Benefits of flood mitigation in AUSTRALIA

BUREAU OF btre TRANSPORT & REGIONAL ECONOMICS

Report 106

DEPARTMENT OF TRANSPORT AND REGIONAL SERVICES

bureau of transport and regional economics

Benefits *of* flood mitigation *in* AUSTRALIA

ISSN 1446-9790
ISBN 1-877081-11-6

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Published by
Bureau of Transport and Regional Economics,
GPO Box 501, Canberra ACT 2601, Australia.

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Cover Design by Racheal Bruhn Design and Desktop Publishing by Thomas Smith

Cover photos
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Printed by New Millennium Print, Canberra

FOREWORD

This is the third publication contributing to the regional theme of natural disaster research identified in the BTRE's research program. This report follows on from Report 103 (*Economic Costs of Natural Disasters in Australia*), which examined natural disasters with an individual cost of more than $10 million. Report 103 found that floods are Australia's most costly disaster type and, on average, cost the Australian community over $300 million each year.

Australian governments allocate resources to reduce the impact of floods through various forms of mitigation. However, little work has been done to assess the effectiveness of mitigation that has been tested by subsequent flooding. This report aims to build on current levels of understanding by investigating the costs avoided by Australian flood mitigation projects. It captures much of the available Australian information on the benefits of flood mitigation through a literature survey, consultations and case studies.

The Disaster Mitigation Research Working Group (DMRWG), chaired by the Department of Transport and Regional Services, oversaw the research. The DMRWG represents a collaborative effort among Commonwealth and State and Territory Governments, Local Government, the Insurance Council of Australia and the New Zealand Government.

The BTRE research team comprised Sharyn Kierce (Project Leader), Neil Gentle, Lara Smigielski and David Wilson, with assistance from Andrew Mogg in the later stage of the report. Joe Motha, Deputy Executive Director, provided professional guidance and valuable comment to the project team.

Tony Slatyer
Executive Director
May 2002

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ACKNOWLEDGEMENTS

The BTRE would like to express its thanks to the many people and organisations who generously gave their time, by contributing assistance and information. The project team would like to thank the Natural Disaster Management Section of the Department of Transport and Regional Services for their assistance throughout the study and the Disaster Mitigation Research Working Group for providing valuable comments and input at various stages of the project.

Many organisations gave their time for discussions with the BTRE during the early stages of the research. The discussions held with those involved in flood mitigation and emergency services in the States and Territories provided a solid foundation for the research. The organisations that participated in these discussions are listed in appendix VI. The report would not have been possible without their efforts and support.

The data and information for the case studies were provided by the State Emergency Services, local councils in Bathurst, Tamworth, Thuringowa and Waggamba and the Department of Infrastructure, Planning and Environment (Northern Territory Government). James Cook University provided data for Thuringowa. In particular, the BTRE would like to record its appreciation to Neil Allen, Brian Bailey, Wilton Boyd, Andrew Galvin, Trevor Gunter, Tony Jacob, David King, Herman Mouthaan, Lakshman Rajaratnam and Craig Ronan. The BTRE gratefully acknowledges the assistance of these people and organisations, which made the case studies possible.

Emergency Management Australia made a significant contribution to the project by funding the initial consultation in each state and territory and the workshop on preliminary findings. The BTRE is especially grateful to the Emergency Management Australia Institute for hosting the workshop in November 2001. Preliminary findings were presented to participants from a variety of fields, including all levels of government, emergency services and academia. The participants provided valuable feedback on the early findings and future research directions. In particular, thanks are due to Peter Koob for his enthusiastic support and generous contribution of both time and expertise to the project. The project team would also like to thank the many people who participated in the workshop and provided comments on the draft report.

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EXECUTIVE SUMMARY

Floods are Australia's most costly disaster type[1]. Their impact can be devastating—lives are threatened and homes, businesses and community infrastructure are damaged and destroyed. The resulting social and economic disruption to communities can be long lasting.

The principal purpose of this research is to examine the benefits of flood mitigation activities. It captures much of the available Australian information on the costs, benefits and performance of flood mitigation works and measures and uses this information to develop case studies. The aim is to build on current levels of understanding by investigating the economic savings from Australian flood mitigation projects. The report examines the realised benefits of mitigation using actual floods and, in particular, the benefits of measures for which very little information currently exists, such as land use planning and other non-structural measures. Other issues such as social and environmental considerations are discussed where appropriate and quantified where possible, but the report does not deal with these complex issues in any depth.

It is important to have a robust methodology for evaluating benefits, because when costs are known, it is possible to calculate the net present value of mitigation options and to rank them according to their benefit-cost ratios. This procedure will considerably assist decision making about the allocation of scarce resources.

Case studies investigated for this report are land use planning in Katherine (Northern Territory), building controls in Thuringowa (Queensland), voluntary purchase of flood-prone properties in Bathurst (New South Wales), levees in Tamworth (New South Wales) and road sealing in the Waggamba Shire (Queensland). The case studies demonstrate the benefits of mitigation and the difficulties involved in accurately measuring these benefits.

The research had three components—literature review, extensive consultation and case studies. The results illustrate that the economic value (or benefit)

1 Floods account for 29 per cent of total natural disaster costs over the past 30 years. On average, floods with a damage bill of more than $10 million cost the Australian community over $300 million each year (BTE 2001a).

of implementing measures to mitigate existing and future risk[2] can be substantial. A number of other important non-economic issues were also raised and serve as a useful source of information and ideas for consideration by researchers and policy-makers.

Flood *mitigation* is defined as measures aimed at decreasing or eliminating the impact of floods on society and the environment. Both structural and non-structural means of mitigating flood risks are included.

LITERATURE REVIEW

The literature review (chapter 2) reveals a variety of approaches to classifying the various mitigation measures. This report classifies mitigation into three categories: flood modification, property modification and response modification. *Flood modification* aims to avoid loss by keeping the water away from development. This is the traditional form of mitigation, provided by structural measures aimed at modifying the flow of floodwater. There has been increasing use of *property modification* measures, which avoid or minimise loss by keeping development away from the floodwater using land use planning or building design, siting and materials. An increasing emphasis on risk management has led to *response modification* measures. These measures seek to modify human behaviour through activities such as awareness campaigns, education, warning systems and planning. This approach recognises that people's reactions to impending floods and warnings have a substantial effect on the losses that subsequently occur. The different approaches to flood mitigation are listed in table ES.1.

Despite growing interest in the effectiveness of mitigation measures and a desire to establish if expenditure has been cost-effective, the literature review reveals that *ex post* studies of flood mitigation are not common. Flood modification measures are more likely to be evaluated before implementation, largely due to a need to allocate scarce resources to projects that will have the most impact. It has been more common for property modification measures to be examined for their effectiveness after being tested by flooding.

Other common themes arising from the literature review are:

- Mitigation needs to suit the circumstances—including physical properties of the floodplain and the priorities of the community.
- It is generally not possible to transfer the benefits of a given measure in one location to other areas with different physical and flooding characteristics.

2 A discussion of existing and future risk is contained in chapter 4.

- Flood modification measures are most effective where they protect a large number of properties from flooding. Both the costs and potential savings are high. However, the limitations of these larger structural measures (for example, the 'levee paradox'[3]) need to be recognised.

- Property modification measures can provide protection from flooding only up to the level for which they are designed. Other than acquisition, property modification measures are usually relatively low-cost, and costs are borne by the users of the floodplain. Voluntary purchase (acquisition), while more expensive, is a permanent solution to existing problems.

- Response modification measures (such as warning systems) are relatively low-cost options with the potential to save lives and property. These measures target continuing risk, especially the risk arising from extreme (including catastrophic) events.

TABLE ES.1 CLASSIFICATION OF MEASURES TO REDUCE FLOOD LOSSES

Classification	*Sample measures*	
Flood modification	Levees	(Structural)
	Dams	
	Diversions and channel improvements	
	Flood gates	
	Detention basins	
Property modification	Zoning and land use planning	(Non-structural)
	Voluntary purchase or acquisition	
	Building regulations	
	House raising	
	Other flood-proofing	
Response modification	Information and education programmes	
	Preparedness (planning for emergency)	
	Forecasts and warning systems	
	State and national emergency services response	

Source BTRE analysis of information from various sources.

3 The 'levee paradox' refers to the increase in potential damage resulting from floods greater than the design level (for example, if development behind levees increases or residents' flood awareness diminishes).

CONSULTATIONS

In May and June 2001, funding under the National Emergency Management Studies Program, administered by Emergency Management Australia (EMA), allowed the Bureau of Transport and Regional Economics (BTRE)[4] to conduct a series of consultations with key players in flood mitigation in each State and Territory in conjunction with representatives from the Natural Disaster Management Section of the Department of Transport and Regional Services (DOTARS) and EMA. A workshop to gain feedback on draft findings was also held at the Australian Emergency Management Institute[5] at Mount Macedon in November 2001.

During this consultation phase of the research, valuable information and ideas were exchanged (documented in chapter 3). Common themes included:

- Land use planning decisions and design levels for mitigation works are generally based on the 1 in 100-year flood level. Revisions of the 1 per cent annual exceedance probability (AEP) level as information improved were widespread.
- Many jurisdictions noted that there had been very few major floods in the last 10 to 50 years. Consequently, community awareness and knowledge of floods are generally poor.
- All jurisdictions emphasised an increasing focus on non-structural measures. The importance of an overall floodplain management strategy, encompassing a mix of approaches to deal with flood problems, was also stressed.
- The importance of community understanding and support were stressed as fundamental to the assessment of mitigation options.
- In general, the economic effectiveness of mitigation measures is not formally assessed after measures are put in place.
- Common problems associated with flood mitigation were: lack of funds; inadequate community awareness; varying community needs; urban infill and higher density redevelopment; uncertain legal liability and court outcomes; political pressures; lack and uncertainty of information; and lack of coordination.

Despite the considerable number of common themes that emerged during the consultations, there were also significant differences across Australia. The major differences are discussed below.

4 The Bureau of Transport Economics (BTE) became the Bureau of Transport and Regional Economics (BTRE) with effect from 1 January 2002.

5 Now known as the Emergency Management Australia Institute.

- Approaches to floodplain management policy vary substantially across Australia, from being virtually non-existent to having a comprehensive policy and legislative framework governing existing and future risk.
- Attitudes toward floodplain mapping differ across Australia (for example, concerning public availability of maps).
- There were differences between rural (or isolated) communities and urban communities in relation to floodplain management (for example, distance and access issues, cultural factors, environmental considerations, demographics and affordability).
- The importance of stormwater was raised by some jurisdictions as a major flood mitigation issue.

CASE STUDIES

The choice of case studies depended primarily on the extent of data and information available. While broad views of flooding, mitigation and risk management have been adopted in this report, it is important to acknowledge that the case studies predominantly focus on riverine flooding in urban town areas. However, the benefits of flood mitigation in residential areas are not limited to the residents alone—they are spread among the whole community. A safe and sustainable residential area is important in supporting local businesses and other sectors of a community.

It was not possible to examine the economic effectiveness of all of the mitigation and risk management options implemented in a case study location. Instead, one mitigation measure from the suite of measures typically included in the location's plan was selected for analysis. It is important to remember that the measures analysed in the case studies are part of a package of measures aimed at addressing flood risk.

The project methodology is essentially set within a benefit-cost analysis (BCA) framework. While the general methodology is that of BCA, the detailed application of the method varies across the case studies due to the different data available in each case. In general, the BTRE attempted to examine the benefits of flood mitigation for a full range of floods over time by measuring the damage with and without the mitigation. That is, the well-established approach of estimating the reduced average annual damage (AAD) due to mitigation was the preferred method. However, in some cases, because of a lack of data, the benefits of reduced damage in particular historical floods were used. Data constraints also prevented the completion of a full BCA in the case studies.

The results of each case study are given in the next section, which outlines the key findings of this report. Together with the literature and consultations, the case studies were used to analyse the key themes and lessons learned in order to reach a more general understanding of the benefits of mitigation (chapter 4). The established framework of existing, future and residual (or continuing) risk was used to structure the discussion.

CONCLUSIONS

This report draws together ideas and analysis on the benefits of a variety of flood mitigation measures. The input and assistance received from the disaster management community provide a unique reference point and snapshot of current thinking on flood mitigation issues. Bringing this information together for debate and discussion is a key outcome of the project.

Key findings

The case studies, consultations and literature surveyed demonstrate evidence of the benefits of various types of flood mitigation. Data limitations prevented the BTRE from evaluating the net benefits of the specific mitigation measures in the case studies. Information on the costs of measures such as land use planning was not available. There were also difficulties in estimating the full benefits of measures. However, in each of the five case studies, there is evidence that the estimated benefits of the various flood mitigation measures in terms of tangible savings are substantial.

- Land use planning in Katherine is estimated to have reduced the AAD by around $0.6 million. In a 1 per cent AEP flood, the planning decision is estimated to save around $29 million in direct and indirect costs.
- Voluntary purchase (VP) in the Kelso area of Bathurst is estimated to have saved $0.7 million in the 1998 flood. If all properties had been purchased before that 1998 event, savings would have been in the order of $1.2 million. When complete, the scheme will save approximately $1.8 million in a 1 per cent AEP event.
- Building controls (minimum floor levels) in Thuringowa appear to have had an effect in reducing the extent of inundation (and therefore internal damage) in the 1998 flood. Given that individuals can pay off the higher construction costs over the life of a mortgage, building design measures enforced through building controls can be a cost-effective and affordable form of mitigation.
- Investment in bitumen-sealed roads (which are more flood-resistant) in the Waggamba Shire is estimated to be economically justified. Analysis suggests that the minimum of 32 trucks per day required to break even is comfortably exceeded in the Waggamba Shire.
- A levee proposed for the Tamworth industrial area would significantly reduce flood damage (the cost of the November 2000 flood is estimated at close to half a million dollars). It is also estimated that the existing CBD levee would avoid at least $5.36 million potential direct damage in a 100-year average recurrence interval (ARI) flood.

These savings typically refer only to direct and indirect costs avoided. Intangible savings (such as reduced stress and ill health) are discussed in the appendices (appendices I to V), but not quantified. The figures therefore underestimate the full benefit of implementing flood mitigation.

A number of important points regarding the benefits of mitigation, economic viability and non-economic factors were also raised:

- The importance of considering flood mitigation options that address all three sources of risk—existing, future and residual (or continuing)—was clearly evident.
- The trends toward non-structural mitigation solutions (which may involve less residual risk) were supported by the Katherine, Bathurst and Thuringowa case studies as well as in discussions with key stakeholders.
- Levees (the most common form of structural mitigation) appear to have been effective in preventing substantial damage and in saving lives across Australia.
- Mitigation of existing risk by altering the way infrastructure is designed and constructed can be a very cost-effective mitigation measure (supported by the Waggamba case study).
- There are considerable similarities in approaches to floodplain management across Australia (for example, the prevalence of the 1 per cent AEP design level). However, there are also some key differences (for example, the use of floodplain maps).
- The uniqueness of each location (in terms of topography, rainfall patterns, community views, affordability of measures, rural or urban development and so on) means that mitigation solutions must be tailored to the location in order to achieve success.
- Community awareness and preparedness together with reliable and timely flood warning systems play an important role in determining the success of mitigation. The Tamworth case study found that the preparedness activities of businesses in the lead-up to the November 2000 flood saved more than 80 per cent of potential damage.
- Equity (and perceived fairness) is a powerful factor in community acceptance and therefore policy decisions regarding proposed mitigation measures. In some circumstances, solutions that may not satisfy economic criteria may be necessary to gain community acceptance.
- Drainage and stormwater issues are intimately linked to other flood issues. Regardless of the source of flooding (such as storm surge or cyclone) it is sensible not to examine mitigation solutions for each in isolation.

Limitations

Problems associated with the methodology used in this report and other limitations of the analysis need to be recognised. These are summarised below.

- The lack of, and uncertainty in, data available to estimate the benefits associated with mitigation limits the accuracy of the case study estimates.
- Capturing and quantifying many indirect and intangible costs and benefits (such as the disruption to businesses and communities and loss of life and memorabilia) are inherently difficult.
- Existing methods of estimating flood damage by relating property damage to the depth of flooding (stage-damage curves) are dated. Although modified in some cases to reflect the increasing value of residential building contents over time, this is still an important limitation of the estimates. Both residential and commercial curves are thought to underestimate the true costs of flood damage significantly. The need for improvements in methodology, particularly of stage-damage curves, was obvious in all case studies and consultations.
- Several concerns about the application of the BCA framework to evaluate the benefits of flood mitigation were raised.
  - For some mitigation measures, and voluntary purchase in particular, BCA may be unable to adequately capture the benefits, which primarily relate to reduced risk to life (and other intangibles).
  - Using BCA in evaluating particular types of non-structural mitigation measures could make them appear unsuitable. Similarly, lower socio-economic groups and those who prepare appropriately for floods could be disadvantaged if BCA is the only decision tool.
  - As a result, BCA, while a powerful economic tool for examining the economic merit of mitigation and prioritising measures, should not generally be the sole decision tool.
- Limitations associated with the case study approach must be emphasised. Generalisation from the case studies to other locations is only sensible where similar conditions apply.
- Assumptions and sources of error discussed in each of the case study appendices should be taken into account.

Despite these issues, the estimates of the benefits of mitigation contained in this report together with the literature surveyed and the information and ideas exchanged during consultations should provide a valuable input, not previously available, to inform policy debate and decision-making in the emergency management field.

Future research priorities

During the BTRE's investigation of the benefits of flood mitigation it became clear that there were areas where further research was needed. The consultations and workshop in November 2001 also provided a rich source of ideas on future research priorities. These are described briefly below (in no particular order).

- Further work to provide broader evidence of the benefits of mitigation, including benefits for types of natural disasters other than floods.
- Improved stage-damage curves for residential and commercial buildings.
- Improved data collection and methods for capturing indirect and intangible costs.
- Guidelines for case study research so that the results are more transferable.
- Continuing improvements in the analysis of proposed mitigation projects across Australia so that public investment can be directed to those projects producing the most benefits and the greatest value for money.
- Examination of how the application of BCA might disadvantage certain measures and people.
- Complementary research examining the social, environmental and other aspects of flood mitigation. In particular, the issue of the long-term economic and social impact of disasters on communities.
- Research that integrates the economic, social and other factors associated with natural disasters with spatial (physical) risk models to produce a holistic multi-disciplinary analytical tool.
- Better methods for evaluating community awareness, education campaigns and the effectiveness of warning systems are required.
- Further work on developing the case for amending the Building Code of Australia for residential buildings in areas subject to flood. Matters for consideration include escape routes from inundated buildings; building strength and structural integrity; and determining recommended minimum habitable floor heights above flood levels.
- Flood mitigation issues in rural areas and with respect to urban drainage problems.
- Better understanding of the cost and impact on communities of less costly and more frequent disasters.

chapter 1

INTRODUCTION

BACKGROUND

On average, floods cost the Australian community over $300 million a year. Floods are Australia's most costly disaster type, accounting for 29 per cent of total natural disaster costs over the period 1967–1999 (BTE 2001a). Flooding causes damage to properties and can affect personal safety, business activity, financial security and general health and well being. All sections of the community are affected by flooding and many private and government agencies are involved in the subsequent recovery phase.

Historic settlement patterns have resulted in Australia having significant development on floodplains, with many towns and cities sited close to rivers. Flood mitigation (risk reduction) is therefore a matter of concern for all levels of government. Governments worldwide have recognised the need for more comprehensive floodplain management practices, to ensure both the long-term survival of river systems and minimise the impacts of flooding on human settlement. Increasingly, flood mitigation activity is being seen as an important aspect of broad-based floodplain management.

Significant amounts of money have been expended in the past to reduce the costs of floods and further expenditure in the future is expected. Understanding the effectiveness, efficiency and appropriateness of mitigation measures allows a better appreciation of their economic merit and improves confidence that money spent on flood mitigation is well spent. The research presented in this report aims to build on current levels of understanding by investigating the economic savings from Australian flood mitigation projects.

Demonstrating the value of mitigation measures adopted in the past also provides support for such measures to reduce risk in future community developments. For example, mitigation measures such as land use planning and building regulations (which may specify floor heights or the use of flood-proof building materials) prevent potential losses and reduce the need for mitigation expenditure in the future.

The research described in this report is part of a longer-term project (Disaster Mitigation Research Project) comprising three modules:

1. estimation of the costs of disasters;
2. estimation of the costs and benefits of mitigation measures; and
3. development of a national picture of natural hazards and risks.

The research arose out of a need for a more thorough assessment of the benefits and costs of mitigation expenditure than has previously been available. The project received the endorsement of the joint Commonwealth, State and Territory National Emergency Management Committee (NEMC)[6] in November 1999. A working group comprised of representatives of stakeholders in emergency management oversaw the research.

The results of Module 1 of the project—*Economic Costs of Natural Disasters in Australia*—were published by the Bureau of Transport Economics (BTE[7]) in March 2001. Module 1 focused on the first objective. The report examined the cost of natural disasters, including floods, storms, bushfires, earthquakes, cyclones and landslides, for the period 1967 to 1999. It also presented a consistent framework for estimating the future costs of natural disasters. Key findings included:

- Natural disasters with an individual event cost of over $10 million cost the Australian community $37.8 billion (in 1999 prices) over the period 1967 to 1999 (including the costs of deaths and injuries).
- The average annual cost of these disasters was $1.14 billion. This translates to an annual cost of approximately $85 per person. The average annual cost was strongly influenced by three extreme events—Cyclone Tracy (1974), the Newcastle earthquake (1989) and the Sydney hailstorm (1999).
- New South Wales and Queensland accounted for 66 per cent of total disaster costs.
- Floods were the most costly of all disaster types, contributing 29 per cent of the total cost. Storms and cyclones caused similar levels of damage.
- There is some evidence that the number of disasters per year is increasing, due partly to better reporting in recent years and possibly to increasing population in vulnerable areas.

This report contributes to the second module of the Disaster Mitigation Research Project by examining the benefits of flood mitigation in Australia. It captures the available Australian information on the costs, benefits and performance of flood mitigation works and measures. Case studies,

6 Now known as the Australian Emergency Management Committee (AEMC).

7 The Bureau of Transport Economics (BTE) became the Bureau of Transport and Regional Economics (BTRE) with effect from 1 January 2002.

consultations and a literature survey are used to illustrate the benefits of flood mitigation.

The primary expected outcome of this report is an assessment of the benefits of flood mitigation measures. The project is expected to assist the Commonwealth and States and Territories to assess mitigation works and measures for their potential effectiveness and consequently enable more effective allocation of government expenditure.

DEFINITIONS

This report adopts EMA's definition (1998, p. 60) of *flood* as the overflowing by water of the normal confines of a stream or other body of water, or the accumulation of water by drainage over areas not normally submerged. This definition of flooding includes all forms of flooding regardless of source, which may be river flooding, flash flooding, stormwater/drainage flooding, storm surge, dambreak, cyclones or tsunami.

The controversy surrounding narrower and more complex insurance industry definitions of flood is not addressed[8]. A broad definition of flooding was used in order to avoid the blurred boundaries between stormwater and flood damage. Feedback from various sources suggested that this approach to defining a flood was important for both communities and governments.

For the purposes of this research, *flood mitigation* is defined as measures aimed at decreasing or eliminating the impact of floods on society and the environment. This includes measures taken in advance of a flood, such as structural works. It includes preparatory actions taken during or when a flood is imminent, such as moving items to safety. It also includes those measures that result from the impetus for action that often occurs in the aftermath of a flood. Many mitigation measures are initiated after a flood has occurred, in preparation for the next event.

Floodplain risk management

Flood mitigation is one aspect of *floodplain risk management*, which includes the systematic application of management policies, procedures and practices to the tasks of identifying, analysing, evaluating, treating and monitoring risk (EMA 1998, p. 105). This report focuses on flood mitigation, but more general floodplain risk management issues are frequently raised and discussed. As a result, it is important that this research be placed within the broader risk management framework established by the *Australia/New Zealand Risk*

8 The common definition of flood from an insurance perspective is the inundation of normally dry land by water escaping from, or released from, the normal confines of any natural water course or lake (whether or not altered or modified) or any dam, reservoir or canal. The consequences of such floods are generally excluded from insurance policies.

Management Standard AS/NZS 4360:1999. The standard sets out the main elements of the risk management methodology (figure 1.1). Emergency risk management is the application of these risk management principles and processes to the emergency management field.

This research is mainly concerned with evaluating and reviewing the risk treatment options that have been implemented as part of the risk management process. All Australian States and Territories employ some form of this risk management process to manage their floodplains. There are five major risk treatment options identified in the risk management standard:

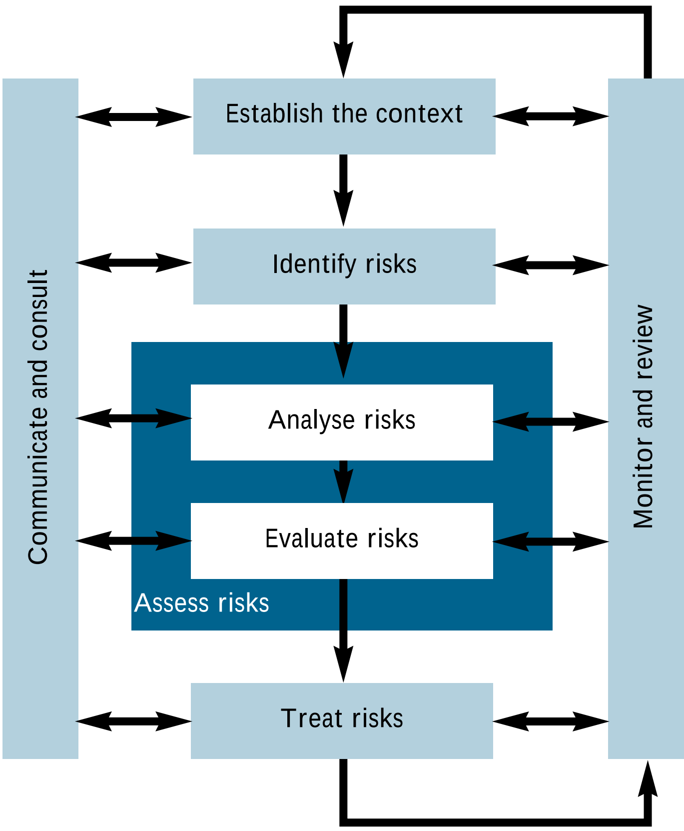
1. accept risk (do nothing);
2. reduce likelihood of occurrence (for example, structural flood modification);
3. reduce consequences (for example, property and response modification);
4. transfer risk in full or part (for example, insurance); and
5. avoid risk (for example, by not building in a flood-prone location).

The focus of this report is on mitigation actions that reduce or eliminate the impact of disasters, that is, treatment options 2, 3 and 5. However, it is important to view this research within the overall risk management process. The risk framework outlined above provides the conceptual context for this research and is drawn on throughout the report, particularly in chapter 4 where the lessons learned in the case studies are examined according to various types of risk.

There are many ways of approaching risk treatment options. An alternative to the standard risk management approach so far described is the prevention, preparedness, response and recovery (PPRR) continuum. This terminology is commonly used in emergency management. The place of mitigation within this continuum is not clear-cut. Traditionally, mitigation was thought of as prevention activity, but the overlap between the concepts has gradually meant that mitigation is increasingly being seen to include aspects of all four elements. For example, preparedness (or readiness) includes flood warnings and planning. Planning for the response and recovery phases also has the potential to reduce the impact of floods. Improvements to infrastructure and buildings made during the post-flood repair period also mitigate against future damage.

Taxonomies and definitions are important tools for communicating the results of research. However, it is important not to let these issues overshadow the key message or findings of the research. Further detail on the mitigation measures considered in this report is contained in chapter 2.

FIGURE 1.1 EMERGENCY RISK MANAGEMENT METHODOLOGY



Source *Australia/New Zealand Risk Management Standard AS/NZS 4360:1999*, p. 8.

SCOPE

This report is focused on the *economic* costs and benefits of flood mitigation. The principal purpose of this research is to examine the economic viability of mitigation. Social and environmental considerations are discussed where appropriate and quantified where possible, but the report does not deal with these complex issues in any depth.

This project is limited to an examination of flood mitigation measures. Floods are the most costly natural disaster type in Australia. They are also the hazard that has been most commonly studied and for which the most information and data are available.

Both structural and non-structural means of flood mitigation are included in the general mitigation framework discussed in chapter 2 and the specific case studies discussed in chapter 4.

Flood insurance issues, although linked to flood mitigation, are not examined as their complexity places them beyond the scope of this report. There are already a number of groups involved in substantial work on flood insurance[9].

Mitigation schemes are usually designed to provide local benefits. Where data permitted, mitigation benefits and costs were examined from both a local and national perspective. Including the local perspective added complexity to the project. For example, boundary issues needed to be examined and more indirect costs needed to be estimated than for a national approach. Good data on some indirect costs were not available for some case studies. It is relatively easy to derive national mitigation benefits once local benefits are known, but not vice versa.

Given the scope of this report, it is vital to stress the importance of placing the report within an overall risk management framework which identifies, analyses, evaluates and treats all risks from a variety of perspectives (including economic, social, environmental and others). Best practice risk management involves communities and governments identifying all sources of risk and implementing a risk management plan or strategy by following the steps described in figure 1.1. This plan will typically involve a variety of mitigation measures aimed at addressing the risk.

While broad views of flooding, mitigation and risk management have been adopted in this report, it is important to acknowledge that the case studies predominantly focus on riverine flooding in urban residential areas. However, the benefits of flood mitigation in residential areas are not limited to the residents alone—they are spread among the whole community. A safe and sustainable residential area is important in supporting local businesses and other sectors of a community.

Issues surrounding mitigation in rural areas are discussed in chapter 3, but are not covered in any of the case studies due to data constraints. It was not possible to examine the economic effectiveness of all of the mitigation and risk management measures implemented in a case study location. Instead, one mitigation measure from the suite of measures typically included in the location's plan was selected to be the focus. It is important to remember that a flood management plan normally includes a package of measures which together mitigate the flood risk.

METHOD

The project was undertaken in seven stages.

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9 For example, research soon to be published on the implications for floodplain management policy of residential flood insurance by Smith and Handmer (2002 in press).

1. Project planning and incorporating the Tamworth study[10] as the first case study. [January-March 2001]
2. A discussion paper, providing background information and outlining data requirements, was distributed to States and Territories as the basis for consultation and data collection. [April 2001]
3. Targeted meetings with representatives in States and Territories, including local councils, State/Territory governments, consultants and emergency services agencies to collect data and anecdotal evidence on the costs and benefits of mitigation measures. [May-June 2001]
4. Follow-up discussions and development of case studies of particular flood mitigation measures (including data analysis). [June-November 2001]
5. A workshop organised by, and conducted at, the Australian Emergency Management Institute[11] to obtain feedback on the draft research findings. [6-7 November 2001]
6. Draft report based on the case studies and feedback from the workshop released for comment. [early 2002]
7. Consider further comments and finalise report for publication. [2002]

Case study approach

The case study approach adopted in this report has many advantages. Being based on real-world rather than hypothetical examples makes the research more relevant and therefore easier to comprehend, and the findings easier to apply. As actual examples, case studies provide hard evidence for particular issues. However, the limitations of the case study approach also need to be recognised. The primary limitation is that specific findings cannot always be generalised and may not be transferable. For example, a case study that finds land use planning a very cost-effective mitigation measure cannot be generalised to imply that all land use planning mitigation will be cost-effective.

The results of case studies can be used to illustrate issues and may provide some evidence of the likely impacts of similar measures, but the results are case-specific. The complex and specific nature of each location, flood problem and mitigation options must be understood when using a case study approach. Case study results are therefore very useful to decision-makers (provided

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10 Floods in Tamworth in November 2000 provided an opportunity for the BTE to follow on from the Module 1 report by estimating the economic costs resulting from the floods in the industrial area and estimating the benefits (costs avoided) in the CBD by the existence of levee banks. This work was published in September 2001 as Working Paper 48. The work also fed into Module 2 and therefore forms the basis for one of the case studies.

11 Now known as the Emergency Management Australia Institute.

they are interpreted appropriately) in that they provide lessons learned from different locations.

Benefit-cost analysis

The project methodology is essentially set within a benefit-cost analysis (BCA) framework. BCA is a way of systematically identifying and quantifying the benefits and costs of a project in order to assist decision-makers. It is a useful decision-making tool for allocating and prioritising scarce resources between competing demands—in this case flood mitigation measures. A wide range of impacts (costs and benefits) are able to be included in a BCA framework, although not all impacts can be adequately quantified. BCA can identify the most economically efficient mitigation option for a particular location.

If reliable estimates of the benefits of flood mitigation measures are not available, BCA would be unable to determine the most economically efficient solution. However, even when benefits are difficult to calculate, an economic approach in the form of cost-effectiveness analysis can be valuable. This technique can establish the least-cost means of accomplishing a predetermined policy goal (such as reducing flood risk). It can also assess the extra costs involved when policies other than the least-cost policy are chosen.

BCA has several limitations, particularly in capturing less tangible factors such as social, health and environmental benefits and costs. BCA is concerned with economic efficiency and does not typically take account of equity issues such as the distribution of benefits and costs. Equity issues can be very important in flood mitigation, but these concerns are more appropriately dealt with by public policy makers and elected representatives. Some specific equity issues and other limitations in the use of BCA to evaluate flood mitigation are discussed in chapter 4 and in the case studies.

BCA should be seen as a tool to assist decision-makers, but should not generally be the sole means of reaching a decision. Other economic tools (such as cost-effectiveness analysis) and non-economic criteria can also be used as a complement to BCA or instead of it. If more than one analytical approach is used in the decision-making process, it is important to ensure that double-counting of costs and benefits does not occur. When prioritising mitigation funding between locations, it is also important that a variety of factors are considered. For example, differences in geographic conditions and the extent of a flood problem will affect the scale of benefits achieved. If BCA is compared across locations, the relative size of the different flood problems may not be accounted for adequately. Ensuring government funds are spent in an economically efficient manner is important, as is ensuring that funds are spent where they are most needed (where flood risks to people and property are most severe).

While BCA is the general methodology adopted in this report, the detailed application of the method varies across the case studies due to the different data available in each case. As a result, the details of the methodology used are discussed for each case study in the appendices. In general, the BTRE attempted to examine the benefits of flood mitigation for a full range of floods over time by measuring the damage with and without the mitigation. That is, the well-established approach of estimating the reduced average annual damage (AAD) due to mitigation was the preferred method. However, in some cases, because of a lack of data, the benefits of reduced damage in particular historical floods were used. It is also important to note that variance does exist in the application of the AAD method. For example, results can vary depending on the shape of the damage curve adopted. It is therefore important that all assumptions and details of the method applied are clearly articulated. This detail is contained in the case study appendices.

Data constraints also prevented the completion of a full BCA in the case studies. Information on the costs of measures such as land use planning was not available. There were also difficulties in estimating the full benefits of measures.

Before flood mitigation measures are funded, a holistic benefits assessment including social, economic, geographic and other factors (such as the relative size of the flood problem) takes place. As part of this process, extensive BCA is conducted in Australia prior to flood mitigation measures being funded and implemented. Given the scarcity of government funds and the need to ensure taxes are spent in a cost-effective manner, the completion of BCA before implementation of mitigation measures is an important part of the decision-making process. Existing floodplain management studies, which typically include BCAs, provide the most readily available source of information on the likely savings resulting from mitigation. The publication of the NSW *Floodplain Management Manual*[12], which identified economic appraisal 'to ensure costs are at least balanced by associated benefits' (p. 14) as an important part of adopting a floodplain management plan, has meant that vast numbers of floodplain management studies, often incorporating BCA, have been completed.

The BTRE has drawn heavily on these existing BCAs in its case studies. However, the primary aim of this project was to examine the realised benefits of mitigation using actual floods—that is, to conduct *ex post* BCA. As discussed in chapter 2, there is very little published evidence available on the actual, rather than predicted, benefits achieved as a result of mitigation. This reports aims to fill some of that gap.

The other important contribution of this report is in quantifying the benefits of measures for which very little information currently exists (for example, land use planning and other non-structural measures).

12 First published in 1986 as the *Floodplain Development Manual*.

The cost framework developed in Module 1 (reproduced here in table 1.1) was used as a basis for examining the costs and benefits of flood mitigation measures. Benefits are examined in terms of the direct, indirect and intangible costs avoided as a result of mitigation. Costs of mitigation include direct capital costs, ongoing maintenance costs and indirect and intangible costs such as environmental consequences, reduced amenity or access and other flow-on impacts (for example, the impact of flooding on residences and businesses outside the target mitigation area).

TABLE 1.1 COST AVOIDED FRAMEWORK

Direct	*Indirect*	*Intangible*
Agriculture—fences, equipment, crops & pastures, livestock	Emergency and relief agencies	Environmental
Residential housing—structure and contents	Alternative accommodation	Death and injury
Commercial buildings—structure and contents (including equipment & stock)	Business disruption	Dislocation
Infrastructure	Clean-up	Memorabilia
	Network disruption	Health impacts
	Agriculture (e.g. agistment)	Cultural and heritage
	Disruption of public services	

Source BTE (2001a).

REPORT STRUCTURE

This introductory chapter provides the background context and outlines the definitions, scope and method employed throughout the report. Chapter 2 sets the scene by providing a general framework and context in which to analyse mitigation. It also examines existing research on the effectiveness of mitigation. Chapter 3 gives details of the case study selection process and the outcomes of the consultation process. Chapter 4 draws on the discussion in chapters 2 and 3, and the case studies contained in the appendices to discuss the benefits of mitigation and the lessons learned. Chapter 5 summarises the key findings of the report and concludes by outlining the possible next steps in natural disaster research.

Appendix I examines land use planning in Katherine (Northern Territory). Appendix II investigates the benefits of residential voluntary purchase (VP) in Bathurst (New South Wales). Appendix III explores issues associated with residential building regulation (minimum floor levels) in Thuringowa (Queensland). Appendix IV examines the economics of upgrading flood-prone roads in the Waggamba Shire (Queensland). Appendix V summarises earlier research on the costs and benefits of levees in the Tamworth industrial and central business districts. Appendix VI provides a list of those organisations consulted in May and June 2001.

Figure 1.2 shows the location of the case study areas.

FIGURE 1.2 CASE STUDY AREAS

Source BTRE.

chapter 2

LITERATURE REVIEW

The first part of this chapter examines the purpose and types of flood mitigation measures available. The second part discusses research that has evaluated the benefits or effectiveness of the various measures.

Governments and the communities they serve have become increasingly aware that there is an opportunity cost to investment choices and a need to weigh the relative merit and likely return of various options. This awareness relates to the need to make choices between various mitigation measures, as well as to choose between flood mitigation and other demands for expenditure.

Much work has been done to assess the effectiveness of proposed mitigation works before implementation (*ex ante* evaluation) to demonstrate that they are likely to be cost-effective or that they rank highly on other criteria. However, reviewing the effectiveness of flood mitigation measures after they have been tested by events (*ex post* evaluation) is not common. Palanisami and Easter (1984, p. 1785) found evidence that actual benefits and costs varied considerably from projections and suggested that more studies are needed after mitigation is put in place.

As increasing accountability and transparency requirements combine with pressure for scarce funds, interest in *ex post* reviews of the cost-effectiveness of flood mitigation expenditure continues to rise. This trend is illustrated by the findings of a recent audit of flood mitigation funding programmes in the United States administered by the Federal Emergency Management Agency (FEMA). The audit report recommended that mitigation be reviewed after flood events to ensure the most cost-effective measures are being used and to improve future decision making (General Accounting Office (GAO) 1999, p. 16).

PURPOSE OF MITIGATION

Before examining the economic benefits of mitigation measures, it is important to briefly describe their purpose and the variety of different measures commonly available. The purpose of flood mitigation is to decrease or eliminate the impact of floods on society and the environment. In some cases, loss of life is the overriding concern and human safety is the target of risk management measures. In others, mitigation protects against the physical damage to property and the disruption and other effects caused by flooding. In many cases both objectives are targeted together.

Mitigation addresses various risks, typically classified as existing, future and residual (or continuing). These aspects of risk are addressed in detail in chapter 4.

While the ideal would be to eliminate flood risk altogether, in most cases this may be not be possible or practical, either because of the physical properties of the location or the cost of implementing the mitigation measures. Smith et al (1995, p. viii) suggest that the aim of flood mitigation should be to 'reduce all forms of flood loss to an acceptable minimum'. In some cases, losses will not be the result of direct damage from inundation, but will arise from the isolation created by the flooding (box 2.1).

BOX 2.1 WEE WAA (NSW)

Mitigation

Ring levee completed in 1978 and augmented in the 1990s.

Flood events

25 floods below the levee height have affected parts of the town over the last 85 years—an average of approximately once every 3.4 years.

Impact

The levee has protected the town and the community from the devastating effects of regular inundation. The levee was constructed in 1978 following repeated flooding in 1971, 1974 and 1976, which resulted in psychological shock, anger and despondency in the community.

The levee has protected the town from repeated inundation, including 3 flood peaks within six weeks in 1998 and the floods in 2000. Without the levee, these floods would have affected around 200 dwellings and many businesses with likely costs of $5-10 million per flood. Small-scale floods can cause substantial damage when they occur frequently.

While the levee now protects the town, the impacts of isolation on business due to long periods of inundation still remain. When normal commercial and other relationships are disrupted, the impact on local and regional economies can greatly reduce community sustainability. A possible solution to this problem is raising some of the back roads to Narrabri.

Source Jim Bodycott, NSW Department of Land and Water Conservation and Chas Keys, NSW State Emergency Service (pers. comm., Dec 2001).

What is regarded as 'acceptable' flood loss will differ between both individuals and communities. Some forms of mitigation can be implemented by individual property owners. For other forms of mitigation—because of their scale and the need for public funding—the trade-off between the cost and the level of protection provided needs to be acceptable to the general community. The diversity of communities means that there will be a range of acceptable risk. The contemporary approach to flood mitigation is for solutions to be driven by community needs. Often, a combination of mitigation measures will provide a better solution than a single measure.

While principally concerned with the economic benefits of mitigation, this report recognises the importance of other benefits. The level of protection favoured by communities is not driven by cost alone, but often by a desire for equity. Communities that are, in general, well protected from flood risk have, in some cases, expressed the equity issue by demanding similar levels of protection for outlying properties. In other cases, the equity issue has been expressed by rejecting flood mitigation measures that provide protection to one location at the expense of increased flooding in another part of the community.

TYPES OF MITIGATION

This chapter examines three approaches to mitigation: flood modification, property modification and response modification. *Flood modification* aims to avoid loss by keeping the water away from development. This is the traditional form of mitigation, provided by structural measures[13] aimed at modifying the flow of floodwater. There has been increasing use of *property modification* measures, which avoid or minimise loss by keeping development away from the floodwater using land use planning or building design, siting and materials. An increasing emphasis on risk management has led to *response modification* measures. These measures seek to modify human behaviour through activities such as awareness campaigns, education, warning systems and planning. This approach recognises that people's reactions to impending floods and warnings have a substantial effect on the losses that subsequently occur. The different approaches to flood mitigation are listed in table 2.1. A brief discussion of flood insurance, which is not considered a mitigation measure in this report, is contained in box 2.2.

Because of the nature of structural mitigation and the frequent need for government funding, flood modification measures can shift the cost of mitigation from land users to the wider community through government expenditure on mitigation. By comparison, some property modification measures, such as building modification, are more likely to be borne by the users of the floodplain.

13 There is some variation in the definition of structural measures. This report adopts the definition used by Smith et al (1995, p. 31). Measures that aim to control the flow of floodwaters are classified as structural, while those that modify development in response to flood risk are classified as non-structural.

BOX 2.2 INSURANCE—MITIGATION OR COST SHARING?

Insurance is considered by some sources as a means of 'personal flood mitigation', reducing the cost of flooding borne by the individual. It is described by Kunreuther and Roth (1998, p. 155) as having 'traditionally served the purpose of reducing the economic impact of individual losses by arranging for the transfer of all or part of the loss to others who share the same risk'. However, in economic terms, insurance does not reduce the costs to the community or coinsured, it merely redistributes the costs. Handmer (1984, p. 5) notes that 'insurance, although often advanced as a non-structural measure, does not by itself reduce flood damage, it acts in the same way as relief to simply redistribute the loss.'

This report defines flood mitigation as those measures that aim to reduce the losses caused by flooding. Because insurance does not directly reduce the damage caused by flooding, it is not considered a mitigation measure in this report. However, this is not to say that insurance is not a legitimate risk management measure.

Insurance does have a number of advantages:

- It can be the best option where the probability of risk is low, consequences are high and people are reluctant to allocate resources to mitigating an event that may not happen, but would have significant consequences.
- The availability of insurance also reduces the cost to the community, providing victims with an alternative source of funds, rather than being reliant on government relief and other forms of assistance. In the United States, FEMA reports that the National Flood Insurance Program has proven to be self-supporting for the average historical loss year.
- By offering reduced insurance premiums to properties for which some mitigation measures have been implemented, insurance can encourage property owners to reduce their risks.

In Australia, residential and small business insurance is not available for most forms of flood. For medium and larger businesses insurance coverage for floods varies from direct damage only to broader business disruption losses.

Whether or not affected property or business owners would choose to take out insurance would depend on their understanding of the risk, the cost of insurance and willingness and ability to pay for mitigation measures.

EFFECTIVENESS OF MITIGATION

It is difficult to generalise about the benefits of any particular mitigation measure from specific events. The Tennessee Valley Authority (TVA) put it well:

> The biggest and most pervasive problem is that the settings in which flood loss reduction techniques are needed vary so widely. Each waterway has

> its own hydrologic characteristics, each floodplain its own morphology, each flood its own duration and intensity and each locality its own social, economic and political attributes, all of which figure in the ultimate effectiveness of a particular mitigation approach. In addition, everything changes over time (TVA 1985, p. 29).

There are some studies that have examined the general benefits of mitigation measures. Research published by Higgins and Robinson in 1981 is among the few comprehensive studies that provide a comparison of the economic effectiveness of various measures (Higgins and Robinson 1981, pp. 9, 17). It is therefore drawn on heavily in the following discussion.

TABLE 2.1 CLASSIFICATION OF MEASURES TO REDUCE FLOOD LOSSES

Classification	*Examples of measures*	
Flood modification	Levees	(Structural)
	Dams	
	Diversions and channel improvements	
	Flood gates	
	Detention basins	
Property modification	Zoning and land use planning	(Non-structural)
	Voluntary purchase or acquisition	
	Building regulations	
	House raising	
	Other flood-proofing	
Response modification	Information and education programmes	
	Preparedness (planning for emergency)	
	Forecasts and warning systems	
	State and national emergency services response	

Source BTRE analysis of information from various sources.

Flood modification measures

Flood modification is largely focused on existing risk and is provided by structural mitigation measures. Historically, the major structural mitigation measure in Australia has been levees, including both larger engineering works built by public authorities and smaller works built by landowners. Levees in Australia have prevented significant damage. A recent stark example is given in box 2.3.

A levee is designed to withstand a particular level of water—this is often referred to as the 'design event'. Levees can provide a high level of protection from flooding where floodwaters do not exceed the design event. In this case, they can prevent widespread losses by excluding water from developed land.

BOX 2.3 GRAFTON (NSW)

Mitigation

Grafton levee (completed in 1970) and South Grafton levees (early 1970s and late 1990s)

Flood events

Grafton—22 floods over the last 160 years, an average of 1 flood every 7 years.

South Grafton—33 floods over the last 160 years, an average of 1 flood every 5 years

Impact

Grafton—Since 1970, there have been 8 floods that peaked above the 6.5-metre level, four of them exceeding 7 metres. Clearly, the levees have saved the town from repeated and periodically severe inundation. Floods before 1970 would not have flooded the town had the levee already been constructed.

South Grafton—14 events on the historical record (or around 1 every 10 years) have involved over-floor flooding of more than 150 dwellings, some up to their eaves. The 1974 flood affected almost 500 properties. The levee built in the 1970s would have protected the town from earlier flooding.

The flood of March 2001, which peaked at 7.75 metres, was successfully kept out of Grafton by the newly-completed levee system. No houses or business premises were inundated and there was no road damage. Without the levee systems in Grafton and South Grafton, the March 2001 flood (the fourth highest flood on record) would have resulted in over-floor flooding in up to 3 500 dwellings and 500 business premises. It is likely that the cost of the March 2001 flood in Grafton without the levees would have been in excess of $200 million. It would also have been necessary to evacuate up to 12 000 people for a number of days. The cost of construction of these levees (probably around $20 million in today's terms) is but a fraction of the damage that would have occurred in the March 2001 flood had they not been constructed.

Source Jim Bodycott, NSW Department of Land and Water Conservation and Chas Keys, NSW State Emergency Service (pers. comm., Dec 2001).

However, levees can be breached or overtopped. If a community places too much faith in a levee and fails to evacuate or move items to safety when flooding is likely to exceed the levee height, this will lead to an increase in damage. If the existence of a levee leads to increased development behind the levee, there is subsequently a greater potential for damage (referred to as the 'levee paradox')[14].

14 See Smith et al 1995 for further detail on the 'levee paradox'.

There are few studies that have evaluated the effectiveness of structural mitigation after it has been tested by a flood. The majority of studies reviewed that have evaluated the economic or financial value of mitigation were based on hypothetical rather than actual events. Australian and overseas work includes the following:

- The Victorian Department of Conservation and Natural Resources[15] commissioned a study to review floodplain management (Water Studies 1995). The report estimated that major levees in Victoria (excluding private rural levees) reduce the total urban AAD by about 10 per cent and the total rural AAD by about 10-30 per cent. This equates to savings of some $100 million over a 25-year period in urban and rural damage, based on current levels of development (Water Studies 1995, p. 14). An example of the savings arising from Victorian levees is given in box 2. 4.
- Granger et al (2001) examined dams as part of their investigation into risk in south-east Queensland. They found that although Wivenhoe and Somerset dams are the principal flood mitigation control in the Brisbane River system, 'their presence alone is not sufficient to prevent major flooding in some situations' (Granger et al 2001, p. 9.13). This evaluation focused on the effectiveness of the mitigation and did not consider the financial benefits of the dams.
- Higgins and Robinson (1981) noted that the benefits of small levees or walls ranged from less than the cost of implementation to significant savings of more than 20 per cent of the value of the structure they protected. This suggests that each case would need to be examined before assuming the benefits will outweigh the costs. They also investigated the cost-effectiveness of river improvement works, concluding that each location would have its own unique characteristics and that costs or benefits per kilometre are not generally transferable.
- Overseas, the US Army Corps of Engineers (USACE) has done considerable work in evaluating the impact of structural works and emergency activities. In 1999, it calculated that damage prevented was worth $US 21.2 billion, close to the ten-year average of $US 22.3 billion (USACE, 1999).

In general terms, there are some conclusions that can be made about the benefits of flood modification measures. There seems to be a consensus that larger-scale structural measures are most cost-effective when they protect a large number of properties. Water Studies (1995, p. 15) found that the benefit-cost of levees around provincial urban areas was much higher than for the levees in rural areas. Higgins and Robinson (1981, p. 7) also reported that mitigation measures become more economical as more properties are protected by the measure, spreading the cost and sharing the benefits of larger

15 Now the Victorian Department of Natural Resources and Environment (VDNRE).

BOX 2.4 WANGARATTA (NORTH-EAST VICTORIA)

Mitigation

Ring levees, diversion channel, house raising, stream works

Flood event

October 1993, 125-year Average Recurrence Interval (ARI)

Impact

95 urban dwellings were flooded above floor level.

Without the mitigation, more than 275 dwellings would have been flooded.

The damage bill for this flood event has been estimated at $2.1 million.

Without the flood mitigation scheme, damage would have been at least $6.1 million (2001 prices).

Source Ian Gauntlett, Department of Natural Resources and Environment (pers. comm., Dec 2001).

measures. They referred to this as 'collective mitigation'. However, they also cited research showing that structural mitigation is most useful in protecting agricultural land subject to flooding during the growing season as well as densely developed urban land. Boxes 2.5 and 2.6 highlight the effects of flooding on agricultural land in some Australian examples.

The literature on flood modification measures is also consistent in raising a number of possible drawbacks. These include the possibility of causing increased flooding elsewhere, adverse environmental impacts and the creation of a false sense of security.

Property modification measures

Property modification has two aspects—remedial to address existing risk and preventative to address future risk. Some measures also deal with continuing risk. Property modification is the only one of the three approaches to flood mitigation to focus on future risk. (While flood modification measures may also provide protection for future developments, they address existing flood problems.) Property modification measures address future risk through land use planning to prevent incompatible land uses in the floodplain and through building regulations covering the design and materials of proposed construction. Property modification measures can also address existing risk to developments already on the floodplain, although this is more costly. House raising and flood-proofing can be appropriate where flood conditions are not too dangerous. Acquisition (and demolition) or relocation of existing properties are more appropriate measures in frequently flooded or high-hazard areas of the floodplain.

BOX 2.5 GOONDIWINDI (QUEENSLAND)

Mitigation

Levee on Macintyre River.

Flood events

More than 60 major floods have occurred since 1886. In 1956, Goondiwindi experienced 3 major floods within 6 months, which prompted the building of levee banks to protect the town. The 1976 flood of 10.5 metres stood as Goondiwindi's record until January 1996 when the Macintyre River reached 10.6 metres. Major flooding close to the 1996 level was also experienced in 1998.

Impact

Evacuation of more than 4 000 people and substantial property damage was avoided due to the levee. However, the 1996 floods caused more than $2 million of damage to livestock and property in the Goondiwindi area.

Source Ken Durham, Queensland Department of Emergency Services (pers. comm., Dec 2001), http://www.abs.gov.au/, http://www.bom.gov.au/ and http://www.ema.gov.au/.

BOX 2.6 CARNARVON (WESTERN AUSTRALIA)

Mitigation

Levee system

Flood event

March 2000

Impact

The town of Carnarvon and its plantation areas are located at the mouth of the Gascoyne River. The catchment of the Gascoyne River is the largest in Western Australia, with an area of approximately 72 000 square kilometres and extends approximately 600 kilometres to the east of Carnarvon.

The town itself, with a population of 7 000, is well protected from major river flooding by an extensive levee system. However, the surrounding plantation areas have minimal flood protection and are prone to severe flood damage. A flood in March 2000 (estimated to be a 25-year ARI flood) caused $20 million of damage to agricultural, residential and commercial property and infrastructure in the unprotected areas. No damage occurred in the CBD and residential areas.

Source Rick Bretnall, WA Water and Rivers Commission (pers. comm., Dec 2001).

In contrast to flood modification measures, property modification measures are more commonly reviewed after implementation than before. Without the large up-front cost of measures such as levees and dams, there appear to have been fewer requirements to justify the expenditure using techniques such as BCA.

Millerd et al (1994, p. 18) pointed out that most non-structural programmes are less expensive, less inequitable and less environmentally intrusive than structural mitigation. Smith et al (1995, pp. 109, 111) considered building modification (acquisition, raising, flood-proofing) 'the best cost-effective mitigation measure' and suggested that property modification measures are considerably less expensive than flood modification. Foster (1976, cited by Millerd et al 1994, p. 18) noted that, in economic terms, property modification measures place the cost of the flood risk on the land, because without flood protection lower property values may be placed on flood-prone land.

Higgins and Robinson (1981) considered the economic effectiveness of a number of measures and concluded that what is cost-effective within the 20-year average recurrence interval (ARI) flood zone may not be appropriate in less frequently flooded zones. As an example, they recommended acquisition of existing structures in frequently flooded zones, while in less frequently flooded zones they suggested the less costly option of acquiring only undeveloped land. Along with varying flood frequency, particular areas will be affected by differing flood depths, velocities, evacuation issues, land values and other aspects that will modify the effectiveness of these conclusions.

Land use planning

Clearly, restricting development to areas outside the floodplain will avoid losses caused by flooding. This approach is examined in the Katherine case study in appendix I. The literature on land use planning as a form of flood mitigation has some consistent themes. Chief among these is that land use planning has the potential to prevent a problem before it arises and is less costly than remedial measures implemented once a flood-prone area is developed. Land use planning is one of the few mitigation techniques that addresses future risk.

By implementing planning laws, governments have a means of preventing inappropriate development in floodplains. The benefits of land use planning measures in Victoria were calculated by Water Studies (1995 p. 15). Recognising that considerable pressure can be exerted to develop floodplains, Water Studies estimates that strict planning measures would reduce growth of development on flood-liable land from 1.5 per cent to 0.5 per cent. This could equate to savings of around $100 million over 25 years. The reduced development in high-risk zones is further demonstrated in box 2.7.

In comparing land use planning across various locations, Higgins and Robinson (1981) found it is most effective in rapidly urbanising areas, where it could

BOX 2.7	LISMORE (NSW)

Mitigation

Development controls

Flood events

Many (most recently in 2001)

Impact

Development controls have been in place in much of NSW since the late 1970s and have reduced the increase in potential flood damage and danger to personal safety. They have also led to fundamental changes in some NSW towns, with development being steered away from flood-prone areas. A prime example is the extension of Lismore to higher land, which has resulted in opening up new residential and commercial areas away from central Lismore and the Wilson River floodplain. This has effectively capped flood damage levels in Lismore during a period when it was growing substantially.

Source Jim Bodycott, NSW Department of Land and Water Conservation (pers. comm., Dec 2001).

prevent construction in high-risk zones. They suggested that the most efficient land use planning regime would prohibit all development on land subject to frequent flooding. Areas with less frequent flooding could be zoned for selected, flood-compatible purposes or as open space, but residential uses should be excluded. This demonstrates an interesting contrast in the treatment of residential and non-residential land use revealed by the literature search. Although residential damage can be far outweighed by commercial and industrial damage, the attention of flood mitigation appears to be strongly focused towards residential protection.

The benefits of most mitigation measures can be assessed by the damage avoided by their implementation. Land use planning creates other benefits when the land is put to more flood-compatible uses, encouraging particular development such as open space and other community facilities. Other, non-monetary impacts include environmental benefits, such as the preservation of wetlands. Smith et al (1995) suggest that despite the difficulty in valuing the benefits of land use planning, the benefits 'are substantial and far outweigh those of any other mitigation measure, structural or non-structural' (Smith et al 1995, p. 107).

There are differing ideas about how the costs of land use planning for flood mitigation should be measured. Higgins and Robinson quote Lind (1967), who argued that land use planning only has economic value if occupiers do not expect to incur flood losses, as the land would otherwise be discounted to take into account the expected losses (cited by Higgins and Robinson 1981, p. 12). Higgins and Robinson suggest that the cost of land use planning should be measured by the loss of value or income from the land in its alternate use

(Higgins and Robinson 1981, p. 12). However, this applies only if the issue involves the zoning of a particular parcel of land. This approach would not be relevant in situations like the Katherine case study, where the decision involved which parcel of land was to be released for development. Handmer makes the point that the cost of land use planning is potentially a major expense if measured as the cost of forgone use (Handmer 1984, p. 209). A simpler, if less economic, approach is used in the overseas example of the Canadian-Ontario Flood Damage Reduction Program, which includes the engineering cost of the flood study, the public information process and an amount for overheads and administration (Millerd et al 1994, p. 21).

Acquisition (voluntary purchase)

Acquisition and land use planning have similar outcomes. Acquisition provides a permanent solution to an existing flood problem and removal of risk to life (addressing existing, future and continuing risk). Land use planning, by preventing incompatible development, comes at virtually no cost to the planning authority. By contrast, removal of existing development—through voluntary purchase, acquisition or relocation programmes—can be much more expensive. Acquisition has been described as a relatively expensive measure to implement, but one providing the ideal solution to the problem of existing development in high-hazard areas (Smith et al 1995, p. 39).

There are three common circumstances where communities are more likely to implement voluntary purchase schemes: immediately after a flood; where structural mitigation is not feasible; or to achieve environmental and other objectives (Burby and Kaiser 1987, p. 13). For example, where alternative options such as levees are not appropriate due to adverse impacts on other residents or where slab on ground houses cannot be raised, voluntary purchase can often be a suitable mitigation solution.

In Australia, acquisition for flood mitigation purposes is usually achieved through voluntary purchase. Fairfield City Council (in New South Wales) has one of the largest and most successful combined voluntary acquisition and house raising programmes in Australia. Following floods in 1986 and 1988, hundreds of properties have been purchased or raised through the programme. This has reduced exposure to flooding and increased community sustainability (May et al 1996, p. 183). Another example is given in box 2.8.

Some reports from the United States look at a related measure—relocation—where the land is acquired and the residence is physically moved to a new location. This is not common practice in Australia, where a property is generally voluntarily purchased, allowing the owners to buy elsewhere. Relocation can be limited as an option by the lack of available land. Often land released for new development is subject to covenants restricting the use of second-hand materials and other similar impediments.

BOX 2.8 GUNNEDAH AND CARROLL (NSW)

Mitigation

Voluntary purchase and voluntary house raising to 1 per cent annual exceedance probability (AEP).

Flood events

17 floods since 1892, an average of about 1 every 6 years.

Impact

The 1 per cent AEP flood inundates about 160 dwellings and much of the CBD.

Over 200 residential and commercial premises were affected by flooding in 1998, some on multiple occasions, with the Department of Community Services providing assistance to 186 families.

The voluntary purchase and voluntary house raising scheme aims at reducing the number of dwellings affected by flooding above floor level and improving personal safety. However, the scheme does not reduce damage to public infrastructure. Some houses have been removed and a few raised, but most of the dwellings built in the flood-liable area still remain.

Source Jim Bodycott, NSW Department of Land and Water Conservation and Chas Keys, NSW State Emergency Service (pers. comm., Dec 2001).

BCA of voluntary purchase is made more difficult by some of the social issues relating to occupants of the floodplain. In some cases, housing on the floodplain is more affordable and attracts a high percentage of low income earners.

> By whatever established poverty criterion is employed … the acquisition areas contain exceptionally high proportions of poor people—of people socially and economically disadvantaged (Handmer 1984, p. 266).

Handmer (1987, p. 212) presented the case for voluntary acquisition by establishing where and how the strategy should be implemented. In Lismore, he found that acquisition is economically viable for properties lying below the 1 in 5 year ARI flood level. This result is consistent with similar USA studies. Two other case studies considered by Handmer were found to be marginal in benefit-cost terms when the same 1 in 5 year ARI flood level criteria were applied (Echuca and Wagga Wagga). However, the results of the analysis varied considerably depending on the assumptions employed. For example, using potential rather than actual damage avoided and applying a lower discount rate would improve the results.

In investigating acquisition (or permanent evacuation) Higgins and Robinson (1981) found the measure to be effective where other measures are uneconomic. They found it was most suited to areas with a high frequency of flooding or a large variation between the 10-year and 100-year ARI flood. The authors cite Johnson (1976), who found that this option provided a positive benefit-cost ratio (BCR) in Atlanta higher than that for structural measures in the same area. This finding highlights an interesting variation between Australian and overseas examples of acquisition programmes. In Australia, acquisition typically has lower BCRs compared to alternative solutions. The literature review provided examples from the USA where acquisition was said to be cost-effective, paying back costs within just a few years.

- In North Carolina, acquisition (relocation) and property raising schemes were tested by hurricanes Denis and Floyd, which occurred ten days apart in 1999. Reviews of the schemes found they were successful in avoiding significant damage in these events. In the counties of Beaufort and Kinston-Lenoir, acquisition and house raising of over 200 properties were estimated to have saved around $US9 million in reconstruction costs, damage to building contents and displacement costs. The average savings exceeded the costs of implementation (North Carolina Emergency Management Division (NCEMD) 2000, pp. 25, 28).
- Record floods in the State of Missouri caused damage costing around $US3 billion in 1993. Following the flood, in response to community reaction the State took the opportunity to implement a large acquisition programme. For example, the Lincoln County acquisition project cost $US3.5 million or around 45 per cent of the federal outlay for the 1993 flood. When major flooding hit Missouri again in 1995, more than 2 000 families had been moved out of harm's way. The programme is said to be cost-effective and already paying for itself (State Emergency Management Agency 1995).

These examples show that the benefits of removing properties from the floodplain can outweigh the costs in a short time. A related example from Texas shows the costs of not removing properties from the floodplain when they are subject to recurrent damage. One home in Texas, valued at $114 500, has received 16 flood insurance payments of $806 600 over 18 years (National Wildlife Federation 1998, p. x).

The question remains: why is acquisition apparently more cost-effective in the USA than in Australia? It may be argued that the USA locations suffer from very damaging events. Clearly, the combination of hurricanes and flooding will cause more damage than floods alone. However, some areas of Australia experience cyclonic conditions and could expect similar damage. It may also be that the USA economic analyses are not initially constrained by financial limitations and therefore include a comparison of all mitigation options including those that are infeasible or prohibitively expensive. The USA reports reviewing the cost-effectiveness of acquisitions all use financial damage—replacement cost—rather than economic cost as used in BCA. This probably explains some of the differences. French and Associates Ltd (2000) found the following:

> Acquisition and relocation of flood-prone buildings is more effective at reducing flood losses than any other approach. Using the replacement cost of the flooded buildings, the theoretical benefit/cost ratio was 1.3:1. Using actual

> experience, 1996—1999, FEMA and the community had a payback in three years (French and Assoc. 2000, p. iv.).

Debate exists over whether the financial or economic cost of damage is more appropriate in deciding whether mitigation is cost-effective. While use of the economic cost represents the cost to the community and discounts the value of the asset already consumed, the financial cost of flooding represents both the cost to individual entities and the actual amount required to replace many assets, including property. Both approaches are useful and have a place in measuring the value of mitigation. The appropriateness of each depends on the perspective taken—the individual or society. As this report is predominantly focused on government spending and benefits to society as a whole, the case studies in this report have been limited to an examination of the economic benefits of flood mitigation.

BCA can be useful in evaluating whether the tangible costs of voluntary purchase are justified by the benefits. However, given that the overriding reason for voluntary purchase is to avoid risk to life (an intangible cost that BCA of flood mitigation does not adequately capture), safety criteria such as those suggested by Handmer (water depth and velocity, warning time and isolation risk) play a critical role in determining whether acquisition is warranted (Handmer 1984, p. 173). In Australia, voluntary purchase is most often implemented in high-hazard areas where alternative mitigation solutions are not feasible.

Building regulations, house raising and flood-proofing

Building construction, siting and design can exclude floodwaters by using flood-proof materials or by raising habitable areas above a given flood level—often the 1 per cent annual exceedance probability (AEP) or the largest known flood in the area. Setting minimum floor levels is considered in the Thuringowa case study in appendix III. House raising and flood-proofing can be incorporated into new constructions as a requirement of building regulations or be implemented after construction, usually at the choice of the home-owner. However, the Building Code of Australia does not currently include any regulations for residential buildings in areas subject to floods. In the case of building design, the responsibility and cost fall on the property owner to a greater degree than for any other mitigation measure.

Building regulations only address internal damage, doing little to reduce external losses or risk to life. A consistent theme in the literature is that this measure is not considered suitable to address floods with high velocities. Furthermore, the effectiveness of minimum floor levels is limited to the design event. Difficulty for existing buildings arises when this event is exceeded, particularly when subsequent flooding leads to a revision of the design level.

In the USA example involving the raising of properties in Beaufort County cited earlier, it was calculated that one-third of the properties that had been raised would otherwise have been substantially damaged. House raising avoided the need to demolish and rebuild the properties (NCEMD 2000, p. 25). In another overseas study, the USACE compared the costs of different measures—acquisition and demolition, relocation, house raising and a combination of house raising and utility relocation—for a single property. House raising was found to be most economical (TVA 1985, p. 18). However, this study applies to only one property, with a given flood liability. Furthermore, the study was done in 1977 and cost ratios are likely to have changed. The lesson from this study is that, if possible, all methods should be considered to find the optimal solution.

Penning-Rowsell and Smith (1987) investigated the economics of house raising in Lismore (New South Wales). They found that house raising is economically worthwhile in terms of tangible flood damage reduction only for areas subject to fairly frequent flooding (Penning-Rowsell and Smith 1987, p. 187). More than 90 per cent of properties on the Lismore floodplain have been raised. Penning-Rowsell and Smith (1987) illustrate that house raising in Lismore has been a useful self-help approach to flood mitigation.

Higgins and Robinson (1981) found the use of flood-proof materials was economically effective and was suitable for new constructions where funds were limited. They suggested flood-proofing should be essential for existing structures that cannot be moved and that are located within the 20-year ARI flood zone. They also recommended flood-proofing for new construction and hazardous buildings subject to less frequent floods (up to the 100-year ARI). By comparison, elevating new structures had benefits that at least matched the costs in all situations and had potential benefits that outweighed costs threefold. It is relatively cost-effective to incorporate flood mitigation measures into buildings in the construction stage.

It is possible to place timber houses on piers or stumps after they have been built, although it is more expensive than if it had been done during construction. In 1976 and 1978, the USACE found the cost-effectiveness of elevating a structure depends on the combination of structure value, frequency of flooding and potential for high damage (quoted in TVA 1985, pp. 15, 19). While it is not usually practical to raise brick houses, they can be flood-proofed. In discussions with governments offering financial assistance with house raising and flood-proofing, the experience is that this is usually more expensive than people expect (Rick Bretnall, WA Water and Rivers Commission, pers. comm., August 2001). The value of an existing building will be a major factor in deciding whether it is worth implementing these mitigation techniques.

Flood-proofing non-residential properties can have significant effects. In researching this issue, Wright (2001) sampled 169 commercial properties in Keswick Creek (South Australia). He found that 50 per cent of damage could be avoided by implementing relatively low-cost physical flood-proofing measures. Interestingly, 76 per cent of estimated damage in the 1 per cent

AEP were incurred by just 21 properties (Wright 2001, p. 128). In this case, flood-proofing of these 21 properties was considered to be more valuable in reducing losses in the area than installation of a flood warning system. The effects of flooding in commercial and industrial areas is considered in the Tamworth case study in appendix V.

The hazard the property is exposed to, including the probable water depth, velocity and evacuation routes will also play a role in determining if house raising is a suitable mitigation method. McCoy (1976) found that house raising was more cost-effective where there is a small difference between the depth of the 100-year and 10-year ARI floods. Higgins and Robinson (1981) added that house raising was most suited to areas that are subject to more frequent flooding than the 10-year ARI.

In cases where the property cannot be raised or flood-proofed, some protection can be provided by temporary measures such as sandbagging or sealing openings. This may be the most cost-effective measure for low-value properties that do not experience frequent flooding or rapid water flows and are located in areas where the difference between the 10-year and 100-year events is not great.

Response modification measures

Flood and property modifications are designed to be effective in a particular flood. Once these mitigation measures are in place to reduce losses, there is very little more that can be done to existing structures that will change the outcome of a flood after the event has started. By contrast, human action or inaction can greatly alter the outcome of a flood. Preparation and emergency planning will make flood response more effective. Sufficient warning will allow people time to act on plans, for example, by lifting and relocating valuables. Understanding the most appropriate time to evacuate can mean the difference between life and death. Response modification is the major measure for targeting continuing risk, especially with respect to catastrophic events.

Flood Warning Systems

The existence of a reliable Flood Warning System (FWS) will increase the community's time to respond to an emergency. The usefulness of the FWS will depend on the nature of the catchment area and the flood itself. Rate of rise will be an essential factor, as a short warning time may preclude the use of any measures requiring human intervention. However, as flood warnings provide the opportunity for action to be taken to reduce damage, the FWS critically depends on human reaction to be effective (Higgins and Robinson 1981, p. 12). It is also important to ensure a FWS is well maintained for accurate forecasts and effective warnings.

Studies on the benefits and costs of FWSs agree that most cost a relatively small amount of money and, in return, allow authorities to respond appropriately and provide an opportunity to reduce avoidable losses. Smith et al (1992, p. 2) found that flood warning is one of the major non-structural measures used to mitigate flood losses. They stated: 'the cost-benefit ratio for urban flood warning systems is extremely favourable. Indeed, investment in urban flood warning systems is likely to be the most cost-effective flood mitigation strategy'. Although the benefit of a FWS is difficult to measure, due to the problem of assessing the level of response of those receiving the warning, the benefit obtained from reduced tangible damage exceeds the cost of installation and maintenance (Smith et al 1995, p. 98).

In benefit-cost terms, only a small amount of damage needs to be reduced to make a FWS worthwhile. In human terms, it allows people to save their lives and their most valuable and irreplaceable assets. Although it is difficult to place a value on these intangibles, most people would agree that it would exceed the cost of installing a FWS. Penning-Rowsell and Handmer (1986, p. 18) make the valid point that 'the assumption that there is some form of acceptable trade-off between performance and cost … may be invalid given that many warning systems may exist primarily to reduce intangible flood damages including the threat to life'.

Higgins and Robinson (1981, p. 11) quote research evaluating the economic benefits of a FWS for Brisbane, estimating a BCR in excess of 6, based on costs and developments at the time. At the time, this value was expected to decrease with further flood storage provision upstream of the city and increase with continuing development on the floodplain.

The literature evaluating the benefits of FWSs suggests that they are useful regardless of the level of experience in the community. The relationship between warning times, flood awareness and reduced damage has been well documented. An experienced community can avoid a considerable proportion of potential damage. As warning times increase, more items can be saved. Regardless of experience, work prepared for VDNRE (2000, p. 22) suggests that two hours of warning is required to effect any real damage reduction, with 12 hours warning time allowing maximum savings to property. Higgins and Robinson (1981) found the maximum benefit occurs where there is a large difference between the total possible flood damage and the value of items that can be raised. In their research they quote a case study showing a BCR of 6 for under-prepared communities and an estimated saving of 30 per cent where a warning time of 8 hours can be provided (Higgins and Robinson 1981, p. 12).

In a study of the 1986 floods in Tamworth[16], Smith (1986) notes that a number of businesses undertook measures such as raising stock and moving vehicles to higher ground in response to early warnings, while other businesses were

16 Tamworth is revisited as a case study following flooding in November 2000.

unable to prepare. When comparing the damage suffered by similar enterprises, he estimated that the savings as a result of preparation were close to 70 per cent of the potential damage. This illustrates that 'tangible savings in the commercial sector can be very large if the warnings are received and acted upon' (Smith 1986, p. 14).

In 1985, the TVA held a seminar to promote the review of mitigation systems, largely to determine which measures are most effective. The review of literature in that publication concerning the effectiveness of FWS is summarised in table 2.2. An important point made by the TVA (1985, p. 65) is that FWS can be implemented by communities with limited access to funds. Recognising that resources are limited, this may be the best option for a community, providing a solution much earlier than would be possible if funds need to be raised for significant structural measures. Flood warning systems may also be the only practical or cost-effective strategy, particularly where there is a low probability of flooding (Penning-Rowsell and Handmer 1986, p. 1).

TABLE 2.2 LITERATURE CONCERNING THE EFFECTIVENESS OF FWS

Report quoted	*Finding*
Owen and Wendell, 1981	• Advance warning is expected to enable a 25 per cent reduction in total damage in one town in Texas. • Officials at Vandenburg Air Force Base estimate that early warnings will cut losses from a flood of the same magnitude as a previous flood by one-half. • 350 automobiles were saved by moving them to higher ground. • At least $25 000 was saved by not overreacting to a potential flooding situation. • A 10-hour advance warning resulted in millions of dollars of savings.
Bartfield and Taylor, 1980	• A $50 000 ALERT system prevented $5 million in damage from a flood that occurred in Ventura County, California in 1980.
Bond, no date	• About $1 million was spent to install satellite telemetry for flood forecasting and state officials believe the system pays for itself whenever 50 mobile homes or 200 automobiles are moved out of the path of a flood.
Susquehanna River Basin Commission	• In the Lycoming County FWSs coupled with flood-proofing measures have reduced damage by 90 per cent.

Note Amounts quoted are US dollars and have not been updated to current values.
Source TVA (1985, pp. 12, 15 and 62).

Education and community response

Regardless of the warning provided, the crucial factor in FWS is human response. Smith put it well when he asked 'what proportion of the population will take advantage of the increased warning time?' (Smith 1986, p. 5). Community response plays a major part in flood mitigation. This is particularly relevant where flood and property mitigation measures alone are insufficient to eliminate damage. People need to respond to protect life and property in cases where water cannot be directed away from developed land or where flooding will exceed the design event. Well-informed and prepared communities are able to create significant savings by lifting belongings above the flood height or moving property to safety. Public education can play a part in influencing the community to respond in an appropriate fashion.

However, in many cases, the community will not respond to advice or direction from authorities. Penning-Rowsell and Handmer (1986, pp. 17, 27) considered the possible reasons for failure to respond to warnings. There was evidence that the factors affecting the individual's need to seek confirmation of the warning—such as the sources of the warning and its credibility and frequency—have a strong impact on whether the warning will be effective. Other factors include the individual's distance from the threat (an increased distance leading to a reduced response), past experience, time to prepare and family composition. Finally, individuals need the ability to respond adequately to the warning. The factors likely to affect warning response are summed up well in Penning-Rowsell and Handmer (1986, p. 28).

In an overseas example, FEMA was interested in people's reactions to public information campaigns (French and Associates 2000, pp. 11, 14). A survey compared two areas, only one of which had been the target of a public information campaign. Of the people surveyed who had been exposed to the campaign, 54 per cent had taken some measure, compared to only 11 per cent of those who had not been targeted. Yet, there was little indication that the information campaign was the source of information that people used to implement mitigation measures. Many people (44 per cent) replied that they had 'figured it out' without assistance from information campaigns.

Granger et al (2001 p. 9.57) discovered that community awareness of flooding in south-east Queensland is generally poor and provided the following common examples of misperceptions:

- A 1 in 100-year flood occurred 20 years ago, therefore another flood of that magnitude will not occur for another 80 years.
- Only buildings which fall within the 1 in 100-year flood line are at risk of flooding and those buildings which fall outside the 1 in 100-year line will never be flooded.
- Because it has not happened before it cannot happen.
- Construction of a levee has made the area behind it flood-free.

CONCLUSIONS

Despite growing interest in the effectiveness of mitigation measures and a desire to establish if expenditure has been cost-effective, the literature review has revealed that *ex post* studies of flood mitigation are not common. Flood modification measures are more likely to be evaluated before implementation, largely due to a need to allocate scarce resources to projects that will have the most impact. It has been more common for property modification measures to be examined for their effectiveness after being tested by flooding.

Other common themes arising from the literature review were:

- Mitigation needs to suit the circumstances—including physical properties of the floodplain and the priorities of the community.
- It is generally not possible to transfer the benefits of a given measure in one location to other areas with different physical and flooding characteristics.
- Flood modification measures are most effective where they protect a large number of properties from flooding. Both the costs and potential savings are high. However, the limitations of these larger structural measures (for example, the 'levee paradox') need to be recognised.
- Property modification measures can provide protection from flooding up to the level for which they are designed. Other than acquisition, property modification measures are usually relatively low-cost and the costs are often borne by the users of the floodplain. Voluntary purchase (acquisition), while more expensive, is a permanent solution to existing problems.
- Response modification measures (such as warning systems) particularly target continuing risk, especially catastrophic events. They are relatively low-cost options with the potential to save lives and property. However, these measures depend on the appropriateness of people's response to be successful.

chapter 3

OUTCOMES OF CONSULTATIONS

In May and June 2001, the BTRE in conjunction with representatives from the Natural Disaster Management Section of the Department of Transport and Regional Services and Emergency Management Australia consulted with key individuals involved in flood mitigation in each State and Territory.

During this consultative phase of the research, much valuable information and ideas were exchanged. The main purpose of this chapter is to document the outcomes of the consultations. In order to capture the information shared and ensure that the process of selecting the case studies is as transparent as possible, the similarities and differences across jurisdictions are discussed along with the possible case studies suggested at the meetings. The BTRE has attempted to accurately represent the views expressed in the consultations and follow-up discussions. The BTRE has not commented on the views expressed, except where a position had to be taken for the purposes of this report.

Although some of the differences in approach to floodplain management among jurisdictions are brought out, this chapter does not attempt in depth coverage of prevailing policy and legislative settings in each jurisdiction. However, it is important to keep the different policy and legislative frameworks in mind when considering the following discussion and the results of the case studies presented later in this report.

THE CONSULTATION PROCESS

Appendix VI contains details of consultation dates and lists the organisations involved.

A discussion paper providing background information on the objectives, origin and approach of the project and outlining the information requirements was distributed to all States and Territories in April 2001. This paper formed the basis for the consultations and information collection that took place in the meetings held in May and June 2001.

Questions asked

The general questions listed below were used as a starting point. Discussions were not limited to these questions and usually covered a diverse range of subject areas.

1. What is your flood management policy?
2. What flood mitigation measures do you use?
3. How do you identify possible measures?
4. How do you choose the most appropriate measures for each situation?
5. How do you measure the success of flood mitigation? What are the current problems faced?
6. What would be the ideal way to measure the success of flood mitigation?
7. Any suggestions or comments on the proposed project approach?

To identify possible case studies, participants were asked whether they had any examples of an area that had suffered historical floods (the cost of which was quantified in some form), subsequently had a mitigation measure implemented (including predicted savings that would result) and had thereafter experienced significant floods.

The responses received to these questions are summarised below.

GENERAL THEMES

Discussed below are a number of common themes that arose during consultations with States and Territories. It is important to note that there were some exceptions to these general views.

Land use planning decisions and design levels for mitigation works are generally based on the 1 in 100-year flood level. Typically, below the 1 in 100-year level, new development approvals are either not given or are restricted with conditions. Protection for existing development is typically provided up to the 1 in 100-year level.

The 1 per cent AEP level was recognised as a moving target that is modified as and when more information becomes available. Revisions of the 1 per cent AEP level as information improved were widespread. The accuracy of the risk assessments (such as the probabilistic return period of a given event) was raised as an issue. In examining the cost-effectiveness of mitigation, it is important to recognise the uncertainty surrounding the risk assessment process.

Many jurisdictions noted that there had been very few major floods in the last 10 to 50 years. Consequently, community awareness and knowledge of floods are generally poor. The general consensus was that it was often necessary to have a significant flood before the community and governments saw mitigation as a priority. However, it was also noted that having experienced a significant flood, poor community understanding of the 1 in 100-year terminology can lead communities to incorrectly believe that they will not experience another significant flood in their lifetime. The importance of increasing the awareness of floods as a continuing risk was therefore stressed.

All jurisdictions emphasised an increasing focus on non-structural measures, particularly land use planning, as the core mitigation strategy targeting future risk. However, given that the impact of planning is limited to new developments, the importance of an overall floodplain management strategy, encompassing a mix of approaches to deal with flood problems, was also stressed. Flood warning systems are the other key non-structural mitigation measures used extensively across Australia. Warning systems were generally seen as a very cost-effective measure. However, it was also stressed that the effectiveness of warning systems depends heavily on the community response to the warning.

Criteria for choosing mitigation measures generally included technical appropriateness, affordability, some form of economic analysis and community views. Social and environmental factors were also included. In many jurisdictions a formal prioritisation process, including BCA, is in place. A trend toward choosing a package of structural and non-structural measures and moving away from relying on a single measure (typically a levee) was evident in all States and Territories. The importance of community understanding and support were stressed as fundamental to the assessment of mitigation options.

In general, the economic effectiveness of mitigation measures is not formally assessed after measures are put in place. Mitigation measures are planned, designed, funded and implemented, but there is typically no formal evaluation after implementation to complete the cycle. Lack of resources and the complexity of the task were the main reasons provided. In some areas, informal evaluations of technical aspects and community views did take place. Where evaluation did occur, it typically concentrated on the shortcomings rather than the benefits of mitigation. The focus on shortcomings is an understandable and important part of using past events to learn lessons in order to improve future mitigation.

Common problems associated with flood mitigation were:

- Lack of funds—all jurisdictions identified this as the primary factor preventing further investment in flood mitigation. Local councils, in particular, argued that their resources were insufficient to meet current funding arrangements for flood mitigation. The difficulty associated with accurately costing proposed works before the detailed designs are completed was also stressed as a problem in flood mitigation funding applications.
- Inadequate community awareness—the high turnover of population in most areas was identified as the main obstacle to community awareness

and therefore education programmes needed to be ongoing. The high turnover also means that local flood knowledge is not being retained.

- Diverse communities—communities are not homogenous. The conflicting values of different community members create difficulties in reaching a mitigation solution satisfactory to the whole community. Varied community pressures can make the mitigation process complicated and somewhat lengthy. However, effective community consultation was also regarded as crucial to achieving a successful mitigation outcome.
- Urban infill and higher density redevelopment are commonly advocated by governments as a means of revitalising older urban areas and optimising the use of existing infrastructure. Although such objectives are sound, problems have arisen where urban renewal is on flood-prone land. This is a sensitive issue for governments and involves difficulties in exercising controls. It is usually cheaper to infill rather than incur the costs (such as for infrastructure and services) of new developments. However, infill development can lead to more people at risk on floodplains and can increase run-off and worsen future flood problems. Planning and building codes (such as floor level requirements) can help control infill development in flood-prone areas.
- Uncertain legal liability and court outcomes were major issues in most jurisdictions. Numerous examples of councils rejecting development applications on the grounds of the land being flood-prone—only to have decisions overturned in the courts—meant that many inappropriate developments were still going ahead. Such a situation diminishes a council's ability to continue fighting inappropriate development. Other legal issues concern a council's duty of care obligations in terms of protecting the community from flooding and ensuring that any mitigation measures do not adversely affect other areas. That proposed structural mitigation works do not adversely affect surrounding areas is now a common condition for their approval.
- Political pressures, in terms of obtaining and prioritising funding across the different areas in need, were mentioned by most parties as a potential problem.
- The uncertainty of information used as a basis for decisions (such as the extent of flood risks, historical and potential damage and the effectiveness of different mitigation measures) was raised by many participants. This uncertainty is also reflected in difficulties associated with legal liability discussed above.
- Coordination between the different parties involved in floodplain management was identified as a problem in many areas. Sources of flooding are typically not confined within discrete local government boundaries, meaning that effective floodplain management decisions often require coordination in order to address a problem. Confusion regarding roles and responsibilities (often stemming from policy and legal ambiguity)

can make the process difficult. This is particularly the case if flooding in one area is the result of activities in another area.

As stated earlier, there are always exceptions to the norm. The common themes discussed above do not apply consistently across Australia. An example illustrates this point. The Rural City of Wangaratta in Victoria has:

- suffered frequent flooding;
- evaluated the effectiveness of mitigation;
- good records of past flood history and continuity of ownership of this knowledge;
- good community awareness of flood issues; and
- good coordination between key parties.

DIFFERENCES ACROSS JURISDICTIONS

Despite the considerable number of common themes that emerged during the consultations, there were also significant differences across Australia. The major differences are discussed below.

Floodplain management policy

Approaches to floodplain management policy varied substantially across Australia, from being virtually non-existent to having a comprehensive policy and legislative framework governing existing and future risk. New South Wales (NSW) and Victoria have more established floodplain management policies and legislative frameworks than most other jurisdictions (table 3.1). In particular, NSW has led the way by planning for continuing risk, that is, events exceeding the design of mitigation measures including the Probable Maximum Flood (PMF).

Floodplain mapping

Attitudes toward floodplain mapping differ across Australia. Most areas have undertaken some form of floodplain mapping, but the purpose, target risk level and public availability of maps has varied (table 3.2). In most jurisdictions, maps are seen as an extremely useful guide for both planning and response to floods.

In 1984, NSW changed its approach to floodplain mapping and questioned the value of flood extent maps because they do not include floor heights, water depth or velocity and are subject to misuse and misinterpretation. In NSW, flood studies typically define the nature and extent of the flood problem in technical rather than map form (NSW Government 2001, p. 10, figure 2.1). The current strategy in NSW, in lieu of maps of flood extent, is to develop flood surface contours for different sized floods. These provide a more comprehensive picture of flood risk in different parts of the floodplain.

TABLE 3.1 COMPARISON OF FLOODPLAIN MANAGEMENT POLICIES

State/ Territory	Policy	Description
ACT	ACT Flood Management Sub-Plan Floodplain management guidelines Planning guidelines	All new land released for residential development must be above the 1 in 100-year level. Pre-existing residential land below 1 in 100 is protected by mitigation works. Industrial and recreational land use is allowed below the 1 in 100 level.
NSW	NSW Flood-prone Land Policy and supporting legislation NSW Floodplain Management Manual (1986, 2001)	Risk mitigation framework: existing risk, future risk and continuing risk. Traditionally, mitigation focused on the 1 in 100-year flood, but now there is more flexibility to tailor protection levels and a greater emphasis on planning for PMF events.
NT	NT Interim Floodplain Management Policy (2001) Floodplain management plans and studies completed for regional centres, e.g. Katherine and Alice Springs Land planning and building controls	Generally apply the 1 in 100 flood for land use planning and building controls (minimum floor levels).
QLD	No existing State policy or guidelines on floodplain management. However, a discussion paper on planning options for disaster mitigation has been released. Integrated Planning Act places the onus on local government.	Some councils have implemented measures such as minimum floor levels and other mitigation, but the variation among councils is considerable.
SA	No existing floodplain management policy at the State level State Floodplain Management Committee established in early 2002 Catchment Water Management Boards have been established (planning role) Legislation (e.g. Development Act 1993 and Water Resources Act 1997)	Focus is on 1 in 100 flood for planning purposes 1 in 100-year floodplain not well defined across the State. Individual councils have local policies and practices Catchment Water Management Boards are taking on a planning role in mitigation.
TAS	No state floodplain management policy Flood Warning Consultative Committee State Emergency Management Plan	Mitigation is the responsibility of individual councils.
VIC	Legislation in 1970s Catchment Management Authorities established in 1997 (regional strategies and studies) Victoria Floodplain Management Strategy 1998 Victorian Planning Provisions (1999) Building regulations	Focus is on 1 in 100 flood for most structural mitigation measures, land use planning and building controls (floor levels).
WA	No overall State policy on floodplain management *A Framework for Floodplain Management in WA* 1998 Ministerial taskforce report State Floodplain Management Council is currently producing a WA floodplain management strategy	Water & Rivers Commission is lead State agency, but advisory role only. Mitigation is the responsibility of individual councils. Focus is on 1 in 100 flood for most structural mitigation measures, land use planning and building controls (floor levels).

Source BTE consultations with States and Territories in May and June 2001.

TABLE 3.2 COMPARISON OF FLOODPLAIN MAPPING POLICIES

State/ Territory	*Mapping*	*Risk Level*	*Use*
ACT	Yes and publicly available.	Varies e.g. 100, 500 & PMF	Emergency response
NSW	Yes for water surface contour maps, not surface boundaries. Flood studies including contour maps are publicly available.	Full range up to PMF	Planning and response
NT	Yes, key risks mapped. PMF information not public.	Varies up to PMF	Emergency response
QLD	Yes for some councils. Public availability varies.	Varies	Varies
SA	Yes for some areas. Public availability varies across councils.	Varies	Varies
TAS	Yes for significant risk areas. Publicly available.	Varies	Planning and response
VIC	Yes. Publicly available.	100-year flood	Planning schemes
WA	Yes. Publicly available.	100-year flood	Planning

Source BTE consultations with States and Territories in May and June 2001.

Public availability of flood maps varies considerably and usually depends on the attitude of Local and State/Territory governments toward both legal liability issues and concerns that flood maps may, at least in the short-term, impact adversely on property values.

Flood maps, like other forms of floodplain management, tend to focus on the 1 in 100-year flood event, although availability of maps at various risk levels up to the PMF is increasing. The target risk level for maps depends on their intended purpose. There is a clear distinction between maps for land use planning (which tend to be 100-year) versus maps for emergency response, (which often include up to the PMF).

Mitigation definition

Other variations included some difference of opinion over exactly what constituted ‘mitigation’. Standard structural and non-structural measures were common, but matters such as insurance and Natural Disaster Relief Arrangements (NDRA) payments were not so clear cut. Mitigation was typically defined as in chapter 1—measures aimed at reducing or eliminating a disaster’s impact on society and the environment. Some saw insurance as a risk management measure taken by individuals in order to reduce losses and argued that it should therefore be included in any definition of mitigation. Others were cautious about including insurance and other financial assistance like NDRA because:

- It would blur the line between mitigation and relief. Including insurance and NDRA means that relief money becomes a mitigation measure.
- Insurance does not reduce losses, it simply redistributes the losses.
- Insurance can actually increase costs if it causes people to take less care (moral hazard argument).

This report has taken the approach of including insurance within the broad risk management framework, but not as a specific mitigation measure. The issue of insurance was a common topic of discussion in consultations, but as described in previous chapters, the complexity of the insurance issue places it beyond the scope of this report.

Rural issues

Differences between rural (or isolated) communities and urban communities in relation to floodplain management were apparent. In the Northern Territory and Western Australia, the remoteness of many communities means that access issues are immense. Mitigation decisions need to take into account the different characteristics of remote communities including the following factors:

- The vast distances involved means that access to alternative services (such as hospitals and businesses) often do not exist, as they might be hundreds of kilometres away. The impact of road transport delays can also be more important because alternative routes and transport modes are less likely to be available. Disruption costs to households, businesses and communities can therefore be more important in rural and remote communities.
- Cultural and environmental factors, such as aboriginality, often mean that different approaches to mitigation are required. Native title and sacred site issues often need to be considered in implementing structural mitigation works.
- Demographics of rural and remote communities in terms of aging populations and the loss of youth to larger cities need to be considered in planning mitigation.
- Many of these communities are struggling to afford basic services, so the affordability of mitigation work for events that ‘might’ happen becomes an even greater issue.
- Increasingly scarce resources and lack of confidence that emergency supplies will be available mean that people are often unable to prepare for what may be long periods of isolation.

In rural areas of some jurisdictions, private structural mitigation works (predominantly levees) constructed in the past are now an issue causing problems. These measures were implemented in a very ad hoc manner and in many cases are now causing more problems than they solve. Removal of these works is a major issue in many rural areas.

Stormwater flooding

For some jurisdictions, such as South Australia, stormwater flooding was seen as the priority flood mitigation issue. Stormwater systems are typically only designed to cope with the approximately 1 in 5-year flood event. Stormwater flooding can be more difficult to control in a flat area and typical mitigation options, such as development controls, are not generally applicable to long established existing development. As previously mentioned, stormwater flooding issues are within the scope of this report and are highlighted in the Thuringowa case study (appendix III).

CASE STUDIES IDENTIFIED

Feedback during the consultations regarding potential case studies was very positive. Table 3.3 briefly describes the possible case studies identified in each jurisdiction. The list is not exhaustive and includes only those areas where flood mitigation measures have been implemented and tested by flood events. For some jurisdictions, such as South Australia and the Australian Capital Territory, there were few, if any, possible case studies of this type.

In addition to these discrete case studies, NSW indicated that they held a considerable amount of data and information that could be used to build on existing methodologies and improve the information available on the benefits of flood mitigation. In Western Australia, the Fire and Emergency Services Authority also indicated that they held useful information on operational costs associated with events.

COMMENTS ON METHODOLOGICAL ISSUES

Feedback on the suggested methodology was mixed. There was general consensus that the case study approach was appropriate. However, as expected, there were very few examples of areas that had suffered historical floods, implemented mitigation measures and suffered subsequent floods.

There was also debate about whether benefits should be measured in relation to a particular flood event or in terms of reduced AAD over a specified time. The ideal would be to measure ‘before and after’ flood damage for a full range of floods over time. The reduced AAD approach is preferable in that it is more comprehensive, holistic and theoretically based. However, it does mean a need to infer data and rely on predicted, rather than actual, information. The

TABLE 3.3 POTENTIAL CASE STUDIES

Area	*Mitigation measure*	*Flood event*	*Notes*
ACT No particular area identified		No major floods	The ACT's unique nature of being a planned city could be explored.
NSW Lismore	Structural measures + land use planning	2001	Lismore is expanding away from the floodplain in view of the large flood problem. Lismore flooding has been studied extensively.
Kempsey	Levees (overtopped), FWS, SES action plans and awareness raising	2001	Considerable work is being done on the 2001 northern NSW floods.
Grafton	Levees (successfully prevented flooding in 2001)	2001	Considerable work is being done on the 2001 northern NSW floods.
Hawkesbury Nepean	Evacuation routes and a range of structural and non-structural measures.	Many	Huge risk area. Mitigation still being implemented.
Wee Waa	Levee		Issue of evacuation routes being cut—continuing risk.
Campbelltown	Land use planning		Used to be regular claims for assistance, these are now rare.
Parramatta	Range of structural and non-structural measures		UPRCT[a] very active in mitigation, but measures have not been tested by an event.
Fairfield	Voluntary purchase and house raising		Large scale scheme with extensive studies done.
Bathurst	Kelso voluntary purchase (began 1986)	1986, 1990 and 1998	RFMP funding application noted actual benefits of scheme in the 1990 and 1998 events.
NT Katherine	Land use planning	1998	Planning decision 20 years ago to locate all new development in East Katherine, out of the 1 per cent AEP event.
Alice Springs	Range of structural and non-structural measures.		
Borroloola	Land use planning	1988	
QLD Gold Coast	Structural works	Many	Considerable work is being done in this area.
Cairns	Elevated floor levels		BCA study done.
Waggamba	Planning and road damage mitigation, levee	1956 & 1976	Good data on road damage mitigation.
Gympie	FWS and response measures		
Warwick	Land use planning		
Mackay	Levees	1918, 1958	
Townsville v Thuringowa	Building controls	1998	Townsville versus Thuringowa damage.

a. Upper Parramatta River Catchment Trust

Source BTE consultations with States and Territories in May and June 2001.

TABLE 3.3 POTENTIAL CASE STUDIES continued

Area	*Mitigation measure*	*Flood event*	*Notes*
Brisbane	Many	1974	Long history of floods.
SA			
River Torrens	Major structural project		Has not been tested.
Gawler River	Major works proposed		
Keswick Creek	Range of minor measures		Regular minor floods.
TAS			
Launceston	Levees		BCA done, but no major test.
Glenorchy	Range of measures	1995-96	Major study done.
Latrobe	Levees		
Hobart	Channel improvements	1960s	
VIC			
Wangaratta	Structural measures in early-mid 1980s. Further work in 1996-99 including an improved FWS	1974, 1986, 1993 & 1998	Structural measures tested and held in 1986 and 1993. Preliminary estimates of savings exist.
Benalla	Mitigation implementation problems	1993	
Gippsland	Lack of FWS	1993	
Geelong	FWS	2001	
WA			
Busselton	Structural measures (including detention basins)	1997	Project is being currently implemented.
Moora	Non-structural measures (development controls, house raising and FWS)	1999	Three major floods in 1999. Mitigation measures currently being developed.
Carnarvon	Structural levees constructed	1960s, 1980, 1995, 2000	Consultant now looking at options to protect more areas.

Source BTE consultations with States and Territories in May and June 2001.

importance of avoiding making comparisons on the basis of a single flood for which there is no probabilistic context was stressed.

Given the diversity of potential case study material, the BTRE acknowledged that a combination of methodologies would be needed.

There was also a general view that it was important to include, and attempt to quantify, the indirect and intangible impacts (benefits and costs) of mitigation—particularly, the benefits of flood warnings, community awareness, SES actions and other factors commonly ignored in measuring mitigation benefits.

CASE STUDY SELECTION

Following the consultations, discussions among the project team led to a draft shortlisting of potential case studies for further follow-up. The shortlist included Katherine (NT), Waggamba (Qld), Thuringowa (Qld), Bathurst (NSW), Wangaratta (Vic), Moora (WA), in addition to the Tamworth case study already underway[17].

The choice of case studies depended primarily on the extent of data and information available. Other issues considered in shortlisting included a variety of structural and non-structural measures, relatively well-defined areas of manageable size, the capacity to add value by conducting research not currently available in Australia, a mix across jurisdictions, a mix of city/country, small/large towns and the relative size of the flood problem.

Further discussions on case study selection with DOTARS, EMA and the States/Territories took place via teleconferencing during 8-10 August 2001. From these discussions it was agreed that five key case studies should be pursued:

- Katherine—land use planning controls;
- Bathurst—Kelso voluntary purchase;
- Thuringowa—building controls;
- Waggamba—road damage mitigation; and
- Tamworth—the levees (already underway).

Wangaratta was the primary case study possibility from Victoria. However, given that preliminary estimates of savings did exist and a re-run of flood models would have been necessary to improve on this estimate, it was agreed not to pursue a Wangaratta case study.

Western Australia presented very useful information on its three main flood-affected areas. Moora, with three major events in 1999, was the key potential case study in Western Australia. However, the implementation of mitigation measures is still being developed and it was agreed, therefore, that it was premature to consider it further for this study.

NSW had many interesting examples of mitigation work, such as Lismore, where land use plans have been successful in keeping development out of the floodway. However, it was decided not to pursue Lismore as a case study because Katherine provided a more well-defined, smaller area to examine

17 Floods in Tamworth in November 2000 provided an opportunity to estimate the economic costs resulting from the floods at Taminda and the benefits (costs avoided) in the CBD by the existence of levee banks. This work was published by the BTE in September 2001 as Working Paper 48. The work also fed into Module 2 and is therefore summarised as one of the case studies.

the benefits of land use planning and two NSW case studies were already being undertaken.

It was agreed that South Australia, Tasmania and the Australian Capital Territory did not have any case studies that fitted the objectives of this report.

Discussions with States and Territories regarding potential case studies were of great benefit to the project team and other Commonwealth representatives who participated. The detailed information on the major flood problems and mitigation implemented and planned in each jurisdiction provided essential background and an improved understanding of the complex issues surrounding flood mitigation. Feedback from individuals in States and Territories suggested that they also found the consultations particularly useful.

chapter 4

BENEFITS OF MITIGATION

Appendices I to V present the five case studies conducted as part of this project. Each case study details the flood history, evaluation method used and results (including limitations) obtained. The purpose of this chapter is to draw together the key themes and lessons learned from the case studies and the consultations and literature discussed in chapter 2 in order to provide a more general understanding of the benefits of mitigation.

The key themes are examined using the established framework of existing, future and residual (or continuing) risks. This risk framework for examining flood problems is adopted by both the *NSW Floodplain Management Manual* (NSW Government 2001) and the *Best Practice Principles and Guidelines for Floodplain Management in Australia* (ARMCANZ 2000). The descriptions below draw heavily on these sources.

Existing risk applies to existing buildings and developments on flood-prone land. It is the risk a community is exposed to as a result of its location on the floodplain.

Future risk applies to buildings and developments that will be built on flood-prone land. It is the risk a community may be exposed to as a result of new development on the floodplain.

Residual or continuing risk refers to the risk associated with floods generally, the risk remaining after mitigation and the risk of an extreme (or catastrophic) event occurring. It includes the risk a community is still exposed to after floodplain risk management measures have been implemented. Few measures entirely eliminate the risk or mitigate the risk up to the probable maximum flood (PMF) level and, as a result, some risk will remain and be realised when floods exceeding design levels occur.

Mitigation has tended to focus on addressing existing and future risk, but ways to deal with the continuing risk of catastrophic events are gaining prominence. The issue of mitigation against catastrophic risk is acknowledged in this report; however, the issue is not dealt with in detail because of its size and complexity. The case studies focus on addressing existing and future risks.

A useful approach to applying this risk framework is set out in the matrix in figure 4.1. Each combination of risk type and impact area (property damage and people) needs to be considered when planning mitigation. Existing and future risk to property and people can be addressed using a range of structural and non-structural mitigation measures (for example, protection works, building controls and warnings). However, the range of tools and measures available to tackle the continuing risk to property and people is more limited. For example, using the risk management terminology outlined in chapter 1, practical risk treatment options for the property losses due to catastrophic events are usually limited to accepting the risk or transferring it via insurance and government assistance. Emergency response planning (including warnings and evacuation routes) is the main measure available to mitigate the continuing risk to people.

FIGURE 4.1 RISK MANAGEMENT TARGET AREAS

Risk	*Property damage/dollars*	*People*
Existing	Strategy A (e.g. protection works, voluntary purchase, house raising)	Strategy X (e.g. FWS, awarenes campaigns, evacuation plans)
Future	Strategy B (e.g. land use planning, building controls)	Strategy Y (e.g. FWS, evacuation routes)
Residual/continuing	Strategy C (e.g. insurance, government assistance)	Strategy Z (e.g. FWS, emergency response planning)

Source Jim Bodycott, NSW Department of Land and Water Conservation (pers. comm., November 2001).

EXISTING RISK

Structural measures are the most common form of mitigation targeting existing risk. However, non-structural measures such as voluntary purchase (VP), house raising, flood warnings and preparedness activities are also extensively used.

Three of the case studies examined for this report—Bathurst, Waggamba and Tamworth—target existing risks.

The preferred approach to tackling existing flood risk is to permanently remove people and property from the risk by, for example, implementing a relocation or VP scheme. However, in many cases, removal of existing developments from floodplains is not possible. The costs may be prohibitive, or other mitigation options may be more appropriate to the circumstances and preferred by the community.

Dealing with existing risk tends to involve the most costly mitigation measures and is also the most complex in terms of the number of challenges that can arise. Some of the key challenges relate to equity issues, which are discussed later in this chapter.

In the three case studies targeting existing risk, a variety of different approaches are being taken. In the Kelso area of Bathurst, it is feasible to virtually eliminate the existing risk (and reduce the residual risk) by removing residents from the high-hazard floodplain areas. The VP scheme in place there has already achieved significant savings. In the Waggamba Shire, roads regularly damaged by floodwaters cannot be moved. Instead, the existing risk is being addressed by altering the way these roads are designed and constructed. These improvements in road design reduce the scope for damage in floods and, in doing so, reduce Council maintenance and road user costs. In Tamworth, levees are used to protect the CBD area and another levee is proposed to protect the industrial area, Taminda.

It is important to note that the measures examined in each of the case studies are typically not the only measures used. Most areas combine a mix of measures, including flood warning systems and education/awareness raising, in their overall floodplain risk management strategy. However, the case studies undertaken only examined the economic benefit of particular measures.

Key themes stemming from the case studies addressing existing risk are discussed below.

Voluntary purchase, where feasible, is an ideal measure as it has the potential to eliminate existing risk.

Given that VP has the potential to eliminate the existing risk, it has intuitive appeal. However, in Australia, it is rare for VP schemes to have favourable benefit-cost ratios. BCA cited in Regional Flood Mitigation Programme (RFMP) applications do not usually show VP schemes to be supportable in benefit-cost terms alone.

In the United States, where risks and damage from floods and hurricanes are large, research has been able to provide evidence of the financial merit of VP (see chapter 2). Consultations with stakeholders also indicated that research in other countries had been successful in proving the economic viability of VP programmes.

Given the lack of Australian evidence, the Kelso VP scheme (102 houses) in Bathurst was chosen as a case study for this research. The analysis, contained in appendix II, shows that the scheme is estimated to have saved $0.7 million in a single event—the 1998 flood. If all properties had been purchased before that 1998 event, savings would have been in the order of $1.2 million. It is also estimated that once all properties have been purchased, the benefits (costs avoided) in a 1 per cent AEP event would be approximately $1.8 million. These savings refer only to direct and some indirect costs avoided. Intangible savings are discussed in the appendix, but not quantified.

The uncertain nature of the data for the Bathurst case study and the inability to capture some key benefits prevented the BTRE from extending the analysis beyond an estimate of the savings in particular events. The Bathurst case study serves to illustrate the limitations of BCA, in that it is not always able to incorporate and adequately value the indirect costs. Intangible costs, although recognised as substantial, still defy quantification. The case study highlights the important point that BCA should not generally be the sole means used to evaluate the worth of a proposed project, as it may not be able to value all of the benefits. In the case of voluntary purchase, these intangible and indirect benefits are particularly important.

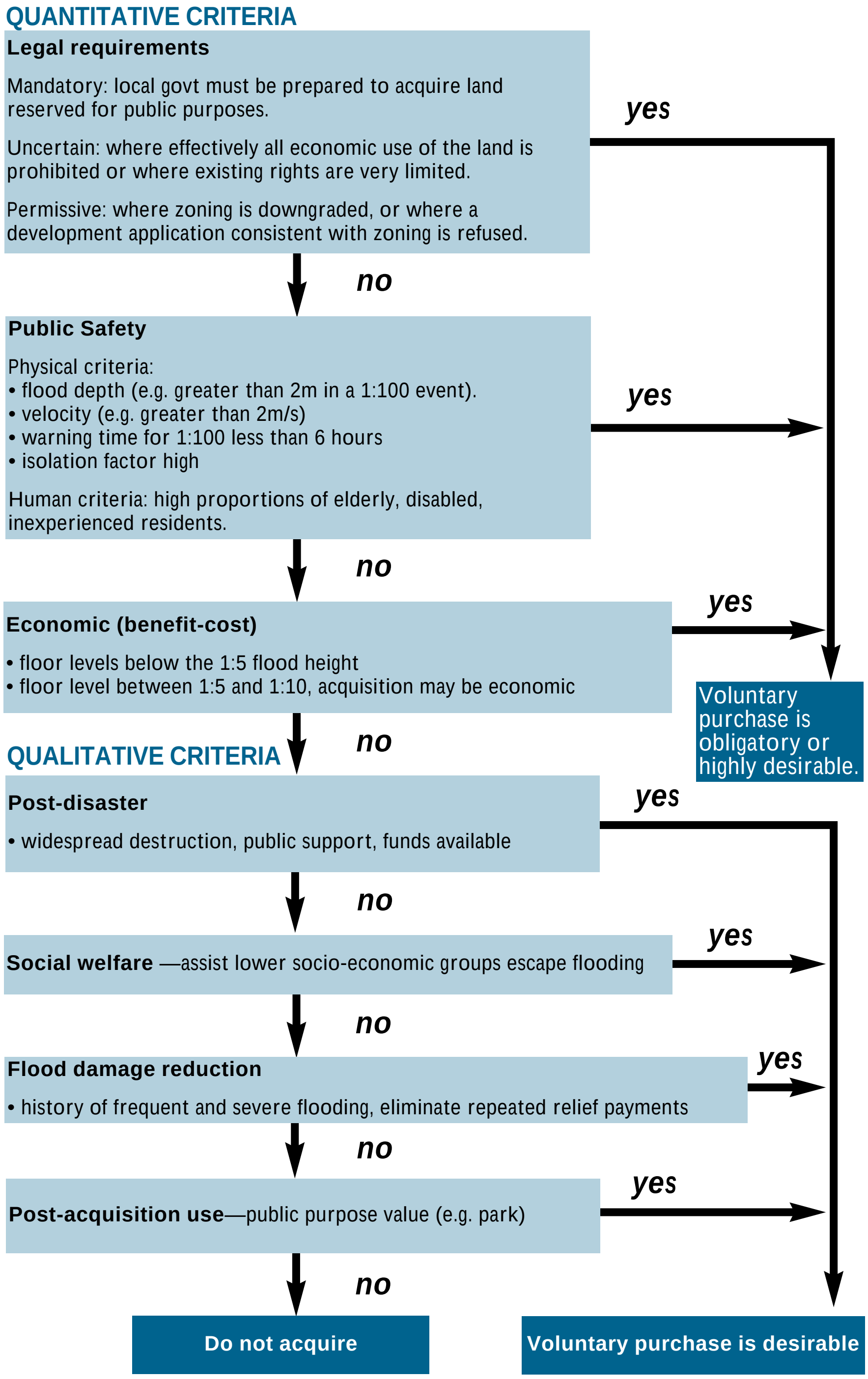
A key finding in the literature, consultations and Bathurst case study was that even where it is not viable on a benefit-cost basis, VP is often the most cost-effective solution to flood problems in high-hazard areas. This finding reinforces the point made in the introductory chapter that there are other tools available to assess the economics of mitigation measures when benefits are difficult to quantify.

Other criteria for evaluating VP schemes have also been put forward. Handmer (1984) presented the policy guidelines and criteria shown in figure 4.2. The economic criteria are based on evidence from Lismore in NSW and the USA which suggest that VP is viable for areas inundated up to the 1 in 5-year flood level (Handmer 1984, pp. 229-244). Handmer (1984) also makes the important point that

> ... human safety should be paramount in planning decisions. To ensure incorporation of safety issues, economic assessments should be undertaken within some comprehensive planning evaluation framework such as multi objective planning, and the physical safety criteria should be applied (p. 208).

The Bathurst case study and other Australian VP schemes suggest that the key benefit (or cost avoided) of VP is not the direct damage to houses, but avoidance of the significant risk to life for both residents living in the floodplain and the volunteers who rescue them in often highly dangerous flood conditions. A stark example from Bathurst is the regularity with which State Emergency Service (SES) volunteers are needed to evacuate people by boat in highly hazardous situations at the peak of a flood. SES are faced with difficult choices about leaving people on 'disappearing islands' or risking more lives by evacuating them in flood-boats. The loss of just one boat in such dangerous conditions could mean the loss of an entire household and volunteers—a substantial human and economic cost.

FIGURE 4.2 CRITERIA FOR VOLUNTARY PURCHASE



Source Handmer 1984, p. 376.

The difficulty in capturing and adequately valuing the voluntary contributions of SES and similar organisations was an issue in most case studies. The time they contribute is not always adequately recorded, but more importantly, the psychological cost of working in hazardous conditions and making decisions that may have life or death consequences cannot be estimated at all.

There are also other intangible benefits of VP that were highlighted during the Bathurst case study. In particular, the value that communities place on the open space created by VP schemes. It is common for areas subject to VP to be put to alternative uses such as sports grounds and community social facilities. These tend to provide communities with significant benefits. There have been several studies on the benefits of providing such sports facilities for young people, from improved social and leadership skills to reduced crime and vandalism. It is difficult to put a dollar value on these benefits.

In addressing existing risk areas, the importance of maintaining freedom of choice through the voluntary nature of these schemes was stressed. In order to ensure the fairest outcome, it is important that VP is an option for those living in high-hazard areas, but that ultimately people retain the choice of whether or not they bear the risk.

Areas subject to VP are often older areas where the houses are typically not of high value and the land itself is usually cheaper (due to the flood risk). Consequently, people with a lower capacity to afford houses elsewhere often locate in these areas. VP gives people an important option if houses in floodplains are difficult to sell and the occupants do not want to accept the risks. However, feedback during the consultations also suggested that the tendency for VP schemes to have no end date can cause difficulties.

Mitigation of existing risk by altering the way infrastructure is designed and constructed can be a very cost-effective mitigation measure.

The idea of improving infrastructure (such as roads) that cannot be moved out of the floodplain so that direct damage, maintenance costs and disruption effects are reduced is commonly discussed. This is particularly so with regard to the disbursement of NDRA funding, which only contributes to the cost of reinstating publicly-owned infrastructure to its pre-disaster condition. The Waggamba case study quantified the benefits of taking a different approach to road construction (appendix IV).

The key finding of the case study was that improving the quality of the roads so that they are more flood-resistant was a very cost-effective mitigation measure. Although the motivation for sealing the roads with bitumen is largely to reduce flood damage, the economic justification relies on benefits that are unrelated to floods or their mitigation. The expenditure to improve the roads could not be justified by the savings in maintenance costs to the Council alone. The benefits to road users in terms of reduced vehicle operating costs also needed to be taken into account. Some flood-related benefits could not be considered in the analysis. For example, there may be benefits of reduced isolation, as the bitumen-sealed roads are less likely to be impassable following a flood. They will not require repair and be useable much sooner after floodwater recedes. It is also important to note that to reduce the damage to a road after a flood, the road should be allowed to dry out sufficiently before usage by vehicles is resumed.

The Waggamba case study illustrates the importance of capturing as many benefits of mitigation measures as possible, rather than the benefits from only one perspective. A minimum of 32 trucks per day is required to produce sufficient benefits in Waggamba to justify the high capital costs of upgrading gravel roads to bitumen-sealed roads. Traffic levels in the Shire comfortably exceed this. The economics of bitumen sealing would be stronger if the value of other potential benefits, such as improved road safety and environmental benefits, were included.

The results of the Waggamba case study depend on the costs associated with the bitumen road upgrade. These costs are affected by a range of factors (such as climate, terrain, traffic levels and type) and can vary widely across Australia. While case study results are not generally transferable, given similar terrain, traffic levels and other conditions it is reasonable to assume that upgrading roads in this manner is likely to be economically justified. The Waggamba case study therefore has lessons for many areas of Australia where rural roads are frequently subjected to flooding. Anecdotal evidence from the Bathurst case study also supports this finding. A key road linking parts of Bathurst, which is subject to inundation, has been re-built to a more flood-resistant standard. By altering the design and materials used, floodwater is allowed to flow unobstructed over the road, resulting in less erosion damage and therefore reduced disruption to the community.

Structural measures such as levees can provide substantial benefits in terms of damage avoided for events up to the design level. However, they also raise a number of other important issues.

There is ongoing controversy about the costs and benefits of levees. Historically, levees have been the most common means of dealing with existing flood risk. There are many Australian examples of levees preventing considerable damage (see boxes 2.1 and 2.3 to 2.6 in chapter 2). The Tamworth case study illustrates several important issues about levees (appendix V).

In November 2000, the industrial area of Tamworth (Taminda) is estimated to have sustained damage costs (direct and indirect) of close to half a million dollars. A levee proposed for the area would reduce this damage. It is also estimated that the existing CBD levee would avoid at least $5.36 million potential direct damage in a 100-year ARI flood[18]. However, the CBD levee is yet to be tested by a flood of this magnitude. The Tamworth case study relies

18 The Tamworth City Council did revised flood modelling after the completion of the Tamworth case study. The use of this revised flood modelling would produce a higher estimate of damage avoided in the CBD due to the levee than that provided in this case study.

on actual estimated costs for the 2000 flood and predicted costs for a 1 per cent AEP event. The case study clearly demonstrates the potential economic savings that can result from levees.

The 'levee paradox' was observed in Tamworth and in more general discussions as well as being discussed in the literature. There would be an increase in potential damage resulting from floods greater than the design level (for example, if development behind levees increases or residents' flood awareness diminishes). Other levee issues that arose in discussions included the possibility of stormwater and drainage problems and changes in flood behaviour in other parts of the floodplain. It is clear from the case studies and consultations that, for some areas, levees are the only sensible option. The importance of recognising and planning for the indirect impacts of these structural mitigation solutions to existing risk problems is also clearly demonstrated.

FUTURE RISK

Non-structural measures are the most common form of mitigation targeting future risk. Two of the case studies—Katherine and Thuringowa—mainly target future risk.

In Katherine, land use planning controls implemented around 20 years ago have meant that all new development is located in East Katherine above the 1 per cent AEP flood line. In Thuringowa, this type of planning solution was not possible. Instead, building controls (which set minimum floor levels) are applied to all new development. As previously mentioned, it is important to note that the measures examined in these case studies are part of broader floodplain risk management plans incorporating a variety of mitigation solutions to address flood problems.

Key themes and ideas arising from the case studies addressing future risk are described below.

Land use planning is the cheapest and most effective means of mitigating future risk.

Non-structural measures such as land use planning and building controls are often regarded as a cheaper and more effective means of mitigating future risk. The costs are relatively low and the potential benefits are considerable. In particular, there is very little initial cost, unlike structural measures. The Katherine case study (appendix I) provides considerable support for this argument. Land use planning in Katherine is estimated to have reduced the AAD by $0.6 million. In a 1 per cent AEP flood the planning decision is estimated to save around $29 million in direct and indirect costs. In other words, land use planning in Katherine is an extremely cost-effective mitigation measure for addressing future risk. Land use planning has the potential to virtually eliminate future flood risk by never allowing development to occur in flood-prone areas. This, of course, depends to a large extent on the design level associated with the planning controls. Methods suggested in the literature to cost land use planning as a mitigation measure are discussed in chapter 2.

The economic merit of land use planning was also raised in discussions with the Australian Capital Territory. Comprehensive land use planning from Canberra's inception was identified as a key factor in reducing its susceptibility to major flooding problems.

Where there is alternative land available for development, distances between locations are not large and infrastructure and other development costs are not dissimilar, the results of the Katherine case study will be generally transferable to other areas. Despite the caution necessary when generalising from case studies, it is reasonable to assume that, given these conditions, land use planning will be a cost-effective mitigation measure. However, the availability of land is the critical issue.

Mitigation measures must be realistic and tailored to each location. What is reasonable in one area may not be reasonable elsewhere.

The difference between the design level of a mitigation measure and the PMF varies hugely across Australia. There is an often-cited example from NSW illustrating the need to select the appropriate recurrence interval with regard to the local topography. In most NSW floodplains, the difference between the 100-year flood level and the PMF is measured in centimetres. As a result, the 100-year flood level may be an appropriate planning standard. However, in the Hawkesbury-Nepean area there is one storey in height difference between the 100-year flood planning level and the 250-year level, and four storeys to the PMF (Gillespie et al 2001, p. 5).

The Thuringowa case study demonstrates the importance of choosing an appropriate design level for building controls consistent with the unique topography and community needs in each location. Because the major source of flooding in Thuringowa is urban run-off and stormwater, structural options such as levees are not feasible. Given the costs of other options and the locational features of Thuringowa, building controls (in this case, minimum floor levels) are the only realistic option to address future risk.

The minimum floor height is at the 50-year ARI flood level plus 450 millimetres freeboard. Given the flat topography of the Thuringowa area, the BTRE was advised that the difference in flood depth between the 50-year ARI flood and larger events is not likely to be great. Evidence from the 1998 flood event in Thuringowa indicates that the building controls have saved significant direct internal damage. However, the limitations of such measures in having little impact on external damage and the remaining safety issues need to be acknowledged. Considerable difficulties with data prevented the BTRE from producing a savings estimate. The available evidence suggests that houses built after the building code was introduced suffered less damage in the 1998 flood.

Building controls such as minimum floor levels and the use of flood-proof materials are a practical means of dealing with future flood risk when preventing development entirely (via land use planning) is not feasible (because, for example, alternative land is not available). Building controls can also be particularly useful when dealing with infill development. The resource constraints of councils are an important practical factor in implementing mitigation measures. Building controls implemented at the time of construction are typically low-cost and the potential benefits are significant depending on the design level chosen. Given that individuals can pay off the higher construction costs over the life of a mortgage, building design measures enforced through building controls can be a cost-effective and affordable form of mitigation.

The importance of tailoring mitigation solutions to individual locations was stressed in all case studies and in consultations. Narrowly focused, one-size-fits-all approaches were not seen to be effective or appropriate. To be effective, mitigation solutions must not only be technically suitable but also reflect community concerns. For some communities, affordability is the overriding decision variable, while for others, a variety of equity issues take precedence. The appropriate mitigation solution varies according to a complex set of interrelated factors, including the extent of flood risk a community is willing to accept.

Drainage and stormwater issues are intimately linked to other flood issues and should not be separated.

Flooding in this report was broadly examined to include all floods regardless of source. The Thuringowa case study and consultations with various jurisdictions, particularly South Australia, demonstrated the importance of this approach. The building controls in Thuringowa are primarily aimed at addressing urban stormwater flood issues, but also relate to the riverine and storm surge flood risks for the area. The case study demonstrates that many of the mitigation issues and the tools available to address them are the same regardless of the source of flooding.

Advice from South Australia, using Adelaide as an example, indicated that urban stormwater flooding issues were the priority funding area for mitigation projects in that State. General impressions from consultations supported the significance of stormwater and drainage flood issues and that these should not be separated from other flood mitigation matters. Given the connections between the sources of flooding, it is sensible not to examine mitigation solutions for each in isolation.

RESIDUAL (CONTINUING) RISK

The most common form of mitigation able to target residual (or continuing) risk is non-structural in the form of emergency management measures (such as evacuation plans, education and awareness raising, preparedness activities, flood forecasting and warnings and emergency service actions). This report does not provide detailed information on the economic merit of these types of measures, but their benefits are discussed in a number of the case studies.

There is some residual risk in all of the case studies investigated. The source of this risk has several causes:

- The diverse nature of communities means that it is impossible to mitigate all the risk. Given the often substantial economic cost of mitigation measures, what is acceptable risk for one person may not be acceptable to another. Individuals and communities may not always know how to act in accordance with risk avoidance principles or may choose not to act. There will always be cases where people do not act in accordance with expectations.
- It is rarely feasible or desirable for mitigation measures to have the PMF as their design level. Mitigating against all flood risk would mean forgoing valuable economic activity that might be compatible with a flood-prone location. Floods exceeding the design level are an inevitable source of continuing risk. It is essential that the risk of catastrophic disasters be given serious consideration. It is worth repeating the often-heard phrase—it is not a matter of if, but when, the 'big one' will occur.
- The uncertainty of current risk assessments (that is, the level of a 10-, 50- or 100-year ARI flood event) is an important source of continuing risk. Because of Australia's short period of records, ARI flood levels are frequently revised after major flooding. Existing ARI levels for large floods have large degrees of uncertainty. Even if it is feasible and desirable to mitigate to a PMF design level, it is impossible to be sure that the risk assessment will not be revised.

Recognising and planning for residual risk is the essential lesson. This requires resources.

In Katherine, floods greater than the 1 per cent AEP could inundate parts of East Katherine despite the success of land use planning. In Waggamba, damage to roads and disruption are reduced, but access and evacuation issues remain while the road is inundated. In Tamworth, floods bigger than the levees will occur, and if communities rely too heavily on the levee protection, the residual risk in terms of both damage and risk to life may even be increased. The false sense of security engendered by levees highlights the need for continuing risk planning to accompany these types of measures. In Thuringowa, a large flood will eventually inundate houses complying with building regulations. Even without over-floor flooding, access is cut off, giving rise to evacuation issues and attendant risk to life. Risk also remains for those houses built before the regulations. In Bathurst, the road through the VP area is still used, with unresolved access and evacuation issues. There is also the continuing risk for any residents who do not take up the VP offer or for those who reside in close proximity but are not part of the scheme. Scheme boundaries rely on current risk assessments of the properties in high-hazard locations.

The core message in regard to residual risk is that recognising and planning for continuing risk is the key to reducing or managing it. In other words, mitigation against continuing risk is about planning for different levels of risk and the effects on both property and people. In figure 4.1, mitigation against residual risk to property includes planning and preparedness activities such as lifting items. Mitigating the continuing risk to people generally involves having well established evacuation routes and plans. This includes having the infrastructure in place, the community ready and able to act and ensuring that the needs of more vulnerable sections of the community are addressed. For example, in the Hawkesbury-Nepean area of New South Wales, considerable resources have been allocated to improving the road infrastructure to allow safer evacuations during floods. It is vital to stress that, while less visible than other forms of mitigation, planning for continuing risk requires resources in the form of time and effort on behalf of both governments and communities. The potential losses from failure to mitigate are immense.

Anecdotal evidence from the Nyngan flood of 1990 suggests that devoting more resources to planning for residual risk (in this case the levee being overtopped) could have saved significant property damage and reduced the risk to life. The Tamworth case study also provides support for the importance of planning for continuing risk. In the November 2000 flood, it is estimated that businesses were able to save more than 80 per cent of their contents by lifting or moving stock and equipment at risk.

It is also important to realise that, for some areas, the residual risk remaining will be small, while for others the consequences will be catastrophic. The size of the flood risk in some areas of NSW has meant that the State has led the way in terms of recognising and planning for continuing risk in the Australian context. For other areas where the residual risk is not so large, the focus on existing and future risk may be appropriate.

Many mitigation measures reduce existing and future risk by attempting to prevent damage and risk to life. Commonly, however, access to homes, businesses, schools and other services is cut off. It is this continuing risk relating to access that can cause high indirect costs due to disruption and the need to supply isolated communities and evacuate people at risk. In the consultations and case studies, the importance of this issue was demonstrated, especially for remote or isolated areas that rely on one major regional centre. Disruption costs are often far larger for these areas when access is cut off. Australia has many remote areas fitting this description where a large area is served by one regional centre whose roads can often be cut off by floods. The size of this residual risk is also dependent on the duration of flooding. For towns such as Katherine where flooding can last for weeks, the risk to both the town and the surrounding areas is large. For regional centres, such as Bathurst, where the duration of flooding, and therefore disruption, is not as long, the residual risk is less.

Residual risk cannot be completely eliminated. However, some mitigation measures would be more effective than others in reducing this risk and the extent of risk reduction will depend on several factors, including the characteristics of the location. Measures such as building controls and some structural measures that leave people in flood-prone areas may have a larger residual risk than measures that remove people from the floodplain or educate and warn communities so that a good understanding of the risk exists.

SHARED THEMES—EXISTING, FUTURE AND RESIDUAL RISK

The various mitigation measures available typically concentrate on one or two risk categories. However, there are a number of issues that cut across all three categories of risk. For example, equity concerns, the value of community awareness and preparedness, and methodological difficulties.

Equity issues associated with mitigation are prevalent and must be addressed in order to achieve a mitigation solution.

Equity issues of various forms arose in the case studies. For example:

- Where should the line be drawn in terms of who is protected?
- Who should fund mitigation?
- Will protecting one area adversely affect any other area?

In the development of flood mitigation schemes, communities are generally reluctant to support measures that provide protection to some residents while leaving other residents, who are equally vulnerable, unprotected.

An example from a case study illustrates the issue. The Bathurst Floodplain Management Study found that levee protection was the most economically efficient mitigation measure for most of Bathurst, but was not feasible for the Kelso floodplain. Leaving the Kelso area unprotected was not acceptable to the community. VP was the most cost-effective means of providing flood protection to residents in Kelso equal to that provided by levees to other residents at risk. By implementing a combined levee and VP scheme, Bathurst was able to address the identified existing flood risk problem across the whole affected area. Combining a number of mitigation measures is often used as a solution to balancing equity and efficiency objectives. A similar approach of combining a number of measures, with high, marginal and low benefit-cost estimates, was also used in Wangaratta in Victoria.

Compensation is another approach to dealing with equity issues that has been considered. However, it is usually rejected as the amount of money offered to unprotected residents (typically calculated by the difference in flooding caused by mitigation) is usually unacceptably low.

The question of who should fund mitigation—governments or the beneficiaries—is a recurring theme in the mitigation field. In Tamworth, business owners in the industrial area argue they should not have to pay extra to receive protection from floods as they have already paid rates that contributed to the construction of the levee protecting the CBD. Others argue that because the levee would solely protect business, governments should not have to pay the full costs of provision and that the businesses, as the beneficiaries, should contribute.

The possibility of mitigation in one area adversely affecting flood risk in a neighbouring area (whether actual or perceived) is a common equity concern. For example, in Bathurst, concerns were expressed about the impact of a new levee on one side of the river increasing the flood level and extent on the opposite side. The philosophy that any proposed measure should not adversely affect others, without an active strategy in place to simultaneously deal with that area, is now entrenched in most States' and Territories' floodplain management policies and/or practices. A related issue is that any unintended environmental impacts must also be considered when implementing mitigation. These types of social equity issues arose in several case studies.

Overall, the case studies reinforce the importance of considering equity issues when making decisions about how to mitigate flood risk.

The value of community awareness and preparedness as a way of reducing risk was a feature of most of the case studies.

The critical role played by community response and understanding of the flood problem in reducing the risk and damage associated with events is well known and documented. This was reinforced by the literature, case studies and consultations. In particular, the Tamworth study found that damage to the Taminda industrial area was reduced by more than 80 per cent due to the flood awareness, preparedness and warning time. However, the reduction in damage costs would have been less in a larger flood, or one that occurred at a less convenient time.

Issues of education and flood experience also arose in both Katherine and Bathurst. Lack of understanding of the existing flood risk was cited as a problem in terms of causing avoidable risk to life and damage to property. A reluctance to believe that an imminent flood might exceed the highest previous flood was common. This was perhaps poignantly demonstrated in the survey of the Tamworth industrial area where respondents situated above the limits of the most recent floods were adamant that they were totally flood-free.

Feedback during consultations highlighted community education, awareness and preparedness as an issue requiring greater attention and coordination. This type of response modification measure, which has the ability to target all three categories of risk, was widely believed to be in need of a coordinating agency with funding and better methods to evaluate the benefits of such activities. Work currently underway in Victoria to examine the issue of measuring community awareness and preparedness is being jointly conducted by the Department of Justice and the Australian Bureau of Statistics (Enders 2000).

Problems associated with community awareness (for example, high population turnover) were commonly raised in consultations and are discussed in chapter 3. It was also emphasised that awareness (or public readiness) needs to include an understanding that different levels of risk require different actions and responses. The case studies, literature and consultations clearly demonstrate that the benefits of a greater focus on these types of mitigation solutions are potentially large.

Improvements in methodology are essential for improving estimates of the costs and benefits of mitigation.

All of the case studies demonstrate the need for improvements in methodology. Improvements are not needed in the BCA framework, as the approach is well established. However, there is a need for improved estimation of costs and benefits as well as a need for better data collection. Particularly useful advancements include better ways of capturing indirect and intangible impacts and updated stage-damage curves to improve the accuracy of direct damage estimates. In the Bathurst and Thuringowa case studies, the analysis was constrained by inability to capture key benefits and the limitations of existing residential stage-damage curves. Other economic techniques, such as cost-effectiveness analysis, may be more appropriate once a certain policy objective regarding mitigation has been established and where the benefits of the mitigation measure are difficult to value.

Stage-damage curves for commercial and industrial premises are possibly in even greater need of updating than residential stage-damage curves. The Tamworth case study (in particular, the CBD survey) provides a useful assessment of methods available for fast, low-cost damage estimation. The method still depends on reliable stage-damage curves, highlighting the need for improved and more widely applicable curves for commercial and industrial enterprises.

Given the problems associated with residential stage-damage curves significantly underestimating damage (discussed in detail in the appendices), the idea of applying average damage values has been suggested by various stakeholders. The use of average values may be appropriate in some circumstances. However, uncertainties about how such values should be calculated and errors involved in using the same average value in all cases led the BTRE to use existing stage-damage curves. The case study analyses attempt to address some of the inherent underestimation in these curves by adjusting to reflect changes in the value of household contents over time. Irrespective of the method adopted, it is important that the method's assumptions and limitations be made explicit. Any method used can produce different results depending on how it is applied.

For example, in calculating an AAD, the results depend on the shape of the curve adopted.

The use of BCA to evaluate flood mitigation options was the subject of considerable debate in consultations with key stakeholders. The advantages of BCA were discussed in chapter 1. It is a useful tool for allocating and prioritising scarce resources in an economically efficient manner. However, it has a number of limitations when applied to the full range of flood mitigation options now available.

BCA was originally designed for use in evaluating large structural works. For mitigation that is primarily aimed at reducing tangible damage, BCA works reasonably well in most circumstances. However, BCA has difficulty in assessing flood mitigation that is intended to reduce the impact of intangibles (such as risk to life, stress and ill-health). Consequently, it is often argued that BCA is less suited for evaluating non-structural measures whose objectives mainly involve intangible effects.

There are also other sources of possible problems associated with BCA methodology as it is currently applied in flood mitigation. It has been argued that the use of BCA disadvantages particular types of mitigation measures (non-structural measures discussed above), certain social groups and people who prepare appropriately for floods[19].

As mentioned in chapter 1, BCA does not take account of equity issues such as the distribution of benefits and costs. BCA methodology, as currently applied to flood mitigation, involves valuing the costs and benefits of mitigation according to the value of what people own. Damage values in stage-damage curves are adjusted to reflect the buildings and contents of particular locations. Flood-prone locations can have higher proportions of people from lower socio-economic groups. As a result, a BCA of mitigation measures for poorer people with relatively lower value belongings and houses will produce commensurately lower benefits and therefore lower benefit-cost ratios than a BCA for wealthier sections of the community. As this issue applies equally to rural/regional/remote areas that tend to have lower value housing and belongings, such locations can also be disadvantaged by the application of the methodology. The use of BCA may therefore entrench existing disparities in standards of living within communities and between locations. To avoid this dilemma, some stakeholders have suggested a standardised approach where the values are based on average, rather than actual, values[20].

19 These concerns were discussed at the workshop held at EMAI in November 2001. The BTRE acknowledges the contribution of John Handmer in raising these issues.

20 The BTRE was advised that this approach is used in the USA to avoid disadvantaging the poorest and most vulnerable parts of the community when prioritising mitigation funding.

In Australia, once stage-damage curves have been estimated to produce potential costs and AADs, a damage reduction factor (DRF) is commonly applied to account for the damage likely to be avoided by people as a result of awareness and preparation activities. When used in BCA of mitigation projects, this adjustment from ‘potential’ to ‘actual’ damage figures can disadvantage people who act appropriately to mitigate damage as the savings or benefits to people who prepare will be lower.

Other methodology issues raised during discussions included:

- the lack of inclusion of water velocity in estimating damage (which is currently related only to flood depth). Velocity is an important variable in damage, particularly with respect to building failure, but methods to incorporate velocity are not yet well established;
- some areas of the community are disadvantaged (for example, small businesses) because economic (societal) rather than financial (individual) costs are considered in BCA[21]; and
- extremely high-risk catastrophic events are virtually ignored in BCA because of their low probability.

These problems associated with the application of BCA to flood mitigation warrant further thought and investigation by both researchers and policy makers. However, this task is beyond the scope of this report.

In summary, the consultations, literature survey and case studies illustrate that the economic value (or benefit) of implementing measures to mitigate existing and future risk can be substantial. However, the continuing (or residual) risk cannot be ignored and needs to be addressed on an ongoing basis.

21 For further discussion on economic versus financial costs refer to BTE 2001a, pp. 4-5.

chapter 5

CONCLUSIONS

This report draws together analysis and perspectives on the benefits of a variety of flood mitigation measures. The input and assistance received from the disaster management community provide a unique reference point and snapshot of current thinking on flood mitigation issues. Bringing this information together for debate and discussion is a key outcome of the project. The main issues associated with the benefits of mitigation have been emphasised throughout the report. This report should help to focus attention on these issues.

This report has captured much of the available Australian information on the costs, benefits and performance of flood mitigation works and measures. While the report has touched on some of the complex environmental, social and other factors relevant to flood mitigation, the economic costs and benefits remain its chief focus. The principal purpose of this research was to examine the benefits of mitigation. The information collected during the consultations and the five case studies have contributed to a qualitative and quantitative demonstration of the benefits of mitigation measures in the Australian context.

In applying the results of this report, it is important to remember that generalisation from case studies to other locations is sensible only where similar conditions apply. For example, it may be reasonable to draw conclusions from a case study on land use planning in Katherine and use them for a similar study in another fairly remote Australian regional centre.

While extensive work has gone into BCA, particularly for structural measures prior to their implementation, a key focus of this research was to attempt to quantify the benefits of non-structural mitigation measures (such as land use planning) for which very little information currently exists. This report has also attempted to examine and quantify the realised benefits of mitigation when tested by actual flood events by conducting *ex post* BCA. Understanding both the predicted and actual benefits of mitigation is important to help ensure that scarce government funding is spent in a cost-effective and efficient manner.

KEY FINDINGS

The case studies, consultations and literature surveyed demonstrate evidence of the benefits of various types of flood mitigation. Data limitations prevented the BTRE from evaluating the net benefits of mitigation in the case studies. Information on the costs of measures such as land use planning was not available. There were also difficulties in estimating the full benefits of measures. However, in each of the five case studies, there is evidence that the estimated benefits of the various flood mitigation measures in terms of tangible savings are substantial.

- Land use planning in Katherine is estimated to have reduced the AAD by around $0.6 million. In a 1 per cent AEP flood, the planning decision is estimated to save around $29 million in direct and indirect costs.
- Voluntary purchase in the Kelso area of Bathurst is estimated to have saved $0.7 million in the 1998 flood. If all properties had been purchased before that 1998 event, savings would have been in the order of $1.2 million. When complete, the scheme will save approximately $1.8 million in a 1 per cent AEP event.
- Building controls (minimum floor levels) in Thuringowa appear to have had an effect in reducing the extent of inundation (and therefore internal damage) in the 1998 flood. Given that individuals can pay off the higher construction costs over the life of a mortgage, building design measures enforced through building controls can be a cost-effective and affordable form of mitigation.
- Investment in bitumen-sealed roads (which are more flood-resistant) in the Waggamba Shire is estimated to be economically justified. Analysis suggests that the minimum of 32 trucks per day required to break even is comfortably exceeded in the Waggamba Shire.
- A levee proposed for the Tamworth industrial area would significantly reduce flood damage (the cost of the November 2000 flood is estimated at close to half a million dollars). It is also estimated that the existing CBD levee would avoid at least $5.36 million potential direct damage in a 100-year ARI flood.

These savings typically refer only to direct and indirect costs avoided. Intangible savings are discussed in the appendices, but not quantified. The figures therefore underestimate the full benefit of implementing flood mitigation.

A number of important points regarding the benefits of mitigation, economic viability and non-economic factors were also raised:

- The importance of considering flood mitigation options that address all three sources of risk—existing, future and residual (or continuing)—was clearly evident. Attention must be focused on implementing both structural and non-structural solutions to address existing risk and prevent future risk, but also recognising and planning for the continuing risk (particularly the risk associated with catastrophic events).

- The trends toward non-structural mitigation solutions (which may involve less residual risk) were supported by the Katherine, Bathurst and Thuringowa case studies as well as in discussions with key stakeholders.
- Levees (the most common form of structural mitigation) appear to have been effective in preventing substantial damage and in saving lives across Australia (illustrated by the examples in chapter 2).
- Mitigation of existing risk by altering the way infrastructure is designed and constructed can be a very cost-effective mitigation measure (supported by the Waggamba case study).
- There are considerable similarities in approaches to floodplain management across Australia (for example, the prevalence of the 1 per cent AEP design level). However, there are also some key differences (for example, the use of floodplain maps).
- The importance of recognising that the measures examined in each of the case studies are part of an overall floodplain risk management strategy which includes a mix of measures to address flood problems.
- The uniqueness of each location (in terms of topography, rainfall patterns, community views, affordability of measures, rural or urban development and so on) means that mitigation solutions must be tailored to the location in order to achieve success.
- The importance of community awareness and preparedness together with reliable and timely flood warning systems in determining the success of mitigation. The Tamworth case study found that the preparedness activities of businesses in the lead-up to the November 2000 flood saved more than 80 per cent of potential damage.
- Equity (and perceived fairness) is a powerful factor in community acceptance and therefore policy decisions regarding proposed mitigation measures. In some circumstances, solutions that may not satisfy economic criteria may be necessary to gain community acceptance.
- Drainage and stormwater issues are intimately linked to other flood issues. Regardless of the source of flooding (such as storm surge or cyclone) it is sensible not to examine mitigation solutions for each in isolation.

LIMITATIONS

Problems associated with the methodology used in this report and other limitations of the analysis need to be recognised. These are summarised below.

- The lack of, and uncertainty in, data available to estimate the benefits associated with mitigation limit the accuracy of the case study estimates. In particular, the accuracy of post-disaster statistics (such as flood and floor level data) was an issue in most case study locations.

- The difficulty inherent in capturing and quantifying many indirect and intangible costs and benefits (such as ill-health, stress, lost memorabilia and loss of life).
- Existing methods of estimating flood damage by relating property damage to the depth of flooding (stage-damage curves) are dated. Although modified in some cases to reflect the increasing value of residential building contents over time, this is still an important limitation of the estimates. Both residential and commercial curves are thought to underestimate the true costs of flood damage significantly. The need for improvements in methodology, particularly stage-damage curves, was obvious in all case studies and consultations.
- Several concerns about the application of the BCA framework to evaluating the benefits of flood mitigation were raised.
  - For some mitigation measures, and VP in particular, BCA may be unable to adequately capture the benefits, which primarily relate to reduced risk to life (and other intangibles). If a policy objective (for example, to reduce risk to life) is already established and there is only one realistic mitigation option, BCA may not be the most appropriate tool to prioritise and evaluate mitigation measures. It may be more appropriate to use or give more weight to other criteria (for example, safety) or methods (such as cost-effectiveness analysis).
  - Using BCA in evaluating particular types of non-structural mitigation measures could make them appear unsuitable. Similarly, lower socio-economic groups and those who prepare appropriately for floods could be disadvantaged if BCA is the only decision tool.
  - As a result, BCA, while a powerful economic tool for examining the economic merit of mitigation and prioritising measures, should not generally be the sole decision tool.
- Limitations associated with the case study approach must be emphasised. Generalisation from the case studies to other locations is only sensible where similar conditions apply.
- Assumptions and sources of error discussed in each of the case study appendices should be taken into account. For example, it is not possible to know with certainty what would have happened in the absence of existing mitigation measures.

Despite these issues, the estimates of the benefits of mitigation contained in this report together with the literature surveyed and the information and ideas exchanged during consultations provide a valuable input, not previously available, to inform policy debate and decision-making in the emergency management field.

FUTURE RESEARCH PRIORITIES

During the BTRE's investigation of the benefits of flood mitigation it became clear that there were areas where further research was needed. The consultations and workshop in November 2001 also provided a rich source of ideas on future research priorities. These are described briefly below (in no particular order).

- Further work, perhaps case studies, to provide broader evidence of the benefits of mitigation, including benefits for types of natural disasters other than floods. Some jurisdictions indicated other potential case study locations and measures that could be studied in the future.
- Improved stage-damage curves for residential, commercial and industrial buildings.
- Improved data collection and methods for capturing indirect and intangible costs. Work is underway on better methods to value the contribution of the SES; however, more research in this area is needed.
- Guidelines for case study research including data collection and methodological consistency so that the results of case study research are more transferable.
- Continuing improvement in the analysis of proposed mitigation projects across Australia so that public investment can be directed to those projects producing the most benefits and the greatest value for money.
- Examination of how the application of BCA might disadvantage certain measures and people. This issue needs to be examined more thoroughly to ensure that the poorest and most vulnerable parts of the community and those who act sensibly to reduce damage are not disadvantaged when prioritising mitigation funding.
- Complementary research examining the social, environmental and other aspects of flood mitigation. In particular, the issue of the long-term economic and social impact of disasters on communities.
- Research that integrates the economic, social and other factors associated with natural disasters with spatial (physical) risk models to produce a holistic multi-disciplinary analytical tool.
- The value of community awareness, warning systems and associated issues. For example, there may be valuable lessons to be learned from other areas such as bushfires, health and road safety where awareness campaigns play a large role. Better methods for evaluating community awareness, education campaigns and the effectiveness of warning systems are required. Research is underway in Victoria on this issue.
- Further work on developing the case for amending the Building Code of Australia for residential buildings in areas subject to flood. Matters for consideration include escape routes from inundated buildings; building

strength and structural integrity; and determining recommended minimum habitable floor heights above flood levels.

- Research on flood mitigation in rural areas. Rural issues were briefly discussed in chapter 3. However, more comprehensive research on the different issues associated with rural flood mitigation is needed.
- Research on flood mitigation with respect to urban drainage problems. Stormwater and drainage issues were included in the broad framework of this research and briefly discussed in chapter 3 and the Thuringowa case study. However, more comprehensive and integrated research examining the impact and mitigation of floods regardless of source (urban drainage, riverine, storm surge, cyclone and so on) is needed.
- Better understanding of the cost and impact on communities of less costly and more frequent disasters.

appendix i

KATHERINE CASE STUDY

Katherine is 314 kilometres south east of Darwin. It is the major commercial centre for a large area of the Northern Territory, with a population of 9 959 at 30 June 2000 (Northern Territory Government 2001). Located in the tropics, Katherine has an average annual rainfall of 1 068 millimetres. It lies on the Katherine River, a major tributary of the Daly River. The Daly River discharges into the Timor Sea at Anson Bay, about 300 kilometres north west of Katherine and south of Darwin.

FLOOD HISTORY

Since December 1897, eight floods in Katherine have exceeded 17 metres on the old railway bridge gauge and one was very close to 17 metres (table I.1)[22]. The most recent of these floods (January 1998) reached a peak level of 20.39 metres and is the largest Katherine flood on record. Studies after the 1998 flood resulted in a revision of ARIs, with the 1998 flood estimated to have had an ARI of about 155 years.

TABLE I.1 RECORDED FLOOD HEIGHTS—KATHERINE

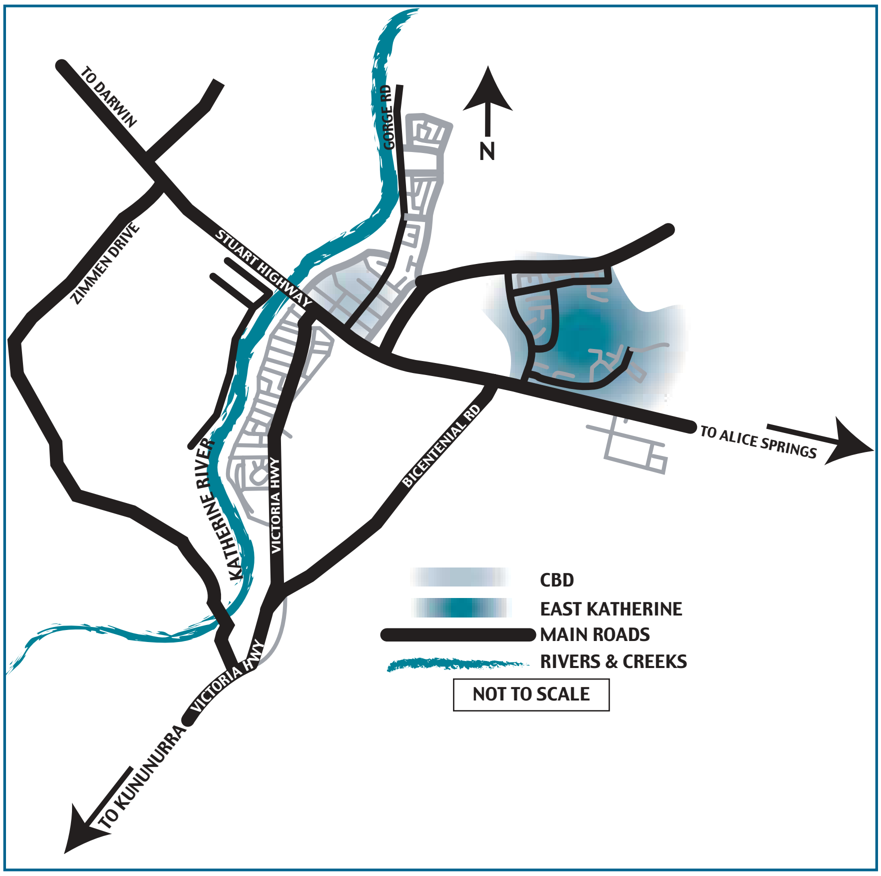
Date	*Gauge height (m)*
Dec 1897	19.0 to 19.5
Jan 1914	18.59
Apr 1931	19.05
Jan 1940	19.26
Mar 1957	19.29
Feb 1968	17.15
Mar 1984	17.36
Feb 1987	16.97
Jan 1998	20.39

Source Barlow (1992, p. ii), Water Studies (2000, p. 17).

In recognition of the flood risk in Katherine, the Northern Territory Government decided, around 1980, that future development in Katherine would occur on higher land at East Katherine, about two kilometres east of the CBD (figure I.1). Also in 1980, the Northern Territory Government approved

22 The moderate flood warning threshold level is 17 metres.

FIGURE I.1 MAP OF KATHERINE



Source Based on Paiva (1996, figure 1.1).

a floodplain management policy that required floor levels of housing in flood-liable land to be a minimum of 350 millimetres above the level of the flood used to define land liable to flooding[23].

The flood of 1998 was the first substantial flood since 1957 to extensively inundate inhabited parts of Katherine. During the 1998 flood, almost all residential, commercial and industrial properties in the town area were flooded. Properties in East Katherine escaped inundation (Water Studies 2000, p. 1). Road access to Katherine, including East Katherine, was cut off. There was substantial damage to the CBD and subsequently several businesses failed. The

23 The floodplain management policy defines flood-liable land as 'land that would be inundated as a result of a flood that is the greater of either the highest on record or that which has a statistical chance of one per cent of occurring in any one year.'

PLATE 1 KATHERINE FLOODS—1998

Source Department of Infrastructure, Planning and Environment, Northern Territory Government.

warning system operated as planned, but many residents were reluctant to evacuate when advised to do so. Many of them, whose properties were shown to be above the 100 ARI flood level on the then existing maps, falsely believed they were in a flood-free zone.

The topography of the eastern floodplain is complex and the gauge readings do not accurately reflect the actual increase in flood levels over those associated with the then accepted 1 per cent AEP flood. In some locations, the increase was over two metres for the 1998 flood. Because of this complexity and earlier modelling only having been done up to what was believed to be the 1 per cent AEP level, emergency services were not in a position to anticipate the true extent of the flooding. Consequently, the implications of the predicted flood levels were not fully appreciated by emergency services personnel and even less so by the general public. The resulting damage to the contents of flood-affected houses was probably larger than necessary (Northern Territory Government representatives, pers. comm., 16 May 2001). The freedom from inundation of houses in East Katherine provided an opportunity to investigate the benefits of land use planning as a flood mitigation measure.

EVALUATION METHOD

The focus of the analysis was to estimate the damage to houses that was avoided by building in East Katherine rather than an alternative site near the existing development. The BTRE was told that, if the East Katherine development had not occurred, the most likely site for development would have been on the western side of the river[24]. Land in this location is flatter and more suitable for construction than East Katherine.

Ideally, damage costs would be estimated using the framework presented in BTE (2001a). The direct damage costs estimated here are consistent with that framework. However, it becomes much more difficult to estimate indirect costs for hypothetical circumstances as considered in this analysis. Nevertheless, an attempt is made to estimate indirect costs, although they are necessarily rough estimates. The problems of dealing with intangible costs are just as difficult as for an actual event and estimation has not been attempted. Although the focus is on residential property, some estimates have also been provided for commercial and public buildings.

The basis of the method of estimating direct damage to houses was to consider what damage would have occurred to houses built in East Katherine if they had been built on flood-liable land in the older part of town. The BTRE was told that the houses in East Katherine were predominantly at ground level. The assumption was made that the decision to build ground level houses in East

24 As new land is required for Katherine, the Northern Territory Government, in consultation with the community, decides what parcels of Crown Land are released for development.

Katherine was linked to cost and fashion rather than for the reason that construction was in an essentially flood-free area. That is, it was assumed that there would have been a preference for ground level houses, even if they had been built in the older part of Katherine.

The method of estimating residential damage involved the following stages:

- estimate the flood damage per ground level house in the old part of Katherine using data from past studies;
- estimate the number of houses in East Katherine; and
- use the estimate of average damage to ground level houses to estimate the damage avoided by building houses in East Katherine.

Studies of Katherine conducted in 1990 (Barlow 1992, Barlow and Rajaratnam 1992) provide estimates of damage to properties arising from 2 per cent AEP and 1 per cent AEP floods. The flood height, as measured by the gauge at the old railway bridge, was based on what was then the accepted 1 per cent AEP flood. The BTRE was fortunate in gaining access to the individual property data for residences, which contained street address, surveyed ground height and estimated floor height for each residence in the data used for the 1990 study.

Residential stage-damage curves used in the 1990 analysis were based on curves in ANUFLOOD[25], modified to reflect typical contents of a house in Katherine (Barlow and Rajaratnam 1992, appendix 2). Separate stage-damage curves were used for elevated and ground level houses. The same stage-damage curves, updated to 2001 prices, formed the basis for the BTRE analysis.

The 1992 report contained estimates of the number of flooded houses but did not provide numbers of affected elevated and ground level houses. The BTRE developed a spreadsheet to estimate damage to both ground level and elevated houses using the ground and floor level data. The 1992 report only contained the height reached at the railway bridge gauge, although the flood level surface slope was taken into account in the flood damage study that formed the basis of the 1992 report. Flood heights for the BTRE analysis were obtained from flood contour maps published by the Northern Territory Department of Lands, Planning and Environment in November 2000. These contours represent post-1998 flood height estimates (revised to take into account the 1998 flood). Flood heights for individual properties were estimated by interpolating between the contours, which were at intervals of 0.25 metres.

If the houses in East Katherine had been built elsewhere, they would have been required to comply with the building regulations existing at the time of construction. That is, they would have been required to have floor levels

25 ANUFLOOD is a computer package developed in 1983 at the Centre for Resource and Environmental Studies. It contains in-built stage-damage curves that are averages of curves developed from past floods. ANUFLOOD is widely used to estimate the damage costs of floods in Australia.

300 millimetres above the pre-1998 accepted 1 per cent AEP flood level[26]. Floor levels in the sample provided to the BTRE were adjusted to meet this requirement.

Floor level adjustment required an estimate of the pre-1998 1 per cent AEP flood levels. These were not available from the flood contour maps, which were for post-1998 levels. The original 1 per cent AEP flood level was between the revised 5 per cent and 2 per cent AEP flood levels. The pre-1998 flood levels were estimated by interpolating between the two post-1998 levels to reproduce the same direct damage costs as Barlow and Rajaratnam (1992) by using their stage-damage curves and the BTRE spreadsheet. The new floor levels were calculated as the pre-1998 1 per cent AEP flood level estimated for each house plus 300 millimetres[27].

Not all houses in the older part of Katherine would suffer over-floor flooding in floods reaching levels used in the analysis. It is reasonable to assume that the number of houses that would be damaged had they not been built at East Katherine would be the same as the number estimated using the 1990 data in the BTRE spreadsheet.

Some modifications were made to the stage-damage curves. The BTRE updated the 1990 stage-damage curves used by Barlow and Rajaratnam (1992) to 2001 prices. Work by Blong (2002) following the 1998 flood suggested that using the 1990 stage-damage curves substantially underestimated the damage sustained in 1998. It is often suggested that existing stage-damage curves—estimated in the early 1980s—should be doubled to make them more representative of typical household contents today. This assumption is supported by figures from Insurance Statistics Australia indicating that the average policy for home contents' insurance in Australia rose 91 per cent between 1988 and 2001, or 42 per cent in real terms. The BTRE increased the stage-damage curves (already updated to 2001 prices) by 29 per cent using the real increase in the average Australian household contents between 1990 and 2001.

The second part of the analysis required an estimate of the number of houses in East Katherine. The number (816) was estimated from an aerial photograph of the area taken in April 1998.

The third part of the analysis involved using the estimated damage cost per house, the number of houses in East Katherine and the proportion of houses flooded to calculate the damage avoided by basing development in East Katherine rather than the western side of the river.

26 Although the policy stipulated 350 millimetres, 300 millimetres was the margin enforced in practice.

27 If the ground level was already above this level, the floor level was set equal to the ground level. If the floor level was 2 metres or more above ground level, the house was assumed to be elevated.

Although houses in East Katherine would generally escape damage in most floods, many of them would be damaged in a PMF. As a result, estimates of damage costs avoided cannot be applied to all 816 houses. Instead, the savings estimates need to be reduced to allow for damage that would occur in East Katherine during a PMF.

The BTRE used the PMF flood map and assumed floor levels were 40 centimetres (the approximate average for houses in the 1990 data) above ground level to estimate the approximate damage to houses in East Katherine during a PMF. The damage estimated in this way was approximately 64 per cent of damage that would have occurred if the houses had not been built at East Katherine. That is, PMF damage costs estimated using the BTRE spreadsheet need to be multiplied by 0.36 to allow for the damage that would occur at East Katherine during a PMF. Possible building failure in a PMF was not considered.

RESULTS

Direct costs avoided

The average potential damage to ground level houses using the adjusted floor levels for a 1 per cent AEP flood was estimated by the BTRE at approximately $26 000 per house. The total residential potential direct damage in the 1 per cent AEP is around $20 million.

Of the ground level houses in the data, 96 per cent were inundated (table I.2). This high percentage is a result of floor heights in the data being set to 300 millimetres above the pre-1998 1 per cent AEP flood levels. The revised 1 per cent AEP flood levels are more than 300 millimetres above the original levels. An indication of the difference is given by the gauge heights, which are 105.63 metres for the pre-1998 1 per cent AEP flood and 106.34 for the post-1998 level.

In contrast, for the more frequent 5 per cent AEP flood, there is no over-floor flooding—all damage is external.

The stage-damage curves used by Barlow and Rajaratnam (1992) are for potential damage. To account for the fact that people take steps to minimise damage, actual damage is determined by multiplying the estimated potential damage cost by a Damage Reduction Factor (DRF) to allow for warning time and prior flood experience. The BTRE considers a DRF of 0.7 appropriate for Katherine, having a warning time of up to 12 hours (Barlow 1992, p. 7) and a population with little experience of flooding (BTE 2001a, figure 4.4). The DRF of 0.7 means that only 30 per cent of potential damage is likely to be avoided.

As discussed in chapter 4, the use of the DRF to calculate actual damage has attracted some criticism when used in BCA of proposed mitigation schemes. It is argued that the use of a DRF penalises those who take action to help themselves, since it reduces the benefits of a proposed scheme. The BTRE has therefore focused on potential, rather than actual, damage, although the results in tables I.2 and I.3 show a DRF. The damage avoided by building at East Katherine, rather than in the older part of Katherine, is shown in table I.2.

TABLE I.2 RESIDENTIAL COSTS AVOIDED—EAST KATHERINE

	5% AEP	*2% AEP*	*1% AEP*	*PMF*
Gauge height (AHD)[a] (metres)	105.23	105.96	106.34	109.48
Prop. of houses damaged (%)	4.78	79.78	96.07	100.00
No. of houses damaged[b]	39	651	784	816
Est. potential damage per house ($'000)	1.3	11	26	31
PMF adjustment[c]				0.36
Total potential damage ($ million)	0.051	7	20	9
DRF[d]	0.7	0.7	0.7	0.7
Total actual damage ($ million)	0.035	5	14	6

Note Damage values are in 2001 dollars. AEP and PMF refer to the post-1998 estimated flood levels. Totals rounded to nearest million dollars.

a. Australian height datum (0.0 metres is approximately mean sea level).

b. Total number of houses in East Katherine estimated at 816.

c. Factor to allow for damage that would occur in East Katherine during a PMF.

d. DRF = Damage Reduction Factor. Actual damage is estimated by multiplying potential damage by the DRF.

Source BTRE estimates based on data used by Barlow and Rajaratnam (1992).

In addition to the residential development in East Katherine, there are also four schools, a child care centre, a small shopping centre, Department of Education residential facility, a motel and a police, fire and emergency services

TABLE I.3 COMMERCIAL COSTS AVOIDED—EAST KATHERINE

	Potential damage[a]		*DRF*[b]	*Actual damage*
AEP (%)	($/m^2)	($'000)		($'000)
5	0	0	0.7	0
2	20	74	0.7	52
1	165	617	0.7	432
PMF	435	581[c]	0.7	407

Note Damage value is in 2001 dollars. AEP and PMF refer to the post-1998 estimated flood levels. Rounding may affect the calculation of totals.

a. Area of shopping centre estimated at approximately 3750 m^2.

b. DRF = Damage Reduction Factor. Actual damage is estimated by multiplying potential damage by the DRF.

c. Factor to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on Barlow and Rajaratnam (1992).

complex (L. Rajaratnam, pers. comm., 27 August 2001). The approximate total area of the shopping centre was estimated from the aerial photo at 3 750 square metres. Damage costs per square metre for the shopping centre were based on those for a commercial establishment in the medium value class published in Barlow and Rajaratnam (1992, table 4.4 appendix B) (table I.3) updated to 2001 prices. Over-floor depths were assumed to be the same as those estimated for houses. The damage at the maximum over-floor depth of two metres in the Barlow and Rajaratnam stage-damage curve most likely underestimates the damage for the over-floor depth of 4.4 metres estimated for the PMF. However, it was not possible to estimate the degree of underestimation and no change was made.

Little information is available on the likely damage to public buildings. A nominal damage value, based on actual damage to schools during the 1998 flood and proportional to over-floor depth for houses, was assigned to each of the public buildings (L. Rajaratnam, pers. comm., 19 October 2001). The PMF damage was taken to be twice the damage for the 1 per cent AEP flood. The motel, although a commercial establishment, was treated in the same way as a public building, because there were no data available to the BTRE to allow estimation of damage costs using commercial stage-damage curves. The damage estimates are shown in table I.4. Given the likelihood that few, if any, people were available to relocate items to safety and much of the damage occurred to objects that could not be moved, very little damage could have been avoided. Therefore, no distinction is made between actual and potential damage to public buildings in this analysis.

TABLE I.4 PUBLIC BUILDING AND MOTEL COSTS AVOIDED—EAST KATHERINE

AEP (%)	*Damage ($/building)*	*Total damage[a] ($'000)*
5	0	0
2	99 400	795
1	440 000	3 520
PMF	313 520[b]	2 508

Note Damage is in 2001 dollars. AEP and PMF refer to the post-1998 estimated flood levels.

a. Total damage based on eight buildings (seven public buildings and one motel).

b. Includes an adjustment to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on information supplied by the NT Government.

Direct damage estimates are summarised in table I.5. Damage to residential buildings dominate the result. For the 1 per cent AEP flood, of the $24 million direct damage avoided, more than 80 per cent is attributable to residential buildings. This is not surprising, as there is little commercial development in East Katherine.

TABLE I.5 POTENTIAL DIRECT DAMAGE COSTS AVOIDED—EAST KATHERINE

AEP (%)	*Residential ($'000)*	*Commercial ($'000)*	*Public ($'000)*	*Total ($'000)*
5	51	0	0	51
2	7 000	74	795	8 000
1	20 000	617	3 520	24 000
PMF	9 000	581	2 508	12 000

Note Cost estimates are in 2001 prices. Figures for residential and total costs are rounded to nearest million dollars. AEP and PMF refer to the post-1998 estimated flood levels.

Source Tables I.2, I.3 and I.4.

Indirect costs avoided

Indirect costs relevant to Katherine include:

- clean-up costs;
- disruption to business;
- emergency services costs; and
- emergency accommodation costs.

There are insufficient data to allow easy estimation of indirect costs for Katherine in this study. Instead, costs derived from other studies for actual floods have been used. Such an approach is inaccurate as each flood is unique and indirect costs can vary substantially. The indirect costs presented below are therefore approximate. Unlike the Bathurst case study (appendix II), the effects of building failure have not been considered in calculating costs arising from the PMF.

Clean-up costs

Reported clean-up times for residential houses vary over a wide range (BTE 2001a, p. 84). The BTRE considers that 20 person-days per household is a reasonable value to use for clean-up effort. However, it can be expected that the more severe the flood, the larger the post-flood clean-up effort required. A sliding scale of clean-up effort proportional to over-floor flood depth was adopted based on a clean-up time of 20 days for the 1 per cent AEP flood (table I.6). The BTRE also considers that clean-up time should be valued at average weekly earnings. Using the same industry weightings as in BTE (2001b, p. 11) the BTRE calculated average weekly ordinary time earnings (AWOTE) to be $738.20 for February 2001 (ABS 2001a). Similar weightings are appropriate because both Tamworth and Katherine are regional centres and

TABLE I.6 CLEAN-UP COSTS AVOIDED—EAST KATHERINE

	Residential						
AEP (%)	*No. of houses*	*Person-days per house*	*Person-days*	*Cost[a] ($'000)*	*Commercial ($'000)*	*Public ($'000)*	*Total ($'000)*
5	39	3	117	17	2	10	30
2	651	5	3 255	481	7	29	517
1	784	20	15 680	2 315	32	129	2 476
PMF[b]	816	88	71 808	3 777	51	203	4 031

Note Figures may not add to totals due to rounding. AEP and PMF refer to the post-1998 estimated flood levels.

a. Costs based on AWOTE of $738.20.

b. PMF costs are multiplied by 0.36 to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on table I.2, BTE (2001a), BTE (2001b), ABS (2001a) and Catchment Management Unit (1990).

it can be expected that similar types of businesses would be found in both towns. The results of the residential clean-up costs are shown in table I.6.

The BTRE (BTE 2001b) estimated preparation and clean-up costs for commercial and industrial enterprises in Tamworth following the November 2000 flood. These costs averaged $0.60 per square metre in preparation and restoration of stock for premises with no over-floor flooding. This is the appropriate cost for the 5 per cent AEP flood which also was estimated as having no over-floor flooding. Applying this cost to the East Katherine shops gives an estimated clean-up cost of $2 250 for the 5 per cent AEP flood. Tamworth premises that did suffer over-floor flooding incurred costs of $1.94 per square metre for an average over-floor depth of 22 centimetres. This depth is very close to the estimated average over-floor depth for the 2 per cent AEP flood. Applying a cost of $1.94 per square metre for the 2 per cent flood gives a total commercial clean-up cost of $7 300. Clean-up costs for other floods were calculated on the assumption that clean-up costs are proportional to over-floor flood depth.

There is little information to assist in the estimation of clean-up costs for public buildings. One of the few estimates available is that for the Nyngan flood of 1990 (Catchment Management Unit 1990, p. 30). Cost estimates for Nyngan public buildings were $16 100 per building in 2001 prices. Using the same estimate for the eight buildings identified in East Katherine gives a total of $129 000. This amount was assumed to apply to the 1 per cent AEP. The costs for other flood severities were assumed proportional to over-floor flood depth. An amount of $10 000 was assumed for preparation costs for the 5 per cent AEP flood. The results of the commercial and public building clean-up cost calculations are shown in table I.6.

Business disruption costs

The economic costs of business disruption are best measured by the loss in value added[28]. Value added lost for retail establishments during the November 2000 flood in Tamworth was estimated from the survey data to be $0.80 per square metre per day (BTE 2001b). Retail establishments in Tamworth lost on average two days trading in the November 2000 flood. Two trading days were also assumed to be lost for the 2 per cent AEP flood in Katherine, as the over-floor flood depths were similar. For the 5 per cent flood, the BTRE assumed one day to be lost to allow for preparation for the floods and restoration of stock afterwards. The number of days lost for other floods was assumed to be proportional to over-floor depth. The results of the calculations are shown in table I.7.

TABLE I.7 BUSINESS DISRUPTION COSTS AVOIDED—EAST KATHERINE

AEP (%)	*Days lost*	*Commercial[a] ($'000)*	*Motel ($'000)*	*Total ($'000)*
5	1	3	2	5
2	2	6	5	11
1	9	27	20	47
PMF[b]	39	42	31	73

Note AEP and PMF refer to the post-1998 estimated flood levels. Rounding may affect the calculation of totals.

a. Cost is value added lost and is calculated at $0.80 per m^2 per day of lost trading.

b. PMF costs are multiplied by 0.36 to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on BTE (2001b) and ABS (2001b).

These business disruption costs are local losses. In many floods, local business losses may not be national losses, as business can be often transferred to other areas. However, this is not so easily done in Katherine. Other business centres are long distances from Katherine and are not realistic alternatives. In addition, road access to Katherine is cut off during severe floods, so that the opportunity for Katherine's residents to transfer their business is limited. The only offsetting factor is that some retail transactions may be delayed rather than lost entirely. It is assumed that the opportunity for shops in East Katherine to delay retail transactions is negligible and that the business disruption costs are national as well as local losses.

The one business that remains to be considered is the motel in East Katherine. If Katherine is inaccessible by road, guests from out of town are less likely to arrive. However, the flood would also prevent existing guests from leaving,

28 Value added, in general terms, represents the value of gross output minus the value of intermediate inputs.

provided the motel itself escapes flooding. For floods up to the 1 per cent AEP event, the motel remains flood-free; but for the PMF, the motel site has up to 1.2 metres of water according to the contour maps. If the motel had been built on the western side of the river, it may have suffered inundation for all but minor floods and consequently its location in East Katherine would have resulted in avoidance of loss. For the PMF, the motel would have experienced some inundation in its existing location, although possibly not as severe as on an alternative site west of the river.

The motel has 100 rooms and the low season rate is currently $65 per person. During the low season, it is assumed that the room occupancy rate is 50 per cent and that 50 per cent of the occupied rooms have one occupant and the remainder have two. The average revenue per occupied room is therefore $97.50. The value added for accommodation is 46.3 per cent, thus giving an economic cost of disruption of the motel business of $2 257 per night. The days of disruption were taken as being the same as for other commercial establishments (table I.7).

Emergency services costs

Little information is available about emergency services costs incurred during the 1998 Katherine flood. Indeed, scarcity of emergency cost information is common for most disasters. Some information was available from speeches made in the Northern Territory Parliament on 17 February 1998, just over two weeks after the flood. Mr Reed, the Deputy Chief Minister, noted in his speech that 1 000 volunteers had travelled from Darwin to Katherine and that up to 300 further volunteers had registered in Katherine. Undoubtedly, there would also have been volunteer efforts by people who did not register. The number of volunteers is therefore assumed to be 1 500. The Minister's speech did not indicate for how long the volunteers worked. Given the severity of the flood, an average time of seven days for each volunteer would seem reasonable. Using these assumptions, Katherine received, on average, about $1 410 of volunteer effort for each of the 1 100 affected residences.

Other emergency services costs include the marginal costs of flying food supplies into Katherine, overtime and allowances for permanent emergency services staff, equipment hire and other expenditure related to the response effort. No information is available on these costs. The BTRE assumed that these additional costs were equal to 50 per cent of the costs of the volunteer effort.

These costs are for the 1998 flood and were assumed to be applicable to the 1 per cent AEP flood. For other floods, the BTRE assumed that emergency services costs per flooded residence were proportional to average over-floor depth (table I.8).

TABLE I.8 EMERGENCY SERVICES COSTS AVOIDED—EAST KATHERINE

AEP (%)	*Cost per house*[a]	*No. of houses*	*Cost ($'000)*
5	30	39	1
2	480	651	312
1	2 115	784	1 658
PMF	9 345	816	2 717[b]

Note AEP and PMF refer to the post-1998 estimated flood levels. Rounding may affect the calculation of totals.

a. Includes cost of volunteer effort as well as SES and other emergency services. Total cost is calculated at cost of volunteer effort plus 50 per cent.

b. PMF costs are multiplied by 0.36 to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on information contained in speech by Deputy Chief Minister to NT Parliament on 17 February 1998.

Emergency accommodation costs

During the 1998 flood, 1 100 houses in Katherine were affected by the floodwaters and 1 822 people registered at emergency centres. That is, 1.7 people for each flood-affected house registered at an emergency centre. Not everyone who registered at emergency centres may have needed emergency accommodation. It is also certain that many people would have found emergency accommodation with friends and relatives without registering. Using a figure of 1.7 people per flood-affected house is likely to underestimate the number of people requiring emergency accommodation.

Based on work by Smith et. al (1979, p. 55), emergency accommodation costs suggested by the BTRE (BTE 2001a, p. 83) are $57.90 per household plus $29 per person-night in 2001 prices.

The average number of nights for which emergency accommodation was required was not mentioned in the information available to the BTRE.

Descriptions of the flood in speeches to the Northern Territory Parliament on 17 February 1998 indicate that it was many days before residents were able to return to their houses. An assumption of seven days accommodation being required for the 1 per cent AEP flood was adopted. Nights of emergency accommodation for other floods were estimated on the basis that the number of nights required was proportional to the estimated average over-floor flooding depth. The results of the calculations are shown in table I.9.

A summary of indirect costs is shown in table I.10. Clean-up costs and emergency services costs are the major indirect costs estimated, accounting for 55 per cent and 37 per cent respectively of the total indirect costs of $4.5 million in the 1 per cent AEP. Business disruption costs are small due to the small volume of commercial activity in East Katherine.

TABLE I.9 EMERGENCY ACCOMMODATION COSTS AVOIDED—EAST KATHERINE

AEP (%)	*No. of houses*	*No. of nights*	*Cost ($'000)*
5	39	0	0
2	651	2	102
1	784	7	316
PMF	816	31	461[a]

Note Costs are based on $57.90 per household plus $29 per person night. It is assumed there are 1.7 people per flood-affected house seeking emergency accommodation. AEP and PMF refer to the post-1998 estimated flood levels. Rounding may affect the calculation of totals.

a. PMF costs are multiplied by 0.36 to allow for damage that would occur in East Katherine during a PMF.

Source BTRE estimates based on information contained in speech by Deputy Chief Minister to NT Parliament on 17 February 1998.

TABLE I.10 SUMMARY OF INDIRECT COSTS AVOIDED—EAST KATHERINE

($'000)

AEP (%)	*Clean-up*	*Business disruption*	*Emergency services*	*Alternative accommodation*	*Total*
5	30	5	1	0	36
2	517	11	312	102	941
1	2 476	47	1 658	316	4 497
PMF	4 031	73	2 717	461	7 282

Note Cost estimates are in 2001 prices. AEP and PMF refer to the post-1998 estimated flood levels. Figures may not add to totals due to rounding.

Source Tables I.6, I.7, I.8 and I.9.

Average annual damage

The total potential costs avoided by building at East Katherine range from $86 000 for the 5 per cent AEP flood to $29 million for the 1 per cent AEP flood (table I.11). The PMF damage costs avoided are lower than the 1 per cent AEP costs due to the damage that would occur in East Katherine during a PMF.

The AAD calculated from the flood damage estimates, after allowing for damage at East Katherine during a PMF, is around $560 000. The AAD is measured up to the PMF by joining the estimates for each flood level by straight lines. In calculating the AAD, no damage costs avoided below the 5 per cent AAD flood were included. The AAD is a measure of the average damage avoided each year by building at East Katherine rather than building in a more hazardous

TABLE I.11 TOTAL COSTS AVOIDED—EAST KATHERINE

AEP (%)	*Direct ($m)*	*Indirect ($'000)*	*Total ($m)*
5	0.051	36	0.086
2	8	941	9
1	24	4 497	29
PMF	12	7 282	19

Note Cost estimates are in 2001 prices. AEP and PMF refer to the post-1998 estimated flood levels. Figures for direct and total costs are rounded to nearest million dollars. Figures may not add to totals due to rounding.

Source Tables I.6 and I.11.

location closer to the Katherine River. In present value terms[29], the benefits are in the order of $12 million in 2001 dollars.

DISCUSSION OF RESULTS

A difficulty with analyses of this type is that it is not possible to know with any precision what would have happened if a different decision had been taken in the past. It cannot be known where houses now existing in East Katherine would have been built if there had been no decision to develop East Katherine. The BTRE was advised that they would most probably have been built on the western side of the Katherine River. However, even with that knowledge, it is not possible to be certain about the number of houses that would have been affected in any flood. The approach taken assumes the same proportion of houses affected in previous floods, but is subject to an unknown margin of error.

Other sources of error include:

- The stage-damage curves used—are they sufficiently accurate? Blong's (2002) data for Katherine suggests that the average cost of direct damage per residential building is much higher than represented in earlier stage-damage curves. The rise in the average value of household contents was integrated into the analysis; however, revised stage-damage curves would be more accurate.
- There is no allowance for building failure in the PMF calculations.
- Commercial direct damage is probably underestimated for the PMF due to the very deep over-floor depth for such an extreme event.
- Assumptions made about the damage to commercial, public and motel buildings would introduce further errors due to paucity of information on which to base the estimates. These are probably not serious, as they are a minor part of the total estimated damage costs.

29 The present value was calculated using a 4 per cent discount rate and a 50-year time period.

- Insurance data from the 1998 flood suggests that the time required for alternative accommodation used in the analysis may significantly underestimate the actual time required and costs incurred.

The analysis has not included the additional infrastructure costs of the decision to develop East Katherine rather than a location closer to existing development. Infrastructure in East Katherine, such as roads and electricity supply, would have had similar costs no matter where the development occurred. However, the distance to East Katherine is longer from existing services than likely alternative development sites. The additional costs of the provision of services to East Katherine would be a cost of the decision. Residents in East Katherine would have less amenity than an alternative location closer to the CBD. Although East Katherine appears to be well endowed with schools, commercial facilities are not well developed. Residents would need to travel further to purchase many of the goods and services available in the CBD. This would also be a cost of the decision. However, given the relative closeness of East Katherine to the CBD, the loss of amenity is not expected to be great.

The analysis has not included estimates of intangible losses avoided by building at East Katherine. The experience of Katherine residents during 1998 and of flood victims elsewhere indicates that intangible costs can be huge. The avoidance of these intangible costs alone might well be sufficient to justify the decision to make East Katherine the focus of future development.

Overall, the likely errors in the analysis suggest that the benefits of the decision to develop East Katherine are underestimated. Although no information is available on the additional costs of developing East Katherine compared with alternative development sites, the evidence based on tangible benefits (costs avoided) suggests that the benefits have exceeded the costs.

appendix

ii

BATHURST CASE STUDY

Established in 1815, Bathurst is the oldest inland settlement in New South Wales. By 1999, it had a population of more than 30 000 (Bathurst City Council, 2001). Bathurst lies 210 kilometres west of Sydney, on the upper reaches of the Macquarie River and Queen Charlottes Vale Creek. Most of the city, including the CBD, is located outside the limits of the 1 per cent AEP flood. However, some older rural and residential areas on the floodplain are within these limits. In particular, the area referred to as the Kelso floodplain lies in a basin bounded on two sides by the Macquarie River and Raglan Creek (figure II.1).

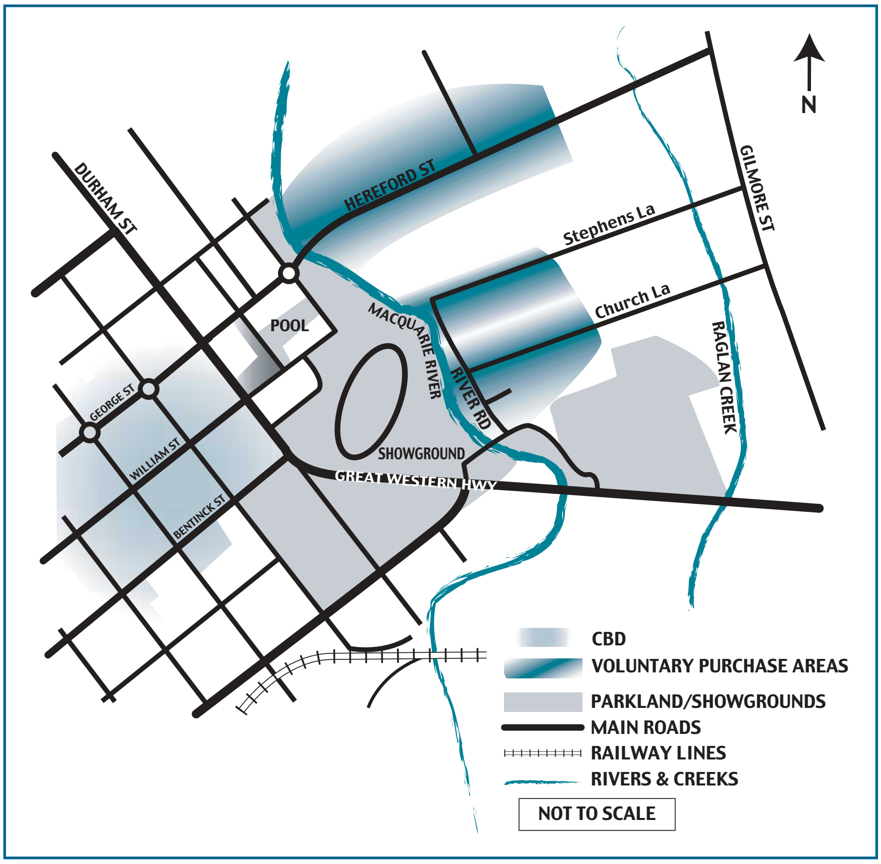
The Bathurst City Council is currently conducting a voluntary purchase (VP) programme, buying eligible residences on the Kelso floodplain. Two large floods (1990 and 1998) have occurred since the start of the programme, providing an opportunity to investigate the benefits of VP as a flood mitigation measure.

FLOOD HISTORY

Bathurst is at the top of the Macquarie River Catchment, which is fed by three upstream tributaries—Campbell's River, Fish River and Queen Charlotte's Vale Creek. As a result, flooding is flashy in nature; warning times are short (a maximum of 13 hours) and the flood peak may only last several hours. The three tributaries create a range of possible flood behaviours, with each flood generated and affected by different catchment responses upstream of Bathurst.

Since 1823, seven major floods (1823, 1916, 1952, 1964, 1986, 1990 and 1998) have affected Bathurst. The 1964 flood acted as a catalyst for major structural mitigation, particularly channel clearing. The 1998 flood is the highest on record at 6.69 metres at the Stanley Street Gauge (Willing and Partners 2000, p. A-8). There have been variations to the floodplain between the last three major floods (1986, 1990 and 1998), resulting in changes to the depth of floodwaters in some areas. Some locations reported higher flood levels in 1986 and other locations were subject to deeper flooding in 1998. As a result, there is some debate over whether the 1986 or 1998 flood was more extensive. Estimates of the ARIs for these three events range from 60 to 100 years. Data provided by Bathurst City Council, based on the 2000 flood modelling, indicated that all

FIGURE II.1 MAP OF KELSO FLOODPLAIN, BATHURST



Source Based on UBD (2000) and information provided by Bathurst City Council.

three events had more than a 1 per cent AEP[30]. With each flood event, records improve and allow more accurate modelling of the floodplain, leading to revisions of the probabilities and associated flood levels.

1986 Flood Inquiry

The concept of flood mitigation in Bathurst has been in existence for many years. In 1986, the Bathurst Flood Inquiry was set up to investigate how effective those earlier measures had been in 1986 and what else could be done to reduce the impact of future floods. The Inquiry found that more than 260 residences had been affected, large-scale evacuations had taken place, roads had been cut off and serious disruption had occurred. Direct costs of damage for

30 That is, have a greater than 1 per cent chance of occurring in any given year.

PLATE 2 BATHURST FLOODS—8 AUGUST 1998

Source © Land and Property Information, Panorama Avenue, Bathurst, 2795, www.lpi.nsw.gov.au the whole Bathurst area were found to be in excess of $5.3 million in 1986 prices (Curran 1986, p. 53).

The 1986 Inquiry investigated four mitigation options:

- do nothing;
- a VP scheme (in the Kelso floodplain);
- levee construction; and
- a combined levee and VP scheme.

The Inquiry found:

> A Voluntary Acquisition Program only for the Kelso floodplain would eventually provide a complete solution for residents of that area, but do nothing for the greater number of residents on the western floodplain. Furthermore, the scheme would be difficult to justify … The net present worth of this option is -$2.15 million, and it cannot therefore be justified on economic grounds (Curran 1986, p. 58).

The levees-only option was found to be the most economically favourable (net present value of $1.15 million and a benefit-cost ratio of two), but would have left Kelso residents unprotected. The combined option (levees and acquisition) addressed the flood risk to all floodplain residents. The Inquiry reported that, despite the combined scheme being sub-optimal in strictly economic terms (lower net present worth), the community considered it the most favourable in terms of social and equity considerations.

The Committee for the Inquiry included the combined levees and VP scheme among its recommendations. The balance between economic, social and equity considerations is a common issue facing decision-makers. In this case, both equity and economic factors played a role in the final decision. Equity concerns in Bathurst centred on the Kelso area where the '…cost of buying or renting is generally lower than elsewhere in Bathurst. As a result, there is a higher than average proportion of low-income earners' (Curran 1986, p. 19).

The Inquiry recommended that a comprehensive floodplain management plan be prepared and implemented as proposed under the then recently released NSW State Government Flood-prone Lands Policy (Curran 1986, p. 6). Given that VP was recommended as the only realistic option for Kelso, the scheme was approved by Council following the 1986 Inquiry and began with the purchase of a single property in 1986–87 (Bathurst City Council, pers. comm., 26 September 2001).

The Kelso VP scheme was considered the only realistic option because:

- levees were found to be impractical due to their impact on flood behaviour;
- it is a high-hazard area where people need to be evacuated in each flood; and

- the Kelso area is subject to a more severe flood risk than other parts of Bathurst and it was important to protect the whole floodplain community.

The Floodplain Management Plan

In November 1993, the *Floodplain Management Plan Report* was published, incorporating the 1986 Inquiry's recommendations. Following extensive community consultation, the Council adopted the *Floodplain Management Plan* in April 1995. The plan involves a mix of structural and non-structural measures including VP, levee construction, development controls and other measures with a total cost of $11.5 million in 1993 prices. The estimated net present worth of the savings in flood damage due to the implementation of the whole plan was $4.4 million (using a 7 per cent discount rate and 50-year design life). This gives a benefit-cost ratio for the whole scheme of 0.5 (Gannon and Allen 1993, p. 17). This estimate is regarded as a minimum, as intangible impacts were not captured.

The plan, developed in 1993, was based on modelling using the 1990 flood data. Five years later—but before the 1998 flood—the model was reconfigured to account for the removal of the Rankens Bridge at Eglinton, which acted as a backwater control in large flooding. The revised model showed a slight drop in the flood levels in the river channel flow path. In 2000, the model was again recalibrated to incorporate the actual 1998 flood data. The analysis that follows uses the 2000 flood model information. Given the revisions to flood levels and changes to the floodplain, comparisons with earlier estimates of the benefits of various flood mitigation options in Bathurst are difficult.

Kelso VP Scheme

The focus of this case study is the VP component of the *Floodplain Management Plan*. The plan included the purchase of residential properties (initially 73) within the Kelso floodplain, predominantly along Hereford Street (figure II.1). The total estimated cost of the VP scheme was $4.6 million (Gannon and Allen 1993, p. 17). In 1995–96 another thirty houses forming a 'disappearing island' along River Road were added to the VP scheme (Bathurst City Council, pers. comm., 26 September 2001).

Priorities for the VP scheme depend on a combination of several factors including whether the property:

- is owner-occupied;
- has a high-hazard rating for the 1 per cent AEP flood;
- has previously experienced over-floor flooding; and
- is adversely affected as a result of other structural measures on the floodplain (Gannon and Allen 1993, p. 43).

A total of 102 properties have now been identified for purchase. While only seven of these had been purchased before the flood of 1990, this number had risen to 50 by the flood of 1998. Sixty-eight properties were purchased under the scheme by 2000–2001. The City Engineer's Report to Council (Allen 1998, p. 9) following the 1998 floods stated that:

> It is obvious that by purchasing these properties, substantial flood damage costs have been saved. Utilising the estimates for flood damage included in the Willing and Partners Computer Based Flood Model Report of 1993, and taking a broad view of the depths of overfloor flooding in both the 1990 and 1998 events, the following estimates, in 1990 dollars, of flood damage costs saved have been calculated—1990 $106 000, 1998 $374 000. These figures do not include the costs of external damage (cars, boats, caravans etc). In 1998 dollars, the damage costs would equate to just short of $0.5 million saved.

Intangible costs and damage to community infrastructure were not included in these estimates.

EVALUATION METHOD

The BTRE's experience in evaluating Regional Flood Mitigation Programme (RFMP) applications has shown that economic analyses of VP measures typically result in lower benefit-cost ratios than alternative solutions, but other factors (particularly hazard level and safety) are taken into account in deciding on VP projects.

It is possible that the full benefits of VP schemes have not been captured in many of the economic analyses done in Australia and the BTRE was keen to investigate this further. The existence of a long-running VP scheme in Bathurst, where floods have occurred over the life of the scheme, provided an opportunity to investigate the full economic benefits of VP as a flood mitigation measure in Australia.

The focus of the analysis was to estimate the damage avoided by the purchase and removal of the residential properties in the Kelso floodplain. The analysis uses the framework developed by the BTE (2001a) for estimating tangible costs. The avoidance of intangible costs is a major reason for opting for VP. This analysis has identified major intangible costs, which are discussed, but not quantified.

There were several options that could be pursued in order to investigate the benefits of the Kelso VP scheme. The ideal methodology would be to calculate the reduction in damage in particular events and in AAD. While there is detailed information available for the 1986, 1990 and 1998 events, there are some inconsistencies in the data, making it difficult to compare these events and calculate an AAD reduction. After examining the available data, the BTRE adopted the following approach:

- estimate the actual savings (cost avoided) in the various events as a result of the property purchases at the time; and
- estimate the potential savings for the whole VP scheme for the 1 per cent AEP, the PMF and actual events assuming all properties had been purchased.

Direct costs avoided

The VP scheme only applies to residential properties. Direct damage to residences includes structural, contents and external damage.

The method of calculating damage to properties involved:

- determining the height of flooding within the properties (above floor height);
- establishing the appropriate stage-damage curves; and
- estimating the damage for each property.

For the majority of properties, the Bathurst City Council was able to provide a database of floor heights and flood levels for 1986, 1990, 1998 and the 1 per cent AEP. In some cases, there were gaps in the data, particularly where houses had been purchased and demolished before 1995–96.

Additional sources of information were used to fill in some of the gaps. The Bathurst City SES conducted a survey of flooded areas in 1998, which included information regarding flood heights (along with alternative accommodation needs of the community, activities taken to reduce loss, awareness and effectiveness of warnings). Studies of Bathurst conducted in 1993 by Willing & Partners (Willing & Partners, 1993) also provided additional data, including some of the missing flood levels. These levels were added to the database from Council.

Remaining gaps (mostly related to flood levels) were filled by interpolating between data for nearby houses and should give reasonable results. The same method was used for estimating missing floor level data. Given similarities in building practices and styles for houses built around the same time and a field inspection which identified that floor heights of the remaining houses were similar in the Kelso area, this method should also give reasonable floor level estimates.

The Willing & Partners report provided stage-damage curves based on actual damage in the Sydney 1986 floods. The report had separate curves for internal and external damage. These were combined to calculate total damage costs. Unfortunately, the data points on the two curves were for different water levels. The BTRE based the combined curve on the data points for internal damage. External damage costs for each of these points were calculated by interpolation and added to the internal damage costs to get the combined stage-damage curves. The Willing and Partners stage-damage curves were updated to 2001 prices using the CPI.

Raw calculations for direct damage to property were straightforward. The over-floor water depth was used to calculate the damage cost for each house using the stage-damage curves. As no flood depths were available for the PMF, the BTRE assumed each house would suffer the maximum damage shown on the stage-damage curves. This assumption will almost certainly underestimate the direct damage during the PMF because water velocity is likely to be high, and many houses will suffer significant structural damage, if not total destruction.

The raw damage figures were modified to take into account two concerns raised by experts in flood damage calculation. Firstly, the stage-damage curves are based on *actual* damage costs, rather than *potential* damage. As discussed in chapter 4, it has been suggested that the use of actual damage in BCA penalises those who work to protect their property. It is believed that a Damage Reduction Factor (DRF) of 0.75 would be appropriate for Bathurst. Converting actual to potential damage therefore requires actual damage costs to be divided by 0.75.[31]

Secondly, existing stage-damage curves are widely believed to significantly underestimate damage. It is commonly suggested that damage derived from existing curves should be doubled to make them more representative of modern day losses. As an indication of the validity of this approach, figures from Insurance Statistics Australia indicate that between 1988[32] and 2001 the average insurance policy for home contents in Australia rose 42 per cent above inflation, or 91 per cent overall.

To allow for the conversion from actual to potential damage and to incorporate the increase in the value of contents, losses estimated using the updated stage-damage curves were multiplied by the final adjustment amount shown in table II.1. The 'contents increase factor' is based on increases in average insurance policies for home contents.

Data for home contents are not available for 1986. The use of data from 1988 as the starting point will underestimate the increase in values of typical household contents, but the underestimation is considered to be small.

Indirect costs avoided

Calculating most indirect costs was straightforward, so the method is discussed together with the results in the next section. However, calculation of indirect damage arising from PMF requires some explanation. The direct damage in a

31 Normally, potential damage is known, and this amount is multiplied by the DRF to estimate actual damage. In this case, as actual damage estimates were available, the BTRE has reversed the process to calculate potential damage.

32 The earliest data available are from 1988.

TABLE II.1 STAGE-DAMAGE ADJUSTMENT FIGURES

Year	Contents Increase Factor	Damage Reduction Factor	Final adjustment
1986	0[a]	0.75	0.75
1990	1.06	0.75	1.42
1998	1.32	0.75	1.76
2001	1.42	0.75	1.90

a. As data for the stage-damage curves were collected in 1986, there was no need to adjust for changes to contents.

Source BTRE analysis based on data provided by Insurance Statistics Australia Limited.

PMF was calculated assuming each property suffered the maximum damage represented in the stage-damage curves, recognising that this approach will understate the damage. For a PMF event, given that many properties are likely to be destroyed, indirect costs cannot be calculated by increasing costs from lesser floods by a given factor. It is necessary to calculate how many properties might be destroyed in a PMF event.

To estimate the number of properties that might be destroyed, the BTRE relied on work by Black (1975). This research showed that a velocity of three metres per second (or 10.8 kilometres per hour) is sufficient to cause building failure in depths of less than one metre for weatherboard houses and significantly less than two metres for brick houses. Other combinations of velocity and depth are shown in figure II.2. In a PMF event in Bathurst, it is likely that these conditions would be met. For the purpose of this analysis, the BTRE conservatively estimates 80 per cent of properties would be destroyed.

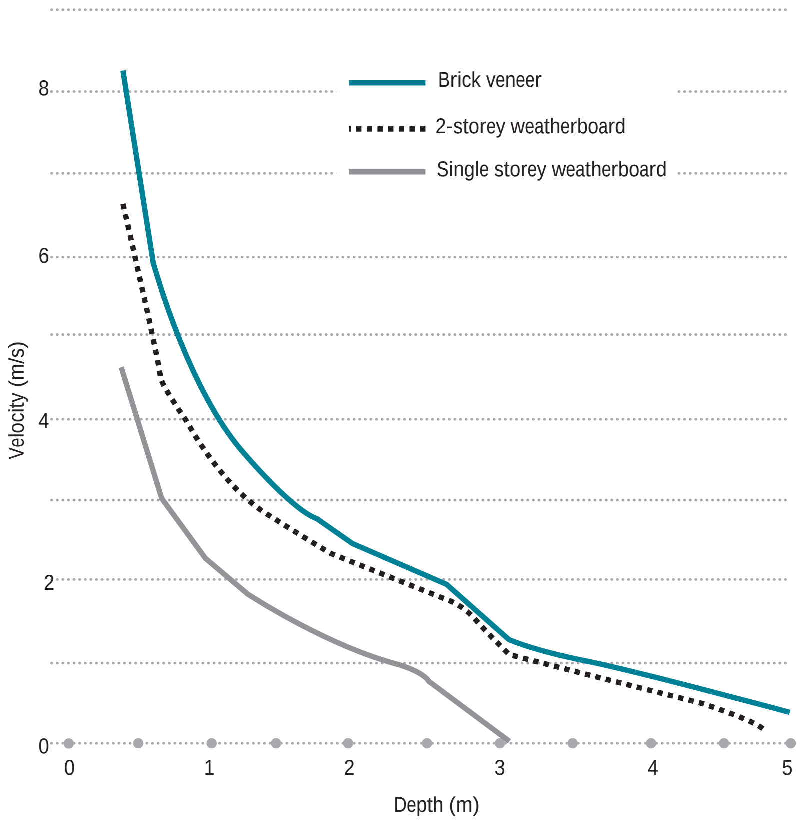
RESULTS

Direct costs avoided

In 1998, fifty houses had been purchased and removed from the floodplain. Using the modified Willing and Partners stage-damage curves, the total direct damage avoided by the removal of these properties was $0.6 million in the 1998 flood. If all the properties in the scheme had been purchased before the 1998 event, the direct savings would have been almost $1 million. In an event with a 1 per cent AEP, the total direct damage that would be avoided by the removal of all 102 properties from the floodplain is calculated to be $1.5 million.

The property damage avoided in various events are shown in table II.2. As previously discussed, damage avoided in a PMF assumes the maximum damage to each property represented in the stage-damage curves. In reality, this will understate the damage, as properties are likely to be destroyed in a PMF.

FIGURE II.2 CRITICAL VELOCITY AND DEPTH FOR BUILDING FAILURE



Source Black 1975.

TABLE II.2 DIRECT COSTS AVOIDED—KELSO

Event	*Savings to properties purchased before event ($)*	*Savings assuming all properties purchased ($)*
1986	0	895 117
1990	81 363	665 642
1998	580 836	974 419
1% AEP		1 537 900
PMF		5 021 688

Source BTRE analysis based on information provided by Bathurst City Council.

Indirect costs avoided

As outlined in BTE 2001a, indirect costs include alternative accommodation, emergency services, clean-up, and disruption to business, roads and other utilities. In this case study, the major contributors are alternative accommodation, emergency services and clean-up costs. While Hereford Street provides a major link between the northern residential area and the CBD, the VP does not address the disruption caused by the loss of this road and it is not considered further in the analysis.

Emergency accommodation costs

Most indirect cost information available to the BTRE was based on the 1998 flood. Of particular benefit was the survey of flooded areas conducted by the Bathurst City SES, which included information regarding the emergency accommodation needs of the community.

The BTRE was advised that the duration of flooding and loss of access to properties might be up to two days for most residences for an event similar to the 1998 flood. There are a small number of properties (less than five), where access is precluded for a longer period (up to four days) as a result of a particularly depressed topography. Based on this information, the BTRE used an average of three nights' accommodation for the 1998 event. This figure was also adopted for the other floods in this case study. The number of nights is not likely to vary largely with flood height, because Bathurst floods tend to rise and fall quickly. The time for which houses are flooded is therefore only weakly dependent on flood severity. However, for more extreme floods, such as the PMF, it is likely that many houses would be destroyed, requiring months of temporary accommodation.

In a PMF, the time required for displaced residents to find new accommodation is difficult to estimate. In some locations in Australia, people may choose to rebuild their homes. However, the BTRE has assumed that people displaced from the floodplain following a PMF in Bathurst would not choose to rebuild in the same location and would be discouraged from doing so by local planning laws. The question then becomes how long it would take for evacuees to move to new homes. The time required would depend to some extent on individual financial circumstances. The BTRE has assumed that alternative accommodation would be required for an average of six months.

Not all houses would be destroyed in a PMF—the remaining properties would suffer a range of damage. Even properties that sustain only minor damage from a PMF would not be habitable for several days due to reduced access. The BTRE estimates for alternative accommodation requirements in a PMF are shown in table II.3.

Based on the number of houses in the Kelso floodplain during the 1998 flood (52) and the number of people evacuated (102), the number of people per

TABLE II.3 PMF ALTERNATIVE ACCOMMODATION REQUIREMENTS

Property condition	*No. of nights*	*Houses affected (%)*	*No. of houses*
Total destruction	190	80	82
Major damage	20	10	10
Significant damage	10	5	5
Moderate damage	5	5	5

Source BTRE estimates based partly on analysis of Black (1975).

house requiring emergency accommodation is assumed to be approximately two. Accommodation costs were calculated at $57.90 per household plus $29.00 per person-night as recommended in BTE (2001a. p. 83), which in turn was based on work by Smith et. al (1979, p. 55). The total estimated accommodation savings for various floods are given in table II.4.

TABLE II.4 ACCOMMODATION COSTS AVOIDED—KELSO

Event	*Savings to properties purchased before event ($)*	*Savings assuming all properties purchased ($)*
1986	0	23 654
1990	1 623	23 654
1998	11 595	23 654
1% AEP		23 654
PMF		925 496

Note Savings assuming all properties were purchased in events up to the 1 per cent AEP are based on three nights of accommodation. PMF assumes some property destruction.

Source BTRE analysis based on information provided by Bathurst City Council and Bathurst City SES.

Emergency services costs

The SES, Rural Fire Service, NSW Fire Brigades, NSW Ambulance Service, NSW Police Service, Bathurst City Council Employees and St John Ambulance all played an important role in the emergency response effort. Tasks performed included alerting property owners at risk, assisting in the evacuation and providing sandbags and support for crews. These organisations were assisted by local residents who volunteered for the duration of the disaster. After the emergency, the local SES were assisted in clean-up activities by 'out of area' SES crews, the Rural Fire Service, NSW Fire Brigades and the Bathurst City Council.

The SES is the lead agency responsible for flood response. The BTRE therefore concentrated on estimating the costs associated with the SES response. In the 1998 flood, the Bathurst City SES evacuated 102 residents from the Kelso floodplain and 472 from elsewhere in Bathurst. The SES volunteers contributed 5 300 person-hours for the whole Bathurst area. Volunteer person-hours

(942) in Kelso were estimated as being in the same proportion as the number of residents evacuated from Kelso.

Other SES units from Burraga, Turon, Lithgow and Portland provided assistance. These 'out of area' SES volunteers were assumed to have contributed one day each to volunteer activities. The 41 non-SES volunteers recorded on the SES volunteer register were assumed to contribute two days of their time.

Volunteer time leading up to and during the event was calculated on the basis of average weekly ordinary time earnings (AWOTE). The average used was calculated using the same weightings used for the Tamworth case study. The rationale is that Bathurst, like Tamworth, is a regional centre and can be expected to have similar industries. While the SES also contributes time after the event to assist with clean-up, this has not been identified separately in the emergency services cost, but is included in the clean-up in the next section.

The average emergency services cost per house in the Kelso floodplain was calculated ($570) and this amount was applied to each house in the floodplain for all floods analysed. As flooding spreads further, SES resources are needed to assist the increasing number of residents affected. In the VP area, it is assumed that all properties will be affected by even a moderate flood. Regardless of the ultimate flood level, once a moderate flood is forecast, preparations need to be made and all residents in the VP area need to be alerted and possibly assisted with evacuation. For this reason, the BTRE has used a constant amount for emergency services savings resulting from the removal of the properties in the VP area for all events requiring evacuation, including the PMF. Table II.5 summarises the costs incurred during the 1998 flood. The estimated emergency services costs avoided are shown in table II.6.

It should be noted that SES resources would need to be stretched further in a larger event. Unlike other costs such as clean-up, which increase with more extreme flooding, it is not always possible to increase SES resources at the time of a flood emergency. By removing the residents from the floodplain, SES

TABLE II.5 SES COSTS, 1998 FLOOD—BATHURST

1998 flood	*Bathurst*	*Other volunteers*	*Out of area SES*	*Total*
Volunteer manhours	942	656	37	1 635
Weekly wage rate ($)	738	738	738	738
Total cost ($)	17 381	12 106	682	30 170
No. of residences	52	52	52	52
$/residence	330	230	10	570

Note Rounding may affect the calculation of totals.

Source BTRE analysis based on information provided by Central West Division, NSW State Emergency Services.

TABLE II.6 EMERGENCY SERVICES COSTS AVOIDED—KELSO

Savings to properties purchased before event ($)	
1986	0
1990	3 990
1998	28 500
Savings assuming all properties purchased ($)	
Any event requiring evacuation	58 140

Source BTRE analysis based on information provided by Bathurst City SES.

officers can be deployed elsewhere. As a result, while the estimates provided here are referred to as 'costs avoided' (savings), it is recognised that these SES resources would be deployed to reduce risks to life and property damage elsewhere in the local area.

Clean-up costs

Clean-up costs for Bathurst were not available. Instead, costs derived from other studies for actual floods were used. Such an approach is inherently inaccurate, as each flood is unique and clean-up times for residential houses vary over a wide range. Based on BTE (2001a), the clean-up time for the 1 per cent AEP flood was taken as 20 person-days, including volunteer SES labour. For other floods, the time taken was calculated as being proportional to average over-floor depth. Labour used in clean-up was calculated on the basis of AWOTE, as for volunteer emergency response labour.

With extreme floods such as the PMF, the likely destruction of properties needs to be considered. Clean-up becomes a more difficult task, involving removal of rubble from some sites. Based on demolition figures from Bathurst City Council, the BTRE has allowed $3 000 per property for clean-up of debris. The clean-up costs avoided in various events are shown in table II.7.

Total indirect costs avoided

The indirect damage avoided in various events is shown in table II.8. The major contributor to indirect costs is the clean-up component, with the exception of the PMF.

The total indirect damage avoided by the removal of the properties in the VP area was over $117 000 in the 1998 flood. If all the properties in the scheme had been purchased before the 1998 event, the indirect savings would have been almost $217 000. In an event with a 1 per cent AEP, the total indirect damage that would be avoided by the removal of all 102 properties from the floodplain is calculated to be almost $300 000.

TABLE II.7 CLEAN-UP COSTS AVOIDED—KELSO

Event	Person-days per house	Savings to properties purchased before event ($)	Savings assuming all properties purchased ($)
1986	17	0	170 672
1990	13	11 516	107 482
1998	15	77 511	135 091
1% AEP[a]	20		215 554
PMF[b]	83		491 082

a. Savings assume all residences have been purchased.

b. Assumes over-floor depth of two metres for the houses that remain standing and $3 000 for those destroyed.

Source BTRE analysis.

TABLE II.8 INDIRECT COSTS AVOIDED—KELSO

	Accommodation	Emergency Services	Clean-up	Total
Savings to properties purchased before event ($)				
1986	0	0	0	0
1990	1 623	3 990	11 516	17 129
1998	11 595	28 500	77 511	117 606
Savings assuming all properties purchased ($)				
1986	23 654	58 140	170 672	252 466
1990	23 654	58 140	107 482	189 276
1998	23 654	58 140	135 091	216 884
1% AEP	23 654	58 140	215 554	297 348
PMF	925 496	58 140	491 082	1 474 718

Note Figures may not add to totals due to rounding.

Source Table II.4, II.6 and II.7.

Total costs

The total costs avoided by the VP programme are shown in table II.9. These do not include any allowance for the intangible costs avoided by the VP scheme, which are discussed in the next section.

The BTRE estimates the existence of the VP scheme in 1998 avoided around $0.7 million in damage in that single event. Had all properties been purchased, the savings would have been close to $1.2 million. Should Bathurst experience a 100-year flood, the completion of the VP programme would avoid over $1.8 million in tangible damage.

TABLE II.9 TOTAL COSTS AVOIDED—KELSO

	Direct	*Indirect*	*Total*
Savings to properties purchased before event ($)			
1986	0	0	0
1990	81 363	17 129	98 492
1998	580 836	117 606	698 442
Savings assuming all properties purchased ($)			
1986	895 117	252 466	1 147 583
1990	665 642	189 276	854 918
1998	974 419	216 884	1 191 304
1% AEP	1 537 900	297 348	1 835 248
PMF	5 021 688	1 474 718	6 496 406

Note Figures may not add to totals due to rounding.

Source BTRE analysis.

INTANGIBLES

Intangibles are, by their nature, difficult to value. They include memorabilia, quality of life, health and the value of life. Parker (1999, p. 39) classified intangible flood losses into primary, secondary and tertiary effects of flooding. Primary effects are loss of life, physical injury and loss of heritage sites. Secondary effects include increased stress and ill health brought about as a result of the flooding. The tertiary effects are most difficult to evaluate and include homelessness, loss of livelihood and loss of community. The cost of VP means that it is usually only implemented when there is no other realistic mitigation option. At the same time, because it avoids many intangible losses, it has benefits that are difficult to measure and include in BCA.

The benefits of flood mitigation projects are usually measured by the reduction in damage, or the savings they create. VP schemes provide additional benefits that are hard to measure. A few examples illustrate the issue:

- Reduced stress experienced by rescue workers, SES and other volunteers who are responsible for the safety of residents living in high-hazard areas of the floodplain. During the 1998 flood, the Bathurst City SES was advised to prepare for three possible contingencies: overflow from the dam, more rainfall and water breaking through the railway embankment upstream. While each of these events was only a possibility and might not have happened, the occurrence of any one of them would have been serious and a combination of events could have been catastrophic. The consequences of all three needed to be considered and a decision made about evacuating residents in a section of the floodplain that had formed a ‘disappearing island’. The stress involved in making these difficult life or death decisions is immense and represents a significant cost.

- The decongesting effect that the removal of properties from the floodplain has on flooding. Houses built across the floodplain have the effect of forming a levee, increasing upstream flooding. At the same time, the debris from properties can create more hazards downstream. It is difficult to quantify the effects of removing houses from the floodway. However, anecdotal evidence suggests that the removal of properties had a noticeable positive effect during the 1998 flood.
- The potential to use the land as public space, providing a community asset. As the VP scheme progresses and the land stocks are consolidated, Bathurst City Council is looking at the opportunity of making the land available to sporting clubs.

The avoidance of risk to life is a major reason for VP programmes. VP areas are often typified by lack of emergency access routes. The Kelso floodplain area is within the waterway during flood conditions, with rescue by flood-boat the only option for residents trapped in their homes. Given the frequency of flooding in Bathurst, the fact that only one life has been lost (in the 1990 flood) testifies to the effectiveness of emergency services.

Handmer and Smith (1995, p. 27) observe that flood deaths in Australia are rare and usually occur when people are in vehicles or on foot. They also note that 'this could be interpreted as indicating that buildings are safe refuges from flooding. But caution is needed as … extreme floods in the recent past… have swept away many houses.' In Bathurst, residents need to be removed from the floodplain largely because of this possibility.

The BTRE has done some work in estimating the economic value of human life, and this is discussed in detail in appendix I of BTE 2001a (p. 128). BTE (2001a) suggests an amount per fatality of $1.3 million in 1998 prices, or $1.4 million in 2001 prices. While placing a dollar-value on human life is somewhat controversial, the use of even a minimum figure illustrates the economic costs involved in losing people to floods.

In the Kelso floodplain, the risk to life is considerable when people need to be rescued by flood-boat. Rescue involves traversing the river channel and Kelso floodplain while avoiding debris. The situation in 1998 was described by the Flood Controller as 'extreme risk'. The loss of one flood-boat while performing a rescue could result in at least five deaths, with an associated economic cost of at least $7 million.

OTHER ISSUES

There were a number of issues raised during this case study that cannot be easily included in a discussion of the benefits and costs of VP as a form of mitigation. Nevertheless, some mention of these issues seems appropriate.

This report has not considered a case study on the effectiveness of Flood Warning Systems (FWS). A FWS was installed in Bathurst after the 1986 flood. By increasing warning times, the FWS can help reduce actual damage. This analysis has concentrated on potential damage and has not taken into account the effects of the FWS. However, anecdotal evidence from Bathurst suggests the FWS was effective in reducing risk to life and property in 1990 and 1998, and was described by the local SES as 'very valuable'.

Following the 1986 flooding, Council decided that all roads, utilities and other public infrastructure reconstructed in the Kelso floodplain should be of a flood-resistant nature. The road across the Kelso floodplain (Hereford St) was subsequently rebuilt. By altering the design and materials used, floodwater is allowed to flow unobstructed over the road, resulting in less erosion damage and therefore reduced disruption to the community and repair costs. Hereford Street was only partially reconstructed in August 1990 when tested by flooding. A report to Council following the 1998 flood on damage avoided as a result of the flood resistant reconstruction stated that roads had fared well in the 1990 and 1998 floods. Council believes 'this certainly justifies the up front capital expenditure argument versus the ongoing repair costs' (Bathurst City Council, pers. comm., 26 Sept 2001). This anecdotal evidence from Bathurst supports the Waggamba case study findings in appendix IV.

Agriculture costs are often overlooked in calculating damage from floods. The Kelso floodplain supports market gardens. This use of the land is considered to be flood-compatible, with much of the remaining non-residential land zoned for this purpose (Bathurst City Council, pers. comm., 26 September 2001). While the residential development is semi-rural and properties in the VP area would have some minor agricultural use, this analysis has not separately considered the agricultural costs of the flooding.

CONCLUSIONS

Results of this case study suggest that significant savings can result from VP schemes. As with all mitigation, savings are only realised when the measures are tested by actual events. Bathurst has been fortunate to have commenced the VP programme before flooding in 1990 and 1998.

There are some sources of error in the analysis. These include the calculation of floor levels, the amalgamation of internal and external stage-damage curves, and the PMF cost estimates. Significant intangible benefits could not be captured. As a result, a full BCA was not possible. Given the limitations of the analysis, the estimated savings in this case study should be considered as minimum amounts. Despite this caveat, the results and issues raised are expected to contribute to an improved basis for decision-making about VP as a flood mitigation measure.

appendix iii

THURINGOWA CASE STUDY

Thuringowa and its adjoining sister-city, Townsville, form a major regional centre for northern Queensland (figure III.1). The 1996 census recorded the population of the region as approximately 140 000, with the population of Thuringowa at close to 38 000.

Thuringowa lies on the east coast of Australia, approximately 1 400 kilometres north of Brisbane and 350 kilometres south of Cairns. Located in the tropics, it has an average annual rainfall of about 1 200 millimetres, with nearly half the average annual rainfall occurring in January and February. Much of this rainfall is delivered in heavy downpours associated with storms and rain depressions resulting from cyclonic conditions.

Heavy storms combined with a relatively flat landscape mean that the area is prone to flash flooding[33]. Building regulations were introduced in Thuringowa in 1991 to mitigate urban stormwater flooding. This case study examines the effectiveness of this measure following a major flood in 1998. Data constraints prevented the effects of an extreme event being considered.

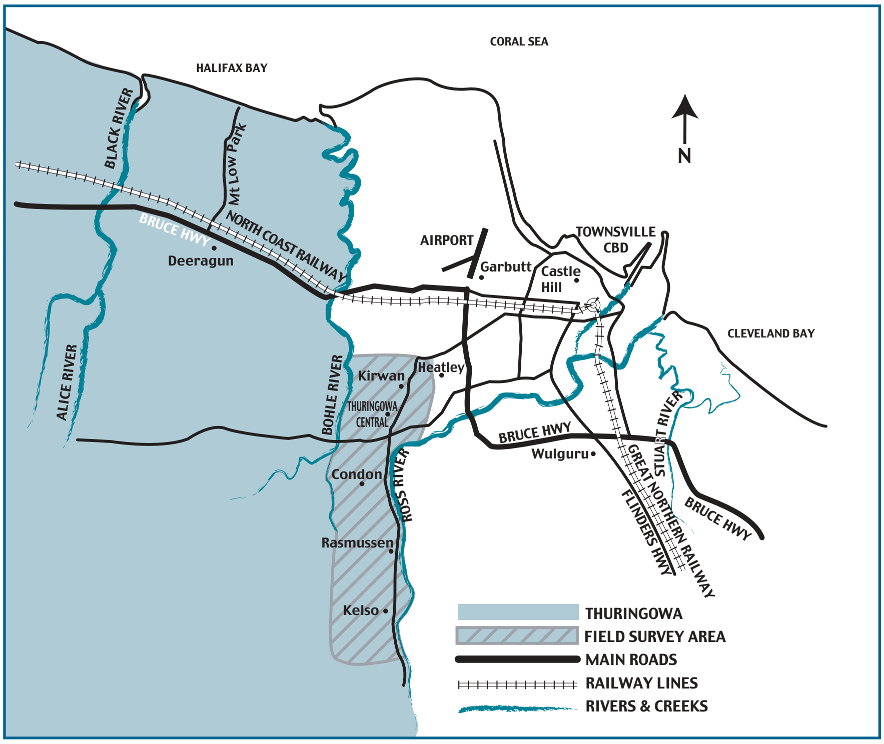
FLOOD HISTORY

Flooding in Thuringowa falls into three categories—stormwater, storm surge and riverine floods. The BTRE was informed that the most frequent form of flooding in Thuringowa is stormwater, with six hours of rainfall enough to create flood conditions (City of Thuringowa Council, pers. comm., 16 October 2001). This means that warning times are very short.

Recent floods in Thuringowa have occurred in 1971, 1990, 1991, 1997, 1998 (January and August) and 2000. These events were all associated with cyclones and storms. Because of the significance of storms in contributing to flooding, much of the data available relate to rainfall rather than flood events (Maunsell McIntyre 2001, pp. 4, 6).

33 For much of urban Thuringowa, the land has a gradient of 1 in 400, with a vertical rise of only 0.25 metres across every 100 metres. This lack of slope provides little drainage for stormwater run-off.

FIGURE III.1 MAP OF THURINGOWA



Source Based on UBD (1997) Bureau of Meteorology (2002) and Electoral Commission Queensland (2000).

Storm surge, riverine flooding and tides also contribute to the flooding problem. The river systems—including the Ross, Bohle, Black and Alice—play an essential role in draining floodplain areas. The major source of riverine flooding in the area comes from the Bohle River, with a 2-year ARI flood event breaking its banks in some places.

The 1998 flood

The largest flood on record for the area occurred in January 1998 with record rainfall from ex-cyclone Syd, which was reported as a 200-year rainfall event. Damage from the storm and accompanying winds contributed to the flooding, with fallen trees blocking waterways. Water had nowhere to escape for several hours, backing up in streets and properties in Thuringowa and Townsville.

News reports stated that 120 people went to relief centres and hundreds more went to stay with friends and family (CNN 1998). Insured damage from the storm and subsequent flood was estimated at over $100 million dollars (GAB Robins 1998). There was one death, several houses were destroyed and

PLATE 3 PROPERTIES IN THURINGOWA ARE TYPICALLY CONSTRUCTED WITH RAISED CONCRETE SLABS TO MEET BUILDING REGULATIONS

Source Department of Infrastructure, Planning and Environment, Northern Territory Government.

cars were washed away. The region was declared a State Disaster Area. In just five days the area received over 1 000 millimetres of rain, close to the annual average rainfall. The actual flood is reported to have lasted 13 hours on the first day of rain, with rainfall reported at between 550-780 millimetres in various areas of the catchment (JCU 1998a, p. 3).

A post disaster survey was conducted by the Centre for Disaster Studies at James Cook University (JCU), immediately after the flood in 1998. The survey provided considerable data relating to the impact of the event on individual households in Townsville and Thuringowa. Building regulations that had been in effect for around seven years allowed for comparison between the impacts experienced by houses that had been built to the code and those that pre-dated the code. These sources of information made it possible to examine the effect building regulations had on reducing flood damage.

Floodplain management

Development between the Ross and Bohle Rivers in the 1970s led to an increase in the number of properties at risk from flooding and a corresponding need for mitigation on the floodplain. The Ross River Reservoir was constructed in 1971 to address flooding from that river. Flood studies for the Bohle River were first commissioned in 1976 and this area continues to be a focus for flood mitigation.

A number of initiatives are currently used to mitigate flooding. To manage risk to existing properties, drainage channels are used to carry stormwater to the river and a large area of grassland has been converted into a park encompassing a detention basin, providing flood control and increased amenity for the community. The Bohle floodplain has seen a significant increase in development in recent years and the trend is continued in the strategic plan for the community. To reduce risk to new growth, a ‘development line’ was established to prevent future development along the Bohle River below the 20-year ARI flood line; a naturally occurring levee has been extended to protect new development from riverine flooding; and building regulations impose a minimum floor level on new buildings.

It was not possible to evaluate the economic effectiveness of the entire floodplain management plan. Instead, one measure—the introduction of building regulations—was examined in this case study. However, it is important to remember that this is just one part of the overall flood management strategy for the area.

Thuringowa building regulations

The City of Thuringowa Council (CoT) instituted minimum floor levels in 1991 to combat frequent stormwater inundation, which can arise from events as frequent as 1.3-years (Maunsell McIntyre 2001, p. 6). The minimum floor level (for all habitable rooms) in the residential (urban) zone is set at 'the 50-year ARI flood level plus 450 millimetres freeboard'. The Council considers that this level should prevent internal inundation for the majority of buildings in a 100-year flood. While this will not prevent flooding of adjacent roads and allotments, water is expected to be shallow and velocities to be low (Maunsell McIntyre, 2001, p. 25). The regulations covering residential subdivisions also require that the minimum level of any lot created be no lower than the 50-year ARI flood level. In practice, during subdivision the ground level is often raised to ensure the property only needs to meet the Building Code of Australia (which requires floor levels to be 270 millimetres above ground level).

Unlike structural mitigation measures that provide flood modification and often require government funds, implementation of building regulations is a property modification measure. It places the cost of flood mitigation on the users of the floodplain, in this case in the form of increased construction costs. The BTRE was advised that to achieve a floor height level of 450–500 millimetres above the natural ground level would cost an additional $3 500 to $5 500 (Lloyd Payne, Glenwood Homes, pers. comm., 22 March 2002). Given that construction is usually funded through a mortgage, the cost of the mitigation is effectively amortised over the life of the loan. Analysis suggests that an average home-loan would be only modestly increased.

JCU Post Disaster Household Survey

JCU conducted a post disaster damage survey of Thuringowa and Townsville households directly after the 1998 event (JCU 1998a). In some areas—west Townsville and north Thuringowa—the city boundary divides neighbouring houses. The telephone survey of 1 014 households (an estimated 2 per cent of households[34] in Townsville and Thuringowa) was conducted within three days of the storm. The data collected included property statistics, flood details (water levels in the yard and house), damage, flood awareness, evacuation and some measure of intangibles.

The JCU report on the January 1998 flood had some interesting conclusions, including:

- 15 per cent of survey respondents reported internal inundation[35] (p. 4);
- houses in urban Thuringowa had significantly less inundation than those in Townsville (p. 2); and
- differences in the degree of internal inundation seem to reflect changes in house construction and development (p. 7).

34 Population was based on the 1996 Census.

35 This includes areas under high-set houses that are not classified as habitable rooms.

A fairly comparable percentage of households in Thuringowa and Townsville experienced external flooding, yet there was a difference in internal inundation between the two areas. This is demonstrated in the breakdown of the JCU data in table III.1.

TABLE III.1 PROPORTION OF TOTAL PROPERTIES FLOODED, BY LOCATION

	Nil flooding (% of total)	*External flooding (% of total)*	*Internal flooding (% of total)*	*Internal flooding (% of external)*
Thuringowa	41	59	10	17
Townsville	39	61	17	28

Source JCU (1998a) and BTRE analysis.

Of the Thuringowa properties surveyed, 59 per cent had external flooding, with 17 per cent of those properties also experiencing internal inundation. By comparison, 61 per cent of Townsville properties surveyed experienced external flooding, yet 28 per cent of these also had internal inundation.

The BTRE assumed that properties with a similar degree of external flooding were likely to have experienced similar flood conditions and therefore that another variable played a role in affecting levels of inundation. The BTRE was particularly interested in the suggestion that Thuringowa had suffered less damage from the flooding—at least to some degree—because of construction and minimum floor level requirements. This analysis examines the effect that the introduction of building regulations had on flooding in Thuringowa.

EVALUATION METHOD

It would appear logical to assume that setting a minimum floor level should result in less inundation and consequently less damage to premises. The BTRE examined the difference that the introduction of building regulations made to the number of properties flooded in Thuringowa. The initial focus of this case study was to test whether there was a measurable difference and if it were possible to evaluate the savings arising from the planning decision. While data constraints prevented a full economic evaluation of the mitigation measure, the case study highlighted a number of issues.

The BTRE was fortunate in obtaining the data recorded in the JCU telephone survey (JCU 1998a). The survey did not identify house age and responses to questions regarding living room floor levels were ambiguous; for example, respondents did not indicate if the ground level had been raised before the house was built. To address the gaps in information, the BTRE conducted a field survey of a sample group from the JCU study.

BTRE field survey

Differing floor levels are just one variable that might affect inundation. The range of rainfall recorded, proximity to the river and drainage provided by the terrain varied between locations in the catchment. The BTRE sample was selected with the aim of finding properties subject to a similar degree of external flooding where the only variable was the height of the floor level. While such an ideal situation is unlikely, the BTRE isolated properties from the JCU survey to maximise the similarities. The sample group included properties from Thuringowa only and concentrated on the southern suburbs along the Bohle River: Condon, Kelso, Kirwan, Rasmussen and Thuringowa Central (figure III.1). These suburbs provided a mix of old and new properties (before and after the introduction of the building code) and all experienced a similar form of flooding—stormwater run-off. Other suburbs in Thuringowa were excluded as they had different flooding conditions.

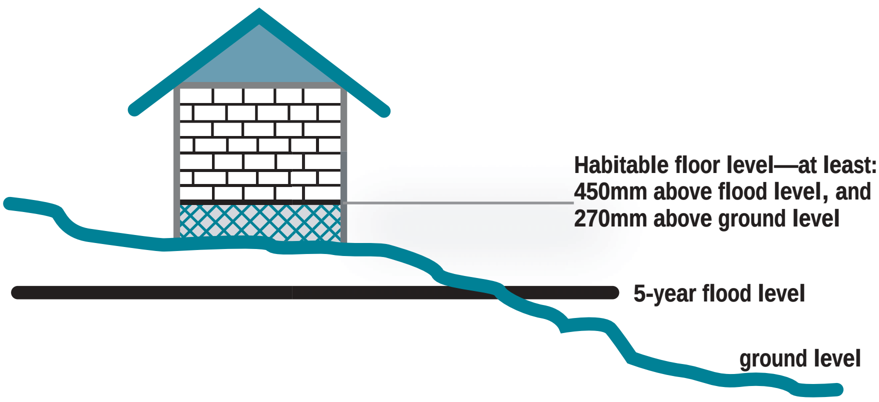
The BTRE survey was conducted jointly by two researchers over three days, collecting:

- physical characteristics, including floor height and construction earthworks, to determine if the construction of the property and foundations had been designed to keep the building above the 50-year flood level;
- age, to indicate whether or not the property was subject to the building regulations; and
- terrain, to record the ability of water to drain away.

Property age was classified broadly as either more or less than ten years old, based initially on a visual inspection and later confirmed by the identification of the new estates and suburbs by the Council. Terrain was measured by both the street and allotment elevations. The field survey highlighted the level nature of much of urban Thuringowa. The majority of allotments were reasonably level, with only 6 per cent of properties built more than a metre above or below the road. While surveying, the researchers observed a minor rainfall event lasting approximately fifteen minutes that resulted in significant pooling of water across roads with virtually no run-off of the rainwater.

The height of floor levels was measured by visual inspection. While it was possible to measure the height of floor levels above the ground with reasonable accuracy, it was not possible to measure the height above the 50-year flood level. As illustrated in figure III.2, the 50-year flood level may be below the ground level. With the introduction of the building regulations in 1991, this is more likely to be the case in areas subdivided since that time. While recognising that in some areas the 50-year flood-level would be below the ground, the BTRE used the ground level as an indicator of the 50-year flood level. As a result, this analysis is likely to underestimate the impact of the building controls.

FIGURE III.2 RELATIONSHIP OF FLOOD LEVEL TO GROUND LEVEL



Source City of Thuringowa Council (pers. comm., 15 February 2001).

Data on the physical characteristics of properties from the BTRE survey were combined with the corresponding damage and inundation data from the JCU telephone survey to form the basis of the analysis. The BTRE used statistical analysis to determine the relationship between the floor levels and the likelihood that properties were internally inundated. To determine the damage avoided in the 1998 flood as a result of the existence of the building regulations required:

- the number of properties that avoided inundation due to floor levels (rather than other factors);
- the floor levels that properties would have otherwise had and the external flood levels affecting those properties; and
- a large enough sample to apply to all other properties built in Thuringowa between 1991 and 1998.

The BTRE has attempted to quantify the variables in the following estimates. The small sample size and varying distribution of rain across the catchment mean that any estimates made in the following analysis should be considered a starting point to assist discussion of the issues, rather than conclusive results.

DATA ANALYSIS

The BTRE surveyed 190 premises in Thuringowa. Of the 190 houses, 117 had experienced external flooding in the 1998 flood and 20 of these had been internally inundated. Table III.2 shows a comparison between the BTRE and JCU surveys. The BTRE field survey represents 56 per cent of the Thuringowa sample from the JCU telephone study. Taking into account the deliberate exclusion of properties outside urban Thuringowa, the BTRE results are consistent with the earlier survey. In both the JCU and BTRE surveys, internal flooding represented 17 per cent of all externally flooded properties.

TABLE III.2 PROPORTION OF TOTAL PROPERTIES FLOODED—THURINGOWA

	Nil flooding (% of total)	*External flooding (% of total)*	*Internal inundation (% of total)*	*Internal inundation (% of external)*
Thuringowa (JCU)	41	59	10	17
Thuringowa (BTRE)	38	62	11	17

Source JCU (1998a) and BTRE analysis.

Effect of floor levels

The first part of the BTRE analysis was to calculate the number of properties that avoided inundation due to the introduction of building regulations in 1991. Of the surveyed properties, 41 houses (22 per cent) were classified as constructed in 1991 or later and therefore subject to the minimum floor level requirement. The remaining 149 houses (78 per cent) were classified as pre-dating the 1991 building code. Flood statistics by age are shown in table III.3. While the sample is small, results suggest a correlation between age (and therefore building regulations) and the likelihood of avoiding internal inundation.

The results indicate that only 8 per cent of houses that were ten years old or less and which were externally flooded were also internally inundated, compared to 19 per cent of houses older than ten years. Investigation of the flood conditions surrounding the two inundated houses that were less than

TABLE III.3 FLOOD STATISTICS BY AGE—THURINGOWA

	Built before 1991		*Built after 1991*		*All properties*	
	Number	*%*	*Number*	*%*	*Number*	*%*
Avoided flooding	38	26	15	37	53	28
Externally flooded (% of total)	93	62	24	59	117	62
Internally inundated (% of total)	18	12	2	5	20	11
All properties—totals	149		41		190	
Internally inundated (% of external)	-	19	-	8	-	17

Source JCU (1998a) and BTRE analysis.

ten years old revealed that these properties were subject to unusual circumstances. One was located within the 20-year ARI development control line (built on the land developed before the 1991 building regulations) and the other was located adjacent to a constricting juncture in a nearby stormwater drain.[36]

The next stage was to confirm that the contributing factor in reducing damage was floor levels rather than other age-related factors. The BTRE survey identified significant differences in habitable floor levels between the houses more and less than ten years old. It must be remembered that the BTRE is using ground level as an estimate of the 50-year flood-level. As previously mentioned, this will understate the number of properties that meet the building regulations, particularly in subdivisions established after 1991. These more recent subdivisions are subject to the requirement that the ground level be no lower than the 50-year ARI. There is also a trend to raise the ground so that meeting the Building Code of Australia (270 millimetres above ground level) will also meet Council requirements (450 millimetres above the 50-year ARI).

The comparison of floor levels is shown in table III.4. Of the houses more than ten years old, less than 42 per cent were constructed with floor levels at least 450 millimetres above ground level, complying with the new building code. In comparison, approximately 83 per cent of houses built after 1991 were recorded as having floor levels at 450 millimetres or more. This leaves 17 per cent of houses recorded as having habitable floor levels less than 450 millimetres. This anomaly is a result of the inaccuracy associated with the ground level and 50-year flood levels assumptions.

The results, shown in table III.4, indicate that the 1991 regulation played an important role in ensuring properties were built to minimise vulnerability to local risks—in this case flooding. Without the regulation it is probable that houses would have continued to be built with low floor levels and therefore be more vulnerable to floods. The low proportion of people in Thuringowa who are long-term residents[37] and the fact that the majority of new developments are ‘greenfield’ sites reduces local knowledge concerning the likelihood of flooding in these locations.

36 This situation highlights the difficulties experienced by local councils in controlling development of land subject to flooding. The BTRE was advised that the Council had granted development approval subject to the developer widening the drain to take additional run-off that would be caused by the proposed development of the housing estate. The decision was modified by the Planning and Environment Court, so that only the drain alongside the proposed estate needed to be widened. Anecdotal evidence suggests that the narrow section of drain was unable to cope with the stormwater, causing backing up and flooding of the nearby property.

37 The 1996 ABS census shows that slightly less than 38 per cent of Thuringowa residents were at the same address five years previously.

TABLE III.4 FLOOR LEVEL DISTRIBUTION—THURINGOWA

	Built before 1991		Built after 1991	
Floor level (mm)	*Total*	*Per cent*	*Total*	*Per cent*
Less than 300	53	36	3	7
300	34	23	4	10
450	34	23	26	63
600	8	5	4	10
750	5	3	0	0
More than 900	15	10	4	10
Total	149	100	41	100

Source BTRE analysis.

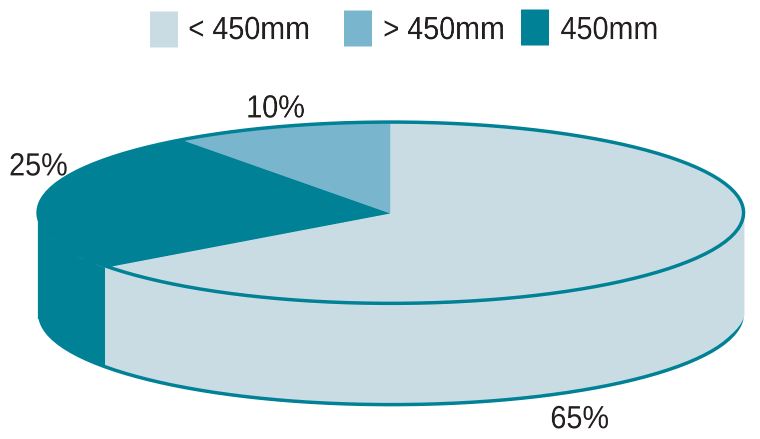
The BTRE field survey was combined with the JCU telephone survey to determine the likelihood of properties being inundated at various floor levels. Analysis suggests the properties that were internally inundated were more likely to have lower floor levels. The breakdown of floor levels for inundated properties is shown in figure III.3. Of all the properties in the BTRE survey that were internally inundated, 65 per cent of the properties had floor levels of less than 450 millimetres. A further 25 per cent of the properties internally inundated had floor levels of around 450 millimetres.

Not only were the properties that were inundated more likely to have low floor levels, the properties with low floor levels were also more likely to be inundated. In the sample group of houses examined in Thuringowa, nearly 14 per cent of all houses with floor levels below 450 millimetres were internally inundated. This percentage dropped to 8 per cent for those houses with floor levels at 450 millimetres and dropped further to just under 6 per cent for houses with floor levels above 450 millimetres. This is shown in table III.5.

Analysis of the 1998 flood data suggests that implementing minimum floor levels can be a significant factor in reducing the risk of internal inundation. However, the risk is not completely removed.

Finally, the BTRE considered the possibility that some properties were not damaged because they were subject to lower floodwaters as a result of either less rainfall or better drainage. The JCU telephone survey collected data on the level of water in the house, the yard and running across the road. The reported depths were based on visual estimation and they appear subject to a considerable margin of error. Scrutiny of the data for external water levels suggests responses were inconsistent and should not be relied upon too heavily. Internal water depths are considered to be more accurate. When combined with the BTRE field survey, the data indicate that more recently developed suburbs (developed after 1991) were subject to deeper flooding than older areas. Table III.6 shows a comparison of the amount of water in the yards in the BTRE sample. It should be noted that newer developments are closer to

FIGURE III.3 FLOOR LEVELS—SURVEYED PROPERTIES INUNDATED



Source JCU (1998a) and BTRE analysis.

TABLE III.5 PROPORTION INUNDATED FOR DIFFERENT FLOOR LEVELS—THURINGOWA

Floor level above ground (mm)	*Internally inundated (%)*
<450	14
450	8
>450	6

Source JCU (1998a) and BTRE analysis.

the Bohle River and more likely to be affected by the backup of water unable to drain into it, as was the case in 1998. This intuitively supports the results in table III.6.

Tables III.3 (age) and III.6 (yard flooding) together demonstrate that the implementation of building regulations to set minimum floor levels for houses in Thuringowa is a sound mitigation measure for reducing the risk of inundation. Despite exposure to floodwaters of greater average depth than older houses, the proportion of internally inundated houses constructed after 1991 was

TABLE III.6 AVERAGE DEPTH OF EXTERNAL FLOODING OF YARDS—THURINGOWA

	Built before 1991	*Built after 1991*
Number of properties externally flooded	93	24
Average depth of yard flooding (mm)	230	290

Source JCU (1998a) and BTRE analysis.

lower. While 12 per cent of houses built before 1991 were internally inundated, only 5 per cent of houses built after 1991 (in areas that appear to have suffered deeper flooding) were subject to internal inundation.

Effect of 1991 building regulations

Having determined that building regulations setting minimum floor levels are likely to have played a part in reducing damage in the 1998 flood, the question remains—how many properties might otherwise have been flooded?

The analysis assumes that, if the 1991 building regulation had not been implemented, trends in floor levels in Thuringowa would have continued in a similar pattern to that established before 1991. The BTRE applied the distribution of floor levels from before 1991 to the 24 externally flooded properties in the sample that were built subject to the building regulations. This resulted in a projection of 58 per cent with floor levels below 450 millimetres (compared with 21 per cent in the original sample, where building regulations were in place). It is possible that lower floor levels for these houses may have led to inundation during the 1998 flood. In other words, building regulations potentially reduced damage in the 1998 flood by approximately 38 per cent. It must be remembered that the assumption that the 50-year flood level is approximated by ground level will cause these benefits to be underestimated (see figure III.2).

Probability of flooding without the 1991 regulations

Having determined the probable number of externally-flooded properties with lower floor levels had controls not been in place, it was still necessary to identify the relationship between floor levels and external flooding. The probability that any of the houses with external flooding may have had a floor level lower than the external floodwaters was calculated. This was applied to each of the houses to determine a likelihood of having a floor level below the external floodwaters.

The BTRE extrapolated the trend for floor levels prior to the implementation of the code and applied a probability for particular floor levels to each of the houses constructed after 1991 that were externally flooded in 1998. It was determined that the rate of internal inundation for the sample group of houses would have increased from 8 per cent to 35 per cent if the building regulation had not been implemented. However, the small size of the sample means that this analysis provides only preliminary guidance about the impact of the building regulations.

Damage costs avoided

While it would have been desirable to have calculated the value of damage that was avoided in the 1998 flood by implementation of the minimum floor level regulations in Thuringowa, the limitations of existing data prevented the BTRE from determining realistic estimates. In particular, flood depths reported by residents in the JCU telephone survey were at best indicative of particular flood heights. The reported depths, based on visual estimation, were subject to a considerable margin of error. It is possible that some of the estimates provided by residents inadvertently either exaggerated or understated the depths of external floodwaters by as much as 200 millimetres. In addition, the properties surveyed represent only a select sample of those affected by a variety of conditions and floodwaters. As a result, it was not possible to extrapolate the conditions or results from the survey group across a larger number of properties to estimate the extent of damage avoided.

The degree of uncertainty in the reported data and the inability to extrapolate conditions across a sufficient sample group to provide a meaningful estimation of loss avoided has limited the findings of the part of the study aimed at quantifying savings. However, the data and information collected do provide evidence of the benefits of the 1991 building regulation in reducing the impact of flooding on residents.

DISCUSSION OF RESULTS

The BTRE investigated the use of building regulations as a flood mitigation measure in Thuringowa, but the analysis has not included estimates of the losses that were avoided. The largest impediment has been that the data samples used have been too small to make any firm estimates of savings arising from building regulations. This, combined with the inconsistency of the telephone survey responses, has meant that any conclusions drawn must be regarded as tentative.

Surveys are a useful tool for collecting information. However, they are subject to various forms of bias and inconsistency. As a result, it is important to be aware of the gaps and limitations inherent in a survey design. The JCU telephone survey captured information that is no longer available and made this case study possible. The value of collecting data immediately after an event cannot be overemphasised. There will always be trade-offs between speedy, cost-effective methods and detailed information gathering.

Given a larger sample, a further difficulty with analyses of this type is that it is not possible to know, with any precision, what would have happened if a different decision had been taken in the past. It cannot be known whether houses constructed in Thuringowa would have been built any differently if there had been no building regulations setting minimum floor levels. Even if this information had been available, it is not possible to be certain about the combination of floor level and external flood conditions for any given house, which is required to calculate the number of houses that would have been inundated in 1998. To overcome this, the BTRE assumed that without the building regulations floor levels would have continued in a similar pattern after

1991. The BTRE then calculated the probability (based on the field survey of older houses) that houses built after 1991 would have been built high enough to avoid inundation. This approach is subject to an unknown margin of error.

The analysis has not considered the effectiveness of building regulations in an extreme event. Lack of data would make any findings speculative at best.

CONCLUSIONS

Some conclusions can be drawn from this analysis of the effects of building regulations in urban Thuringowa.

- Regulations have been effective in ensuring properties are built to a standard suited to local hazards. Many factors can reduce the number of people that take steps to avoid flood risk (such as ignorance, reluctance to believe that they will be affected and a desire to reduce construction costs) so that appropriately targeted and enforced legislation is needed to override these factors.
- Property modification measures can allow individuals to build flood modification into their homes. This places both the responsibility and cost of flood mitigation features on the users of the floodplain. The additional cost is generally small when included in the construction. It can be amortised over the life of a loan, making this form of flood mitigation affordable to many people. This is particularly attractive when the alternative option is major flood modification measures that require financial assistance from all levels of government, thereby creating competition for scarce public funds.
- The analysis supports the intuitively sensible suggestion that higher floor levels reduce the likelihood of inundation and the amount of internal damage sustained. While only covering a small sample, the BTRE field survey found that new properties were largely protected by the building code when tested by a 200-year storm, despite apparently being subject to more water than older areas of Thuringowa.
- This case study has not separately considered an extreme event. Like many other mitigation measures, the building regulations are likely to fail when faced with a flood or storm greater than the design event. The design event is based on the 50-year ARI plus a freeboard of 450 millimetres, to address the problem of frequent flooding. The building regulations appear to be successful in avoiding the majority of damage arising from regular stormwater flooding. This highlights the importance of selecting the right level of protection given local circumstances.
- The level nature of much of Thuringowa also makes this mitigation method suitable for the area. Two factors crucial to the success of raising floor levels are the low velocity of water to which the property is subject and a relatively small difference in depth between the 100-year and 10-

year floods. As McCoy (1976) found, this improves the cost-effectiveness of house raising.

While it is not possible to quantify the benefits, the case study confirms minimum floor levels as a sound mitigation measure for reducing the risk of inundation.

appendix

iv

WAGGAMBA CASE STUDY

Waggamba Shire is located in Queensland on the border with New South Wales. Goondiwindi is the major commercial centre (figure IV.1). Although the Shire is subject to frequent flooding, mitigation measures have been successful in substantially protecting most towns. The major issue faced is the damage caused to flood-prone roads and the resultant costs to Council and road users.

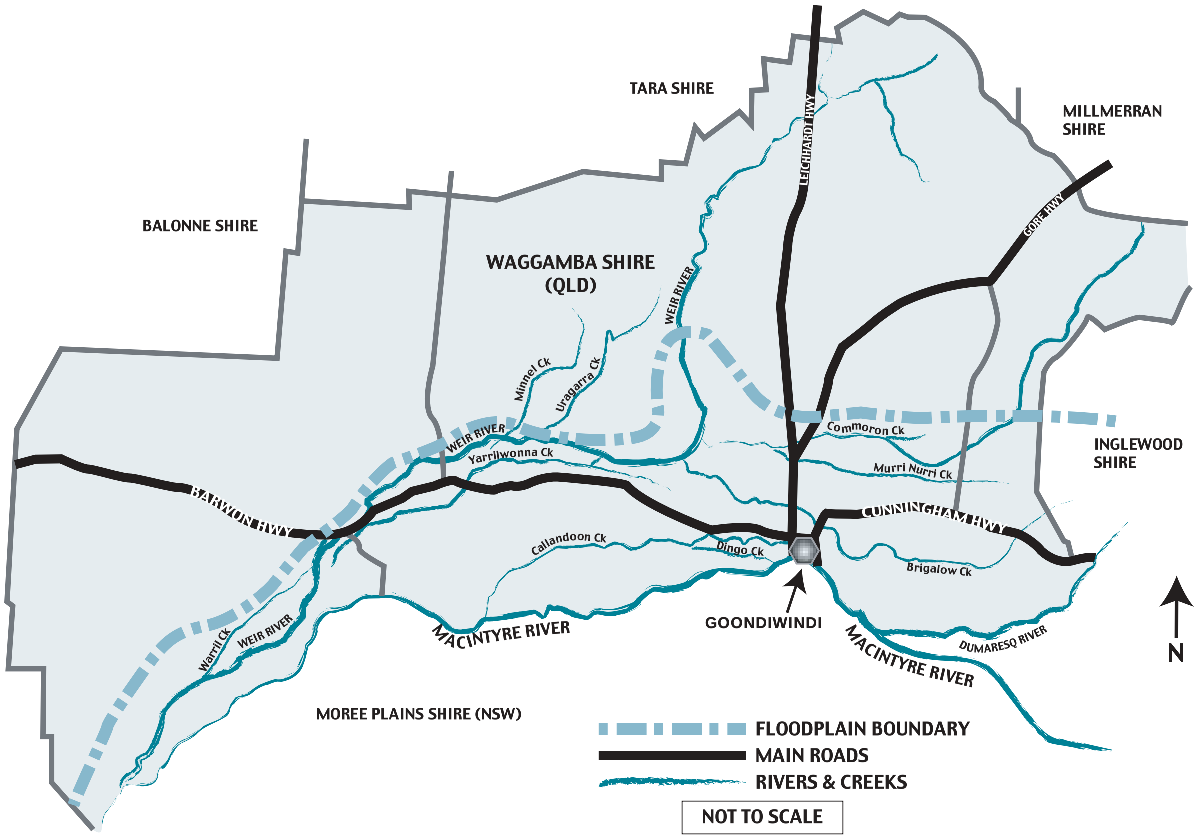
Shire-controlled roads are used extensively for the transport of cotton—one of the major products of the Shire. The Council is committed to a programme of progressively upgrading flood-prone roads from gravel surfaces to single lane bitumen-sealed roads. Bitumen-sealed roads are designed to not impede the flow of floodwater over them and to also inhibit the erosion of road shoulders (figure IV.2). Waggamba Shire has adopted the following process to protect flood-prone roads and found this effective for local conditions:

1. The top 200 millimetres of the existing surface is removed, mixed with water, replaced and rolled. This process is referred to as wet mixing the pavement.
2. A primer seal—a mixture of one part bitumen to 10 parts kerosene—is sprayed on the surface at a rate of 1.0 to 1.2 litres per square metre. The sprayed surface is covered with 7 millimetres of aggregate and rolled.
3. The surface is sprayed with bitumen, at a rate of 1.6 litres per square metre. The sprayed surface is covered with 14 millimetres of aggregate and rolled.

In practice, the design has proved successful and the Council advised the BTRE that flood damage to its bitumen-sealed roads has been negligible.

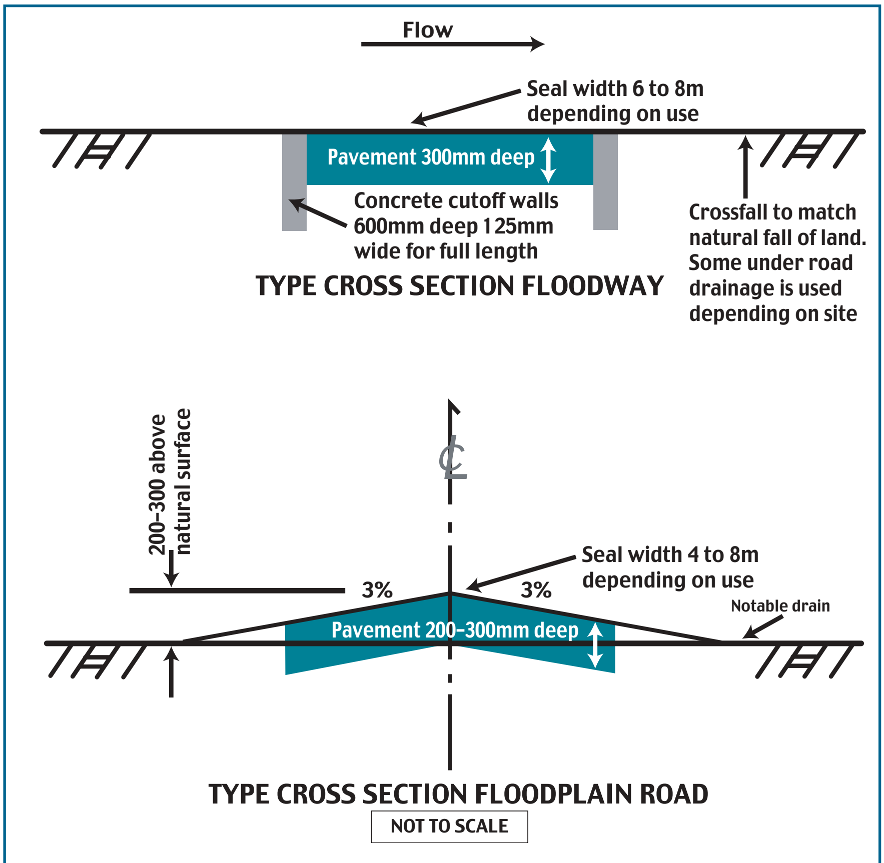
A large proportion of NDRA funds are expended in the restoration of flood-damaged roads. However, Commonwealth assistance is not currently available for the restoration or replacement of a public asset above the pre-disaster standard. Critics of the NDRA have suggested that upgrading roads to a standard that will ensure that they will not be damaged in subsequent floods

FIGURE IV.1 MAP OF WAGGAMBA SHIRE



Source Based on UBD (1997), Bureau of Meteorology (2002), and Graham Callaghan (pers. comm., May 2001).

FIGURE IV.2 DESIGN OF BITUMEN-SEALED ROADS



Source Graham Callaghan (pers. comm., May 2001).

would be a good investment. The programme adopted by the Waggamba Shire provided an opportunity to investigate this issue.

Sealing a road with bitumen incurs a substantial capital cost estimated at $50 000 per lane-kilometre by the Council. However, lower maintenance costs offset the high capital costs. The Waggamba Shire estimates that bitumen-sealed roads require resealing on average every ten years at a cost of $5 600 per lane-kilometre. Resealing involves spraying the surface with bitumen at a rate of 1.3 to 1.4 litres per square metre and then covering the sprayed surface with aggregate and rolling it.

In flood-prone areas, gravel roads require resheeting every five years at a cost of $8 000 per kilometre. In contrast, gravel roads in areas not subject to floods, require resheeting at intervals of 10 to 15 years.

Road vehicle operating costs are also affected by road condition. On gravel roads, travel speeds are usually slower and the rougher surface results in higher maintenance costs compared with bitumen-sealed roads.

EVALUATION METHOD

The BTRE used a benefit-cost framework to analyse the economic merit of sealing a road with bitumen rather than continue with repairing and resheeting flood-prone gravel roads.

In the base case, the gravel road is resheeted in year 1 at a cost of $8 000 per kilometre and at five-year intervals thereafter. In the project case, the road is sealed with bitumen in year 1 at a cost of $50 000 per lane-kilometre and resealed at ten-year intervals thereafter.

These assumptions rely on cost estimates specific to the Waggamba Shire. The costs of sealing, resealing and resheeting roads vary widely depending on local conditions. Terrain, climate, geology, traffic volumes, heavy vehicle usage, frequency and type of flooding, road use behaviours and many other local factors can cause both the costs and the time intervals to be highly variable across different locations. For example, the BTRE was advised that resealing costs for Commonwealth-administered roads are typically in the order of $14 000 per lane-kilometre compared to the $5 600 estimated for the Waggamba Shire. Resealing can also occur at intervals longer than 10 years (up to around 15 years). As a result, it is important to consider local factors affecting costs when using the results of this case study.

Although bitumen-sealed roads clearly have lower maintenance costs for the Council, the lower costs may not be sufficient to fully offset the high capital costs required to seal the road. Benefits to road users can be considerable and may be sufficient for the upgrading to a bitumen seal to be economically justified. Benefits to truck operators involved in the cartage of cotton in the Waggamba Shire were therefore included in the analysis.

Road vehicle operating costs were estimated using the Austway Commercial Road Transport Costing System (referred to as the Austway model in the following discussion). The truck operating costs are based on a semi-trailer travelling fully loaded in one direction and empty in the other. This would be relevant to cotton transport operations typical of the Waggamba Shire. Truck speeds are assumed to be 80 kilometres per hour on gravel surfaces and 100 kilometres per hour on bitumen surfaces (table IV.1). On gravel roads, a truck will cover 640 kilometres in a 12-hour working day after allowing for loading and unloading time. At 100 kilometres per hour on a bitumen road, the same transport task can be completed in 10.4 hours. The time saved would be of considerable benefit to truck operators. It is unlikely that the time savings of faster truck speeds would be of any benefit to cotton producers, and consequently these have not been evaluated.

TABLE IV.1 AUSTWAY MODEL INPUT DATA

Truck and operational characteristic	*Model input*
Type of operator	Owner operator (fully owned)
Description of unit	Flat top semi-trailer (22 wheel combination)
Value of prime mover ($)[a]	124 165
Value of trailer ($)[a]	21 300
Registration	Registered in Queensland
Age	4 years (both the prime mover and trailer)
Load	25 tonnes of cotton in one direction, nothing in the other
Driver remuneration	Paid according to State award
Round trips per day	8
Round trip distance (km)	80
Loading time (hrs)	2
Unloading time (hrs)	2
Fuel price (cents/litre)	92.0
Average speed (km/hr)	
gravel road	80
bitumen road	100

a. Model default value.

Source BTRE input to Austway model.

The BTRE analysis was based on calculating the number of semi-trailers per day that are required for the sealing of roads with bitumen to break even. Traffic mixes on Shire roads are much more diverse than that assumed for this analysis. As well as semi-trailers, there will be a range of other truck types and cars.

Focusing the analysis on just one vehicle type will tend to understate the benefits of the road upgrading, as benefits to other vehicle types are ignored. However, the analysis is designed to be illustrative and this is aided by the simplicity gained by including only one vehicle type.

Discounting of the costs and benefits is based on a 50-year project life and a discount rate of 4 per cent.

RESULTS

The present value of the gravel road base case is $39 730 per kilometre. Capital and resealing costs for the bitumen-sealed road have a present value of $60 020 per kilometre. The difference between the two present values is $20 290 per kilometre in favour of the gravel road. For the bitumen-sealed road to be economically justified, savings to truck operators must have a present value of $20 290 or greater.

The Austway model estimates that trucks on gravel roads cost 124.13 cents per kilometre and 114.26 cents per kilometre on bitumen-sealed roads. Converting to a bitumen-sealed road therefore generated truck savings of 9.87 cents per kilometre (table IV.2). If trucks operate for 300 days per year, the average number of trucks required each day to generate savings with a present value of $20 290 is approximately 32.

The Shire Council advised the BTRE that typically during the harvest period from March to July, 100 semi-trailers would travel on any given section of road. At other times of the year, there would still be a small number of semi-trailers. Also, throughout the year, there are several commercial vehicles, such as tankers delivering fuel to farms, using the Shire's roads.

Assuming a six-day week, there are about 130 days from the beginning of March until the end of July on which trucks can be expected to operate.

TABLE IV.2 AUSTWAY MODEL OUTPUT

(cents/km)

Type of cost	*Gravel road*	*Bitumen road*	*Difference*
Fixed costs (prime mover)			
Return on investment	4.53	4.53	0.00
Insurance	2.93	2.93	0.00
Registration & CTP	2.18	2.18	0.00
Administration	7.57	7.57	0.00
Fixed costs (trailer)			
Return on investment	0.78	0.78	0.00
Insurance	0.50	0.50	0.00
Registration & CTP	0.57	0.57	0.00
Semi-variable costs (prime mover)			
Other over heads	3.83	3.83	0.00
Driver's remuneration	35.48	28.75	6.73
Variable costs (prime mover)			
Fuel	36.19	34.88	1.31
Repairs and maintenance	13.66	13.17	0.49
Tyres	6.45	5.83	0.62
Variable costs (trailer)			
Repairs and maintenance	3.10	2.99	0.11
Tyres	6.36	5.75	0.61
Total	124.13	114.26	9.87

Note Figures may not add to totals due to rounding.

Source Austway Commercial Road Transport Costing System.

Therefore, over this period there would be about 13 000 semi-trailers using the typical road. The 32 trucks per day required for the bitumen-sealed roads option to break even is equivalent to 9 570 trucks per year. Based on the information provided to the BTRE, it appears that the use of bitumen-sealed roads in Waggamba Shire is comfortably justified. The economics of bitumen sealing would be stronger if the value of other potential benefits, such as improved road safety and environmental benefits, were included.

CONCLUSIONS

The results will overstate the number of trucks required to break-even to some extent for the reasons discussed earlier. In addition, no account is taken of the road safety benefits of the better quality road. Furthermore, the Waggamba Shire reported that suitable gravel for road making is becoming harder to find within the Shire. The cost of gravel resheeting is therefore likely to increase faster than the cost of bitumen sealing.

Although the motivation for sealing the roads with bitumen is largely to reduce flood damage, the economic justification relies on benefits that are unrelated to floods or their mitigation. Also, some flood-related benefits have not been considered in the above analysis. For example, there may be benefits of reduced isolation as the bitumen-sealed roads are less likely to be impassable following a flood. They will not require repair and be useable much sooner after floodwater recedes.

Waggamba Shire has some natural advantages for the economics of bitumen road sealing. The sub-grade conditions are generally good, so that preparation prior to sealing is less costly than for other locations with poor sub-grade conditions. The terrain is flat which simplifies drainage requirements. The roads subject to bitumen sealing generally have low traffic volumes so that the low-cost bitumen sealing method is appropriate. Other locations with poor sub-grade conditions, hilly terrain and larger traffic volumes would face higher costs.

appendix V

TAMWORTH CASE STUDY

Situated on the Peel River, 408 kilometres north west of Sydney in New South Wales, Tamworth has a population of over 35 000 (TCC 2001) and an average annual rainfall of 650 millimetres. Floods have been a regular occurrence in Tamworth, with about 40 floods occurring since the commencement of records in 1925. The largest floods (since 1925) occurred in 1955 and 1962, reaching 7.16 metres and 6.86 metres on the Tamworth flood gauge respectively (PPK 1993, p. 3). Significant flooding also occurred in 1984. It is thought that the flood of 1955 corresponded to a 75-year ARI flood and the flood of 1984, which was less severe, was approximately a 20-year ARI flood.

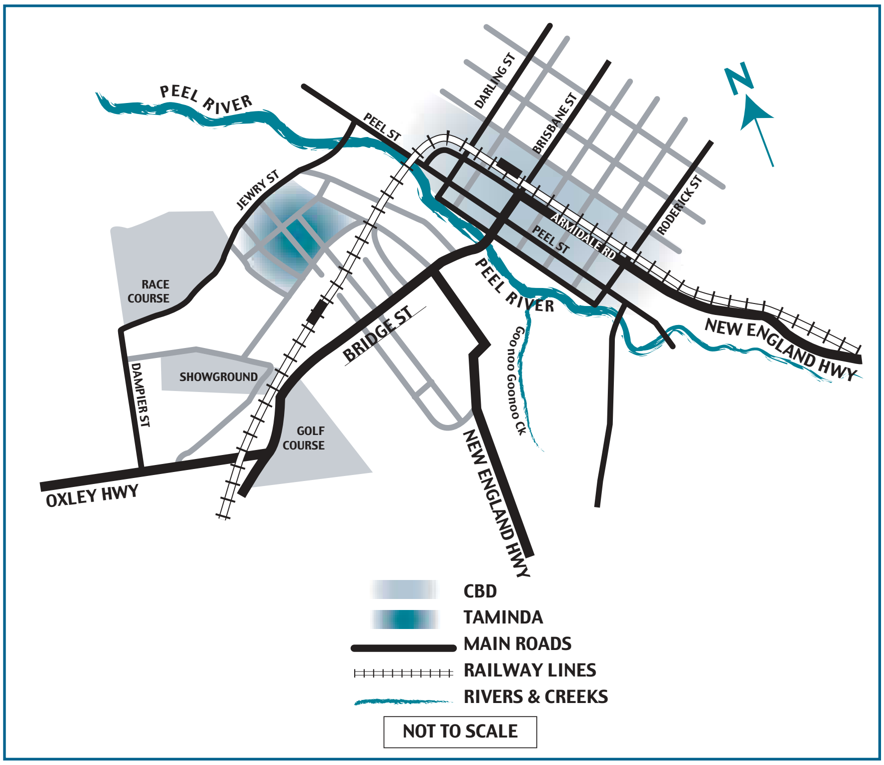
November 2000 was the wettest November on record for NSW. In the first twenty days of the month, inland regions of northern NSW, including Tamworth, received between one and a half to three times their average annual rainfall. Numerous rivers in western and inland NSW, including the Peel River, broke their banks and flooded. Early on the morning of November 20, the flooded Peel River surged into Tamworth. The floodwaters broke the western banks and flooded part of Taminda, the industrial area of Tamworth. The Peel River rose above the town’s two road bridges early in the afternoon, splitting Tamworth in two for around four hours. While it is difficult to give a precise recurrence interval for the flood of November 2000, at the time of the analysis the Council advised the BTRE that it would have been close to a 10-year ARI.

The part of Taminda that was inundated in the November 2000 flood does not have any structural protection. A conceptual design for a levee has been completed with detailed design work to commence in the first half of 2002. The CBD, which is protected by a recently upgraded levee, suffered no inundation. Taminda and the Tamworth CBD are shown in figure V.1

NOVEMBER 2000 FLOOD STUDY

The November 2000 flood provided an opportunity to estimate the savings in costs that would have occurred in Taminda if there had been a levee to protect the area. The flood also provided an opportunity to explore methods of

FIGURE V.1 MAP OF TAMWORTH



Source Based on UBD (2000) and BTE (2001b).

estimating damage costs avoided by the existence of a levee—as was the case for the Tamworth CBD. The study therefore had two objectives:

- Estimate the economic costs resulting from the November 2000 floods at Taminda.
- Estimate the costs avoided in Tamworth by the CBD levee bank during the November 2000 flood.

A number of previous studies have considered floods in Tamworth. In 1993, the Tamworth City Council commissioned PPK Consultants Pty Ltd to develop a Floodplain Management Study (PPK 1993). The study made a number of recommendations on mitigation measures for parts of Tamworth subject to flooding and included a detailed hydrological survey for various heights of the Peel River. An earlier study of the 1984 flood was undertaken by Smith and Greenaway (1984) and included a calculation of flood damage to Taminda of $1.44 million ($2.91 million in 2000 prices). It was possible to draw on these prior studies as reference for the study of the November 2000 flood. However,

PLATE 4 TAMWORTH CBD LEVEE—FLOODING DURING CONSTRUCTION—1998

TAMWORTH CBD LEVEE—COMPLETED

Source Tamworth City Council.

the November 2000 flood also provided an opportunity to adopt a different focus and to consider some additional factors relevant to flood mitigation and the estimation of damage costs.

The 1984 flood occurred in the early hours of the morning on a long-weekend. As such, only a few businesses were able to make preparations for the flood. In the 2000 flood, businesses in Taminda had several hours warning of the impending flood. There have been few studies of floods in predominantly industrial areas that allow estimation of the savings that can be made by good use of the time available from when a warning is given until premises are flooded. Because Taminda is almost entirely industrial, the November 2000 flood provided an opportunity to examine the effect of floods on industrial enterprises and the effectiveness of flood preparation.

The Taminda study was relatively straightforward, as the techniques for estimating the economic cost of a natural disaster are well established[38]. However, this was not the case for the CBD study.

Estimating the effect of a levee after its construction is not straightforward. The task is to judge what might have happened if the levee had not been there. Although estimating potential direct damage is a matter of using standard stage-damage curves, estimating the likely actual damage is much more speculative. Far more difficult is the estimation of the indirect costs associated with disaster response by the SES and volunteers and the effects of business disruption. The study of the Tamworth CBD is therefore as much a means of testing the usefulness of the adopted reconnaissance method as it is of estimating the savings due to the levee bank.

EVALUATION METHOD

The study had two distinct components—the Taminda investigation and the CBD investigation.

Taminda investigation

The primary source of information was a face-to-face survey of business people in their offices in Taminda. The interviewer used a questionnaire as an aid to discussion and a vehicle for reporting responses. The questionnaire was designed to allow fast collection of information and did not require respondents to spend a lot of time searching through records.

The survey sought information on:

- the site;
- flood mitigation measures;
- flood warnings;

38 See BTE (2001a).

- direct damage;
- damage reduction as a result of mitigation measures;
- indirect losses;
- other adverse effects;
- insurance
- other information on the enterprise (annual turnover and stock held); and
- the Taminda levee.

In addition to the interviews, information on infrastructure costs was obtained from the Tamworth City Council. Information on the response effort was obtained from the SES and the local fire brigade.

Cost estimates included direct and indirect costs, but not intangible costs. Direct costs included damage to stock, equipment and materials of the affected businesses as well as damage to public infrastructure. Indirect costs included the costs of preparing for the flood, clean-up costs and emergency services costs. Cost of lost trade was also calculated.

CBD investigation

There was no actual flood damage to properties in the CBD. Information available to the BTRE at the time indicated that a 10-year ARI flood (such as in November 2000) would fail to inundate even the most low-lying buildings in the area of the CBD, with or without a levee[39].

The study undertook a reconnaissance survey of all buildings within the Tamworth CBD area subject to the Probable Maximum Flood (PMF) as given in the PPK study. A field survey was conducted recording information for all the individual commercial and industrial premises in the CBD up to the PMF flood level. The survey included the area from Roderick Street in the east to Darling Street in the west.

The information recorded for each enterprise was:

- location—street (and number where available);
- an estimate of size category of the enterprise;
- type of enterprise, later classified according to the Australian Standard Industrial Classification, ASIC (ABS 1983);

39 Flood modelling carried out by Tamworth City Council after the completion of the case study revealed that this is not the case. The new modelling indicates that a flood of similar magnitude to the November 2000 event would inundate parts of the CBD in the absence of the levee. As a result, the estimated damage avoided in the CBD due to the levee should be regarded as an underestimate.

- an estimate of the value category of the enterprise; and
- an estimate of the height of floor level above ground level.

The merit of the 2001 survey was that the field time was the equivalent of two person-days, with about three person-days for analysis. The style of the reconnaissance survey was possible because a suitably detailed hydrological survey in map form was available from the PPK (1993) report.

An approximate approach was adopted for estimating the potential direct damage to commercial enterprises in the CBD if there had been no levee and if the flood was a 100-year ARI event. Each enterprise was allocated to a size and value class. Each combination of size and value class had an approximate stage-damage curve that was used to estimate potential damage (Smith 1994, BTE 2001a, pp. 67–68).

The results were compared with those obtained using the Rapid Appraisal Method (RAM)[40] and with the estimation of damage costs (updated to 2000 prices) provided in the 1993 PPK Study.

TAMINDA—FINDINGS

The 2001 study of Taminda included all buildings inundated in the November 2000 flood and the majority of buildings inundated in the 1984 flood. A total of 99 businesses were surveyed, although this included a number of buildings that did not experience inundation in November 2000.

Direct costs

A total of 21 businesses reported direct damage costs (table V.1). Direct damage costs for businesses amounted to $144 460, with the highest damage attributed to stock and equipment damage (approximately $80 000 and $57 000 respectively). Damage to the fabric of the building was not large and only made a minor contribution to direct damage costs.

The November 2000 flood was estimated to be smaller than the 1984 flood. It occurred during business hours, affording greater opportunity for businesses to make preparations for the flood. These factors contributed to a difference in damage estimates between the 2000 and 1984 events. The direct damage costs to Taminda in 2000 were significantly less than the $787 900 ($1 640 000 in 2000 prices) reported by Smith and Greenaway (1984, p. 10) for the 1984 flood.

The preparation effort in Taminda was generally successful. Despite some reported difficulties in effective utilisation of sandbags, responses from

40 The RAM was developed for the Victorian Department of Natural Resources and Environment (VDNRE 2000) to provide a quick method for calculating damage costs. Standard damage values are calculated based on size and value to estimate potential and actual direct damage.

TABLE V.1 DIRECT DAMAGE COSTS FOR TAMINDA—NOVEMBER 2000

Damage category	*No. of businesses*	*Damage cost ($)*
Stock	14	80 140
Equipment	7	57 300
Fabric	9	7 020
Total	21[a]	144 460

a. Figures do not add to total because some businesses reported damage in more than one category.

Source BTE (2001b, p. 9).

businesses indicate that preparatory efforts, including the lifting or movement of stock and equipment at risk, were able to reduce the direct damage that would otherwise have been experienced by $781 000. This is significant and suggests that actual direct damage was only 16 per cent of the potential direct damage. A few of the enterprises in the Taminda area had flood warning action plans, although there was an apparent lack of awareness and correlation of the relationship between floor height and flood stage. Nevertheless, the use of flood warning action plans as a measure to mitigate potential losses in a flood event would appear to be warranted.

While the figure calculated for damage avoided demonstrates the effectiveness and value of preparations and warning time, the relatively minor nature of the flood must be emphasised. Caution should be exercised in extrapolating the direct damage avoided to larger floods. This point is further illustrated through a consideration of the Campbell's warehouse in Taminda.

Campbell's experienced an over-floor inundation of 0.25 metres throughout the whole store in November 2000. Had the warehouse been constructed at the time of the 1984 flood, the depth would have been 0.65 metres. In the event of a 100-year ARI flood or a PMF, the depth of water above floor level would be 1.15 metres or 4.85 metres respectively. Campbell's stock and equipment was reliably estimated to be $2.15 million.

Previous studies have suggested that over-floor inundation of 0.75 metres would cause losses of some 50 per cent of stock and equipment, notwithstanding that reasonable preparations were made. Higher inundations would obviously result in even greater losses.

While stock and equipment may be raised, it would be rare that these would be removed from the site. As the level of water over the floor increases, a point is reached where raising stock and equipment is no longer effective. Forklift motors would become useless at depths of 0.75 metres or more and, due to reduced traction in water, are of marginal assistance at smaller inundation levels. The forklifts themselves would suffer significant, if not total, damage at greater depths. It would appear that while preparatory actions at

Campbell's could significantly reduce the damage experienced in minor floods, this cannot be claimed with any certainty for larger floods.

Direct costs to infrastructure

Tamworth City Council provided damage estimates from the November 2000 flood for roads, bridges, river works and other infrastructure. A major component of these costs is labour, which is included in the figures.

The total infrastructure cost for Tamworth City Council was close to $2 million. Most of this was repaid to the Council from NDRA funds. Of the total approved for the Tamworth City Council, only $31 781 related to Taminda (for emergency road closures and repairs to road surfaces and road shoulders).

Indirect costs

Following the recommendations in BTE (2001a), indirect costs include:

- costs of preparing for the flood;
- clean-up costs;
- lost trade costs; and
- emergency services costs.

Whether the costs of lost trade for local businesses should be included in indirect costs depends on the perspective taken by the analysis. The economic costs of lost trade should be included if a local perspective is taken. However, a national perspective would exclude most instances of lost trade on the grounds that trade lost during a flood would be taken up by other businesses unaffected by the flood, or deferred in time. An estimate of the costs of lost trade is included in the following analysis.

Costs of preparation

Preparation for the November 2000 flood involved lifting at-risk stock above the expected flood height and, in at least one case, the removal of stock to a flood-free location by truck. In-house labour was used exclusively for preparation. The value of the preparation effort was based on average weekly ordinary time earnings (AWOTE) for November 2000 (ABS 2001a). The ASIC was used to estimate a weighted average AWOTE for the businesses responding to the survey. The weekly rate, estimated by this procedure, was $718.80.

The total person-hours reported by the 73 establishments that prepared for the flood was 1 400, giving a total preparation cost of $25 150. The average cost per square metre was 49 cents.

Costs of clean-up and restoration

Clean-up and restoration costs included the costs of materials and additional labour, as well as the cost of in-house labour. Even if a property was not inundated, respondents reported that the time to restore stock to shelves was much longer than to lift it prior to the flood. This is to be expected, because restoration of stock that was removed under emergency conditions involved a degree of sorting and restacking.

The 65 properties reporting both a preparation time and a clean-up and restoration time reported a total of 2 921 person-hours of in-house labour for clean-up and restoration at a cost of $52 490. These same properties took 1 267 person-hours in preparation. That is, clean-up and restoration required 2.3 times the in-house labour required for preparation. A further three properties reported a clean-up and restoration time, but no preparation time.

In addition, businesses reporting times for clean-up and restoration spent $2 030 on cleaning materials. Although almost without exception clean-up was undertaken with in-house labour, a total of $1 250 was spent in hiring additional labour to assist in-house staff. The total clean-up and restoration cost was $56 200 and averaged $1.20 per square metre.

Lost trade

The average time during which it was not possible to open for business was 1.9 days for the 80 businesses reporting lost trade. Most businesses (78 per cent) reported two days or less trading time lost. The maximum trading time lost was seven days (one business only).

The economic effect of the lost trade depends on where the boundaries of the analysis are drawn. If a national perspective is taken, the economic effect of the lost trade would be small (BTE 2001a, p. 77). However, if the analysis is confined to the Taminda area, the economic effect would be approximately equal to the value added[41] that was lost during the time of business interruption.

Survey respondents were asked if the trade lost was subsequently made up. The answers were mixed. Some said they normally worked close to full capacity, so it was not possible to make up any lost trade. Others said that their competitors and some customers were similarly disrupted and so the opportunity to make up the loss existed.

Service providers had the greatest difficulty in making up lost trade. For example, an ice cream distributor commented that ice cream sales were mostly impulse purchases and, once lost due to an inability to supply the product, the sale subsequently could not be regained. It was also evident that some lost services could not be attributed totally to the flood. For example, a car washing

41 Value added is the difference between the total revenue of a firm and the cost of bought-in materials, services and components.

business operator commented that he lost business whenever it rained. His business was disrupted, but it would have been disrupted by the rain irrespective of the occurrence of a flood.

The following results are based on the assumption that all trading time lost during the flood led to a loss of value added. However, it is clear that this will be an overestimate of the economic effect.

Lost value added was estimated from annual turnover data using information on value added and sales contained in ABS (2001b). The turnover for each business reporting lost trade was multiplied by the relevant ratio of value added to sales to give an estimate of the lost value added for the disrupted business. The estimated loss of value added obtained in this way was $214 300. As noted above, this estimate overstates the value added that was lost due to the Taminda flood.

The financial loss to flood-affected businesses is measured by the loss in profit. Profit lost on the days during which trading was not possible was estimated using data on operating profit before tax found in ABS (2001b). The estimated lost profit was $58 700, which is significantly less than the economic loss.

Emergency services costs

SES

The Tamworth–Parry [Shire] SES unit recorded 1 020 total person-hours for the period 16–23 November. The opportunity cost of this labour using AWOTE of $718.80 is $18 330. Direct costs for payment of fuel, sand, sandbags, phone/fax and other consumables totalled $8 600.

There is no formal breakdown of the costs for Taminda, as the Tamworth/Parry Unit covers a larger geographical area. However, it is thought that 75 per cent of the overall costs could be allocated to Taminda, where the sandbagging operations were predominantly used. The total cost is therefore $20 200 ($13 750 for labour and $6 450 for materials).

For a larger flood, it is likely that a larger proportion of the SES assistance, and thereby costs, would be directed elsewhere in the wider Tamworth/Parry area. In part, this is because the November flood caused relatively little inundation of residential buildings.

Bush Fire Brigade

Like the SES, the Bush Fire Brigade is a volunteer organisation. Its headquarters share the same buildings and storage areas as the SES at the edge of the flood-prone area of Taminda. Its main contribution to the flood response in November 2000 was to make its three units available during the immediate clean-up phase. This was a task that it shared with the Tamworth Fire Service—the full-time fire service.

Three mobile Bush Fire Brigade pump units with a total crew of ten persons worked for a full day immediately after the floods to assist with the clean-up of industrial enterprises in Taminda. The estimated opportunity cost of the labour is $1 440.

The service was much appreciated by firms that had experienced over-floor flooding. For instance, at Campbell's (a large wholesale grocery depot and store) the smaller mechanised pumping units were able to motor up and down the aisles and use adapted high pressure hoses to clean out the river sediment that is a feature of floods of this kind.

Other facets of emergency management

The city fire brigade and police are important and additional elements of emergency services active during a flood. These are essentially professional organisations and no estimate is given of the costs of their involvement. The relevant cost would be the marginal costs incurred because of the flood (BTE 2001a, p. 86).

Taminda—total costs

The total estimated cost of the Taminda flood was $493 500 (table V.2). The largest component of the estimated cost is business disruption. This cost, as

TABLE V.2 SUMMARY OF TAMINDA FLOOD COSTS

Cost category	*Cost ($)*
Direct costs	
Buildings & contents	144 460
Council assets (infrastructure)	31 781
Sub-total	*176 241*
Indirect costs	
Preparation	25 152
Clean-up	56 205
Business disruption	214 279
SES	20 197
Bush fire brigade	1 438
Sub-total	*317 270*
Total	**493 511**

Note Figures may not sum to total due to rounding.

Source BTE (2001b, p. 15).

explained earlier, is believed to overstate the economic effect of the flood on the local community. The estimate of $493 500 is therefore an upper estimate.

If a national perspective is taken, the total estimated cost falls to about $280 000. This will understate the total economic costs due to the observation made earlier that some lost trade cannot be made up, no matter where the boundaries of the analysis are drawn.

At the time of this analysis (mid-2001) the Taminda flood was considered to be small (about a 10-year ARI). Damage would increase substantially for deeper floods. The relatively minor nature of the November 2000 flood means that extrapolation of the estimated costs to larger floods requires caution.

Most respondents to the survey received warning of the flood from several sources, but mostly from radio, neighbours and the SES. Their assessment of the warnings was mixed, with some regarding the warnings as good and others regarding them as totally inadequate. Businesses made good use of the warning time available to them. Shifting of stock and equipment above expected flood levels resulted in an estimated reduction in direct losses of $781 000 (84 per cent).

The flood illustrated the substantial amount that can be saved if timely warnings are given and acted on. Businesses with prior flood experience generally had effective flood action plans. It was fortunate that the 2000 flood occurred during business hours, allowing even those without flood action plans to prepare. Scope exists to encourage other businesses in Taminda to develop flood action plans and these would be of great benefit during future floods, especially if they are larger and occur at less convenient times.

The approach adopted was both quick and undemanding on business respondents in the Taminda district. The survey was conducted sufficiently close to the time of the flood for memories to be still reliable and far enough removed in time for damage costs to have been estimated with reasonable accuracy.

CBD—FINDINGS

The November 2000 flood did not inundate the CBD and there was no damage to calculate. Instead, a survey was conducted to trial a methodology that could perhaps be used in future studies of this kind. At the same time, the survey provided a chance to review the PPK (1993) study and to consider the effectiveness of the RAM approach to calculating damage.

Direct costs

The field survey identified 387 premises below the PMF level, 314 of which were below the 100-year ARI flood level. A total of 88 per cent of the properties surveyed were classified as either value class 2 or 3 (lower value classes) and 87 per cent of the properties were in the small size range. The

TABLE V.3 CBD POTENTIAL DIRECT DAMAGE

Value class	No. buildings	Average damage[a] ($/building)	Total damage ($'000 1993)	Total damage ($'000 2000)[b]
Size 1				
2.4	273	10 200	2 784.6	3 341.5
Size 2				
1	1	10 000	10.0	12.0
2	23	20 000	460.0	552.0
3	12	40 000	480.0	576.0
4	2	80 000	160.0	192.0
Sub-total	*38*		*1110.0*	*1332.0*
	Square metres	*($/m²)*		
Size 3				
3	11 500	50	575.0	690.0
Total			4 469.6	5 363.5

a. Damage figures from BTE (2001b, p. 34) for over-floor depth of 0.5 metres.

b. Updated to 2000 prices using a factor of 1.2.

Source BTE (2001b, p. 35).

number of properties in the survey below the 100-year ARI flood level is consistent with the number reported by PPK (1993). However, there is a marked difference in the number of properties at risk from the PMF. The PPK number is much higher (587) and is thought to be due to the different methods used. It is considered that the survey approach used in this study is superior.

The stage-damage curves used for estimating direct damage are based on a combination of size and value class of the business and are those used in a number of earlier ANUFLOOD surveys (updated to 2000 prices). The total potential direct damage from a 100-year ARI flood estimated using these stage-damage curves was $5.36 million (table V.3). Using a Damage Reduction Factor (DRF) of 0.6 gives an estimate of actual direct damage of $3.2 million. The DRF is used to provide an adjustment to the potential direct damage calculation to estimate the damage that would actually occur. It is hypothesised that communities experienced in responding to floods and with adequate warning time can significantly reduce the actual damage sustained in floods. As discussed in chapter 4, the use of a DRF is controversial. The BTRE therefore provides both a potential and actual estimate.

Comparison of results

To crosscheck the results of the reconnaissance method, results were compared with those obtained using the RAM and by PPK (1993). The RAM gives an estimate of potential direct damage of $9.5 million (table V.4) and an actual direct damage (using a DRF of 0.6) of $5.7 million in 2000 prices. The

TABLE V.4 CBD POTENTIAL DIRECT DAMAGE USING THE RAM

Size category	*No. buildings*	*Total area (m^2)*	*Damage ($)*	*Total damage*[a] *($'000)*
1	273		22 500	6 142.5
			($/$m^2$)	
2[b]	24	24 000	45	1 080.0
	12	12 000	80	960.0
	2	2 000	200	400.0
Sub-total	38	38 000		2 440.0
3	3	11 500[c]	80	920.0
Total	**314**			**9 502.5**

a. 2000 prices.

b. All size 2 properties are assumed to have a floor area of 1000 m^2.

c. Total floor area from table V.3.

Source BTE (2001b, p. 37).

larger damage costs are due to larger unit area damage costs used in the RAM compared with those implied in the stage-damage curves used in the current analysis. The PPK (1993) results were much higher ($33 million) for actual direct damage costs in 2000 prices (table V.5).

The significantly higher results derived by PPK are perhaps due to higher unit area damage costs than in the stage-damage curves used in this analysis and possibly deeper over-floor flood heights. However, there is insufficient detail in the PPK report to be certain. It has also been suggested that the PPK study may have included a telephone exchange and pump station (two significant infrastructure assets) that have not been included in the BTRE analysis.

Comparison of the three approaches highlights the need for good quality information on stage-damage curves for commercial and industrial premises.

TABLE V.5 CBD ACTUAL COMMERCIAL AND INDUSTRIAL DAMAGE (PPK STUDY)

	Number of properties		*Damage ($ million)*[a]		
Flood event (AEP %)	*Flood affected*	*Damaged*	*Direct*	*Indirect*	*Total*
5	13	11	0.39	0.09	0.48
2	383	308	11.30	2.43	13.74
1	394	394	33.37	5.95	39.32
PMF	587	580	56.76	9.90	66.66

a. Updated to 2000 prices using a factor of 1.2.

Source BTE (2001b, p. 27).

Inconsistency in results due to variance in the stage-damage curves applied pose a significant challenge for the comparison of study results.

CBD—conclusions

The CBD survey illustrates the potential use of the reconnaissance method to obtain fast estimates of flood damage. It is estimated that the CBD levee would avoid at least $5.36 million potential direct damage from a 100-year ARI flood. Using a DRF to adjust this figure, $3.2 million actual direct damage would be avoided for a 100-year ARI. The results compare favourably with the RAM results, which estimate potential direct damage at $9.5 million and actual direct damage at $5.7 million, but are considerably different to the PPK results, which estimate actual direct damage at $33 million.

The survey highlights the need for improved and widely applicable stage-damage curves for commercial and industrial enterprises. Further research on commercial and industrial stage-damage curves is required if consistent and reliable damage estimates are to be obtained.

appendix vi

CONSULTATION PARTICIPANTS

Place	*Date*	*Participants*
Australian Capital Territory	18 June 2001	ACT Roads & Stormwater, Bureau of Meteorology, Ecowise Environmental, Emergency Services Bureau, Urban Services
New South Wales	21 May 2001	Department of Land & Water Conservation, Floodplain Management Authorities of NSW, State Emergency Service, Tamworth City Council
Northern Territory	16 May 2001	Bureau of Meteorology, Department of Lands, Planning & Environment, Northern Territory Emergency Service
Queensland	30 May 2001	Bureau of Meteorology, Cairns City Council, CRES (ANU), Department of Emergency Services, Department of Main Roads, Department of Natural Resources & Mines, Emerald Shire Council, Environmental Protection Agency, Gold Coast City Council, Insurance Council of Australia, Centre for Disaster Studies (JCU), Local Government Association of Queensland, Logan City Council, Queensland Transport, Ullman & Nolan Consulting Engineers & Town Planners, Waggamba Shire Council
South Australia	23 May 2001	Adelaide Hills Council, Bureau of Meteorology, Department for Water Resources, Emergency Services Administration Unit, Local Government Association, SA State Disaster Committee, State Emergency Service, Tonkin Consulting, Transport SA

Place	*Date*	*Participants*
Tasmania	18 May 2001	Bureau of Meteorology, Department of Primary Industry, Water & Environment, Glenorchy City Council, Huon Valley Council, Hydro Tasmania, State Emergency Service
Victoria	2 May 2001	Bureau of Meteorology, Department of Natural Resources & Environment, Goulburn Broken Catchment Management Authority, Melbourne Water, North Central Catchment Management Authority, Rural City of Wangaratta
Western Australia	24 May 2001	Fire & Emergency Services Authority, Water & Rivers Commission
Commonwealth	Feb-April 2001	Bureau of Meteorology, Department of Transport & Regional Services, Emergency Management Australia, Geoscience Australia

GLOSSARY

100-year event	The magnitude of an event, with a mean return period of 100 years, i.e. a flood with a 1 per cent chance of occurring in any one year.
Acceptable risk	That level of risk that is sufficiently low that society is comfortable with it. Society does not generally consider expenditure to be justifiable in further reducing those risks.
Acquisition	The process of governments obtaining land from property owners. In flood mitigation, this typically involves voluntary purchase of flood-prone properties.
Actual and potential damages	Actual damages are the damages that occur due to a flood after preventative measures, such as moving valuables to higher ground, have been taken. They may be measured after a flood, or may be the predicted damages that are likely to be caused by a flood. Potential damages are the maximum damages that could occur in a flood. In assessing potential damages, it is assumed that no actions are taken to reduce damage.
Annual Exceedance Probability (AEP)	The likelihood of occurrence of a flood of a given size or larger in any one year. The AEP is usually expressed as a percentage. If a given flood level has an AEP of 5 per cent, it means there is a 5 per cent risk (i.e. a probability of 0.05 or a chance of 1-in-20) of a flood that size or larger occurring in any one year.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Annual Damage (AAD)	The average damage per year that would occur in a nominated development situation from flooding over a very long period of time. AAD provides a basis for comparing the economic effectiveness of different management measures against floods of all sizes, i.e. their ability to reduce the AAD. If the damage associated with various events is plotted against their probability of occurrence, the AAD is equal to the area under the consequence-probability curve.
Average Recurrence Interval (ARI)	ARI is another way of expressing the likelihood of a flood event. It is the long-term average number of years between the occurrence of a flood as big as, or larger than, the selected event (e.g. a flood as big as, or larger than, the

	20-year ARI flood event will occur on average once every 20 years).
	The ARI of a flood should not be taken as an indication of when a flood of that size will occur next.
Benefit-Cost Analysis (BCA)	An analysis tool used to rank alternative projects by identifying and quantifying the benefits (or losses avoided) and costs to society. It aims at valuing benefits and costs in money terms and producing a summary measure of net benefit, typically a Benefit Cost Ratio (BCR). If the ratio of benefits to costs (BCR) is greater than or equal to one, the project is considered to provide a positive net benefit to society.
Cost-effectiveness analysis	An attempt to determine the least-cost means of achieving a given objective. It does not attempt to value the benefits of meeting the objective.
Cyclones	Large-scale, atmospheric pressure systems characterised by relatively low barometric pressure and strong winds. They are referred to as *cyclones* in the Indian Ocean and South Pacific, *hurricanes* in the western Atlantic and eastern Pacific and *typhoons* in the Western Pacific.
	Cyclones have extreme winds that may exceed 200 km/h. These winds can cause injuries and fatalities along with extensive property damage. Cyclones can also produce flood rains and storm surges, which can cause further damage and risk to life.
Dam	An artificial barrier constructed for the storage, control or diversion of water.
Damage Reduction Factor (DRF)	An adjustment factor expressed as a decimal. It is applied to convert the calculated 'potential' damage to an estimate of 'actual' damage, taking into account warning time and prior flood experience. For example, in estimating actual flood damage, the use of a DRF of 0.7 implies that 30 per cent of damage may be avoided as a result of prior experience and warning time.
Design event or design flood	The flood risk level chosen as a basis for the design of mitigation measures expressed in terms of ARI or AEP. Mitigation measures are designed to provide protection in events up to the level of the design flood.
Detention basin	A generally small self-draining area, constructed on a creek or drain, that mitigates downstream flooding by providing temporary storage for floodwaters.
Discount rate	It is standard in BCA to discount future benefits, using a 'discount rate', to assign them a lower value than benefits that arise earlier. A dollar's consumption in the future is usually worth less than a dollar's consumption in the present.
	Future costs and benefits are discounted to a 'present value', to allow comparison of options with expenditure and benefits that occur at different times.

Economic and financial analysis

Economic analysis—considers the costs and benefits for society as a whole. It is concerned with efficiency and impacts on resource consumption and includes broader social effects such as ill health and stress that may not have a market value.

Financial analysis—considers costs and benefits to an individual or entity. It is based on the cash value of the resources and effects with no market value are not considered.

***Ex ante* and *ex post* analysis**

Ex ante—analysis of the expected or intended impact of proposed mitigation measures, undertaken before implementation.

Ex post—analysis of the impact of mitigation measures, undertaken after implementation.

Existing, future and residual flood risk

Existing risk applies to existing buildings and developments on flood-prone land. It is the risk a community is exposed to as a result of its location on the floodplain.

Future risk applies to buildings and developments that will be built on flood-prone land. It is the risk a community may be exposed to as a result of new development on the floodplain.

Residual or continuing risk refers to the risk associated with floods generally, the risk remaining after mitigation and the risk of an extreme (or catastrophic) event occurring. It includes the risk a community is still exposed to after floodplain risk management measures have been implemented. Few measures entirely eliminate the risk or mitigate the risk up to the probable maximum flood (PMF) level and, as a result, some risk will remain and be realised when floods exceeding design levels occur.

Flash flood

Flooding that is sudden and unexpected, often caused by heavy rainfall. It is sometimes defined as flooding that occurs within six hours of rainfall.

Flood

The overflowing by water of the normal confines of a stream or other body of water or the accumulation of water by drainage over areas not normally submerged.

Flood mitigation

Both structural and non-structural measures aimed at decreasing or eliminating the impact of floods on society and the environment.

Structural—physical measures that aim to control the flow of floodwaters.

Non-structural—measures that modify development or behaviour in response to flood risk.

Flood Warning System (FWS)

A system defining the level of flooding at which a warning will be initiated, the physical means by which it will be relayed and the persons to whom it will be given. The system includes all the necessary hardware such as water level actuators and radio transmitting and receiving equipment.

Flood, property and response modification	Flood modification—mitigation measures that aim to modify the behaviour of floodwater, keeping it away from development. Property modification—mitigation measures that aim to keep development away from (or above) floodwaters. Response modification measures—mitigation measures that aim to modify human behaviour.
Floodplain	Land subject to inundation by floods up to and including the probable maximum flood (PMF).
Floodplain risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, evaluating, treating and monitoring flood risk.
Flood-proofing	A combination of measures incorporated in the design, construction and alteration of individual flood-prone buildings and structures to reduce or eliminate flood damage.
Freeboard	A margin of safety applied when setting design levels for mitigation to compensate for effects that may increase flood levels or reduce the level of protection.
Hydrology	The study of the rainfall run-off process as it relates to the development of flooding at different locations in a river system. Often associated with hydraulics, the study of water flow in a river and across the floodplain.
Land use planning	The development and application of a legally enforceable land use plan by a local planning authority. A land use plan allocates permitted uses to areas of land, often referred to as zones. It can restrict particular types of developments in flood-prone locations.
Levee	Water retaining earthworks used to confine a stream's flow within a specified area along the stream or to prevent flooding due to waves and tides.
Levee paradox	The increase in potential damage resulting from floods greater than the design level (for example, if development behind levees increases or residents' flood awareness diminishes).
Loss—direct and indirect	Direct—loss resulting from the physical destruction or damage to buildings and their contents, infrastructure, vehicles and crops. Indirect—loss resulting from the consequence of the event occurring, but not due to the direct impact.
Loss—intangible and tangible	Intangible—loss that cannot be valued in monetary terms (with no market value), e.g. death, loss of memorabilia and environmental impacts. Tangible—loss that can be valued in monetary terms (with a market value), e.g. damage to goods and possessions and loss of income or services.

Minor, moderate and major flooding	Minor—causes inconvenience such as the closing of minor roads and the flooding of low-level bridges. Moderate—low-lying areas are inundated requiring the removal of stock and/or the evacuation of some houses and main traffic bridges may be flooded. Major—appreciable urban areas or extensive rural areas are flooded and properties, villages and towns may become isolated.
Natural disaster	A serious disruption to a community or region caused by the impact of a naturally occurring hazard that threatens or causes death, injury or damage to property and which requires significant and coordinated multi-agency and community actions. 'Natural occurring hazards' are any one, or a combination, of the following: bushfire; earthquake; flood; storm including hailstorm; cyclone; storm surge; landslide, tsunami; meteorite and tornado.
Natural Disaster Relief Arrangements (NDRA)	The arrangements under which the Commonwealth Government assists the State and Territory governments to provide financial assistance to eligible persons and organisations following natural disasters.
Opportunity cost	The value of a resource in its best alternative use.
Present Value	The discounted value of a financial sum arising in a future period (see discount rate). The Net Present Value (NPV) is the value of all benefits, net of all costs, discounted back to the present date.
Probable Maximum Flood (PMF)	The greatest possible flood arising from the worst flood-producing catchment conditions, including precipitation and snowmelt.
Stage	Equivalent to 'water level'.
Stage-damage curves	Stage-damage curves relate the depth of over-floor flooding to potential damage costs for properties having similar structures and contents.
Storm surge	The increase in coastal water levels caused by the: • wind driving water shorewards; and • increase in ocean water levels caused by the low pressure area of a storm or cyclone.
Stormwater flooding	Inundation caused by local run-off rather than water rising from a watercourse. It includes run-off exceeding the capacity of the drainage system.
Tsunami	Low crested wave generated in the ocean by a sudden change in the seabed resulting from an underwater volcano, landslide or earthquake.

Value added	The difference between the total revenue of a firm and the cost of bought-in materials, services and components.
Voluntary purchase	A form of acquisition where the landowner has the right to choose whether or not to sell to a purchasing authority.

REFERENCES

Agriculture & Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Floodplain Management in Australia: Best Practice Principles and Guidelines*, SCARM Report 73, CSIRO Publishing, Collingwood.

Allen, N.E. 1998, *City Engineer's Report to Council on the August 1998 Bathurst Flood*, Bathurst City Council, 16 September 1998, unpublished.

Australian Bureau of Statistics (ABS) 1983, *Australian Standard Industrial Classification*, Cat. No. 1202.0, 2 volumes, Canberra.

Australian Bureau of Statistics (ABS) 2001a, *Average Weekly Earnings*, Cat. No. 6302.0, Canberra.

Australian Bureau of Statistics (ABS) 2001b, *Summary of Industry Performance, Small and Medium Businesses*, Cat. No. 8142.0.55.002, Canberra.

Barlow, F.T.H. 1992, *Katherine Floodplain Management Study*, Volume 1, Report 60/92D, Power & Water Authority, Darwin.

Barlow, F.T.H. & Rajaratnam, L. 1992, *Katherine Floodplain Management Study*, Volume 2, Report 60/92D, Power & Water Authority, Darwin.

Bathurst City Council 2001, Bathurst, viewed September 2001, <http://www.bathurst.nsw.gov.au>.

Bathurst City SES 1998, *Survey of Flooded Areas*, Bathurst City SES, Bathurst.

Black, R.D. 1975, *Flood-proofing Rural Residences*, Report to US Department of Commerce, Economic Development Administration, Washington, cited in Smith 1994.

Blong, R. 2002, 'Estimating residential flood damage' in Smith, D.I. & Handmer, J. (eds) 2002, *Residential Flood Insurance: The Implications for Floodplain Management Policy*, Water Research Foundation, Sydney, chapter 11 (in press).

Burby, R.J. & Kaiser, E.J. 1987, *An Assessment of Urban Floodplain Management in the United States: The Case for Land Acquisition in Comprehensive Floodplain Management*, Technical Report 1, Association of States Flood Plain Managers, Madison.

Bureau of Meteorology 2002, Canberra, viewed 18 April 2002, <http://www.bom.gov.au/hydro/flood/qld/brochures/river_maps.shtml>.

Bureau of Transport Economics (BTE) 2001a, *Economic Costs of Natural Disasters in Australia*, Report 103, BTE, Canberra.

Bureau of Transport Economics (BTE) 2001b, *Flood Damage in Tamworth: Costs of the November 2000 Flood*, Working Paper 48, BTE, Canberra.

Catchment Management Unit 1990, *Nyngan: April 1990 Flood Investigation*, NSW Department of Water Resources, Sydney.

CNN 1998, Cable News Network, Atlanta, viewed October 2001, <http//www.cnn.com.weather/9801/11/aussie.floods>.

Curran, J. (Committee Chair) 1986, *Bathurst Flood Inquiry 1986*, Report to the Hon. Janice Crosio M.P. Minister for Local Government and Minister for Water Resources.

Electoral Commission Queensland 2000, Brisbane, viewed March 2002, <http://www.ecq.qld.gov.au/ecq/election01/maps/map_Thuringowa.pdf>.

EMA 1998, *Australian Emergency Management Glossary*, Australian Emergency Manuals Series, Part I The Fundamentals, Manual 3, Canberra.

Enders, J. 2000, *Measuring Community Awareness and Preparedness for Emergencies in Victoria*, Department of Justice Victoria, Melbourne.

Foster, J.H. 1976, 'Flood management: who benefits and who pays', *Water Resources Bulletin*, 12(5), pp. 1029–1039.

French & Associates Ltd 2000, *Evaluation of CRS Credited Activities During Hurricane Floyd*, prepared for FEMA.

GAB Robins 1998, Greenwich (NSW), viewed October 2001, <http//www.gabrobins.com.au/news/townsville.html>.

Gannon, P.J. & Allen, N.E. 1993, *City of Bathurst Floodplain Management Plan Report*, prepared by Willing & Partners Consulting Engineers Pty Ltd for Bathurst City Council.

GAO (US General Accounting Office) 1999, *Disaster Assistance: Opportunities to Improve Cost-Effectiveness, Determinations for Mitigation Grants*, report to Congressional Committees, GAO/RCED-99-236.

Gillespie, C., Grech, P. & Bewsher, D. 2001, 'Reconciling development with flood risks—the Hawkesbury-Nepean dilemma', *Second Victorian Floodplain Management Conference—Planning for the Inevitable*, Traralgon, 10-12 October.

Granger, K., Hayne, M., Middelmann, M., Scott, G., Jones, T., Steele, J. & Hall, S. 2001, *Natural Hazards and the Risks they Pose to South-East Queensland*, AGSO—Geoscience Australia, Record 2011/29.

Handmer, J.W. 1984, *Property Acquisition for Flood Damage Reduction*, Phd thesis, Australian National University (ANU), Canberra, unpublished.

Handmer, J.W. 1987, 'Guidelines for floodplain acquisition', *Applied Geography*, vol. 7, pp. 203–221.

Handmer, J.W. & Smith, D.I. 1995, *Cost-effectiveness of Flood Warnings: Flood Loss Assessment*, vol. 1, Centre for Resource and Environmental Studies (CRES), ANU, Canberra.

Higgins, R.J. & Robinson, D.J. 1981, *An Economic Comparison of Different Flood Mitigation Strategies in Australia: A Case Study*, Technical Paper No. 65, Australian Water Resources Council.

James Cook University (JCU) 1998a, *Townsville Thuringowa Floods January 1998: Post Disaster Household Survey*, report prepared for Department of Emergency Services (Qld), Bureau of Meteorology and Emergency Management Australia.

James Cook University (JCU) 1998b, *Townsville Thuringowa Floods January 1998: Business and Infrastructure Post Disaster Survey*, report prepared for Department of Emergency Services (Qld).

Kunreuther, H. & Roth, R.J. Sr. 1998, *Paying the Price—the Status and Role of Insurance Against Natural Disasters in the United States*, Joseph Henry Press, Washington D.C.

May, P.J., Burby, R.J., Ericksen, N.J., Handmer, J.W., Dixon, J.E., Michaels, S. & Smith, D.I. 1996, *Environmental Management and Governance: Intergovernmental Approaches to Hazards and Sustainability*, Routledge, London and New York.

Maunsell McIntyre 2001, *Bohle River Floodplain Management Study Report*, prepared for City of Thuringowa Council, April 2001.

Millerd, F.W., Dufournaud, C.M. & Schaefer, K.A. 1994, 'Canada-Ontario flood damage reduction program case studies', *Canadian Resources Journal*, vol. 19, no. 1, pp. 17–26.

McCoy, R.E. Jr 1976, 'Flood proofing at Logan, Ohio and the flood hazard factor', *Proceedings of a Seminar on Nonstructural Flood Plain Management Measures*, USACE, California.

National Wildlife Federation (NWF) 1998, *Higher Ground: a Report on Voluntary Property Buyouts on the Nations Floodplains*, NWF, Washington.

New South Wales Government 1986, *Floodplain Development Manual*, New South Wales Government, Sydney.

New South Wales Government 2001, *Floodplain Management Manual: The Management of Flood Liable Land*, New South Wales Government, Sydney.

North Carolina Emergency Management Division (NCEMD) and Federal Emergency Management Agency (FEMA) 2000, *Hazard Mitigation in North Carolina: Measuring Success*, NCEMD.

Northern Territory Government 2001, viewed October 2001, <http://www.nt.gov.au/ntg/publications/ataglance/content.shtml>.

Paiva, J. 1996, *Katherine Levees*, Report 42/1996D, Department of Lands, Planning & Environment, Darwin.

Palanisami, K. & Easter, K.W. 1984, 'Ex-post evaluation of flood control investments: a case study in North Dakota', *Water Resources Research*, vol. 20, no. 12, December, pp. 1785-1790.

Parker, D. 1999, 'Flood' in *Natural Disaster Management: a Presentation to Commemorate the International Decade for Natural Disaster Reduction (IDNDR) 1990–2000*, Jon Ingleton (ed), Tudor Rose, Leicester, pp. 38-40.

Penning-Rowsell, E.C. & Handmer, J.W. 1986, *Evaluating Flood Warning Effectiveness: the Conceptual, Methodological and Practical Research Problems*, CRES Working Paper 1986/6, CRES, ANU, Canberra.

Penning-Rowsell, E.C. & Smith, D.I. 1987, 'Self-help hazard mitigation: the economics of house-raising in Lismore, NSW, Australia', *Tijdschrift voor Econ. en Soc. Geografie*, 78, Nr. 3, pp. 176–189.

PPK 1993, *Tamworth City Council: Floodplain Management Plan*, 2 volumes, PPK Consultants Pty. Ltd.

Smith, D.I. 1986, 'Flood warning in Australia: a review', Paper presented to the *NSW Annual Flood Mitigation Conference*, Murwillumbah, 21-23 May, CRES, ANU, Canberra.

Smith, D.I. 1994, 'Flood damage estimation—a review of urban stage-damage curves and loss functions', *Water South Africa*, July vol. 20 no. 3, pp. 231–238.

Smith, D.I., Den Exter, P., Dowling, M.A., Jeliffe, P.A., Munro, R.G. & Martin, W.C. 1979, *Flood Damage in the Richmond River Valley New South Wales: An Assessment of Tangible and Intangible Damages*, ANU Press for the Richmond Interdepartmental Committee, Canberra.

Smith, D.I. & Greenaway, M.A. 1984, *Commercial and Industrial Flood Damage: Case Study for the Taminda Estate – Tamworth NSW*, CRES Working Paper 1984/14, CRES, ANU, Canberra.

Smith, D.I. & Handmer, J.W., (eds) 2002, *Residential Flood Insurance: Implications for Floodplain Management Policy*, Water Research Foundation of Australia, (in press).

Smith, D.I., Handmer, J.W. & Taylor, D. 1992, 'How effective would improved flood warning systems be in reducing rural flood losses?', Paper presented at the *32nd Annual Conference of Flood Mitigation Authorities of NSW*, Bankstown, 12-15 May, CRES, ANU.

Smith, D.I., Handmer, J.W., McKay, J.M., Switzer, M.A.D. & Williams, B.J. 1995, *Non-structural Measures for Flood Mitigation—Current Adoption in Urban Areas*, Volume 1, Report to the National Landcare Programme, CRES, ANU, Canberra.

Standards Australia and Standards New Zealand 1999, *Australia/New Zealand Risk Management Standard AS/NZS 4360:1999*, Standards Association of Australia, Strathfield.

State Emergency Management Agency (SEMA) 1995, *Out of Harm's Way: The Missouri Buyout Program*, SEMA, Missouri.

Tamworth City Council (TCC) 2001, Tamworth, viewed November 2001, <http://www.tamworth.nsw.gov.au/tcc/index.html>.

Tennessee Valley Authority (TVA) 1985, *Evaluating the Effectiveness of Floodplain Management Techniques and Community Programs*, proceedings of a seminar conducted 31 April-1 May 1984, Special publication 10.

United States Army Corps of Engineers (USACE) 1999, *Annual Flood Damages Report to Congress for Fiscal Year 1999*, viewed November 2001, <http://www.usace.army.mil/inet/functions/cw/cecwe/flood99/index.htm>

Universal Business Directory (UBD) 1997, *Queensland State Street Directory: Cities and Towns, 13th edition*, UBD, Brisbane.

Universal Business Directory (UBD) 2000, *NSW Country Cities and Towns Street Directory, 13th edition*, UBD, Sydney.

VDNRE 2000, *Rapid Appraisal Method (RAM) for Floodplain Management*, Victorian Department of Natural Resources & Environment, Prepared by Read Sturgess & Associates, Melbourne.

Water Studies 1995, *A Review of Floodplain Management in Rural and Provincial Victoria*, report for the Victorian Department of Conservation & Natural Resources.

Water Studies 2000, *Katherine River Flood Study*, Report 02/2000D, Department of Lands, Planning & Environment, Darwin.

Willing & Partners 1993, *Computer Based Floodplain Model*, Final Report, prepared for Bathurst City Council, Crows Nest.

Willing & Partners 2000, *Macquarie River, Bathurst August 1998 Flood Investigation and Model Review*, Final Report, prepared for Bathurst City Council Crows Nest.

Wright, C. 2001, *Flash Flooding in an Urban Environment*, Master's thesis, University of Adelaide, South Australia, unpublished.

ABBREVIATIONS

AAD	Average Annual Damage
ABS	Australian Bureau of Statistics
AEMC	Australian Emergency Management Committee
AEP	Annual Exceedance Probability
AGSO	Australian Geological Survey Organisation
AHD	Australian Height Datum
ANU	Australian National University
ARI	Average Recurrence Interval
ASIC	Australian Standard Industrial Classification
AWOTE	Average Weekly Ordinary Time Earnings
BCA	Benefit-cost analysis
BCR	Benefit-cost ratio
BTE	Bureau of Transport Economics
BTRE	Bureau of Transport and Regional Economics
CBD	Central Business District
CoT	City of Thuringowa Council
CRES	Centre for Resource and Environmental Studies
DOTARS	Department of Transport and Regional Services
DRF	Damage Reduction Factor
EMA	Emergency Management Australia
EMAI	Emergency Management Australia Institute
FEMA	Federal Emergency Management Agency (United States)
FESA	Fire and Emergency Services Authority (Western Australia)
FWS	Flood Warning System
GAO	General Accounting Office (USA)

JCU	James Cook University
m	metres
m/s	metres per second
NCEMD	North Carolina Emergency Management Division
NDRA	Natural Disaster Relief Arrangements
NEMC	National Emergency Management Committee
NSW	New South Wales
Pers. comm.	Personal communication
PMF	Probable Maximum Flood
PPRR	Prevention, Preparedness, Response, Recovery
RAM	Rapid Appraisal Method
RFMP	Regional Flood Mitigation Programme
SES	State Emergency Service
TVA	Tennessee Valley Authority
UPRCT	Upper Parramatta River Catchment Trust
USA	United States of America
US	United States of America
USACE	United States Army Corps of Engineers
VDNRE	Victorian Department of Natural Resources and Environment
VP	Voluntary Purchase