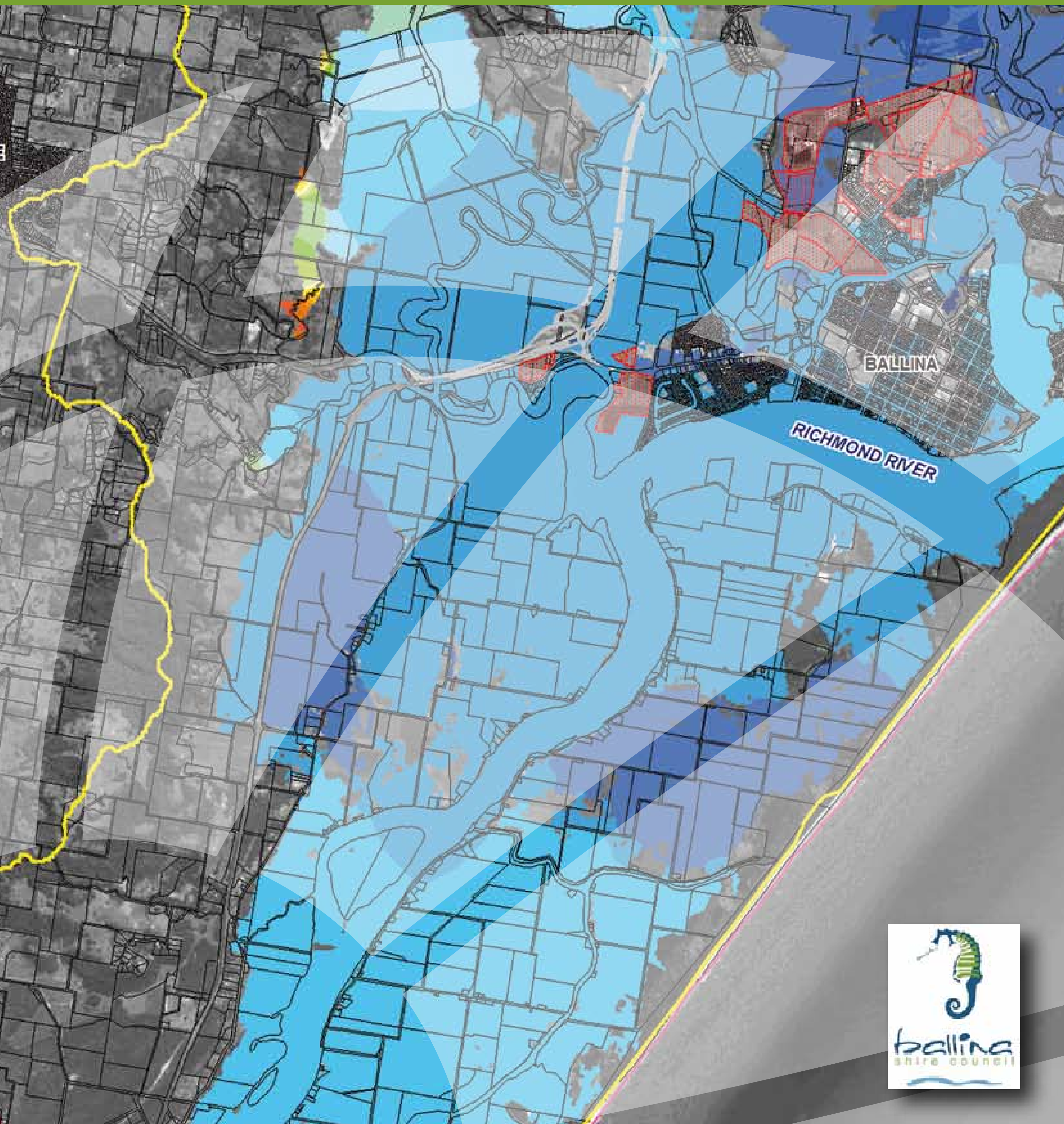
BALLINA FLOODPLAIN RISK MANAGEMENT STUDY

Exhibition Version - Volume 1

January 2012-01-12



Ballina Floodplain Risk Management Study

Volume 1: Main Report

Exhibition Version

January 2012

Prepared For:	Ballina Shire Council
Prepared By:	BMT WBM Pty Ltd (Member of the BMT group of companies) Bewsher Consulting Pty Ltd Grech Planners Pty Ltd

Offices

Brisbane
Denver
Mackay
Melbourne
Newcastle
Perth
Sydney
Vancouver

DOCUMENT CONTROL SHEET

BMT WBM Pty Ltd

BMT WBM Pty Ltd
Level 8, 200 Creek Street
Brisbane 4000
Queensland Australia
PO Box 203 Spring Hill 4004

Tel: +61 7 3831 6744
Fax: + 61 7 3832 3627

ABN 54 010 830 421

www.wbmpl.com.au

Document :	R.B17316.005.03.FRMS.doc
Project Manager :	Richard Sharpe
Client :	Ballina Shire Council
Client Contact:	Paul Busmanis
Client Reference	

Title :	Ballina Floodplain Risk Management Study, Volume 1, Exhibition Version
Authors :	Richard Sharpe, Ben Caddis, Drew Bewsher, Paul Grech
Synopsis :	**Volume 1:** This report outlines the existing flood problem in the Ballina Shire Local Government Area and discusses possible and recommended floodplain management options. **Volume 2** (separate report): This report contains flood maps created as part of the study.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	CHECKED BY		ISSUED BY	
0	15/09/2011	BMC		RGS	
1	04/10/2011	BMC		RGS	
2	05/12/2011	BMC		RGS	
3	12/01/2012	BMC	12/01/2012	RGS	RJSharpe

DISTRIBUTION

DESTINATION	REVISION			
	0	1	2	3
Ballina Shire Council	PDF		PDF	PDF
Office of Environment & Heritage	PDF		PDF	PDF
State Emergency Service	PDF		PDF	PDF
Bewsher Consulting	PDF			
Grech Planners	PDF			
BMT WBM File	PDF	PDF	PDF	PDF
BMT WBM Library	PDF	PDF	PDF	PDF

FOREWORD

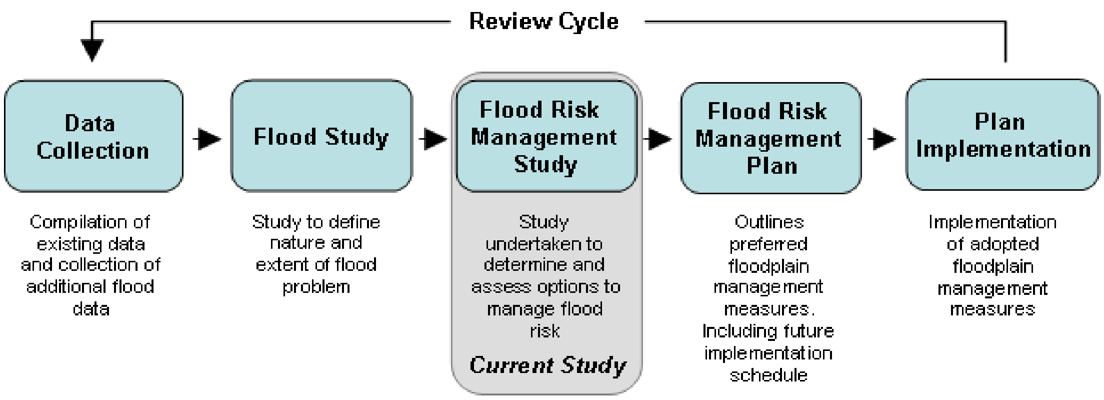
Section 733 of the Local Government Act 1993 exempts Local Government from liability with respect to flood liable land on condition that planning instruments and manuals for the management of flood liable land are prepared in accordance with the principles of the relevant government manual. In 2005 the New South Wales (NSW) Department of Infrastructure, Planning and Natural Resources (now the Office of Environment and Heritage) revised their Floodplain Development Manual (DIPNR, 2005), which relates to management of development on flood liable land to assist Local Governments to meet their obligations under the afore mentioned Act.

The manual incorporates the NSW Government's Flood Prone Land Policy, which aims to reduce the impact of flooding on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. The policy is directed towards providing solutions to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the policy, the management of flood prone land remains the responsibility of Local Government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in their floodplain management responsibilities.

The policy provides for technical and financial support by the State Government through the Floodplain Risk Management Process, which is illustrated in the image below.

For Ballina Shire, the first and second step in this process (Data Collection and Flood Study) were completed by in 2008 (BMT WBM, 2008). In early 2009, Ballina Shire Council engaged BMT WBM to undertake the third and fourth steps of the Flood Risk Management Process (Floodplain Risk Management Study and Floodplain Risk Management Plan). The Floodplain Risk Management Study is presented in this report. A separate report contains the Floodplain Risk Management Plan.



EXECUTIVE SUMMARY

Background

The study area lies within Ballina Shire and the Richmond River catchment in the Northern Rivers area of New South Wales (NSW). It encompasses the town of Ballina and its surrounding communities, which are proximate to the ocean, Richmond River, North Creek, Emigrant Creek, Maguires Creek and other minor creeks. Hence, there are a number of potential sources of flood risk in the study area.

There are many people living and working within the floodplain, i.e. within the Probable Maximum Flood (PMF) Extent. The community is also recognised to be highly vulnerable to the impacts of flooding. In general, the population is older than other areas of the state, there are often a large number of tourists who are unfamiliar with local flood risk, and there are many riverside caravan parks. As such, there is a significant flood risk to the communities within the study area, which is likely to get worse in future due to the impacts of climate change.

The 2005 Floodplain Development Manual lays out a process to manage flood risk in NSW. This process embraces a staged approach to flood risk management: Data Collection, Flood Study, Floodplain Risk Management Study, Floodplain Risk Management Plan and Plan Implementation. The focus of this report is on the Floodplain Risk Management Study stage, and the work documented herein is preceded by the Data Collection and Flood Study stages which were carried out through the Ballina Flood Study Update (BMT WBM, 2008a).

The primary objective of this study has been to identify and evaluate options available to manage flood risk in the study area, in order to inform the development of a Floodplain Risk Management Plan.

Flood Risk and Consequence

To achieve this objective, it was first necessary to reexamine flood risk in the study area for both current day and in the future due to anticipated increases in sea levels and rainfall intensity through climate change. The consequences of flooding were then assessed by estimation of flood damage to property and the capability of the community to evacuate.

The total annualised damage for the study area has been estimated at $9 million per year on average. This is through damage to residential property, commercial property, public infrastructure and sugar cane crops. Over half the damages are attributed to residential property, and a quarter to commercial property.

The outcomes of the evacuation capability assessment indicate that for extremely large and rare flood events (i.e. assessing the PMF), it may not be possible to fully evacuate Ballina given current prediction and warning practices. For flood events up to and including the 100 year ARI (excluding climate change), however, evacuation routes servicing the most densely populated area, Ballina Island, do not close; thus enabling evacuation of the majority of the population in the study area.

Flood Risk Management Measures Overview

The flood risk and consequence assessments laid the foundation for appraising floodplain risk management options. Floodplain risk management options were reported to Council, the SES and community representatives throughout the course of the study via dissemination of discussion papers and regular presentations. An agreed list of pertinent options has been collated into two floodplain risk management schemes, of which one scheme has been recommended to be carried forward into the floodplain risk management plan (in the next stage of the floodplain risk management process). The recommended measures are discussed below.

Property Modification Measures

Often the most effective way of managing flood risk is through implementation of well devised planning and development controls. To this end, a draft Development Control Plan (DCP) has been written in close collaboration with Council's planners. The DCP places stronger restrictions on more vulnerable development (e.g. hospitals) and areas associated with higher flood risk. A key feature of the DCP is the introduction of a Flood Risk Precinct Map, which imposes different degrees of control on different flood risk precincts.

Voluntary house purchase is an expensive approach that is only promoted in areas of extreme flood hazard. None of the properties in the study area qualified for this measure. However there are a number of properties that do qualify for voluntary house raising. Under this scheme home owners may receive a two thirds state grant, with a recommended cap of $40K, to raise their habitable floor levels. It has been recommended that the 49 properties within the 20 year ARI flood extent are considered for inclusion in the scheme.

Response Modification Measures

It is anticipated that much improvement can be made to the current flood forecasting and warning methods. This will benefit the community's evacuation capability. There are a number of methods that can be used to forecast flooding, and it may be worth considering the Richmond River catchment as a whole rather than just Ballina Shire in isolation. It has been recommended that a more detailed feasibility study be implemented to resolve the best approach.

To further enhance the evacuation capability, and the community's resilience to flooding, it has also been recommended that public awareness of flooding and how to react during a flood is improved through a community awareness campaign. Various options and examples have been presented.

Flood Modification Measures

Floodway options were assessed using a cost-benefit analysis. This assessment indicated that a 100m wide floodway through the man-made Gallans Road Cycleway embankment is an economically viable option; whereby the estimated benefit from flood damage reductions outweighs the cost of implementing the scheme. The option has therefore been included in the recommended scheme. It should be noted that some properties in the North Creek floodplain are adversely impacted by this option. There will therefore need to be further consideration of compensatory measures before full implementation of this option.

An assessment of a floodway across a low lying natural ridge at Sandy Flat was also undertaken. This indicated that it is not currently an economically viable option. However, under future climate conditions the option does become viable. Therefore it has been recommended that this option is revisited in future studies.

The impact of Deadmans Creek Road on flood levels in the Emigrant Creek valley has been assessed. The results indicate that the road embankment has a significant impact on flood levels, and it has been recommended that the road is either lowered or removed.

Climate Change

Sea level rise is a significant concern for the town of Ballina. Current day flood risk on Ballina Island is relatively low, but will increase dramatically in future. Estimated annualised flood damages increase by a factor of 10 by 2100. This is largely due to smaller, more regular, flood events affecting many more properties than currently. For example, the flood damage from a 5 year ARI flood event in 2100 is more than three times the current day 100 year ARI flood damage.

Implementation of planning and development controls provides the best mechanism for adaptive management of flood risk in a changing climate. The adopted philosophy for managing future flood risk is to maintain minimum filling criteria to Ballina Island and surrounding low-lying densely populated areas to the predicted 2050 100 year ARI flood level. This will promote drainage and mitigate regular nuisance flooding beyond 2050. Undeveloped areas, where it is easy to fill to higher levels, will be encouraged to fill to a level based on the predicted 2100 100 year ARI flood level.

Conclusion

The final conclusion of this study is to adopt the recommended scheme into the Floodplain Risk Management Plan. The DCP promotes reducing future flood risk to private land through filling. It is also recommended that additional work is undertaken to determine how best to protect and upgrade public infrastructure in light of future filling on Ballina Island. Prompted by community representatives, a recommendation has also been made to initiate a study into siltation of minor creeks, with a view to improve floodplain drainage and health.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Study Area

Administered by Ballina Shire Council (Council), Ballina is a coastal town located at the mouth of the Richmond River in the Northern Rivers Region of New South Wales, approximately 750km north of Sydney and 200km south of Brisbane. The town is the administrative centre for the Ballina Shire (total area 484km²), which is one of five local government areas lying within the Richmond River catchment (total area 6,900km²).

Ballina's population of 17,000 people accounts for 40% of the Ballina Shire's total population of 39,000 people (Council's website). Other population centers within the Shire include the smaller towns of Alstonville (15%), Wollongbar (5%), Wardell (1%), Lennox Head and Skennars Head (20%). The remaining 19% of people are distributed across the rural parts of the Shire.

The study area (Figure 1–2) is defined by the extent of the Richmond River floodplain from Empire Vale in the south to Ross Lane in the north. The major tributaries of North Creek, Maguires Creek and Emigrant Creek are included in the study area, because flooding across Ballina's urban area is influenced by these creeks as well as the Richmond River itself.

Ballina's town centre is bounded by the Richmond River on its southern end, North Creek on its eastern end and the North Creek Canal joining them along the north-western side. The three watercourses form an island referred to here as Ballina Island. The developed areas surrounding Ballina Island to the east of North Creek, north of the canal and west of the canal are referred to as East Ballina, North Ballina and West Ballina respectively. Ballina Island is adjacent to the Richmond River mouth and is, therefore, also subjected to high ocean tides that propagate up the Richmond River and North Creek.

1.2 General Floodplain Management Approach

Floodplain management in NSW generally follows the approach described in the 2005 Floodplain Development Manual (DIPNR, 2005; hereafter referred to as the Floodplain Development Manual, or the Manual). The Manual states that the implementation of the flood policy requires a floodplain management plan that ensures:

- The use of flood prone land is planned and managed in a manner compatible with the assessed frequency and severity of flooding;
- Flood prone lands are managed having regard to social, economic and ecological costs and benefits, to individuals as well as the community;
- Floodplain management matters are dealt with having regard to community safety, health and welfare requirements;
- Information on the nature of possible future flooding is available to the public;
- All reasonable measures are taken to alleviate the hazard and damage potential resulting from development on floodplains;
- There is no significant growth in hazard and damage potential resulting from new development

on floodplains; and

- Appropriate and effective flood warning systems exist, and emergency services are available for future flooding.

The steps involved in formulating a Floodplain Risk Management Plan are outlined in the Manual and are shown in Figure 1–1. The process includes:

1 Establishment of a Floodplain Risk Management Committee;

2 Collection of Data;

3 Preparation of a Flood Study;

4 Preparation of a Floodplain Risk Management Study;

5 Preparation of a Floodplain Risk Management Plan; and

6 Implementation of the Plan.

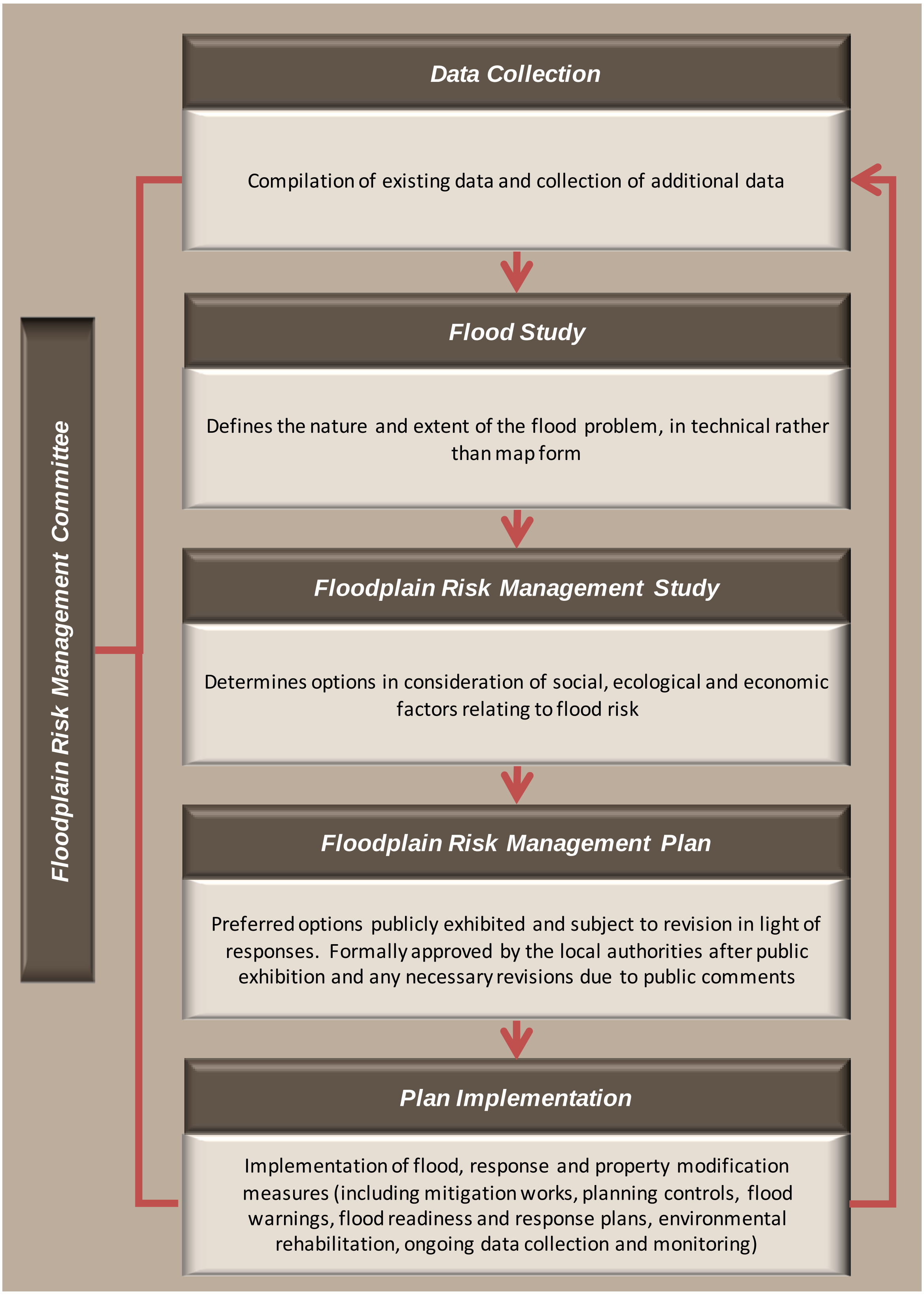


Figure 1–1 NSW Flood Risk Management Process

1.3 Previous Studies

The Richmond River catchment in the vicinity of Ballina Shire has been the subject of a number of flood related studies including:

- *Ballina Ocean Level Study* (Lawson & Treloar, 1994)- study of elevated ocean water levels at the Richmond River entrance due to tropical cyclones and frontal storms. Of relevance to the current study was the preparation of a series of water level hydrographs for ocean storm surge events.
- *Ballina Floodplain Management Study* (WBM Oceanics, 1997) – flood behavior, flood hazard and management options were investigated covering the floodplain from Broadwater to the river mouth at Ballina. Key outcomes from the study were:
  - A one-dimensional (1D) hydrodynamic flood model of the Lower Richmond River; and
  - Issue of Policy Statement No. 11 from Council's Development Control Plan (DCP), which describe the minimum fill requirements applicable to floodplain development.
- *Summary of Flood Assessments around Ballina, 1997 - 1999* (WBM Oceanics, 1999) – flood impact assessments associated with the Ballina Bypass and various land development projects are summarised.
- *Wardell and Cabbage Tree Island Flood Study* (Patterson Britton, 2004) – flood behavior and hazard were assessed and documented for the Richmond River floodplain upstream from Empire Vale.
- *Wardell and Cabbage Tree Island Floodplain Risk Management Study* (Patterson Britton, 2008) – floodplain management measures were assessed and recommended for implementation.
- *Ballina Flood Study Update* (BMT WBM, 2008a) - Flood behavior downstream of Empire Vale was re-assessed using an upgraded one and two-dimensional flood model. This was the first study where anticipated flood impacts associated with climate change were assessed. A series of structural flood modification measures were also assessed in conjunction with approved and rezoned land development and infrastructure projects. Key outcomes from the study were:
  - Integrated one and two-dimensional (1D/2D) hydrodynamic flood model of the Lower Richmond River; and
  - A revision to Policy Statement No. 11 from Council's DCP incorporating an allowance for climate change.
- *Flood Impact Assessment for the Ballina Bypass* (BMT WBM, 2008b) – Flood impacts and associated mitigation measures are documented for the concept design and refined design phases.
- *Ballina Integrated Flood Modelling Summary of Flood Assessments around Ballina, 2005 - 2009* (BMT WBM, 2009) – flood impact assessments using Council's 1D/2D integrated flood model are summarised. Assessments included the Ballina Bypass and Woodburn to Ballina Pacific Highway Upgrade projects, various land development projects and the master planning for the West Ballina and Southern Cross precincts.

1.4 Role of the Floodplain Management Committee

A Floodplain Management Committee (referred to throughout this document as the 'Committee') was formed prior to the commencement of the 2008 Flood Study Update. The main function of the Committee has been to oversee the floodplain management process and to ensure that issues important to the Ballina community have been addressed. The Committee comprises:

- Community Reference Group (CRG) of local land owners, community representatives and property developers;
- Civil Committee of local councillors;
- Council representatives;
- Office of Environment and Heritage representatives; and
- State Emergency Services (SES) representatives.

A series of discussion papers were presented and reviewed during the course of the Ballina Floodplain Risk Management Study. These discussion papers represent the collective ideas of the consultants (BMT WBM, Bewsher Consulting and Grech Planners) and the Committee. The discussion papers outlined the essential information about each floodplain management measure and, based on this information, the Committee deliberated on these measures.

The Community Reference Group (CRG) was established a number of years ago. This group has been involved in a number of studies in Ballina Shire, including the Ballina Flood Study Update and various design stages of the Ballina Bypass. Regular CRG meetings were arranged by Council during the course of the floodplain risk management study, where attendees were updated on study progression and outcomes. These meetings enabled those attending to voice their opinions and concerns.

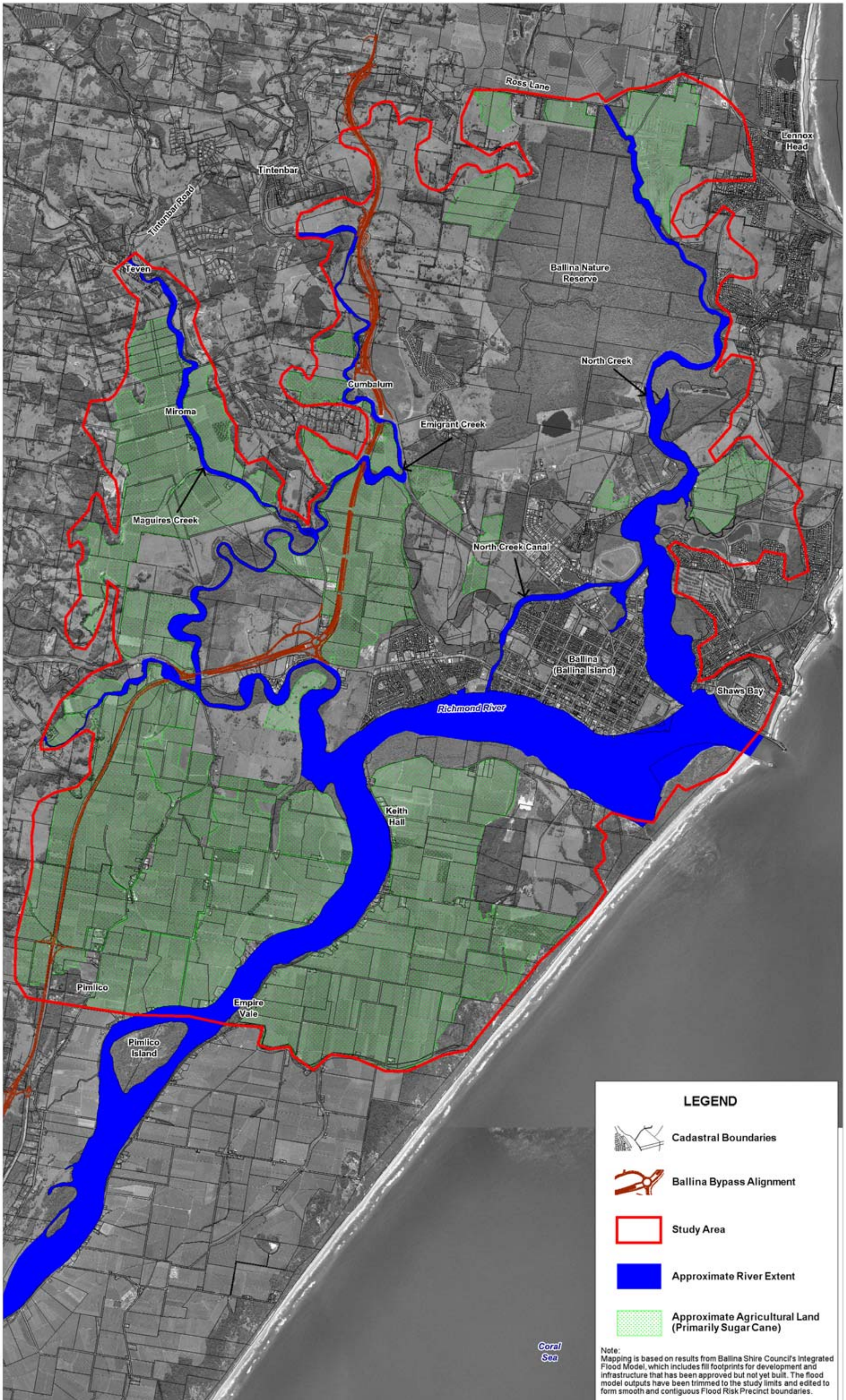
1.5 Floodplain Risk Management Study

This report documents the Floodplain Risk Management Study. The objective of the study is to derive an appropriate mix of management measures to effectively manage the flood risk for the study area. The study includes:

- Review of Council's existing policies, strategies and planning instruments;
- Consultation with the CRG to provide and gather information, enable participation in the decision making process and gain community acceptance of the management study findings and the subsequent plan;
- Investigation of flood risk and hazard;
- Investigation of the current evacuation capability of the community;
- Estimation of the cost of flooding to the community;
- Identification and appraisal of flood risk management measures;
- Identification of potential for new development or redevelopment in the floodplain; and
- Identification of modifications required to current policies and planning instruments.

This report discusses the flood problem and canvasses various flood management options. It then goes on to conclude with recommendations to be carried forward to the Floodplain Risk Management Plan.

Figure 1–2 Location Plan



Title:
Location Plan

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1 2
Approx. Scale

Figure: 1-2

Rev: C

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_1-2.wor

2 FLOOD BEHAVIOUR

2.1 Catchment Description

This study considers the flooding behaviour of Emigrant Creek, Maguires Creek, North Creek and the lower Richmond River. The catchments are dominated by rolling topography and hills with slopes ranging from 5% to 30%. The flood model also includes three of Emigrant Creek's tributaries: Sandy Flat Creek, Chilcotts Creek and Duck Creek.

The catchment consists of a series of elevated ridges that run along the coastal escarpment at the boundary of the Alstonville Plateau and the Richmond River and North Creek floodplains. Low lying landscape features include the Ballina Nature Reserve to the east of the plateau.

The majority of the catchment areas have been cleared for agricultural purposes or for development on the lower floodplain. Rural land use is dominated by cropping, primarily sugar cane which covers approximately 35% of the study area. Extents of the sugar cane crops are shown in Figure 1–2.

A detailed description of the river catchments is provided in the Flood Study Update (BMT WBM, 2008a). In summary, the main watercourses in the study area are:

- Emigrant Creek – flowing in a southerly direction through Cumbalum and joining the Richmond River at West Ballina;
- Maguires Creek – flowing in a south easterly direction from Teven and joining Emigrant Creek on the lower floodplain;
- North Creek – flows in a southerly direction from Ross Lane passing Ballina Nature Reserve on its right bank before dissecting Ballina Island and East Ballina at its confluence with the Richmond River; and
- Richmond River – flows in a north easterly direction adjacent to the coastline through a wide rural floodplain. It turns east at its confluence with Emigrant Creek before passing Ballina and meeting North Creek near its outfall into the Pacific Ocean.

2.2 Historical Flooding

The Richmond Valley has been subjected to significant flooding in the past. The earliest known flood occurred in 1846. Records of flooding on the Richmond River date back to 1857 at Coraki and 1880 at Lismore. Twenty-six floods were reported to have occurred before 1900 (SKP, 1980). In the 1940's a series of flood recording stations and gauges were established, which were upgraded and extended in the early 1970's. For Ballina the records extend back to 1944. There have been a number of floods in the Richmond Valley since 1900, with the largest being in 1954 and 1974. Records from flooding in March 1974, February 1976 and June 2005 were used in the Ballina Flood Study Update (BMT WBM, 2008a) to calibrate and verify the flood model.

2.3 Flood Modelling

Flood modelling provides a valuable tool for assessing flood behaviour and testing the effectiveness of flood management options. Council's 'Integrated Flood Model' has been used to formulate the 'base case' catchment flood behaviour. This flood model includes all currently approved infrastructure, including the RTA's Ballina Bypass, and current and future developments. The study is therefore established upon a baseline that represents the floodplain at a future point in time. Most of the approved development is expected to be constructed within the next 10 years. The 'base case' scenario is, therefore, considered to relate to approximately 2020. A number of updates have been applied to the flood model as part of this study. These updates are documented in Appendix A, along with further details of the proposed development that has been included in the model.

2.4 Existing Flood Behaviour

The flood model has been used to evaluate the existing flood risk, i.e. the flood risk under today's climate. The 5, 10, 20, 50, 100, 500 year ARI and Probable Maximum Flood events were simulated. The results for these model simulations are mapped in Volume 2 of this report. The methodology used to generate these maps is discussed in Appendix A.

2.4.1 Sources of Flooding

There are three main sources of flooding in the study area:

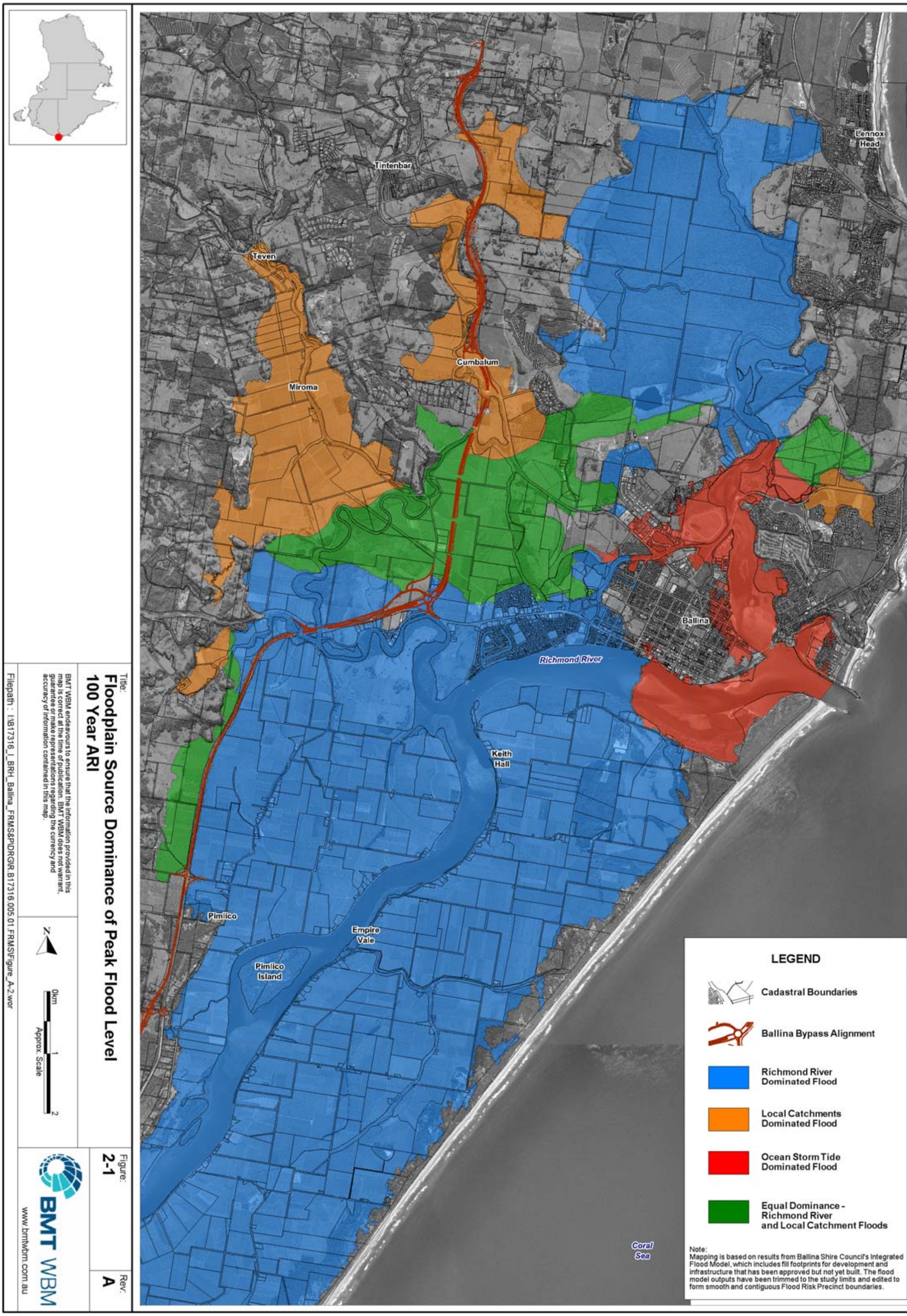
1 Richmond River flooding caused by a widespread storm system (with precipitation typically occurring over a few days) over the broader Richmond River catchment. These floods rise and fall relatively slowly at Ballina, with flood conditions lasting a few days.

2 Local catchment flooding caused by smaller storm systems in the local creek catchments with intense rainfall bursts typically lasting less than 12 hours. Flood waters rise and fall quickly. This form of flooding presents a high hazard due to short warning times and fast flowing water.

3 Ocean storm surge flooding caused by low pressure systems, strong onshore winds and storm wave conditions, which lead to higher than usual ocean levels. This form of flooding is influenced by tides, and will typically occur in combination with one or two high tides.

The dominance of these sources of flooding (for the 100 year ARI flood event) is illustrated in Figure 2–1.

Figure 2–1 Floodplain Source Dominance of Peak Flood Level 100 Year ARI



Title:
Floodplain Source Dominance of Peak Flood Level 100 Year ARI

Figure: 2-1

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&PDRGIR.B17316.005.01.FRMS\Figure_A-2.wor

Richmond River Flooding causes the most widespread flooding through the study area. This form of flooding is also the most dominant in terms of peak water levels through the majority of the study area. Flood water on the Richmond River travels in a north easterly direction towards Ballina, spilling out into the floodplain to the south of Ballina. These floodwaters also affect flooding on the local catchment creeks, especially in their lower reaches. Flood levels in the North Creek valley, to the north of Ballina Island, are dominated by this form of flooding due to the catchment being relatively flat and the long time period over which flooding occurs.

Local catchment flooding dominates flood levels in the Emigrant and Maguires Creek valleys. These valleys spread out and flatten towards their confluences with the Richmond River, where local catchment and Richmond River flooding become equally dominant.

Ocean storm flooding dominates in the lower reach of the Richmond River and North Creek, thus affecting parts of West Ballina, Ballina Island, Shaws Bay, East Ballina and North Ballina. These areas constitute the most concentrated urban development, which highlights the importance of this form of flooding in Ballina.

2.4.2 Rural Areas

The Maguires Creek valley south of Teven and the Emigrant Creek valley south of Tintenbar are susceptible to frequent flooding. These rural valleys are bounded by steep hill slopes, thereby confining the flood extents and leading to hazardous flow conditions in the larger flood events.

The North Creek floodplain north of Ballina Airport is also frequently inundated. This area is largely nature reserve.

The Richmond River floodplain upstream of Ballina is frequently inundated, particularly within the lower reach of Emigrant Creek and surrounding the confluence. Flooding in the Lower Richmond River floodplain becomes extensive from the 50 year ARI flood event.

These rural areas within the floodplain contain much agricultural land. There is therefore a risk to farmers' livelihoods as well as their personal welfare where rural residential dwellings are also on flood prone land.

2.4.3 Urban Areas

Much of the urban areas comprising West Ballina, Ballina Island and North Ballina lie within the floodplain (i.e. within the PMF flood extent). The welfare of the inhabitants in these areas is therefore at risk, as well as their property and possessions. There are also a number of commercial and industrial properties at risk.

West Ballina is the urban centre with the highest flood risk. The Emigrant Creek floodplain flows towards West Ballina near its confluence with the Richmond River. West Ballina is higher in elevation than the floodplain to the north, and is only flood affected from the 50 year ARI flood event.

The other urban centres have a lower flood risk, with Ballina Island, North Ballina and Shaws Bay incurring some inundation for the 100 year ARI flood event. Severe flooding occurs in these areas during the 500 year ARI flood event.

East Ballina rises steeply from the banks of North Creek. Therefore, only a few properties are flood affected along the fringe of this urban centre.

2.5 Future Flood Behaviour – Climate Change

As discussed above, there is an existing flood risk to both rural and urban areas in the study area. This flood risk may be exacerbated by future climate change. Scientists are predicting sea levels to rise, which is a concern for Ballina being sited on relatively low lying land. The NSW Department of Planning recently released a planning guide on *Adapting to Sea Level Rise* (DoP, 2010). The guide presents two planning horizons:

- An increase above 1990 mean seal levels of 40cm by 2050; and
- An increase above 1990 mean sea levels of 90cm by 2100.

Another consequence of a changing climate is increased rainfall intensity, which may increase the frequency and severity of flooding. In 2007 the NSW Department of Environment, Climate Change and Water[1] (DECCW) published a floodplain risk management guideline titled *Practical Consideration of Climate Change* (DECCW, 2007a). DECCW recommend that a sensitivity analysis on rainfall intensity is undertaken, considering increases of 10%, 20% and 30%. Previous flood modelling and consultation with DECCW has led to the following conclusions on rainfall intensity in the Ballina Shire:

- Considering sea level rise coupled with a 10% increase in rainfall intensity, sea level rise is shown to dominate flooding in the Ballina Shire;
- Considering sea level rise coupled with a 30% increase in rainfall intensity shows the Richmond River to be the dominant source of flooding in the Ballina Shire. The Committee has considered this scenario to be overly conservative; and
- Although the DECCW document recommends the sensitivity analyses, it does identify that the projected increase in rainfall intensity by 2070 for the NSW Northern Rivers catchments to be in the order of 5% to 10% (Table 1 in *Practical Consideration of Climate Change* (DECCW, 2007a)).

In light of the above, the following two climate change scenarios have been adopted for Ballina Shire:

- 2050 horizon – 10% increase in rainfall intensity and 40cm increase in sea levels; and
- 2100 horizon – 10% increase in rainfall intensity and 90cm increase in sea levels.

Flood risk for the projected 2050 and 2100 climate change scenarios have been modelled for the 5, 10, 20, 50, 100, 500 year ARI and Probable Maximum Flood events. The results for these model simulations are mapped in Volume 2.

There is a marked increase in flood risk due to climate change. This is highlighted in Figure 2–2 and Figure 2–3, which show the predicted impact of climate change on flood levels for the 100 year ARI flood event. Flooding in the future is, therefore, likely to become more frequent and the large infrequent floods more severe.

---

[1] *Note that DECCW has now formed part of the Office of Environment and Heritage*

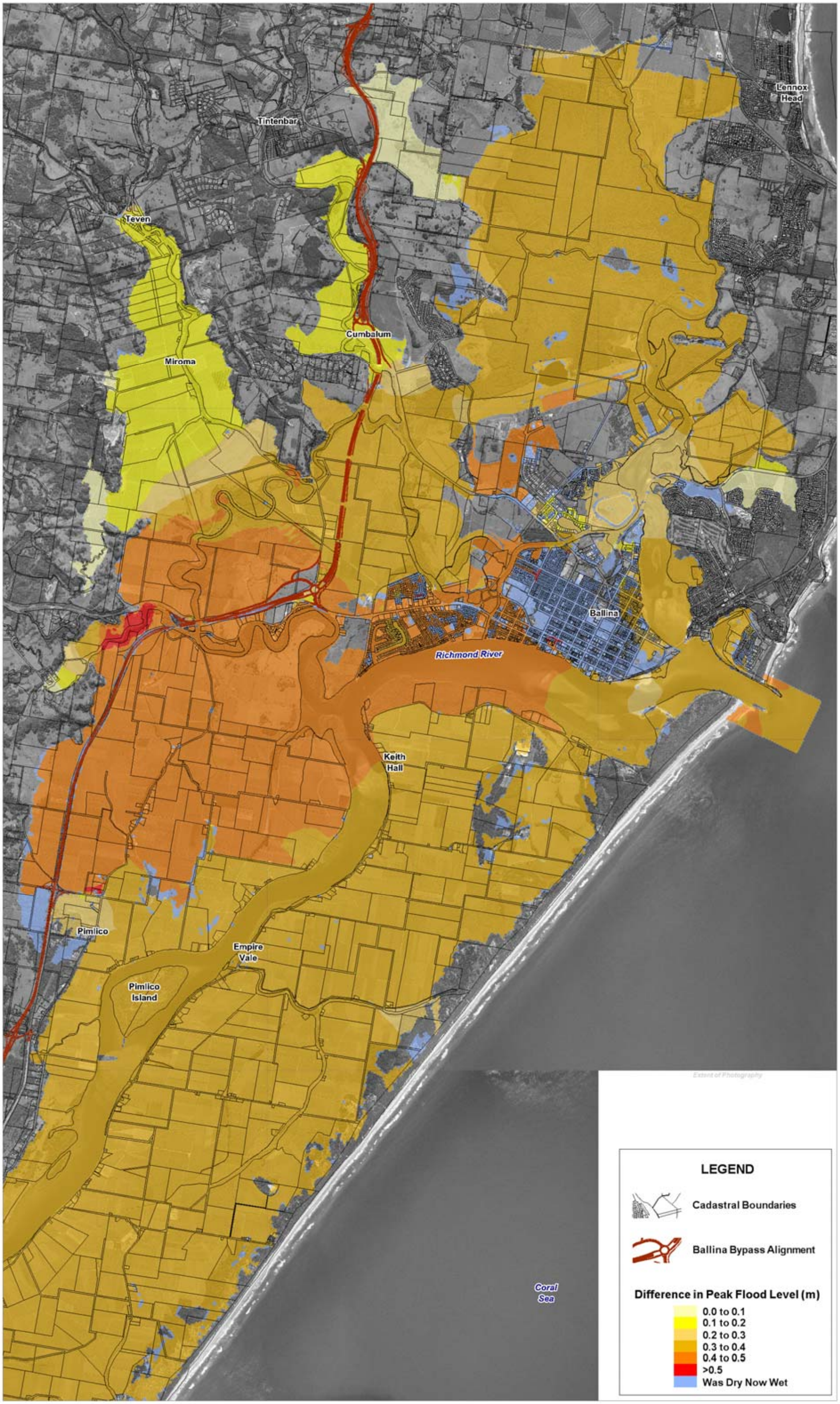
Figure 2–2 Flood Impact of 2050 Climate Change Horizon 100 Year ARI Flood Event

Title:
Flood Impact of 2050 Climate Change Horizon 100 Year ARI Flood Event

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

Figure:
2-2

Rev:
A

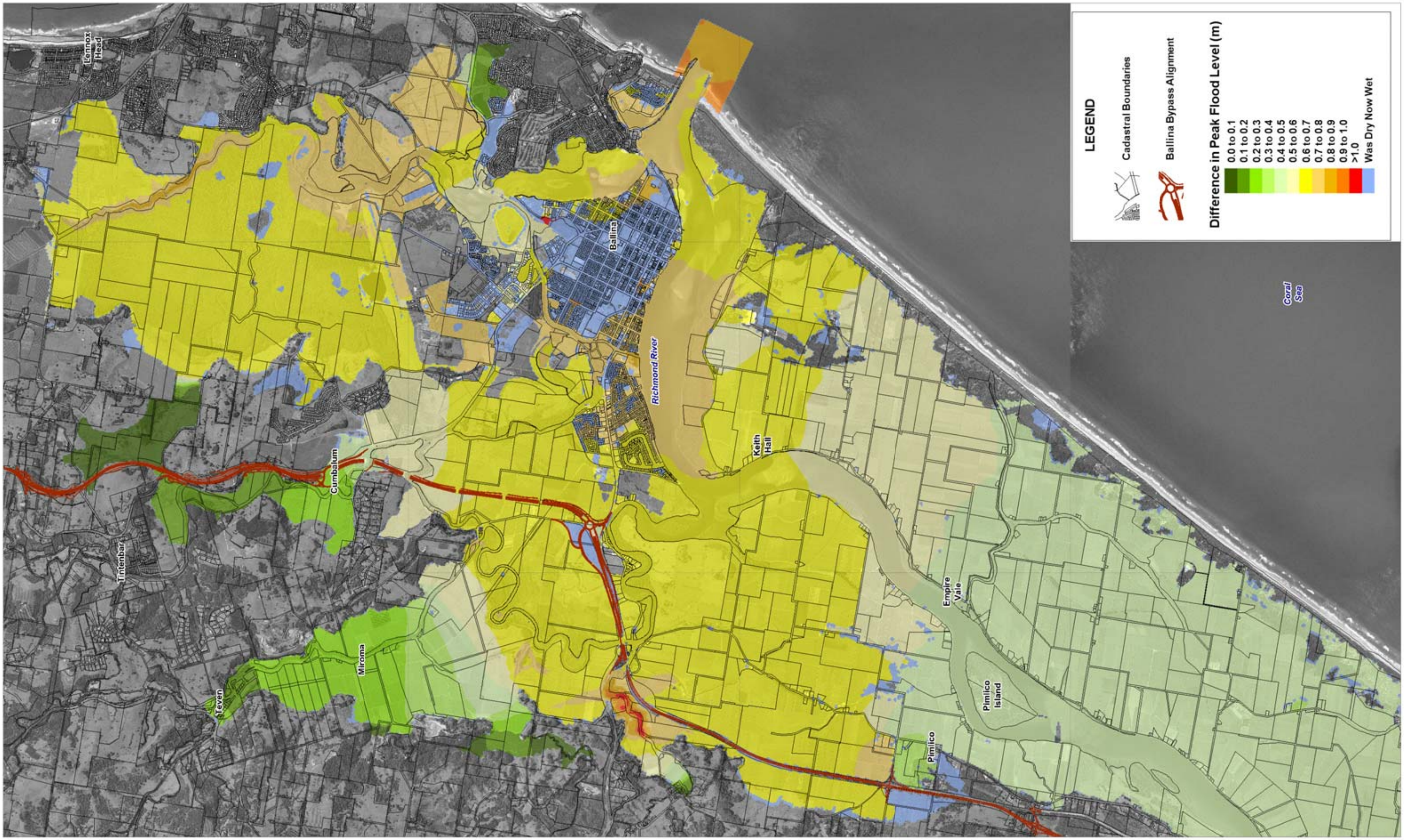


BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&PIDRGR.B17316.005.01.FRMS\Figure_2-2.wor

Figure 2–3 Flood Impact of 2100 Climate Change Horizon 100 Year ARI Flood Event



Title:
Flood Impact of 2100 Climate Change Horizon
100 Year ARI Flood Event

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1 2
Approx. Scale

Figure:
2-3

Rev:
A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_2-3.WOR

3 EVACUATION CAPABILITY ASSESSMENT

3.1 Background

The Ballina Shire has a population of approximately 39,000, of which 20% are over the age of 65,(Australian Bureau of Statistics). People in this demographic are likely to require assistance during evacuation and may be socially isolated, resulting in delayed awareness of evacuation warnings (State Emergency Service, 2008). Approximately 3% of the population are estimated to live permanently in caravans (Housing New South Wales, 2008). Areas with a high proportion of senior citizens or caravan parks are considered to be particularly vulnerable to the effects of flooding.

With serious flooding having not occurred since the 1970's and a growing community since then, a large percentage of residents in Ballina will not have experienced flooding. This may affect the community's preparedness to respond to a flood in an emergency. An estimate of the residential dwellings and population at risk for each design flood event is listed in Table 3-1.

Table 3-1 Estimation of Population at Risk

Flood Event	Dwellings	Population
PMF	4,764	9,766
500 year ARI	4,698	9,631
100 year ARI	1,924	3,944
50 year ARI	964	1,976
20 year ARI	629	1,289
10 year ARI	426	873
5 year ARI	281	576

Notes: 1) Number of dwellings estimated by comparing modelled flood extents with the property database, i.e. includes properties within flood extent with floor levels higher than flood level.

2) Population calculated by multiplying number of dwellings by 2.05 (approximate ratio of people per dwelling calculated from census data).

3) Only currently built dwellings considered, i.e. ignored dwellings associated with approved development that has not yet been built. Numbers listed in Table 4-1 include future development.

In order to better understand the risk of flooding to the community, the ability to evacuate has been assessed.

3.2 Agency Responsibilities

The NSW State Emergency Service (SES) is the lead agency for evacuation planning, supported by other agencies / parties. Key responsibilities are outlined in Table 3-2. Note this only summarises evacuation planning and related responsibilities; not flood warning or emergency response.

Table 3-2 Evacuation Planning Responsibilities

Agency	Responsibilities	Relevant Documents
NSW State Emergency Service	Designated flood combat agency Development of state and local flood plans and FloodSafe community guides	Ballina Shire Local Flood Plan NSW State Flood Plan FloodSafe Guides
Ballina Shire Council	Liaison with SES local and regional controllers	Ballina Shire Local Flood Plan
	Lead agency for floodplain risk management	Floodplain Risk Management Plan
	Statutory responsibility for land use planning	Development Control Plan Local Environmental Plan
NSW Office of Environment and Heritage	Technical agency for floodplain risk management	Floodplain Risk Management Plan Floodplain Development Manual
NSW Department of Planning	Lead agency for land use planning	Development Control Plan Local Environmental Plan
NSW Department of Community Services	Management of evacuation centres	
Ballina Floodplain Risk Management Committee (FRMC)	Committee responsible for floodplain risk management	Floodplain Risk Management Plan
Local Community	Familiarity with local flood risk and FloodSafe guides	Local FloodSafe guides Private flood plans, where appropriate

The Bureau of Meteorology (BoM) monitor gauges on the Richmond River upstream of Ballina, a rainfall radar gauge at Grafton and ocean levels along the east coast. They issue information to the SES local controller. There are no formal flood warning processes in place for Ballina. Responsibility lies with the SES to make a decision on whether to evacuate Ballina.

3.3 Local Flood Plan

The Local Flood Plan (LFP) for the Ballina Shire was prepared by the SES in 2008 (SES, 2008). The plan outlines preparedness measures, the conduct of response operations and the coordination of recovery measures for all flooding events within the area. However, there is no formal evacuation plan within the study area.

3.4 Local Catchment Flooding – Flash Flooding

Local catchment flooding affects the rural regions of the study area along Emigrant, Maguires and North Creeks. Local storms in these areas produce the severest flood conditions and have a much faster response than Richmond River and ocean storm surge flooding. Flash flooding conditions are known to occur.

Also, evacuation is difficult and dangerous during such flood events. Rainfall is more intense during short duration events and is likely to overwhelm local drainage systems. In addition, faster flowing water would make driving conditions extremely hazardous. Evacuation is, therefore, not advised during flash flooding events (opinion of the FRMC) and it may be preferable for residents to 'shelter in place'. Such advice would remain at the discretion of the SES, who would balance the relative risks of evacuation against isolation and inundation for a particular flood event.

In light of the rapid onset of this form of flooding and uncertain practicality of evacuation and prediction, a prediction time for this source of flooding cannot be adequately estimated. Council has two formal measures in place to manage this form of flooding:

- Council disseminate road closure information during wet weather through the establishment of a temporary Call Centre. This service is a major provider of information to the public during flood emergencies. Council has developed guidelines for establishment a Call Centre (BCS, 2006). These guidelines have been developed so that members of the public are not placed at risk through the provision of flood and road closure information.
- A flash flooding warning system has been installed on Maguires Creek to warn of impending floods in the Teven Valley. The system relays real time rainfall and stream level information to SES headquarters, who forward the warning to local residents and SES personnel via SMS.

3.5 Evacuation Zones and Routes

Based on consultation with the SES, the study area has been divided into six distinct evacuation zones. For each zone, evacuation routes, with corresponding traffic flow direction, have been provided by the SES. These evacuation zones and routes have been adopted as current emergency response practice in this study, and are presented in Figure 3–1 and listed in Table 3-3.

Table 3-3 List of Evacuation Zones and Routes

Zone	Area	Evacuation Route	Evacuation Destination
Zone A	Ballina Island (West)	Angels Beach Drive	East Balina
Zone B	Ballina Island (East)	Kingsford Smith Drive	East Ballina
Zone C	North Ballina	Old Pacific Highway	Cumbalum Ridge
Zone D	West Ballina	Old Pacific Highway / Bruxner Highway	Alstonville
Zone E	Rural South Ballina	River Drive / Wardell Road	Alstonville
Zone F	Rural Maguires Creek Valley	Teven Road	Bangalow

The evacuation route for Zone C uses the old Pacific Highway and Deadmans Creek Road to access Cumbalum Ridge. These roads are low-lying and known to flood during minor local catchment flood events. However, as discussed in Section 3.4, this assessment focuses primarily on extreme flooding from the Richmond River and ocean storm tides. This type of flooding is associated with longer prior warning periods than local catchment flooding, which enables evacuation before the route is flooded.

3.6 Evacuation Centres

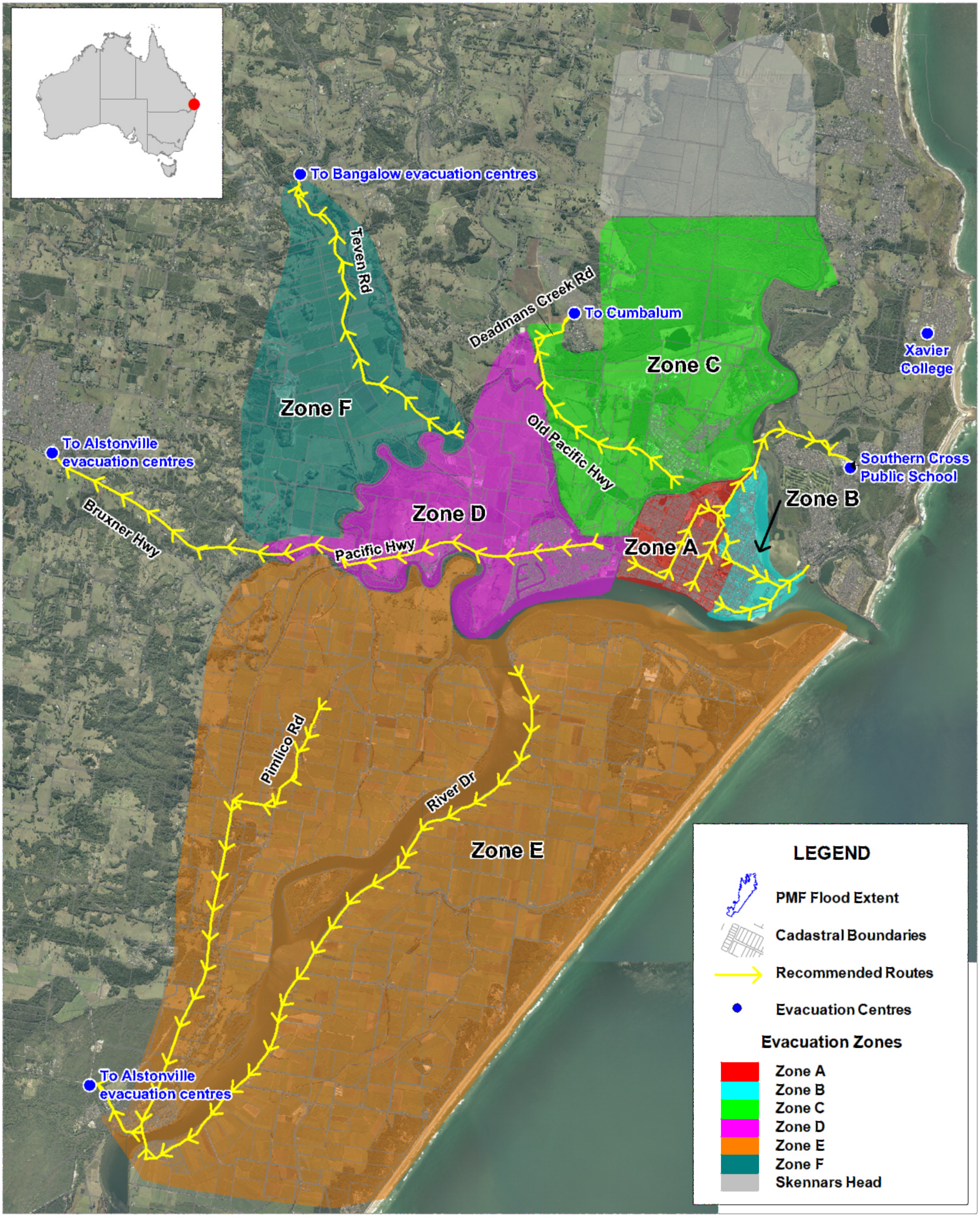
A large proportion of the developed areas of Ballina are in the floodplain (i.e. within the Probable Maximum Flood extent), which makes identification of local evacuation centres difficult. The LFP identifies the Gunundi Anglican Camp & Conference Centre (Shelley Beach Road, East Ballina) as an evacuation centre. However, this centre has since been sold. Within the township of Ballina, the only other site which has been identified for potential use as an evacuation centre is the Southern Cross School (Chickiba Drive, East Ballina).

Additional sites which may be suitable for use as evacuation centres are located out of Ballina, such as the following:

- Xavier College, 2 Redford Drive, Skennars Head;
- Teven Public School, Fredericks Lane, Tintenbar;
- St Joseph's School, 11 Perry Street, Alstonville;
- Alstonville High School, Cawley Close, Alstonville;
- Alstonville Public School, 58 Main Street, Alstonville;
- St Bartholomew's Anglican Church, 8 The Avenue, Alstonville; and
- Alstonville Leisure & Entertainment Centre, Commercial Rd, Alstonville.

The evacuation centre for Zone C is at Cumbalum. While there is currently no infrastructure at Cumbalum suitable for use as an evacuation centre, a school is planned for Ballina Heights. The identified locations will require confirmation from the NSW Department of Community Services (DoCS) as to suitability, capacity and available facilities.

Figure 3–1 Evacuation Routes and Zones



Title:

Evacuation Routes and Zones

Figure: **3-1**

Rev: **A**

N

0 1.5 3km

Approx. Scale

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_3-1.wor

3.7 Timeline Approach

The current evacuation capability for the study area has been assessed using a timeline approach to estimate whether there is sufficient time available to evacuate during a flood. The methodology is detailed in Appendix C. In essence, the time taken to evacuate is compared against the time available, to determine if the evacuation can be completed. The time available is the difference between the prediction time and route closure time. The safety margin is the residual time available after the evacuation is completed. If the evacuation route closes prior to the completion of the evacuation, the additional time (rescue phase) required to complete the evacuation has been estimated. Timeline plots are shown in Figure 3–3 and Figure 3–4.

A key assumption in the analysis is that the evacuation is not limited by SES resources or evacuation centre capacity (SES resource requirements to match this assumption is discussed in Section 3.12). The primary constraint is the road capacity (see Section 3.14.5 for further details on the assumptions and limitations associated with the analysis).

3.8 Design Flood

The Probable Maximum Flood (PMF) has been used to evaluate the road closure times, flooded population and flood prediction times. The PMF is a hypothetical flood, or combination of floods, which represents a theoretical 'worst case' scenario. According to the NSW *Floodplain Development Manual* (DIPNR, 2005) it is generally not economically or physically possible to provide complete protection against an event of this magnitude. However, it is important that the PMF is used in the evacuation assessment to define the scope and magnitude of potential evacuation requirements. Therefore, the use of the PMF for evacuation assessment constitutes a conservative approach.

An assessment of road closure times has also been presented for the 100 year ARI flood event. A discussion of road closure between the PMF and 100 year ARI event and the three flood sources is discussed in Section 3.14.

3.9 Flood Prediction

Prediction time is one of the most significant parameters in the evacuation capability assessment. The flood prediction time will depend on the source of flooding. The methodology used to derive the prediction time is discussed in detail in Appendix C.

In summary, the prediction time for a Richmond River flood and ocean storm surge flood were compared. Local catchment flooding was not considered, as this form of flooding occurs rapidly and evacuation is not advised (see Section 3.4). Prediction times were based on information provided by the Bureau of Meteorology and the SES. The prediction time for Richmond River dominated flooding is related to the timing of flooding at gauges further upstream (such as Kyogle, Casino and Coraki) and the flood wave travel time; it typically takes 24 hours to 48 hours for flood waters to travel down river to Ballina. The prediction time for ocean storm surges is related to the time between high tides, assuming that the impending storm surge is predicted on the preceding high tide (i.e. 12 hours before the peak ocean storm surge level, see Figure 3-2).

The results of the flood prediction assessment were:

- The prediction time associated with an ocean storm surge flood was estimated to be 22 hours after the start of the hypothetical PMF design flood simulation; and

- The prediction time for a Richmond River dominated flood was estimated to be 14.5 hours after the start of the hypothetical PMF design flood simulation.

The ocean storm surge flood prediction time (22 hours after commencement of the hypothetical design flood event) was selected for use in the assessment, because it is later than the Richmond River flood prediction time and is therefore a more conservative approach.

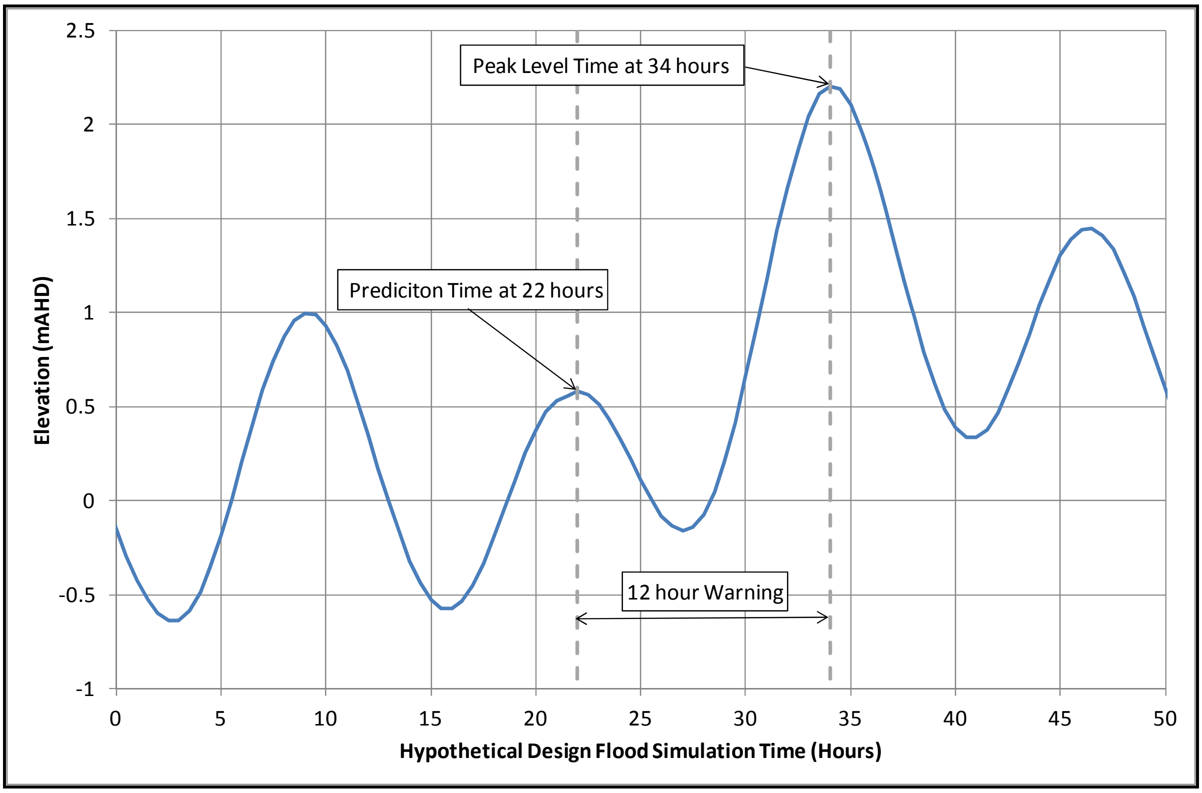


Figure 3–2 Plot of 500 Year ARI Storm Tide Levels Indicating Prediction Time

3.10 Evacuation Route Closure Times

The flood model has been used to estimate evacuation route closure times and locations. For each route, the adopted road closure criterion was 300mm of water over the road surface, which is the depth when roads are generally considered no longer trafficable by standard vehicles. The location and route closure times for each zone are shown in Appendix D.

The Skennars Head area was not included in the assessment. Properties in this area are off Ross Lane, which runs along the edge of the model extent and upstream model boundary at North Creek. It is, therefore, not possible to use the model results to determine route closure times on Ross Lane.

3.11 Demographic Data

A demographic database was developed for the study area using the methodology outlined in Appendix B. The database was based on a 2006 census. However, since the flood model includes future development and is estimated to represent the catchment in approximately 2020 (see Section 2.3), the demographic data have been projected based on information provided by Council; including infill development projected to 2020, and populations linked to future developments have been incorporated assuming 2.16 people per residential dwelling (shire-wide long-term occupancy rate projection).

A summary of demographic data for each evacuation zone is presented in Figures D-1 to D-7, Appendix D. Table 3-4 lists the population details associated with each of the evacuation zones.

Table 3-4 Evacuation Zones and Population

Zone	Dwellings (As per 2006 census)	Population (As per 2006 census)	Projected Dwellings (Additional)	Projected Population (Additional)	Total Baseline Dwellings	Total Baseline Population
A	1,903	3,771	238	524	2,141	4,295
B	1,679	3,030	168	352	1,847	3,382
C	481	1,038	424	916	905	1,954
D	1,301	2,808	295	682	1,596	3,490
E	521	1,228	0	0	521	1,228
F	33	90	0	0	33	90

Notes: Additional population and dwellings reflect the unbuilt residential development that is included in the flood model and population projections for infill development till 2020.

The number of dwellings include the number of caravans

3.12 SES Resources

The assessment assumes unlimited availability of SES resources with 'door knocking' by SES teams to be the method of warning the public. Teams are made up of two people and the door knocking rate is 12 dwellings per team per hour. The number of teams deployed by the SES has been calculated by ensuring that the evacuation routes are always at full capacity. See Table 3-5 for a list of the number of teams estimated for each zone.

Table 3-5 Number of SES Teams For Each Zone

	Number of SES Teams
Zone A	49
Zone B	54
Zone C	40
Zone D	41
Zone E	34
Zone F	25
Total	243 Teams or 486 people

3.13 Evacuation Capability Results

3.13.1 Results for Evacuation Zones

The results for the current evacuation capability assessment are summarised in Table 3-6 below. Note that uncompleted evacuations are displayed with negative hours, which indicate the hypothetical length of time estimated to complete the evacuation after route closure (referred to as the rescue phase). The primary comparative factors used in the evacuation capability assessment are defined below.

- A **safety margin** is determined when evacuation is possible, i.e. evacuation route closes after the evacuation has been completed. The safety margin is the residual time available after the evacuation has been completed until the route closes.
- A **rescue phase** is required when evacuation is not possible, i.e. evacuation route closes before the evacuation has been completed. The rescue phase is the extra time that is required after route closure to complete the evacuation.

Table 3-6 Evacuation Assessment Results

	Zone A	Zone B	Zone C	Zone D	Zone E	Zone F
Safety Margin / Rescue Phase (in hours)	-1.1	-0.1	2.1	-0.1	-0.8	2.1

Note: Safety margins are shown as positive and shaded green.

Rescue phases are shown as negative and shaded red.

Timeline plots of the evacuation assessments for each zone are provided in Figure 3–3 and Figure 3–4. The times in these figures relate to the time after the start of the hypothetical PMF design flood event.

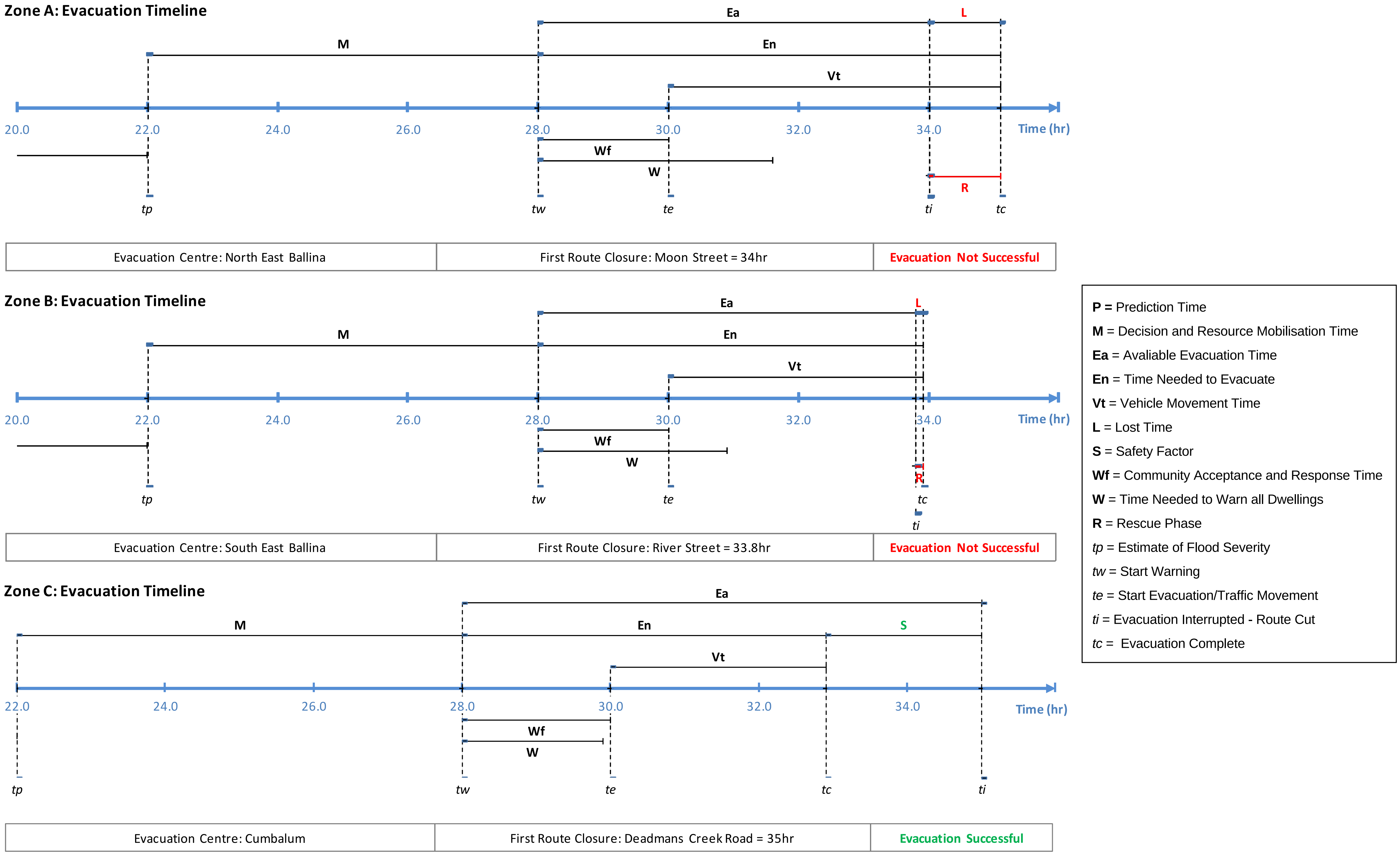


Figure 3–3 Baseline Evacuation Timeline Results (Zones A to C)

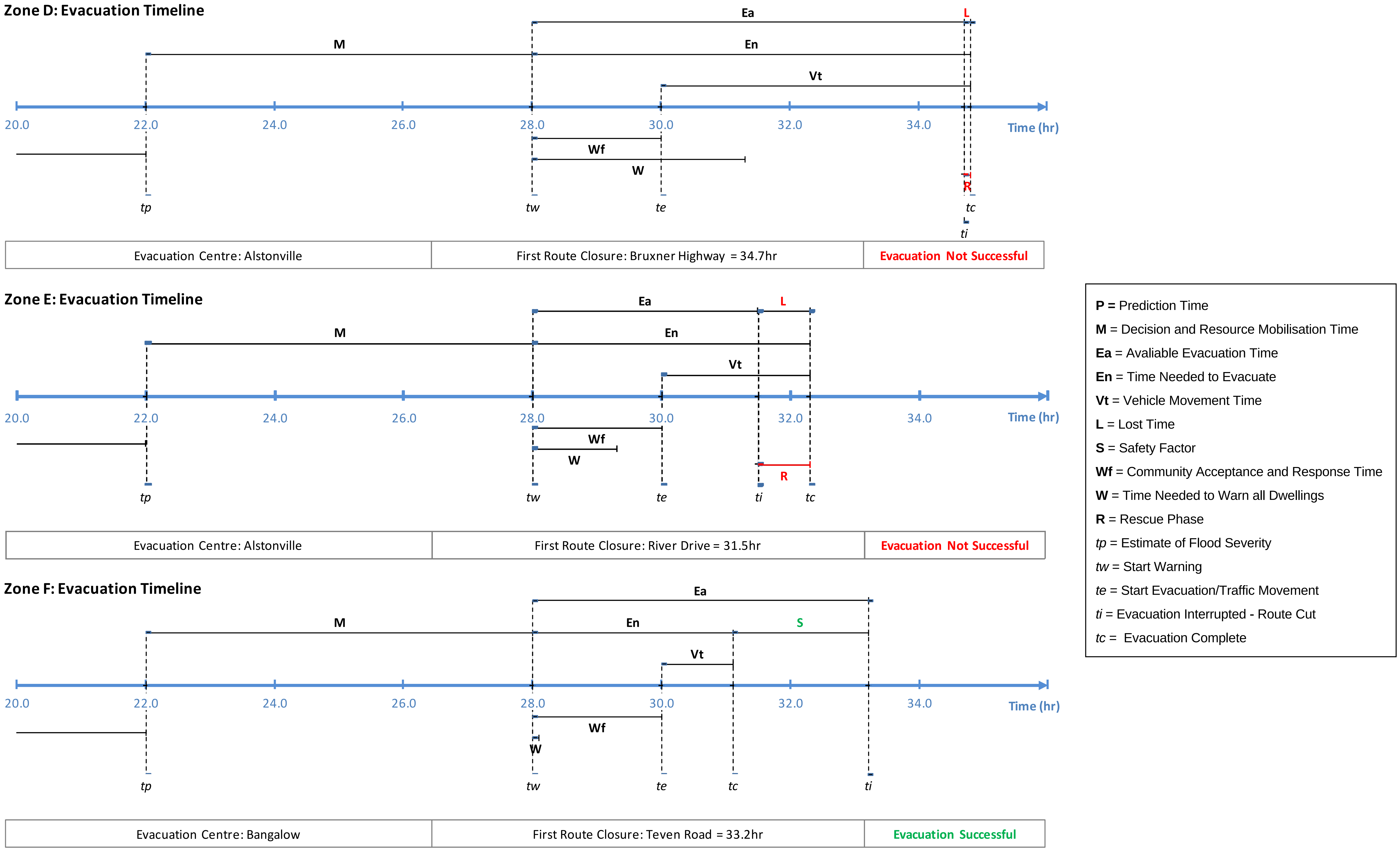


Figure 3–4 Baseline Evacuation Timeline Results (Zones D to F)

Based on the adopted assessment method and design flood event, there is likely to be insufficient time for all residents within Zones A, B, D and E to evacuate. Flood response management options (discussed in Section 7) will improve the evacuation capacity of these zones.

For residents in Zones C and F, evacuation may be possible. The safety margin may be sufficient for safe evacuation, however it is recommended that flood response management options are explored in order to improve the safety margin and consider future development.

3.13.2 Evacuation Capability for Shaws Bay

The porous northern headwall on the mouth of the Richmond River allows floodwater to flow into Shaws Bay affecting the properties surrounding the bay. However, there is high ground directly adjacent to this area. It is recommended that residents drive to the East Ballina Evacuation Centre via Suvla Street. An evacuation capability assessment has not been carried out as the dwellings are directly adjacent to high ground and will use minor roads to access the high ground.

3.13.3 Alternative for Zone D – Using the Ballina Bypass

The evacuation procedure for Zone D (West Ballina) is to drive to Alstonville via the Bruxner Highway. At present the Ballina Bypass is being constructed and will have an interchange off the Pacific Highway near Teven Road. This will enable an alternative route for Zone D along the Ballina Bypass towards Cumbalum Ridge. There is no northbound off-ramp on the Ballina Bypass at Cumbalum. Therefore, vehicles would need to drive to the next interchange at Ross Lane and turn around to head south on the Ballina Bypass. Traffic would then take the southbound Cumbalum off-ramp and travel up to Cumbalum Ridge via a proposed new road.

Using the Ballina Bypass changes the location where the route is closed by flooding. The route closes in West Ballina before traffic reaches the interchange (see Figure D-5 in Appendix D). The route closes 1 hour later than the previous scenario (i.e. using the Bruxner Highway), resulting in a safety margin of 0.9 hours for Zone D. Once the Ballina Bypass has been opened, this new route may, therefore, present a preferable option. However, consideration should also be given to the capacity of the evacuation centres. The route is also flooded on the bypass south of the Cumbalum interchange only 0.2 hours after the route closure in West Ballina. Some evacuees may therefore need to keep travelling north on the Ballina Bypass towards Bangalow. The Bruxner Highway may be a better option if flooding is dominated by an ocean storm event, as shown in the flood source comparison analysis discussed below.

3.14 Flood Source and Routes Closure Comparison - 100 Year ARI

3.14.1 Overview

Potential evacuation routes have been identified and overlayed upon the digital elevation model in a GIS database.

Route closure locations and times are influenced by the source of flooding (local catchment, Richmond River or ocean storm surge) and the size of the event. Figure 3–5 and Figure 3–6 illustrate route closure locations and hours to closure for scenario A (Richmond River flooding predominance), scenario B (local catchment storm flooding predominance) and scenario C (ocean storm flooding predominance), all presented for a 100 year ARI event.

It should be noted that the relative timing between scenarios A, B and C is based on the hypothetical setup of the design flood events. Thus route closure times across scenarios A, B and C cannot be directly compared.

The following observations have been made from the route closure comparison figures:

- Routes servicing Ballina Island do not close for any of the 100 year ARI design event scenarios;
- The old Pacific Highway in the direction of Tintenbar closes earlier than Deadmans Creek Road in the direction of Cumbalum;
- The Bruxner Highway is closed for Richmond River and local catchment flooding, but not ocean storm surge flooding; and
- River Drive, in South Ballina, is not closed during the local catchment flooding event.

As water levels rise it is likely that the SES will not know how high flood levels will ultimately reach until the flooding starts to recede. Even then, there is the likelihood of additional peaks, especially considering tidal influences. Therefore, a conservative approach is assumed whereby the population at risk under a PMF event will be evacuated for smaller flood events (such as a 100 year ARI flood event). However, with smaller events the route closure times will change. Table 3-7 shows that there is generally a significant delay in the time at which route closure occurs for a 100 year ARI flood event. Although this does not necessarily mean there is more time available for evacuation, as discussed below.

Table 3-7 Comparison of Route Closure Times

	PMF (hours) Prediction Time = 22 hours	100 Year ARI Scenario A (hours) Prediction Time = 45.5 hours	100 Year ARI Scenario B (hours) Evacuation not recommended	100 Year ARI Scenario C (hours) Prediction Time = 22 hours
Zone A	34	No closure	No closure	No closure
Zone B	34	No closure	No closure	No closure
Zone C	35	54	40	44
Zone D	35	56	41	No closure
Zone E	32	33	No closure	58
Zone F	36	50	38	40

Note: Prediction times are the times at which flood predictions are made relative to the start of the hypothetical design floods.

3.14.2 Richmond River Flooding

This later road closure time does not necessarily lead to a greater length of time available for evacuation during a Richmond River Flood, because there is a slower rate of rise of flow in the Richmond River for a 100 year ARI event as opposed to a PMF event (see Figure C-2, Appendix C). This slower rate of rise results in a later prediction time. Applying the same technique as discussed in Appendix C Section 5.1 results in a prediction time 23.5 hours later than the predication time used in the Evacuation Capability Assessment (ECA) for a PMF event.

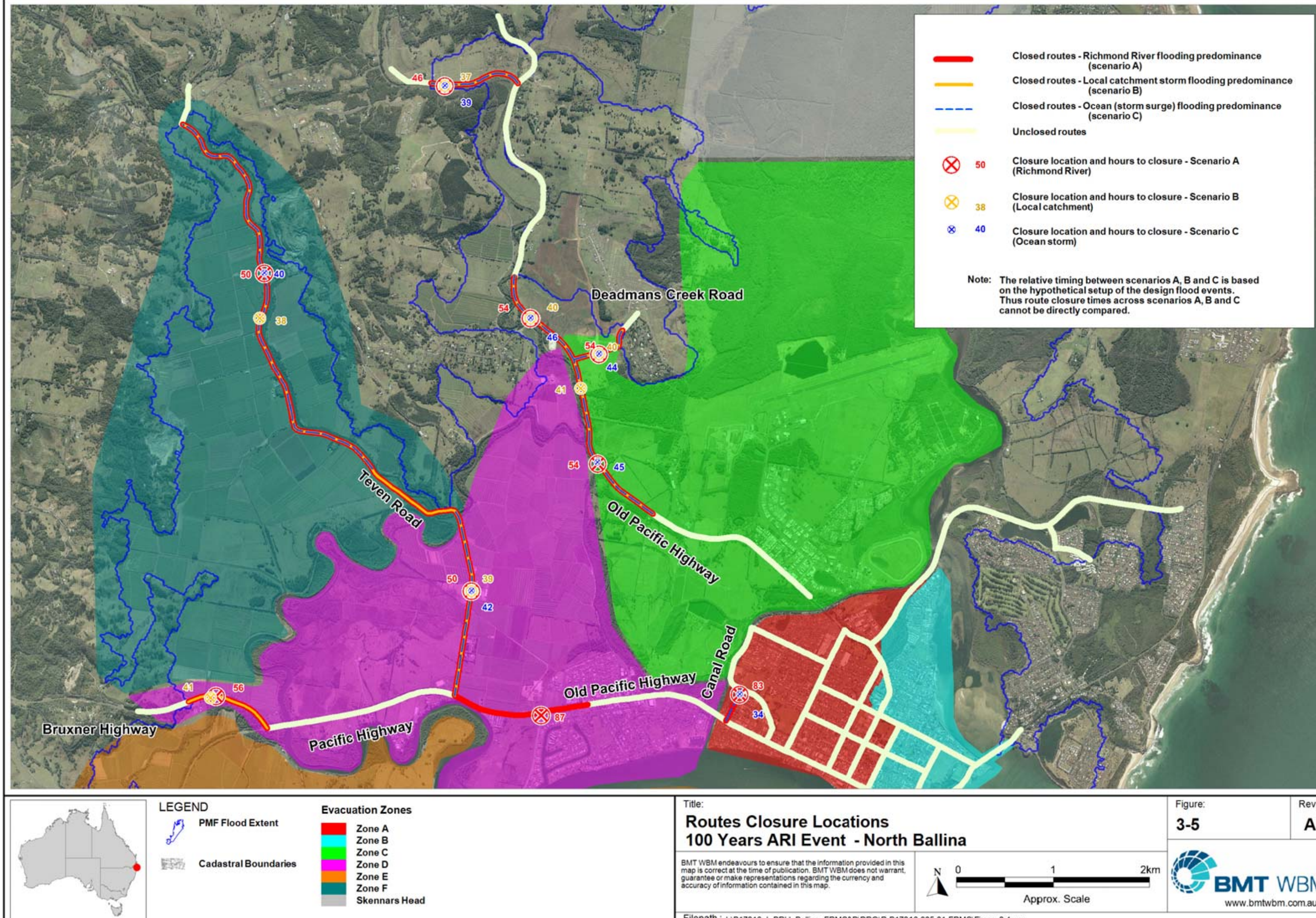
The routes in Zones A and B do not close. Therefore evacuation of Ballina Island is possible. There is 4.5, 2.5, 22.5 and 9.5 hours less time available for evacuation compared to the PMF event for Zones C, D, E and F respectively. Therefore, full evacuation for these zones may not be possible with the assumed prediction time. This highlights the value that a flood forecasting system on the Richmond

River will bring to the Ballina area.

3.14.3 Ocean Storm Flooding

For ocean storm flooding the warning time remains at 22 hours. There is, therefore, much more time available for evacuation. Evacuation is possible for Ballina Island and West Ballina (Zones A, B and D) as the routes do not close. North Ballina, South Ballina and the Maguires Creek valley (Zones C, E and F) have additional 9, 26 and 4 hours of time available compared to the PMF event respectively. Therefore, if the flood prediction is triggered on the preceding high tide, evacuation is generally considered achievable for this event.

Figure 3–5 Routes Closure Location 100 Year ARI Event – North Ballina



Title:

Routes Closure Locations
100 Years ARI Event - North Ballina

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

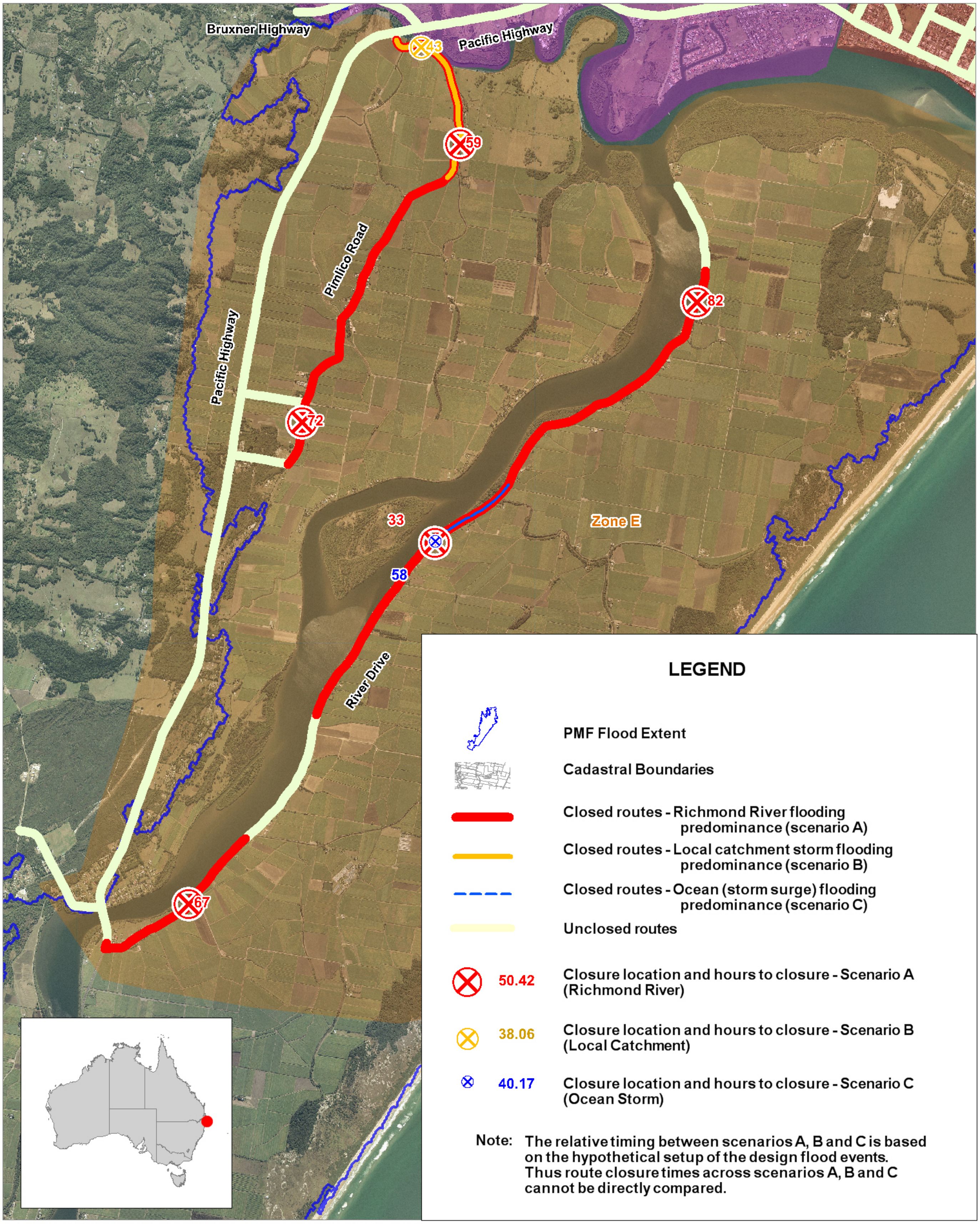
Figure: 3-5

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_3-4.wor

Figure 3–6 Routes Closure Location 100 Year ARI Event – South Ballina



Title:

Routes Closure Locations Scenarios Comparison 100 Years ARI Event - South Ballina

Figure: 3-6

Rev: B

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS3\Figure_3-5.wor

3.14.4 Climate Change

The potential increase in sea levels and rainfall intensity associated with climate change cause evacuation routes to close quicker, thus reducing the evacuation capability. The evacuation capability assessment was repeated for the two climate change scenarios. The results are summarised in Table 3-8.

Table 3-8 Summary of Evacuation Capability Results

Zone	Current	2050 Horizon		2100 Horizon	
	Safety Margin / Rescue Phase (hours)	Safety Margin / Rescue Phase (hours)	Difference (hours)	Safety Margin / Rescue Phase (hours)	Difference (hours)
A	-1.1	-2.1	-1	-3.2	-2.1
B	-0.1	-1.1	-1	-2.2	-2.1
C	2.1	2.1	0	1.1	-1
D	-0.1	-0.4	-0.3	-1.5	-1.4
E	-0.8	-1.7	-0.9	-24.1	-23.3
F	2.1	2.1	0	2.1	0

Notes: *Safety margin is presented as positive hours and highlighted green.*
Rescue phase is presented as negative hours and highlighted red.
Negative differences depict a reduction in the evacuation capability compared to the current climate.
Refer to Figure 3–1 for a location plan of the evacuation zones.

There is a marked decrease in the evacuation capability of South Ballina (Zone E). This is because the evacuation route, River Drive, runs along the right bank of the Richmond River and is flooded very quickly with 2100 sea level rise projections. Zone F, which is in a rural area along Maguires Creek, is not affected by climate change. This zone is higher up in the catchment and is, therefore, not significantly impacted by sea level rise. The evacuation capability for the other zones is generally reduced by approximately 1 hour for the 2050 horizon and 1 to 2 hours for the 2100 horizon.

3.14.5 Assumptions and Limitations

A number of assumptions have been established for the evacuation capability assessment.

- The car flow rate has been set to 600 cars per lane per hour as recommended by the SES. This number accounts for adverse driving conditions such as heavy rain or darkness, and represents a conservative calculation of the probable car flow rate.
- All lag time parameters such as mobilisation time and community acceptance have also been estimated with a conservative approach by the SES.
- The assessment has been undertaken in a PMF condition which represents a theoretical 'worst case' scenario.
- The number of teams (two people make up a team) that are deployed by the SES have been calculated by ensuring that the evacuation routes are always at full capacity. This leads to a high number of teams per zone which may be unreasonable. However, it is possible that the SES will use different or additional warning methods to the assumed door knocking approach. This study has recommended use of additional flood warning methods (see Section 7.3).

- It has been assumed that the evacuation centres have unlimited capacity. This assumption applies to the evacuation centre's sheltering capacity and availability of parking space. For the purposes of Ballina's Local Flood Plan, it is recommended that the capacity and identification of evacuation centres be considered further through consultation with DoCS.
- The added resources and / or time required for the evacuation of vulnerable centres such as schools, hospitals, aged care accommodation and caravan parks has not been accounted for in the evacuation capability assessment. Vulnerable centres are marked on Figures D-1 to D-7 in Appendix D. It is recommended that separate, detailed assessments are undertaken to ensure the evacuation requirements of these centres can be met in the event of a flood.
- Due to the limitations of the flood modelling and the location of evacuation routes, the evacuation capability assessment has not included the Skennars Head area (marked in grey in Figure 3–1). It is recommended that this area evacuate to high ground near Lennox Head.
- For local catchment flooding (flash flooding), it is difficult to assess the flood prediction time and it may not be advisable to attempt an evacuation in the hazardous weather conditions. The evacuation capability assessment, therefore, only considers Richmond River and ocean storm surge flooding.

3.15 Conclusion

An assessment of Ballina's evacuation capability has been undertaken. It was assumed that there would be unlimited availability of SES resources, which resulted in 243 SES teams door knocking to warn the community. This is clearly impractical, thus a better warning mechanism will need to be implemented. This is discussed again in Section 7.3.

The ECA indicates that evacuation of Zones A, B, D and E may not be completed before the respective evacuation routes close during a PMF flood event. It is interesting to note that the sum of the safety margins/rescue phases for Zones A, B, C and D is 0.8 hours. Thus evacuation may be possible for all these zones by diverting evacuation from Zones A, B, and D when their respective evacuation routes close to the Zone C evacuation route (Cumbalum Ridge via the old Pacific Highway). The evacuation routes for the most densely populated part of Ballina, i.e. Ballina Island, do not close during a 100 year ARI flood event.

The results show that an additional hour is needed under current climate conditions and 3 hours under climate conditions in 2100 (ignoring rural South Ballina) to fully evacuate. There are a number of options available to improve the evacuation capability (see Section 7), which, if implemented, may enable full evacuation.

4 FLOOD DAMAGES

4.1 Overview

A flood damage assessment has been carried out to establish the socio-economic costs of flooding to society within the study area. This assessment also forms a baseline for quantifying the benefits of certain mitigation measures investigated later in this study The methodology used to estimate flood damages is discussed in detail in Appendix G. Flood damages have been determined for the full range of modelled flood events using the flood modelling output (shown in Appendix B) to determine the depth of flooding at each property. Flood damages at properties were estimated using the following two methods:

1 The ANUFLOOD method (CRES, 1992) was used to calculate flood damages for commercial properties; and

2 The Department of Environment and Climate Change Residential Flood Damages Guideline (DECCW, 2007b) for residential properties, which supersedes the ANUFLOOD (CRES, 1992) method for residential damages estimation.

A property database has been developed to inform this assessment. The methodology used to develop the database is discussed in Appendix E. In summary, the property data was collected from floor level surveys conducted in 1979 and 2009. Since the base case scenario applies to 2020, future development that is represented in the flood model has been appended to the property database. For this task, Ballina Shire Council provided information on the expected number of dwellings associated with future development.

The main comparative factor that is derived from the flood damage assessment is the Average Annual Damage (AAD). AAD represents the estimated tangible damage sustained every year on average over a long period of time. The AAD is determined using the full range of flood events, from events causing negligible damage to those causing catastrophic damage, such as the PMF event. The flood model is only considered appropriate for assessment of events greater than or equal to the 5 year ARI, therefore, the damage curve has been extrapolated to the 2 year ARI event where negligible damage is assumed at Ballina. The damage for each event is plotted against the corresponding Annual Exceedance Probability (AEP) of the flood event (e.g. 100 year ARI corresponds with a 1% AEP). The AAD is equal to the area under this curve, as shown in Figure 4–1.

4.2 Results

The contribution of the damages from each type (residential, commercial, infrastructure and rural) are shown in Table 4-1 and Figure 4-2. The estimated flood damages for different parts of the catchment are summarised in Figure 4–3 and Figure 4-4.

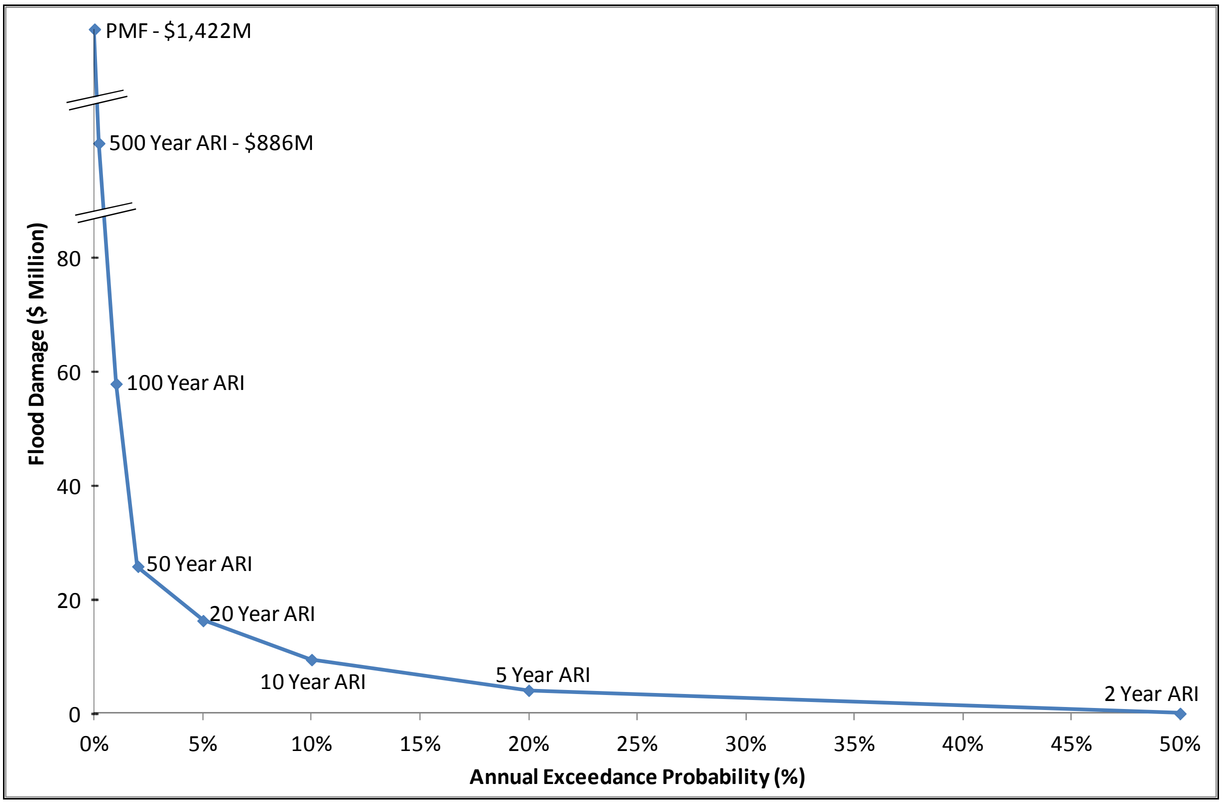


Figure 4–1 Total Damage versus Annual Exceedance Probability (AEP) Curve - Existing Case

Notes: Average Annual Damage corresponds to the area under this curve.

PMF damages are the worst damages possible, and are therefore used to define the 'damage axis' intercept value.

Flood events more frequent than 2 year ARI (50% AEP) are assumed to be 'in bank', thereby incurring zero damage.

Table 4-1 Baseline Model Flood Damages Results

ARI	AEP	Residential		Commercial		Infrastructure	Rural	Total
		Number of Dwellings	Damages	Number of Dwellings	Damages			
5 year	20%	178	$2,528,000	12	$858,000	$462,000	$209,000	$4,057,000
10 year	10%	272	$6,323,000	19	$1,608,000	$1,104,000	$411,000	$9,445,000
20 year	5%	428	$11,354,000	26	$2,385,000	$1,934,000	$608,000	$16,281,000
50 year	2%	722	$17,771,000	51	$4,088,000	$3,061,000	$873,000	$25,793,000
100 year	1%	1646	$41,530,000	116	$7,989,000	$7,003,000	$1,294,000	$57,817,000
500 year	0.2%	6419	$523,644,000	1240	$256,551,000	$103,396,000	$2,171,000	$885,762,000
PMF	0%	6558	$745,763,000	1464	$512,190,000	$161,493,000	$2,211,000	$1,421,657,000
AAD			$5,527,000		$2,336,000	$1,055,000	$139,000	$9,058,000

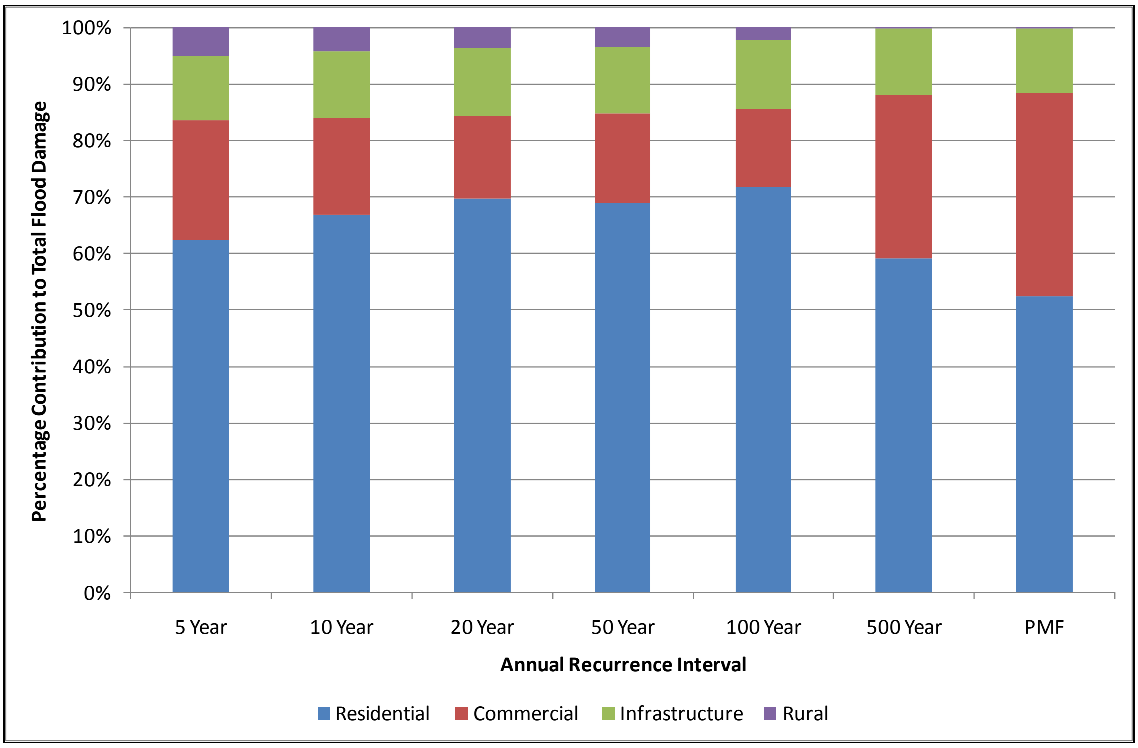


Figure 4–2 Flood Damage Contribution

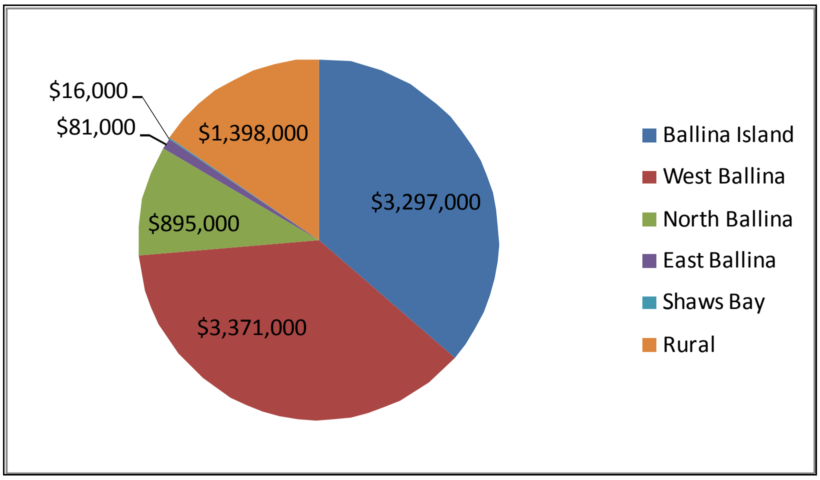
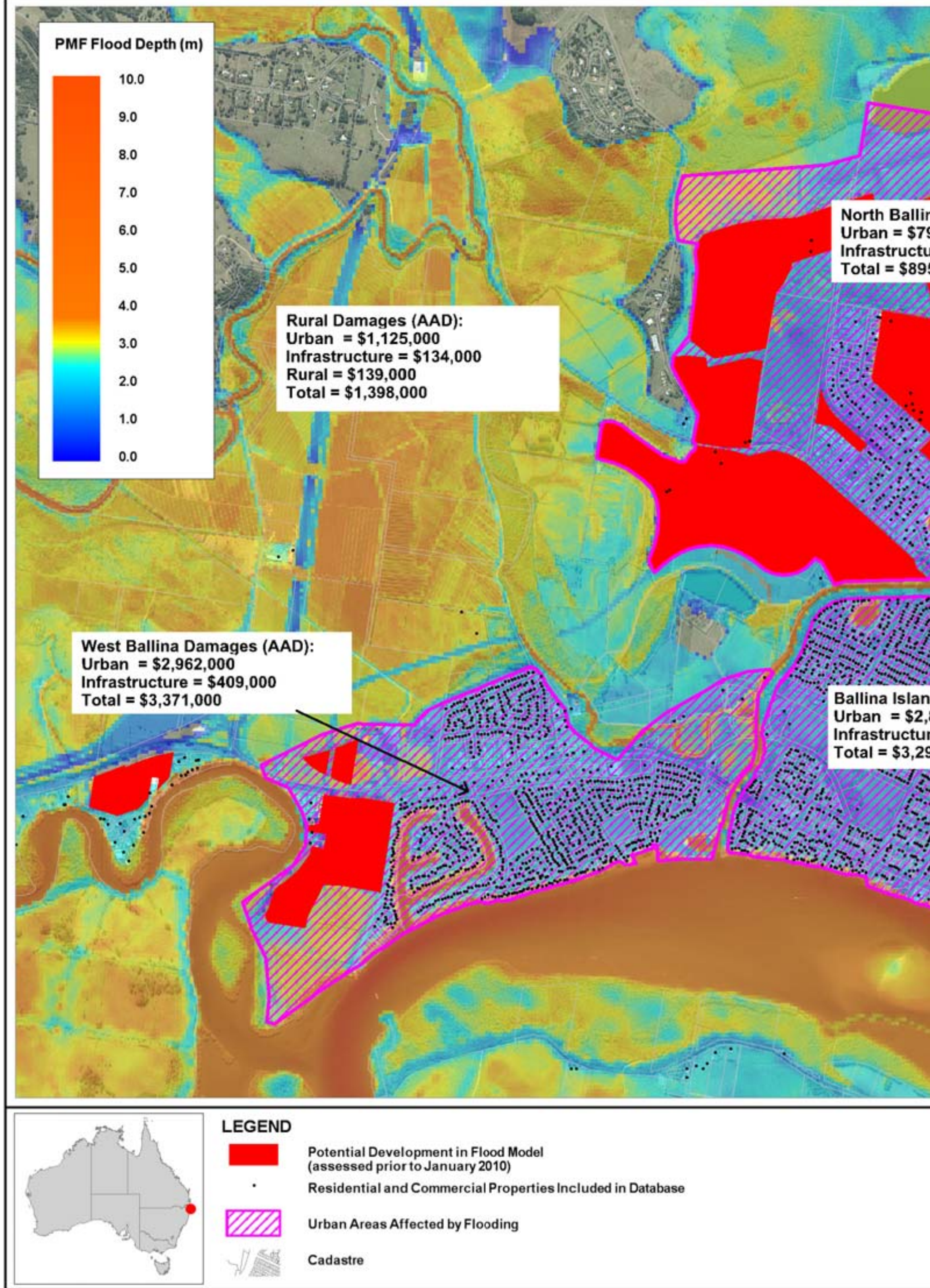


Figure 4–3 Summary of Total Average Annual Damage by Sector

Figure 4–4 Ballina Current Flood Damages Summary



Title:
Ballina Current Flood Damages Summary

Figure: 4-4

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_4-4.WOR

4.3 Climate Change

The affects of climate change have been shown to result in higher flood levels, causing an increase in inundated properties for a given flood event. This, in turn, will lead to an increase in flood damages as shown in Figure 4–5 The substantial increase in 2100 flood damages associated with the more frequent events (2, 5 and 10 year ARI) have a dominating influence on the AAD. Less frequent events (500 year ARI and PMF) have a smaller influence due their infrequent occurrence. Table 4-2 shows a comparison of the AAD for the climate change scenarios.

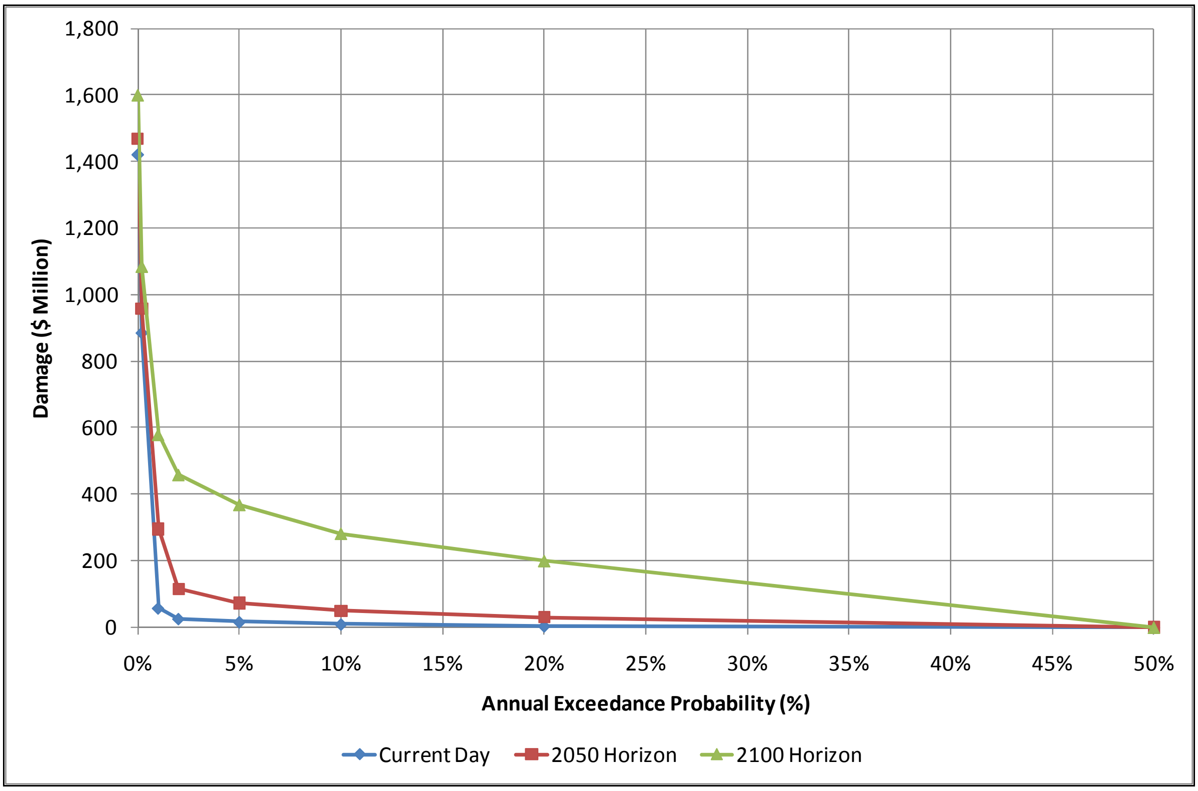


Figure 4–5 Comparison of Damage Curves

Table 4-2 Comparison of Average Annual Damages

	Current	2050 Horizon		2100 Horizon	
	AAD	AAD	AAD Increase	AAD	AAD Increase
Ballina Island	$3,297,000	$10,585,000	$7,288,000	$59,665,000	$56,368,000
West Ballina	$3,371,000	$8,461,000	$5,090,000	$22,618,000	$19,247,000
North Ballina	$895,000	$1,695,000	$800,000	$5,155,000	$4,260,000
East Ballina	$81,000	$159,000	$78,000	$602,000	$521,000
Shaws Bay	$16,000	$277,000	$261,000	$2,925,000	$2,909,000
Rural	$1,398,000	$2,757,000	$1,359,000	$6,187,000	$4,789,000
Total	$9,058,000	$23,934,000	$14,876,000	$97,152,000	$88,094,000
		Percentage Change:	164%		893%

The total AAD is heavily influenced by areas of concentrated urban development such as Ballina Island and West Ballina. Ballina Island and West Ballina are also located close to the Richmond River mouth, thus being highly susceptible to sea level rise and thereby compounding the increased damages.

5 FLOODPLAIN MANAGEMENT MEASURES OVERVIEW

The purpose of this Floodplain Risk Management Study is to investigate measures to reduce the flood risk to people and property in the Ballina area. The Floodplain Development Manual defines three floodplain management categories, namely:

1 Property Modification Measures: - modifications to existing buildings to remove them from flooding and/or imposition of controls on property and infrastructure development.

2 Response Modification Measures: - aimed at increasing the ability of people to respond appropriately in times of flood and/or enhancing the flood warning and evacuation procedures in an area.

3 Flood Modification Measures: - designed to alter the behaviour of the flood itself by reducing flood levels and/or velocities, or by excluding flood waters from areas at risk.

A Floodplain Risk Management Plan needs to consider all three as an integrated and effective mix, appropriate to the specific circumstances of the community.

During the course of this study, each of the floodplain management measures investigated was presented to the Committee via discussion papers and/or presentations. This has given the Committee an opportunity to provide input on the options and to decide which individual measures were to be incorporated into a Floodplain Management Scheme.

The following chapters discuss the flood management options that were explored as part of the study.

6 PROPERTY MODIFICATION MANAGEMENT MEASURES

6.1 Planning and Development Controls

6.1.1 Introduction

The imposition of planning controls can be an effective means of managing flood risks associated with future development (including redevelopment). Such controls might vary from prohibiting certain land uses to specifying development controls such as minimum floor levels and building materials. Planning and development controls can generally be implemented for minimal cost and would ensure that the potential for flood damage does not increase in the future.

In principle, the degree of restriction that is imposed on development due to flooding relates to the level of risk that the community is prepared to accept after balancing economic, environmental and social considerations (i.e. the application of the merits based approach required by the Floodplain Development Manual). In practice, the planning controls that may ultimately be imposed are influenced by a complex array of considerations including state imposed planning policy and directions, existing local planning strategies and policies, and ultimately the acceptability of conditions that could be imposed through the development application process.

Development Control Plans (DCP) are local government planning instruments that provide specific guidelines for certain types of development in a local government area. The guidelines within a DCP are in addition to other planning instruments, such as State Environmental Planning Policies and Local Environmental Plans. DCPs provide a flexible means of identifying additional development controls for addressing development issues without the need for a formal statutory plan. They are, therefore, a useful vehicle for imposing flood related development controls. As such, a draft DCP has been developed as a recommended floodplain management measure (see Appendix G).

6.1.2 Existing Development Control Plan

Ballina Shire Combined DCP 2006, Policy Statement No. 11 - Flood Levels was adopted by Council on 26 August 2010. This latest version of the DCP relating to flooding has taken into account rising sea levels due to climate change according to the 2009 NSW Sea Level Rise Policy, the adoption of a 500mm freeboard (recommended in the Floodplain Development Manual) and preliminary flood modelling from the current Ballina Floodplain Risk Management Study.

The DCP stipulates minimum fill levels and minimum floor levels for different types and locations of development. These levels defined on 2 sets of maps, which depict the current 100 year flood levels and the predicted 2100 100 year flood levels.

While these controls will manage future flood risk, a more flexible approach to managing future flood risk could be considered. Hence the development of a proposed draft DCP is described further below.

6.1.3 Proposed Draft Development Control Plan

Proposed development controls are documented in the draft DCP attached in Appendix G. The DCP imposes a range of flood planning levels (FPLs) depending on the type of development and its location in the catchment. It is considered more flexible than the current DCP, and will therefore provide Council with a more sophisticated tool for appraising proposed development in the floodplain. The proposed draft DCP incorporates the following:

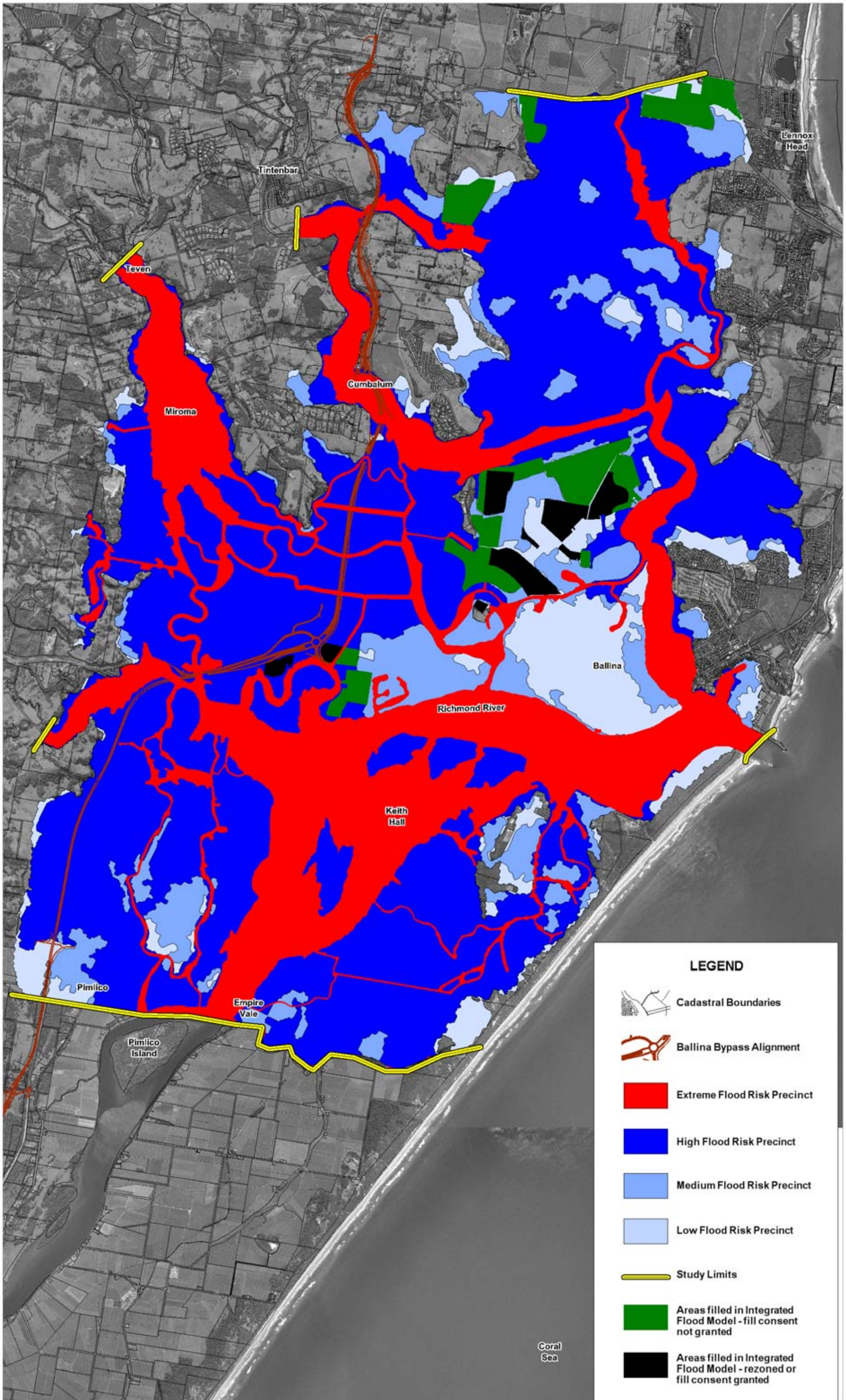
- Managing future flood risk allowing for sea level rise and increased rainfall intensity due to climate change. Provisions are made to impose FPLs at 2100 flood levels where this can be achieved with minimal cost and inconvenience. Where 2100 flood levels are more difficult to implement (e.g. within urban areas surrounded by existing development), 2050 flood levels are applied.
- In urban areas, filling of flood liable allotments to facilitate drainage may also be required. This has been introduced to combat the drainage problems that sea level rise is expected to cause. The minimum fill level for drainage is based on king tide and sea level rise predictions.
- Different FPLs apply to different land uses within a development (e.g. habitable floor levels, non-habitable floor levels and car parking areas may all be subject to different FPLs).
- Different FPLs apply to different types of development. For example, critical facilities such as hospitals will have more stringent FPLs than recreational development.
- Development controls are adjusted to suit the flood hazard. This has been implemented by defining flood risk precincts (FRP) across the floodplain (FRPs are discussed further below). Different development controls apply within each FRP.

A key aspect of the proposed draft DCP is the application of different controls within each FRP. These FRPs describe the degree of flood risk across the floodplain according to four categories: Low, Medium, High and Extreme. Lower category FRPs have looser development controls, as the consequences of flooding are less severe (in terms of risk to life and third party flood impacts). FRPs were determined by investigating the flood hazard (i.e. flood depth and flow velocity) and the flood impact caused by filling areas in the Medium FRP.

Figure 6–1 shows a map of the Flood Risk Precincts. The methodology used to develop this map is discussed in more detail in Appendix F.

In conclusion, the proposed DCP has been devised to manage future flood risk and to ensure that flood risk does not worsen under a changing climate. A major recommendation of this study is to adopt the proposed draft DCP. In light of potential future changes in the recommended allowances for climate change, ongoing reviews of the DCP may be required to keep the controls up to date.

Figure 6–1 Flood Risk Precinct Map



Title:
Flood Risk Precinct Map

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

Filepath : I:\B17316_I_BRH_Ballina_FRMS&PDRGR.B17316.005.01.FRMS\Figure_6-1.WOR

N

0km 1 2
Approx. Scale

Figure: 6-1

Rev: A

BMT WBM
www.bmtwbm.com.au

6.2 Voluntary House Purchase

6.2.1 Background

Under a voluntary purchase scheme, Council offers to purchase existing properties that have been identified as severely flood affected if and when they become available for purchase, and subject to the availability of funds at the time. As the name suggests, voluntary purchase is voluntary and not compulsory acquisition. Affected property owners can expect to receive market values, since property valuations assume no scheme is in place and disregard development constraints that may apply on that land due to its flood prone nature. Land purchased under a voluntary purchase scheme should ultimately be rezoned to open space or some other flood-compatible use.

The main problem with voluntary purchase schemes is the high cost in acquiring properties. The schemes often extend over a relatively long time-frame since there are usually only sufficient Government funds to purchase a few properties every year. A good example is a scheme commenced by Liverpool Council in the early 1980s. A total of 174 properties were originally identified for voluntary purchase, and over 20 years later some 70 properties still remain to be purchased. Also, due to increased property prices over the last 20 years, the cost of completing the scheme remains higher than the original cost estimate at the start of the project.

However, despite unfavourable benefit-cost ratios, voluntary purchase schemes may still gain funding if the properties are subject to extreme flood hazard, and where other measures are impractical or uneconomic. The Manual recognises that in such circumstances '*it may be appropriate to cease occupation of such properties in order to free both residents and potential rescuers from the danger and cost of future floods'*.

Voluntary purchase schemes in NSW are usually restricted to areas that have been designated as high hazard floodways, or for dwellings where the depth and velocity of floodwaters is such that the structure may not withstand the forces of a major flood and there is consequent risk to life. Dwellings that qualify for voluntary purchase typically experience inundation depths in excess of 1.0m and velocities in excess of 1.0m/s in a major flood (such as the 100 year event).

There has been no previous voluntary purchase scheme within the study area, although one flood-affected dwelling adjacent to Maguires Creek was previously acquired by Council after it was destroyed by fire.

6.2.2 Merits of a Voluntary Purchase Scheme

The merits of including residential dwellings in a voluntary purchase scheme at Ballina have been reviewed by inspection of the property database. There are a total of 218 residential buildings (some of which are multi-dwelling buildings) that are estimated to be inundated above floor level in a 100 year flood under existing conditions. Of these, there are only 14 residential buildings, including 1 caravan park, which would experience inundation depths in excess of 0.5m in a 100 year flood. Conditions experienced by these properties, including flood damage estimates, are summarised in Table 6-1.

Table 6-1 Most Severely Affected Dwellings (100 Year ARI Flood)

Property ID	Type	Number	Type	Above Floor Depth (m)	Max. Velocity (m/s)	AAD ($)	Present Value ($)
NW018	Dwelling	1	DS	1.4	0.6	$28,000	$383,000
SE080	Dwelling	1	LS	0.8	0.5	$9,000	$123,000
NW500	Dwelling	1	LS	0.7	0.2	$13,000	$177,000
SE014	Dwelling	1	LS	0.7	0.4	$34,000	$472,000
SW003	Dwelling	1	DS	0.7	0.3	$15,000	$211,000
SW007	Dwelling	1	LS	0.6	0.2	$7,000	$98,000
NW027	Dwelling	1	DS	0.6	0.9	$6,000	$78,000
SW004	Dwelling	1	DS	0.6	0.4	$5,000	$70,000
A	Caravan Park	65	LS	0.6	0.7	$755,000	$10,425,000
SW102	Dwelling	1	LS	0.6	0.6	$4,000	$50,000
NW003	Dwelling	1	LS	0.6	0.2	$11,000	$149,000
153//31154	Dwelling	1	LS	0.6	0.2	$31,000	$430,000
SW051	Dwelling	1	LS	0.5	0.3	$7,000	$94,000
SW008	Dwelling	1	DS	0.5	0.2	$8,000	$104,000

Note: Property type 'LS' refers to 'low set' and 'DS' refers to 'double storey'.

The most severely affected dwelling is a double storey house that experiences a maximum inundation depth of 1.4m above floor level in the 100 year flood. The property is located on Teven Road, adjacent to Maguires Creek. The dwelling is a two-storey house, with the upper level above the 100 year flood level. The maximum flood velocity is also relatively low at 0.6m/s. It is unlikely that these conditions would warrant the inclusion of this property in a voluntary purchase scheme from a hazard viewpoint. The other 13 residential dwellings listed in Table 6-1 experience less hazardous conditions.

From an economic perspective, voluntary purchase can only be justified if the savings in flood damage by removing the dwellings from the floodplain exceeds the acquisition cost. The present value of flood damage that would be saved by removing the fourteen buildings (ignoring the caravan site) from the floodplain is estimated at $2.4M. The acquisition cost (based on an average purchase cost of $400,000) is estimated at $5.6m. This provides a benefit/cost ratio of 0.44, which would be difficult to justify based on economics alone.

The caravan park (Ballina Waterfront Village in West Ballina) listed in Table 6-1 is included in the residential property database. The site contains a mixture of permanent cabins and removable caravans. Aerial imagery suggests that the site contains more cabins than caravans. The flood damage for the caravan park is very high ($10.4M or $160k per cabin). This is due to the park lying on the left bank of Emigrant Creek, and thereby being flood affected for small frequent floods (i.e. inundated during a 5 year ARI flood event). Purchasing all 65 cabins would therefore be costly. The approximate value of the cabins is also $160k, resulting in a cost-benefit ratio of approximately 1. Given that the flood hazard in not high, it is recommended that the flood risk is better managed through voluntary house raising (next Section) and development controls.

A voluntary purchase scheme does not appear to be justified for Ballina, based on the consideration of hazard and economic factors under current flood conditions.

6.2.3 Impacts of Climate Change

The impacts of climate change will see flood levels increase throughout the study area, which may have an influence on decisions regarding a voluntary purchase scheme.

There is presently only one dwelling that experiences above floor flooding of over 1.0m in the 100 year flood. Under projected 2050 conditions the number of dwellings increases to 4, and under projected 2100 conditions the number increases to 40. An increase in flood damages will also be evident under future conditions.

Whilst a voluntary purchase scheme is difficult to justify today, a scheme involving a modest number of dwellings (less than 40) might be feasible under future conditions. The properties are fairly distributed throughout the study area, and include 9 properties at Ballina Island, 22 properties in West Ballina, and 7 properties along Emigrant Creek.

To date the State Government has not made a policy commitment to fund future flood mitigation schemes to address climate change. As the potential damage bill from climate change is substantial and the cost of mitigation is similarly very large, Council should be cautious about assuming that any State funding may become available in the future to address climate change impacts.

6.3 Voluntary House Raising

6.3.1 Background

House raising typically involves the raising of dwellings that are below a nominated level (such as the 100 year flood level) to a level that is above Council's flood planning level. Houses can be raised vertically on piers; reconstructed at a higher level on fill or piers; or relocated within the property.

House raising has been an effective floodplain management measure in a number of jurisdictions in NSW, including Fairfield and Lismore. Table 2.2 records some advantages and disadvantages of voluntary house raising (VHR). House raising is expected to reduce tangible and intangible flood losses. However, it may not be appropriate in all cases (e.g. for elderly residents) and the implications of house raising for emergency management require careful thought.

An important influence on the ability to raise houses, and on the nature of house raising, is building material. It is easiest to raise houses of either timber or fibro construction. Adjusted to 2010 dollar terms, the cost of raising this sort of house has been estimated at about $40K (Penning-Rowsell & Smith, 1987) or $46K (Maclean Shire Council, 1999; Paterson Consultants, 2000). The experience of Fairfield Council in Prospect Creek has shown that $60K to $70K is more applicable.

It may appear costly and impractical to raise brick veneer, full brick, or double-storey houses. Fairfield Council has piloted a number of innovative approaches towards dealing with these types of houses. At one house, the roof was converted to a living area and the ground floor vacated at a cost of $60K.

At another property, Fairfield Council purchased and demolished the house then sold the vacant land on the open market with building conditions on the title that complied with Council's Flood Policy. The typical net cost for this option was about $80K. For double-storey houses, if the flood planning level is less than a metre above floor level, Fairfield Council has undertaken a form of flood-proofing by replacing carpets and gyprock with more flood-compatible materials and by raising power-points and other services like air conditioning units. This option costs in the order of $20K/house.

Table 6-2 Advantages and Disadvantages of House Raising[2]

Advantages	Disadvantages
Reduced tangible flood damage.	The occupation of areas beneath a raised house may offset reduction in damage potential.
Reduced risk to personal safety and intangible costs such as anxiety, stress and post-flood trauma.	People living in raised houses may be less likely to evacuate, increasing the threat to life in the rare event that a flood reaches the floor level; Risk to emergency services if rescue required.
Provision of under-house space for a garage, laundry or storage.	House isolated at times of flood; some intangible costs remain; Risk to emergency services if rescue required due to medical emergency.
Enhanced resale value of property.	Building may prove to be incapable of withstanding force of floodwater and debris loading, resulting in structural collapse. [Note that the Floodplain Development Manual regards VHR as a suitable management measure only for low hazard areas of the floodplain].
	Steps to gain access to the house may not be suitable for older people or those with disabilities.
	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.

Where voluntary house raising in a specific area is identified in an adopted Floodplain Risk Management Plan as a means of protecting a significant number of houses at serious risk of flooding, it becomes a formal management measure and, as such, is eligible for Government financial assistance (DIPNR, 2005). Where economically justified, a subsidy based on the full cost of house raising may be provided. This is generally the case for timber or fibro houses with floor levels located below the 20 year flood level. In marginal cases, subsidies have been provided in other parts of the State for the first $10K to $20K cost to raise a particular house, with the homeowner required to pay the difference.

[2] B*ased on Penning-Rowsell & Smith. 1987; NSW Government, 2005*

6.3.2 Voluntary House Raising Scheme

The merits of including residential dwellings in a voluntary house raising scheme at Ballina have been reviewed by inspection of the property database. There are a total of 218 residential buildings (some multi-dwelling buildings) that are estimated to be inundated above floor level in a 100 year flood under existing conditions. The depth of inundation is relatively shallow for the majority of these dwellings, as illustrated in Figure 6–2. Most (42%) of these buildings experience inundation depths that are no more than 0.1m, whilst almost all (94%) experience flooding that is no more than 0.5m above floor level.

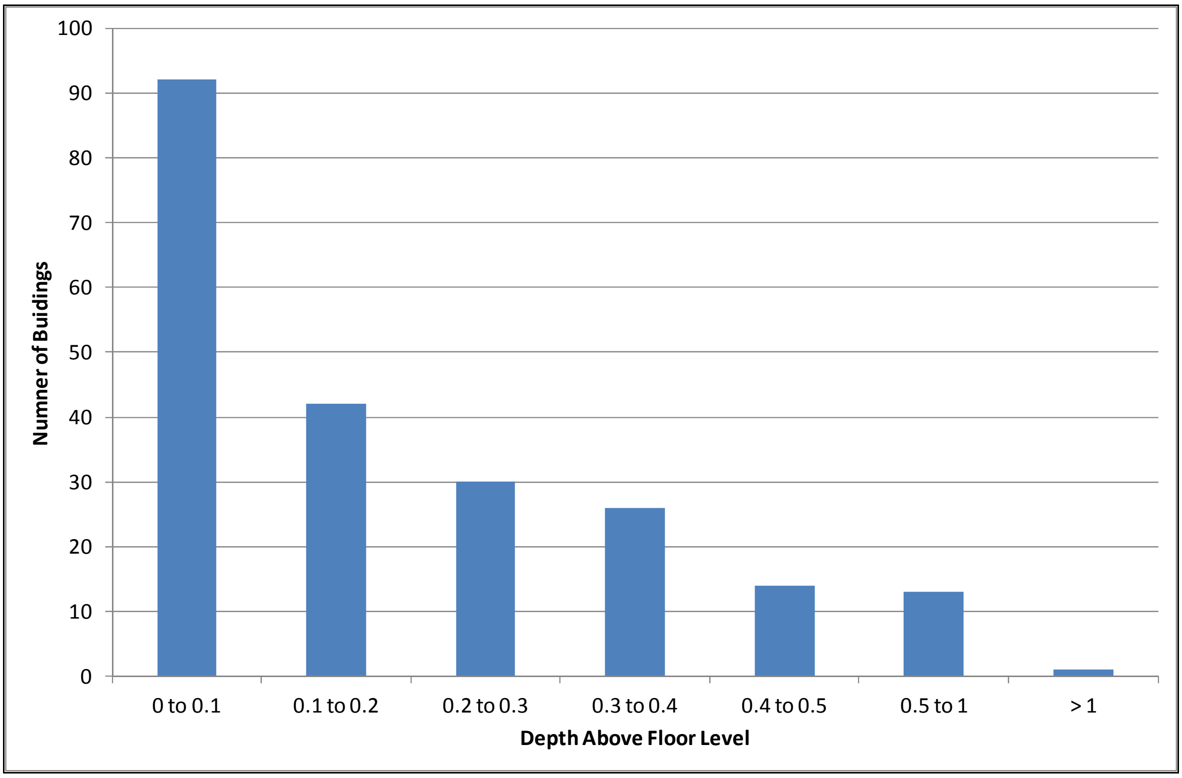


Figure 6–2 Number of Buildings Inundated Above Floor Level

The properties have also been separated into those that would experience flooding more frequently than 20 years; between 20 and 50 years; and between 50 and 100 years. The number of houses within each category are summarised in Table 6-3 and their locations shown on Figure 6–3.

Table 6-3 Buildings Inundated Above Floor Levels

	20 Year Flood or More Frequent
20 Year Flood or More Frequent	49
Between 20 Year and 50 Year Flood	17
Between 50 Year and 100 Year Flood	152

Based on the limited depth of flooding and the number of properties that flood on a relatively infrequent basis, it is unlikely that a full cost subsidy could be justified for all properties that experience above floor flooding in the 100 year event, under existing conditions. Many of the dwellings are also brick-veneer and/or slab on ground, and will be difficult to raise by conventional measures.

Full cost subsidy schemes contain a number of disadvantages. Apart from the high costs to implement, there are a number of equality issues to consider. For example, should owners of a brick home receive more funds to raise/rebuild their home (say, $80K) than the owner of a timber clad home that can be easily raised (say $40K)? Should homes that are more difficult to raise be excluded from the VHR scheme? Also, because Council is subsidising the full cost of house raising, there is more onus on Council to fully manage the project – from negotiations with builders, signing contracts, supervising works, making part payments, handling disputes between builder and owner, etc. In all, full cost subsidy schemes can result in a significant administrative burden on Council.

It is recommended, therefore, that the house raising subsidy is capped, thus precluding buildings that are uneconomical to raise. The capped subsidy does not cover the full cost of house raising, but is intended to provide a financial incentive for owners to raise their own homes. As the owner is committing a large proportion of their own funds, it is reasonable to expect that they would be happy to accept responsibility for their own building work, resulting in less administrative burden on Council. Of course, Council would still need to promote the Scheme, approve design drawings and make a one-off subsidy payment (to the owner) at some stage during the project.

Another advantage of the capped subsidy scheme is that it provides the owner more flexibility to incorporate other building improvements or modifications at the same time, providing that the ultimate goal of raising habitable floor levels above Council's flood planning level is satisfied. With such flexibility, it should be possible for any building type to be raised (or modified) to achieve this goal. This may be through physically raising existing dwellings, demolition and rebuilding, or through relocation/rebuilding of an existing dwelling to higher ground within the property (particularly suited to rural dwellings). Under this scheme there is no discrimination on the type of existing dwelling.

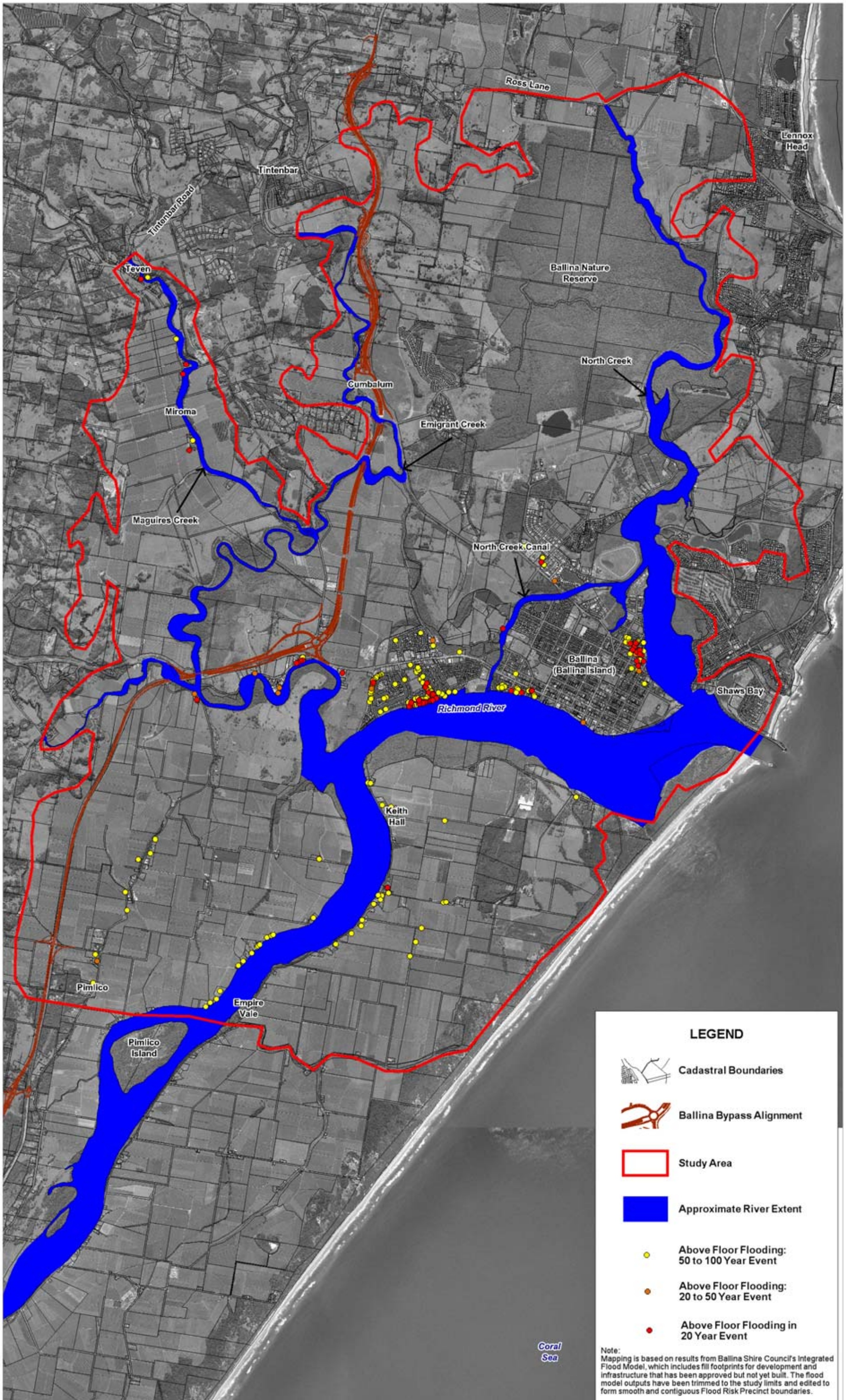
State Government funding for house raising is generally a two thirds contribution, with the other third contribution coming from the owner or shared between Council and owner. With house raising typically costing $60,000, it is recommended that the voluntary house raising grant is capped at $40,000, and increased each year to account for inflationary trends.

Voluntary house raising schemes take considerable time to implement. It may take 10 to 20 years to raise the 49 buildings that flood in a 20 year ARI flood event. It is important, therefore, to prioritise buildings with higher flood risk. It is recommended that the voluntary house raising scheme targets the 49 building that flood in a 20 year ARI flood event. Other buildings, with lower flood risk, could be reconsidered during the next floodplain risk management study

Assuming that all 49 buildings are raised, the total cost of this scheme would be $2.94 million (based on $60,000 per house). The flood damage reduction is estimated at $8.28 million, resulting in a cost benefit ratio of 2.8. In reality, however, it is unlikely that raising all 49 buildings will be economically feasible or practical. The total capital required to fund the scheme is, therefore, uncertain and can only be estimated following a more detailed property survey.

The raised floor levels for properties taking part in the scheme will comply with the FPLs proposed in the draft DCP, thus having an allowance for climate change. Floor levels should be limited to 3.5m above ground level due to practicality and aesthetic reasons. The onus will be on the owner to engage a contractor and undertake the works. The grant will be provided following completion of the works and Council inspection.

Figure 6–3 Location of Residential Buildings Inundated Above Floor Level



Title:
Location of Residential Buildings Inundated Above Floor Level

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1 2
Approx. Scale

Figure:
6-3

Rev:
A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_6-3.wor

7 RESPONSE MODIFICATION MANAGEMENT MEASURES

7.1 Overview

Response modification management measures target options that modify the response of the population at risk to better cope with a flood event. A number of options have been listed below. The Evacuation Capability Assessment (described in Section 3) has been used to quantify the benefit associated with some of these options.

Contraflow (i.e. using the inbound lane as a secondary outbound lane) has not been considered as an appropriate response modification option. The SES has indicated that the incoming lane will be used for emergency vehicle traffic and as a backup option if the outgoing lane becomes blocked.

Three critical aspects to consider when planning for flood evacuation are:

- To ensure that a robust and decisive flood forecasting mechanism is in place;
- Effective flood warning systems are available; and
- That the emergency services and community are aware of how to respond to the flood warning.

If one of these aspects fails during a flood emergency, then the overall flood emergency response will fail. Also, a comprehensive evacuation plan that documents the planned evacuation procedure is critical for formalising a standard and efficient evacuation. There is scope for much improvement to current practices in Ballina. This is explored further below.

7.2 Improve Flood Forecasting System

7.2.1 Background

One of the most crucial elements in reacting to a flood is being able to predict when there is a pending flood risk. The earlier the flood risk can be predicted, the more time is available to act on the appropriate response. Also, reliable and timely flood predictions enable better and quicker decisions on the appropriate course of action to be made.

Flood forecasting systems run real-time measured rainfall and stream gauge data through catchment models to predict flood levels further down the catchment. Some systems also make predictions using forecast precipitation, thus attempting to extend the lead-time available for flood prediction.

7.2.2 Current Service

The BoM provide a national flood forecasting service. They use rainfall-runoff models to forecast flood flows, and in some instances they also use pre-existing flood model results to assist with predicting flood levels. The BoM currently provides flood forecasting and flood warning to major towns along the Richmond River up to the downstream end of Woodburn.However, they don't currently have a formal flood forecasting system that covers Ballina Shire. A flood warning system was installed for the Teven valley in 2010.

For the Ballina area, BoM has a weather system that they use to issue a flood watch. Gauges in the Richmond River catchment are then monitored by the SES, who has ultimate responsibility for deciding whether to evacuate.

7.2.3 Scope for Improvement

Given the flood problem in Ballina Shire, installation of a formal flood forecasting system could provide significant flood risk benefit to the community. There are already a number of gauges in the catchment that may be incorporated into the system. Such a system could also include a decision support mechanism, whereby pre-defined flood emergency responses are triggered by specific predicted flood levels at the stream gauges. Such an approach would support the SES with making evacuation decisions. The improved efficiency in flood prediction and evacuation decision making could improve the time available for evacuation by enabling an earlier prediction time for Richmond River flooding. It would also provide a backing for decisions made by the SES, which may reduce the burden of their responsibilities.

7.2.4 Limitations

There are no real-time numerical models that predict storm surge heights in the vicinity of Ballina. It is, therefore, not currently possible to predict flood levels resulting from ocean storms. Some areas within the study area are also susceptible to flash flooding, which occurs rapidly and is difficult to predict with adequate lead time. Flood forecasting in Ballina is, therefore, limited.

However, ocean storm flood predictions can also be made by comparing measured and expected levels at the mouth of the Richmond River. When anomalies occur, i.e. measured levels are higher than expected levels, it can be inferred that the following high tide will be higher than normal. This approach was assumed for the ECA, which indicates that evacuation for a 100 year ARI ocean storm dominated event is possible.

7.2.5 Recommendations

Despite the limitations, it is possible to develop a flood forecasting system for flood waves propagating down the Richmond River. This form of flooding poses a serious risk to Ballina. A flood forecasting system would help manage this risk. It may be possible to use results of flood models and/or recorded data from gauges in the catchment to develop a basic flood forecasting system.

If considering developing a more sophisticated system through the use of purpose built flood forecasting hydrology and hydraulic models which are linked and fed with real-time recorded data using a system such as Delft-FEWS, it would also be worth considering the Richmond River catchment as a whole; thus creating a flood forecasting system that will benefit all communities along the Richmond River.

It is recommended that the feasibility of developing a flood forecasting system is investigated in more detail. It is envisaged that a feasibility study would examine existing data in the area and discuss available options for developing a flood forecasting system for Ballina. This study would need to include consultation with the NSW Flood Warning Consultative Committee, who would need to approve the final solution before it is implemented.

7.3 Improve Flood Warning Systems

Warning people about anticipated flooding is a critical part of the flood management process. The time taken to warn all flood exposed dwellings plays a major role in an evacuation. The time taken to warn people depends on the warning method and resources deployed by the SES.

In the current analysis, door knocking has been assumed. The warning rate is 12 dwellings per team per hour. However, the analysis has been undertaken based only on the constraints of evacuation route capacity. The number of SES teams used in the analysis is defined by the number of teams that would be required to maintain maximum road capacity (i.e. assumed unlimited SES resources). Therefore, the evacuation capability analysis in its current form cannot be used to directly assess an improved flood warning dissemination rate.

Significant time-savings could be made by opting for a fast warning method such as broadcast radio and television, mass telephone dialling, mobile telephone SMS or sirens warning. Increasing use of social media by society may also provide an opportunity for enhancing flood warning. Use of a website such as 'Twitter' may provide a fast means of sharing flood information between emergency services and the public. If a purpose built website is used for dissemination of flood information, the website should be designed such that it is capable of handling high web traffic during a flood event.

However, these methods cannot ensure that all people are warned, especially considering the high proportion of elderly people in Ballina. Several warning methods can also be used simultaneously to improve the time of response. Note that the improved evacuation capability may be limited by the road capacity; a very short warning time can lead to traffic congestion.

The evacuation capability assessment includes a 6 hour period after receiving a flood prediction for SES to decide on a strategy and mobilise resources. Improving the flood warning system may also provide efficiencies and alleviate the SES's resource requirements for disseminating flood warnings, which may improve this 6 hour SES response timeframe.

In conclusion, it is strongly recommended that alternate warning methods to door knocking are investigated. It is understood that the SES has already begun looking at other options.

7.4 Improve Evacuation Planning

Evacuation planning in the Shire in specific trouble areas like Cabbage Tree Island and Teven Valley have been thought-out and documented in the local flood plan (SES, 2008). However, there is little structure to the evacuation procedure within the current study area. As such, this study provides an opportunity to update and improve the evacuation plan. In doing so, the following points should be regarded/resolved:

1. Check Viability of Evacuation Centres

The NSW Department of Community Services (DoCS) should be engaged to determine the adequacy of facilities at the proposed evacuation centres and identify further possible centres where necessary. The evacuation routes may need to be revised where the facilities are insufficient, or preferred alternatives are found.

2. Mark the Evacuation Routes and Zones

The SES has developed the evacuation zones and routes shown in Figure 3–1. The viability of the evacuation centres needs to be confirmed to finalise the routes and zones. Once the routes are finalised, methods should be implemented to communicate and mark out these zones and routes on the ground, thereby assisting emergency staff and the community to respond accordingly during an evacuation. This could be achieved using a combination of the following:

- Information guides at various locations around Ballina;
- Use of signs along evacuation routes (see Figure 7–1 for an example). Each zone can be assigned a different coloured shape. Every road would require a sign with the arrow pointing in the direction of the evacuation route; and/or
- Colour banding on telegraph poles and road markings to mark routes.

Figure 7–1 Example Signage for Marking Zone A Evacuation Route

Notes: Evacuation route for Zone A at the Angels Beach Drive and Bangalow Road intersection
Zone A has been colour coded red and assigned a diamond shape as an identifier
Background imagery is from Google Street View (©2011 Google)

3. Consider Sequencing the Flood Warning

If practical to implement, sequencing of the flood warnings can improve the evacuation capability. The practicality of this option should be determined by experienced emergency services personnel. Alternatively, similar improvements to the evacuation capability can be achieved by raising some low points along the evacuation routes (see Section 7.6.1).

The concept of sequencing the flood warnings is to divide the evacuation zones up into subsectors. By focusing on evacuating the subsectors whose routes close earliest, the evacuation capability can be significantly improved. This sequencing process is not applicable for Zones C, D and F, as the earliest route closure point occurs beyond the communities that the routes are servicing (see Figure D-8 to Figure D-10 in Appendix D).

The method of optimising the flood warning sequencing in Zones A, B and E is illustrated in Figure D-8 to Figure D-10 in Appendix D. The estimated evacuation safety margin improvements are summarised in Table 7-1 below.

Table 7-1 Sequencing Results

Zone	Rescue Phase / Safety Margin (hours) Base Case	Rescue Phase / Safety Margin (hours) Sequencing	Improvement (hours)
Zone A	-1.1	+2.7	+3.8
Zone B	-0.1	+0.5	+0.6
Zone E	-0.8	+0.6	+1.4

Notes: Rescue phases are shown as negative hours and shaded red.
Safety margins are shown as positive hours and shaded green.

4. Monitor Road Depressions/Crossings

Locations along evacuation routes which are known to be liable to flooding should be monitored. Telemetric monitoring could warn the SES and the public (through Council's call centre) when a route closes due to flooding.

5. Compose a Revised Local Flood Plan

When the evacuation planning has been completed, the procedures should be documented into a revised local flood plan. Thus creating a formal record of the evacuation plan and assisting with dissemination of the plan.

7.5 Improve Community Awareness

The human response to warning is another fundamental parameter. The evacuation process can be improved when residents have been educated about flooding and flood evacuation. It is likely that some people may be reluctant to evacuate until they see evidence of flooding.

Following on from this study, the Ballina Local Flood Plan will be updated. Also, more efficient flood warning systems may be employed by the SES. For these to be effective, the community needs to know how to react when receiving a flood warning. It is, therefore, recommended that an ongoing flood education programme is implemented, as the community is dynamic and may constantly change. Lismore City Council runs a successful programme through one of its committees. It is recommended that Ballina Shire Council adopt a similar programme.

There are various media that can be used to implement a flood awareness campaign. Two options are discussed below:

1. Brochures

Distribution of flood related brochures may partly address the issue of educating the public about flood issues. To make the distribution of the brochures more effective, the brochures should be distributed annually at the beginning of the wet season (October). Within the content of the brochure should be contact details and helpful tips on what to do in a flood situation. Details on the SES's evacuation plan should also be conveyed, so that the public are aware of the evacuation routes.

2. On-line Website

The internet provides an excellent platform for sharing knowledge. Its use is increasing, with more devices being able to access it and more people learning how to access it and browse through websites. There are still portions of the community who do not use the internet, so it should not be the sole provider of flood awareness. However, it is anticipated that a large portion of the community use the internet, and given the excellent visual tools available on websites, a website could be an excellent flood education tool.

This has been recognised by the Richmond Valley Council who are currently developing a flood information website[3] in collaboration with the SES and OEH. The aim of the website is to collate flood information, making it easy for the public to access this information. It will provide information on current and future flood risk, historical flooding, what to do in a flood, road closure details during an emergency, and provide information to assist developers with understanding flood constraints.

7.6 Improve Evacuation Route Capacity

7.6.1 Raising Road Levels

Another option to consider is raising the level of the evacuation routes, particularly around the critical closure locations. An assessment has been made for each zone, applying a road level increase of 400mm at specific locations. The road raising locations are marked in Figure D-1 to Figure D-7, in Appendix D. The estimated safety margin improvement due to raising road levels is summarised in Table 7-2 below.

Table 7-2 Raising Road Level Results

	Rescue Phase or Safety Margin (in hours) - *Base Case*	Rescue Phase or Safety Margin (in hours) - *Raising Road Level*	Safety Margin Improvement (in hours)
Zone A	-1.1	2.7	+3.8
Zone B	-0.1	0.5	+0.6
Zone C	2.1	2.4	+0.3
Zone D	-0.1	0.4	+0.5
Zone E	-0.8	0.8	+1.6
Zone F	2.1	2.4	+0.3

Note: Safety margins are shown as positive and shaded green.
Rescue phases are shown as negative and shaded red.

For Zones A and E, raising road levels has significant positive impacts on the evacuation process. However, this option does not significantly improve the evacuation capability in Zones B, C, D and F.

[3] *Draft website located at: http://gis.wbmpl.com.au/RichmondValleyWeb/Catchment%20Flooding.html*

A full assessment of this option beyond the broad 400mm raising applied here would need consideration of flood impacts. Raising road levels further may improve evacuation capability further, although the eventual solution will need to balance evacuation improvement benefits against flood impacts and other design constraints (such as landscape, services and/or economic constraints).

7.6.2 Construct Dual Lane Roads

Constructing dual lane roads along the main evacuation routes could also improve the evacuation capability by increasing the road capacity. However, this option is only relevant if the number of lanes is increased along the full length of the evacuation route. This is an impractical option in developed areas where there is limited space. There are also obvious cost limitations. This option targets the vehicle movement part of the evacuation timeline, which is generally relatively small compared to the other factors affecting the evacuation timeline in Ballina.

The improved evacuation capability is summarised in Table 7-3 below.

Table 7-3 Dual Lane Roads Option Results

	Rescue Phase or Safety Margin (in hours) - *No option*	**Rescue Phase or Safety Margin (in hours) - *Raising Road Level option***	**Safety Margin Improvement (in hours)**
Zone A	-1.1	1.2	+2.3
Zone B	-0.1	1.3	+1.4
Zone C	2.1	3.0	+0.9
Zone D	-0.1	2.1	+2.2
Zone E	-0.8	-0.2	+0.6
Zone F	2.1	2.1	+0.0

Note: Safety margins are shown as positive and shaded green.
Rescue phases are shown as negative and shaded red.

Note that for this option to work, the SES would also need to increase their resources for disseminating flood warnings (i.e. increase the number of teams required to keep the routes at full capacity). Given the impracticalities of this option, this is not considered a viable option for the Ballina Shire.

7.6.3 Construct New Evacuation Route

Upgrading Gallans Road so that it can function as a new evacuation route to Cumbalum Ridge has previously been raised by the Committee. Implementation of this option would need consideration of the Gallans Road Cycleway flood modification proposal discussed in Section 8.2.2. For this broad assessment of evacuation benefit, integration with flood modification has not been considered.

This proposed route would service Zone C, which covers north Ballina. The evacuation capability assessment shows that evacuation is already likely to be possible in this zone (with a 2 hour safety margin). As shown in Section 3.13.1, simply increasing the number of lanes does not necessarily provide a significant benefit. The new route would need to have a good flood immunity along the low lying land south of Cumbalum Ridge (along the cycleway), to delay the current route closure time of

35 hours into the design flood simulation.

Under the scheme, traffic would flow along the old Pacific Highway before diverting onto Gallans Road. This section of the old Pacific Highway closes at 35.5 hours into the design flood simulation. The old Pacific Highway flood immunity would, therefore, also need to be improved in order for the new route to benefit flood evacuation.

8 FLOOD MODIFICATION MANAGEMENT MEASURES

8.1 Background

Beyond the planning and response measures previously discussed, a further way to reduce flood risk is using structural means to change flood behavior. Such change could be the reduction of flood levels or velocities, or exclusion of flood water from a particular area.

During the latter phases of the Ballina Flood Study Update (BMT WBM, 2008a) and work associated with the Ballina Bypass, a range of flood modification measures were assessed. Since completion of the Ballina Flood Study Update, two measures are being implemented:

- North Creek Canal Floodway (completed) – a 20m wide floodway connecting the lower Emigrant Creek floodplain to the North Creek Canal past the Ferngrove development.
- Emigrant Creek Overflow Culverts (under construction) – 50% enlargement of the proposed Ballina Bypass culverts between Emigrant Creek and the Teven intersection.

Two further measures are currently proposed:

- Realignment of Cumbalum Way (now referred to as Ballina Heights Drive; under design) – the previously proposed Cumbalum Way joined the old Pacific Highway along Deadmans Creek Road. The proposed scheme will realign Cumbalum Way to the fringe of the floodplain, allowing the Deadmans Creek Road embankment to be reduced in height.
- West Ballina Flood Relief (proposed) – a set of culverts connecting the lower Emigrant Creek floodplain at West Ballina to Emigrant Creek, under the old Pacific Highway.

Since these mitigation measures have already been adopted in principle by Ballina Shire Council, they have been incorporated into the 'Integrated Flood Model' which forms the base case scenario in this study. As such, the benefit of these adopted flood modification measures has not been assessed here.

8.2 Description of Assessed Flood Modification Options

The viability of two additional flood modification measures have been investigated here. It should be noted however, that it is a 'high level' assessment, which has not considered other physical, social or environmental constraints. The assessment, therefore, serves as a broad overview, upon which a decision whether to incorporate into the Ballina Floodplain Management Plan and/or to pursue a more detailed feasibility study can be made. These mitigation measures are described below.

8.2.1 Sandy Flat Floodway

Between Emigrant Creek and North Creek, north of Cumbalum Ridge, is an area known as Sandy Flat. There is a low-lying ridge dividing the Emigrant Creek and North Creek floodplains. This ridge is a natural floodway for events greater than the 50 year ARI. The mitigation concept involves excavating a floodway through the low-lying ridge, thus connecting the Emigrant Creek and North Creek floodplains.

This floodway provides a new passage for floodwater in the Emigrant Creek floodplain to flow from the Emigrant Creek floodplain into the wider North Creek floodplain in the vicinity of Ballina Nature Reserve. Flood levels in the Emigrant Creek Valley will consequently be reduced. This benefits development in the Emigrant Creek Valley, including the Cumbalum, North Ballina and West Ballina regions.

The floodway has been assumed to be 40m wide, with an invert elevation of 1mAHD. Refer to Figure 8-1 for a plan of the Sandy Flat Floodway layout.

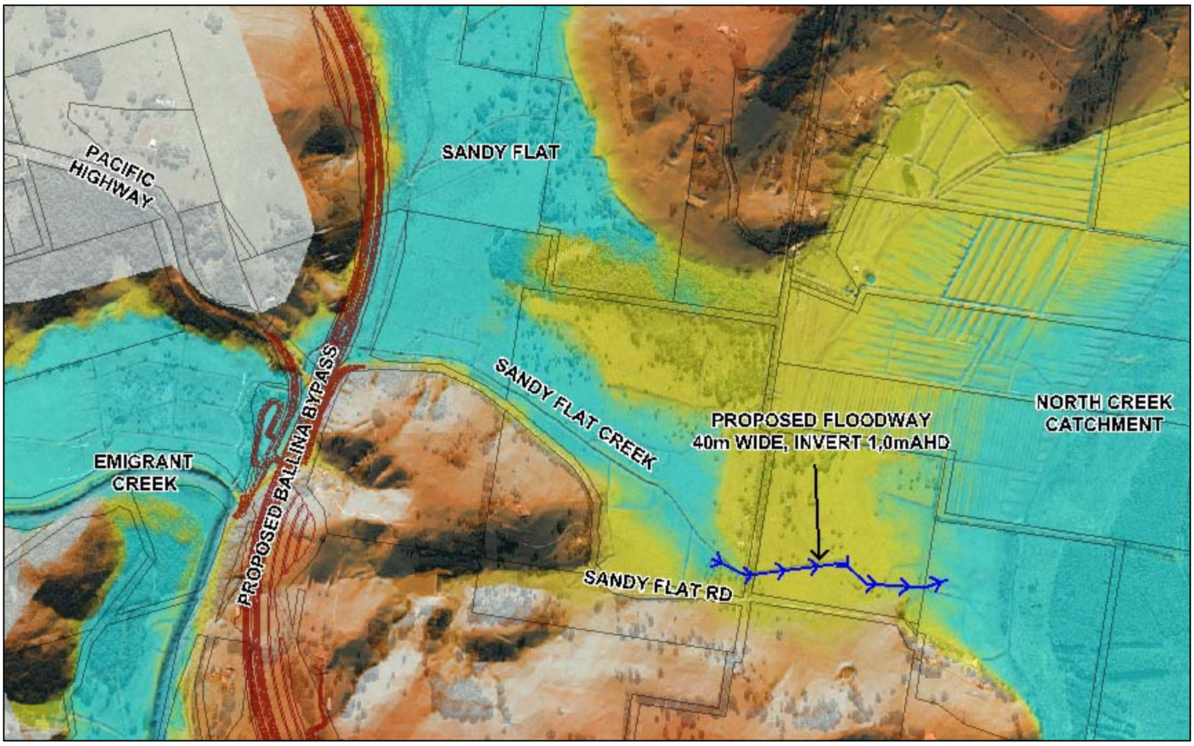


Figure 8–1 Plan of Sandy Flat Floodway

8.2.2 Gallans Road Cycleway Floodway

8.2.2.1 Overview

Lying to the south of the Cumbalum Ridge between the Emigrant Creek and North Creek floodplains is the Gallans Road Cycleway (Refer to Figure 8–2). The cycleway has been constructed on an embankment containing water and sewer rising mains which service Ballina Heights. Minimal cross drainage infrastructure has been provided to allow flow between Emigrant Creek and North Creek. A set of culverts (2 cells of 2.1m wide by 2.1m high) have been provided over a drainage path previously referred to as Roberts Creek. This watercourse has almost entirely been silted up over the past few decades.

The cycleway has been a contentious issue amongst the community since embankment construction in the 1970's and then the cycleway constructing in the 2000's. Modelling has shown the embankment to restrict the movement of flood water between the Emigrant Creek and North Creek floodplains. A floodway through the cycleway would restore this natural passage of floodwater into North Creek past the airport, thus reducing flood levels in the Emigrant Creek Valley. Development in the Emigrant Creek Valley, including the Cumbalum, North Ballina and West Ballina regions would benefit from this proposal.

Improvement of transverse drainage is complicated due to the presence of and minimal cover over the two hydraulic services. There is a variety of design options, which could range from a few culverts to an elevated boardwalk along the full length of the cycleway. Each option would have a different outcome in a cost-benefit analysis. For the purposes of this study, two options have been investigated:

1 Option 1 – representing the absolute maximum possible benefit involves complete removal of the cycleway embankment.

2 Option 2 – representing a more realistic option whereby only the southern 100m of the embankment is removed.

It is envisaged that the services would be diverted by digging a trench parallel to the services within the embankment footprint itself (due to dense vegetation and swamp on each side of the existing embankment) and laying new services in this trench. The newly laid services would then be linked up to the existing services, making the existing services within the embankment redundant. This would then enable the embankment to be removed and the redundant services disposed. After removal of the cycleway embankment, the cycleway will be replaced with an elevated timber cycleway.

The flood modification measures also incorporate clearing of drains and Roberts Creek, thus improving drainage across the floodplain into North Creek, although this has not been allowed for in the costing.

8.2.2.2 Option 1

Option 1 involves removal of the full 600m length of the embankment, which would require diverting 600m of water main and 500m of dual sewer rising mains. Refer to Figure 8–2 for a plan of the Gallans Road Cycleway Floodway Option 1 layout.

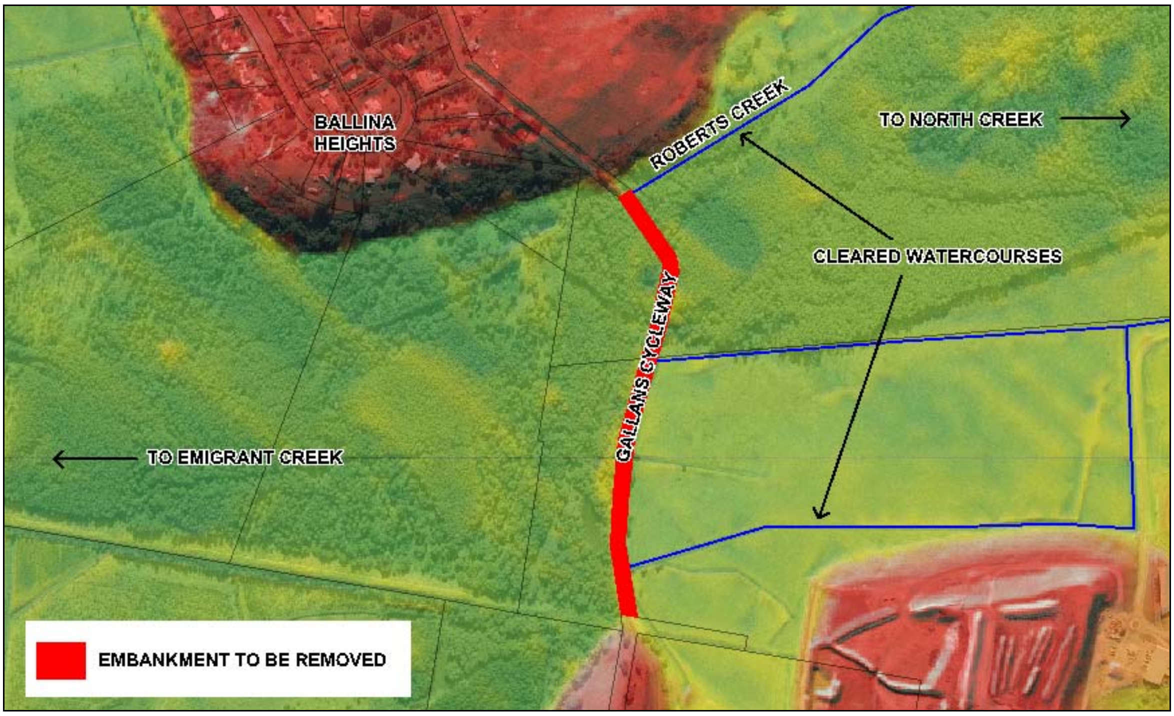


Figure 8–2 Plan of Gallans Road Cycleway Floodway Option 1

8.2.2.3 Option 2

Option 1 was found to provide significant benefit. However there was concern about the practicality of due to the site constraints. It was, therefore, decided to pursue a second option with substantially lower construction costs.

This option involves removal of the southern 100m of the embankment, where there is no sewer rising main and only the water main will require diversion. The amount of works associated with this option is substantially less than Option 1. A plan of Option 2 is shown in Figure 8-3.

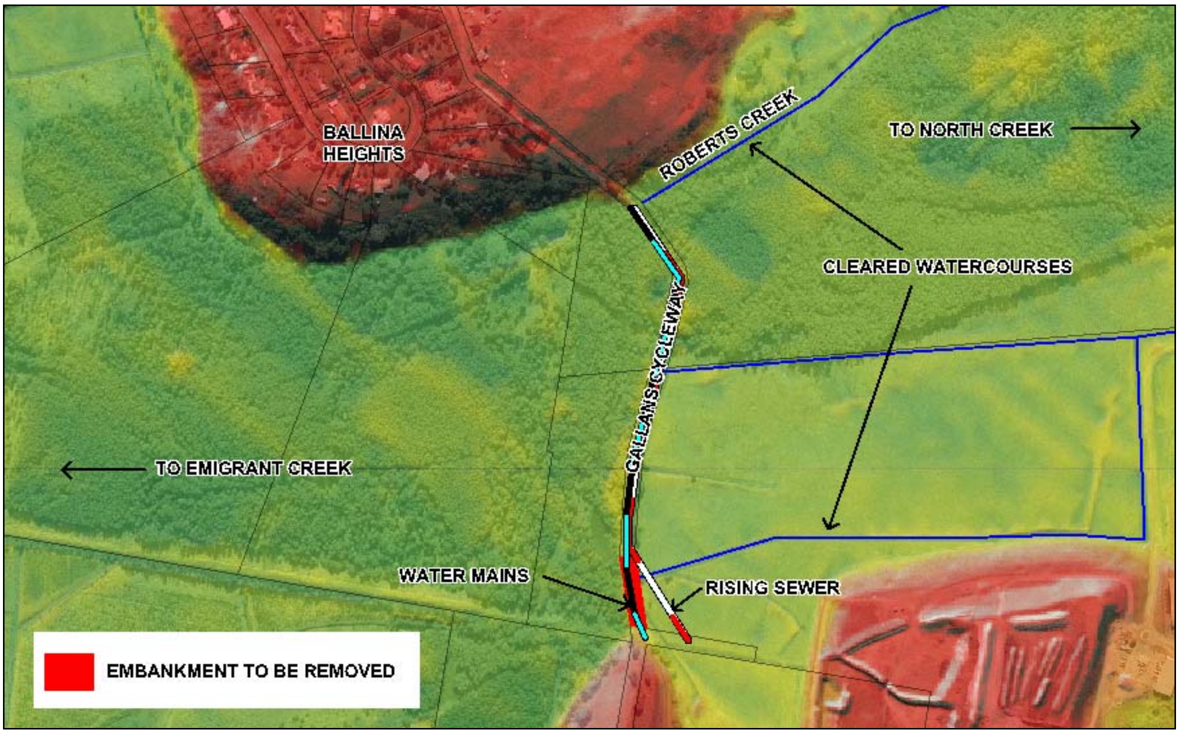


Figure 8–3 Plan of Gallans Road Cycleway Floodway Option 2

8.3 Damage Assessment and Economic Benefit

A flood damage assessment has been undertaken using the methodology described in Section 4. The difference between the AAD before and after implementation of a proposed flood mitigation option gives an initial indication of the economic benefit of that mitigation option (average annual benefit). The total benefit of the flood modification option is calculated by summing up the average annual benefit year on year over its design life (50 years) and at the same time discounting (7% discount rate) future benefit (net present worth factor = 13.8). The reason for discounting future average annual benefit is that money earned in the future is worth less than money earned today, due to the lost potential to invest that money and earn a return on it.

Table 8-1 Summary of Average Annual Damages

	Base Case	Sandy Flat Floodway	Gallans Road Cycleway	
			Option 1	Option 2
Ballina Island	$3,297,000	$3,296,000	$3,289,000	$3,289,000
West Ballina	$3,371,000	$3,361,000	$3,321,000	$3,337,000
North Ballina	$895,000	$888,000	$885,000	$886,000
East Ballina	$81,000	$82,000	$82,000	$82,000
Shaws Bay	$16,000	$16,000	$16,000	$16,000
Rural	$1,398,000	$1,385,000	$1,356,000	$1,367,000
Total	$9,058,000	$9,028,000	$8,949,000	$8,976,000

Note: Dollar values are rounded to the nearest $1,000

Table 8-2 Summary of Average Annual Benefits

	Sandy Flat Floodway	Gallans Road Cycleway	
		Option 1	Option 2
Ballina Island	$1,000	$8,000	$8,000
West Ballina	$10,000	$49,000	$33,000
North Ballina	$7,000	$10,000	$9,000
East Ballina	-$1,000	$0	$0
Shaws Bay	$0	$0	$0
Rural	$13,000	$42,000	$31,000
Total	$29,000	$109,000	$81,000
Total Benefit	$405,000	$1,501,000	$1,121,000

Note: Dollar values are rounded to the nearest $1,000

8.4 Cost Benefit Analysis

In order to make a decision on whether the flood mitigation options are economically viable, the estimated cost of implementing the options is weighed against the benefit that the mitigation options provides in terms of reducing flood damages. If the benefit outweighs the cost, then the option is economically viable.

In the absence of reliable cost estimates associated with intangible damages, a multiplier can be applied to the cost-benefit ratio of a mitigation measure. A rule of thumb that has been used in NSW is to adopt a multiplier of two, i.e. a mitigation measure should have a minimum cost-benefit ratio of 0.5 if it is to be considered further.

The Ballina Bypass Alliance (BBA) has previously estimated construction costs of $460,000 for a similar (20m wide floodway) mitigation option (BBA, 2008) at Sandy Flat. Allowing for inflation the cost is estimated for a 20m wide floodway is $495,000 as at the end of 2010. Uplifting this cost by 50% to account for the floodway being twice as wide (40m) results in a final cost for the Sandy Flat

Floodway of $743,000.

Costs for the two Gallans Road Cycleway floodway options were estimated based on Rawlinsons Australian Construction Handbook (Rawlinsons, 2006). The estimated costs are shown in Table 8-3.

Table 8-3 Summary of Cost-Benefit

Flood Modification Option	Cost	Benefit	Cost-Benefit Ratio	
			Without Intangibles	With Intangibles
Sandy Flat Floodway	$743,000	$405,000	0.54	1.09
Gallans Road Cycleway - Option 1	$2,300,000	$1,501,000	0.65	1.30
Gallans Road Cycleway - Option 2	$400,000	$1,121,000	2.80	5.60

Notes: Dollar values are rounded to the nearest $1,000

Intangible damages accounted for by multiplying the Cost-Benefit ratio by 2

The cost-benefit ratios shown in Table 8-3 suggest that the second Gallans Road Cycleway floodway option is the most economically viable and is viable with or without accounting for intangible damages. The Sandy Flat Floodway is only viable if intangible damages are accounted for. The floodway could be enlarged to improve the benefit, but the flow capacity of the Pacific Highway culverts (connecting Sandy Flat with Emigrant Creek) will ultimately limit the total benefit that is achievable.

The future flood benefit considering climate change has also been analysed for the Sandy Flat Floodway option. As sea levels rise and rainfall intensities increase, the frequency of flooding increases. This has a significant impact on the damages. The average annual benefit in 2100 including current climate change predictions is $1,794,000. This is substantially higher than the average annual benefit under today's climate of $29,000. This option has not been recommended under this study. But, in light of possible increased future benefits due to climate change, it is recommended that the Sandy Flat Floodway option is reconsidered during the next floodplain risk management.

8.5 Adverse Impact of Floodways

The analyses above indicate an overall economic benefit through reduction of flood damages. This is achieved by enabling flood waters in the Emigrant Creek valley to spill into the North Creek floodplain. As a result flood levels in the Emigrant Creek Valley fall, causing less flood damages to rural property in the Emigrant Creek valley and West Ballina. However the extra floodwater spilling into the North Creek floodplain causes flood levels within the North Creek valley to rise. This rise is small, but flood levels at some properties do increase.

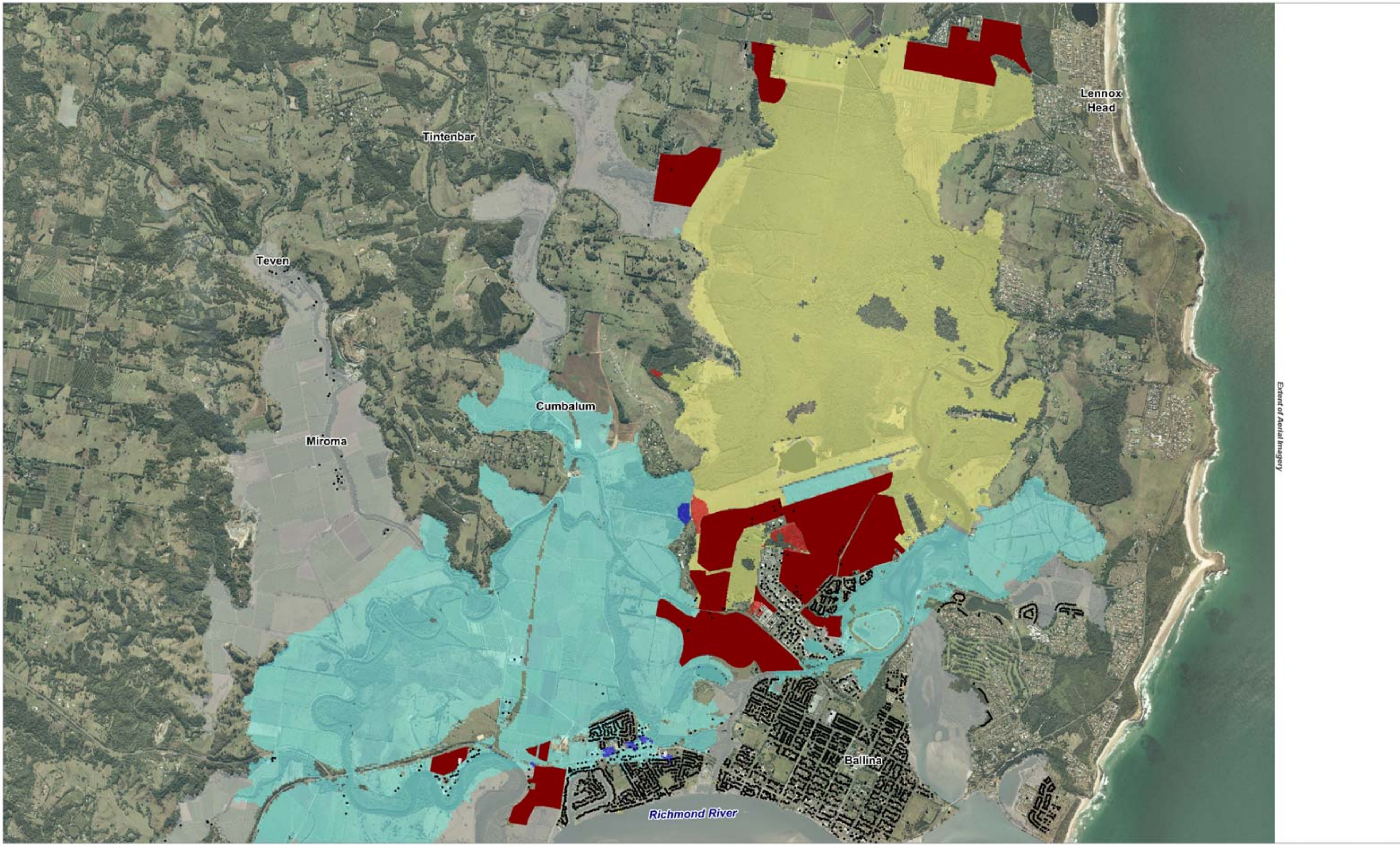
The Gallans Road Cycleway Option 2 floodway has been selected to investigate this issue in more detail. It is best to look at a specific source of flooding in order to avoid masking adverse flood impacts. The floodway does not provide much benefit for ocean storm dominated flooding, as the floodway is designed to alleviate headwater derived flooding in the Emigrant Creek valley. The floodway, therefore, primarily alleviates local catchment flooding, but also benefits broader Richmond River catchment flooding.

Figure 8–4 shows the adverse flood impact associated with the Gallans Road Cycleway Option 2 floodway for a 100 year ARI local catchment flood. Flood levels in the North Creek valley have increased in the region north of Ballina Island up to the model boundary at Ross Lane. The following properties are adversely affected:

- Ballina Gardens Caravan Park in North Ballina – estimated 30 caravans with up to 0.06m increase in flood level;
- Two houses on the old Pacific Highway in North Ballina (house number 304) – 0.02m increase in flood level;
- Six properties on Ross Lane on the edge of the study area – 0.03m increase in flood level; and
- Future proposed development at Southern Cross Precinct, Cumbalum Precinct B, and Barretts Development – up to 0.06m increase in flood level for scenario B (local catchment flooding) and 0.03m for scenario A (Richmond River Flooding).

In summary, while there is a significant overall economic benefit, it should be recognised that these flood modification options may marginally discriminate against a small portion of the community. This aspect should be explored in more detail before implementing these flood modification options to ensure that remedial measures can be put in place.

Figure 8–4 100 Year ARI Flood Impact Scenario B – Gallans Road Cycleway Option 2



LEGEND

Potential Development Included in Flood Model

Residential and Commercial Properties

Flood Impact

- more than 50mm
- 5mm to 50mm
- 5mm to -5mm
- -5mm to -50mm
- less than -50mm

Title:
100 Year ARI Flood Impact Scenario B - Gallans Road Cycleway Option 2

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 1 2km

Approx. Scale

Figure: 8-4

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_8-4.WOR

8.6 Deadmans Creek Road

Deadmans Creek Road connects Ballina Heights, on Cumbalum Ridge, to the old Pacific Highway in Cumbalum. The road crosses the Emigrant Creek floodplain at a level ranging from approximately 1.0mAHD to 1.3mAHD. The natural ground level in the vicinity of the road is 0.5mAHD. As such, the road forms a barrier to flow across the floodplain, thereby raising water levels upstream of the road embankment.

The Ballina Bypass's Cumbalum interchange will be located approximately 1km north of Deadmans Creek Road on the edge of the Emigrant Creek floodplain in the lee of Cumbalum Ridge. A new road will be built at this point, connecting the Cumbalum interchange, old Pacific Highway and Ballina Heights Development. This new road (currently named Ballina Heights Drive) will run along the periphery of the floodplain up to Ballina Heights, thus having little impact on flood levels in the Emigrant Creek valley.

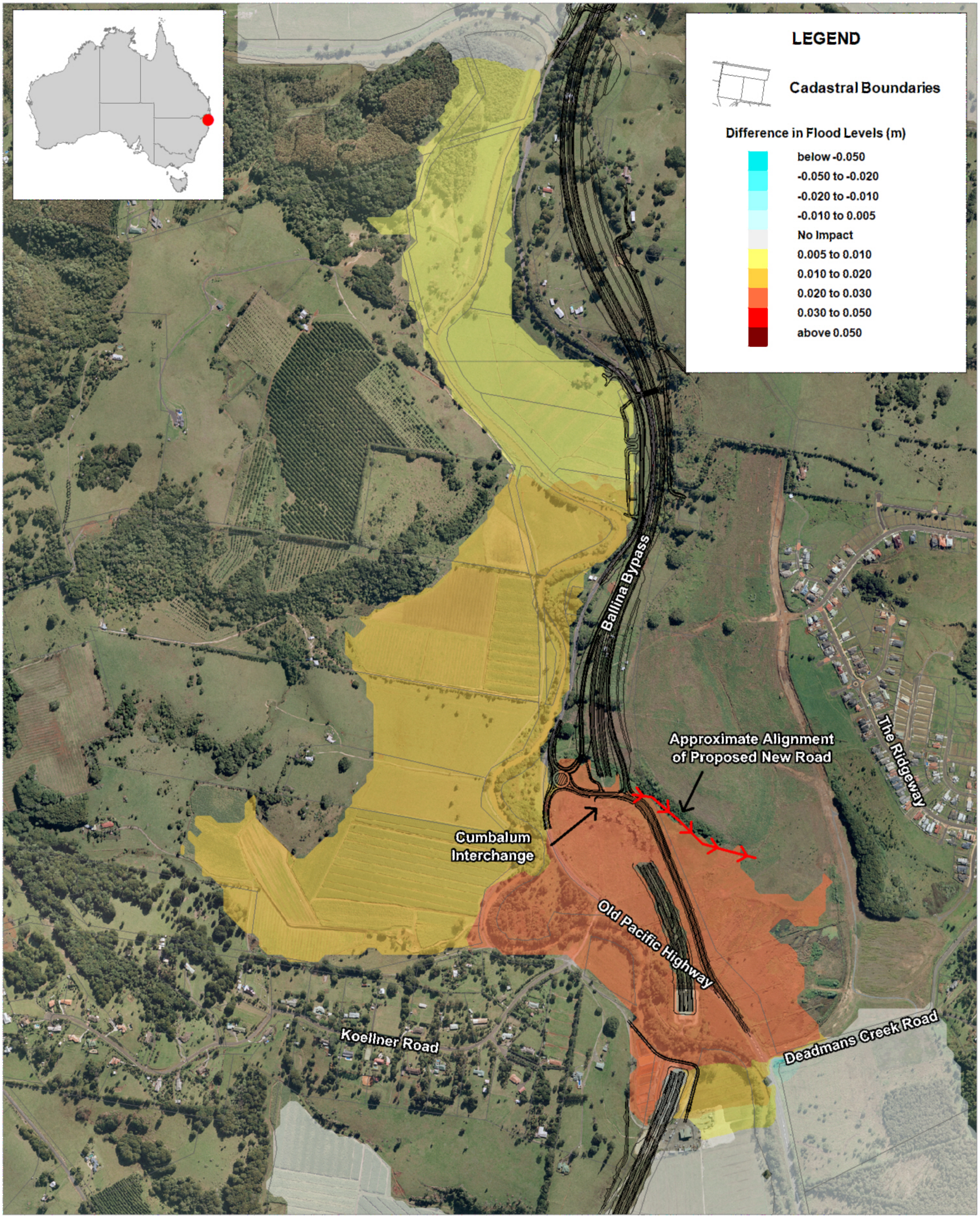
The new road will provide an alternative route for residents living in Ballina Heights, thus rendering Deadmans Creek Road redundant. During a previous assessment, removal of the Deadmans Creek Road embankment to create a floodway was proposed and subsequently adopted in principle. This mitigation measure was incorporated into the Integrated Flood Model and is, therefore, incorporated into the base case for this study.

An assessment of the impact that the Deadmans Creek Road embankment has on flood levels within the Emigrant Creek valley has been undertaken as part of this study. This assessment was carried out by reintroducing the embankment into the flood model and comparing the resulting flood levels against the base case flood levels for the 100 year ARI and 20 year ARI flood events. The results are illustrated in Figure 8-5 and Figure 8–6.

The results indicate that for the 100 year ARI flood event the inclusion of Deadmans Creek Road has an impact of between 10mm and 20mm immediately upstream of the road. The impact drops to less than 10mm from about 1.5km upstream of the road and becomes negligible where the old Pacific Highway and Emigrant Creek alignments diverge. Deadmans Creek Road has more of an impact on smaller, more frequent flood events, as is evident by the larger flood impacts for the 20 year ARI flood event which are between 30mm and 50mm upstream of Deadmans Creek Road.

Due to the significant flood impact caused by Deadmans Creek Road, it is recommended that the road is lowered or removed. Culverts under the road have been assessed in the Ballina Flood Study Update, but were found to be cost prohibitive. It is recommended that water levels in Emigrant Creek are monitored over a period of time to determine if the road can be lowered to a level that does not flood regularly and at the same time not cause significant flood impacts.

Figure 8–5 Deadmans Creek Road Flood Impact 20 Year ARI



Title:

Deadmans Creek Road Flood Impact 20 Year ARI

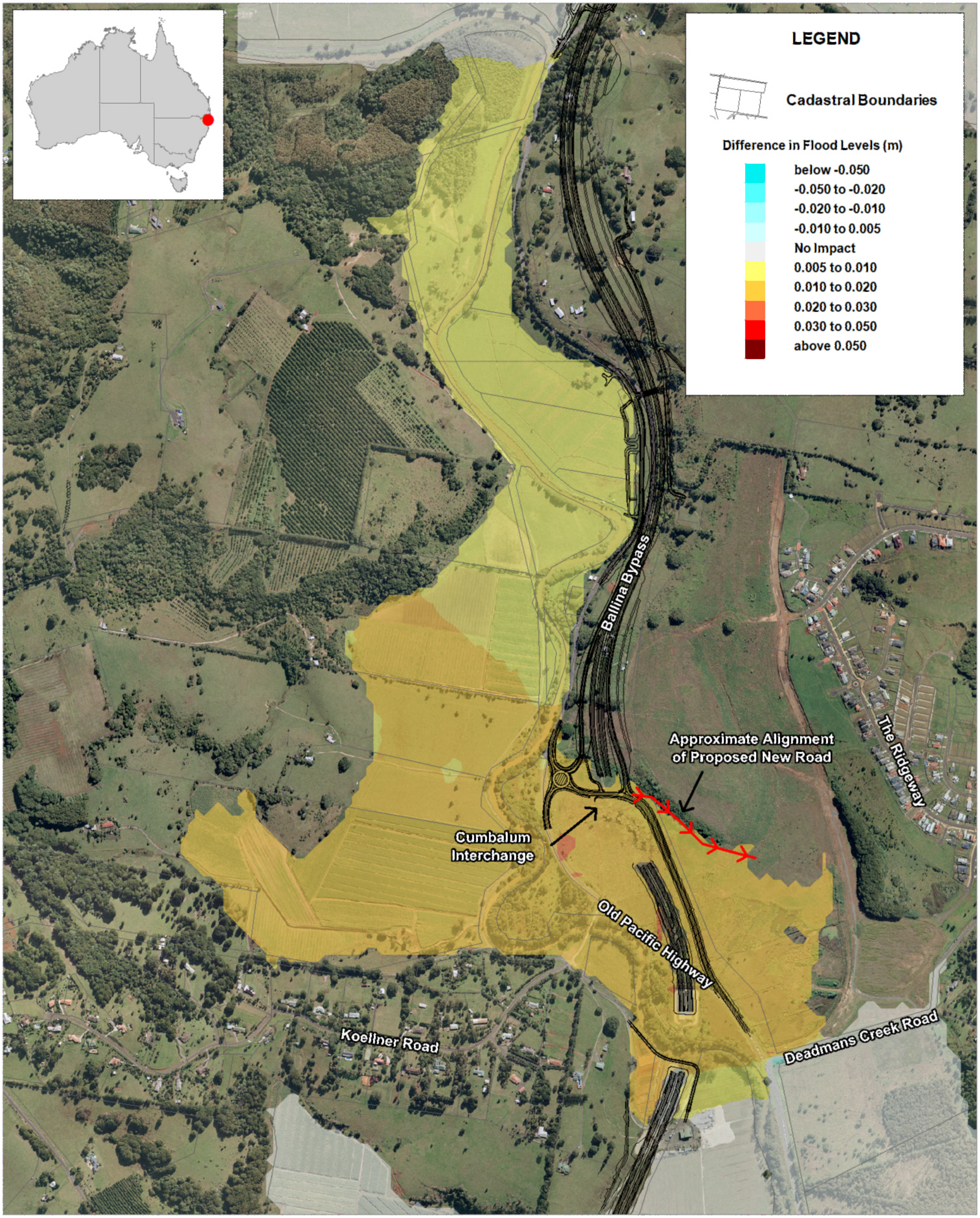
Figure: 8-5

Rev: A

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_8-5.wor

Figure 8–6 Deadmans Creek Road Flood Impact 100 Year ARI



Title:
Deadmans Creek Road Flood Impact
100 Year ARI

Figure: **8-6**

Rev: **A**

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_8-6.wor

9 MANAGING FLOOD RISK IN A CHANGING CLIMATE

9.1 Introduction

Under current climate conditions, flood risk on Ballina Island, the most densely developed area in the study area, is generally relatively low (i.e. most of Ballina Island is dry for the 100 year ARI flood event). However, if current sea level rise projections are realised, inundation of the Island will occur far more frequently in the future. As such, developing a plan on how to manage future flood risk is one of the most challenging and fundamental aspects of this study. For this reason, climate change is a recurring point of discussion in this document.

In order to further emphasise the importance of climate change in the study area, this chapter focuses purely on managing the projected future flood risk and elaborates on earlier such discussions in this report.

9.2 Floodplain Risk Management Options

A number of floodplain risk management options have been discussed in the preceding chapters. However, in terms of specifically addressing the projected future flood risk on Ballina Island, the following options have been considered:

- Do nothing;
- Planned retreat;
- Build a system of levees and pumps; and
- Update/improve planning and development controls.

Doing nothing is a form of unplanned retreat, and retreating has not been considered a viable option by the committee. Levees introduce risk of breach, overtopping and an increased maintenance burden on the community. With climate change being a gradual change over time, and current predictions uncertain, a gradual and adaptive floodplain management option would be well suited to dealing with the impacts of climate change. Land use planning is just such a mechanism, and the policies are implemented on the ground relatively slowly, thus providing an opportunity to update the controls if required.

9.3 The Adopted Strategy

The recommended approach for managing future flood risk is to enforce appropriate controls on development in the floodplain. This is implemented through the draft DCP in Appendix G, by defining minimum Flood Planning Levels (FPLs), which are based on future flood level predictions, for development.

Where new large developments are proposed a precautionary approach has been taken (i.e. using 2100 climate change conditions), because this can be achieved more easily than in developed areas. FPLs for infill development are based on 2050 climate change conditions as this is more practical in existing urban areas. The proposed development controls promote filling of entire lots to the 100 year ARI 2050 flood level. This flood level is approximately 200mm higher than the King Tide level plus 900mm sea level rise (2100 horizon forecast). Thus the proposed controls will mitigate regular tidal flooding beyond 2050.

This approach has been adopted on the premise that, with a 100 year ARI 2050 flood immunity, developed areas will have a lower than 100 year ARI flood risk leading up to 2050 and a higher than 100 year ARI flood risk beyond 2050. And the flood immunity will be approximately 100 year ARI on average over the next 90 years.

9.4 Conclusion

Climate change poses a threat to the sustainability of Ballina due to a significant increase in future flood risk. If a strategy to manage this risk is not implemented, much of Ballina will succumb to regular flooding. This floodplain risk management study has recommended that future flood risk is managed through planning and development controls, which stipulate minimum floor levels for development. Over time, through redevelopment, this approach will lead to filling of Ballina Island and surrounding low-lying developed areas. This approach is also adaptive, whereby if future climate change science predicts different sea level and rainfall intensity changes, development controls can be updated as required.

While this strategy will encourage filling of private land, it does not specifically address public infrastructure such as roads and stormwater drainage. The strategy will therefore need to be supplemented with further investigation into required improvement and flood mitigation of public infrastructure; which is a recommendation of this study.

10 FLOODPLAIN RISK MANAGEMENT SCHEMES

10.1 Choice of Management Scheme

A floodplain management scheme is a combination of a selection of floodplain management measures approved by the Committee. The major outcome of the Ballina Floodplain Risk Management Study is the formulation of a preferred floodplain management scheme that will form the basis of the Ballina Floodplain Risk Management Plan.

In order to formulate floodplain risk management schemes, the options discussed in this report have been listed in Table 10-1 below. A recommendation on whether to adopt/reject each measure is also included in Table 10-1.

Table 10-1 Summary of Floodplain Management Measures

Property Modification Measures:			
1	Planning Policy	Efficient method of managing future flood risk.	Adopt
2	Voluntary House Purchase	Flood hazard criteria not met.	Reject
3	Voluntary House Raising	Provides incentive to reduce flood risk through variable su bsidy.	Adopt
Response Modification Measures:			
4	Flood Forecasting System	Current flood forecasting method is inadequate.	Adopt
5	Flood Warning System	Flood warning methods should be improved.	Adopt
6	Revise Evacuation Planning and Local Flood Plan	New evacuation plan has been conceptualised by the SES through this study.	Adopt
7	Community Awareness	Need to inform community on new evacuation plan.	Adopt
8	Improve Evacuation Route Capacity	Raising low points along some evacuation routes will improve evacuation.	Adopt
Flood Modification Measures:			
9	Sandy Flat Floodway	Low cost benefit ratio, can only be justified if adjusting for intangible benefits.	Defer
10	Gallans Road Cycleway Floodway - Option 1	Superseded by option 2.	Reject
11	Gallans Road Cycleway Floodway - Option 2	Good cost benefit ratio.	Adopt

In total two schemes were identified for further assessment by the committee. These schemes are identified as Scheme A and Scheme B. Table 10-2 outlines the measures included in the two proposed schemes.

Table 10-2 Composition of Assessed Schemes

Recommended Measure	Scheme A	Scheme B
Gallans Road Cycleway Option 2	X	✓
Development Control Plan	✓	✓
Voluntary House Raising	✓	✓
Improve Flood Prediction	✓	✓
Improve Flood Warning	✓	✓
Increase Flood Awareness	✓	✓
Improve Evacuation Planning	✓	✓
Improve Evacuation Routes	✓	✓

10.2 Scheme A

Scheme A does not modify the flood behavior, but focuses instead on property and response modification. Scheme A includes the following flood management measures.

10.2.1 Property Modification

The newly developed DCP aims to control future development in Ballina, thereby reducing flood risk to all new development. The DCP restricts development in high risk flood liable lands. Use of the developed DCP will reduce future flood damages resulting from inappropriate development on the floodplain. The cost of this measure is minimal, and will become integrated within Council's normal operating budget. With significant benefits in reduction to future flood damages and risk to life and low cost to implement, this option is an efficient floodplain management measure.

A voluntary house raising scheme will be introduced to encourage residents to raise their properties. The incentive is scaled according to flood risk, to promote floor raising to those properties most at risk. If all home owners that qualify take part in the scheme, it would require a sizable capital outlay. However many properties will be difficult/impractical to raise, and will therefore not take part in the scheme. The absolute cost and benefit of the scheme cannot be computed without a detailed survey of the properties that qualify, but the total cost-benefit ratio for all qualifying properties (see Section 6.3.2) indicates that the option is economically beneficial.

10.2.2 Response Modification

Currently no formal flood prediction system is in place within the study area. There are numerous options available for flood prediction. These could range from simple flood gauge correlation techniques to hydrological and hydraulic flood forecasting models. There are many communities in the Richmond River floodplain. It is, therefore, advisable to consider a catchment wide approach to flood prediction. Hence it is recommended that a thorough assessment of flood prediction options is undertaken through a targeted Richmond River flood prediction feasibility study.

The flood warning method at the inception of this study was door knocking. The SES has been exploring other options. Use of multiple warning methods is advised.

A preliminary evacuation plan has been prepared by the SES during the study. The adequacy of the evacuation centres still need to be ratified through collaboration with DoCS. As such, the evacuation plan remains to be finalised. Once adopted, the zones and routes will need to be clearly marked out on the ground and formalised in a revised Local Flood Plan.

The proposed flood awareness measures aim to raise community awareness. Community awareness and preparedness is an important factor in reducing flood risk during an event. A flood aware community is able to understand flood warnings, how they relate to their particular situation and how to respond appropriately.

Opportunities exist to improve the evacuation capability by raising low points in the evacuation routes. It is recommended that closure locations are surveyed and compared to assumed levels in the model. It can then be established where genuine ‘trouble spots’ are and what magnitudes of raising should be employed.

The costs and benefits associated with these measures cannot be quantified. However the cost associated with implementing these measures is small relative to the benefit of achieving a more efficient evacuation. The current evacuation capability ranges from a rescue phase of 1.1 hours for Zone A to a safety margin of 2.1 hours for Zones C and F. Much of the time needed for an evacuation is made up from the decision and resource mobilisation time (6 hours), time needed to warn dwellings (12 dwellings/team/hour) and community acceptance and response time (2 hours). It is anticipated that by implementing the afore mentioned response modification measures the evacuation capability can be significantly improved, thus making the evacuation possible for all evacuation zones during a Richmond River dominated flood or ocean storm dominated flood event.

10.3 Scheme B

Scheme B builds upon Scheme A with the addition of a structural modification measure. The Gallans Road Cycleway – Option 2 is included in this scheme. This measure involves opening up a floodway across the Gallans Road Cycleway embankment, thus reopening a natural flow path between the Emigrant and North Creek floodplains. The cost of implementing the structural modification option is estimated at $400k. This will result in a reduction in flood depths for a number of properties in the Emigrant Creek valley and West Ballina. The reduction in flood depths is generally less than 50mm for the 100 year ARI flood event. The benefit is therefore subtle, and may not be physically noticeable to those that benefit. However the reduced flood damages over time is substantial, with a net present worth of $1,1M. This gives the scheme a cost-benefit ratio of 2.80. Remediation may be required for those few properties that are adversely affected by this measure (see Section 8.5 and Table 10-3). The benefit of the structural measure in terms of reduced flood levels for residential dwellings is shown in Table 10-3.

Table 10-3 Summary of Structural Measure Effects on Dwellings

Number of Units Where:	20 Year ARI	100 Year ARI
Flood levels increase (less than 50mm)	4	36
Flood levels decrease by less than 50mm	92	640
Flood levels decrease by more than 50mm	1	45
No longer inundated	8	47

Note: Number of dwellings refers to both residential dwellings and commercial units

Flood level increases are less than 50mm

Flood levels do not decrease by more than 100mm

Unit count includes flood damaged properties with flood level below floor level

Changes in flood level of less than 5mm were considered negligible

The structural measure has reduced the number of residential buildings that qualify for voluntary house raising by 2 for the 20 year ARI flood event and 10 for the 100 year ARI flood event. This results in a saving of $200k for the voluntary house raising scheme.

11 CONCLUSIONS AND RECOMMENDATIONS

This floodplain risk management study has investigated the flood problem in the study area, estimated the damage caused by flooding and assessed the capability of the community to evacuate. Various floodplain risk management measures have been canvassed and recommended floodplain management options have been grouped into two floodplain risk management schemes. These schemes will reduce current and future flood risk in the study area, thereby reducing both flood damage and improving the communities' capability to evacuate. The recommendations of the study area as follows:

- Scheme B provides more benefit than Scheme A, and has therefore been selected as the preferred scheme. The primary recommendation of this study is to carry Scheme B forward into the Ballina Floodplain Risk Management Plan.
- The Community Reference Group is concerned with the silting up of minor watercourses in the catchment. This has affected drainage of the floodplain after flood waters in the main creeks have subsided. It is recommended that consideration is given to implementing a study that investigates this issue. It is envisaged that the study would assess which creeks have silted up, the cause of siltation, consequences on the waterway/floodplain health and options to clear and prevent future siltation in the affected watercourses.
- The preferred floodplain risk management scheme mitigates future flood risk due to climate change by filling and raising floor levels. This is implemented primarily through development controls contained in the DCP. However, this does not consider public infrastructure such as roads or the storm water network. To implement the scheme successfully it will be necessary to assess how public infrastructure should be maintained/improved to match the changing climate and ground levels. It may therefore be necessary to undertake further studies to assess:
    - Options to mitigate future flood risk and drainage issues to public infrastructure; and
    - The storm water system capacity under future climate and catchment conditions. The aim of this assessment will be to analyse what improvements need to be made to the storm water system to mitigate future changes to ground levels, rainfall intensities and sea levels.

12 REFERENCES

Australian Bureau of Statistics (2010), Data Online, accessed 14th September 2009, http://www.abs.gov.au/CDataOnline

Australian Sugarcane Annual (2009), Australian Sugarcane, http://www.australiansugarcane.com.au

Barton, C.L., Viney, E.L., Heinrich, L., Turnley, M. (2002), *The Reality of Determining Urban Flood Damages*, NSW Flood Mitigation Conference, Coffs Harbour, May 2002.

BBA (2008), *BBA Information Document - Flood Assessment Stakeholder Consultation*, Document No. BBA-DR2402-ID01-FD_[02], August 2008.

BSC (2006), Wet Weather Road Closure Information, Ballina Shire Council – Corporate Services, 2006.

BMT WBM (2009), *Ballina Integrated Flood Modelling - Summary of Flood Assessments around Ballina, 2005-2009* prepared by BMT WBM for Ballina Shire Council, June 2009.

BMT WBM (2008a),*Ballina Flood Study Update*, BMT WBM Pty Ltd, March 2008.

BMT WBM (2008b), *Flood Impact Assessment for the Ballina Bypass, Final Design Report BBA-DR2402*, BMT WBM Pty Ltd, August 2008.

BMT WBM (2009) *Ballina Integrated Flood Modelling, Summary of Flood Assessments around Ballina, 2005 – 2009*, BMT WBM, June 2009.

BMT WBM (2010), *Richmond River Flood Mapping Study, Volume 1, Final Report*, BMT WBM Pty Ltd, April 2010.

BSES (2008), MANAGING FLOOD DAMAGED CROPS – The best approach, BSES Limited, 2008.

BTRE (2001), *Economic Costs of Natural Disasters in Australia*, Bureau of Transport and Regional Economics, Commonwealth of Australia, 2001.

CANEGROWERS (2009), *Annual Report 2009*, Queensland Cane Growers Organisation Ltd, 2009.

Hooper, S. (2008), *Financial performance of Australian sugar cane producers*, Commonwealth of Australia, September 2008.

CRES (1992), *ANUFLOOD: A Field Guide*, prepared by D.I. Smith and M.A. Greenaway for Centre for Resource and Environmental Studies (Australian National University), Canberra, 1992.

CSIRO (2000), *Floodplain Management in Australia: Best Practice Principles and Guidelines*, SCARM Report 73.

DECCW (2007a), *Floodplain Risk Management Guideline: Practical Consideration of Climate Change*, NSW Department of Environment, Climate Change and Water, October 2007.

DECCW (2007b), *Floodplain Risk Management Guideline: Residential Flood Damages*, NSW Department of Environment and Climate Change, October 2007.

DIPNR (2005), *Floodplain Development Manual: The Management of Flood Liable Land*, Department of Infrastructure, Planning and Natural Resources, NSW Government, April 2005.

DoP (2010), *NSW Coastal Planning Guideline: Adapting to Sea Level Rise*, NSW Department of Planning, August 2010.

EMA (2002), *Disaster Loss Assessment Guidelines*, Emergency Management Australia, Commonwealth Australia and Queensland Department of Emergency Services, State of Queensland, 2002.

Kingston et al (1999) – See Johnston River Flood Study (2003).

NRM (2002), *Guidance on the Assessment of Tangible Flood Damages*, Queensland Government, Natural Resources and Mines, March 2002.

Opper (2004), *The Application of Timelines to Evacuation Planning*, paper presented at the NSW Floodplain Management Authorities Conference, Coffs Harbour, 2004.

Patterson Britton (2000), *Shaws Bay, East Ballina, Estuary Management Plan, Volume 1, Issue No. 3*, Patterson Britton & Partners Pty Ltd, January 2000.

Rawlinsons (2006), *Rawlinsons Australian Construction Handbook, Edition 24*, Rawlhouse Publishing Pty Ltd, 2006.

SES (20008), *Ballina Shire Local Flood Plan – A Sub-plan of the Ballina Shire Local Disaster Plan (DISPLAN)*, State Emergency Service, February 2008.

SKP (1980), *New South Wales Coastal Rivers Flood Plain Management Studies – Richmond Valley*, Sinclair Knight & Partners Pty Ltd, December 1980.

Smith, D.I. (1994), *Flood Damage Estimation – A Review of Flood Damage Curves and Loss Functions*, Published in *Water South Africa*, July 1994.

VDNRE (2000), *Rapid Appraisal Method (RAM) for Floodplain Management*, Victorian Department of Natural Resources and Environment, State Government of Victoria, May 2000.

APPENDIX A: FLOOD MODELLING

A1 INTRODUCTION

The flood behaviour around Ballina was investigated in previous studies, with the most recent study being the Ballina Flood Study Update (BFSU) (BMT WBM, 2008). Computer modelling was used in these prior studies to assess the flood behaviour within the study area. These computer models have been updated and reused in this floodplain risk management study. Details of the flood modelling approach and updates are discussed in this Appendix.

A2 HYDROLOGICAL MODELLING

In order to assess the quantity of rainfall and runoff in the catchment, hydrological models of the catchment have been developed. The outputs of the hydrological modelling are used, in turn, as inflows to the hydraulic model.

Hydrological modelling was done previously for the BFSU. The previous hydrological modelling used the XP-RAFTS software. Since a catchment-wide hydrological model was developed using the WBNM software by BMT WBM for the Richmond River Flood Mapping Study (RRFMS) (BMT WBM, 2010) more recently, the WBNM model has been used to supersede the XP-RAFTS modelling. The WBNM model was calibrated to the 2009, 2008 and 1974 historical flood events for the entire Richmond River catchment.

The following assumptions and adjustments to the BFSU hydrological modelling have been adopted for this study in order to be consistent with the Richmond River Flood Study:

- Four different regions have been identified for intensity-frequency-duration (IFD) design rainfall parameters. The regions are summarised below.
    - Alstonville – based on the revised IFD parameters defined during the Ballina Floodplain Management Study (WBM, 1997);
    - Newrybar – based on the maximum IFD parameters within the region;
    - Wardell – based on the maximum IFD parameters within the region; and
    - Tuckean – based on the maximum IFD parameters within the region.
- During the RRFMS, the rainfall intensities derived using the above parameters were cross checked against those listed in the *Northern Rivers Local Government – Handbook of Stormwater Drainage Design (2006)*. The RRFMS rainfall intensities were generally equal to or higher than the design guidelines.
- Zone 1 (from Australian Rainfall and Runoff) temporal patterns have been applied, resulting in higher peak flow rates within the local catchments than used in the BFSU.
- The areal reduction factors (ARFs) used for the previous Ballina flood modelling are now considered overly conservative. The Cooperative Research Centre for Catchment Hydrology (CRCCH) (1996) has derived an empirical method for calculation of ARFs. Higher ARFs are calculated for longer duration and higher frequency events as presented in Table A-1.

Since the CRCCH method also accounts for catchment area, the following criteria have been used:

- For the local catchment storm events (short storm duration), the Lower Richmond River catchment area of $387km^2$ has been used; and
- For the broader Richmond River catchment storm events (long storm duration), the entire Richmond River catchment area of $6,900km^2$ has been used.

Table A- 1 lists the areal reduction factors used in the WBNM hydrology model.

Table A- 1 Revised Areal Reduction Factors

Event Duration	Areal Reduction Factor for ARI			
	10 year	20 year	50 year	100 year
12 hour	0.81	0.81	0.80	0.80
72 hour	0.86	0.85	0.83	0.82

A3 HYDRAULIC MODELLING

A3.1 Background

Originally, a 1D flood model was developed for the previous floodplain risk management study using software called ESTRY (WBM, 1997). This model was then updated as part of the BFSU by removing much of the 1D floodplain component from the model and replacing the floodplain representation with 2D domains using the TUFLOW modelling software.

The flood model developed for the BFSU was subsequently updated on a regular basis for development assessments. This was done to enable Council to assess the cumulative flood impact of development in the floodplain. The model has been used extensively for this purpose, and is commonly referred to as the integrated flood model. The integrated flood model forms the basis of the flood model that has been developed for this study.

Much of the flood model structure, assumptions and parameters are discussed in detail in the BFSU report. A brief description of the model layout, adjustments made to the model during this study and approved development that is included in the model is discussed below.

A3.2 Model Extent and Schematisation

The model extent covers the lower Richmond River and parts of its major tributaries: Maguire Creek, Emigrant Creek and North Creek. The model extent is illustrated in Figure A-1. Two 2D domains are used: a 40m 2D grid for North Creek, Maguires Creek and the Richmond River areas, and a 10m 2D grid for Ballina Island, West Ballina and Emigrant Creek.

The Richmond River channel is represented using a 1D network from the upstream boundary to Empire Vale on the downstream side of Pimlico Island. Downstream of this point, flow through the river channel is modelled in the 40m 2D domain.

The North Creek, Emigrant Creek and Maguires Creek channels are represented using a 1D network, as well as a number of drains and smaller creeks in the catchment.

The 1D river channel networks, 10m 2D domain and 40m 2D domain are all dynamically linked, thereby enabling flow to transcend across these separate components in real time during the model simulation.

A3.3 Topography

2004 photogrammetry captured for the BFSU covers the 2D domain extents, north of Pimlico Island. For the extension of the 2D domain applied in this study (discussed in Section A3.6) additional topographic data was acquired.

A Digital Elevation Model (DEM) of the Richmond River catchment developed for the RRFMS was available, which was built using a number of data sources. This DEM was used to define the topography in the extension of the 2D domain. The bulk of the topographic data in the extended 2D domain originates from a DEM (based on photogrammetry) created for the Wardell and Cabbage Tree Island Flood Study. Other parts of the DEM in the area covered by the extended 2D domain were based on photogrammetry acquired by the Roads and Traffic Authority (RTA) for the Woodburn to Ballina Pacific Highway Upgrade Project.

A3.4 Model Boundaries

A3.4.1 Upstream Boundaries

There are five upstream boundaries in the flood model. All of these boundaries use flow-time boundary conditions. The flow conditions applied at the North Creek, Emigrant Creek and Maguires Creek upstream boundaries are based on hydrographs developed from the hydrological model. The flow conditions applied at the Tuckean Broadwater and Richmond River upstream boundaries are derived from a synthetic stage-time boundary that was developed during the Ballina Floodplain Management Study (WBM, 1997).

A3.4.2 Intervening Catchment Runoff

Rainfall falling over the sub-catchments within the flood model extent has been applied by using a TUFLOW modelling method that initially inserts the runoff associated with a particular sub-catchment at the lowest cell within that sub-catchment, and subsequently spreads the runoff evenly across all wet cells in the sub-catchment.

A3.4.3 Downstream Boundary

The downstream boundary is located at the outfall of the Richmond River at the Pacific Ocean. Water levels at the downstream boundary are therefore dictated by local tidal conditions. A stage-time boundary has been used, as per the BFSU.

A3.5 Model Roughness Parameters

Land use (surface roughness) definition for the Ballina area remains unchanged from the BFSU. For the extended 2D domain between Broadwater and Pimlico Island, land use is based on that used for the RRFMS, which is based on Council's 2004 aerial photography.

A3.6 Updates Applied to the Flood Model

A number of enhancements to the integrated flood model have been implemented as part of this floodplain risk management study. These include:

- **Extension to southern extent of the 2D domain**
  The southern extent of the 2D domain was originally at Empire Vale near Pimlico Island, and the Richmond River floodplain upstream of the 2D domain extent was represented using 1D elements. These 1D floodplain elements have been removed and the 40m 2D domain has been extended to the upstream boundaries on Richmond River and Tuckean Broadwater.
- **Richmond River bathymetry update**
  Bathymetry for the Richmond River between Broadwater and Pimlico Island has been updated with a survey captured for DECCW's (now Office of Environment and Heritage) estuary program.
- **Change to location of Richmond River upstream boundary**
  The upstream boundary and model extent on the Richmond River has been moved three kilometres further upstream to Rileys Hill. The floodplain at this location is constricted, and is therefore a more appropriate location for the upstream boundary.
- **Change to Richmond River and Tuckean Broadwater upstream boundary type**
  The integrated flood model used head-time upstream boundaries on the Richmond River and Tuckean Broadwater. These boundaries have now been changed to flow-time boundaries. This change has been applied to ensure that the flow through the river systems remains consistent across future model versions.
- **Update to the model inflows**
  The WBNM hydrological modelling results have been applied to the flood model, replacing the XP-RAFTS hydrological inflows that were being used previously.
- **Enable flow through porous rock headwall at Richmond River mouth**
  The northern headwall on the Richmond River mouth blocks water in the Richmond River mouth from entering into the Shaws Bay area. The model was originally set up such that this headwall was impervious. Therefore the model was indicating little flood risk in the Shaws Bay area. However in reality this wall is porous, allowing flood waters to flow into Shaws Bay. The model has been updated by creating some voids in the headwall. The assumptions used for this model adjustment have been informed by the Shaws Bay, East Ballina Estuary Management Plan (Patterson Britton, 2000).

A3.7 Development and Infrastructure Included in the Flood Model

The integrated model has been used to quantify the cumulative flood impact of a number of proposed developments. The following proposed development and infrastructure were previously assessed and included in the flood model:

Ballina Shire Council Studies

- West Ballina Master Plan
- Part of the Southern Cross Precinct Master Plan

- North Creek Road
- West Ballina Arterial Road

Roads and Traffic Authority Studies

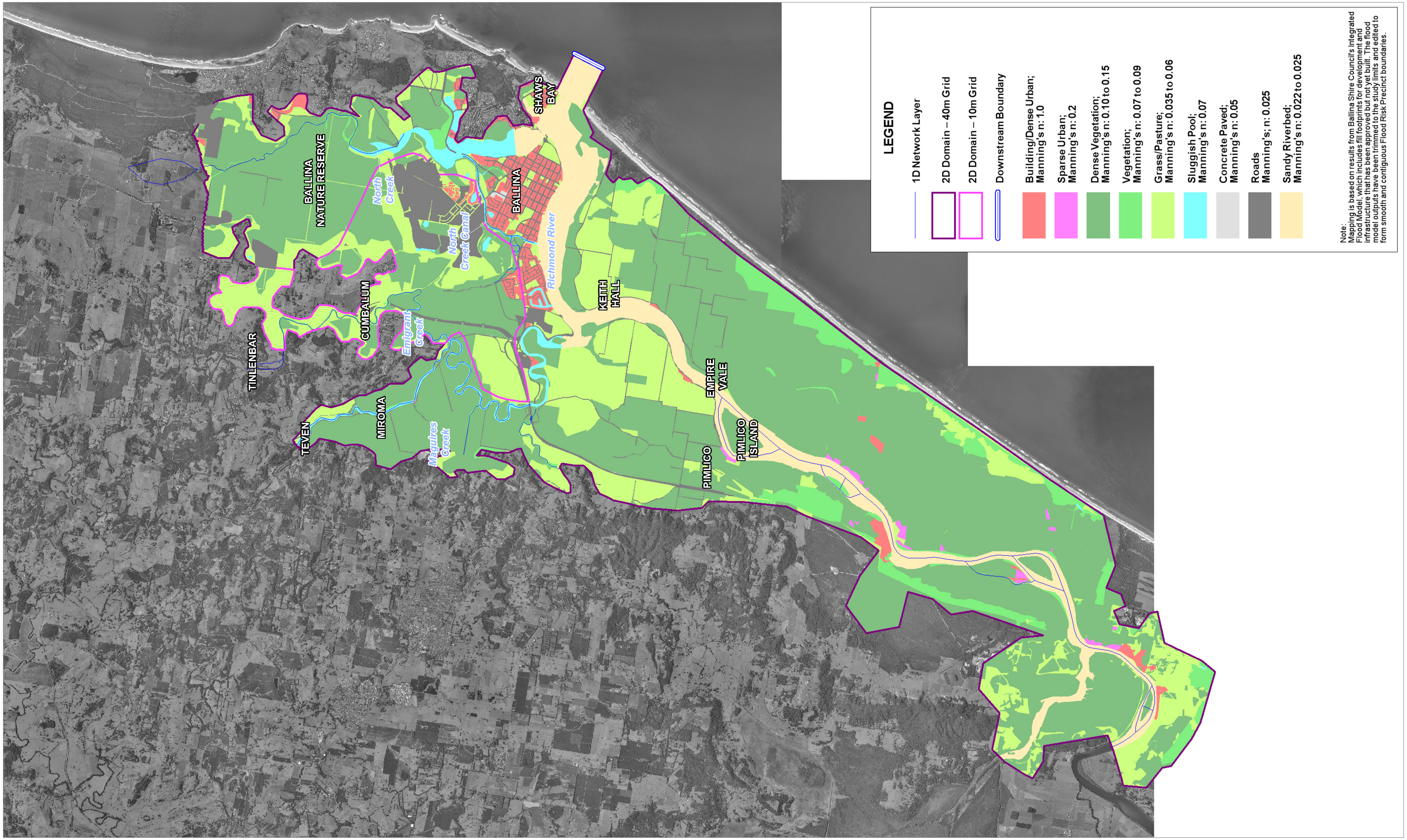
- Ballina Bypass Pacific Highway Upgrade
- Woodburn to Ballina Pacific Highway Upgrade
- Garney Koellner Road Bridge

Residential/commercial development

- Natuna
- Ferngrove (previously called Riveroaks)
- Ballina Waterways
- Ballina Heights
- Cumbalum Precinct B
- Barrets
- Dr Stewarts
- Various Tevan Road filling

Note that while an assessment has been undertaken for a proposed development (highway service centre) at Lot DP238009, this development is not included in the model as the development had not been approved at inception of this study. The western portion of the site has since been approved.

Since the developments listed above have been included in the flood model, the model does not represent the catchment's current conditions. It is estimated that the development will be built over the next few years, and that that the model therefore relates to catchment conditions expected by approximately 2020.



Title:
Flood Model Schematisation

Figure: **A-1**

Rev: **C**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 2 4
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_A-1.wor

A4 DESIGN FLOOD EVENTS

The study area is prone to three sources of flooding, namely: Richmond River, local catchment (i.e. tributaries of the Richmond River) and ocean storm flooding. In reality, a variety of combinations of these flood sources can occur. However, for the purpose of developing hypothetical design flood events the flood study (BMT WBM, 2008) defined three separate design flood scenarios which are dominated by a particular flood source. These are:

Scenario A – Richmond River dominated event;

Scenario B – Local catchment dominated event; and

Scenario C – Ocean storm surge dominated event.

These three scenarios have been modelled independently for the 20, 50, 100, and 500 year Annual Recurrence Interval (ARI) flood events. For small flood events (i.e. 5 and 10 year ARI), it is assumed that there is no flood source dominance, and each flood source is applied concurrently (Scenario D).

The Probable Maximum Flood (PMF) is a hypothetical flood, or combination of floods, which represents a theoretical 'worst case' scenario. The PMF design floods were developed using a 10,000 year ARI flow in the Richmond River and 500 year ARI ocean storm levels at the downstream boundary. For local catchment flows, the Probable Maximum Precipitation (PMP) storm has been determined and applied to the flood model considering three different storm centres:

Scenario E – PMP storm centred on Maguires Creek catchment;

Scenario F – PMP storm centred on Emigrant Creek catchment; and

Scenario G – PMP storm centred on North Creek catchment.

In summary, the 5, 10, 20, 50, 100, 500 year ARI and PMF events have been simulated using the flood model. For a given return period flood event, the flood model results for each scenario have been amalgamated by selecting the most severe flood condition at each location, thus generating the 'worst case' flood conditions.

Table A- 2 Design Flood Event Scenarios

	Scenario	Richmond River Level (ARI)	Local catchment storm (ARI and storm duration)	Ocean Storm Surge(ARI)
PMF	E	10,000 year	PMP[1] (centred on Maguires Ck catchment)	500 year
	F	10,000 year	PMP[1] (centred on Emigrant Ck catchment)	500 year
	G	10,000 year	PMP[1] (centred on North Ck catchment)	500 year
500 year ARI	A	500 year	500 year (72 hours)	10 year
	B	100 year	500 year (12 hours)	10 year
	C	100 year	100 year (12 hours)	500 year
100 year ARI	A	100 year	100 year (72 hours)	10 year
	B	10 year	100 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	100 year
50 year ARI	A	50 year	50 year (72 hours)	10 year
	B	10 year	50 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	50 year
20 year ARI	A	20 year	20 year (72 hours)	10 year
	B	10 year	20 year (12 hours)	10 year
	C	10 year	10 year (12 hours)	20 year
10 year ARI	D	10 year	10 year (12 hours)	10 year
5 year ARI	D	5 year	5 year (12 hours)	5 year

Notes: 1. PMP = Probable Maximum Precipitation is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of year.

A5 MAPPING THE MODEL RESULTS

The flood model computes a number of hydraulic characteristics through the modelled extent, such as flood level, flood depth, flow velocity and the depth velocity product (used to assess flood hazard). These are captured in the flood model's results files. TUFLOW's results files are output in a format that is compatible with software called SMS (Surface-water Modeling System, developed by the US Army Corps of Engineers). The SMS file format stores the model results at the 2D domain's computational grid cell corners rather than at the grid centre. Thus the resolution of TUFLOW results is generally half the resolution of the 2D domain's computational grid size, i.e. 20m for the flood model used in this study.

Each design event comprises the three sources of flooding described in Section A4. Therefore, to generate maps of the flood model results for each design event, the maximum result from each of the three source events have been overlayed and the maximums extracted. This provided a maximum envelope of peak flood levels, depths, velocity and depth velocity product across the model area.

Figure 2-1 in Section 2 of the body of this report shows the dominance of the different sources of flooding for the 100 year ARI flood event. Richmond River flooding tends to be dominant across the Richmond River floodplain to Ballina Island, across the lower Emigrant Creek floodplain and across the North Creek catchment. Local catchment flooding is the dominant source of flooding in upper Emigrant and Maguires Creeks, whilst the area covering Ballina Island to the ocean, experiences worst flooding from elevated ocean levels.

APPENDIX B: DERIVATION OF DEMOGRAPHIC AND PROPERTY DATABASE

B1 PURPOSE

A property and demographic dataset has been developed for use in the flood damage estimation and the evacuation capability assessment. This dataset combined a large amount of information about individual properties, including floor level, building type and number of residents. Importantly, the database spatially distributes the property information, enabling identification of flood effects on individual properties and residents.

B2 PROPERTY DATABASE

The property database is derived from 1979 survey information, supplemented with additional survey commissioned for this study. This additional survey was required in areas which were developed or modified during the last 30 years.

The following methodology has been applied to generate the property database:

1 The existing 1979 survey data has been reviewed to determine which properties required updated survey. Properties which appeared to have been rebuilt or have modified floor levels have been removed from the 1979 dataset. The survey review has been based on aerial photography, cadastral data and ground inspection. Approximately 1,090 residential and 170 commercial/ industrial properties remained in the 1979 survey dataset at the end of this process.

2 Residential, commercial and industrial properties not covered by the revised 1979 survey dataset have been identified. This process focussed on identifying those properties that are within or near the floodplain, i.e. properties on high ground have not been included. Floor levels and building data for these properties have been surveyed by Landsurv (Tweeds Head Office) in 2009. In total 2,340 residential properties and 380 commercial/industrial properties were surveyed. The 1979 and 2009 surveys have been merged into one residential floor level survey and one commercial/industrial floor level survey.

3 A small number of isolated properties were not included in the original or supplementary survey. Details of these developments have been estimated using aerial photogrammetry data, cadastre data and Google imagery.

4 The number of units within properties surveyed in 1979 has been estimated from cadastre type, property type, Google imagery and ground inspection where necessary.

5 The building areas of commercial properties have been determined based on the cadastre parcel sizes and, for large buildings, digitised from aerial photos.

It is noted that flood damages assessments are typically combined for commercial and industrial properties. For simplicity, both types of properties and damages are referred to as *commercial* herein, but in all cases refer to *commercial and industrial*.

In total, approximately 3,770 residential and 550 commercial properties have been identified within the study area and incorporated into the dataset.

Additional assumptions used to derive the property data set and associated parameters are listed in Table B-1 to Table B-3.

B3 DEMOGRAPHIC DATABASE

Population data has been used to estimate the number of people requiring evacuation and the number of vehicles which will be used to evacuate. This information has been combined with the property database to determine which properties are predicted to be flood affected.

Due to the uncertainty regarding the size of the impending flood event at the time of flood prediction, it is necessary to evacuate the entire population at risk of flood inundation or isolation in a PMF.

Information regarding population and vehicles has been derived from the 2006 census (Australian Bureau of Statistics 2010), as this is the most recent data available.

B4 FUTURE DEVELOPMENT AND POPULATION

The flood model includes assessed development that is yet to be built. Therefore the future development has been accounted for in the property database and projected population estimates included in the demographic database. This has been implemented by developing an additional dataset consisting of only the unbuilt assessed development to supplement the database of existing properties. The following assumptions have been made to derive this supplementary dataset:

- Numbers of residential dwellings have been derived from a *Housing Demand and Supply Forecast Methodology Statement* provided by Ballina Shire Council;
- Dwelling types have been assumed to be low set (i.e. single storey slab on ground);
- Floor levels have been assumed to be set according to the current planning level, i.e. 100 year flood level including climate change for the 2100 horizon plus 500mm freeboard;
- Commercial building areas have been assumed to be of medium size, i.e. 650m²;
- Value class for commercial buildings have been assumed to be of medium value, i.e. value class of 3; and
- The numbers of commercial dwellings have been estimated by assuming that two-thirds of the commercial development area will be covered by commercial property and that the commercial property size will be 650m² on average. The commercial development areas have been calculated based on the development footprint sizes in the model.

Note that the unbuilt assessed development contributed little to the overall flood damages because the floor levels are relatively high compared to the flood levels.

The projected population estimates have been added to the demographic database. The population linked to future development has been projected by assuming 2.16 people per residential dwelling (shire-wide long-term occupancy rate projection provided by Ballina Shire Council). Population has also been projected to 2020 in consideration of infill development. The estimated population data are summarised in Table 3-4 in Section 3 of the body of this report.

Table B- 1 Property Data

Property Data	Residential Properties	Commercial and Industrial Properties
Property type	Based on information collected during survey in 1979 and 2009, aerial photography and cadastre. See Table B-2 and B-3 for more details.	Based on information collected during survey in 1979 and 2009, aerial photography and cadastre. See Table B-2 and B-3 for more details.
Number of properties	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details. Where no information was collected the number of properties has been assumed based on aerial photography, cadastre and site visits.	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details. Where no information was collected the number of properties has been assumed based on aerial photography and cadastre.
Location of properties	As digitised in survey data. East Ballina and Shaws Bay – aerial photography and cadastre.	As digitised in survey data. East Ballina and Shaws Bay – aerial photography and cadastre.
Dwelling type	As collected in 2009 survey 2007 survey, East Ballina and Shaws Bay – determined from aerial photography and cadastre.	Not applicable.
Floor area	Not applicable.	Parcels < 200m^2 – small. Parcels 200 to 700m^2 – medium. Parcels > 700m^2 – approx building area digitised from aerial photography and cadastre.
Business value	Not applicable.	Based on information collected during survey in 1979 and 2009, see Table B-2 and B-3 for more details.
Floor level	Survey undertaken in 1979 or 2009 East Ballina and Shaws Bay – based on a digital elevation model created from airborne laser scanning and aerial photogrammetry data.	All properties – survey undertaken in 1979 or 2009
Flood level	All properties – flood level in building / at survey point.	All properties – flood level in building/ at survey point.

Table B- 2 Derivation of Property Type and Business Value based on Survey Information (2009 Survey)

2009 Survey	TYPE	Class Value
Dwelling	residential	NA
Townhouse	residential	NA
Garage	residential	NA
Units	residential	NA
Shed	residential	NA
Amenity	commercial	1
Commercial	commercial	3
Club	commercial	1
Bowls Club	commercial	1
Church	commercial	1
Pump station	commercial	4
Industrial	commercial	3
Caravan park	commercial	2
Resort	commercial	3
School	commercial	1
Motel	commercial	3
Hospital	commercial	3
Airport	commercial	4
Hall	commercial	1
Museum	commercial	3
Community Centre	commercial	1
Vets	commercial	2
Stable	commercial	2
Age care	commercial	3

Table B- 3 Derivation of Property Type and Business Value based on Survey Information (1979 Survey)

1979 Survey	TYPE	Class Value
Dual Occupancy	residential	NA
Duplex	residential	NA
Dwelling	residential	NA
Flats	residential	NA
Strata Parent	residential	NA
Aged Accommodation	commercial	3
Bank	commercial	3
Bed & Breakfast	commercial	3
Car Park	commercial	3
Caravan Park	commercial	2
Church	commercial	1
Club	commercial	1
Combined Use	commercial	3
Commercial	commercial	3
Court House	commercial	3
Hall	commercial	1
Hostel	commercial	3
Hotel	commercial	3
Industrial	commercial	3
Mobile Home Park	commercial	2
Motel	commercial	3
No Improve Details	*commercial*	*3*
Office	commercial	2
Office/Dwelling	commercial	2
Other	commercial	3
Pre School	commercial	1
Public Authority	commercial	1
Public Reserve	commercial	1
Public Utility	commercial	1
School	commercial	1
Service Station	commercial	4
Shop	commercial	2
Shop/Dwelling	commercial	2
Storage/Warehouse	commercial	2
Surgery	commercial	2

APPENDIX C: EVACUATION TIMELINE METHODOLOGY

C1 OVERVIEW

The methodology utilised in this evacuation capability assessment has been based on the 'Evacuation Timeline' approach developed by the NSW State Emergency Services (SES) (Opper, 2004). This approach utilises timeline project management to determine the estimated timeframes of various elements during an evacuation procedure. The total available time for evacuation is marked along a timeline; the timeline commences when the storm commences and ends when evacuation is no longer possible due to road closures, or when everyone is safely evacuated. Between these times, a number of key evacuation processes must occur in sequence. Mapping these on a timeline can be used to highlight a number of important features of the process, including:

- What processes must be completed during evacuation; and
- How much time is available to safely complete evacuation.

An example timeline is shown in Figure C-1 and further description of the various elements and parameters is provided in Section C4. For further detail on the SES 'Evacuation Timeline' methodology, input parameters and applications, refer to Opper (2004).

C2 UNCERTAINTY

The ECA is based upon results from a flood model in conjunction with assumptions regarding flood prediction time, SES requirements and behavioural factors such as warning response time. Flood behaviour is based on hypothetical design floods; real flood combinations and durations can result in different flood behaviour to the model. Therefore, factors such as flood behaviour and community response can be extremely difficult to predict.

Nonetheless, ECAs form a vital part of the flood risk management process and should not be avoided due to uncertainties and the risk of error. There is always a degree of uncertainty in results relying on models and assumptions. Despite this uncertainty, the flood intelligence contained in this document is considered sufficient to identify constraints in the current evacuation capability, highlight the need for action and provide guidance on future evacuation decisions.

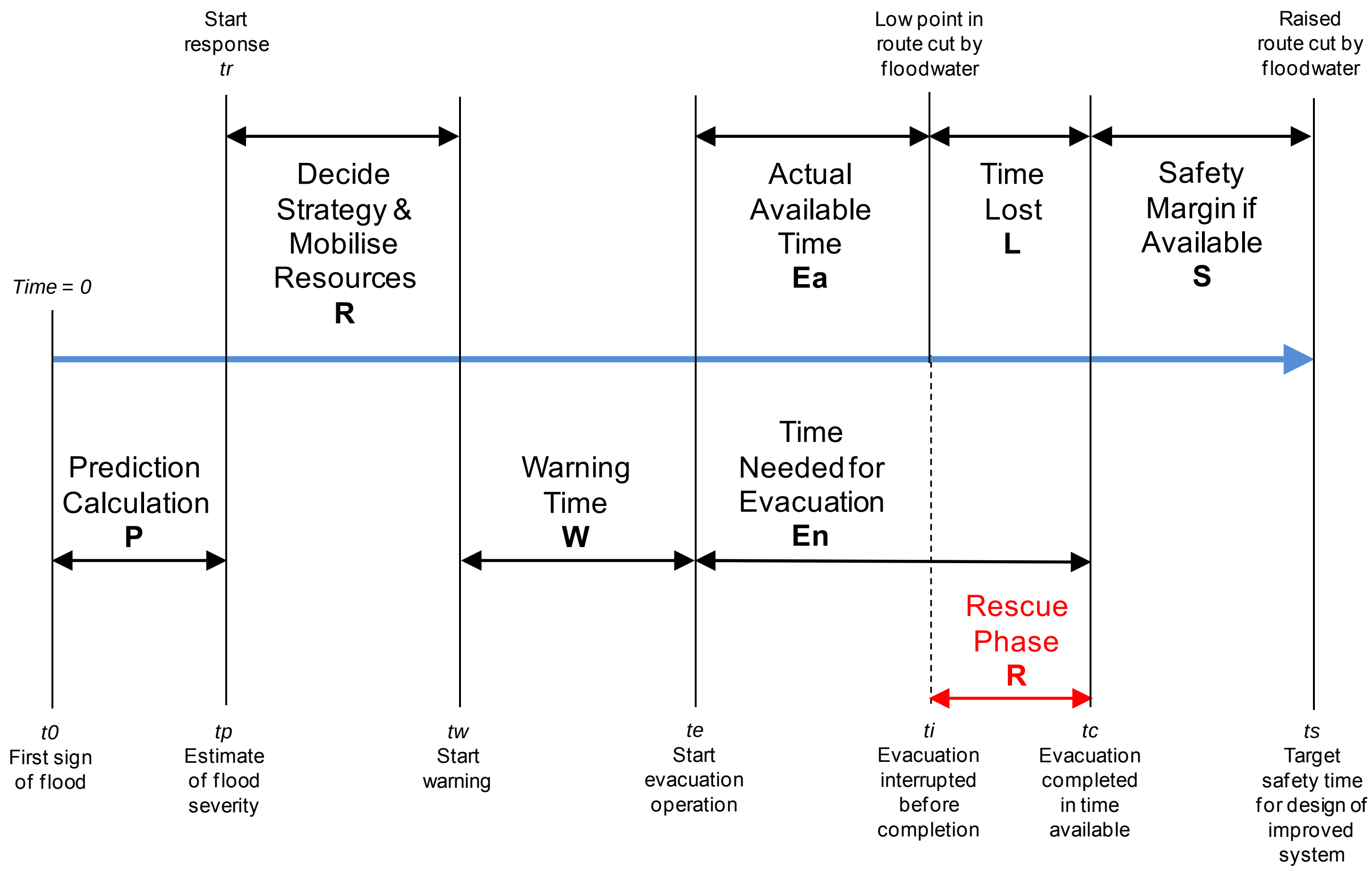


Figure C- 1 Time Line of Emergency Response for Flood Evacuation (Opper, 2004)

Note: S will be a negative value (Safety Margin <0) when ti occurs earlier than tc. S will be zero when all available time needed (En) is used. Only when ti occurs after tc does a Safety Margin begin to accrue. The magnitude of S has to be determined by reference to the capacity to cope with uncertainty and interruptions. The time elements are not drawn to scale in this diagram.

C3 KEY TIMELINE PARAMETERS

C3.1 Prediction

C3.1.1 Overview

Prediction time is one of the most significant parameters in the evacuation capability assessment. It is also one of the most uncertain, relying on a combination of quantitative data, such as stream gauge and pluviograph readings, and qualitative assessments such as lead-up storm behaviour. In addition, the following, conflicting objectives must be balanced:

- Late prediction may not allow sufficient time for safe evacuation of residents; and
- Early prediction may result in unnecessary evacuations. As well as the associated cost and inconvenience, residents may be less likely to heed evacuation advice in the future.

There are three sources of flooding considered in the study area, namely, local catchment, Richmond River and ocean storm flooding. Note that a variety of combinations of these flood sources can occur in a real flood event.

C3.1.2 Local Catchment Flooding

Local catchment flooding affects the rural regions of the study area along Emigrant, Maguire and North Creeks. Local storms in these areas produce the severest flood conditions and have a much faster response than Richmond River flooding and ocean storm surge flooding. Flash flooding conditions are known to occur.

Also, evacuation is difficult and dangerous during such flood events. Rainfall is more intense during short duration events and is likely to overwhelm local drainage systems. In addition, faster flowing water would make driving conditions extremely hazardous. Evacuation is therefore not advised during flash flooding events and it is preferred for residents to 'shelter in place'. Such advice would remain at the discretion of the SES, who would balance the relative risks of evacuation against isolation and inundation for a particular flood event.

In light of the rapid onset of this form of flooding and uncertain practicality of evacuation and prediction, a prediction time for this source of flooding cannot be adequately estimated.

C3.1.3 Richmond River Flooding

Storms originating in the upper Richmond River catchment tend to have a much longer critical duration than local catchment flooding. This longer duration, in conjunction with a long travel time for the peak flood wave to move down the catchment, allows flood prediction to be made prior to peak flood levels reaching Ballina.

Predictions are made based on river levels recorded at stream gauges higher up the catchment, such as Kyogle, Casino and Coraki. BoM have advised that the flood wave takes approximately 24 to 48 hours to travel from these upstream gauges to Ballina. Therefore, during a Richmond River flood event, a flood prediction can be issued for Ballina 24 hours after a trigger level is reached on the upstream gauges.

No formal trigger levels are currently used for flood warning on the Richmond River. For the purposes of this assessment, the trigger level has been designated as the peak level in a 50 year ARI event. This particular size event has been selected because during an event of this size, the banks of the Richmond River are significantly overtopped. The peak 50 year ARI design flow in Ballina is estimated to be 2,700 m^3/s. In the flood model, for a PMF event, this flow is reached 38.5 hours after the commencement of the storm. The corresponding flood prediction time is therefore at 14.5 hours into the design flood simulation, i.e. 24 hours earlier than when the trigger level is reached. See Figure C-2 for an illustration of this concept.

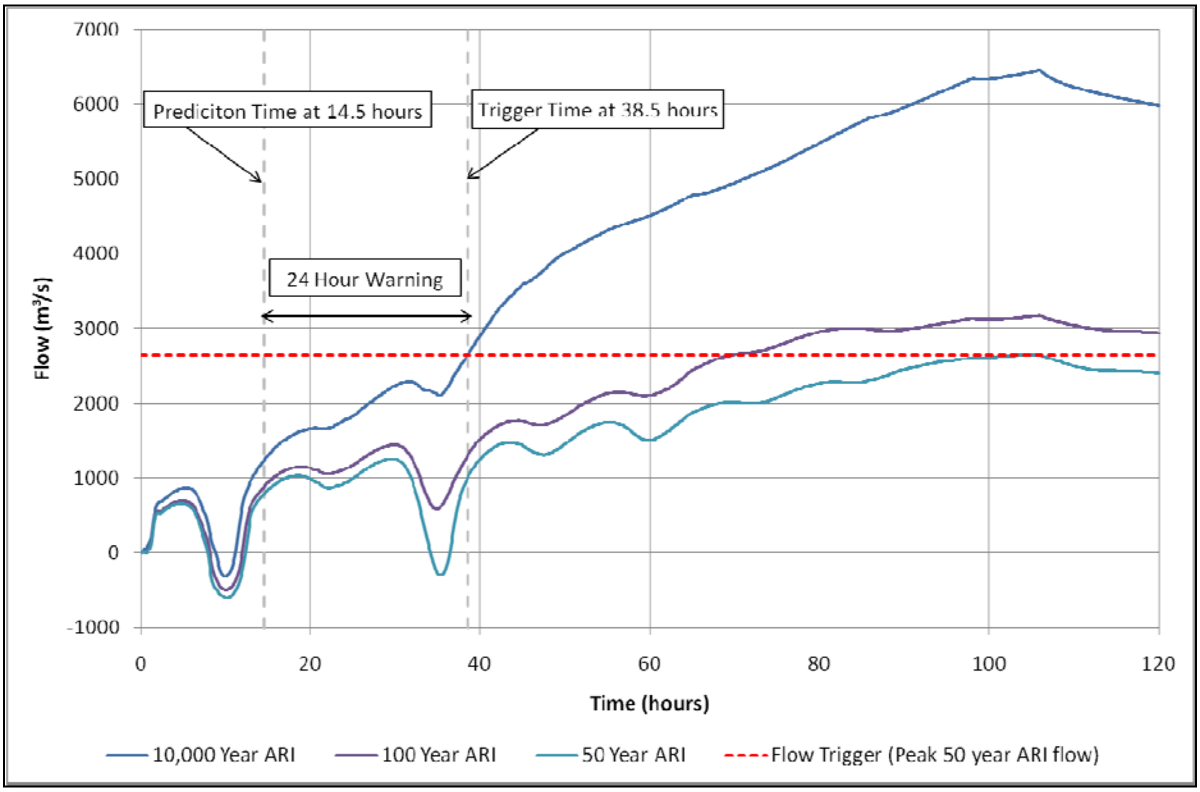


Figure C- 2 Richmond River Flood Prediction Time

C3.1.4 Ocean Storm Flooding

Ocean flooding has a faster response than Richmond River flooding. Flood warning occurs on the high tide preceding the peak surge tide, which is triggered by an anomaly in the measured tidal data compared to predicted tide levels. Therefore, storm surge predictions can be issued 12 hours in advance. Based on the relative timings adopted in the PMF flood model, this would occur 22 hours into the design flood simulation (see Figure C- 3).

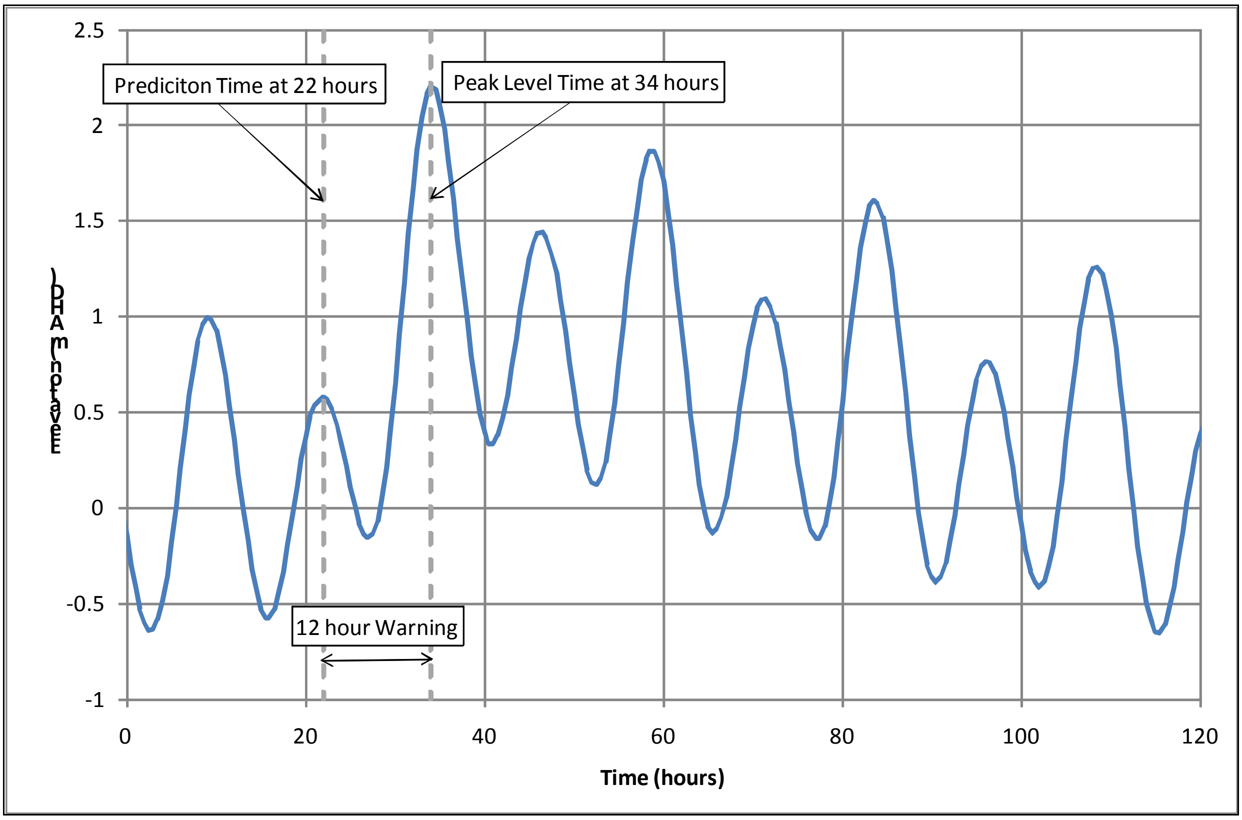


Figure C- 3 Ocean Storm Flooding Prediction Time

C3.1.5 Selected Prediction Time

The prediction time associated with storm surge flooding (i.e. at 22 hours into the design flood simulation) has been selected for use in the evacuation capability assessment for the following reasons:

- Local flooding occurs too quickly for meaningful prediction (and evacuation is not advisable);
- Storm surge flooding dominates part of Ballina Island, which is the most densely populated region of the study area; and
- The prediction time for storm surge flooding occurs after the prediction for Richmond River flooding and is, therefore, the more conservative of the two options.

C4.2 Resource Mobilisation

This is the period of time required by the SES prior to commencement of evacuation and encompasses such factors as data collection, decision and mobilisation of resources. Although this period is difficult to predict, the SES recommends a period of no less than six hours. This assessment has used a response time of six hours.

C4.3 Route Capacity

Route capacity is described by the number of available lanes and a fixed traffic flow rate. The traffic flow rate is derived from a rural design flow rate of 1200 vehicles / hour / lane, which is scaled down by a factor of two to account for adverse driving conditions, such as inclement weather. This assessment uses a traffic flow rate of 600 vehicles / hour / lane.

C4.6 Road Closures

Information regarding location and timing of route closure is captured using specific TUFLOW output. As this information is derived from design flood models, the times are indicative only and could be shorter in real flood events.

This output can be defined with multiple cut-off criteria to represent road closure for different users, such as pedestrians, standard vehicles and emergency vehicles. For the purposes of this assessment, the adopted road closure criterion was 300mm of water over the road surface.

'Evacuation interrupted' is the time of first road closure within a defined evacuation route system.

Note that road closures due to known stormwater and local drainage issues have not been used in the timeline assessment.

C4.7 Community Acceptance and Response Time

Community acceptance refers to the time lost due to initial reluctance to commence evacuation. The SES has found that most residents under-react to warnings and wait for clearer environmental cues before deciding to evacuate.

Response time is the time taken by residents to prepare and pack, following an evacuation warning.

This assessment includes a two hour delay in the commencement of evacuation to account for community acceptance and response time, as per SES recommendations.

C4.8 Doorknocking Rate

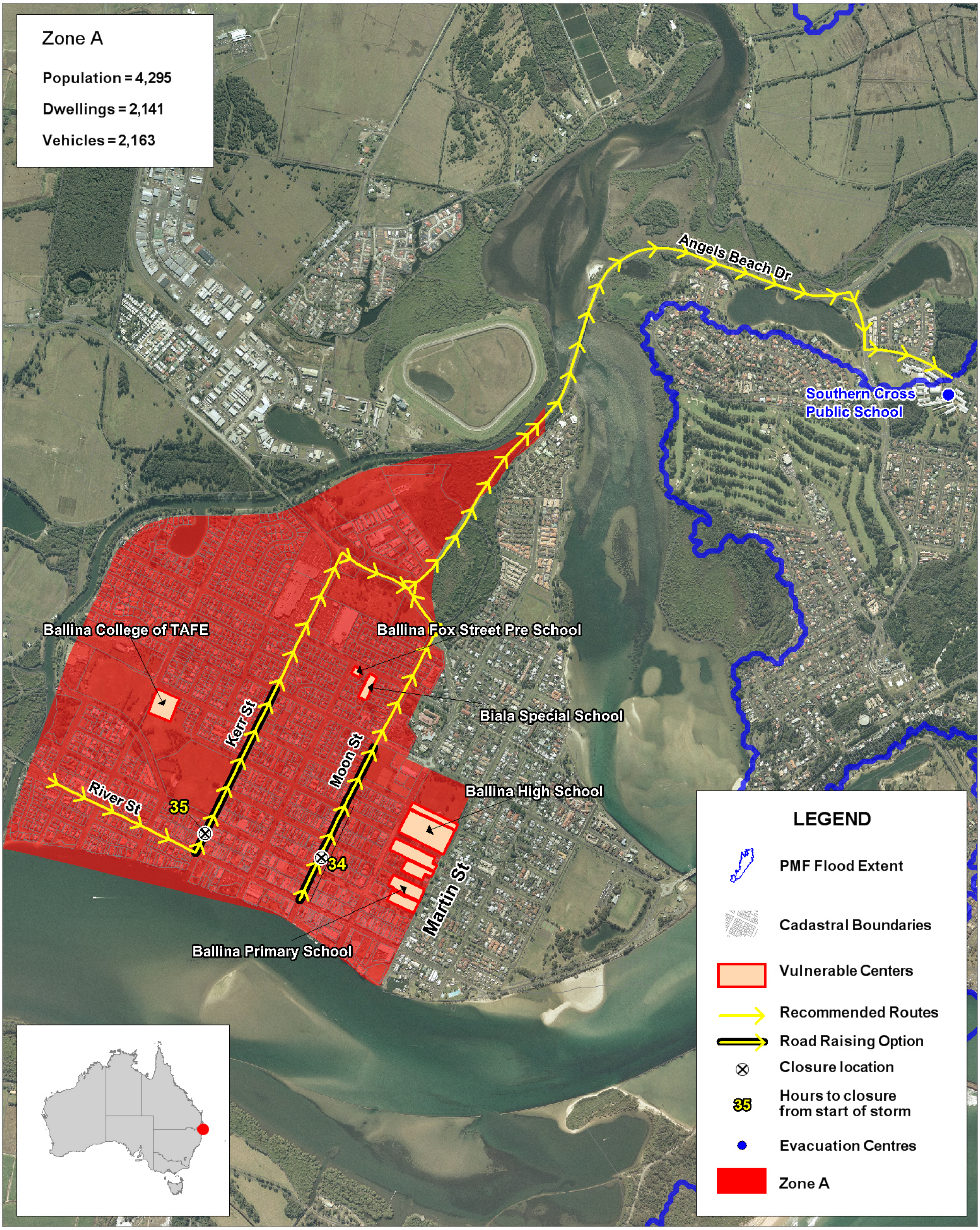
Doorknocking is considered the most conservative and reliable means of warning the community, although other means such as radio, TV, sirens and telephones can be used. The SES recommends that it takes each SES team of two people approximately five minutes to warn each house. This value has been adopted for this assessment (equivalent to 12 houses / team / hour).

C4.9 Traffic Safety Factor

A traffic safety factor, which delays the evacuation process, has been included to account for delays caused by traffic incidents or a tree / power line falling onto the evacuation route. The safety factor is dependent on the total vehicle movement time. This assessment adds one hour traffic safety factor for the first three hours of vehicle movement and an additional 30 minutes for each additional three hours of vehicle movement.

APPENDIX D: EVACUATION CAPABILITY FIGURES

LIST OF FIGURES



Title:

Ballina Floodplain Risk Management Study
Evacuation - Zone A

Figure: D-1

Rev: A

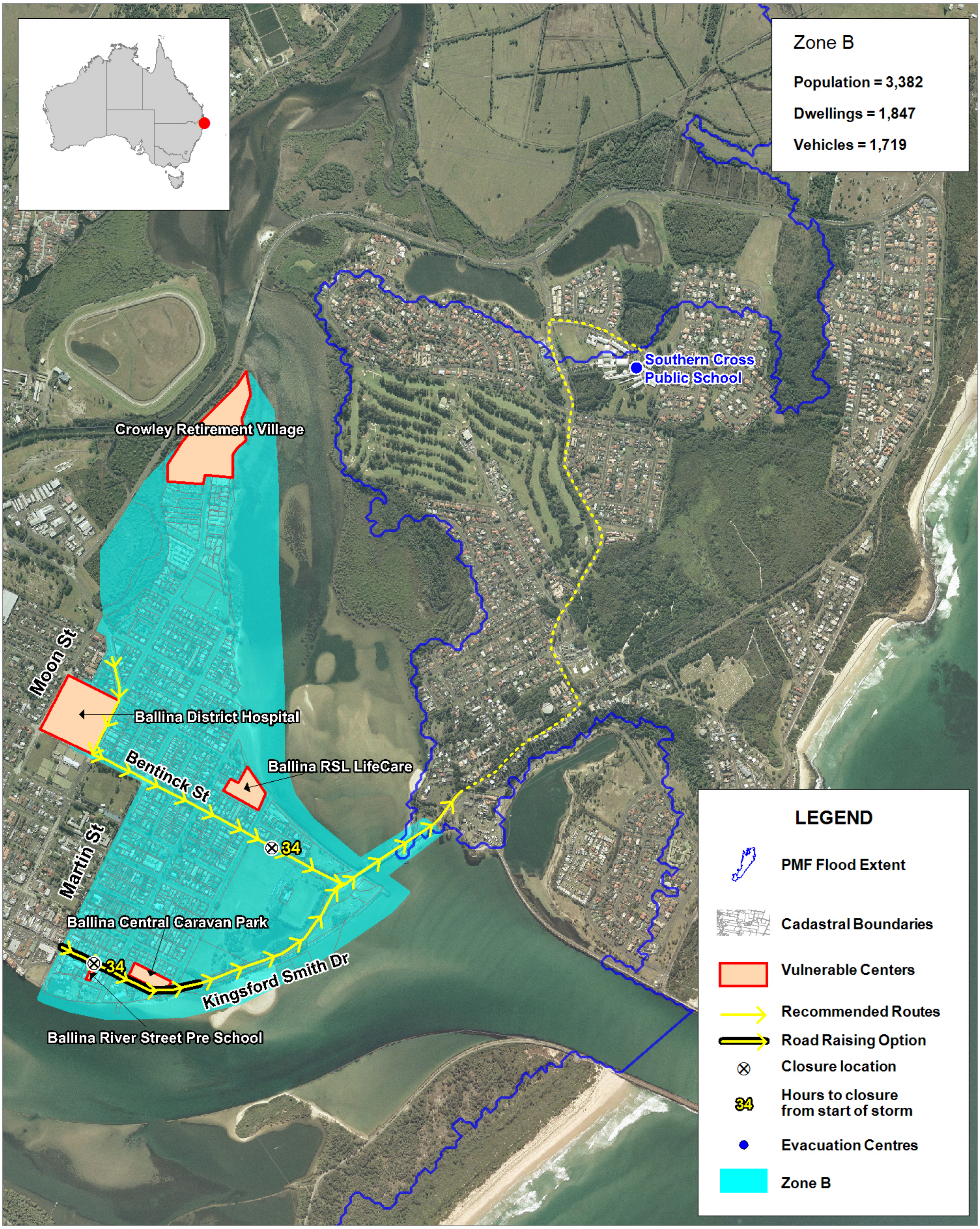
N

0 0.5 1km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_002_110927_Evacuation_Zone_A.WOR



Title:
Ballina Floodplain Risk Management Study
Evacuation - Zone B

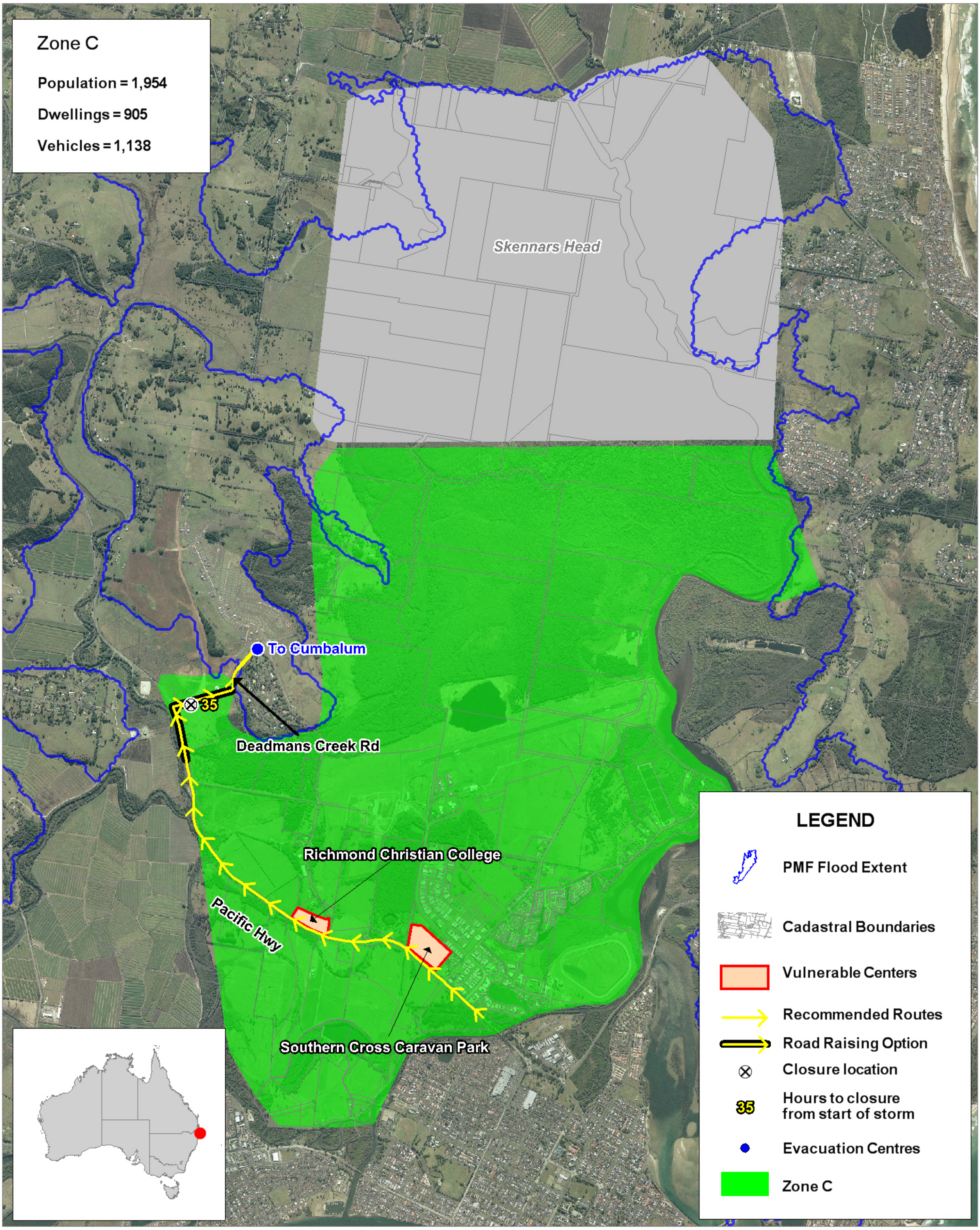
Figure: D-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_003_110927_Evacuation_Zone_B.WOR



Title:

Ballina Floodplain Risk Management Study
Evacuation - Zone C

Figure: D-3

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

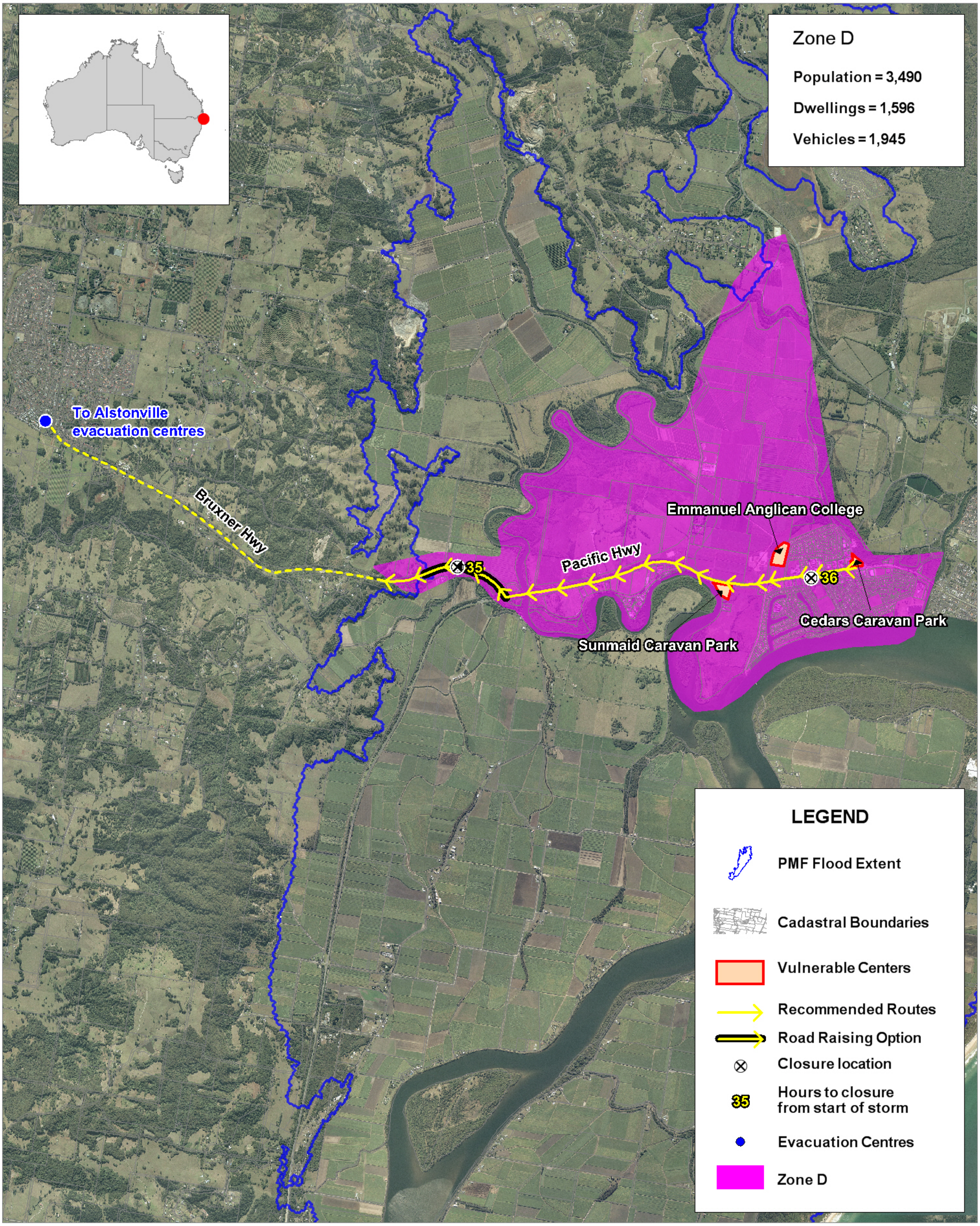
N

0 1 2km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_004_110927_Evacuation_Zone_C.WOR



Title:

Ballina Floodplain Risk Managment Study
Evacuation - Zone D

Figure: D-4

Rev: A

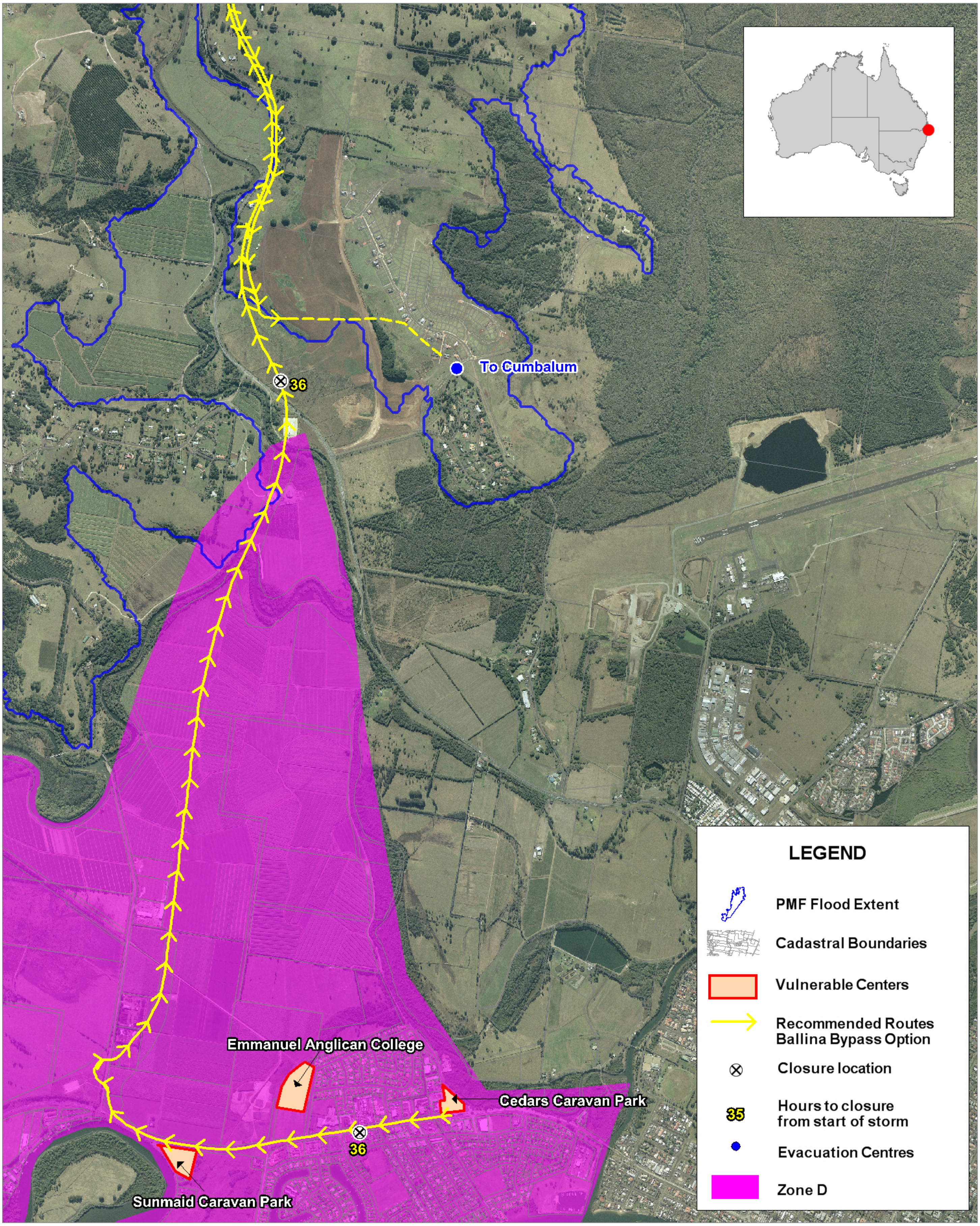
N

0 1 2km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_005_110927_Evacuation_Zone_D.WOR



Title:

Ballina Floodplain Risk Managment Study
Evacuation - Zone D Via Ballina Bypass

Figure: **D-5**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

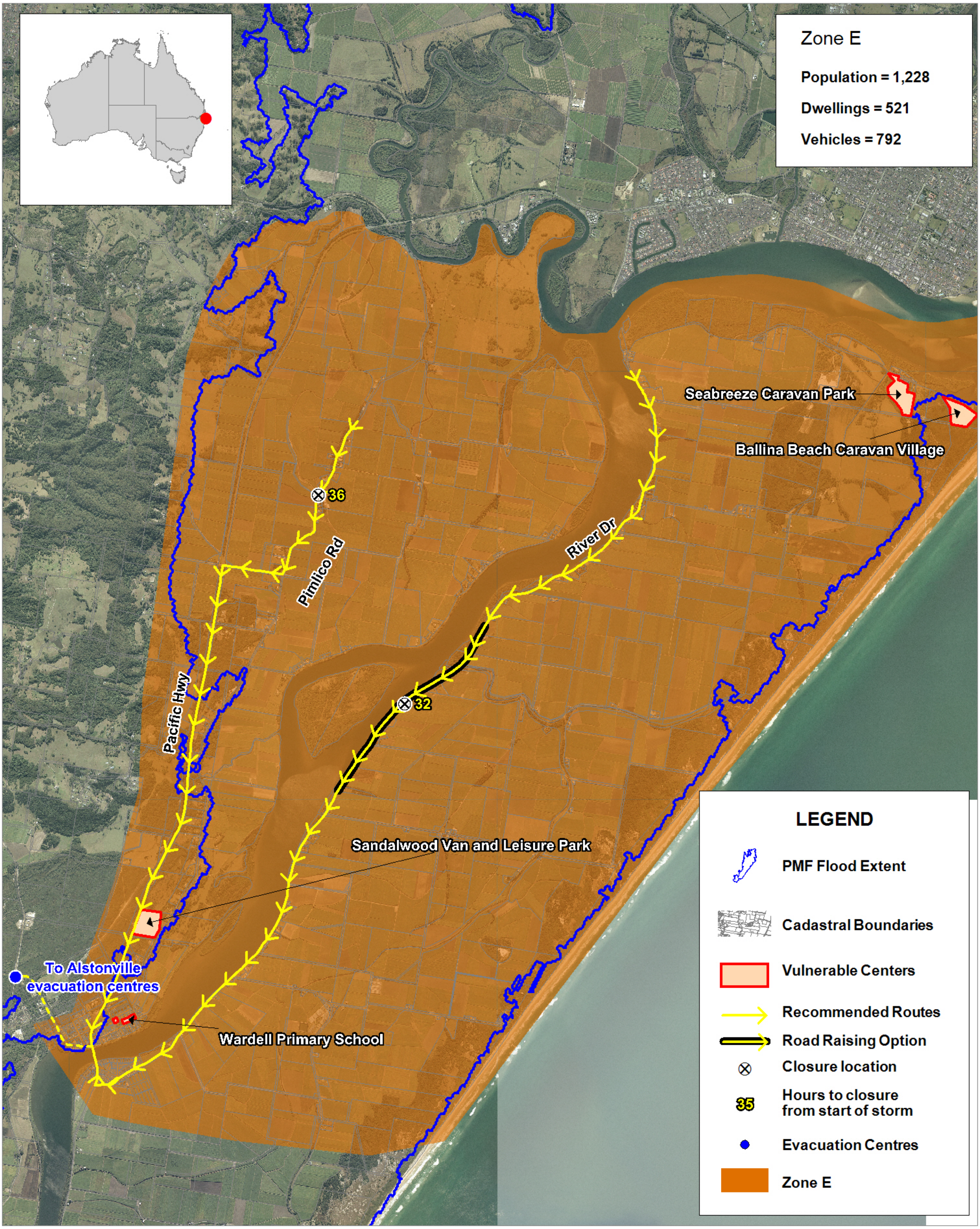
0 0.5 1km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_006_110927_Evacuation_Zone_D_inc_BB.WOR



Title:

Ballina Floodplain Risk Management Study
Evacuation - Zone E

Figure: **D-6**

Rev: **A**

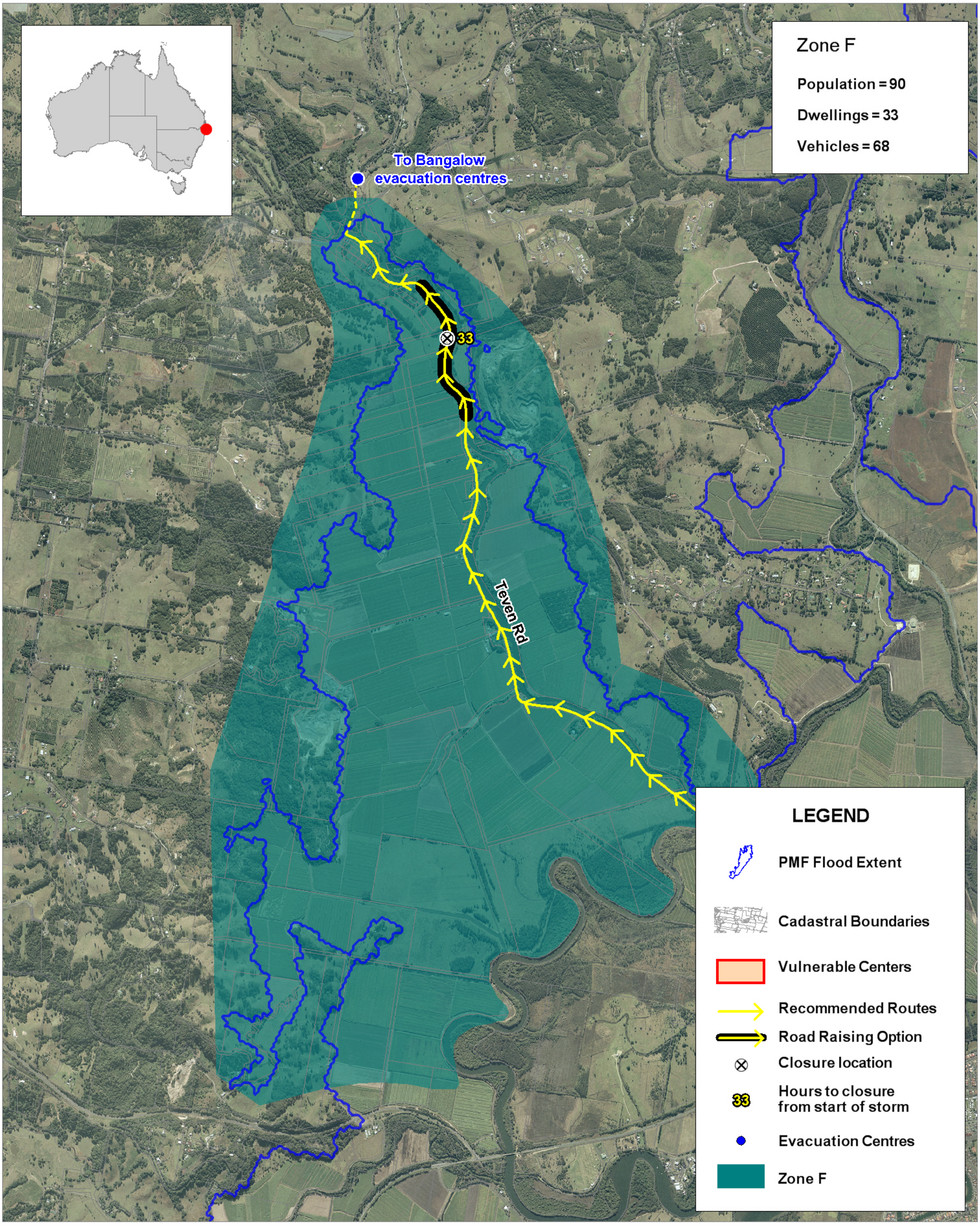
N

0 1.5 3km

Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_007_110927_Evacuation_Zone_E.WOR



Title:

Ballina Floodplain Risk Managment Study
Evacuation - Zone F

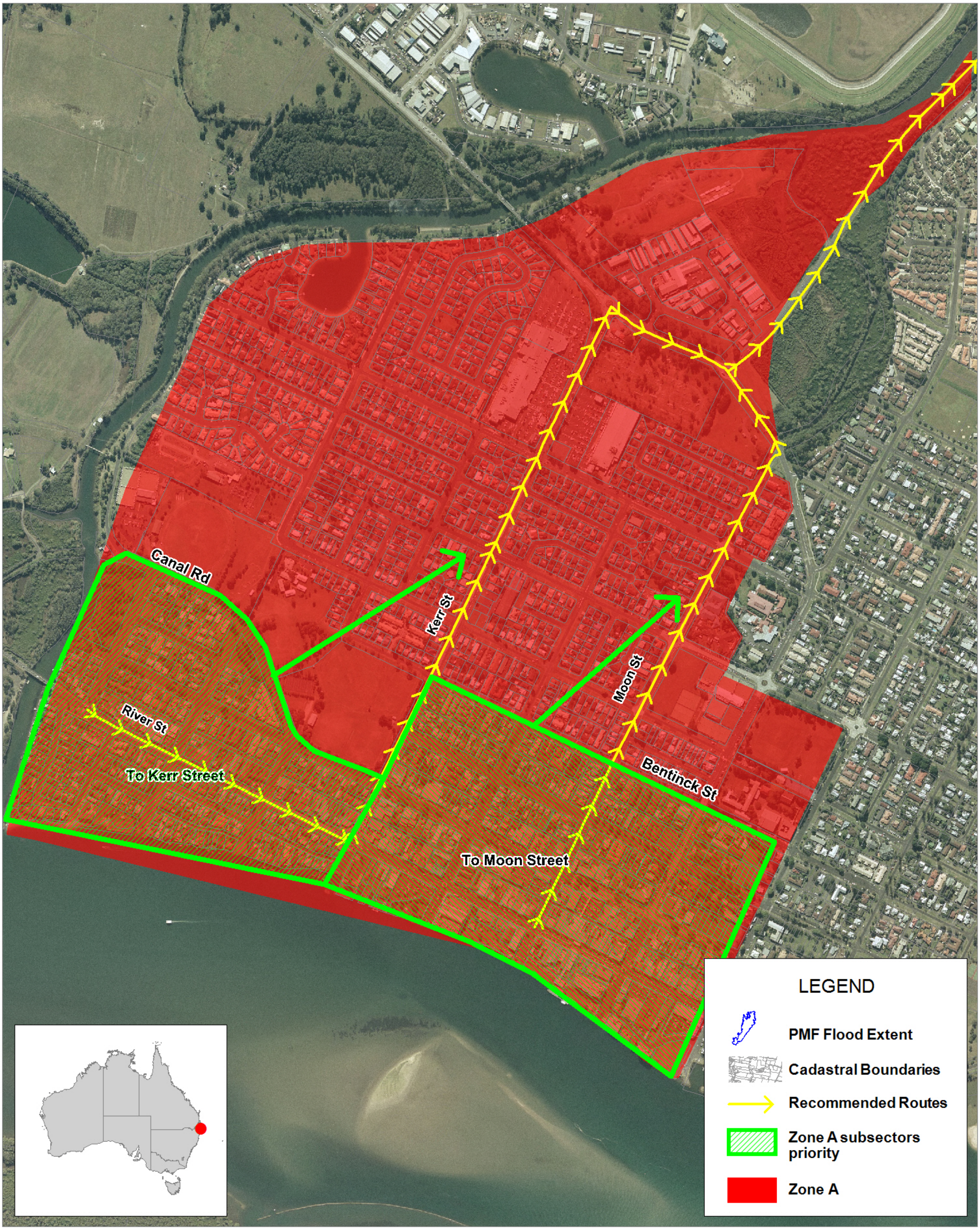
Figure: D-7

Rev: A

N 0 1 2km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_008_110927_Evacuation_Zone_F.WOR



Title:

Response Modification Option
Zone A Sequencing

Figure: **D-8**

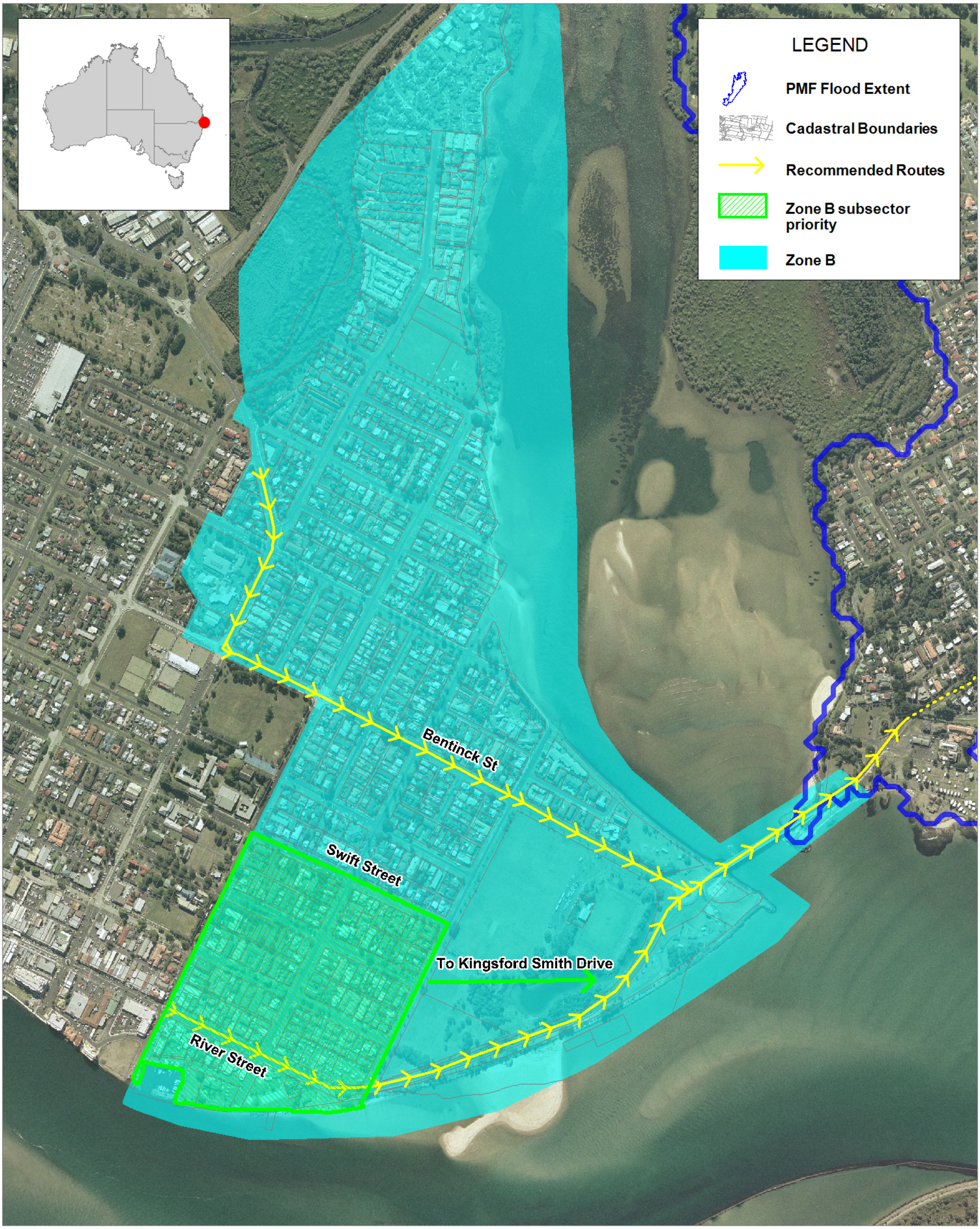
Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 250 500m Approx. scale

BMT WBM www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_011_110927_Sequencing_Zone_A.WOR



Title:

Response Modification Option
Zone B Sequencing

Figure: D-9

Rev: A

N

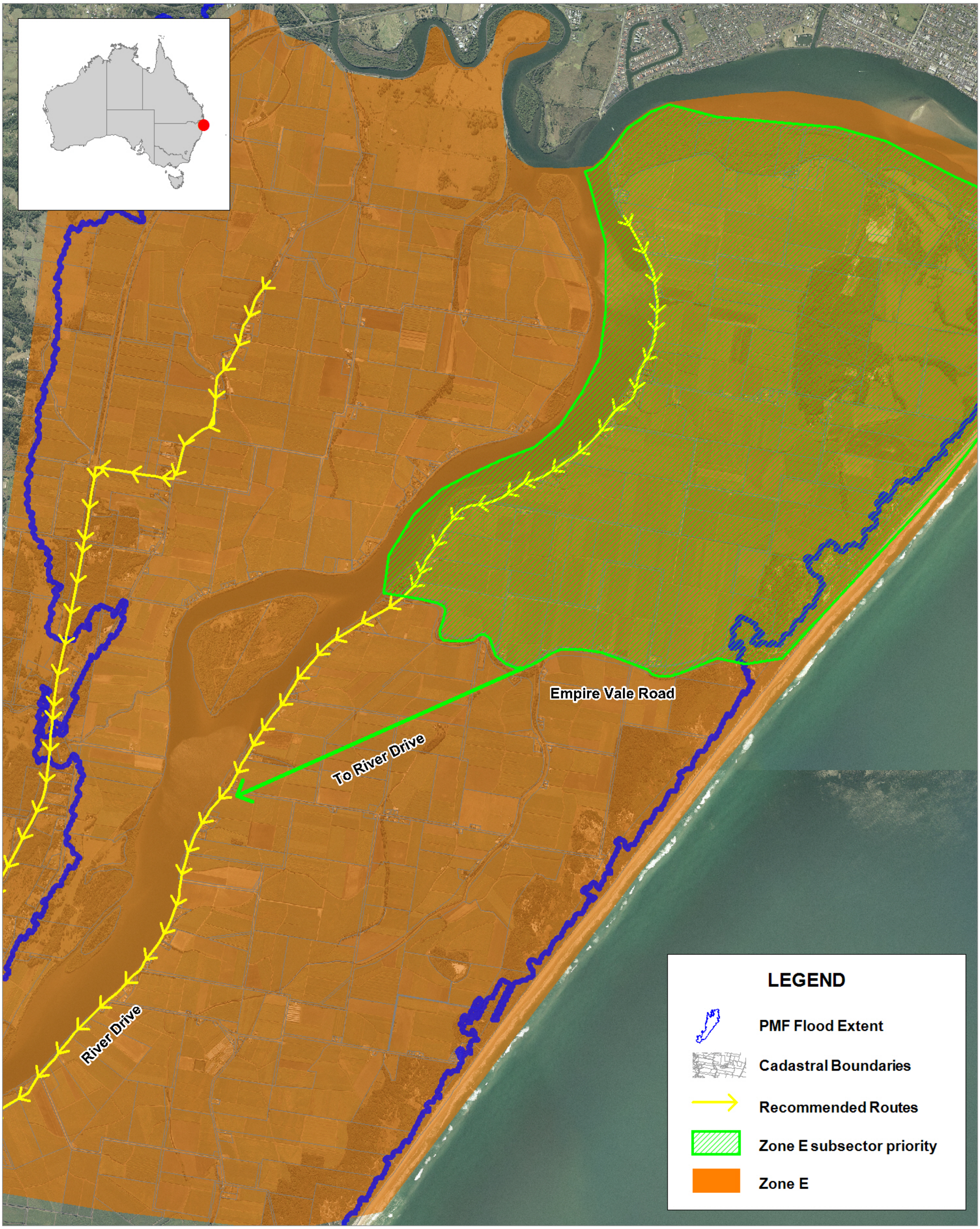
0 250 500m

Approx. scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_012_110927_Sequencing_Zone_B.WOR



Title:
Response Modification Option
Zone E Sequencing

Figure: **D-10**

Rev: **A**

N

0 1 2km

Approx. Scale

www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Appendix D\FLD_013_110927_Sequencing_Zone_E.WOR

APPENDIX E: FLOOD DAMAGES METHODOLOGY

E1 BACKGROUND

Flood damages are classified as tangible or intangible, reflecting the ability to assign monetary values. Intangible damages arise from adverse social and environmental effects caused by flooding, including factors such as loss of life and injury, stress and anxiety. Tangible damages are monetary losses directly attributable to flooding.

Tangible damages may be direct or indirect flood damages. Direct damages result from the actions of floodwaters, inundation and flow, on property and structures. Indirect damages arise from the disruptions to physical and economic activities caused by flooding. Examples include losses due to the disruption of business, expenses of alternative accommodation, disruption of public services, emergency relief aid and clean-up costs.

Direct damages are typically estimated separately for urban, rural and infrastructure damages. The assessment focussed on quantifying estimates of urban damages and rural damages, together with preliminary estimates of infrastructure damages. Urban damages are typically further separated into damage to residential and commercial / industrial properties, and internal, external and structural components.

A detailed breakdown of flood damage classifications is provided in Figure E-1.

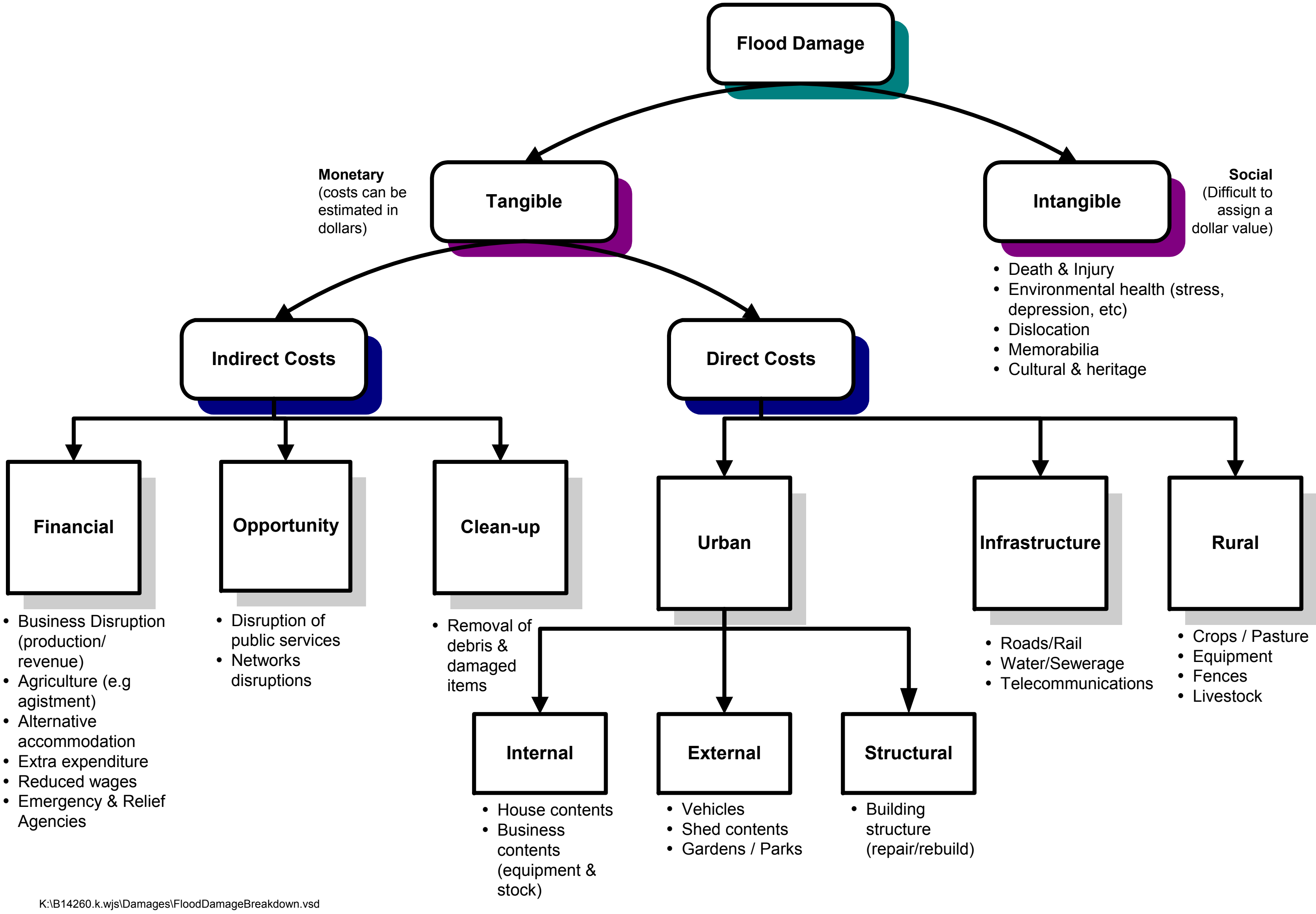


Figure E- 1 Flood Damages Classification

E2 INPUT DATA

E2.1 Overview

The assessment of flood damages required the following input data:

- Property data, as outlined in Appendix B;
- Design flood data including peak flood level, velocity and depth at the properties for a range of flood event magnitudes (used for the estimation of internal and structural damages);
- Ground level data at the properties (used for the estimation of external flood damages);
- Spatial coverage of sugar cane crops;
- Standardised methods for estimating tangible damages; and
- Other relevant information.

The source of the input data and relevant assumptions are discussed below.

E2.2 Sugar Cane

The primary crop grown in the study area is sugar cane. In order to estimate the flood damage associated with sugar cane, its spatial coverage in the study area had to be determined. Aerial photography has been used to manually digitise areas identified as being sugar cane fields.

E2.3 Flood Data

The flood model results have been used to derive peak flood levels at each property in the dataset for a range of design flood events, including the 5, 10, 20, 50, 100 and 500 year ARI[1], as well as the PMF[2].

Together with the floor levels, the flood levels have been used to estimate the depth of above-floor flooding at each property for internal damages. The flood model results have also been used to derive peak depth, velocity and depth-velocity product at each property for estimating structural damages. The methodology for deriving these damages is outlined in Section E3.

E3 TANGIBLE DAMAGES

E3.1 Overview

As discussed in Section E1, tangible damages are those for which a monetary value can be assigned. Direct damages are perhaps the most easily quantifiable damages, as they are those damages that are directly attributable to the floodwater, such as damage to house and business contents. Direct damages are typically estimated separately for urban, rural and infrastructure damages. Indirect damages, such as disruption of business and alternative

[1] *Average Recurrence Interval*
[2] *Probable Maximum Flood*

accommodation costs, tend to be more difficult to quantify and are often included as a proportion of direct damages. A summary of the adopted methodology for assessing tangible damages is provided in Table E-1 with more detail provided in the following sections.

Table E- 1 Tangible Damages – Summay of Methodology and Assumptions

<table>
<tr><td rowspan="9">T A N G I B L E</td><td rowspan="7">DIRECT ►</td><td rowspan="5">Urban►</td><td rowspan="2">Internal►</td><td>Commercial►</td><td>NRM Stage-Damage Curves</td></tr>
<tr><td>Residential►</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td rowspan="2">External►</td><td>Commercial►</td><td>Negligible</td></tr>
<tr><td>Residential►</td><td>DECCW Stage-Damage Curves</td></tr>
<tr><td>Structural►</td><td colspan="2">$20,000 per property based on high depth / velocity criteria</td></tr>
<tr><td>Infrastructure►</td><td colspan="3">15% of total direct damages (DECCW)</td></tr>
<tr><td>Rural ►</td><td colspan="3">15% reduction in sugar cane yield where flood depth is greater than 1.2m (BSES 2008)</td></tr>
<tr><td rowspan="2">INDIRECT►</td><td>Commercial►</td><td colspan="3">55% of Direct Damages (NRM)</td></tr>
<tr><td>Residential►</td><td colspan="3">DECCW Stage-Damage Curves</td></tr>
</table>

E3.2 Urban Damages

E3.2.1 Stage-Damage Curves

Stage-damage curves (or relationships) are typically used to estimate internal damage sustained by a particular property based on the depth of flooding. For example, if floodwaters inundate a house to a depth of 1 metre, a stage-damage curve is used to estimate the average damage (in $) that water 1 metre deep is likely to cause. Similarly, if floodwaters inundate a shop to a depth of 0.5 metre, a stage-damage curve is used to estimate the average damage that 0.5 metre of water in a shop is likely to cause. An example of how a stage-damage curve is used to estimate flood damage for a particular type of building is shown in Figure E-2.

Derivation of stage-damage curves can be a complex and time-consuming process, based on loss adjustor surveys of houses, businesses and contents to estimate the relationship between depth of flooding and damage. For the purposes of this study, two different approaches have been adopted for residential and commercial properties. These approaches are discussed further in the following sections.

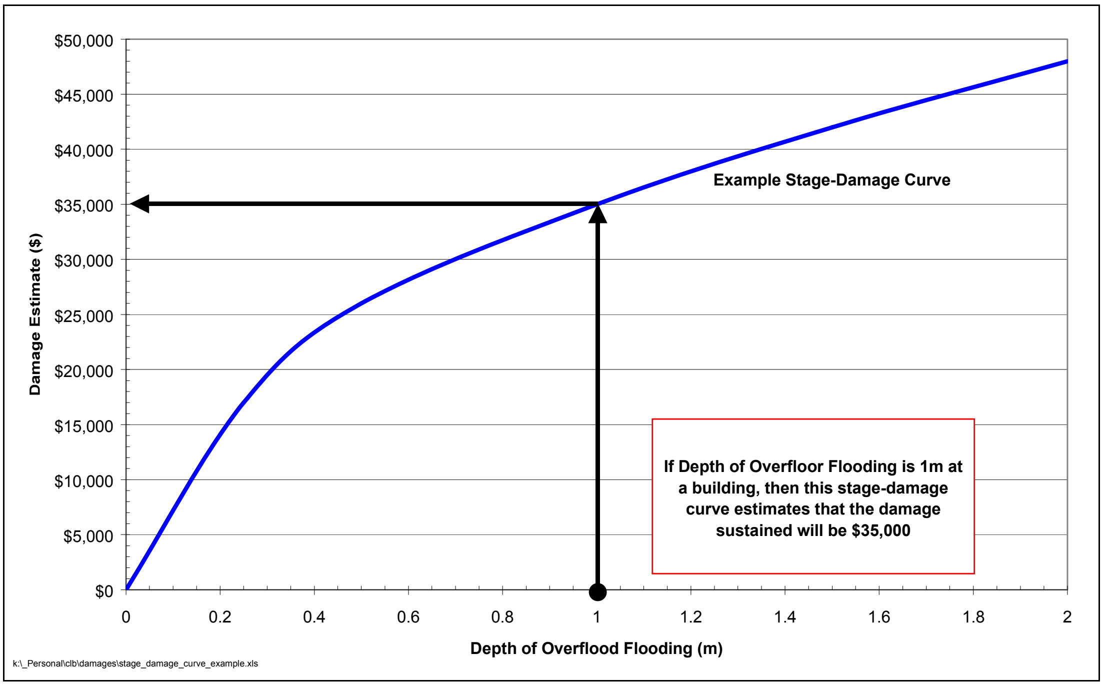


Figure E- 2 Example of Stage Damage Curve

E3.2.3 Residential Damages

For residential properties, the DECCW[3] methodology outlined in *Floodplain Risk Management Guideline: Residential Flood Damages* (DECCW, 2007b) has been adopted. This approach is based on stage-damage curves developed by Risk Frontiers for three different typical types of residential dwellings in the floodplain; low set, high set and double storey. The curves are based on a number of input parameters including typical house size, bench and storey heights, CPI, regional and scale cost factors, and awareness and warning times. The parameters adopted for this study are detailed in Table E-2. The three resultant residential stage-damage curves for low set, high set and double storey dwellings in the Ballina Shire are shown in Figure E-3.

It is noted that the DECCW methodology does not explicitly account for multi-unit dwellings. In lieu of any data specific to multiple unit damages, it has been agreed to directly factor estimated damages by the number of units per storey.

[3] *Now Office of Environment and Heritage*

Table E- 2 Input Parameters for DECC (2007) Residential Stage-Damage Curves

Input Parameters	Adopted	Explanation
Post 2001 $ Adjustment Factor	1.46	Calculated based on changes to average weekly earnings since late 2001 based on data collected from Australian Bureau of Statistics.
Regional Cost Variation Factor	1.07 (Rawlinsons, 2006)	Adjusting material cost to be specific to Tweed
Post Flood inflation Factor	1.4 (DIPNR, 2004)	Ranges from 1.0 to 1.5 (DIPNR, 2004)
Building Damage Repair Factor	1 hour	Typical reduction factor for long duration immersion (DECC 2007)
Typical House Size	300m^2	
Average content value	$75,000 (DIPNR, 2004)	Average content value, calculated based on average house size (DIPNR, 2004)
Flood level awareness	Low (DIPNR, 2004)	Flood level awareness, used to calculate the preparedness of the resident and opportunity to relocate possessions above flood waters (DIPNR, 2004)
Effective flood warning time	0 hours	
Contents Damage Limitation Factor	0.80 (DIPNR,2004)	Typical for a short to medium duration event (DIPNR, 2004)
Typical Bench Height	0.9m	Typical Bench Height used to calculate damages to property shifted to bench level instead of total relocation to higher ground

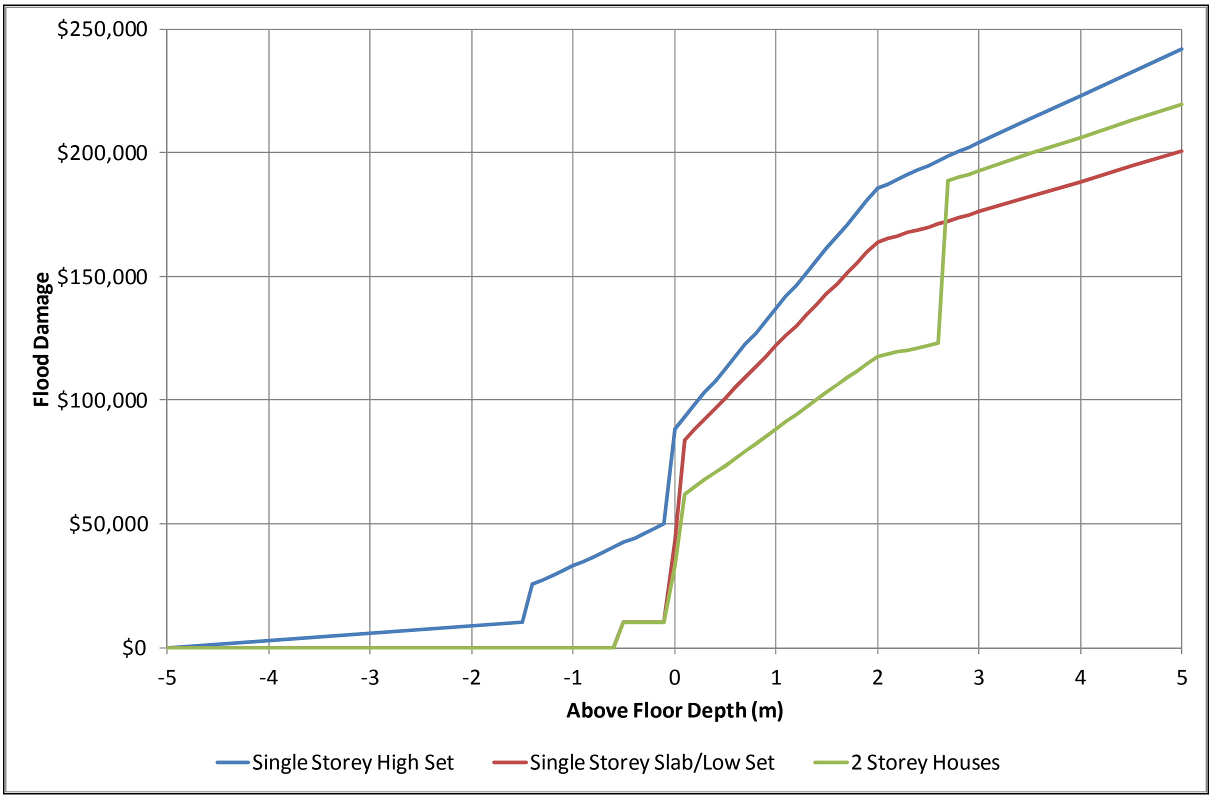


Figure E- 3 Ballina Shire Residential Stage Damage Curves

E3.2.4 Commercial Damages

The Office of Environment and Water does not presently have specific NSW guidance on commercial flood damages. The Queensland NRM[4] methodology has therefore been adopted, as outlined in *Guidance on the Assessment of Tangible Flood Damages* (2002) and based on stage-damage curves developed for ANUFLOOD[5]. This is consistent with approaches adopted for a number of other northern NSW assessments.

The NRM methodology comprises 15 different stage-damage curves based on a combination of building size and contents value categories:

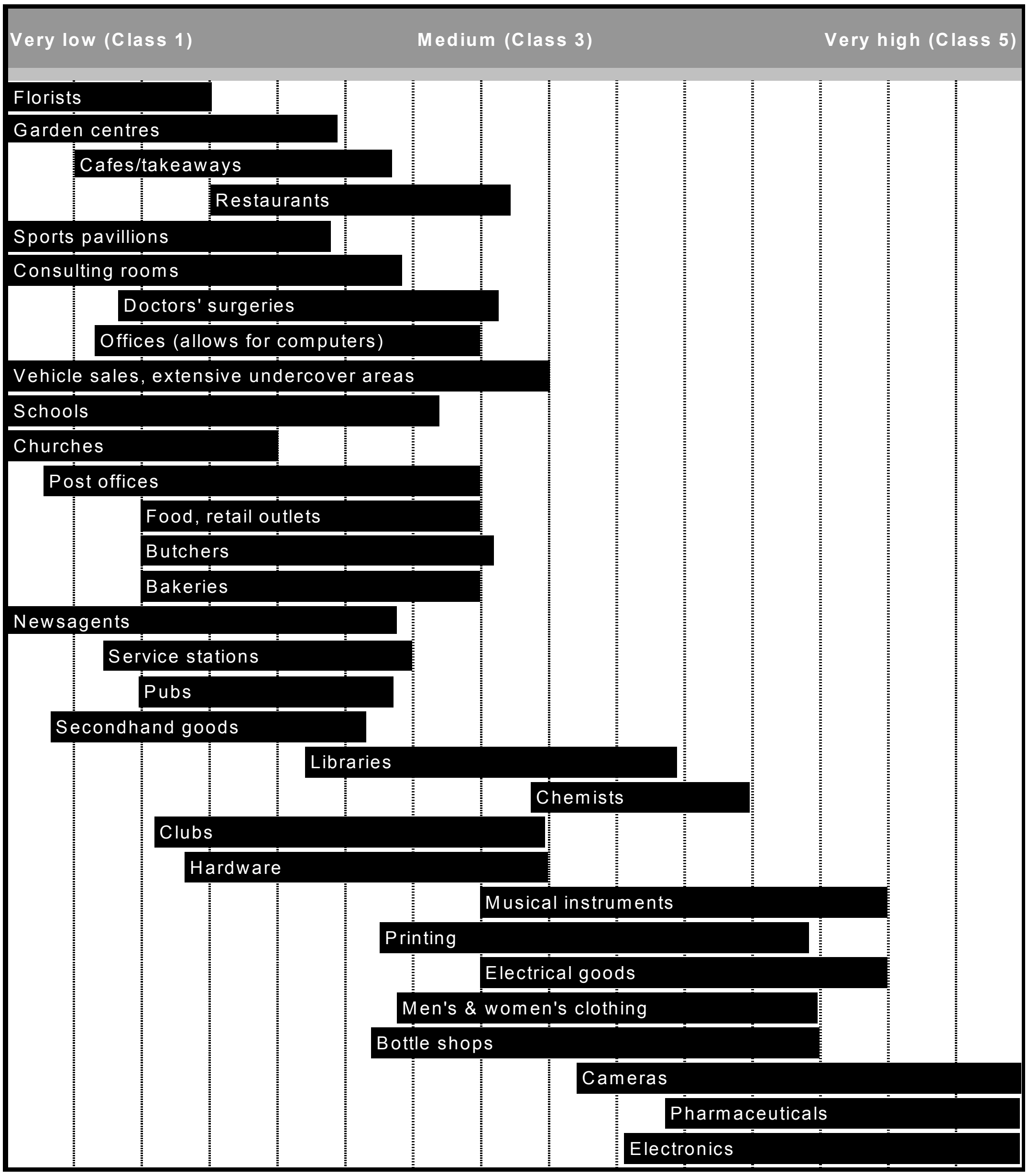
- 3 building size categories based on floor area:
  - Small < 186 m^2;
  - Medium 186 to 650 m^2; and
  - Large > 650 m^2.
- 5 contents value categories based on the nature of the business, from class 1 (low) to class 5 (high).

Examples of the contents value categories are presented in Figure E-4. The curves for small and medium buildings provide typical damage estimates per property, however the curves for large buildings provide damage estimates per unit floor area (i.e. per m^2).

---

[4] *Department of Natural Resources and Mines*

[5] *Computer model developed by Australian National University to assess flood damages to urban buildings.*



Source: CRES (1992)

Figure E- 4 Value Categories for NRM (2002) Commercial Stage-Damage Curves

The commercial stage-damage curves have been updated using CPI to present day values. Figure E-5 shows the lower and upper range of curves for each of the 3 building size categories (small, medium and large) based on the low (class 1) and high (class 5) contents value curves respectively.

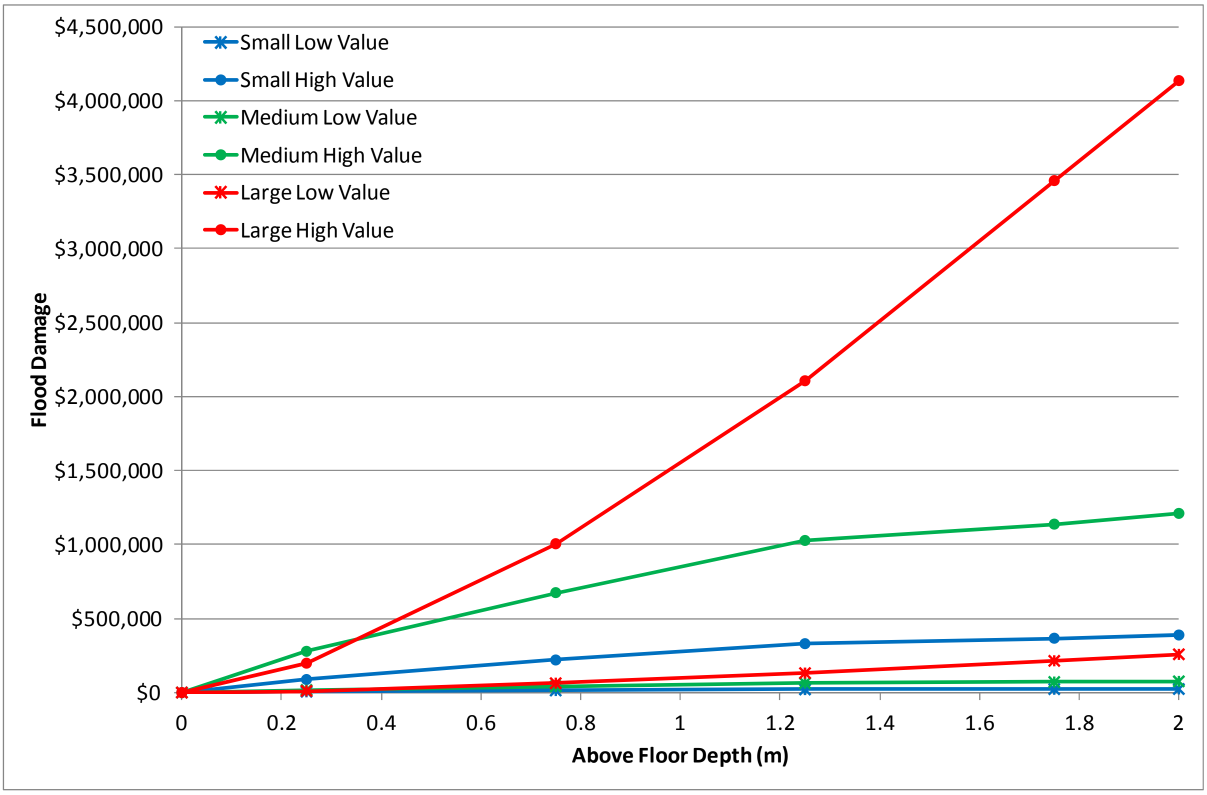


Figure E- 5 Ballina Shire Commercial Stage-Damage Curves

Note: Large commercial property flood damages are based on the property area. An area of 650m² has been used in the figure above.

E3.2.5 Actual versus Potential Damage

Potential damage is the maximum damage that would occur if there was no action taken by residents to protect their possessions from floodwaters. As residents usually do take some action in times of flood, actual damages are typically less than potential damages. The amount by which actual damages are less than potential is a function of warning time, flood preparedness and depth of flooding. For example, with no warning time a resident would be unable to move many belongings to a higher area but the number of belongings moved to a safe position would increase with the increase in warning time. Alternatively, a resident may be unprepared for flooding. They may not expect to be affected by a flood and so may not move any belongings regardless of warning time as they do not realise that they are threatened.

The DECCW residential stage-damage curves are actual damage estimates, taking warning time into account. The NRM commercial stage-damage curves are potential damage estimates. For this initial assessment however, it has been assumed that businesses will be unprepared for flood events, and that actual commercial damages will be similar to potential estimates.

E3.2.6 External Damages

The DECCW residential stage-damage curves include for external damages to items such as mowers, gardens, tools and shed contents. Based on the adopted methodology, this has been estimated at approximately $9,200 per inundated residential property in the study area.

Vehicles are typically not included in damage assessments, despite being classed as a valid external damage, as these are often moved to higher ground during a flood, and to ensure vehicle damage does not drive justification for mitigation works.

External damages to commercial and industrial property have been assumed to be negligible, with the majority of property damage typically expected to be attributable to the contents of the building.

E3.2.7 Structural Damages

Structural damage can include water damage to the fabric of the building, water damage to wiring, gas piping, g√ates and fences. Internal structural damage (such as built-in cupboards, internal walls, and wiring) is estimated as part of the internal damages (Sections 5.5.2 and 5.5.3) however structural failure of a building needs to be assessed separately.

Structural failures can begin at a range of flood depth-velocity combinations. Even at shallow depths, velocities greater than 2 m/s can lead to scour of foundations. Conversely, at low velocities with depths greater than 2 metres, damage to light-framed buildings from water pressure, flotation and debris loads can occur. Typically, such damage is considered likely to occur when the velocity-depth product is greater than 1 m^2/s (DIPNR, 2005; NRM, 2002).

Based on these criteria, structural failure of buildings has been assumed for properties experiencing any of the following flood conditions:

- Velocity-depth product > 1 m^2/s; or
- Depth (above floor) > 2 metres; or
- Velocity > 2 m/s.

Note that 'structural failure' may not necessarily mean complete destruction of a building. Structural damages have been nominally based on $20,000 per property in line with some other northern NSW assessments (Walcha Floodplain Risk Management Study, 2009).

E3.4 Infrastructure Damages

It is often difficult to estimate infrastructure damages due to flooding, as it usually requires input from several agencies, which may or may not know the value of their asset nor the damage that it is likely to sustain in a flood. To overcome this difficulty, DECCW recommends that infrastructure damages be estimated as being 15% of direct damages (pers. comm. Duncan McLuckie, January 2005). This recommendation has been adopted for the Ballina study area. Typical infrastructure damaged during a flood event includes (non-exhaustive list) schools, hospitals, bridges, railway, energy and telecommunication networks, sewers, wastewater treatment plants.

E3.5 Rural Damages

The estimation of rural damages has been restricted to sugar cane, due to the dominance of this crop in the rural areas of the Ballina floodplain. Although other rural land uses are likely to be flood affected, their damages are difficult to estimate and are considered to be relatively small compared to the more extensive sugarcane plantations. Therefore other rural land uses have been omitted from this study. As such, rural damage estimates are likely to be underestimated in areas of other rural land uses.

The methodology used to estimate sugar cane damages is the same as that used by BMT WBM on the Johnstone River Flood Study (2003), which was largely derived from Kingston et al (1999).

Sugar cane crops in the floodplain have been mapped, with flood damages estimated using the following assumptions:

- Flooding typically occurs when stalks are relatively mature with an average height of over 1.2m;
- 84 Ha of sugar can is harvested from an average sized 110 Ha plot of sugar cane (CANEGROWERS 2008). This equates to approximately 27% of land remaining fallow at any time.
- An average yield in the northern NSW area is 131 tonnes per hectare (Hooper 2008);
- Yield loss is between 15 and 20% after 5 days submergence, with the least loss for mature cane (BSES 2008). A 15% reduction in yield has been assumed for this study; and
- According to the Australian Sugarcane Annual (2009), the average return to Australian growers for cane in 2009–10 is forecast to be $43.40 a tonne, compared with $30.78 a tonne in 2008–09 and $26.39 a tonne in 2007–08. An average price for cane of $43/tonne has been assumed.

E3.6 Indirect Damages

The DECCW residential stage-damage curves include for indirect damages such as clean-up costs and alternative accommodation. Based on the adopted methodology, this has been estimated at approximately $6,400 per inundated residential property in the study area.

Indirect damages for commercial properties can be much more substantial as they include loss of production / revenue, extra expenditure, disruption of public services, network disruptions, and clean-up costs. While it is difficult to place a value on these losses, the NRM methodology recommends an estimate of 55% of direct commercial damages, which has been adopted for this study.

E4 INTANGIBLE DAMAGES

Intangible damages incorporate direct and indirect impacts for which there is no commonly agreed method of evaluation (EMA, 2002). Intangibles compose of things without market value i.e. cannot be brought or sold, which makes their dollar value difficult to calculate. Most methods are experimental or not generally accepted (EMA 2002).

There are a number of intangible costs to the community including:

- Loss of life and injury;
- Inconvenience;
- Isolation/evacuation;
- Stress and anxiety;
- Disruption; and
- Health issues.

Some of the above are discussed further below.

E4.1 Health Issues

Health issues related to flooding can include stress and psychological problems and physical health problems. In VDNRE (2000), "*The anxiety and stress which residents experience as a result of a flood probably depend both upon the characteristics of the resident and the nature of the event*". For example, a resident with prior experience to flooding is usually better able to cope with the stress induced by floods (BTRE, 2001). Flooding can induce stress through mechanisms such as loss of personal possessions, injury to individuals and others, fear of future flooding, inconvenience (eg. disruption to daily routines), isolation and evacuation.

Physical health issues resulting from flooding include over-exertion through relocating personal belongings eg. furniture, contact with contaminated water, and injury directly related to the flooding (VDNRE, 2000).

Health issues are difficult to assign monetary values to as every individual reacts differently to the one event. Self-reporting surveys have been used for a range of studies to determine the impacts of flooding on a community's health. While self-reporting has obvious implications (all individuals perceive their losses differently), several studies have suggested this method to be reliable (BTRE, 2001).

E4.2 Loss of Life and Injury

There is always a possibility of loss of life and injury during a flood event. Considerable research has been conducted on the value of human life. There has been, however, no commonly agreed method for valuing the loss of a life (VDNRE, 2000). Economic methods have been developed including the 'human capital approach', which uses the lifetime earnings of the individual concerned as the value of their life and the 'willingness to pay approach', which considers the value of an individuals life to be the price they are willing to pay to achieve a reduced risk of death. Both of these methods result in a broad spectrum of values for different individuals and cause a moral dilemma with different individuals being valued higher than others (VDNRE, 2000).

A method developed by the NRE as part of the Rapid Appraisal Method (RAM) is the Average Annual Population Affected (AAPA). The AAPA is calculated using the same process as the

AAD, determining the population affected for a range of flood events and calculating the area under the curve to provide the AADA. The AADA should be used in conjunction with, and as a supplement to, the benefit-cost analysis (VDNRE, 2000). VDNRE, 2000 discusses the AAPA, "*…the assumption that the impact of flooding on human temperament, health and mortality is directly proportional to the size of the resident population is a very crude one. Nevertheless, it is a readily available measure that is likely to capture rapidly the scale effects involved for most forms of management measures. The concept of AAPA, however, does not provide a good measure of the change of health, safety and personal impacts in the case of changes in warning times."*

It was recognised from the outset that evacuation capability would be a significant issue facing this study. The Ballina floodplain has a large number of people that could require evacuation, as well as a large number of relatively new residents that are unfamiliar with local flood behaviour. This aspect of the floodplain risk management process has been investigated by assessing the evacuation capability.

E4.3 Environment

Environmental losses tend to be perceived as minor costs in natural disasters such as flooding (BTRE, 2000). Impacts caused by flooding to the environment can be interpreted as natural processes for which the environment has built in mechanisms to cope with. As flooding is a natural phenomenon the reduction of flooding produced by mitigation measures should be considered as losses. These include benefits to floodplains from enhanced fertility and ground water recharge, maintenance of wetland communities and floodplain vegetation, movement of species between stream and floodplain and provision of conditions for important lifecycle stages (VDNRE, 2000). The NSW EPA has produced a database collating environmental valuation studies. This online database called ENVALUE provides a range of studies and the method used to determine indirect costs. The methods suggested include the 'Travel Cost Method' and 'Contingent Evaluation'. The Travel Cost method assumes the costs that people are willing to incur in travelling to an area represents a minimum of what they would be willing to pay for the recreational experience. Contingent Evaluation uses surveys to find out what people are willing to pay for a specified improvement in the provision of a good, which has no market price. These, along with most methods of assessing indirect costs are highly variable, controversial and are yet to achieve widespread acceptance through the economic community (EMA, 2000).

E4.4 Summary

Intangible damages are inherently difficult to measure in monetary terms. The greatest difficulty faced by those calculating indirect damages is finding uniformity in the value assigned to various intangibles including loss of life, loss of possession and illness. This is made difficult as different individuals react differently and perceive their losses in different ways (eg. some individuals may value their gardens more than their memorabilia.

The Bureau of Transport and Regional Economics (BTRE, 2001) states, "*Estimating costs for intangibles when a method of estimation is not well developed, or the data are unreliable, may lead to results that are no better than guesses. Estimates of intangible costs are best limited to those costs for which the data and method are both capable of producing defensible results.*

Unfortunately there will still remain a large body of cost for which estimation is not feasible".

For the valuation of stress, stress related illness, and mortality, the AAPA approach allows impacts on the population to be incorporated into the damages assessment without requiring a monetary value to be assigned. This method is non discriminatory as the levels of population that could be affected in a location is weighted against the probabilities of that location being inundated. This method can prove useful in damage assessments by providing an indication of the population benefiting from flood mitigation methods.

Due to these limitations, intangible damages have not been determined.

E5 UNCERTAINTY

The certainty of the flood data depends on the flood model characteristics and resolution. The most recent, integrated flood model results have been used in the flood damage assessment, thereby maximising the degree of certainty that can be achieved with current hydraulic modelling practice.

It is acknowledged that, as a result of the approach to estimation of property parameters, the property dataset adopted for this study has an inherent degree of uncertainty. Floor level data are considered appropriate as these have been primarily surveyed.

While the methodologies used to estimate flood damages are well established (as laid out by DECCW[3] and Department of Natural Resources and Mines), it is recognised that the urban flood damages estimation methodology is an uncertain process. The purpose of the assessment is not to derive highly accurate flood damage estimations, but to develop a general understanding of flood damage in the study area and to assist with appraising flood mitigation options. As such, the input data and urban flood damage estimation methodology are considered appropriate for the purposes of this study.

For rural damages the location and spatial extent of sugar cane has been determined by observation of aerial imagery. This process carries an innate uncertainty in the observer's interpretation of the imagery. However sugar cane stands can be clearly distinguished in the aerial photographs, and is overwhelmingly the main crop grown in the floodplain. Therefore substantial errors are unlikely and the main cause of uncertainty will be from the methodology used to estimate the reduction in yield. It should be noted that sugar cane prices are affected by market volatility, and depending on the extent of forward hedging and foreign exchange activity, the final selling price for sugar cane could be significantly different from that used in this assessment. As mentioned above, the focus of this assessment is not on absolute damages, but on relative damages. The methodology is therefore considered appropriate for the objectives of this study.

APPENDIX F: DEVELOPING THE FLOOD RISK PRECINCTS

F1 INTRODUCTION

The draft DCP defines development controls according to four different Flood Risk Precincts (FRPs).This Appendix describes the methodology that has been used to delineate the study area into different FRPs.

F2 EXTREME FLOOD RISK PRECINCT

The extreme FRP layer has been developed by first looking at high flood hazard areas; where flood hazard is defined by the product of flood depth and flow velocity (VD). The 100 year ARI 2100 flood event results have been used to identify the high hazard areas. As a starting point, VD values of greater than $0.4m^2/s$ (critical value for pedestrian safety according to the *Queensland Urban Drainage Manual*) have been classified as high FRPs. The results generated disconnected patches of extreme FRP areas, and therefore required some manipulation to ensure that the extreme FRP layer was contiguous. VD values of $0.3m^2/s$ have been mapped out as a guide for connecting patches of extreme FRP. In many places patches of extreme FRP have also been connected by inspection of the DEM and following paths of low lying land.

Areas in the floodplain that are critical for interconnection of flood storage areas have also been marked out and included in the extreme FRP layer. This has been done by inspection of the DEM, aerial photography and flood extent maps.

F3 HIGH FLOOD RISK PRECINCT

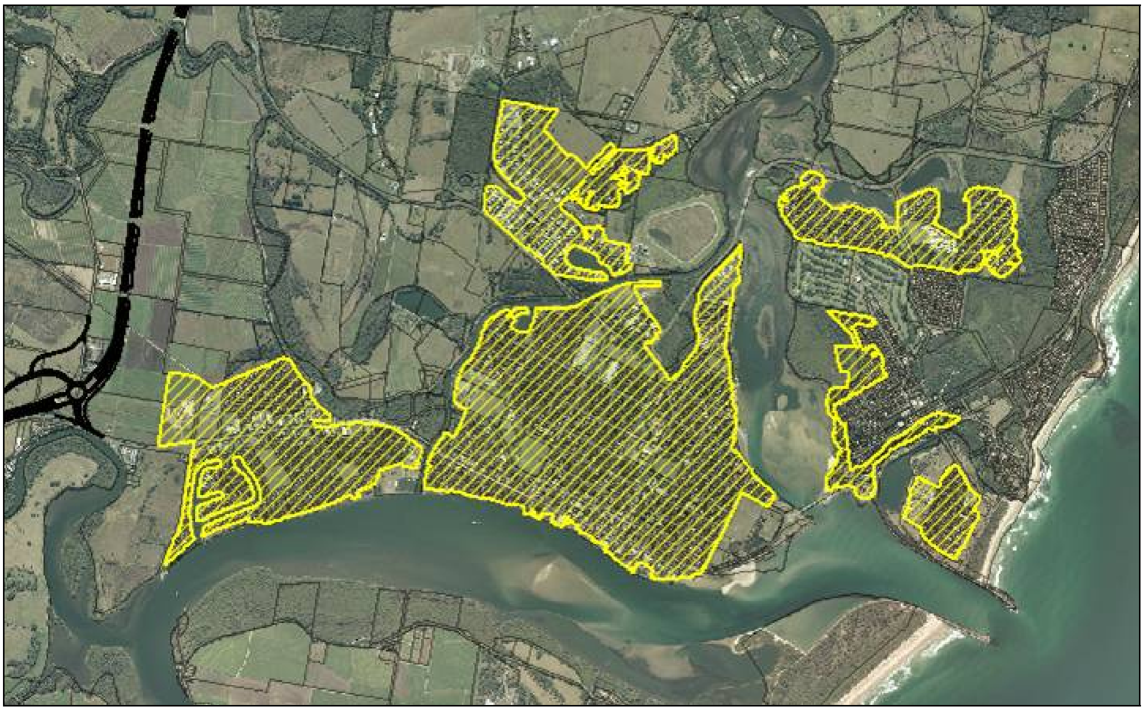
Extreme and medium FRPs have been mapped prior to development of the high FRP. High FRPs have been defined as areas within the 100 year ARI flood extent that have not been classified as extreme or medium FRPs.

F4 MEDIUM FLOOD RISK PRECINCT

Two steps have been undertaken to derive the medium FRP layer. These steps are as follows:

Step 1 – assess potential for fill in existing urban areas

Historically filling has been the standard approach adopted to mitigate flood risk in and around Ballina. There is considerable pressure for more development in the study area. To continue with this approach, it is important to determine how much more filling can take place in the floodplain without causing excessive flood impacts to existing development. There is substantial flood risk to existing development, particularly when accounting for current climate change predictions. It is therefore expedient to first assess the capacity for further fill in areas with existing development before considering potential future development; thus facilitating management of future flood risk in established urban areas. The first step towards defining the flood risk precincts was therefore to assess the flood impact caused by filling areas of existing development in Ballina Island, West Ballina, North Ballina and East Ballina. Areas that have been filled in this assessment are shown in Figure F-1.



Note: Yellow hatching marks the areas that have been filled

Figure F- 1 Existing Development Fill Areas

The results showed that there was negligible flood impact (less than 5mm). This suggests that the filled areas lay within flood storage portions of the floodplain, and the lost flood storage due to the fill is small relative to the total flood storage available in the floodplain. Filling in existing urban areas is therefore acceptable in terms of flood impact.

Step 2 – assess potential for fill in rural areas

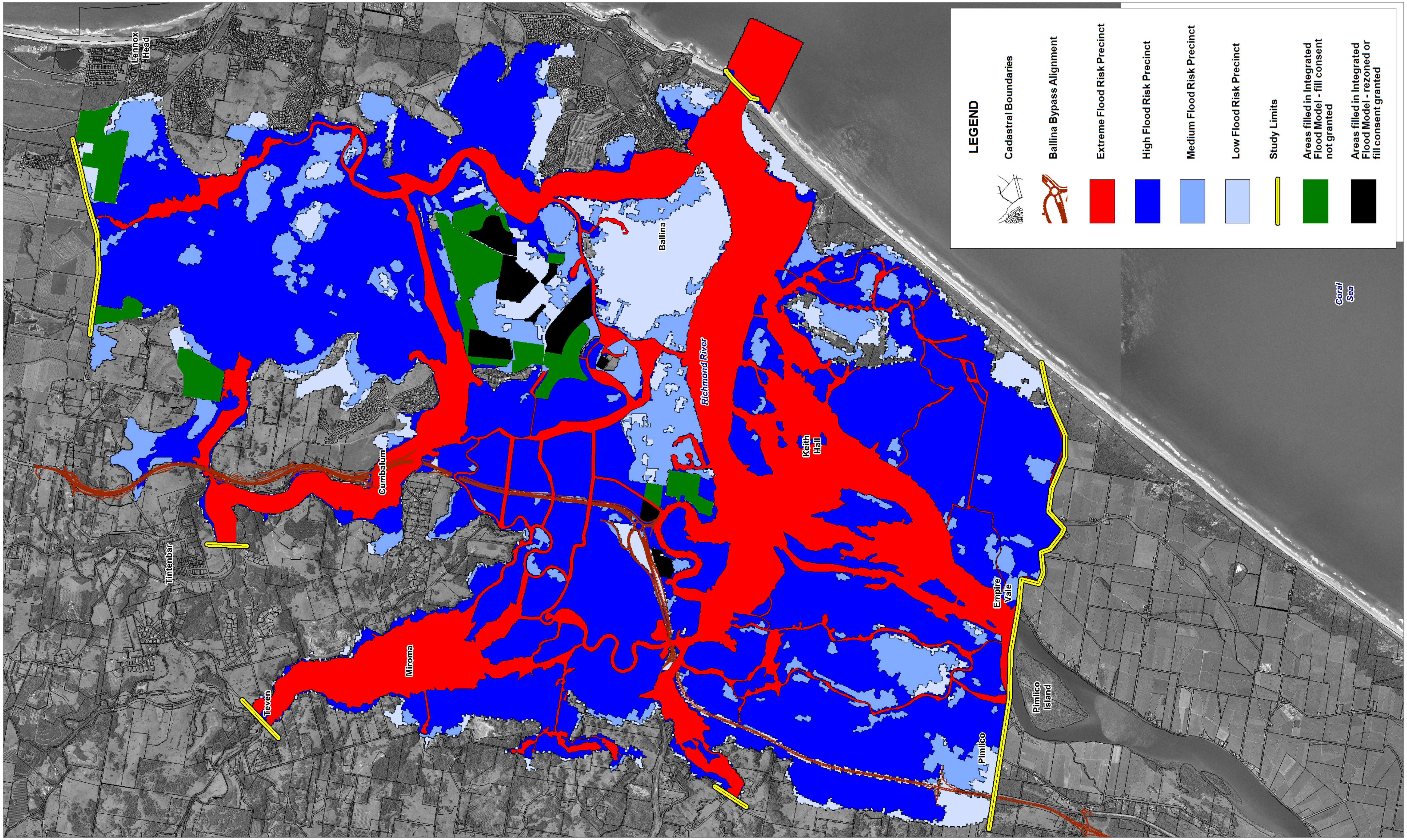
The results in step 1 also indicate that there is potential for further fill in the catchment. An assessment of the capacity for further filling in currently undeveloped areas has therefore been undertaken. Filling is most appropriate in areas where the consequences of flooding are low, i.e. shallow flood depths and low flow velocities. Areas of low flood hazard have been selected using the flood model results (VD of $0.025m^2/s$ and $0.05m^2/s$ for the 100 year ARI flood event) and filled in the model. The flood impact resulting from the filled low hazard areas (in combination with the urban fill areas from *Step 1*) has been assessed. Fill areas where the resulting flood impacts were significant (i.e. greater than 100mm) have been revised, and the corresponding flood impacts reassessed. This trial and error process has been repeated through a number of iterations. Many small islands of fill (areas less than 0.5ha) surrounded by flooding have also been removed to produce a cleaner more practical solution. The final combination of low hazard rural fill and urban fill areas which cause insignificant flood impact at a regional scale (less than 100mm) have been defined as medium flood risk precinct.

F5 LOW FLOOD RISK PRECINCT

Low FRPs have been defined last. They are the remaining areas in the floodplain (i.e. within the PMF flood extent) which are not classified as extreme, high or medium FRPs.

F6 RATIONALISE FLOOD RISK PRECINCTS

The FRP layers obtained at the pre-rationalised, stage are shown in Figure F-2. The FRP layers have subsequently been rationalised by removing isolated ‘islands’ and smoothening the edges of the layers. This process has been done in consultation with Council’s planning team. The final (rationalised) map is shown in Figure 6-1 in Section 6 of the main body of this report.



Title:
Pre-rationalised Flood Risk Precinct Map

Figure: **F-2**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0km 1 2
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : I:\B17316_I_BRH_Ballina_FRMS&P\DRG\R.B17316.005.01.FRMS\Figure_F-2.WOR

APPENDIX G: DRAFT DEVELOPMENT CONTROL PLAN

SEE SEPARATE LINK

BMT WBM Brisbane	**Level 8, 200 Creek Brisbane 4000** **PO Box 203 Spring Hill QLD 4004** **Tel +61 7 3831 6744 Fax +61 7 3832 3627** **Email wbm@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Denver	**14 Inverness Drive East, #B132** **Englewood Denver Colorado 80112 USA** **Tel +1 303 792 9814 Fax +1 303 792 9742** **Email wbmdenver@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Mackay	**Suite 1, 138 Wood Street Mackay 4740** **PO Box 4447 Mackay QLD 4740** **Tel +61 7 4953 5144 Fax +61 7 4953 5132** **Email wbmmackay@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Melbourne	**Level 5, 99 King Street Melbourne 3000** **PO Box 604 Collins Street West VIC 8007** **Tel +61 3 8620 6100 Fax +61 3 8620 6105** **Email wbmmelbourne@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Newcastle	**126 Belford Street Broadmeadow 2292** **PO Box 266 Broadmeadow NSW 2292** **Tel +61 2 4940 8882 Fax +61 2 4940 8887** **Email wbmnewcastle@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Perth	**1 Brodie Hall Drive Technology Park Bentley 6102** **Tel +61 8 9328 2029 Fax +61 8 9486 7588** **Email wbmperth@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Sydney	**Level 1, 256-258 Norton Street Leichhardt 2040** **PO Box 194 Leichhardt NSW 2040** **Tel +61 2 9713 4836 Fax +61 2 9713 4890** **Email wbmsydney@wbmpl.com.au** **Web www.wbmpl.com.au**
BMT WBM Vancouver	**1190 Melville Street #700 Vancouver** **British Columbia V6E 3W1 Canada** **Tel +1 604 683 5777 Fax +1 604 608 3232** **Email wbmvancouver@wbmpl.com.au** **Web www.wbmpl.com.au**