.4	0.3	1.1
G	16.4	21.0	22.8	**24.4**	16.6	16.7	14.1	12.5	12.9	8.9	24.4
J	18.8	23.5	24.9	**26.5**	18.1	18.7	15.8	14.0	14.7	10.2	26.5
K	6.0	6.4	**7.2**	7.0	4.2	3.8	2.9	2.6	2.6	1.8	7.2
L	24.3	29.6	30.3	**33.2**	22.4	24.3	20.7	18.4	19.6	13.8	33.2

ARI = 10

RAFTS	Duration (min)										Max
Node	30	60	90	120	180	270	360	540	720	1080	
A	3.5	3.7	**4.4**	3.9	2.7	2.7	2.5	2.2	2.1	1.6	4.4
B	1.9	2.3	**2.7**	2.4	1.8	1.6	1.3	1.2	1.2	0.8	2.7
C	5.6	6.4	**7.7**	7.1	5.2	5.4	4.9	4.3	4.4	3.2	7.7
D	1.8	2.2	**2.6**	2.5	1.8	1.6	1.3	1.1	1.2	0.8	2.6
E	7.5	9.4	11.1	**11.2**	7.7	8.3	7.3	6.5	6.8	4.8	11.2
F	1.8	2.2	**2.6**	2.4	1.8	1.6	1.3	1.1	1.1	0.8	2.6
H	0.7	0.8	**0.8**	0.7	0.5	0.4	0.3	0.3	0.3	0.2	0.8
G	10.1	13.4	15.2	**16.0**	11.1	11.8	10.4	9.2	9.5	6.8	16.0
J	11.6	15.2	16.7	**17.7**	12.0	13.4	11.7	10.4	10.9	7.8	17.7
K	4.6	4.7	**5.4**	5.1	3.0	2.8	2.2	1.9	2.0	1.4	5.4
L	15.3	19.5	20.4	**22.5**	14.7	17.5	15.2	13.6	14.6	10.5	22.5

ARI = 5

RAFTS	Duration (min)										Max
Node	30	60	90	120	180	270	360	540	720	1080	
A	3.0	3.1	**3.7**	3.3	2.2	2.3	2.1	1.9	1.8	1.4	3.7
B	1.5	1.8	**2.2**	2.0	1.4	1.4	1.1	1.0	1.0	0.7	2.2
C	4.6	5.2	**6.3**	5.7	4.1	4.5	4.2	3.7	3.8	2.8	6.3
D	1.4	1.7	**2.1**	2.0	1.4	1.4	1.1	1.0	1.0	0.7	2.1
E	5.9	7.5	**9.0**	8.9	6.1	7.0	6.2	5.6	5.8	4.2	9.0
F	1.5	1.7	**2.2**	1.9	1.4	1.3	1.1	1.0	1.0	0.7	2.2
H	0.5	0.6	**0.7**	0.6	0.4	0.4	0.3	0.2	0.2	0.2	0.7
G	7.9	10.7	12.3	**12.8**	8.7	9.9	8.8	7.9	8.1	5.9	12.8
J	9.1	12.2	13.6	**14.2**	9.5	11.2	9.9	8.9	9.3	6.7	14.2
K	4.0	4.0	**4.7**	4.4	2.5	2.4	1.9	1.7	1.7	1.2	4.7
L	13.5	15.8	16.7	**18.2**	11.8	14.7	12.9	11.6	12.5	9.1	18.2

PMF

RAFTS	Duration (min)										Max
Node	15	30	45	60	90	120	150	180	240	300	
A	22.3	22.6	**23.5**	20.6	18.4	15.6	14.1	13.2	11.4	10.4	23.5
B	**14.7**	13.4	13.0	10.9	9.6	8.4	7.7	7.1	6.1	5.5	14.7
C	44.5	45.5	**47.4**	41.5	38.1	32.3	29.3	27.1	23.6	21.4	47.4
D	**14.9**	13.3	12.9	10.8	9.7	8.4	7.7	7.1	6.0	5.5	14.9
E	68.0	68.9	**71.2**	63.2	57.8	49.1	44.6	41.2	35.7	32.4	71.2
F	**14.3**	13.0	12.6	10.5	9.4	8.2	7.5	6.9	5.9	5.3	14.3
H	**4.2**	3.3	3.1	2.6	2.4	2.1	1.8	1.7	1.4	1.3	4.2
G	96.3	96.1	**99.2**	88.6	80.8	68.9	62.4	57.7	50.0	45.5	99.2
J	100.7	106.9	**111.4**	99.7	91.1	78.4	71.0	65.5	56.6	51.4	111.4
K	**24.8**	21.8	21.3	18.2	16.0	13.8	12.8	11.7	10.4	9.3	24.8
L	116.4	136.0	**144.4**	129.3	120.5	104.5	94.6	87.0	74.9	67.6	144.4

TABLE D2-3: BEAVAN PLACE RAFTS 'SEPP5' 100 YEAR FLOOD FLOWS (m^3/s)

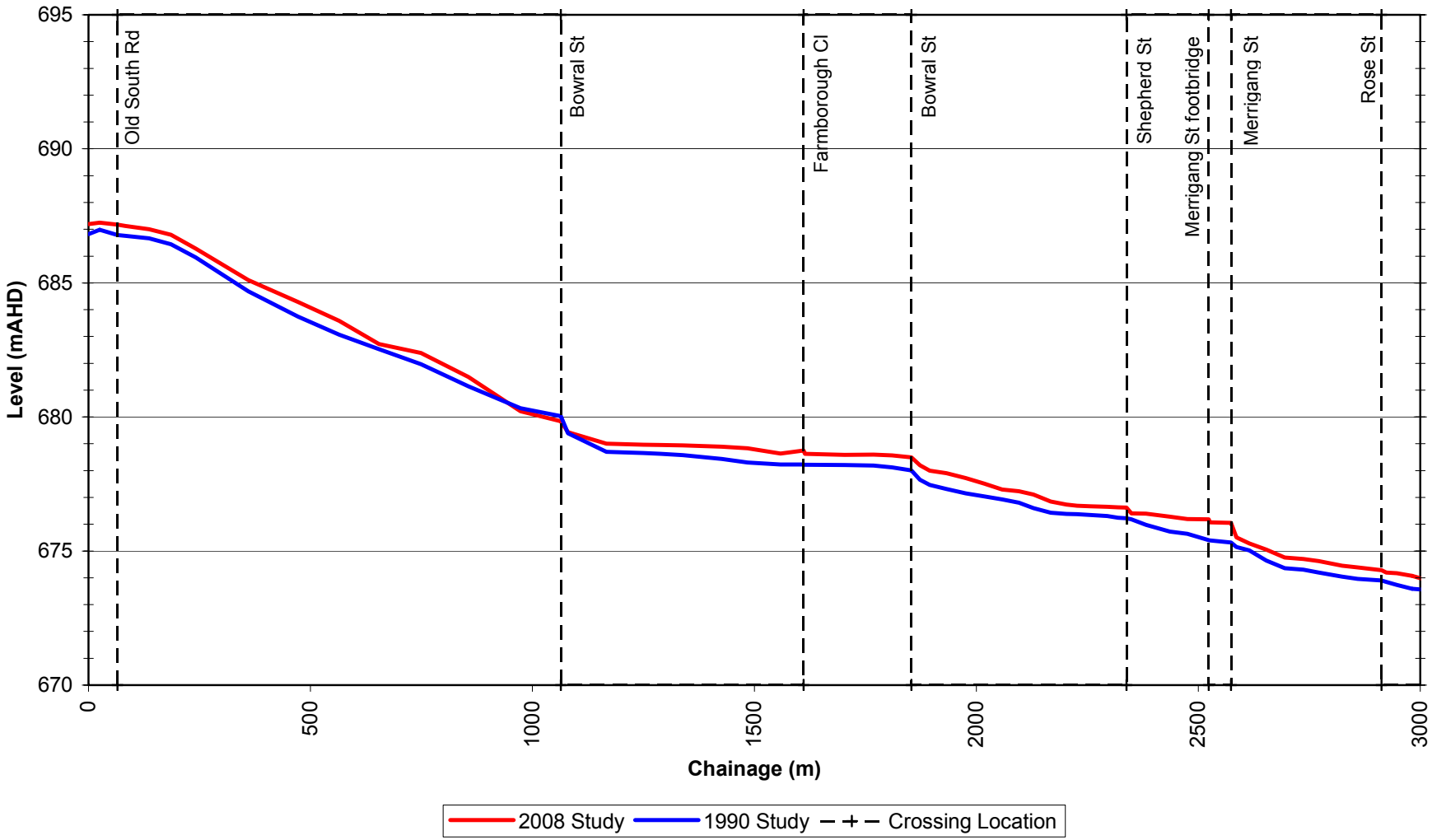
RAFTS	Duration (min)																					
	30		60		90		120		180		270		360		540		720		1080		Max	
Node	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase	Flow	% Increase
A	6.4	15	7.1	12	**8.1**	10	7.5	14	5.1	5	4.5	4	3.8	1	3.3	1	3.3	1	2.3	0	8.1	10.1
B	4.0	15	4.4	9	**4.8**	8	4.4	13	2.9	0	2.5	1	2.0	2	1.8	1	1.8	0	1.2	2	4.8	8.2
C	11.1	15	12.7	11	**14.2**	7	13.7	8	9.5	3	9.0	2	7.6	1	6.7	1	6.8	0	4.8	1	14.2	7.1
D	3.8	14	4.4	9	**4.6**	8	4.2	8	2.9	0	2.5	0	2.0	1	1.7	1	1.7	0	1.2	3	4.6	8.3
E	15.4	9	18.4	6	20.6	5	**20.9**	5	14.0	2	13.7	2	11.4	1	10.1	1	10.4	0	7.3	1	20.9	5.2
F	4.1	22	4.4	12	**4.8**	12	4.5	20	2.8	0	2.5	3	1.9	2	1.7	2	1.7	1	1.2	3	4.8	11.6
H	1.2	3	1.2	3	1.2	4	**1.2**	14	0.7	0	0.6	5	0.5	3	0.4	3	0.4	1	0.3	-1	1.2	4.2
G	20.8	5	25.4	3	26.8	1	**29.7**	4	19.7	2	19.3	1	16.2	1	14.4	1	14.7	0	10.2	1	29.7	4.4
J	23.4	4	28.2	3	29.1	1	**32.2**	4	21.9	3	21.6	1	18.0	1	16.1	1	16.8	0	11.6	1	32.2	4.0
K	7.0	1	7.4	1	**8.3**	1	8.1	1	4.7	0	4.3	1	3.3	0	2.9	0	3.0	0	2.0	0	8.3	0.8
L	29.7	3	35.0	2	35.9	3	**39.7**	3	26.7	2	28.0	1	23.7	1	21.1	1	22.4	0	15.7	1	39.7	3.2

Note: % Increase relative to design flow model.

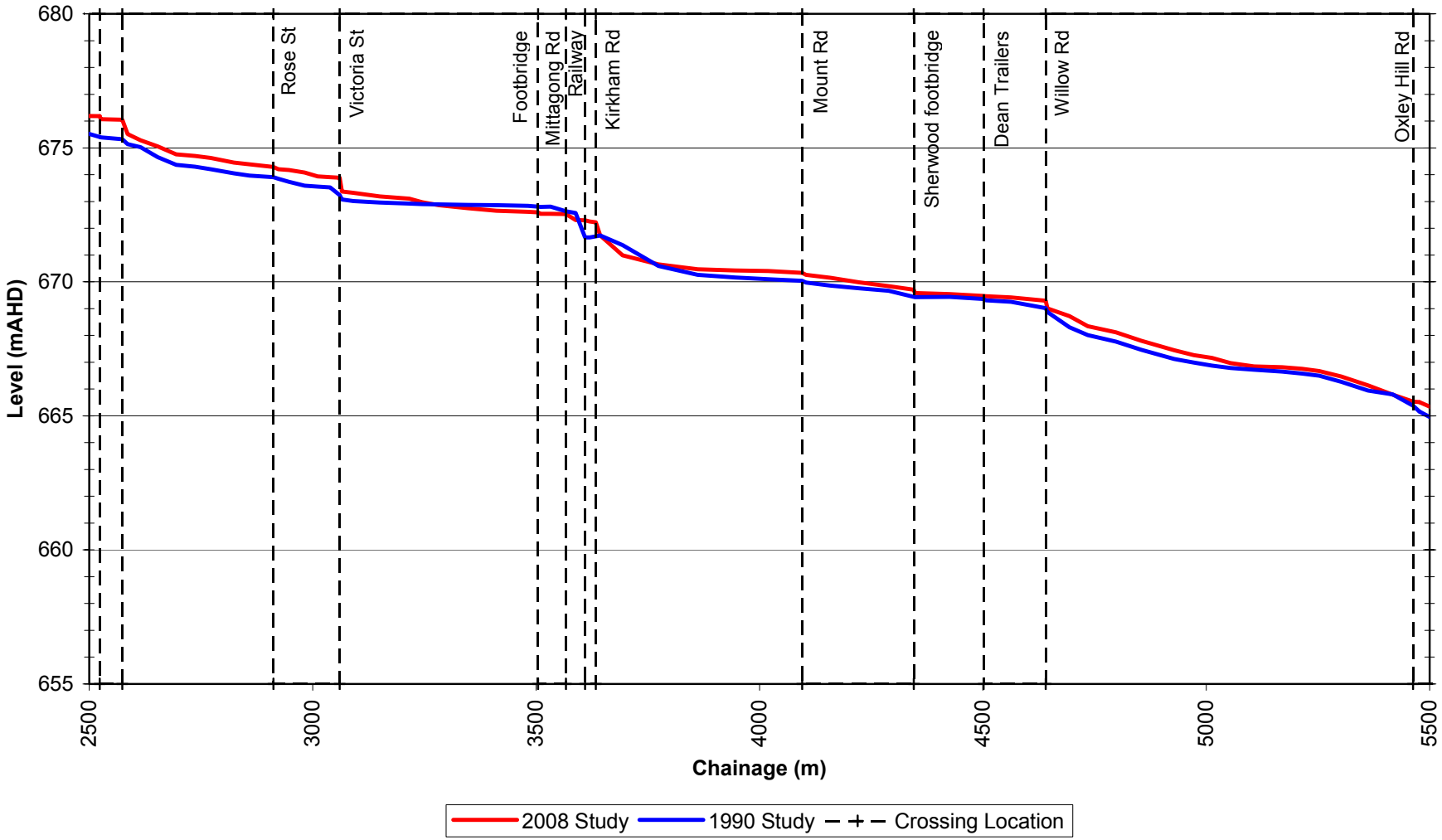
APPENDIX E

COMPARISON OF 100 YEAR FLOOD LEVELS BETWEEN CURRENT FLOOD STUDY AND 1990 MITTAGONG RIVULET FLOOD STUDY

Mittagong Creek 100 Year ARI Flood Profiles (1)



Mittagong Creek 100 Year ARI Flood Profiles (2)



APPENDIX F

FLOOD DAMAGES SUMMARY TABLES

TABLE F1: Residential Property (Containing a Home) Affected By Flooding

Location	5 Year Flood		10 Year Flood		50 Year Flood		100 Year Flood		PMF	
	Property	Homes	Property	Homes	Property	Homes	Property	Homes	Property	Homes
Old South Road to Bowral Street Bridge	13	5	17	8	34	26	36	30	204	171
Bowral Street Bridge to Railway Line	19	4	24	7	54	28	56	33	185	161
Downstream Railway Line	4	1	4	2	7	5	9	5	20	19
Beavan Place Sub-catchment	15	0	19	0	25	4	31	8	71	49
TOTAL	51	10	64	17	120	63	132	76	480	400

TABLE F2: Commercial, Industrial & Public Sector Properties (Containing a Building) Affected By Flooding

Location	5 Year Flood		10 Year Flood		50 Year Flood		100 Year Flood		PMF	
	Property	Building	Property	Building	Property	Building	Property	Building	Property	Building
Old South Road to Bowral Street Bridge	0	0	0	0	0	0	0	0	1	1
Bowral Street Bridge to Railway Line	2	1	4	1	4	3	4	3	22	21
Downstream Railway Line	13	4	17	5	23	13	24	15	38	37
Beavan Place Sub-catchment	9	1	9	2	13	4	13	5	14	12
TOTAL	24	6	30	8	40	20	41	23	75	71

TABLE F3: Inundation Depths for Homes Affected by the 100 Year Flood

Location	Below Floor Flooding (Number of Houses)		Above Floor Flooding (Number of Houses)				
	-0.5 to -0.2	-0.2 to 0.0	0.0 to 0.2	0.2 to 0.5	0.5 to 1.0	> 1.0m	TOTAL
Old South Road to Bowral Street Bridge	2	4	6	12	12	0	30
Bowral Street Bridge to Railway Line	12	15	8	19	4	2	33
Downstream Railway Line	3	1	1	2	2	0	5
Beavan Place Sub-catchment	13	9	7	1	0	0	8
TOTAL	30	29	22	34	18	2	76

TABLE F4: Inundation Depths for Commercial & Industrial Buildings Affected By the 100 Year Flood

Location	Below Floor Flooding (Number of Buildings)		Above Floor Flooding (Number of Buildings)				
	-0.5 to -0.2	-0.2 to 0.0	0.0 to 0.2	0.2 to 0.5	0.5 to 1.0	> 1.0m	TOTAL
Old South Road to Bowral Street Bridge	0	0	0	0	0	0	0
Bowral Street Bridge to Railway Line	0	0	0	1	2	0	3
Downstream Railway Line	7	5	7	4	3	1	15
Beavan Place Sub-catchment	6	2	2	2	1	0	5
TOTAL	13	7	9	7	6	1	23

TABLE F5: Number of Cadastral Parcels Intersected by each Flood Risk Precinct

Location	Flood Risk Area			
	High Risk	Medium Risk	Fringe Low Risk	Low Risk
Mittagong Creek model area	264	425	630	885
Beavan Place model area	45	192	224	229
TOTAL	309	617	854	1114

Notes: Flood risk precincts (FRPs) for the Mittagong Creek floodplain were mapped on the basis of the December 2008 flood model, using the maximum envelope of blocked and unblocked model runs for the 100 year flood extent, and the blocked model run for the PMF extent. Cadastre was provided by Council on 12 March 2009. In this analysis, (1) no account is taken of ownership of properties, (2) a property may be affected by more than one FRP, and (3) even properties affected by a "sliver" of a FRP are counted.

TABLE F6: Predicted Total Flood Damages Under Existing Conditions ($May 2004)

Location	Damage in Flood Event					**Average Annual Damage**	**Present Value of Damage**
	5 Year	10 Year	50 Year	100 Year	PMF		
Old South Road to Bowral Street Bridge	0.3M	0.5M	1.7M	2.4M	16.1M	220,000	2,310,000
Bowral Street Bridge to Railway Line	0.4M	0.5M	2.0M	2.5M	17.8M	260,000	2,710,000
Downstream Railway Line	0.8M	1.0M	2.3M	3.2M	21.1M	360,000	3,840,000
Beavan Place Sub-catchment	0.2M	0.3M	1.1M	1.7M	7.8M	140,000	1,460,000
TOTAL	1.6M	2.4M	7.2M	9.8M	62.9M	970,000	10,320,000

APPENDIX G

COMMUNITY CONSULTATION MATERIAL

- Mittagong Rivulet FMS Newsletter, January 2004
- Bowral FMS Newsletter, July 2004 (for Beavan Place catchment only)
- Mittagong Rivulet FMS Survey, January 2004
- Bowral FMS Survey, July 2004 (for Beavan Place catchment only)
- Selection of Responses to Bowral FMS Survey
- Agency and Interest Group Survey, March 2004
- Responses to Agency and Interest Group Survey
- Responses to Exhibited Draft FRMP, May 2005
- Council's Q&A fact sheet, June 2005

MITTAGONG RIVULET, BOWRAL,
FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN

COMMUNITY NEWSLETTER
JANUARY 2004

Introducing the study

Wingecarribee Shire Council is carrying out a study to understand and manage flood risks along the Mittagong Rivulet. This study is called the **Mittagong Rivulet Floodplain Risk Management Study and Plan**. The study area extends from Old South Road to the Wingecarribee River, as shown on the attached map.

Why do we need to worry about floods?

The Mittagong Rivulet flows through the heart of Bowral. Significant floods have occurred in 1915, March 1975, April 1988 and October 1999. Perhaps you know of other floods, too!

The 1975 and 1988 floods were estimated to have been no larger than 20 year floods. Bigger, rarer floods are likely. We should not dismiss floods as only 'nuisance value'. A previous investigation estimated that some 60 to 70 houses and businesses could be flooded in a 100 year flood. Many more would be inundated in an even more extreme flood.

1915 flood: Shepherd Street, with PL Travers (later, the author of Mary Poppins) standing on the bank

April 1988 flood: Merrigang Street

Nobody likes to think that floods might affect them. However, living close to a watercourse means that we need to be aware of the risks and plan ahead to minimise the damage and heartache that floods can cause.

Why do we need a study?

Under the NSW State Government's Flood Policy, the management of floodplains is the responsibility of local councils. As such, Wingecarribee Shire Council is responsible for local planning, development controls and land management within the Mittagong Rivulet floodplain.

The NSW Government's Flood Policy states that councils need to prepare a Floodplain Management Study and Plan to outline how they plan to manage floodplains now and in the future. The Mittagong Rivulet Floodplain Management Study and Plan will meet these obligations, and also open the way for Council to apply for State and Federal Government financial assistance to carry out works and other measures to reduce the flood risk.

please turn over ➔

Who is responsible for the study?

Council's Floodplain Management Committee will assist and advise Council in the Mittagong Rivulet floodplain management process. The Committee represents the 'community voices' for the flooding problems within the study area. Current members are:

- Mayor Phil Yeo (Chair)
- Councillor Nick Campbell-Jones
- Councillor Gordon Lewis
- Councillor Larry Whipper
- Councillor David Wood
- Kalyan Mondal — Council Director Technical Services
- Michael Brearley — Council Design & Projects Manager
- Mark Scotland — Council Surveyor
- Alan McGill — Council Draftsman
- Raj Upreti — Dept Infrastructure, Planning and Natural Res.
- Lyn Ritchie — State Emergency Service, Wingecarribee
- Roy Perry — Community member
- Tony Springett — Community member
- Dorothy Weber — Community member
- Ted Westwood — Community member

Council and the Department of Infrastructure, Planning and Natural Resources have commissioned Bewsher Consulting Pty Ltd to conduct the Floodplain Management Study and Plan for the Mittagong Rivulet. This is an independent company specialising in flooding and floodplain risk management.

What will the study be about?

The first step of the study, which is now nearing completion, is to prepare a flood model to simulate flood behaviour throughout the study area. This model will be fine-tuned to reproduce the flood behaviour experienced in April 1988 and October 1999. The model will then be used to simulate flood behaviour in larger events, such as the 100 year flood.

The Floodplain Management Study will then consider various options that may be able to reduce the damages caused by floods. Local residents' views, as well as environmental, social, economic and engineering factors, will all be taken into account. Among the options that could be considered are these:

Measures that modify the way a flood behaves

a. Clearing the creek of debris;
b. Creek widening;
c. Enlarging bridges and culverts;
d. Levees;
e. Filling low-lying land;

Measures that modify property

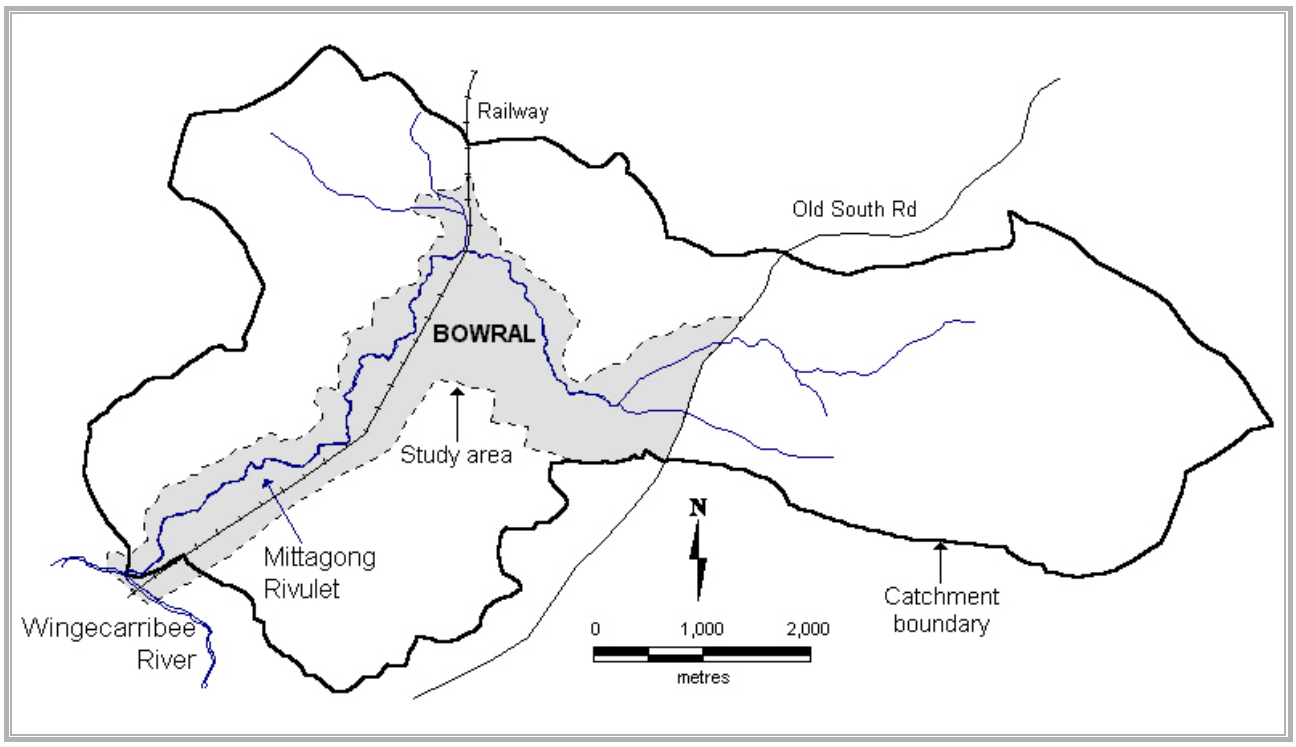
f. Voluntary house-raising;
g. Voluntary purchase of severely flooded houses;
h. Controls on new buildings;

Measures that modify people's response to flooding

i. Providing flood warning systems;
j. Improving formal evacuation procedures;
k. Promoting community flood awareness
   - Installing flood markers (for example, on telegraph poles) to act as reminders of the heights of previous floods;
   - Providing a certificate to all residents stating whether their property is flood-affected;
l. Promoting community flood readiness
   - Assisting potentially flood-affected people to prepare Flood Action Plans, which outline WHAT people should do, WHERE they should go, and WHO they should contact if there is a flood.

This list is by no means exhaustive and we need your input to hear your opinions and ideas to make sure all options are considered.

The recommendations of the Study will include the best possible, most equitable, and locally supported measures to reduce flood problems. Recommendations will be brought together in the Mittagong Rivulet Floodplain Management Plan, which will guide Council in managing the floodplain.



Mittagong Rivulet catchment, showing Study Area in grey

April 1988 flood: downstream of Old South Road causeway

October 1999 flood: Farmborough Close

How can I be involved?

The success of the Mittagong Rivulet Floodplain Management Study and Plan hinges on your input and acceptance of the proposals.

You can participate in the study in several ways.

1) A community survey has been sent to all households and businesses in the study area. If you have received a survey, please take a few minutes to complete it and return it in the reply paid envelope by 2 February.

2) From 2-13 February, posters will be displayed in Springett's Arcade. These will show the results from the flood model for the 1988 and 1999 floods. Please take the opportunity to inspect the display and to complete a feedback form. You are most welcome to speak to members of the Floodplain Management Committee, the Council, or the consultant, who will attend the display on 13 February.

3) If you have any information on flooding in the study area or any thoughts on flood-related issues, we would love to hear from you.

What is a '100 year flood'?

A '100 year flood' means that in any one year there is a '1 in 100' or 1% chance that a flood of this size or larger will happen. Over many centuries, a '100 year flood' will happen on average once every 100 years.

What is a 'probable maximum flood'?

Floods bigger than a 1 in 100 year flood can occur. Floods bigger than a 100 year flood devastated the towns of Nyngan (1990), Coffs Harbour (1996), Katherine (1998) and several suburbs of Wollongong (1998).

The 'probable maximum flood' is the largest flood that could possibly happen. Under the NSW Government's Flood Policy, councils are now required to consider the risks of flooding up to this largest possible flood.

What is a floodplain?

The words 'floodplain' and 'flood-prone land' now include all land that would be flooded by all floods up to the probable maximum flood.

Who can I contact for more information?

For more information about the Mittagong Rivulet Floodplain Management Study and Plan, please contact:

Wingecarribee Shire Council
Michael Brearley
Phone: (02) 4868-0888
E-mail: Michael.Brearley@wsc.nsw.gov.au

Bewsher Consulting Pty Ltd
John Maddocks
Phone: (02) 9868-1966
E-mail: jmaddocks@bewsher.com.au

Thank you for being part of this study

WINGECARRIBEE SHIRE COUNCIL

Department of Infrastructure, Planning and Natural Resources

SES STATE EMERGENCY SERVICE

Bewsher Consulting
Floodplain Management Consultants

BOWRAL FLOODPLAIN RISK MANAGEMENT STUDY & PLAN
COMMUNITY NEWSLETTER
JULY 2004

Introducing the study

Over the past year, Wingecarribee Shire Council has been carrying out a study to understand and manage flood risks along Mittagong Creek, which flows through Bowral. The study area extends from Old South Road to the Wingecarribee River, as shown on the attached map.

A questionnaire was sent to residents within the study area in January 2004. Several people suggested that the study area should be extended to include flood risks along tributaries of Mittagong Creek. In view of the history of flooding problems in the Beavan Place and Alcorn Street areas, as well as the pressure for medium density redevelopment in the Kangaloon Road area (which may increase runoff from hard surface areas), Council recently resolved to extend the study area to include the Beavan Place sub-catchment. The limits of this catchment are indicated on the attached map.

In order to reflect the broader scale of the study, the study is now known as the **Bowral Floodplain Risk Management Study & Plan** (previously it was the Mittagong Rivulet Floodplain Risk Management Study & Plan).

March 1978 flood: Beavan Place
Source: Berrima District Historical Society

November 1985 flood: Beavan Place
Source: Berrima District Historical Society

Why do we need to be concerned about floods?

Mittagong Creek has a history of flooding. Significant floods are known to have occurred in 1915, March 1975, March 1978, April 1988 and October 1999.

Areas near Beavan Place and Alcorn Street have also experienced flooding problems. The attached photographs show flooding in March 1978 and November 1985.

It is estimated that the 1975 and 1988 floods were no larger than 20 year floods. Rarer, bigger floods will occur one day. Floods should not be regarded as only 'nuisance value'. In the order of 100 houses and businesses along Mittagong Creek could be flooded in a 100 year flood. A greater number would be inundated in an even more extreme flood.

Why do we need a study?

Under the NSW State Government's Flood Policy, the management of floodplains is the responsibility of local councils. As such, Wingecarribee Shire Council is responsible for local planning, development controls and land management within Bowral's floodplains.

please turn over ➔

The NSW Government's Flood Policy states that councils need to prepare a Floodplain Management Study and Plan to outline how they plan to manage floodplains now and in the future. The Bowral Floodplain Management Study and Plan will meet these obligations, and also open the way for Council to apply for State and Federal Government financial assistance to carry out works and other measures to reduce the flood risk.

Who is responsible for the study?

The Bowral Floodplain Management Committee advises and assists Council in the management of Bowral's floodplains. The Committee represents the 'community voices' for the flooding problems within the study area. Current members are:

- Clr Phil Yeo (Chair)
- Clr Nick Campbell-Jones
- Clr Gordon Lewis
- Clr Larry Whipper
- Michael Brearley (WSC Design & Projects Manager)
- Mark Scotland (WSC Surveyor)
- Alan McGill (Council Draftsman)
- Peter Malloy (Council Town Planner)
- Raj Upreti (DIPNR)
- Lyn Ritchie (Wingecarribee SES Unit)
- Roy Perry (Community member)
- Tony Springett (Community member)
- Dorothy Weber (Community member)
- Ted Westwood (Community member)

Council and the Department of Infrastructure, Planning and Natural Resources (DIPNR) have commissioned Bewsher Consulting Pty Ltd to conduct the Floodplain Management Study and Plan for Mittagong Creek and the Beavan Place catchment. This is an independent company specialising in floodplain risk management.

What will the study be about?

The first step of the floodplain risk management process is the preparation of a **Flood Study**. This uses state-of-the-art computer modelling to simulate flood behaviour through the study area.

The **Floodplain Management Study** considers various options that may be able to reduce the damages caused by floods. This evaluation takes into account local residents' views, as well as environmental, social, economic and engineering factors. Among the options that could be considered are:

<u>Measures that modify the way a flood behaves</u>

a. Detention basins in the golf club;
b. Property acquisition and an overland flow path to convey flows in excess of pipe capacity;
c. Increasing the size of the culverts under the railway embankment to reduce backwater effects from Mittagong Creek;
d. Clearing the creek of debris;
e. Creek widening;

<u>Measures that modify property</u>

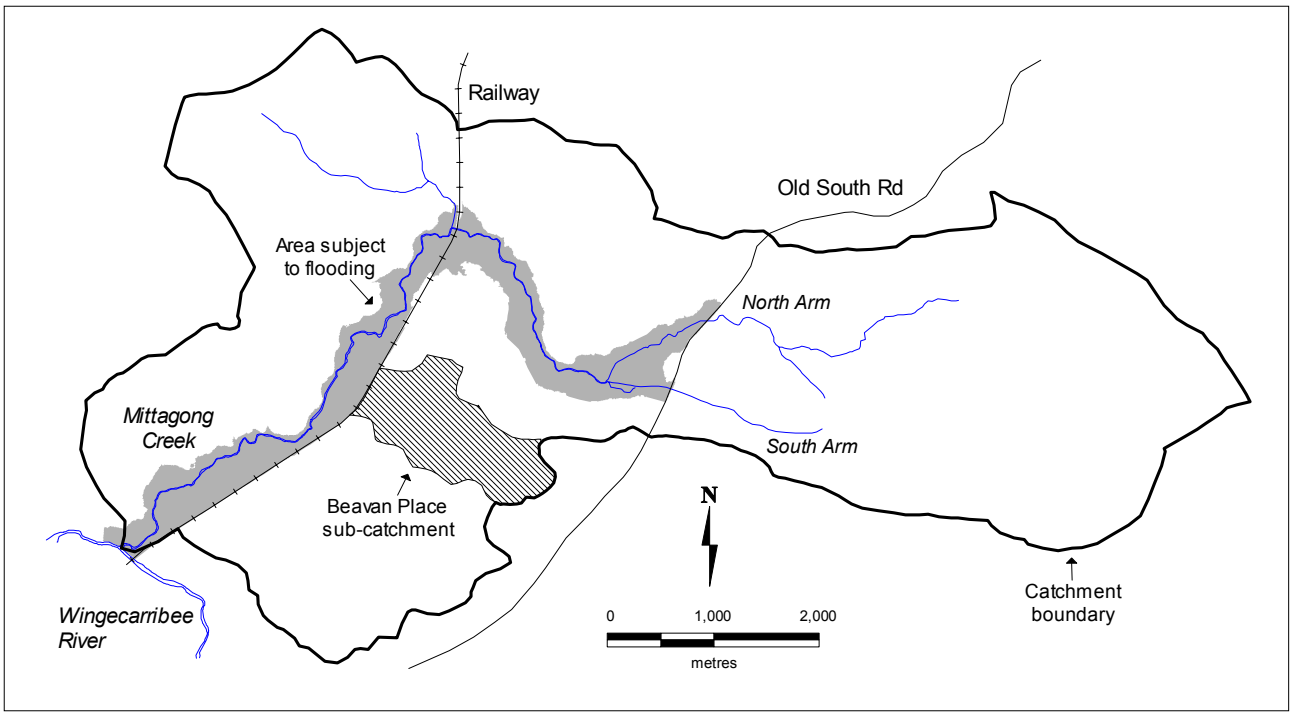
f. House-raising in the Beavan Place/Alcorn Street area;
g. Voluntary purchase of severely flooded houses;
h. Planning controls (e.g., limits on percentage impervious, requirement for on-site detention);

<u>Measures that modify people's response to flooding</u>

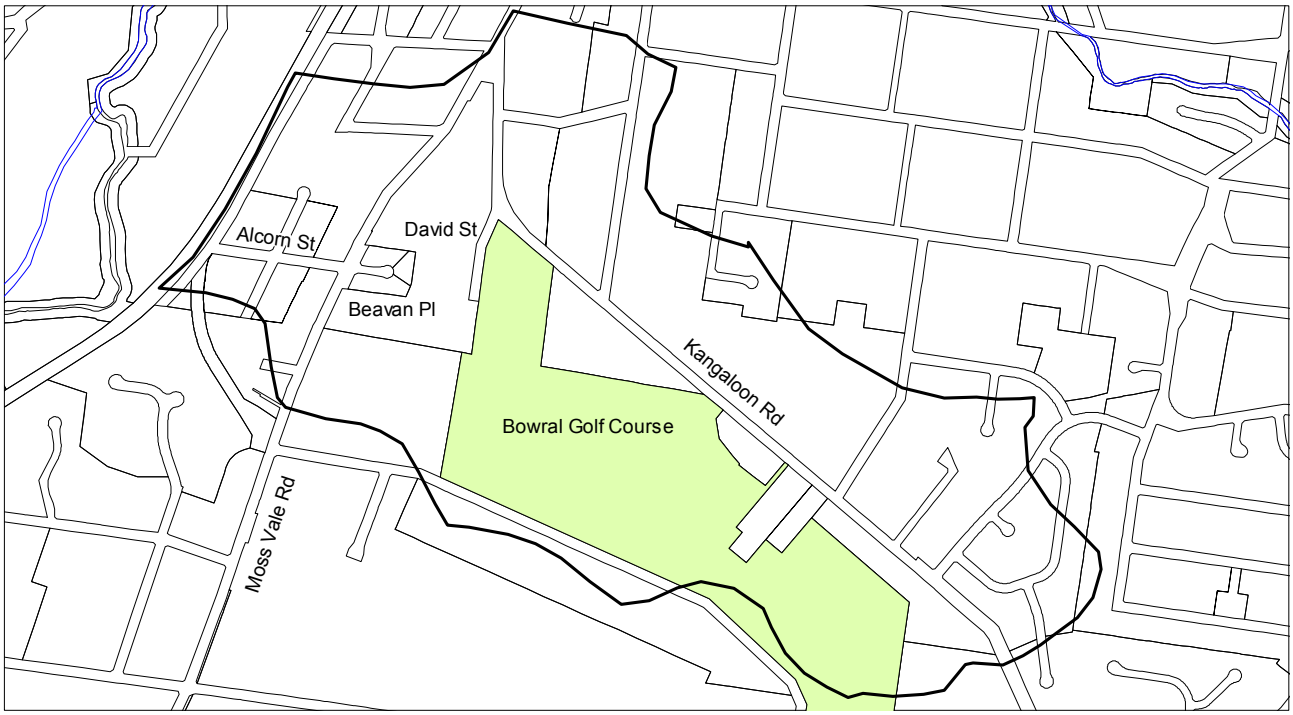
i. Promoting community flood awareness
   - Installing flood markers (for example, on telegraph poles) to act as reminders of the heights of previous floods;
j. Promoting community flood readiness
   - Assisting potentially flood-affected people to prepare Flood Action Plans, which outline WHAT people should do, WHERE they should go, and WHO they should contact if there is a flood.

This list is by no means exhaustive and we would value your input to hear your opinions to make sure all options are considered.

The recommendations of the Study will include the best possible, most equitable, and locally supported measures to reduce flood problems. Recommendations will be brought together in the Bowral **Floodplain Management Plan**, which will guide Council in managing the floodplain.



Mittagong Creek catchment, Bowral



Beavan Place sub-catchment

How can you be involved?

The success of the Bowral Floodplain Management Study and Plan hinges on your input and acceptance of the proposals. You can participate in the study in several ways.

1) A community survey has been sent to all households and businesses in the Beavan Place sub-catchment, downstream of the golf course. If you have received a survey, please take a few minutes to complete it and return it in the reply paid envelope by 30 July.
2) If you have any information on flooding in this area or any thoughts on flood-related issues, we'd love to hear from you.

1915 flood: Shepherd Street

What is a '100 year flood'?

A '100 year flood' means that in any one year there is a '1 in 100' or 1% chance that a flood of this size or larger will happen. Over many centuries, a '100 year flood' will happen on average once every 100 years.

What is a 'probable maximum flood'?

Floods bigger than a 1 in 100 year flood can occur. Floods bigger than a 100 year flood devastated the towns of Nyngan (1990), Coffs Harbour (1996), Katherine (1998) and several suburbs of Wollongong (1998).

The 'probable maximum flood' is the largest flood that could possibly happen. Under the NSW Government's Flood Policy, councils are now required to consider the risks of flooding up to this largest possible flood.

What is a floodplain?

The words 'floodplain' and 'flood-prone land' now include all land that would be flooded by all floods up to the probable maximum flood.

Who can you contact for more information?

For more information about the Bowral Floodplain Management Study and Plan, please contact:

Wingecarribee Shire Council
Michael Brearley
Phone: (02) 4868-0888
E-mail: Michael.Brearley@wsc.nsw.gov.au

Bewsher Consulting Pty Ltd
Stephen Yeo
Phone: (02) 9868-1966
E-mail: syeo@bewsher.com.au

Thank you for being part of this study

WINGECARRIBEE SHIRE COUNCIL

Department of Infrastructure, Planning and Natural Resources

SES STATE EMERGENCY SERVICE

Bewsher Consulting
Floodplain Management Consultants

Department of **Infrastructure, Planning & Natural Resources**

Bewsher Consulting Floodplain Management Consultants

Mittagong Rivulet, Bowral, Floodplain Management Study
Community Survey (January 2004)

1. Do you think your property could be flooded sometime in the future?

- ❑ No
- ❑ Yes, over the yard only
- ❑ Yes, over the floor of the house

2. Are there any specific problem areas that you think this Study should look at in detail?

_____ (please continue on back)

3. What floodplain management measures do you think this Study should consider?

_____

_____

_____ (please continue on back)

4. Do you have any other suggestions about what the Study should address?

_____ (please continue on back)

5. How do you think information about the risks of flooding should be provided to the local community? (Tick one or more boxes)

- ❑ Council should provide no advice about flood problems or what to do to reduce the flood risk
- ❑ Council should tell only those people who ask them for information about possible flood problems
- ❑ Council should advise property buyers of possible flood problems
- ❑ Council should send to all residents a certificate that says whether their property is flood-affected
- ❑ Council should have flood maps available on their web-site
- ❑ Community education programs
- ❑ Install flood markers (e.g., on telegraph poles) as reminders of heights of previous floods

6. What further involvement would you like to have in this Study? (Tick one or more boxes)

- ❑ Please include me on your mailing list
- ❑ Please contact me for a phone interview
- ❑ I plan to visit the poster display in Springett's Arcade from 2-13 February
- ❑ I am interested in attending meetings

7. Your Contact Details (see privacy note below).

Name: _____ Telephone number: _____

Address: _____ (Best time to call: _____)

_____

Privacy note: Any personal details you give us are for use in this study only and will not be shared with other organisations. Information provided in this survey will only be reported in aggregate form.

Please return the completed questionnaire to Bewsher Consulting in the attached reply-paid envelope.

Thank you for your assistance.

Department of **Infrastructure, Planning & Natural Resources**

Bewsher Consulting Floodplain Management Consultants

Bowral Floodplain Management Study
Community Survey (July 2004)

1. Have you ever witnessed any flooding in the vicinity of your current property?

- ☐ No
- ☐ Yes, in the street only [Year(s)? _____]
- ☐ Yes, over the yard [Year(s)? _____]
- ☐ Yes, over the floor of the house [Year(s)? _____]

2. Do you think your property could be flooded sometime in the future?

- ☐ No
- ☐ Yes, in the street only
- ☐ Yes, over the yard
- ☐ Yes, over the floor of the house

3. What one or two solutions for dealing with the flood problem do you think deserve most consideration? Why?

_____

_____

_____ (please continue on back)

4. Are there any specific locations that you think this Study should look at in detail?

_____ (please continue on back)

5. Do you have any other suggestions about what the Study should address?

_____ (please continue on back)

6. What further involvement would you like to have in this Study? (Tick one or more boxes)

- ☐ Please include me on your mailing list
- ☐ I am interested in attending meetings
- ☐ No further involvement

7. Your Contact Details (see privacy note below).

Name: _____ Telephone number: _____

Address of property in study area: _____

Postal address (if different): _____

Privacy note: Any personal details you give us are for use in this study only and will not be shared with other organisations. Information provided in this survey will only be reported in aggregate form.

Please return the completed questionnaire by 30 July to Bewsher Consulting in the attached reply-paid envelope or by posting (no stamp required) to:

Reply Paid No. 32
Bewsher Consulting
PO Box 352
EPPING NSW 1710

Thank you for your assistance.

A Selection of Responses to Community Survey

ID	Suggested floodplain management measures
25	1) Absolutely no further building on the floodplain 2) No redevelopment proposal for land with existing buildings on the floodplain to be countenanced 3) Fluvial geomorphologists should locate areas in which Rivulet can safely be encouraged to flood out away from existing development 4) Avoid filling of low-lying land 5) Levees, if used at all, to be few and carefully sited 6) Information about risks of flooding readily available, including posting of flood maps on Council web-site
95	1) Subsequent to the removal of the willows, the 'rushes' in the Rivulet bed have multiplied at an unbelievable rate. The thickness and extent of the rushes has at least doubled. It's suggested the rushes 'filter' the flow and remove sediment. That's one side of the argument. They also obstruct the flow of the creek in high flow situations, and contribute to the creation of the flooding problem. Additionally, the dead/decaying foliage from the rushes clogs the Rivulet, again contributing to the flood problem. It's claimed that the regenerated growth of native species along the banks of the Rivulet will in time suppress the rush growth. The native planting will never form the 'umbrella' provided by the willows, and the growth of the rushes will thus not be suppressed by 'natural causes'. 2) In addition to a reduction in the presence of rushes, the Rivulet requires to be cleaned out, silted areas dredged and a limited amount of straightening undertaken. Importantly, any such work undertaken MUST then be the subject of regular on-going maintenance. 3) The banks of the Rivulet need to be stabilized. In two areas of the Rivulet bordering my property, significant erosion occurred. On being approached, WSC wanted no part of the corrective action needed and were singularly unhelpful. Eventually, I had a contractor who undertook rockwork with a backhoe. Eventually I was able to recover 50% of the labour cost from a State Govt entity, but had to bear the rest myself, including the cost of materials. The authorities have undertaken some stabilization, but much more is required, and such should certainly not be at the cost of property owners bordering the Rivulet. 4) Most of the bridges upstream from the main Mittagong road Bridge act as dams in flood situations. This contributes to flooding and the closure of roads. In recent years the Shepherd St Bridge was largely reconstructed, but no steps were taken to lift the 'new' bridge to allow a free flow of water in flood times. The result is water continues to build up, flows across the road necessitating its closure, and risking flood damage to adjoining properties. The matter was raised with the Council engineer in charge of the project, who flatly denied the bridge interfered with the Rivulet's flow in flood conditions. I have photos that graphically show otherwise... Bridgework should be undertaken from downstream up - the reverse would result in greater flood problems at downstream bridges, due to enhanced flow created if upstream bridges were to be reconstructed first. The Victoria Rd Bridge (closed to traffic) should be demolished - if necessary it could be replaced by a proper footbridge, constructed in a manner so as not to obstruct the Rivulet's flow in flood periods.

ID	Suggested floodplain management measures
120	**1) Existing conditions.** A simple map of existing conditions would help understanding and response. In particular there seem to be two historical methods of floodplain management. One is the extensive concreting of the creek where it crosses Mittagong Rd near the Swimming Centre. What is the history, purpose and result of this? The other is the more natural treatment upstream from that point to Bowral St with reeds now growing in the creek bed, and the removal of willow trees in the last two or three years. There has also been some improvement of the banks and course of the creek with rocks protecting entry points of stormwater, the construction of small artificial wooden 'weirs', and some small scale planting. What is the purpose and outcome of this quite different treatment? **2) Development in the catchment.** Planning policies and zoning provisions in the catchment area are leading to increasing density of development as medium-density and attached housing replaces separate houses often on large lots. A good example is that of 117 Bowral St where 12 large four-bedroom 'cluster houses' and their surrounding hard paved areas replaced one old dwelling on a largely permeable lot. This development obviously increased storm-water discharge into drainage systems both in terms of volume and concentration in time. Representations have been made about this and similar developments in the Council's consultation process about applications. The response has been that Council's engineers stipulate design criteria which withhold stormwater on site until after the event passes and then releases the water gradually into the system. But there is no explanation as to what that actually means in terms of increased flooding risk in different storm events, or any account of the cumulative effects of continued developments of this kind on the characteristics of stormwater discharge and their impact on the disposal system. Both these matters indicate that more information is needed firstly on changes in the built environment in the catchment and their effect on stormwater volume and discharge; and secondly on the intent and result of past 'improvements' to the creek.
147	Road bridges too low making blockage possible. Bank collapsing in several areas. Reeds are blocking flow. Some straightening would help. Widening in some areas would help. In one area the creek is less than 1m wide. Water retention of flow from Northern arm of creek. Ongoing maintenance of total length i.e. willow removal and rubbish, stabilizing banks. Removal of trees that are undermined and will collapse into the creek. Removal of cyclone wire from road bridges and replace with something that allows clear flow and no blocking. Levy tyre bank at Farmborough Close in form of nature strip, i.e. planted with shrubs, etc. Examine impact of Berrima weir during flooding and benefit of lowering or removal; (being examined and recommended for removal by DLWC and NSW Fisheries in review for State Weirs Policy). Removal of all illegal structures in floodplain, also fences.
182	Problems: 1) Sewer overflow and blockages 2) Drivers who ignore barriers, driving through create waves which further inundate properties Measures to consider: 1) Clearing creek bed of reeds, blackberry and other ferals, errant trolleys and assorted rubbish 2) Maintaining cleared creekbed by regular dredging [want to encourage healthier waterway and return of wildlife] 3) Planting of suitable native grasses, shrubs and small trees with a view to building banks of creeks, beautifying surrounds and providing safe havens for wildlife; provision for recreation areas with safe walkways and cycleways, protected from motorised vehicles 4) Any creek-widening should not be to detriment of existing plantings; a more sympathetic approach is required with full consultation with residents/ratepayers whose properties adjoin the creek 5) Restrictions on buildings in flood-prone areas as (a) buildings induce greater runoff during storms, (b) less area of land to absorb water in rain or flood 6) Perhaps a return to original plan for creek by former Bowral Municipal Council – regular dredging of creek to free it of weeds and rubbish; also active plan to acquire land adjoining creek as 'green belt' to restrict building on a floodplain, and to assist in beautifying the area

ID	Suggested floodplain management measures
184	Problems: 1) Stormwater drains fill with road base and debris, which then deposit these debris into the creek via drain pipes, this then lessens the natural depth of the creek bed, leading to the creek being unable to carry as much water capacity 2) Council not being responsible for the general cleaning of the creek, which relates back to the previous problem above e.g. overgrowth of rampant growing reeds of several species which trap rubbish from stormwater drain causing slower flow; this rubbish includes car tyres, lounges, plastic of all descriptions; the build up of silt and kerb-side litter all cause various problems along the creek; some bridges also should be removed or repaired Measures to consider: 1) Council should play biggest part to ensure creek flows; our Landcare group maintains the banks; Council should be more responsible in creek's upgrade, even to the point where severe build up of silt and road base should be dredged out at trouble spots regularly; remove blackberries, noxious weeds, vines; keep grass growth out of gutters at creek bridges 2) A 'positive' look at the over-development in the Shire e.g. lawn and garden to concrete driveways
190	Measures to consider: 1) Bridges: the now closed, narrow and sagging Rose St [*sic*, Victoria St] Bridge needs to be replaced and reopened for 2-way traffic; in the event of flood, SES, Council workers and residents need proper and quick access through here; raise existing bridges; concerned about debris banking up against Bowral St, Shepherd St and Merrigang St Bridges and also the foot bridges, and impeding the flow of flood water 2) Maintaining clear culverts and drains: perhaps more pollution traps are needed, and regularly cleared of vegetation, gravel etc; 3) Reeds: some authorities say that *Fragmites* and *Typha* help filter the water as it passes through; although some reed could be tolerated, the fact is that it is rapidly advancing up the creek and increasing in density each season; it will be many years before the trees being planted are tall enough to shade the creek and reduce their growth; even though they will be flattened in a flood, flattening them does not reduce their volume as they would take up a considerable volume of the creek's flood water capacity and therefore raise the level of flooding; the reeds also collect huge amounts of rubbish up against and tangled in them, thus impeding flow 4) Creek widening: should try to avoid altering the natural flow; while filling low areas and building levees may help some people, it could leave others much worse off 5) Information: residents need information on flood preparedness, say, a booklet, with info such as number to ring, how info on flood levels will be issued, where to collect sandbags, who local coordinator is, what elderly residents need to do to get help, residents only routes to prevent sight-seers getting in the way, where people can take their belongings, how to get help to shift belongings 6) Household tanks to reduce volume of stormwater runoff 7) Reduce concrete and paved areas 8) Construction of man-made lake or diversion pond
246	Rivulet is an important environmental resource as it is in an urban area and acts as an important riparian corridor. Any flood mitigation plan should ideally consider the aesthetics of the area to improve it for use for locals and visitors for recreation such as walking and bicycle riding and consider the environmental future. This includes flora and fauna, both of which are already extensive. A bird watching group is collecting records of avian diversity over an area of 2 km south east of Merrigang St and the early results demonstrate a surprising diversity and the area is a proven breeding ground not only for ducks but birds such as the Australian warbler. Any clearing and widening would need sympathetic planning to protect these species, particularly in relation to the reeds. Further studies are needed of the flora and fauna of the rivulet and local groups could probably assist. The flood mitigation planning and work could turn the rivulet into a safe and beautiful recreational area in the centre of Bowral. I would be interested in input in the environmental area.

ID	Suggested floodplain management measures
282	Reforestation of catchment and river areas; keep flood prone areas as recreation space, don't build on them; minimise runoff in town by encouraging people not to concrete over their yards; for car parking spaces use the type of brick that allows grass to grow between – better absorption of water; regular maintenance and clearing of drainage pipes; look carefully at the catchment areas: how much erosion > rapid runoff is there?; would more dams/water storage systems higher up prevent floods further down; leave Mittagong Rivulet in a state as natural as possible, it is one of Bowral's assets; the concreting of the Rivulet bottom under the railway bridge may be helpful but it looks awful – better solutions?

MITTAGONG RIVULET, BOWRAL, FLOODPLAIN MANAGEMENT STUDY

MARCH 2004

QUESTIONNAIRE FOR AGENCIES, AUTHORITIES & INTEREST GROUPS

1. Could you please complete the following table:

Name of Organisation:	
Contact Name:	
Position of Contact Person(s):	
Postal Address:	
Contact Phone number:	
Contact Fax number:	
Best time to call you:	

2. What is the potential damage that COULD occur to your asset/property/service if inundated by floodwaters?

Please refer to the Study Area on page 3 of the newsletter, which gives a rough indication of the area subject to flooding. Items that could be damaged by floodwaters could include road surfaces, buildings, pumps, pumping stations, electricity substations, traffic signals, other electrical equipment, equipment and/or stock piles at depots, monitoring equipment, and cables/conduits/pipes that could be damaged if undermined by erosion during a flood.

Could you please complete the following table using the examples as a guide. Attach a separate sheet if required.

Please describe the property/ asset/service that could be damaged by floodwaters.	Please provide the location of the property/ asset/service.	Please describe the type of damage that could be sustained if inundated by floodwaters.	Please estimate the approximate cost of damage that could be sustained.	Approximately, how long would it take to repair the damage.	How critical would the property/asset/service be to the community if it were damaged by floodwaters?	Could potential damage be reduced if flood mitigation works were constructed or if warnings were issued? Please give details.
Sewer Pumping Station	Corner Smith and Jones Streets	Pumps would fail if inundated by more than 300 mm of water	$50,000	About 1 week	There would be no sewer to about 400 homes for up to 5 days	Pumps may be protected with at least 2 hours warning.
Road surface	Brown Street	Damage to road surface if inundated for > about 3–6 hrs	$100 per m^2 of affected pavement	About 2 weeks	About 5000 vehicles/day would have to find alternative routes for up to 2 weeks	Damage may be reduced if Brown Street bridge was enlarged.

3. Does your organisation have any planned future works within the Mittagong Rivulet (Bowral) Study Area that could be affected by flooding, or could have an impact on possible floodplain management options?

Floodplain management options could include clearing the creek of debris, creek widening or dredging, enlarging bridges and culverts, levee banks, filling low-lying land, road raising, detention basins, etc.

Could you please complete the following table using the example as a guide. Attach a separate sheet if required:

Proposed Work	Location	Approximate Cost	Indicative Time Frame
600 mm dia sewer rising main	Crosses the river upstream of the William Long bridge	$10 million (2004 estimate)	Within next 5–10 years

4. Are you aware of any reports, studies, designs, etc. that may be applicable to our study?

Could you please complete the following table.

Report prepared by	Date	Title of report	Report prepared for	Published by	Does your office have a copy we could borrow if required?

5. Do you have any other comments about flood related issues?
Do you have any specific issues that you think the floodplain management study should address?

Attach a separate sheet if required.

_____

_____

_____

_____

_____

_____

_____

_____

Please post your completed questionnaire by **12th April 2004** to:

BEWSHER CONSULTING PTY LTD
PO BOX 352
EPPING NSW 1710

Attention: Stephen Yeo

For further information about the Mittagong Rivulet Floodplain Management Study, please contact John Maddocks from Bewsher Consulting on 9868-1966

Thank you for your time and assistance

Agency and Interest Group Survey Responses

Bowral Urban Landcare Group (BULG)[1]

Contact: Jennifer Cox (Vice President), PO Box 1570, Bowral 2576

Potential damage:
Erosion of creek banks and bed from Old South Rd to Bong Bong St

Future works:
Ongoing riparian restoration – planting of grasses and sedges on creek banks, small groups of shrubs at top of bank – but not a continuous wall of shrubs – and scattered eucalypts on the floodplain which when mature can provide dappled shade over water, therefore reducing reed density. We also have one bed control structure (300mm high) planned for 2004 and possibly three more, further downstream, to control bed erosion.

Relevant reports:
Wollondilly Catchment Management Committee 2002. 'Riparian Management Guidelines for Wollondilly & Wingecarribee Rivers', S.C.A., available from DIPNR.

Other comments:

Bowral Urban Landcare Group (BULG) is a community based voluntary organisation which developed out of concern about the impact of urban flooding in Bowral. Local representation to Council to remove willows led to the formation of BULG and its program of riparian restoration of the creek from Old South Road to Bong Bong Street.

Our work to date is located between Shepherd and Merrigang Sts, a portion of the bank west of Rose Street Bridge and some early plantings in Stanley Park. See **Figure G1**.

This has involved the removal of environmental and noxious weeds and stabilisation of the stream banks by planting indigenous plants in the riparian zone. The Group's technical advisor is the Department of Planning, Infrastructure and Natural Resources (DIPNR). All work is approved by Council. The planting however differs from recommended riparian restoration in that our work is in an urban area and we are aware of the tension between conservation practices of dense planting and the need to allow overbank stream flow move without restrictions in flood time.

As a result we plant a very large number of grasses and sedges on the stream bank rather than shrubs. Scattered trees are planted along the riparian zone which will stabilise the banks and provide some shade over the water and reduce the density of reeds in some areas. Small groups of shrubs are planted at the top of the bank.

To arrest bed erosion, BULG has arranged for the installation of six bed controls and two rock walls in the creek, funded through grants programs with construction supervised by DIPNR. Locations are shown on **Figure G1**. We have approval to install another bed control and will be seeking funds for three more. Locations of the bed controls and rock wall are in the attachment.

Management Issues:

- We would like to see Council develop an overall management plan for the creek in which flood management is one part. This would be in the interest of a more cohesive approach to integrate environmental, engineering, parks management and urban planning issues.
- Weed control is a major activity along and in the creek. BULG has just received funds to continue the removal of willow regrowth, willow seedlings (e.g. pussy willow), blackberry, honeysuckle, ivy, hawthorn, privet and other woody weeds on Council owned land. This will now be an ongoing function of the Group. While we are concerned about the growth of these weeds for environmental reasons, local residents consider them as possible traps for debris in flood time and ongoing removal is required.
- Proper management of the creek is hampered by the existence of riparian rights where private householders own land to the creek bank, making weed control and maintenance difficult in some areas. Specific problems exist from Bowral to Shepherd Street (east bank) and Victoria Street (south bank). Many owners do not remove woody weeds such as willows, blackberry and privet.

[1] In a letter tabled at the Bowral Floodplain Management Committee meeting of 17 February 2005, three community members of the Committee stated their objection to the inclusion of this BULG submission, being of the view that these were personal views and not necessarily those of BULG members overall. The main point of dissension appears to centre on the issue of the reeds – whether to remove or not.

- Our Group does not support the removal of reeds from the stream bed as a flood measure. *Phragmites australis* and *Typha orientalis* have increased in density since the willows were removed and will be reduced when the trees planted along the bank provide sufficient shade over the water. The reeds have a water quality and bed retention function and where they have been removed in the past such as at the Rose Street Bridge the water level has dropped and erosion is active along the banks. A headcut of about 450mm has formed at the sharp bend in the section between Merrigang and Rose Street and is eroding upstream. This is one of the locations for a bed control when funds become available.
- The Cherry Walk is being planted along the pedestrian path near the creek. While we support its memorial function, we are concerned that Council has agreed to its installation in some places in the riparian zone within a few metres from the top of the bank. A particular area of concern is the above mentioned sharp bend where tree planting is not possible on the outer bend because of the proximity of trees.
- In the next 20-40 years, it is predicted that rainfall will reduce in the area but the incidence of storm episodes may increase. The latter has consequences for the creek. We believe it to be important that proper riparian management be continued in conjunction with flood control measures. Specifically Council should be looking at those sections of the creek bank where slumping could occur and ensure that appropriate tree planting can take place. This may require the pedestrian path to be moved in some places to enable trees and creek bank binding vegetation to be planted.
- It is generally agreed that the design of the bridges hinders the flow of water along the floodplain in flood time. The Shepherd Street Bridge, for example, has a stone wall on its south side with only a small entry for water. Once the water travels under the bridge it spreads out scouring the banks and depositing material midstream thus widening the stream and creating islands. We want to see bank instability reduced and a more appropriate design of bridges introduced.
- The parkland and pedestrian path along the creek is one of the most desirable and well used items of public infrastructure in Bowral. It is important to the community for both cross town access and for exercise. Aesthetics, safety, good maintenance and coordinated planning are a priority and should be taken into account in any flood warning/management activity.

Bowral Urban Landcare considers riparian restoration as an important part of the recovery of the environment, water quality, habitat and aesthetic qualities of the creek. We want to ensure that any measures introduced do not affect those qualities.

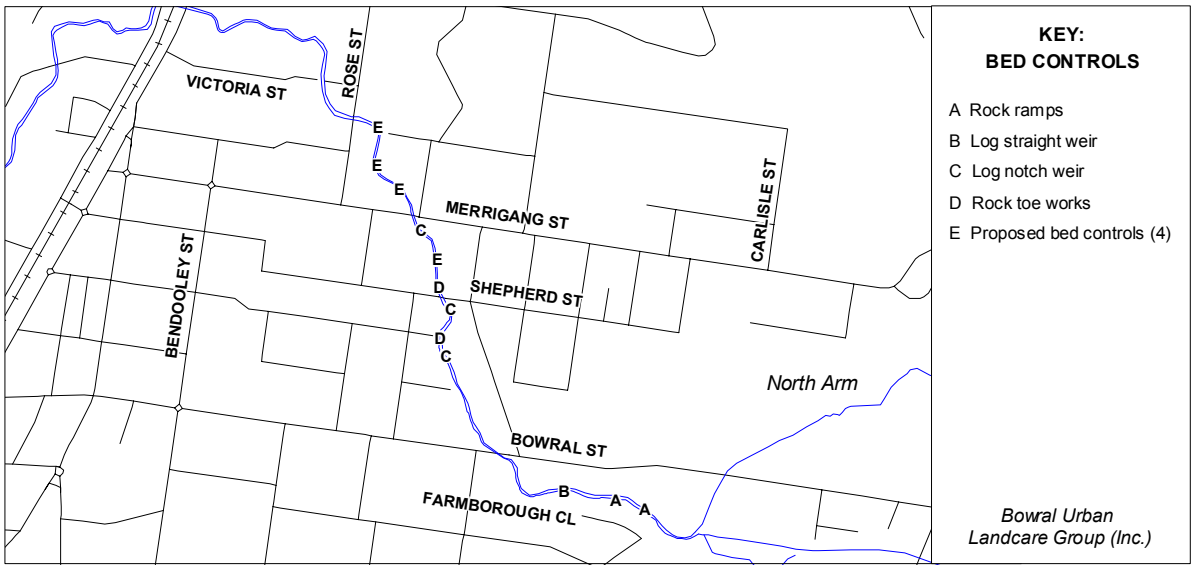


FIGURE G1
Bed Control Structures along Mittagong Creek
Source: Bowral Urban Landcare Group (Inc.), March 2004

Department of Infrastructure, Planning and Natural Resources (DIPNR)

Contact: Karen Elton (Natural Resource Project Officer), PO Box 449, Moss Vale 2577

Future works:
In-stream bed controls (10-20) downstream of Shepherd St, $200,000, within next 5 years

Relevant reports:
By Brad Davies, bed control designs, for Mittagong Rivulet Group, published by DIPNR

Other comments:
Flooding needs to be assessed and managed in accordance with best management practice and with consideration of other riparian functions. Consideration needs to be given to restoring and enhancing urban streams. Considerable interest and habitat value has been achieved through the construction of log weirs, rock ramps and v-notch weirs and through the native vegetation re-introduced along the creek. The council needs to look at adopting a similar process and study as the Illawarra Riparian Corridor Management Study.

NSW Agriculture

Contact: Wendy Goodburn (Agricultural Environment Officer), PO Box 389, Goulburn 2580

Other comments:
NSW Agriculture is concerned about impact of floodwaters on agricultural land, farm buildings and rural dwellings. Address impact of floodplain development on downstream agriculture and associated infrastructure.

NSW Fisheries

Contact: Michelle Perry (Conservation Manager, Central), Cronulla Fisheries Centre, PO Box 21, Cronulla 2230

Other comments:
Support preparation of FRMS provided these issues are considered:
1) Any structure that may obstruct the free passage of fish such as block banks, levees, weirs and causeways will not be permitted by NSW Fisheries;
2) A significant amount of aquatic/fish habitat has been and is currently being alienated by inappropriate floodplain development. There is a need to reinstate a natural flooding regime for many wetlands and natural waterways wherever possible to encourage fish reproduction;
3) The potential presence of threatened aquatic species will require that any proposal, which may have an impact on these species, will need to be assessed;
4) NSW Fisheries will not accept any further alienation of floodplain habitat unless appropriate compensation is provided (e.g. by opening up other areas of aquatic habitat for fish and aquatic invertebrates.

NSW Fisheries will not approve activities that result in the modification and/or destruction of fish habitat.

Roads and Traffic Authority

Contact: Robyn Lyster (Area Maintenance Manager), PO Box 477, Wollongong 2520

Potential damage:
Mittagong Rivulet Bridge, Bowral-Mittagong Rd: inundation would close road during event; railings damaged by debris would cost $20,000 and take 2 weeks to repair – also a safety issue; pavement damage would cost $100,000 and take 2 weeks to repair – worst-case scenario full road closure affecting 18,000 vehicles/day

State Emergency Service

Contact: Lyn Ritchie, PO Box 694, Bowral 2576

Other comments:
- Flood plan is currently being revised in view of template developed by Chas Keys.
- Previous flood hotspots have been Farmborough Close and Shepherd Street.
- Police, Council and SES would liaise re road closures.
- Improvements to channel near the swimming pool (concrete) and at the railway underpass are thought to have reduced flood risk.
- Community flood education brochures have been forwarded to Council.

Telstra Country Wide

Contact: Alan Maher (Service & Technical Operations Manager, Illawarra), Alan.Maher@team.telstra.com

Potential damage:
A number of major cable routes would be affected in the event of a flood:

- Across Shepherd St: P100 (c6 a 400pr cable in duct)
- Across Merrigang St: 2XP.p100 (30/F 2001 BOWL-NEWT. O/F CABLE OPTUS.)
- Across Oxley Hill Rd: 2X p100 (3x100, 24F 1204 BOWL.)
- In area of Alcorn St: 4x A100 (100pr,200pr,30F BOWL-NEWT, 6F 3001, 1800pr cable)

Wingecarribee Indigenous Advisory Committee

Contact: Annemaree Dalziel (Cultural Officer), PO Box 141, Moss Vale 2577

Other comments:
River banks may be sites indicating earlier Aboriginal land use, and if flood mitigation works are to be carried out, contractors should be aware of this. Should archaeological sites be found – most likely on relatively undisturbed portions of the floodplain – it is appropriate that the committee be notified and appropriate archaeological survey is undertaken. Consult NPWS register of known sites.

Bowral Floodplain Risk Management Study & Plan : Display of Recommended Plan - Summary of Responses Received to 23 June 2005														
Surv. #	**Date**	**Q1 Support recomm. measures?**			**Q2 Consider meas. not recomm.?**			**Q3 Consider other measures?**			**Q4 Support prop. plann. & dev. cont.?**			**Q5 Other comments**
		Yes	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	
1	24-May	1		Retford Park retention ponds		1	Agree that levee around Farm. Cl would trap local runoff	1		Measures to address stormwater runoff from Ascot Rd - drain running down Albert St can't cope; road works required to change camber on Albert St to redirect water to the open area to the east				Flooding of Farmborough Cl in 1999 and 2005 was stormwater runoff. Careful re further development along Ascot Rd.
2	26-May	1		Bowral Golf Course detention basin										
3	26-May				1		Widen/dredge the creek for immediate protection							
4	26-May		1		1							1		Negative effects on property values for properties previously not considered flood prone - grossly unfair
5	26-May		1		1			1			1			
6	26-May		1			1		1			1			Wanted someone to speak to at display
7	26-May	1	1	Rubbish removal regularly would be a great benefit to flow of the stream - should be high priority. Demolition of existing buildings absurd.		1			1		1		Development control on future buildings	
8	26-May	1	1			1								
9	26-May	1				1	Consider only if recommended measures no longer feasible				1			
10	26-May		1		1							1		As usual it makes no sense
11	26-May	1	1	Most measures OK. Object to removing Victoria St Bridge - develop as an attractive feature of the Cherry Tree walk.				1		Drainage in Victoria Street Bowral inadequate	1		Within reason	Public consultation is good
12	26-May	1	1	Most OK - leave Victoria St Bridge - kids need to get to school - part of "walking zone"	1			1		Drainage in Victoria Street Bowral inadequate - 1 drain fro 95% of street is totally blocked in spite of several years of complaints			Within reason	
13	26-May		1		1			1				1		
14	26-May		1		1				1		1			Why approve this flood plan when it is only theoretical and yet affects so many properties adversely. Irrespective of new flood levels, the remedial works still need to be done based on old flood levels.
15	26-May		1	Surely some Creek cleaning should be undertaken	1		Stop development close to creek until improvements done	1		A wet detention basin on land owned by WSC bounded by Old South Road, McDonald and Shepherd Sts		1	Houses in Farmborough Close were built to recommended standards so hardly fair they be demolished at owners' expense	Victoria St bridge should be rebuilt higher if only for safety of proposed retirement village residents
16	26-May	1			1		Levees	1		A query re Oxley Bridge - i.e. a private wooden bridge behind the industrial area - it does get blocked	1			Regular maintenance of creek once major clearing of weeds etc
17	26-May	1			1			1			1			
18	26-May		1		1			1		Include stormwater		1	It means we will have to raise our house with our own money	
19	26-May	1		But concerned about how many will actually get done - studies are fine - Retford Park detention basin is vital				1		No mention of filtration traps for rubbish or regular removal of gravel	1			Council has dredged the creek from Merrigang St to the pool - what about from Bowral St to Merrigang St - it has as much rubbish and weeds and reeds. More houses in Bowral St west and south of creek are in danger of flooding. Why do half the job?
20	26-May	1				1					1			

Bowral Floodplain Risk Management Study & Plan : Display of Recommended Plan - Summary of Responses Received to 23 June 2005														
Surv. #	**Date**	**Q1 Support recomm. measures?**			**Q2 Consider meas. not recomm.?**			**Q3 Consider other measures?**			**Q4 Support prop. plann. & dev. cont.?**			**Q5 Other comments**
		Yes	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	
21	26-May													Were all the bridges considered to be blocked simultaneously or one by one? If all together why? Were the bridges considered blocked to 50% in 1988 and 1999 flood models? Were the 1988 and 1999 floods ARIs determined and if so how? How were the Berrima Flood Studies by Bewsher Consulting used in the preparation of the Report? How was the model calibrated, were ratings curves used from downstream? By placing a 1:100 design storm into a model of the stream then applying a blockage factor what flood are you really predicting? What evidence is there of a high debris load to cause 50% blockage of all bridges? Why was the proposed basin east of Old South Road stopped at the boundary of Retford Park? What effect has the new basin off Boardman Rd south of Retford Park? What RI were the 1988 and 1999 floods? Why disregard OSD for yet to be developed lands up to the 1:100? An error of 0.3-0.4m in accuracy has an effect on those properties affected by the 1:100 year flood.
22	31-May		1		1			1		Storm water		1	What controls?	
23	31-May		1	No way	1		Correct data	1		Storm water		1	What controls?	Half a report of flawed data at a cost of $210,000 is a waste of ratepayers money
24	31-May		1		1			1		Why was not the stormwater infrastructure not included in the brief? Where do you think the water comes from - underground?			What controls? Little seems to be evident, certainly that which significantly affects additional stress on sewerage and drainage	
25	31-May													Grave reservations about accuracy of the Berrima Flood Study and the Bowral Flood Study
26	31-May													Against 50% blockage factor, this could be reduced to approx 5% by removing from creek all debris, weeds and reeds etc and by widening and deepening the creek
27	31-May		1	Against Retford Park basin - of no benefit	1		Immediate dredging and widening required							Disputes entire study
28	31-May	1		Fast track Retford Park detention basin	1		Immediate work to clear, widen, straighten and reinstate collapsed banks of creek over its full length; make available in forthcoming budget sufficient funds to carry out initial clearing and mitigation works and ongoing funds to maintain the waterway							Proposed plan (e.g., for residents to pay to raise houses) has caused distress and anger. Threaten legal action. Advised that some insurance companies and lenders would not cover properties or finance renovations or prospective purchasers in the area.
29	31-May	1			1		Mittagong Creek must be cleared of reeds, growth and debris, also widened in areas	1		Council to regularly clean gutters and stormwater drains		1	There are too many homes being built in low areas that are flood-prone (Ascot Road)	This work is required urgently.
30	31-May		1		1		Priority - clean out Mittagong Creek							First step: clear out rubbish and overgrowth vegetation. Secondly, doesn't agree that residences in low risk area need be raised up. Third, need larger pipes and more control over where houses are permitted to be built. Council needs to do remediation work before the Plan is implemented.
31	31-May													Flood water from creek has been no threat since moved to property in 1979. No levees please - ugly and may breach. Retention basin would create a safe and attractive area. Regular clearing of creek would allow creek to flow freely. Use volunteers to make creek a safe and popular area.

Bowral Floodplain Risk Management Study & Plan : Display of Recommended Plan - Summary of Responses Received to 23 June 2005														
Surv. #	**Date**	**Q1 Support recomm. measures?**			**Q2 Consider meas. not recomm.?**			**Q3 Consider other measures?**			**Q4 Support prop. plann. & dev. cont.?**			**Q5 Other comments**
		Yes	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	*Yes*	*No*	*Explanation*	
32	31-May	1	1	Supports Retford Park Detention Basin would reduce downstream flooding and alleviate stress and anxiety. Objects to use of flood certificates.										Detailed letter. Foresees legal action over past council actions. Need more consideration of local (stormwater) flooding. Details items included in brief but not done (as far as he can see). Queries blockage factors. Queries new design flood levels at his property. Objects to flood certificates. Objects to use of McGuire's Crossing rainfall. Need Flood Plan. Does not want to see new flood levels adopted (?). If flood certificates are issued, would remove the PMF/extreme flood level, but add an advice clause to the effect that there may be a very remote possibility that an extreme flood could occur that would exceed designated levels. Details the Bowral Street Bridge 'debacle'. Questions blockage factors applied for 5 year and 10 year floods.
33	1-Jun	1		Strongly support Retford Park basin	1		The Bowral Street detention basin	1		Concerned about stormwater from Myrtle St and Elm St - no proper drainage (see letter for more detail)				Further housing development and its component of hard surfaces should be closely controlled.
34	1-Jun	1		Supports Retford Park Detention Basin	1		The atrocious condition of the creek from the railway underpass to below Oxley Hill Rd bridge should be investigated thoroughly. This is where the bottleneck occurs.	1		The stormwater system must be upgraded	1			Disappointed with Council's responses to questions at public meeting. Sympathises with those whose properties will be devalued as a result of the Study.
35	1-Jun					1	Creek needs immediate attention, dredging, widening, deepening, regular maintenance							Against rezoning of area which is expected to adversely affect property values
36	3-Jun													Having been through '88 and '99 floods and seen that floodwater came nowhere near his property, doubtful about design flood levels. Blockage assumptions seem very unlikely. What increase or decrease in flood levels would there be at his property?
37	3-Jun													Stormwater should have been addressed. Do not believe Council has sufficient accurate data on hand to make any informed decisions.
38	3-Jun													Insistence that creek needs to be cleared, disputes consultant's finding that clearance would make little difference, rejects recommendation for Riparian Corridor Management Study, insists on immediate clearance of creek
39	16-Jun		1	Oppose proposed Bowral Golf Course detention basin because 2m earth wall would severely affect visual amenity of a number of residences in Berida Park and would spread waters in a maximum flood across wider flow path. Careful construction and maintenance of wall required to avoid erosion and failure in major flood with catastrophic results downstream.				1		Construct a series of detention and storage (10,000 to 30,000 m3) basins upstream of the 1st fairway of Bowral Golf Course - flood mitigation and water storage for golf course, and supplement onsite storage requirements for new and expanded developments along Kangaloon Road. Install much larger culverts under Moss Vale Road to remove damming effect of MV Rd on Beavan Place.				Detailed submission. All development approvals for properties upstream of Berida Park be required to incorporate OSD. The flood risk management for the Beavan Place sub-catchment should be available for review by the residents and the Bowral Golf Course Board of Directors prior to its finalisation.

BOWRAL FLOODPLAIN RISK MANAGEMENT STUDY & PLAN

Feedback Questions and Answers

Why not take stormwater/overland flow into account?

The study is a floodplain study. Therefore it involves looking at resolving issues related to flooding of the creek.

Council is looking to undertake further investigations to try and resolve the localised flooding issues relating to stormwater / overland flows e.g. Farmborough Close.

Why not widen and deepen the creek?

We are talking about very large creek flows in this study. In the 1 in 100 year event, the flow at the Bowral Street Bridge is estimated as 150 cubic metres per second or 150,000 litres per second.

If the water was flowing along the creek at 1metre per second and the creek was 3m deep we would need a channel 50m wide to contain the flow. Even if the flow velocity was 2 metres per second we would still need a channel 25m wide to contain the flow.

The flow increases to be approximately 200m^3/s immediately downstream of the railway underpass. So the channel would need to be 67m wide (1m/s) or 34m wide (2m/s).

The flow velocity in the creek is estimated at between 1 and 2m/s.

If the existing creek is 5m wide by 3m deep we would have to excavate about 465,000 cubic metres of material to widen the creek to 25m from Bowral Street to the Wingecarribee River. If we pay $20 per cubic metre for excavation it would cost approximately $9.3M. That is without disposal costs for the excavated material. This could also involve costly property acquisitions and demolition of privately owned structures along the creek.

Even then there would still be narrowing of the creek at the existing bridges which would restrict the flow capacity unless all the bridges were also replaced to the new creek width.

This process makes no environmental considerations for the creek ecosystem.

Why doesn't Council clear the creek?

Council has to consider the environmental impacts as well as flooding when dealing with the creek.

The floodplain risk management study recommends that Council undertakes a riparian study along the creek corridor. This study would be expected to come up with recommendations for management of the creek corridor after considering flooding, environmental and other considerations as well as the resident, recreational and environmental needs.

This would provide Council with a plan for care of the creek system.

The increased reed growth is believed to be a response to increased levels of plant nutrients in the creek water. For example fertiliser from people's lawns and gardens washes into the creek and improves growing conditions for the reeds.

Concentrate on the present and not the future.

The floods described in the study are theoretically possible according to the current computer modelling methods for stormwater analysis in Australia.

The size of the events we are considering are very large and therefore experience and estimation are the only methods available. As no-one has experienced anything like the 1 in 100 year flood event in Bowral it can only be estimated.

It is not a prediction of a flood in 100 years time. It is possible for a 1 in 100 year flood event to happen tomorrow, so Council is really trying to find solutions for the existing potential flooding situation along the creek.

Why use blockage factor in the modelling?

Blockage factors are a recently added factor in flood modelling. Council's previous 1990 study did not allow for any blockage of the bridges and culverts along the creek.

Following the experience of Wollongong in 1998 where large culverts were blocked and caused flooding, during a large storm event, consideration of blockage is now included in these types of studies.

Wollongong now employs a 100% blockage factor for all structures with less than a 6m clear span. The blockage factors adopted for the Bowral study are less than this.

The level of blockage included in the modelling is an engineering judgement that was considered by the floodplain management committee.

Why apply blockage factors to all structures at the same time?

The effects of the blockage factors by increasing flood levels are localised to the area immediately upstream of the bridge or culvert. In the Bowral case, this flooding remains localised and does not increase the flood levels at upstream structures.

Why waste money on building a structure at Retford Park?

The proposed Retford Park detention pond is anticipated to be an earth structure similar to the detention basin at the Pony Club at Burradoo on Moss Vale Road only larger.

This structure would have an effect on stormwater flows in larger storm events. In this way the natural flow in the creek is maintained most of the time.

Properties that would be flooded in the 1 in 10 year flood event may still experience some flooding. But they would be protected from catastrophic flooding in larger storm events.

This structure would have the greatest impact of all the proposed measures on flood levels in Bowral.

Why not construct detention basins in the Centennial Road area?

The computer models indicate that the peak flow from the Centennial Road area would pass through the creek system before peak flow from the rest of the catchment arrives. Restricting the flow from this area would only serve to increase the flow in the main creek system.

Why is the new Bowral Street Bridge overtopped in the 1 in 100 storm event?

Bowral Street would still be flooded to the east so there was minimal benefit in maintaining access along Bowral Street by constructing the bridge higher.

Why is Council proposing to classify some properties as "Low Flood Risk" when previously they were not "flood prone"?

Before 2001, only properties inundated in a 1 in 100 year flood were considered "flood prone". In 2001, the State Government expanded the definition of flood prone land to include land flooded in the probable maximum flood (PMF). The PMF is a very rare flood, much bigger than in the 1 in 100 year flood. With this change in definition, many more properties are now officially "flood prone" than was previously the case. Council cannot change this definition but is considering classifying land as "Low Flood Risk" which is not flooded in a 1 in 100 year flood but is inundated in the PMF. This seems the best way of complying with the State Government's requirements yet recognising the flood risks as being low when compared with other land which is flooded in the 1 in 100 year event (which is proposed to be classified as "Medium" or "High" flood risk). The proposed system of flood risks is not a zoning. No changes to existing zones under Council's LEP are currently being considered due to flooding.

APPENDIX H

RECOMMENDED LEP PROVISIONS

(Revised November 2008, Amended June 2009)

DEFINITIONS

[To be inserted into the Dictionary of the Template LEP in alphabetical order:]

Flood liable land (being synonymous with ***flood prone land*** and ***floodplain***) is the area of land which is subject to inundation by floods up to and including a probable maximum flood (PMF).

> ***NOTE:*** At the time of writing, there was no consensus between DoP and DECC about the desirability of defining flood liable land in the LEP by maps. While in the Consultant's view, this is undesirable (see Chapter 6 of the Bowral FRMS&P, Final Report, June 2009), a compromise position would be to leave the above formal definition but to say that flood liable land *also* includes any land identified on a map held in the office of Council as may be amended from time to time.

Probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location.

STANDARD CLAUSE

[To be inserted as Clause 5.13 in the LEP Template]

5.13 Development on Flood Liable land

(1) The objective of this clause is to ensure that the risk to human life and damage to property due to flooding is appropriately managed by controlling development.

(2) When undertaking an assessment required by this clause, Council must take into consideration

  (a) the impact of the development in combination with the cumulative impact of development which is likely to occur within the future, within the same floodplain; and

  (b) the potential for changes to flood conditions in the future due to climate change.

(3) Consent must not be granted to development on flood liable land unless the development:

  (a) is consistent with any floodplain risk management plan adopted by Council in accordance within any relevant Manual as published by the State Government;
  (b) is consistent with any development control plan adopted by Council to manage flood risks;
  (c) does not detrimentally increase the potential flood effect on other development or property;
  (d) does not significantly and detrimentally affect the environment of the floodplain by causing avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of the riverbank or watercourse
  (e) will not result, to a substantial degree, in an increased risk to human life; and
  (f) is unlikely to result in additional economic and social cost which could not reasonably be managed by potentially affected persons and the general community.

APPENDIX I

DRAFT STANDARD FLOOD RISK MANAGEMENT PROVISIONS DEVELOPMENT CONTROL PLAN

(Revised November 2008, Amended June 2009)

DRAFT

Standard Flood Risk Management Provisions

Development Control Plan

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To be adapted and inserted into Part A of future DCPs

Provisions Applicable to All Land

Section numbering and format adopted from preliminary version of Draft DCP for Moss Vale

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A4.3 Flood Liable Land

A4.3.1 Introduction

This section applies to any development for which consent is required that is located on land affected by flooding (flood liable or flood prone land).

In 1984, the State Government introduced its Flood Prone Land Policy applicable to New South Wales. The first Floodplain Development Manual (FDM) was published in 1986, providing guidelines for the implementation of the government's Flood Prone Land Policy and the merit approach that underpins its application.

In 2005, the State Government released revised guidelines under the *Floodplain Development Manual* (FDM April 2005) to support the Flood Prone Land Policy, the primary objective of which is:

> *"to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible."*

Local Government is the primary authority responsible for both flood risk management and land use planning New South Wales. The State Government's flood policy provides for a flexible merit based approach to be followed by local government when preparing controls for planning, development and building matters on flood liable land. For Council to fully carry out its responsibilities for management of flood liable land, it is necessary to prepare a local *"Floodplain Risk Management Plan*" (FRMP).

The FDM requires that Councils prepare *Floodplain Risk Management Studies* (FRMS) as a prelude to the formulation of a FRMP that, among other things, would control development and other activity within the floodplain. The process for preparing a FRMS and FRMP is depicted by **Figure 1**.

The following controls are consistent with the State Government's "Flood Prone Land Policy" and the FDM. The controls in this section represent an application of the State Policy that reflects local circumstances as identified for some floodplains, through the preparation of FRMSs and FRMPs.

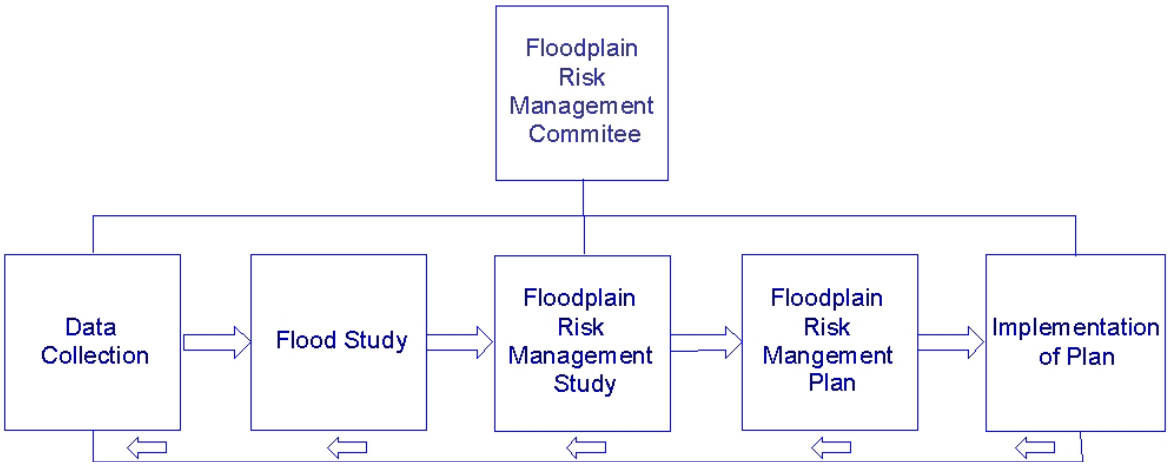


Figure 1 *- Floodplain Risk Management Process (FDM, 2005)*

The purpose of this section is to guide development to ensure risk to life and property associated with flooding is minimised in a manner consistent with the Policies of Council formulated under the NSW Flood Policy and Floodplain Development Manual.

A4.3.2 Objectives

The objectives of this section are to:

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

A4.3.3 How to Use This Section

The following is a summary of the major steps to be followed in applying this section of the DCP:

Step	Task	Based on information from:
1	Determine the relevant floodplain (e.g. Bowral Floodplain). **Note**: The controls applying to "all other floodplains" are interim only until catchment specific Floodplain Risk Management Plans are prepared as required by the Floodplain Development Manual	Enquire with Council or refer to Council's flood maps.
2	Determine the Flood Risk Precinct within which your site is situated	Enquire with Council regarding existing flood risk mapping or whether a site-specific assessment may be warranted in your case (for example, if there is no existing riverine flood mapping or local overland flooding is a potential problem).

3	Determine the development category relevant to your proposal. **Note**: A property may be located in more than one Flood Risk Precinct, in which case the assessment must consider the controls relative to each Flood Risk Precinct.	Firstly confirm how it is defined by the relevant environmental planning instrument and secondly by ascertaining the applicable development category (refer to section 4.3.4 and **Schedule 2** of this Part of the Plan).
4	Check if the proposal will satisfy controls for different development categories in different Flood Risk Precincts.	Refer to sections below

The assistance of Council staff or an experienced floodplain consultant may be required at various steps in the process to ensure that the requirements of this Plan are fully and satisfactorily addressed.

A4.3.4 Requirements and Controls

A4.3.4.1 How to Determine Compliance

In formulating development proposals on land that is affected by flooding it is important to recognise that different controls will apply to different land uses, depending on the flood hazard applying to the land. The controls in this part of the DCP comprise:

- **The objectives** which are a statement of the purpose intended to be achieved by each control, to assist in understanding the control.
- **The performance criteria** which are controls that state a desired outcome and a means of assessing whether the desired outcome will be achieved.
- **The prescriptive controls** which are preferred ways of achieving the desired outcome. While adherence to the prescriptive controls may be important, it is paramount that the objectives and the performance criteria are clearly satisfied.

Step	Task	Based on information from:
1	Identify the applicable development category of the development and Flood Risk Precinct	Section 4.3.4 (and Schedule 2) for general development (fencing is separately controlled)
2	Assess whether the proposal complies with the performance criteria	Sections 4.3.5.2 for riverine flooding or 4.3.7.2 for only overland flow flooding (4.3.6.2 for fencing)

3	Assess whether the proposal complies with the prescriptive controls	Sections 4.3.5.3 for riverine flooding or 4.3.7.3 for only overland flow flooding (4.3.6.3 for fencing)
4	If the proposal does not comply with any prescriptive controls, any variations must be justified by demonstrating compliance with the performance criteria are nonetheless clearly complied with and the relevant objectives are satisfied.	See Step 2

A4.3.4 Development Categories

The range of potential development types listed within the Draft LEP 2008 has been grouped into major development categories based on the sensitivity to flood risks. The eight development categories are:

- Critical uses and facilities
- Sensitive uses and facilities
- Residential
- Subdivision (***Note**: Applies to Berrima Floodplain only*)
- Commercial or industrial
- Tourist Related Development (***Note**: Applies to Berrima Floodplain only*)
- Recreation and non urban
- Concessional development

The development categories are outlined **Schedule 2**.

A4.3.4 Flood Risk Precincts

The objective of dividing the floodplain into flood risk precincts is to grade the relative severity of flood risks across the floodplain to provide a basis to assign controls on development.

Each of the floodplains within the local government area can be divided into precincts based on different levels of potential flood risk. The relevant Flood Risk Precincts (FRPs) for each of the floodplains are outlined below.

<u>High Flood Risk Precinct</u>

This has been defined as the area of land below the 100 year flood that is either subject to a high hydraulic hazard in the 100 year flood (as defined in Figure L2 of the NSW Government's Floodplain Development Manual, 2005) or where there are significant evacuation difficulties. In the case of the Berrima Floodplain, high hazard areas are taken to be those areas subject to inundation in a 20 year ARI flood event. The high flood risk precinct is where high flood damages, potential risk to life, and evacuation problems would be anticipated or development would significantly and

adversely 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 that is not subject to a high hydraulic hazard and where there are no significant evacuation difficulties. In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

Fringe-Low Flood Risk Precinct (***Note**: Does not apply to Berrima Floodplain*)

The land between the extents of the 100 year flood and the 100 year flood plus 0.5m in elevation (being a freeboard). In this precinct there would still be a significant risk of flood damage, but these damages can be minimised by the application of appropriate development controls.

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 any of the above Flood Risk Precincts. The Low Flood Risk Precinct is where risk of damages is low for most land uses and most land uses would be unrestricted within this precinct.

A4.3.5 Controls for General Development

This section outlines the controls that apply to general development (excluding fencing) on flood liable land other than land affected only by local overland flooding. The development controls are graded relative to the severity and frequency of the potential floods based on the findings of a floodplain risk management plan or council's interim considerations when such a plan does not yet exist.

It is intended that development controls and a planning matrix for other floodplains within the Shire will be included in the Schedules of this Part of the DCP following the completion of more floodplain risk management plans.

A4.3.5.1 Objectives

The objectives of the controls for general development are:

1. To require development with high sensitivity to flood damages or danger to life to be sited and designed so that it is subject to minimal flood hazard.
2. To allow development with low sensitivity to flood damages or danger to life to be located within a floodplain subject to design and siting controls and provided the chance of personal harm and damage to property is minimised.
3. To ensure that the design and siting controls and built form outcomes required to address the flood hazard do not result in unreasonable impacts on the:
    - amenity and character of an area;
    - streetscape and the relationship of the building to the street;

- social and economic outcomes; and the
- environment and ecology.

4. To ensure the flood risk within the development, comprising danger to life and damage to property, is minimised and not increased beyond the level acceptable to the community.
5. To ensure that the proposed development does not exacerbate flooding on other properties.

A4.3.5.2 Performance Criteria

The performance criteria for general development are:

(a) The flood risk associated with the development comprising danger to life and damage to property is minimised and not increased beyond the level acceptable to the community.

(b) The additional economic and social cost which may arise from damage to property from flooding is not greater than that which can reasonably be managed by the property owner and general community. The cost of damages that may be incurred over the expected life of a development should be no greater than that which could be reasonably expected to be met by the occupants and/or the developer without Government assistance.

(c) Effective warning time and reliable access is available for evacuation from an area potentially affected by all floods to an area free of risk from flooding.

(d) Motor vehicles associated with the development are able to be relocated, undamaged, to an area with substantially less likelihood from flooding, within the effective warning time.

(e) Appropriate procedures (such as warning systems, signage or evacuation drills) for development categories of “critical uses and facilities” and “sensitive uses and facilities” be in place, if necessary, so that people are aware of the need to evacuate personnel and relocate goods and motor vehicles during a flood, and are capable of identifying an appropriate evacuation route.

(f) Development does not detrimentally increase the potential flood effects on other development or properties either individually or in combination with the cumulative impact of development that is likely to occur in the same floodplain. Development should not change the height or behaviour of floodwaters elsewhere in the floodplain in a manner which is likely to affect other property. The assessment of these effects must include the potential for similar impacts that would arise as a consequence of other development in the floodplain that has the potential to occur in the future under current zoning and planning controls.

(g) Development does not result in significant impacts upon the amenity of an area (e.g. by way of unacceptable overshadowing of adjoining properties) or privacy impacts (e.g. by unsympathetic house-raising).

(h) Development must be compatible with the existing and planned streetscape and character of the locality.

(i) The design of car parking (enclosed or uncovered) and associated driveways should not result in unacceptable environmental or amenity impacts such as visual intrusion from elevated driveways and parking structures and overshadowing of adjoining residential properties.

(j) The proposal must not have an unacceptable adverse impact upon the ecological value of the waterway corridors, and where possible, should provide for their enhancement.

(k) Development does not prejudice the economic viability of any Voluntary Acquisition Scheme, by significantly increasing the value of property above the existing or likely future funds available in the scheme.

A4.3.5.3 Prescriptive Controls

The prescriptive controls for general development are:

(a) Compliance with the requirements of the planning matrix for the relevant floodplain within the Shire as contained in Schedules 4 and 5.

(b) Development within the commercial centres must ensure that design solutions address flood risk management objectives as well as providing appropriate urban design outcomes, particularly in regard to:

  (i) Ground floor levels that are consistent with existing adjoining commercial development or form part of an integrated design which incorporate the frontage of a whole street block. Note: design solutions could include, flood proofed shop front windows at street level and confined active spaces (such as eating areas) at the street level which are substantially constructed of flood compatible materials and building components or able to be closed off with flood proof doors. Ground floor areas away from the street interface may vary subject to being adequately integrated.

  (ii) Acceptable access for persons with disabilities; and

  (iii) An overall building height that is compatible with the existing and planned streetscape.

(c) Proposals for house raising must provide appropriate documentation including:

  (i) a report from a suitably qualified engineer to demonstrate that the raised structure will not fail from the forces of floodwaters in a 100 year ARI flood; and

(ii) the provision of details such as landscaping and architectural enhancements which ensure that the resultant structure will not result in significant adverse impacts upon the amenity and character of an area.

(d) Notwithstanding any other provision, where a property is identified within a Voluntary Acquisition Scheme area, Council will only consent to further development being "concessional development"; provided:

(i) the development is for only minor works such as small awnings over existing balconies or in-ground swimming pools; and

(ii) capital investment intended for the property is, in the opinion of Council, not greater than the minimum required to satisfy acceptable standards.

A4.3.6 Controls for Fencing

Fencing can have a significant influence on the distribution of flood waters. The implications of fencing are greater where flood waters are deeper and faster moving such as is expected in a high flood risk precinct.

A4.3.6.1 Objectives

The objectives of the controls for fencing are to ensure that development involving fencing has fencing constructed:

1. in a manner that does not affect the flow of flood waters so as to result in additional flood impacts on surrounding land; and
2. so as to withstand the forces of floodwaters, or collapse in a controlled manner to prevent the undesirable impediment of flood waters.

A4.3.6.2 Performance Criteria

The performance criteria for fencing are:

(a) Fencing is to be constructed in a manner that does not affect the flow of flood waters so as to detrimentally change flood behaviour or increase flood levels on surrounding land.

(b) Ability to be certified by a suitably qualified engineer, that the proposed fencing is adequately constructed so as to withstand the forces of floodwaters, or collapse in a controlled manner to prevent the undesirable impediment of flood waters.

A4.3.6.3 Prescriptive Controls

The prescriptive controls for fencing are:

(a) Fencing within a High Flood Risk Precinct must be security/ permeable/ open type/safety fences. Council may require such fencing to be able to be opened at the bottom with the force of floodwaters. (This requirement may be secured by a Section 88B instrument burdening the title of the land).

(b) An applicant will need to demonstrate that any fence would create no impediment to the flow of floodwaters. Appropriate fences must satisfy the following:-

(i) An open collapsible hinged fence structure or pool type fence;

(ii) Other than a brick or other masonry type fence (which will generally not be permitted); or

(iii) A fence type and siting criteria as prescribed by Council.

A4.3.7 Controls for Overland Flow

The effects of overland flow, also defined as local overland flooding, are to be assessed in the same manner as mainstream flooding. In addition there are other specific considerations as outlined below.

A4.3.7.1 Objectives

The objectives of the controls for overland flow are:

1. To ensure that the impacts and flood risks associated with overland flow are addressed when assessing a development proposal.

A4.3.7.2 Performance Criteria

The performance criteria for overland flow are:

(a) The performance criteria for general flood prone land apply.

A4.3.7.3 Prescriptive Controls

The prescriptive controls for overland flow are:

(a) Proposals involving collecting and piping overland flow through the subject property or upgrading a section of Council's existing pipe-infrastructure, will generally not be acceptable for the following reasons:

i. there is a substantial potential for system blockage due to the limited number of inlets available;

ii. the natural detention storage available within the catchment is reduced and flow velocities are increased; and

iii. due to greater rates of flow, it may cause localised increases in hazard at the system outlet and greater scour of natural creeks and/or disturbance of the downstream river bed.

(b) Proposed land subdivisions of lots affected by overland flow will not be approved unless the applicant can demonstrate to Council that it is possible to provide an acceptable development on the newly created

lot that satisfies general planning considerations while meeting the overland flow management criteria outlined in this document.

A4.3.8 Information Requirements

A4.3.8.1 Introduction

This section outlines the information that is likely to be required in the formulation of a competent development proposal on flood liable land and to assess the acceptability of the proposal.

A4.3.8.2 Objective

To ensure that adequate information is available in the formulation and assessment of a development proposal on flood liable land.

A4.3.8.3 Information Requirements

1. Applications must include information that addresses all relevant controls listed above, and the following matters as applicable.
2. Applications for Concessional Development (see **Schedule 2**) to an existing dwelling on flood liable land shall be accompanied by documentation from a registered surveyor confirming existing floor levels.
3. A survey plan showing: -
   (a) The position of the existing building/s or proposed building/s;
   (b) The existing ground levels to Australian Height Datum around the perimeter of the building and contours of the site; and
   (c) The existing or proposed floor levels to Australian Height Datum.
4. Applications for earthworks, filling of land and subdivision shall be accompanied by a survey plan (with a contour interval of 0.25m) showing relative levels to Australian Height Datum.
5. For large scale developments, or developments in critical situations, particularly where an existing catchment based flood study is not available, a flood study using a fully dynamic one or two dimensional computer model may be required. For smaller developments the existing flood study may be used if available and suitable (e.g. it contains sufficient local detail), or otherwise a flood study prepared in a manner consistent with the “Australian Rainfall and Runoff” publication, any relevant Council Drainage Design Code and the Floodplain Development Manual, will be required. From this study, the following information shall be submitted in plan form:
   a. water surface contours (including the 100 year flood and PMF extents);
   b. velocity vectors;

c. velocity and depth product contours;

d. delineation of Flood Risk Precincts relevant to individual floodplains; and

e. show both existing and proposed flood profiles for the full range of events for total development including all structures and works (such as revegetation/ enhancements).

This information is required for the pre-developed and post-developed scenarios.

6. Where the controls for a particular development proposal require an assessment of structural soundness during potential floods, the following impacts must be addressed:

a. hydrostatic pressure;

b. hydrodynamic pressure;

c. impact of debris; and

d. buoyancy forces.

Foundations need to be included in the structural analysis.

Dictionary

(To be inserted in alphabetical order into DCP)

Adequate Warning Systems, Signage and Exits is where the following is provided:

(a) an audible and visual alarm system which alerts occupants to the need to evacuate, sufficiently prior to likely inundation to allow for the safe evacuation of pedestrians and vehicles;

(b) signage to identify the appropriate procedure and route to evacuate; and

(c) exits which are located such that pedestrians evacuating any location during any flood do not have to travel through deeper water to reach a place of refuge above the 100 year flood, away from the enclosed car parking.

"Annual" is a dwelling site in a caravan park used as a "holiday van" site. "Holiday van" is defined in the *Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 2005* as "a moveable dwelling (other than a tent) that is or usually is continuously located on a short-term site and used primarily by its owner for occasional occupancy for holiday purposes".

Australian Height Datum (AHD) is a common national plane of level corresponding approximately to mean sea level.

Average Recurrence Interval (ARI) means the long-term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.

Compensatory Works refers to earthworks where material is excavated (or "cut") from one location in the floodplain and placed (or "filled") at another location in the floodplain, with no net importation of fill material, such that the volume available for storage of flood waters is not altered for all floods.

Conveyance is a direct measure of the flow carrying capacity of a particular cross-section of a stream or stormwater channel. (For example, if the conveyance of a channel cross-section is reduced by half, then the flow carrying capacity of that channel cross-section will also be halved).

Design floor level or ground level means the minimum floor level that applies to the development. If the development is concessional development, this level is determined based on what development category would apply if it was not categorised as Concessional Development.

DISPLAN means a step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.

Ecologically Sustainable Development (ESD) is using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased.

Effective warning time is the time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being

undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.

Enclosed car parking means car parking which is potentially subject to rapid inundation, which consequently increases danger to human life and property damage (such as basement of bunded car parking areas). The following criteria apply for the purposes of determining what is enclosed car parking:

(a) Flooding of surrounding areas may raise water levels above the perimeter which encloses the car park (normally the entrance), resulting in rapid inundation of the car park to depths greater than 0.8m, and

(b) Drainage of accumulated water in the car park has an outflow discharge capacity significantly less than the potential inflow capacity.

Flood is a relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage as defined by the FDM before entering a watercourse.

Note: Consistent with the Floodplain Development Manual, this section of the DCP does not apply in the circumstances of local drainage inundation as defined in the Floodplain Development Manual and determined by Council. Local drainage problems can generally be minimised by the adoption of urban building controls requiring a minimum difference between finished floor and ground levels.

Flood awareness is an appreciation of the likely effects of flooding and knowledge of the relevant flood warning and evacuation procedures.

Flood compatible building components means a combination of measures incorporated in the design and/or construction and alteration of individual buildings or structures subject to flooding, and the use of flood compatible materials for the reduction or elimination of flood damage.

Note: A list of typical flood compatible building components is provided in **Schedule 1**.

Flood compatible materials include those materials used in building which are resistant to damage when inundated.

Note: A list of typical flood compatible materials is provided in **Schedule 1**.

Flood evacuation strategy means the proposed strategy for the evacuation of areas within effective warning time during periods of flood as specified within any policy of Council, the FRMP, the relevant SES Flood Plan, by advices received from the State Emergency Services (SES) or as determined in the assessment of individual proposals.

Flood prone land (being synonymous with flood liable and floodplain) is the area of land which is subject to inundation by the probable maximum flood (PMF).

Floodplain Development Manual (FDM) refers to the document dated April 2005, published by the New South Wales Government and entitled “Floodplain Development Manual: the management of flood liable land”.

Floodplain Risk Management Plan (FRMP) means a plan prepared for one or more floodplains in accordance with the requirements of the Floodplain Development Manual or its predecessors.

Floodplain Risk Management Study (FRMS) means a study prepared for one or more floodplains in accordance with the requirements of the Floodplain Development Manual or its predecessors.

Freeboard provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for a FPL is actually provided. It is a factor of safety typically used in relation to the setting of flood levels, levee crest levels, etc. (as specified at Section K5 of the FDM). Freeboard is included in the flood planning level.

Habitable floor area means:

- in a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom;
- in an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

Note: Separate considerations are specified for the car parking area of a development irrespective of the land use with which it is associated.

Hazard is a source of potential harm or a situation with a potential to cause loss. In relation to this plan, the hazard is flooding which has the potential to cause harm or loss to the community.

Infill development is development which is proposed within established existing urban area and usually involves the development of a vacant residential site, or the removal of an existing residential or retail/commercial building to provide a replacement building for a similar use.

Local drainage means small scale inundation in urban areas outside the definition of major drainage as defined in the Floodplain Development Manual. Local drainage problems invariably involve shallow depths (less than 0.3m) with generally little danger to personal safety.

Local overland flooding (being synonymous with overland flow) means inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.

Outbuilding means a building that is ancillary to a principal residential building and includes sheds, garages, carports and similar buildings but does not include granny flats.

Practical means that which in the opinion of Council can be achieved within the design of the development, while not necessitating:

(a) floor levels to be raised in a way that would unreasonably hinder access to and from existing floor levels or ground levels on the same site or adjacent public areas; and

(b) the raising of a structure to a height that would result in unacceptable impacts on the amenity of adjacent residential properties; and

(c) the height or presentation of a building that would be inconsistent with the existing or planned streetscape.

Note: Examples of where the preferred design may not be practical include:

Example 1: A minor extension to an existing dwelling (falling within the "Concessional Development" development category) where an additional room would require a floor level higher than what otherwise exists within the dwelling constraining internal movements or resulting in an unusual external appearance to the building.

Example 2: The rebuilding or refitting of a singular shop in a traditional street shopping centre where existing ground floor levels of the site and adjoining sites relate closely to the footpath level. In this case the width of the site would not be sufficient to allow for a redevelopment that could incorporate a podium level or colonnade along the street frontage at the preferred design floor flood level while remaining compatible with the existing or planned streetscape. The site would have insufficient frontage to the road to enable the creation of a site specific streetscape presentation that was compatible with, but not consistent with that otherwise prevailing in the shopping centre (eg. the site does not occupy a whole street block).

Example 3: The topographical site constraints of a site would require a driveway to be elevated more than 1 metre above natural ground in a location that would not allow the driveway to be incorporated in the final landscape or visually and acoustically screened from habitable rooms associated with dwellings on the site or adjacent properties. The resultant garage design and driveway levels may also be unable to meet Australian Standards. In this case the development of the site for the proposed residential purposes would otherwise be a reasonable expectation having regard to the planning controls and existing development in the locality.

Primary habitable floor area means the majority of habitable floor area and in a residential situation includes the majority of bedrooms, main living area, kitchen and first bathroom.

Probability is a statistical measure of the expected chance of flooding (see ARI).

Probable maximum flood (PMF) is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation. In the case of the Berrima Floodplain, the PMF is identical to the "extreme flood" referred to in the Berrima Flood Study (Revised) (2000) and the Berrima Floodplain Risk Management Study (2002), or later updates to these studies.

Probable maximum precipitation (PMP) is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is often the primary input to the estimation of the probable maximum flood.

Raised fill pad level is a raised area of ground upon which a dwelling or ancillary buildings must be constructed on rural or other non-urban zoned lands.

Rebuilt dwelling refers to the construction of a new dwelling on an allotment where an existing dwelling is demolished.

Reliable access during a flood means the ability for people to safely evacuate an area subject to flooding, having regard to the depth and velocity of flood waters and the suitability of the evacuation route, without a need to travel through areas where water depths increase.

Risk means the chance of something happening that will have an impact. It is measured in terms of consequences and probability (likelihood). In the context of this plan, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.

Site Emergency Response Flood Plan (not being an SES Flood Plan) is a management plan that demonstrates the ability to safely evacuate persons and include a strategy to move goods above the flood level within the available warning time. This Plan must be consistent with any relevant flood evacuation strategy, flood plan or similar plan.

Survey plan is a plan prepared by a registered surveyor which shows the information required for the assessment of an application in accordance with the provisions of this Plan.

Schedules

SCHEDULE 1
FLOOD COMPATIBLE MATERIALS & BUILDING COMPONENTS

BUILDING COMPONENT	FLOOD COMPATIBLE MATERIAL	BUILDING COMPONENT	FLOOD COMPATIBLE MATERIAL
Flooring and Sub-floor Structure	• concrete slab-on-ground monolith construction • suspension reinforced concrete slab.	**Doors**	• solid panel with water proof adhesives • flush door with marine ply filled with closed cell foam • painted metal construction • aluminium or galvanised steel frame
Floor Covering	• clay tiles • concrete, precast or in situ • concrete tiles • epoxy, formed-in-place • mastic flooring, formed-in-place • rubber sheets or tiles with chemical-set adhesives • silicone floors formed-in-place • vinyl sheets or tiles with chemical-set adhesive • ceramic tiles, fixed with mortar or chemical-set adhesive • asphalt tiles, fixed with water resistant adhesive	**Wall and Ceiling Linings**	• fibro-cement board • brick, face or glazed • clay tile glazed in waterproof mortar • concrete • concrete block • steel with waterproof applications • stone, natural solid or veneer, waterproof grout • glass blocks • glass • plastic sheeting or wall with waterproof adhesive
Wall Structure	• solid brickwork, blockwork, reinforced, concrete or mass concrete	**Insulation** **Windows**	• foam (closed cell types) • aluminium frame with stainless steel rollers or similar corrosion and water resistant material.
Roofing Structure (for Situations Where the Relevant Flood Level is Above the Ceiling)	• reinforced concrete construction • galvanised metal construction	**Nails, Bolts, Hinges and Fittings**	• brass, nylon or stainless steel • removable pin hinges • hot dipped galvanised steel wire, nails or similar.

Electrical and Mechanical Equipment For dwellings constructed on land to which this Plan applies, the electrical and mechanical materials, equipment and installation should conform to the following requirements.	**Heating and Air Conditioning Systems** Heating and air conditioning systems should, to the maximum extent possible, be installed in areas and spaces of the house above the relevant flood level. When this is not feasible every precaution should be taken to minimise the damage caused by submersion according to the following guidelines.
Main power supply - Subject to the approval of the relevant authority the incoming main commercial power service equipment, including all metering equipment, shall be located above the relevant flood level. Means shall be available to easily disconnect the dwelling from the main power supply.	**Fuel -** Heating systems using gas or oil as a fuel should have a manually operated valve located in the fuel supply line to enable fuel cut-off.
Wiring - All wiring, power outlets, switches, etc., should, to the maximum extent possible, be located above the relevant flood level. All electrical wiring installed below the relevant flood level should be suitable for continuous submergence in water and should contain no fibrous components. Earth core linkage systems (or safety switches) are to be installed. Only submersible-type splices should be used below the relevant flood level. All conduits located below the relevant designated flood level should be so installed that they will be self-draining if subjected to flooding.	**Installation -** The heating equipment and fuel storage tanks should be mounted on and securely anchored to a foundation pad of sufficient mass to overcome buoyancy and prevent movement that could damage the fuel supply line. All storage tanks should be vented to an elevation of 600 millimetres above the relevant flood level.
Equipment - All equipment installed below or partially below the relevant flood level should be capable of disconnection by a single plug and socket assembly.	**Ducting -** All ductwork located below the relevant flood level should be provided with openings for drainage and cleaning. Self draining may be achieved by constructing the ductwork on a suitable grade. Where ductwork must pass through a water-tight wall or floor below the relevant flood level, the ductwork should be protected by a closure assembly operated from above relevant flood level.
Reconnection - Should any electrical device and/or part of the wiring be flooded it should be thoroughly cleaned or replaced and checked by an approved electrical contractor before reconnection.	**Ancillary Structures (steps, pergolas, etc) -** Suitable water tolerant materials should be used such as masonry sealed hardwood and corrosive resistant metals. Copper Chrome Arsenate (CCA) treated timber is not a suitable material.

SCHEDULE 2

DEVELOPMENT CATEGORIES

Critical Uses and Facilities	Sensitive Uses and Facilities	Residential
Emergency services facilities; administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events (e.g. SES Headquarters and Police Stations); Hospitals.	Community facility; Telecommunications facility; Institutions; Educational establishments; Liquid fuel depot; Public utility undertaking (including electricity generating works and utility installations) which is essential to evacuation during periods of flood or if affected would unreasonably affect the ability of the community to return to normal activities after flood events; Residential care facility; Seniors housing.	Attached dwelling; backpackers' accommodation; bed and breakfast accommodation; boarding house; caravan park (with approved long-term sites and/or "annuals"); child care centre; dual occupancy; dwelling; dwelling house; exhibition home; group home; home-based child care centre; home business; home industry; home occupancy; home occupation (sex services); hostel; hotel or motel accommodation; moveable dwelling; multi dwelling housing; neighbourhood shop; permanent group home; residential accommodation; residential flat building; secondary dwelling; semi-detached dwelling; serviced apartments; tourist and visitor accommodation and transitional group home.

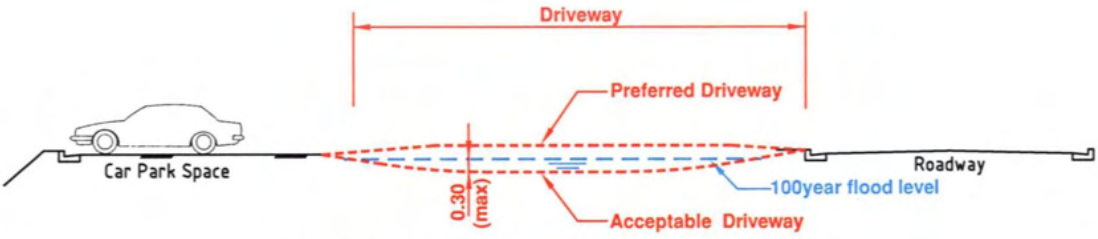
Notes

1. ***Subdivision*** where referred to in the context of flood risk management controls means any subdivision of land which involves the creation of new allotments.
2. ***Tourist related development*** where referred to in the context of flood risk management controls means cabins, camping or caravan sites which do not provide for long term occupation or any tourist facility which does not include accommodation.

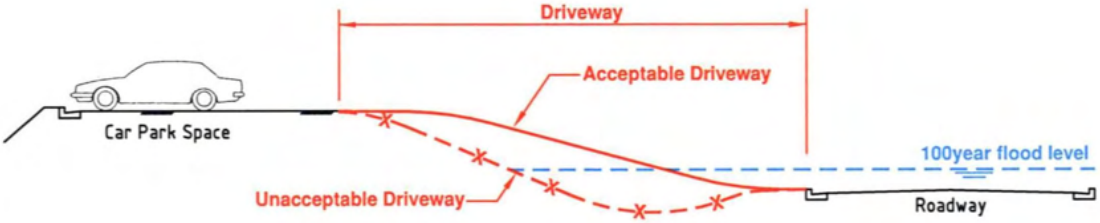
Commercial or Industrial	Recreation and Non-Urban	Concessional Development
Air transport facility; airport; amusement centre; brothel; bulky goods premises; business premises; community facility (other than critical and sensitive uses and facilities); correctional centre; crematorium; depot; entertainment facility; exhibition village; food and drink premises; freight transport facility; function centre; funeral chapel; funeral home; hazardous industry; hazardous storage establishment; health care professional; health consulting rooms; health services facility; heavy industry; heliport; highway service centre; industrial retail outlet; industry; liquid fuel depot; light industry; market; medical centre; mixed use development; mortuary; night club; offensive industry; offensive storage establishment; office premises; passenger transport facility; place of public entertainment; place of public entertainment; place of public worship; pub; public administration building (other than critical uses and facilities); recreation facility (major); registered club; restaurant; restricted premises; retail premises; self-storage units; service station; sex services premises; shop top housing; storage premises; take away food or drink premises; timber and building supplies; transport depot; truck depot; vehicle body repair workshop; vehicle repair station; vehicle sales or hire premises; veterinary hospital; warehouse or distribution centre; waste disposal facility; waste management facility; waste or resource management facility; waste or resource transfer stations; and wholesale supplies.	Animal boarding or training establishment; biosolid waste application; biosolids treatment facility; boat launching ramp; boat repair facility; boat shed; caravan park (with no approved long term sites and no "annuals"); charter and tourism boating facility; environmental facility; environmental protection works; extensive agriculture; extractive industry; information and education facility; horticulture; kiosk; landscape and garden supplies; marina; mine; mining; moveable dwelling; port facilities; public utility undertaking (other than critical uses or facilities); recreation area; recreation facility (indoor); recreational facility (outdoor); research station; resource recovery facility; restriction facilities; utility installations (other than critical uses and facilities); water recreation structure; water recycling facility; and water storage facility.	(a) In the case of residential development: (i) an addition or alteration to an existing dwelling of not more than 10% or 30m^2 (whichever is the lesser) of the habitable floor area which existed at the date of commencement of this Plan; (ii) the construction of an outbuilding with a maximum floor area of 20m^2; or (iii) rebuilt dwellings which substantially reduce the extent of flood affectation to the existing building. (b) In the case of other development: (i) an addition to existing buildings of not more than additional 100m^2 or 10% of the floor area which existed at the date of commencement of this DCP (whichever is the lesser); (ii) rebuilding of a development which substantially reduces the extent of flood risks to the existing development; (iii) a change of use which does not increase flood risk having regard to property damage and personal safety; or (iv) subdivision that does not involve the creation of new allotments with potential for further development.

Schedule 3 – Car Parking and Driveway Access Examples

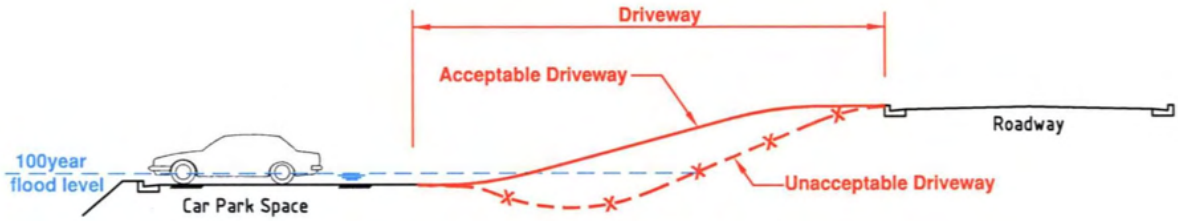
Note: Refer to Council's standard drawings for driveway details (SD 108, 109 & 110) and gradings (SD 123).



HIGH ROADWAY AND CAR PARK SPACE
(No part of driveway more than 0.3m below 100 year flood level)



LOW ROADWAY
(Driveway inundation depth not greater than roadway inundation depth)



LOW CAR PARK SPACE
(Driveway inundation depth not greater than car park inundation depth)

LOW ROADWAY AND CAR PARK SPACE
(Driveway inundation depth not greater than car park or roadway inundation depth)

Schedule 4

Berrima Floodplain

Prescriptive Controls

Template: V6.1

Planning Consideration	Low Flood Risk								Medium Flood Risk								High Flood Risk							
	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Subdivision	Residential	Commercial & Industrial	Tourist Related Development	Recreation & Non-Urban	Concessional Development
	Flood Risk Precincts (FRP's)																							
Floor Level		3		2	2	2						2	2 or 5	2	1	2,4							1	2,4
Building Components		2		1	1	1						1	1	1	1	1							1	1
Structural Soundness		3										2	2	2	2	2							1	1
Flood Effects		2	2		2	2					1	2	2	2	2	2							1	1
Evacuation		2,3									1,3	1,3	1, 3	1,3	1,3	1,3							1,3	1,3
Management & Design		4,5									1		2,3,5	2,3,5	2,3,5	2,3,5							2,3,5	2,3,5

No Controls Unsuitable Development Type (refer to General Note **b**)

General Notes:

a Freeboard equals an additional height of 500mm.

b The relevant environmental planning instruments (generally the Local Environmental Plan) identify development permissible with consent in various zones in the LGA. Notwithstanding, constraints specific to individual sites may preclude Council granting consent for certain forms of development on all or part of a site.

c Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.

d Refer to Section 4.3.6 of the DCP for planning considerations for proposals involving only the erection of a fence. Any fencing that forms part of a proposed development is subject to the relevant flood effects and Structural Soundness planning considerations of the applicable development category.

e Refer to Sections 4.3.5.2 and 4.3.5.3 of the DCP for special considerations such as for house raising proposals and development of properties identified for voluntary acquisition.

f Terms in italics are defined in the glossary of this plan and Schedule 2 specifies development categories. These development types are generally as defined within Environmental Planning Instruments applying to the LGA.

Floor Level

1 All *floor levels* to be no lower than the 20 year flood level plus *freeboard* unless justified by site specific assessment.

2 *Habitable floor* levels to be no lower than the 100 year flood level plus *freeboard* .

3 *All floor* levels to be no lower than the *PMF* level.

4 Floor levels to be no lower than the *design floor level* . Where this is not *practical* due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level is to be as high as *practical* , and, when undertaking alterations or additions, no lower than the existing floor level.

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 the premises to be flood proofed below the *design floor level* .

Building Components & Method

1 All structures to have *flood compatible building components* below the 100 year flood level plus *freeboard.*

2 All structures to have *flood compatible building components* below the *PMF* level.

Structural Soundness

1 Engineer's report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below). In the case of alterations or additions to an existing development, the structure to be certified is that which is proposed to be newly constructed or otherwise required to be of a specified standard to satisfy other controls.

2 Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below). An engineer's report may be required.

3 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a *PMF* . An engineers report may be required.

Flood Effects

1 Engineer's report required to certify that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance* ; and (iii) the cumulative impact of multiple potential developments in the floodplain.

2 The flood impact of the development to be considered to ensure that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance* ; and (iii) the cumulative impact of multiple potential developments in the floodplain. An engineer's report may be required.

Evacuation

1 Reliable access for pedestrians or vehicles required during a 100 year flood.

2 Reliable access for pedestrians or vehicles is required during a *PMF* .

3 The development is to be consistent with any relevant DISPLAN or flood evacuation strategy.

Management and Design

1 If this application involves subdivision, Applicant to demonstrate that potential development as a consequence of the subdivision, can be undertaken in accordance with this DCP.

2 *Site Emergency Response Flood Plan* required where floor levels are below the *design floor level,* (except for single dwelling-houses).

3 Applicant to demonstrate that area is available to store goods above the 100 year flood level plus *freeboard.*

4 Applicant to demonstrate that area is available to store goods above the *PMF* level.

5 No storage of materials below the *design floor level* which may cause pollution or be potentially hazardous during any flood.

Schedule 5 **Bowral & Other Floodplains**

Prescriptive Controls

Template: V6.0

Planning Consideration	Flood Risk Precincts (FRP's)																					
	Low Flood Risk						Fringe-Low Flood Risk						Medium Flood Risk						High Flood Risk					
	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development	Critical Uses & Facilities	Sensitive Uses & Facilities	Residential	Commercial & Industrial	Recreation & Non-Urban	Concessional Development
Floor Level		3						3	2,6,7	5,6,7	1,6	4,7			2,6,7	5,6,7	1	4,7					1	4,7
Building Components		2						2	1	1	1	1			1	1	1	1					1	1
Structural Soundness		3						3	2	2	2	2			2	2	2	2					1	1
Flood Effects		2						2	2	2	2	2			2	2	2	2					1	1
Car Parking & Driveway Access		1,3,5, 6,7						1,3,5, 6,7	1,3,5, 6,7	1,3,5, 6,7	2,3,4, 6,7	6,7,8			1,3,5, 6,7	1,3,5, 6,7	2,3,4, 6,7	6,7,8					2,3,4, 6,7	6,7,8
Evacuation		2						2	2	1 or 2	3	2			2	1 or 2	3	2					3	2
Management & Design		1,4,5						1,4,5	1	1,2,3,5	1,2,3,5	1,2,3,5			1	1,2,3,5	1,2,3,5	1,2,3,5					1,2,3,5	1,2,3,5

No Controls Unsuitable Development Type (refer to General Note **b**)

General Notes:

a Freeboard equals an additional height of 500mm.

b The relevant environmental planning instruments (generally the Local Environmental Plan) identify development permissible with consent in various zones in the LGA. Notwithstanding, constraints specific to individual sites may preclude Council granting consent for certain forms of development on all or part of a site.

c Filling of the site, where acceptable to Council, may change the FRP considered to determine the controls applied in the circumstances of individual applications.

d Refer to Section 4.3.6 of the DCP for planning considerations for proposals involving only the erection of a fence. Any fencing that forms part of a proposed development is subject to the relevant flood effects and Structural Soundness planning considerations of the applicable development category.

e Refer to Sections 4.3.5.2 and 4.3.5.3 of the DCP for special considerations such as for house raising proposals and development of properties identified for voluntary acquisition.

f Terms in italics are defined in the glossary of this plan and Schedule 2 specifies development categories. These development types are generally as defined within Environmental Planning Instruments applying to the LGA.

Floor Level

1 All floor levels to be no lower than the 5 year flood level plus *freeboard* unless justified by site specific assessment.

2 *Habitable floor* levels to be no lower than the 100 year flood level plus *freeboard* .

3 *Habitable floor* levels to be no lower than the *PMF* level. Non-*habitable floor* levels to be no lower than the *PMF* level unless justified by a site specific assessment.

4 Floor levels to be no lower than the *design floor level* . Where this is not *practical* due to compatibility with the height of adjacent buildings, or compatibility with the floor level of existing buildings, or the need for access for persons with disabilities, a lower floor level may be considered. In these circumstances, the floor level is to be as high as *practical* , and, when undertaking alterations or additions, no lower than the existing floor level.

5 The level of *habitable floor areas* to be equal to or greater than the 100 year *flood* level plus *freeboard* . If this level is not *practical* for a development in a Business zone, the floor level should be as high as possible.

6 Non-*habitable floor* levels to be equal to or greater than the 100 year flood level plus freeboard where possible, or otherwise no lower than the 5 year flood level plus *freeboard* unless justified by site specific assessment.

7 A restriction is to be placed on the title of the land, pursuant to S.88B of the Conveyancing Act, where the lowest *habitable floor area* is elevated above finished ground level, confirming that the undercroft area is not to be enclosed, where Council considers this may potentially occur.

Building Components & Method

1 All structures to have *flood compatible building components* below the 100 year flood level plus *freeboard.*

2 All structures to have *flood compatible building components* below the *PMF* level.

Structural Soundness

1 Engineer's report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below). In the case of alterations or additions to an existing development, the structure to be certified is that which is proposed to be newly constructed or otherwise required to be of a specified standard to satisfy other controls.

2 Applicant to demonstrate that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a 100 year flood plus *freeboard,* or a *PMF* if required to satisfy evacuation criteria (see below). An engineer's report may be required.

3 Applicant to demonstrate that any structure can withstand the forces of floodwater, debris and buoyancy up to and including a *PMF.* An engineers report may be required.

Flood Effects

1 Engineer's report required to certify that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance* ; and (iii) the cumulative impact of multiple potential developments in the floodplain.

2 The flood impact of the development to be considered to ensure that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood *conveyance* ; and (iii) the cumulative impact of multiple potential developments in the floodplain. An engineer's report may be required.

Car Parking and Driveway Access

1 The minimum surface level of open car parking spaces or carports shall be as high as *practical* , and not below: (i) the 5 year flood level plus freeboard; or (ii) the level of the crest of the road at the location where the site has access; (which ever is the lower). In the case of garages, the minimum surface level shall be as high as *practical* , but no lower than the 5 year flood level plus freeboard.

2 The minimum surface level of open car parking spaces, carports or garages, shall be as high as *practical* .

3 Garages capable of accommodating more than 3 motor vehicles on land zoned for urban purposes, or *enclosed car parking,* must be protected from inundation by floods equal to or greater than the 100 year

4 The driveway providing access between the road and parking space shall be as high as *practical* and generally rising in the egress direction.

5 Where the level of the driveway providing access between the road and parking space is lower than 0.3m below the 100 year flood, the following condition must be satisfied - the depth of inundation on the driveway during a 100 year flood shall not exceed: (i) the depth at the road; or (ii) the depth at the car parking space. (Refer to Schedule 3). A lesser standard may be accepted for single detached dwelling houses where it can be demonstrated that risk to human life would not be compromised.

6 *Enclosed car parking* and car parking areas accommodating more than 3 vehicles (other than on Rural zoned land) with a floor level below the 5 year flood level plus *freeboard* or more than 0.8m below the 100 year flood level, shall have *adequate warning systems, signage and exits* .

7 Restraints or vehicle barriers to be provided to prevent floating vehicles leaving a site during a 100 year flood.

8 Driveway and parking space levels to be no lower than the *design ground/floor levels* . Where this is not *practical* , a lower level may be considered. In these circumstances, the level is to be as high as *practical* , and, when undertaking alterations or additions, no lower than the existing level.

Note: a. A flood depth of 0.3m is sufficient to cause a small vehicle to float.
b. Enclosed car parking is defined in the glossary and typically refers to carparks in basements.

Evacuation

1 Reliable access for pedestrians or vehicles required during a 100 year flood.

2 Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest *habitable floor* level to an area of refuge above the *PMF level* , or a minimum of 20% of the gross floor area of the dwelling to be above the *PMF* level. In the case of alterations or additions to an existing development, this may require retro-fitting the existing structure if required to support a refuge above the PMF.

3 The evacuation requirements of the development are to be considered. An engineers report will be required if circumstances are possible where the evacuation of persons might not be achieved within the *effective warning time* .

Management and Design

1 If this application involves subdivision, Applicant to demonstrate that potential development as a consequence of the subdivision, can be undertaken in accordance with this DCP.

2 *Site Emergency Response Flood Plan* required where floor levels are below the *design floor level,* (except for single dwelling-houses).

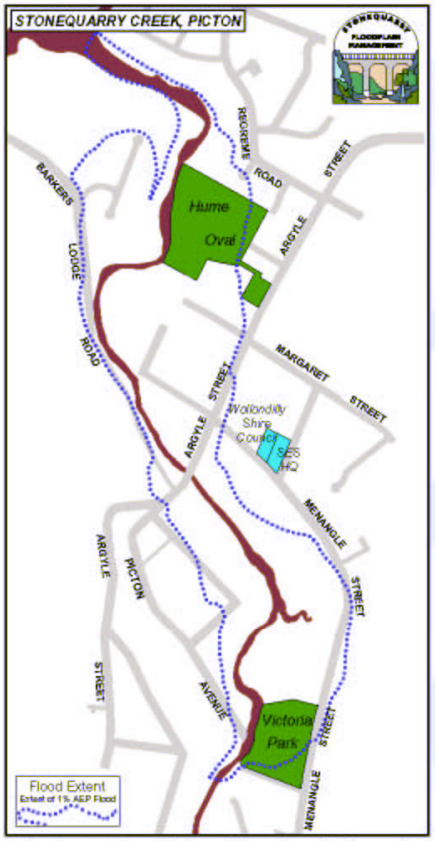
3 Applicant to demonstrate that area is available to store goods above the 100 year flood level plus *freeboard.*

4 Applicant to demonstrate that area is available to store goods above the *PMF* level.

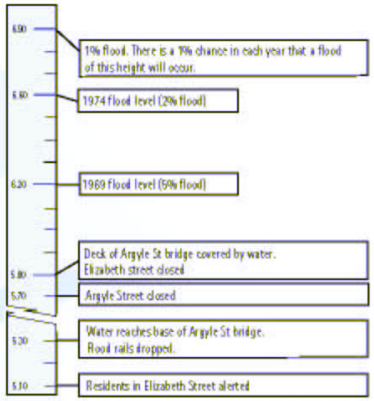
5 No storage of materials below the *design floor level* which may cause pollution or be potentially hazardous during any flood.

APPENDIX J

PICTON FLOODSAFE BROCHURE



Flood extent in a 1% flood (There is a 1% chance in each year that a flod of this height will occur)



Key heights in metres at the Argyle Street Bridge for Stonequarry Creek

Prepare yourself

Some basic measures you can take right now include keeping a list of emergency numbers near the telephone and assembling an emergency kit.

Your emergency kit should contain at all times:

- A portable radio with spare batteries
- A torch with spare batteries
- A first aid kit
- Rubber gloves
- Candles and waterproof matches
- Important papers including emergency contact numbers
- A waterproof bag for valuables

When flooding is likely, place in your emergency kit:

- A good supply of required medications
- Any special requirements for babies and the disabled, infirm or elderly
- Strong shoes
- Fresh food and drinks

How the SES can help you

The State Emergency Service is responsible for dealing with floods in NSW. This includes planning for floods and educating people about how to protect themselves and their property.

During floods, the SES is responsible for flood information, safety advice, evacuation, rescue and providing essentials to people cut off by flood waters. Wollondilly Shire Council can also provide information on how to protect yourself and your property from floods.

FOR EMERGENCY HELP IN FLOODS AND STORMS CALL THE SES ON

132 500

SES web site	www.ses.nsw.gov.au
Wollondilly SES	02 4677 1417
Wollondilly Shire Council (business hours)	02 4677 1100
Bureau of Meteorology website	www.bom.gov.au

Proudly supported by Group 6 Rugby League

FloodSafe Picton

Better FloodSafe than Sorry

Protecting yourself from a flood

Flooding along Stonequarry Creek – during the 1930s and in 1988

Picton

Better FloodSafe than Sorry

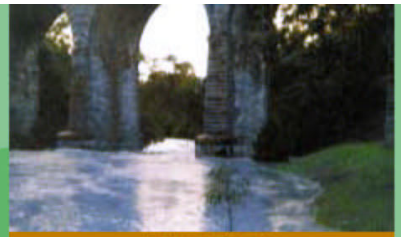
Picton has a long history of flooding. The most serious flood occurred in 1962 with flood waters reaching 1.5 metres above the Argyle St bridge. Other significant floods occurred in 1964, 1966, 1969 1974 and 1976.

The areas most affected by flooding in Picton are the central business district and surrounding residential areas including Argyle St, Menangle St and Menangle St West, Elizabeth St, Davies Pl, Coull St, Cliffe St, Barkers Lodge Rd and Picton Ave.

Low level bridges and roads may be cut by flood waters. Crossing flooded bridges and roads is dangerous and should not be attempted. Rural property dwellers should closely monitor river levels and take action early to protect stock and equipment.

If flooded, deciding to remain in your home, even if it has been raised, can be dangerous. Flooding may last for several days. Even if water does not enter your house, it may become a refuge for vermin, snakes and spiders. There may be no water, sewerage, power, telephone or other services for several days. You may be unable to call for help. You need to know what to do for yourself – and where to turn for help.

Sandbagged businesses in Argyle Street.



Viaduct in Flood

Photograph courtesy of F. Pullman

Stay informed

Wollondilly Shire Council has information on how flooding may affect your property.

Flood-prone properties have been issued a sticker for placement on their meter box. Street signs showing key flood heights are located in flood-prone areas of Picton.

The Wollondilly SES Unit can give you information on what you can do to reduce the effects of flooding on your family and your property.

Further information, including a copy of the Picton Local Flood Policy, may be obtained from www.stonequarrycreek.org

How you will be advised of a coming flood

Flood information including generalised flood forecasts, livestock and pump warnings, road closures and advice on evacuations and property protection will be broadcast over local radio stations C91.3 FM, Highland FM 107.1, 2MCR FM 100.3 and ABC Illawarra FM 97.3.

When flooding is likely

- Stack your possessions on benches and tables, electrical goods on top
- Secure objects that are likely to float and cause damage
- Relocate waste containers, chemicals and poisons well above floor level
- Raise commercial stock, records and equipment or relocate them to high ground
- Locate important papers, valuables and mementoes and put them in your emergency kit
- Move agisted animals, especially horses, to high ground
- Rural landholders should move livestock and farm equipment and relocate pumps to high ground. Sheds and outbuildings should be checked and equipment, stockfeed and chemicals raised or moved to higher ground.

During a flood

- Avoid driving or walking through flood water – it is the main cause of death during floods as water is often deeper or faster flowing than people think and contains hidden snags and debris. Crossing flooded bridges and causeways is dangerous and should not be attempted
- Keep listening to a local radio station for further information and advice
- Keep in contact with your neighbours
- Be prepared to evacuate if advised

Every family should make an emergency kit.

If you need to evacuate

- Take your emergency kit with you
- Turn off the electricity, gas and water as you leave
- You will be told which evacuation centre to go to
- Don't leave your pets behind – they may die. Put them on leads or in approved pet containers. Dogs should be muzzled.

When you evacuate

Proceed to the evacuation centre you are asked to go to. You must leave well before roads to high ground are closed by flood water.

Help will be available at the evacuation centre which will be established by the Department of Community Services (DoCS). This centre will also be staffed by representatives from community agencies such as the Red Cross, Salvation Army, Adracare, St Vincent de Paul and Anglicare.

Information on the location of the evacuation centre will be provided at the time of the flood. Help available from the evacuation centre includes:

- Temporary accommodation
- Financial assistance
- Personal support
- Refreshments and meals
- Clothing and personal needs
- Contacting family and friends

Recovering from a severe flood

A local recovery centre will be established by DoCS. This centre will be staffed by representatives from a range of government departments and community agencies to help you return to normal living. At the centre you will be able to get advice on everything from insurance to counselling. In the event of a flood, information will also be available from the DoCS State Disaster Recovery Centre on 1800 018 444.

APPENDIX K

PRELIMINARY COST ESTIMATE OF PROPOSED FLOOD MITIGATION MEASURES

MEASURE NO.	DESCRIPTION		ITEM	BASIS	COST
1.1A	**Retford Park Detention Basin**	Scoping study		Estimate, including detailed ground survey	$25,000
		Implementation	General set up		$50,000
			Earthworks	Topsoil: 14,000 m^2 @ $8/$m^2$	$112,000
				Bulk (imported): 43,000 m^3 @ $60/$m^3$	$2,580,000
			Drainage	Three 1.95m diameter, 50 m long pipes @ $2,000/m	$300,000
				Inlet structure	$20,000
				Outlet structure	$20,000
			Remediation	Trees	$10,000
				Grass (reinforced): 14,000 m^2 @ $15/$m^2$	$210,000
			Sub-total		$3,302,000
			20% contingency		$660,400
			Total		**~$4.0M**
1.1D	**Bowral Golf Course Detention Basin**	Scoping study		Estimate, including detailed ground survey	$25,000
		Implementation	General set up including survey		$50,000
			Earthworks	Topsoil: 2,500 m^2 @ $8/$m^2$	$20,000
				Bulk (imported): 2,200 m^3 @ $60/$m^3$	$132,000
			Drainage	One 25m box culvert @$1,000/m	$25,000
			Rock protection	20 m^3 @ $60/$m^3$	$1,200
			Remediation	Grass (reinforced): 2,500 m^3 @ $60/$m^3$	$37,500
				Trees	$10,000
			Sub-total		$275,700
			20% contingency		$55,140
			Total		$330,840
			Total (Council estimate)		**~$0.5M**
1.4	**Control runoff from new development**	Continue OSD policy		Council staff costs	Nil
		Devise WSUD program		Council staff costs	?

MEASURE NO.	DESCRIPTION		ITEM	BASIS	COST
1.5	**Modify bridges and culverts**	Remove Victoria Street Bridge		Estimate	$20,000
		Amplify culvert north of Nerang Street		Based on cost of similar scheme south of Alcorn Street – represents a minimum cost, not allowing for any work upstream and downstream for excavation and erosion protection/ channel lining	$60,000+
1.6	**Manage riparian corridor**	Establish creek maintenance program		Estimate	$40,000 (+$20,000 pa maintenance
		Prepare Mittagong Creek Riparian Corridor Management Plan		Estimate	$20,000
1.8	**Farmborough Close levee**	Scoping study		Estimate	$20,000
2.2	**Voluntary house raising/reconstruction**	Scoping study		Estimate	$25,000
		Raising		7 fibro/weatherboard houses @ $50K/house (based on experience of Fairfield City Council)	$350,000
		Reconstruction		7 brick houses @ $80K/house (based on experience of Fairfield City Council)	$560,000
2.3	**Flood-proofing**	Guidelines		Estimate	$5,000
2.4	**Revise planning and development controls**	Amend Wingecarribee LEP; Amend DCP 34; Amend Section 149(2) Certificates		Council staff costs only	Nil
3.1	**Improve flood warning system**	Install rain and/or stream gauge		Advice from Mr Gordon McKay, Bureau of Meteorology	$6,000 (+$500 pa maintenance)
3.2	**Improve emergency management**	Revise Local Flood Plan		SES staff costs	Nil
3.3	**Improve public awareness**	Develop/distribute Bowral FloodSafe brochure and web-site		Quote from Mr Phil Campbell, SES	$1,000 (1,000 brochures)
		Install flood marker/sign		Based on cost of Berrima sign	$6,000 (+$1,000 pa maintenance)
		Update/distribute flood certificates		Council staff costs	Nil (+$5,000 pa maintenance)
		Institute hazard awareness days		Council staff costs	Nil (+$5,000 pa maintenance)