

In the matter of the *Commissions of Inquiry Act 1950*

Commissions of Inquiry Order (No.1) 2011

Queensland Floods Commission of Inquiry

Second Witness Statement of Peter Baddiley

Annexure "PB2-4"



Managing the Floodplain

**AUSTRALIAN EMERGENCY
MANUALS SERIES**

PART III

Emergency Management Practice

Volume 3—Guidelines

Guide 3

MANAGING THE FLOODPLAIN

EMERGENCY MANAGEMENT AUSTRALIA

© Commonwealth of Australia 1999
First published 1999
ISBN 0 642 47345 3

Basic editing and typesetting by PenUltimate
Edited and published by Emergency Management Australia
Printed in Australia by Union Offset Printers, Canberra, ACT

THE AUSTRALIAN EMERGENCY MANUALS SERIES

The first publication in the original AEM Series of mainly skills reference manuals was produced in 1989. In August 1996, on advice from the National Emergency Management Principles and Practice Advisory Group, EMA agreed to expand the AEM Series to include a more comprehensive range of emergency management principles and practice reference publications. The Series is now structured in five parts as set out below.

Parts I to III are issued as bound booklets to State and Territory emergency management organisations and appropriate government departments for further dissemination to approved users including local government. Parts IV and V (skills and training management topics) are issued in loose-leaf (amendable) form to all relevant State agencies through each State and Territory Emergency Service who maintain State distribution/amendment registers. All private and commercial enquiries are referred to EMA as noted at the end of the Foreword on page v.

AUSTRALIAN EMERGENCY MANUALS SERIES STRUCTURE AND CONTENT

		Publishing Status—Jun'99
PART I—THE FUNDAMENTALS		
Manual 1	Emergency Management Concepts and Principles (3 rd edn)	A/R
Manual 2	Australian Emergency Management Arrangements (6 th edn)	R
Manual 3	Australian Emergency Management Glossary	A
Manual 4	Australian Emergency Management Terms Thesaurus	A
PART II—APPROACHES TO EMERGENCY MANAGEMENT		
<i>Volume 1—Risk Management</i>		
Manual 1	Emergency Risk Management	D
<i>Volume 2—Mitigation Planning</i>		
	Titles to be advised (covering PPRR)	P
<i>Volume 3—Implementation of Emergency Management Plans</i>		
	Titles to be advised	P
PART III—EMERGENCY MANAGEMENT PRACTICE		
<i>Volume 1—Service Provision</i>		
Manual 1	Emergency Catering	D
Manual 2	Disaster Medicine	A/R
Manual 3	Disaster Recovery	A/R
<i>Volume 2—Specific Issues</i>		
Manual 1	Evacuation Planning	D
Manual 2	Safe and Healthy Mass Gatherings	D
Manual	Civil Defence	D
Manual	Community Emergency Planning (3 rd edn)	A/R
Manual	Urban Search and Rescue (Management)	P
Manual	Lifelines	D
Manual	Land Use Planning	D
<i>Volume 3—Guidelines</i>		
Guide 1	Multi-Agency Incident Management	A
Guide 2	Community and Personal Support Services	A
Guide 3	Managing the Floodplain	A
Guide 4	Flood Preparedness	A
Guide 5	Flood Warning	A
Guide 6	Flood Response	A
Guide 7	Medical Aspects of NBC Hazards	D
Guide	Disaster Victim Identification	A/R

AUSTRALIAN EMERGENCY MANUALS SERIES STRUCTURE AND CONTENT

		Publishing Status—Jun'99
PART IV—SKILLS FOR EMERGENCY SERVICES PERSONNEL		
Manual 1	Storm Damage Operations (2 nd edn)	A
Manual 2	Operations Centre Management	A
Manual 3	Leadership	A
Manual 4	Land Search Operations (2 nd edn—Amdt 1)	A
Manual 5	Road Accident Rescue (2 nd edn)	A
Manual 6	General Rescue (4th edn—formerly Disaster Rescue)	A
Manual 7	Map Reading and Navigation (Amdt 1)	A
Manual 8	Four-Wheel-Drive Vehicle Operation (Amdt 1)	A
Manual 9	Communications (2 nd edn)	A
Manual 10	Flood Rescue Boat Operation (2 nd edn)	A
Manual	Vertical Rescue (2 nd edn)A/R	
PART V—THE MANAGEMENT OF TRAINING		
Manual 1	Small Group Training Management (2 nd edn)	R
Manual 2	Exercise Management	D

Key to status: A = Available A/R = original version Available/under Review
D = under Development; P= Planned; R = under Review/Revision

FOREWORD

The purpose of this Guide is to provide a national reference for guidelines on the floodplain management planning process. It has been developed for use by local government, emergency services agencies and other agencies associated with flood emergency planning.

Details of the development of the Guide and other related publications in the Australian Emergency Manuals Series are noted in the Preface on page ix. This Guide was sponsored, edited and published by Emergency Management Australia.

Proposed changes to this Guide should be forwarded to the Director General, Emergency Management Australia, at the address shown below, through the relevant State/Territory emergency management organisation.

This publication is provided free of charge to approved Australian organisations. Copies are issued to relevant users automatically (and upon request) through their State/Territory emergency management organisations.

To support the International Decade for Natural Disaster Reduction, the Australian Government will allow approved overseas organisations to reproduce the publication with acknowledgement but without payment of copyright fees. Manuals and Guides may be supplied to other Australian or overseas requestors upon payment of cost recovery charges.

Consideration will be given to requests from developing countries for multiple copies without charge.

Enquiries should be sent to the Director General, Emergency Management Australia, PO Box 1020, Dickson, ACT 2602 Australia, (facsimile +61 (02) 6257 7665, e-mail: ema@ema.gov.au).



CONTENTS

FOREWORD	v
PREFACE	ix
BEST PRACTICE PRINCIPLES	x
CHAPTER 1 INTRODUCTION	1
OBJECTIVE	1
FLOODING, FLOODPLAINS AND RESIDUAL RISK	2
Feasibility Limits	2
FLOODPLAINS—A NATIONAL ASSET	3
Agriculture	4
Urban Centres and Industry	4
Mining Operations	4
Environmental Change	4
Integrated Catchment Management	4
FLOODPLAINS—A NATIONAL COST	5
FLOODPLAIN MANAGEMENT MEASURES	8
The Three Flood Problems	8
The Four Groups of Management Measures	8
FLOODPLAIN MANAGEMENT PLANS AND FLOOD EMERGENCY PLANS	10
LOCAL AGENCIES	11
CHAPTER 2 FLOODPLAIN MANAGEMENT PROCESS	12
OVERVIEW	12
FLOODPLAIN PLANNING	12
The Planning Process	12
Statutory Planning	14
FLOODPLAIN MANAGEMENT	14
Policy	14
Advisory Committee	15
Flood Study	16

	Floodplain Management Study	17
	Floodplain Management Plan	22
	FLOOD EMERGENCY MANAGEMENT	26
	Flood Hazard Analyses	26
	Flood Warning Systems	26
	Flood Emergency Plan	27
	Education, Training and Research	29
CHAPTER 3	FLOOD EMERGENCY PLANNING	30
	OVERVIEW	30
	EMERGENCY MANAGEMENT IN AUSTRALIA	30
	ROLES AND RESPONSIBILITIES	31
	Prevention Activities	33
	Preparedness Activities	34
	Response Activities	35
	Recovery Activities	36
	NEED FOR A COORDINATED APPROACH	36
	Planning Opportunities and Special Considerations	37
	REFERENCES	40
ANNEX A	THE FLOOD STUDY	42
ANNEX B	FLOODPLAIN MANAGEMENT MEASURES	51
ANNEX C	FLOODPLAIN MANAGEMENT STUDY	65
ANNEX D	FLOODPLAIN MANAGEMENT PLAN	69
ANNEX E	FLOOD HAZARD	73
	GLOSSARY	81

PREFACE

This Guide has been prepared by a team of experienced floodplain managers from around Australia. It is a condensed version of a comprehensive manual prepared under the auspices of the Standing Committee on Agriculture and Resource Management (SCARM). It is one of four Flood Guides sponsored by Emergency Management Australia to improve our reaction to one of Australia's major natural hazards. The other Guides are, 'Flood Preparedness', 'Flood Warning' and 'Flood Response'. The project was coordinated by Major General Hori Howard, Director General of New South Wales State Emergency Service.

The aim of this Guide is to foster better integration of the floodplain management planning process and the flood emergency planning process. In particular, the Guide aims to acquaint personnel from local government, emergency service agencies and other agencies associated with flood emergency planning of the opportunities to contribute to and obtain useful information from the floodplain management planning process. This will help when preparing flood emergency plans and will facilitate integration of flood emergency management into floodplain management.

In this Guide, the term 'best practice principles' is taken in its broadest sense to mean the underlying principles that need to be considered when formulating floodplain management plans, leading to effective, equitable and sustainable land use across Australia's floodplains.

This Guide is generic in nature rather than prescriptive. It presents an amalgam of principles and practices concerning our current knowledge and understanding of how best to undertake 'floodplain management' in Australia. It will be subject to revision as the nature and our understanding of floodplain management issues change, and as technology develops with associated opportunities for better management.

BEST PRACTICE PRINCIPLES

The following **edited extract** is from *Best Practice Principles, Floodplain Management in Australia*, Standing Committee on Agriculture and Resource Management, July 1998.

The best practice principles have been reproduced in full to emphasise the comprehensive and all-embracing nature of the floodplain management planning process, of which flood emergency planning forms an integral part. Where necessary, best practice principles have been amplified to reflect the specifics of flood emergency management. **Best practice principles specific to flood emergency management are shown in bold type.**

INTRODUCTION

This section consists of a compendium of best practice principles for floodplain management in Australia. These principles have been defined by floodplain managers from all States and Territories of Australia, together with representatives from the Commonwealth and local agencies, on the basis of practical on-going experience with floodplain management over the last 10 to 20 years.

It is stressed that these principles *are guidelines and not directives*. The principles deal with issues that should be considered as part of the floodplain management process. Some issues may not be appropriate to specific situations. However, failure to diligently consider all relevant principles may leave agencies and parties exposed to negligence under 'duty of care' obligations.

This document is concerned with managing flood risk associated with human occupation of the floodplain for both urban development and agricultural production. It addresses that risk in full recognition that management decisions taken regarding human occupation of the floodplain need to satisfy the social and economic needs of the community as well as be compatible with maintaining or enhancing the natural ecosystems the floodplain sustains.

Floodplains are a resource of immense value. They are the sites of most of our towns and cities and they provide the natural resources to support many of our most productive rural industries. They are areas of primary environmental significance and their well-being is essential to the survival of many ecosystems.

In recent times, the significance of floodplain ecosystems has been clearly recognised. Floods are a critical factor in the health of the floodplain, the rivers and coastal estuaries. It is now realised that some of our historical uses of floodplains, and the infrastructure we have introduced, can interfere markedly with these ecosystems. However, the detailed management of floodplain ecosystems is beyond the scope of this manual and is dealt with in the context of integrated catchment management, in particular by plans such as River Management Plans, Native Vegetation Plans and Wetland

Management Plans.

The primary objective of floodplain management is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood-prone property, and to reduce private and public losses resulting from floods. At the same time, implementation of the objective recognises the benefits of floodplain occupation and the particular social, economic and ecological attributes of flood-prone land.

A PRO-ACTIVE RESPONSE

In the past, floodplain management measures in Australia were often only introduced after a serious flood event had occurred, ie a reactive approach. Typically, such an approach was limited in scope and effectiveness and did little to control the ever-growing levels of flood hazard across the nation.

The most fundamental best practice guideline of this document is the need to adopt a pro-active response to floodplain management in Australia. This is best described as a response that first recognises the various flooding problems and management issues described in this document, and then moves to address these issues and problems before they develop to extreme levels. *It must be stressed that this document does not supply the solutions to the problems of flooding; it provides the methodology that can be followed to achieve a sustainable solution.*

With respect to flood emergency management, this indicates the need to prepare flood emergency plans for flood-prone areas of the nation as a matter of course and as quickly as resources allow.

COMMUNITY EXPECTATIONS

It is not unreasonable for the community to expect that the nation's floodplains will be developed and used in an ecologically, economically and socially sustainable fashion and in accord with the broader principles of 'sustainable natural resource and environment management' and of 'integrated or total catchment management'.

Best practice principles dictate that floodplain management must strive to ensure the community is:

- able to live and work on floodplains at no untoward risk to life and limb or unacceptable risk of damage to goods, possessions and infrastructure because of flooding—to achieve this expectation it will be necessary to put in place site-specific integrated floodplain management measures that address existing, future and residual flood problems;
- secure in the knowledge that, in the aftermath of the inevitable future floods, effective arrangements will be put in place to alleviate the economic and social costs of flooding, both on an individual and

community basis, and foster recovery of the flooded area and its residents/occupants; and

- actively involved in the floodplain management process, both in developing a floodplain management plan and in meeting their obligations under that plan.

If flood emergency management is to be successful, it is essential the local community is involved in the flood emergency planning process and is informed and trained with regard to their responsibilities and actions when floods occur.

POLICY AND IMPLEMENTATION

Effective policy and legislation are essential to provide a reliable social and legal foundation for floodplain management. **Best practice is that there is an integrated policy framework within all agencies (Commonwealth, State and local) that supports floodplain management and addresses reduction of flood risk to life and property.**

This principle should be supported in the following ways:

- State, Territory and Commonwealth Governments need to actively work together to develop and implement integrated strategies to deal with flood risk incorporating legislative, financial, logistical and technical support.
- Each State and Territory needs to develop and promote a comprehensive floodplain management policy, supported by appropriate legislation, regulations, standards, guidelines and planning policies clearly and unambiguously defining the responsibilities and liabilities of all agencies involved in the floodplain management process. **With respect to flood emergency management, a single agency in each State and Territory should be made responsible for coordinating preparedness, response and recovery activities for dealing with flood emergencies, ie a lead agency for flood emergency management.**
- All decision-makers involved in the floodplain management process need to be aware of their 'duty of care' for decisions with respect to the use of flood-prone land, and for developing and implementing floodplain management plans.
- Responsible agencies need to prepare a floodplain management plan based on an understanding of the impacts of the full range of possible flood events and dealing with existing, future and residual flood risk through a floodplain management process similar to that described in this document.
- Local agencies should liaise with the emergency management agency with regard to flood emergency management and actively

contribute (with manpower, equipment and facilities) to flood emergency plans for preparedness, response and recovery from floods. Integrating development of floodplain management and emergency management plans is fundamental to protecting life and property and minimising the impacts of floods.

- All agencies must recognise the importance of public consultation in developing and implementing floodplain management plans and with regard to flood risk management issues.
- All agencies must implement the provisions of a floodplain management plan in a timely fashion after the plan has been finalised and adopted. In particular, land use planning measures should be incorporated into appropriate statutory planning instruments as a matter of course immediately the management plan has been adopted.
- Agencies should review the floodplain management plan and its risk management provisions as required or at regular intervals of not more than five to 10 years.
- Agencies and the community must recognise there will always be a residual flood risk which cannot be eliminated by structural or non structural management strategies (eg river improvement works, levees, land use controls).
- The Commonwealth Government should continue providing specialist national resources relevant to floodplain management and flood emergency management, eg flood forecasting activities of the Bureau of Meteorology, use of the Defence Force in evacuation and recovery activities and emergency management training activities, both provided through Emergency Management Australia.
- Relief funding must continue to be provided to aid recovery of areas devastated by severe floods.

RISK AWARENESS

If floodplain management is to be successful, the local community needs to understand and appreciate the concept of flood risk and exposure to flood hazard, ie the local community needs to be 'flood aware'.

Best practice principles to foster this understanding and awareness include the following:

- Adopting nationally an appropriate flood risk terminology. Risk is defined (AS/NZS 4360) as 'the chance of something happening to impact on objectives', in this case a flood. The terminology to describe the severity of flood events must also indicate the chance involved. Accordingly, this document adopts the nomenclature of 'annual exceedance probability' (AEP) throughout. For example, the

flood that has one chance in 100 of occurring in any given year is the 1 per cent AEP flood.

- Local agencies documenting flood risk in an easily understood fashion on flood maps, certificates of title and information brochures to enable individuals and the local community to assess flood risk.
- Local agencies, in conjunction with emergency management agencies, promoting and communicating flood risk awareness in the local community.

CHAPTER 1

INTRODUCTION

IN A NUTSHELL ...

Effective flood risk management requires land use planning, floodplain management and flood emergency planning.

Flood problems can be divided into:

- *existing problem—developments on flood-prone land which are subject to risk;*
- *future problem—developments which may be built on flood-prone land; and*
- *residual problem—risk associated with floods which exceed management measures.*

OBJECTIVE

1. The Standing Committee on Agriculture and Resource Management recently prepared a comprehensive manual outlining best practice principles for managing flood risk and flood hazard in Australia (SCARM, 1998). The manual identifies three distinct planning processes for managing flood risk and flood hazard, they are:
 - **A statutory land use planning process** for which local councils are generally responsible. The appropriate flood management 'deliverable' from this process is an amended town plan, local development plan or other local planning instrument that incorporates land use zones appropriate to flood risk.
 - **A floodplain management planning process** for which the appropriate local agency is responsible. The 'deliverable' from this process is a floodplain management plan that comprises an integrated mix of measures to address existing, future and residual flood risk.
 - **A flood emergency planning process** for which there is a single responsible state level agency. The 'deliverable' from this process is a flood emergency plan that addresses the risk associated with flood events of all severities. Important components of the flood emergency plan are flood awareness, flood warning, flood evacuation and flood recovery.
2. If flood management in Australia is to be effective, it is essential to closely integrate and coordinate these three planning processes and their outcomes.

3. Integration of the floodplain management planning process and the statutory planning process are discussed in detail in the national manual (SCARM, 1998).
4. This Guide (Managing the Floodplain) seeks to facilitate integration and coordination of the floodplain management planning process and the flood emergency planning process.
5. In particular, this Guide aims to help flood emergency managers across Australia contribute to the floodplain management planning process, to ensure flood emergency considerations are addressed in the floodplain management plan and to obtain relevant emergency information (velocity, depth, duration of flooding) from the floodplain management planning process to help prepare the flood emergency plan. This is achieved by defining a set of best practice principles for integrating floodplain management and flood emergency management considerations (see Best Practice Principles on page x).

FLOODING, FLOODPLAINS AND RESIDUAL RISK

6. In Australia, flooding can be caused by four different mechanisms, namely, heavy rainfalls, storm surges, tsunamis and dam failures.
7. The most common and significant threats to the social and economic well-being of flood-prone communities in Australia arise from heavy rainfall and storm surge flooding. Whilst dambreak and tsunami flooding could cause catastrophic damage and high loss of life, the likelihood of such flooding is low in Australia.

Feasibility Limits

8. The 'floodplains' of this manual are defined in terms of the most extreme rainfall flood that could occur, ie the probable maximum flood (PMF). The area defined by the PMF event is 'flood-prone'. The area outside the PMF is truly 'flood-free', as shown on Figure 1:1, at least with respect to rainfall floods. However, dambreak floods, extreme storm surge floods and tsunami floods may inundate areas outside the 'floodplains'. This needs to be borne in mind when developing management plans for these events. Although this document concentrates on 'rainfall flooding', the principles developed here are equally applicable to the other three types of flooding but the management measures will differ in detail.
9. In general, it is not economically or practically feasible to provide 'full' flood protection up to the PMF event. As a result, lesser flood events are typically adopted for planning and development purposes, ie 'defined flood events' (DFEs), and represent a compromise between the level of protection we can afford and the risk we are prepared to take with the consequences of larger floods. Figure 1:1 shows the relationship between areas flooded by a PMF and by a DFE.

10. In contrast, for flood emergency planning purposes, emergency management agencies typically adopt the most extreme flood event that could conceivably occur. This is generally the PMF or a dambreak flood. However, the likelihood of such floods occurring is remote. Emergency management agencies consider all floods as potential emergencies. To address less severe and more common floods, flood emergency plans are developed to address a range of floods up to the extreme events.
11. **Residual flood risk** represents the flood risk not addressed by physical or regulatory floodplain management measures, such as structural measures, land use controls and building and development controls. Typically, residual flood risk is the risk associated with floods greater than the DFE. Flood emergency plans are the only means of managing residual flood risk.

Figure 1:1—Flood-Prone and Flood-Free Land

FLOODPLAINS—A NATIONAL ASSET

12. Australia's floodplains are the commercial, social and ecological

arteries of the nation. As such they constitute a national asset; an asset subject to damage when floods occur.

Agriculture

13. Floodplains are generally the more fertile areas of our continent. A significant proportion of Australia's agricultural output is produced on floodplains, which are the homes of extensive and intensive agriculture, including irrigated agriculture. Regular flooding of these areas enhances agriculture by increasing soil moisture, recharging groundwater tables and depositing fertile silt.
14. Flooding can also interfere with agricultural practices. Typically, high value irrigated crops, such as cotton which can return \$20,000–\$30,000 per hectare, are protected from flooding by levees but much farm activity goes on without such 'security'.

Urban Centres and Industry

15. Much of the urban and industrial development across inland and coastal Australia is centred on the nation's waterways and their floodplains. Floodplains, by virtue of their fertile soils, water and timber resources, were obvious places for towns to develop. Such urban centres typically originated as centres of agriculture and at times were the focus of river-borne transport. Because of the nature of their origins, many towns across the nation are subject to flooding. Levees are often used to reduce the flood hazard for these urban areas.

Mining Operations

16. Many mining operations are partly or completely located on floodplains. Such operations can range from small-scale sand and gravel extraction activities in the waterbody itself or on the neighbouring floodplain, to massive open cut metalliferous or coal mines. Tin is typically found in conjunction with alluvial sediments. Recently several major gold and copper mines have been proposed in close proximity to principal waterways and wetlands of inland Australia.

Environmental Change

17. Finally, over the past decade or so Australia has become increasingly aware of the fundamental importance of waterways and their associated wetlands and floodplains in providing habitat to native plants and animals. The ecological significance of floodplain habitat, much of which has been lost through land clearing operations, cannot be over-emphasised.

Integrated Catchment Management

18. In view of the fundamental importance of floodplains to the commercial, social and ecological well-being of the nation, we have an

obligation to present and future generations to manage our floodplains in a responsible and sustainable manner. This is best achieved through applying the principles of total or integrated catchment management.

19. Catchment management involves a broad range of inter-dependent facets that require strategic planning to ensure sustainable use of the catchment's natural resources, such as vegetation, wetlands, biodiversity and the risks associated with using the floodplain. **Managing the flood risk associated with using the floodplain (referred to throughout this document as floodplain management) is a critical part of the overall catchment management process** and it is to this specific facet that this manual is directed. The manual does not address the issues of vegetation or wetland management, protecting threatened species or biodiversity in any detail, except as they relate to human occupation of the floodplain. However, these issues must still be accounted for when producing and implementing a floodplain management plan.

FLOODPLAINS—A NATIONAL COST

20. In terms of tangible damages, or damages that can be relatively easily and meaningfully measured in dollar terms, the average annual cost of flooding in Australia in 1992 was estimated by the Department of Primary Industries and Energy (DPIE) to be \$350 million. This represented the costs of urban damages caused by both stormwater and mainstream flooding, together with rural flood damage. Tables 1:1 and 1:2 show details of urban and rural damages respectively on a State-by-State basis. The figures in these tables are estimates but are the best currently published (DPIE, 1992).
21. A recent, but unpublished, survey of potential flood damage in Queensland indicates the situation in that State may be significantly underestimated. A similar caution regarding underestimation also applies to stormwater and rural damage. In fact, recent estimates by the Australian Water Resources Council show an annual average cost to the nation of \$400 million (in 1998 values) and this estimate is supported by data gathered by Emergency Management Australia.

Table 1:1—Estimated Average Annual Cost of Urban Flood Damage in Australia

State	Stormwater		Mainstream		Total urban	
	Properties	(\$m)	Properties	(\$m)	Properties	(\$m)
NSW	41,000	18.8	69,000	81.2	110,000	100
Vic	8,500	4.8	17,200	21.2	25,700	26
Qld	30,000	14.0	25,000	46.0	55,000	60
WA	3,000	1.4	6,500	5.2	9,500	6.6
SA	300	0.2	1,600	3.3	1,900	3.5
Tas	1,000	0.4	1,000	2.0	2,000	2.4
NT	1,000	0.4	2,000	1.1	3,000	1.5
Total	84,800	40	122,300	160	207,000	200

Source: DPIE, 1992

Notes: Values adjusted for CPI Increases to 1998 \$ terms. Queensland damage costs may be underestimated.

Table 1:2—Estimated Average Annual Cost of Rural Flood Damage in Australia

State	Rural enterprises ^a (\$m)	Public infrastructure ^b (\$m)	Total rural (\$m)
NSW	32.2	15.8	48.0
Vic	17.0	5.3	22.3
Qld	32.7	33.2	65.9
WA	5.9	4.6	10.5
SA	1.3	0.7	2.0
Tas	0.4	0.2	0.6
NT	0.5	0.2	0.7
Total	90	60	150

Source: DPIE, 1992

Notes: Values adjusted for CPI increases to 1998 \$ terms. Queensland estimates may be underestimated.

^a Livestock, agriculture, etc.

^b Roads, railways, etc.

22. With respect to urban flood damage, some 160,000 urban properties are susceptible to flooding by the 100-year average recurrence interval (ARI) mainstream flood event. A further 40,000 properties across the nation are susceptible to stormwater flooding by 100-year ARI storm events. A much greater number of properties are exposed to flooding

by the PMF event. Based on the revised total cost (\$400m) detailed in para 21, the average annual cost of **urban** flood damage to the nation is over \$230 million per year, most of which occurs in New South Wales (50 per cent) and Queensland (30 per cent).

23. With respect to **rural** flood damage, the average annual cost to Australia is estimated to be over \$170 million per year. It is made up of about \$102 million of damage per year to rural enterprises and \$68 million of damage per year to public infrastructure in rural areas. Again, Queensland and New South Wales account for most of the nation's total rural flood damage bill (about 45 per cent and 30 per cent respectively).
24. Massive infrastructure such as roads, railways, electricity distribution and telephone communications systems has been constructed across Australia's floodplains to service agriculture, urban, mining and other developments. This infrastructure is subject to the risk and consequence of flooding. Severe floods often cause massive disruption to transport and communications systems.
25. The national average annual flood damage cost of \$400 million per year (1998 values) is not fully realised each and every year. A number of years may pass before severe flood events occur, such as the:
 - 1955 Hunter River flood, NSW (\$500 million, in 1998 values);
 - 1974 Brisbane flood, Qld (\$980 million, in 1998 values);
 - 1990 floods in western NSW and Qld (over \$300 million, in 1998 values);
 - 1993 Spring floods in Victoria (\$400 million, in 1998 values);
 - 1998 Summer flood ,Townsville region, Qld (\$210 million);
 - 1998 Summer flood, Katherine, NT (\$180 million); and
 - 1998 Winter floods in north-west NSW (over \$250 million).

(Data source: Emergency Management Australia Disaster Events Database)

26. In the intervening years, less severe floods occur relatively frequently across the nation. The damage and disruption caused by these floods may be low, on an individual event basis, but collectively it is estimated to be significant although definitive damage data are not available. Damage caused by these lesser floods provides an on-going base level of national damage punctuated at relatively frequent intervals (say every five years or so) by severe flood events across the nation that cause marked damage.
27. Not only is the average annual national damage figure of \$400 million per year a significant sum in its own right, it is a sum that will inexorably increase from year to year unless effective floodplain management

measures are put in place on a national basis.

28. The challenge of floodplain management is to reduce the current damage bill and to limit the increase in future flood damage. This can only be done effectively through integrating the three flood planning processes described above.

FLOODPLAIN MANAGEMENT MEASURES

- 29 Best practice floodplain management requires that an appropriate and integrated mix of floodplain management measures be identified and implemented to address the issues of existing, future and residual flood risk in the area of interest.

The Three Flood Problems

- 30 Modern floodplain management recognises three distinct types of 'flood problems', namely the existing, future and residual problems.
- ***The existing problem*** refers to existing buildings and developments on flood-prone land. Such buildings and developments, by virtue of their presence and location, are exposed to an existing risk of flooding.
 - ***The future problem*** refers to buildings and developments that may be built on flood-prone land in the future. Such buildings and developments will be exposed to a future flood risk, ie a risk does not materialise until the developments occur.
 - ***The residual problem*** refers to the risk associated with floods generally and with those floods that exceed management measures already in place. That is, unless a floodplain management measure is designed to withstand the probable maximum flood, it will be exceeded by a sufficiently large flood at some time in the future. **It is not a matter of 'if', but of 'when'.**

The Four Groups of Management Measures

31. Floodplain management measures to reduce flood risk are described in detail in Annex B. They can be grouped into the following four major categories.
- ***Structural flood mitigation works***, such as levees or channel improvements, which are aimed at modifying flood behaviour, ie 'keep water away from people'.
 - ***Land use planning controls***, such as zoning, which are aimed at ensuring land use is compatible with flood risk, ie 'keep people away from the water'.
 - ***Development and building controls***, such as minimum floor levels and floodproofing, are aimed at reducing the risk of

inundation and amount of damage that occurs when such a flood eventuates. These are based on the expectation that 'the water will get to people at some time'.

- **Flood emergency measures**, such as flood warning, evacuation and recovery plans, are aimed at reducing flood hazard by modifying the response of the population at risk so they will be able to better handle actual flood events, ie 'teach people what to do'.

32. Some management measures are more appropriate to certain flood problems than others. Table 1:3 applies these four categories of management measures to the three types of flood problems above. Certain features of Table 1:3 which should be noted are:

- flood emergency measures are appropriate to all three flood problems;
- all measures can be used to address the future flood risk problem; and
- only flood emergency measures can be used to address the residual flood risk problem.

Table 1:3—Applicability of Floodplain Management Measures to Flood Problems

Floodplain management measure	Flood problem		
	Existing	Future	Residual
Structural measures	×	×	
Land use planning measures	× ^a	×	
Development and building controls	× ^b	×	
Flood emergency measures	×	×	×

^a Removal of building and development from unduly hazardous areas

^b Some dwellings can be flood proofed after initial construction

33. With respect to the cost-effectiveness of the various groups of floodplain management measures, the following points should be noted:

- Structural works are typically expensive but, if well designed, constructed and maintained, are effective in providing protection up to the defined flood event. When a larger flood overwhelms structural works, eg overtopping levees, considerable threat to life and limb, damage and social disruption can occur, such as happened at Nyngan NSW, in April 1990.

- Land use planning measures are the most cost-effective of all floodplain management measures in controlling the growth of future flood damage.
- Appropriate development and building controls are cost-effective floodplain management measures.
- To realise the full benefit of flood emergency measures, it is necessary to ensure the floodplain population is 'flood aware', ie people know what to do and how to do it when a flood eventuates.
- In some situations, flood emergency measures may be the only economically justified management measure.

FLOODPLAIN MANAGEMENT PLANS AND FLOOD EMERGENCY PLANS

34. It is important to distinguish between floodplain management plans and flood emergency plans.
35. **A floodplain management plan** is a comprehensive document that addresses all issues related to land use on the floodplain and associated existing, future and residual flood risks. Various aspects of a floodplain management plan are discussed in detail in Annex C.
36. **A flood emergency plan** (sometimes known as a flood plan) is prepared to mitigate the risk to life and limb and flood damage associated with actual flood events, ie the hazards associated with flooding. Flood emergency plans are discussed in some detail in Chapter 3. Such plans describe flood warning, defence, evacuation, clean-up and recovery arrangements to be activated in the face of a flood.
37. Flood emergency plans and floodplain management plans are complementary. Best practice requires a floodplain management plan to be prepared on behalf of the local community by the appropriate local agency. By legislation, regulation or Orders in Council, various State and Territory emergency agencies or local agencies are charged with preparing flood emergency plans.
38. The main aspects of floodplain management plans and flood emergency plans which should be noted are:
 - cooperation and liaison between local agencies and emergency agencies is essential when preparing both types of plans;
 - the flood emergency plan covers the entire floodplain (as defined by the PMF), whereas the land use planning provisions of a floodplain management plan may be restricted to that area of the floodplain inundated by the defined flood event adopted for planning purposes; and

- local agencies as well as state emergency agencies need to know about flood hazard; local agencies from the point-of-view of determining land uses appropriate to hazard, and emergency agencies from the point-of-view of determining operational response plans, etc.
39. **If the community is to obtain the best value from the flood emergency planning process and the floodplain management planning process, it is essential that there is an integration of effort in the planning process.**

LOCAL AGENCIES

40. In this document:
- the term 'local agency' is used in a generic fashion to refer to the agency best suited to oversee the floodplain management process, ie the agency that most strongly and effectively reflects the concerns and desires of the local community with respect to floodplain matters;
 - in urban areas, the appropriate local agency will generally be a local council but in the two Territories the local agency will be a Territory body; and
 - in rural areas, the appropriate local agency might be a local council, Catchment Management Board, River Trust or locally or regionally constituted Catchment Trust but in the two Territories the local agency may be a Territory body.
41. Local agencies, be they urban or rural, generally have characteristics which include the fact that:
- they are composed of elected representatives who are in the best position to know or determine community wants and desires with respect to developing and managing floodplains;
 - they often have responsibility for local land use planning and for subdivision of land approval and implementation processes; and
 - they may command significant resources of manpower, facilities and equipment that can be used in flood emergencies.
42. Notwithstanding differences between urban and rural local agencies and local agencies from the different States and Territories, it is essential that an appropriate 'local agency' play the lead role in the development of floodplain management plans.

CHAPTER 2

FLOODPLAIN MANAGEMENT PROCESS

IN A NUTSHELL ...

A floodplain management advisory committee is the first step in floodplain management.

A flood study is the second step.

A floodplain management study is the third step.

A floodplain management plan is the fourth step.

Flood emergency management is an integral part of floodplain management implementation.

OVERVIEW

1. This Chapter describes a recommended process for floodplain management in Australia, ie the steps involved in formulating and implementing a floodplain management plan. It will acquaint flood emergency managers and others associated with developing and applying flood emergency plans with an overview of the floodplain management process and how the floodplain management and flood emergency management processes intermesh with each other and with the statutory planning process.
2. The floodplain management process, which is depicted in Figure 2:1, encompasses the three systems of:
 - floodplain planning;
 - floodplain management; and
 - flood emergency management.
3. Developing and implementing effective floodplain management and flood emergency management plans requires coordination and integration of various elements of these three systems.

FLOODPLAIN PLANNING

4. The first of the principal systems that constitute the recommended floodplain management process is floodplain planning which can be sub-divided into the planning process and statutory planning.

The Planning Process

5. Flood-prone land is used for many purposes which are often in conflict, eg land clearing for agricultural or other types of development results in

a loss of habitat. In attempting to control flood hazard at one location, planners need to ensure the hazard is not increased elsewhere. Using levees to protect particular areas of the floodplain may increase flood levels or direct flood waters elsewhere and so increase hazard there.

6. Floodplain management essentially involves managing people, land use and the environment in areas subject to flood risk and other types of constraints. This is a complex, multi-objective process that requires consideration of a variety of inter-related issues, such as community aspirations concerning the use of flood-prone land, the social, ecological and economic costs and benefits of possible land uses and management measures, as well as the hazard and social disruption caused by flooding.

Individual Planning Issues

7. In developing a floodplain management plan, a number of separate planning issues, each with individual objectives, need to be addressed, including:
 - **economic planning**, or consideration of the nature and rate of future growth in the area of interest;
 - **infrastructure planning**, or assessment of the capability of existing infrastructure to service future growth and the need for new infrastructure;
 - **resource management planning**, or consideration of how best to use the natural resources of the floodplain;
 - **risk management planning**, or how to most effectively deal with the likelihood and consequences of flooding across the floodplain;
 - **flood emergency planning**, or measures to deal with the management of actual floods; and
 - **land use planning**, which encompasses all the above issues and is aimed at achieving the multiple and often conflicting objectives of the community's desired use of the floodplain.
8. If floodplain management is to be successful, it is essential it is undertaken from within a broad planning framework which identifies and considers all factors and issues affecting the management process and its outcomes. Further, it is essential to adopt an appropriate planning horizon: 20 to 30 years would be appropriate. This document describes a planning framework for developing successful floodplain management plans, ie the floodplain management process.
9. A key outcome of the floodplain management process is the floodplain management plan, which embodies the community's considered opinions and balanced compromises regarding how best to manage floodplains on an objective, sustainable and equitable basis for the

benefit of present and future generations. The types of measures available are described in Annex B.

Statutory Planning

10. The statutory planning system, ie town plans, local environmental plans and other formal planning instruments, provides a basic planning foundation for the floodplain management process. Whilst floodplain management plans may have no statutory basis, the statutory planning process provides a suitable and effective vehicle for preparing floodplain management plans and for implementing their land use provisions. All States and Territories have a State planning (and development) agency of some type and a statutory planning system.
11. Floodplain management is essentially a multi-objective land use planning exercise best directed by the agency responsible for local planning—typically a local council or equivalent ‘local agency’ (collectively referred to as the ‘local agency’). Preparation of a floodplain management plan is essentially the same as any other land use planning exercise, with the additional need to take into account the constraints of flood risk and flood hazard, ie risk management considerations.
12. Land use planning controls are the most cost-effective of all floodplain management measures, particularly with respect to limiting the growth in future flood damage. Best practice floodplain management requires that appropriate land use controls are identified and their power and effectiveness preserved by incorporation in statutory planning instruments.

FLOODPLAIN MANAGEMENT

13. The second of the principal systems that constitute the recommended floodplain management process is floodplain management which can be sub-divided into developing policy, establishing the floodplain management advisory committee and devising, implementing and reviewing the floodplain management plan.

Policy

14. As part of the floodplain management process it is recommended that, as part of the strategic planning and operational processes of all agencies:
 - all States and Territories develop floodplain management policies that reflect flooding problems and their management in that State or Territory;
 - all States and Territories develop flood emergency policies that reflect flood emergency management in that State or Territory; and

- local agencies develop a local floodplain management policy that represents a succinct summary of the local agency's floodplain management plan and is part of its corporate planning and operational activity.
15. Floodplain management policies help raise and sustain State, Territory and local levels of flood awareness. The local policy serves as a comprehensive introduction to flooding matters and management of flooding in the local community. An important component of this policy is the local agency's views on using and developing flood-prone land.

Advisory Committee

16. The first step in the floodplain management process is formation of a floodplain management advisory committee. Such committees are typically formed and chaired by the local agency.
17. **Role** –The principal objective of the committee should be to help local agency(s) develop and implement a plan for managing the floodplain area(s) under consideration. However, the committee also has a primary role in:
- formulating the objectives of local agency's floodplain management policy and plan;
 - developing strategies for implementing floodplain management plans;
 - directing and monitoring the progress and findings of any study being undertaken as part of the floodplain management process; and
 - reviewing the plan as required.
18. **Membership** – The membership and functioning of a floodplain management advisory committee are important elements in developing and implementing a floodplain management plan. Membership should involve a balanced mix of elected, administrative and community representatives, together with technical experts.
19. Typically, a floodplain management advisory committee could comprise elected members and engineering and planning staff from local agencies, local community representatives and technical representatives from the principal State agencies concerned with floodplain management (eg water resource agencies, natural resource management agencies, planning agencies, emergency management agencies, etc.). Officers from other government agencies may be appointed to the committee as and when required (eg river trusts, road and rail transport agencies).
20. It is important that the link between floodplain management and integrated or total catchment management is appreciated. A floodplain

management plan may form a component of a total catchment management plan. Hence, representatives of the local catchment management committee or catchment management trust should be included on the floodplain management advisory committee.

21. Community representatives should include representatives from affected residential and business areas, together with people who can effectively inform the affected community of the committee's deliberations and so foster a wider understanding of the floodplain management process.
22. In certain circumstances it will be desirable to establish a committee involving a number of adjoining local agencies, eg when structural, land use or flood management measures in one local agency area are likely to influence the effectiveness of mitigation measures or flooding behaviour in another local agency area(s).
23. **Initial Tasks** – The committee's first tasks are to establish policy and management objectives; initiate a flood study; and initiate studies to collect and interpret social, economic and environmental data of relevance to community aspirations concerning future development and use of the river and floodplain environment—such data could include:
 - past flood data, including flood behaviour in general, principal flow paths, peak flood levels, flood damage, etc.;
 - current levels of flood awareness;
 - likely community disruption caused by flooding;
 - current land use;
 - proposed future land use;
 - population growth;
 - locations of spare capacity in existing infrastructure systems (roads, water supply, sewerage);
 - feasibility and costs of infrastructure expansion; and
 - flora and fauna surveys of river and floodplain habitat, and the significance of this habitat within the context of the entire catchment.

Flood Study

24. A flood study consists of a comprehensive technical investigation of flood behaviour (see Annex A). It defines the nature and extent of flood hazard across the floodplain by providing information on the extent, level and velocity of flood waters and on the distribution of flood flows. The flood study forms the basis for subsequent management studies

and will need to address these issues for the full range of flood events up to and including the PMF.

25. The two principal components of a flood study are determination of:
 - flood discharges throughout the study area for floods of various severities (hydrologic aspects); and
 - water levels, velocities, etc. throughout the study area, for the various flood events (hydraulic aspects).
26. A variety of analytical tools can be used in flood studies, depending on the availability of data, the nature of the flow situation, the nature and extent of existing development on the floodplain and the level of detail required. It is recommended that these tools be used by experienced practitioners.
27. An important objective of the flood study is to determine, for various flood events, the extent of defined floodway and defined flood fringe areas of the floodplain and the variation of hazard across the floodplain. Depending on the degree of hazard, certain land uses are generally more appropriate than others.
28. As part of the flood study, it is essential to investigate the full range of possible flood events up to and including the PMF. This enables changes in the nature of flooding to be assessed as the severity of the flood increases, ie in velocity and depth, changes in flood hazard, the creation and/or submerging of 'islands', etc. All this information needs to be weighed up when selecting 'defined flood events' for planning purposes and for emergency management plans.
29. Finally, the warming of the earth postulated to occur because of the 'Greenhouse Effect' will also affect flood behaviour: sea levels may rise and the patterns of and rainfalls from flood-producing storms may intensify. These issues need to be considered as part of a flood study.

Floodplain Management Study

30. The purpose of the floodplain management study is to identify and compare various options to manage flood hazard, including an assessment of their social, economic and environmental costs and benefits, together with opportunities to enhance the river and floodplain environments. Selection of the optimum mix of management measures is no easy task. Compromises have to be made and detailed studies and professional judgements will be needed.
31. Management of flood risk ('flood risk management'), together with economic, social and environmental assessments, form the basic cornerstones of the floodplain management process of this document.
32. In essence, a floodplain management study is an exercise in multi-objective decision-making which, to be successful, requires a

comprehensive multi-disciplinary approach and active public consultation.

33. Once the results of the flood study and data collection and review studies are to hand, the floodplain management advisory committee then oversees the floodplain management study (see Annex C). The models developed and studies undertaken during the flood study include:
 - hydrologic and hydraulic models which allow the impact of structural mitigation measures and different land use options on flooding behaviour and flood hazard to be assessed; and
 - data collection exercises which provide the necessary information to assess the social, economic and environmental costs and benefits of the various mitigation measures and future land use possibilities.
34. The edited extract of the SCARM Best Practice Principles at the beginning of this document provides general guidelines for the appropriateness of different types of land use and developments across the floodplain. These guidelines, which are based on the hydraulic and hazard characteristics of the floodplain, are indicative only.
35. The floodplain management plan, when complete, will identify constraints and opportunities for land uses and developments, whilst ensuring that existing flood levels and flood behaviour are not compromised.
36. **Flood Risk Management** – This is a formal means of identifying and managing the existing, future and residual risks of flooding. The nature of the flood hazard is discussed in Annex E. Suffice to say here, key elements of the process include:
 - identifying the stakeholders exposed to or affecting the risk of flooding;
 - identifying public and private property, social systems and environmental elements at risk of flooding;
 - estimating flood risk, ie the likelihood and consequences of flooding;
 - assessing the acceptability of flood risk; and
 - defining flood risk management strategies.
37. Earlier approaches to floodplain management were based on providing 'protection' up to a pre-determined flood event, typically the 1 per cent AEP flood. Important differences between this earlier approach and the risk management approach are as follows:

- the risk management approach recognises the need to explore the risks associated with a full range of flood events up to the PMF;
 - in the risk management approach, the defined flood event(s) to be used for planning and control purposes are not pre-determined, but emerge from the analysis itself; and
 - the risk management approach explicitly recognises the residual flood risk and manages it via a flood emergency plan that is complementary to the floodplain management plan.
38. In addition, the risk management approach requires that 'societal risk', or the risk to the community of fatalities caused by flooding, be reduced to 'acceptable levels'. These acceptable levels may be quite low if based on levels currently accepted for dambreak flooding and industrial and nuclear accidents, eg one fatality for the 1 per cent AEP flood event, and if adopted for rainfall flooding, would indicate the need to devote far higher levels of resources to risk management. This risk is much lower than the risk of death by flooding that society currently bears.

Economic Appraisal

39. Economic appraisal is an essential component of a floodplain management study. If government financial assistance is to be sought, a comprehensive economic analysis of options and impacts is generally a prerequisite. Economic appraisal provides a common framework for assessing the impacts of management options, be they positive or negative in magnitude, and social, environmental or financial in nature.
40. An economic appraisal of proposed management measures will generally need to be undertaken to ensure 'costs' are justified by associated 'benefits'. The economic appraisal usually follows conventional cost-benefit procedures. In addition to project costs and benefits, the appraisal should also include social, environmental and equity costs and benefits, as far as these can be quantified.
41. Economic analysis can also be used to determine the optimum size of a single management measure or the optimum mix (and size) of multiple management measures. One of the significant 'costs' to be included in an economic analysis is the 'cost' of flooding itself (see Floodplains—A National Cost on pages 5 to 7).
42. Economic appraisal deals principally with tangible costs readily quantified in dollar values (direct and indirect costs). However, it is not unusual to proceed with urban flood mitigation schemes on largely social grounds, ie on the basis of the reduction in intangible costs and social and community disruption. It has been found across the world that many flood mitigation schemes are only marginally economic or even 'uneconomic' in strict tangible cost-benefit terms. They may be justified, however, in other terms.

43. As well as costs, there are also 'benefits' associated with flooding, such as improved soil fertility through silt deposition across floodplain areas used for agriculture. In addition, flooding episodes are essential to the wellbeing, growth and breeding of many riparian plants and animals along river and creek systems. Floodplain management measures that limit the extent of flooding or reduce the frequency and magnitude of flooding may diminish or even eliminate these 'benefits'. These effects need to be assessed and taken into account in the economic analysis within a floodplain management study.

Habitat

44. Floodplains, by virtue of their waterbodies, wetlands, fertile soils and associated vegetation, provide important habitat for a variety of animals and plants, as well as people.
45. Human occupation of the floodplain for forestry, agriculture and urban development has led to the clearing and draining of vast areas of natural vegetation and the loss of much riparian habitat. Much of what remains is under threat.
46. Stream 'improvement', or the clearing of bed and bank vegetation and obstructions from waterways to facilitate flood flows, was a relatively common structural management measure in the past. However, we now recognise that the riffles, pools, snags and immediate riparian vegetation of the bed and banks of natural waterways provide essential habitat for a wide diversity of creatures. The biological 'costs' of any work or measure that impacts on the riverine bio-community need to be assessed as part of a floodplain management study.
47. The floodplain management process provides the community with an opportunity firstly, to preserve, protect and extend remaining areas of habitat, and secondly, to improve or reinstate degraded habitat areas affected by past flood risk reduction measures. Modification to natural channels such as vegetation clearing, channel formalisation or structural measures which interfere with natural sediment budgets or result in concentration of flows can all affect the stability of the riverine system. Instability causes loss of equilibrium and the effect of the system seeking equilibrium is often degradation. The opportunity for and benefits from 'environmental improvement' as part of developing and implementing a floodplain management plan should not be overlooked.
48. Thus, an important part of the floodplain management study will be an expert analysis of the habitat of the river and its floodplain, including its importance and relationship to other habitats within the catchment.

Water Quality

49. The quality of creek, river, estuarine and coastal waters affects their use as habitat by a wide variety of flora and fauna, as well as the visual

aesthetics and recreational use of these waterways and their surrounds.

50. Floodplain development for forestry, agricultural and urban purposes can have a variety of detrimental effects on water quality. Surface runoff may contain high levels of silt, nutrients, pesticides, heavy metals and organic matter, which degrade water quality and can lead to the eutrophication of waterways.
51. It should be recognised that some structural mitigation measures, if appropriately designed, can have associated water quality benefits, eg detention basins can be designed to promote a reduction in suspended solids and adsorbed nutrients by settling within the basin.
52. Both the potential ecological benefits and costs of structural measures need to be kept in mind in a floodplain management study.

Sustainable Use

53. These days, it is recognised that the soil, water, vegetation and mineral resources of the floodplain need to be managed in a sustainable way for future generations. A floodplain management study provides an opportunity to address these issues in an effective and integrated fashion.

Social Considerations

54. Important social considerations to be addressed in a floodplain management study include the local community's wants and desires with respect to developing and using flood-prone land, integrating these factors with flood hazard and any regional or local development strategies, and social impacts of flooding on the community. Again, a floodplain management study provides an opportunity for all these factors to be aired and weighed.

Planning Horizon

55. If the floodplain management process is to serve as a useful tool into the future, it is essential that an appropriate planning horizon be adopted for appraising future land use: **20 to 30 years** is appropriate. This may seem extreme; obviously we cannot be certain of the state of the population, economy, society or technology some 30 years into the future. However, it is essential that the planning horizon encompass possible future urban development (based on State and regional planning concepts, as well as local needs) and the possibility of urban renewal on a potentially large scale. All buildings ultimately have to be replaced or substantially renovated; land uses appropriate 50 years ago may not be so in a further 30 years.
56. One significant option in a floodplain management plan is a complete change of land use through redeveloping large areas of existing development. It is essential that the floodplain management study look

sufficiently far ahead to encompass and assess these options.

57. More detail about the floodplain management study is in Annex C.

Floodplain Management Plan

58. The floodplain management plan comprises a coordinated mix of measures that address existing, future and residual flood problems.
59. The plan should specify the objectives of managing the particular area of floodplain under consideration, as well as how this is to be done. It will include, in both written and diagrammatic form, information describing how particular areas of land are to be used and managed to achieve specified objectives. The plan should also include a description and discussion of various issues, problems, special features and values of the area, together with specific management measures to be implemented, along with the means and timing of implementation.

Draft Plan

60. Using the results of all studies undertaken as part of the floodplain management study, a draft floodplain management plan is formulated. The draft plan should take into account a number of diverse considerations, including:
- flood behaviour, including risk, prevailing hazard and changes occasioned by proposed future land developments;
 - links between the floodplain management plan and the flood emergency plan;
 - economic analysis of potential works and measures, together with the cost of flooding to the private and public sectors which must include a strict cost-benefit analysis, ie costs to the environment (see Annex C) and how, if works are to be implemented, achievement (or otherwise) of the established cost-benefit ratio is to be measured;
 - environmental factors, including enhancement and restoration of the river and floodplain environment;
 - social factors, including the needs of the local community and intangible flood costs; and
 - local, regional and state planning needs, restrictions and opportunities.
61. Preparing a draft floodplain management plan is not easy. It is time consuming and involves trade-offs between different objectives and between different stakeholders. As noted earlier, this is probably the most important and most difficult task of the floodplain management advisory committee.

Exhibition and Public Comment

62. Community consultation is an essential element in formulating, accepting and implementing a floodplain management plan. Best practice principles require that local agencies actively involve representatives of the public, particularly owners of land in defined flood areas, in preparing and reviewing the floodplain management plan.
63. Irrespective of any statutory requirements, the draft floodplain management plan should be exhibited and public comment sought and be taken into account before the plan is finalised.

Adoption and Implementation

64. Once the local agency has adopted a floodplain management plan, the next phase is implementation. Certain components can be implemented relatively quickly, such as development and building controls, flood education and public awareness programs.
65. Statutory planning instruments are the most effective means of controlling development of flood-prone land. After adopting a floodplain management plan, local agencies should foster, as a matter of urgency, preparation or amendment of appropriate statutory planning instruments to give effect to proposed land use and development controls.
66. It is unlikely that all provisions of a floodplain management plan can be implemented immediately. Available funding will determine when certain options can commence (eg structural measures and voluntary property purchase). Consequently, a strategy needs to be developed to implement the various elements of the plan over time. The strategy should include staging of components dependent on funding availability and adoption of interim measures.
67. If a local agency seeks State or Commonwealth Government financial assistance to implement a floodplain management plan, it will be required to:
 - provide advice on the methods used to seek public comment;
 - take account of the submissions received;
 - formulate a balanced plan acceptable to the community; and
 - propose safeguards to minimise any adverse environmental impacts.
68. The floodplain management study, if properly and thoroughly undertaken, should provide all the support necessary for application of government funds.

Review of Plan

70. A floodplain management plan represents the community's considered judgement on how its floodplains should be developed. The plan is not a static document and should be reviewed at regular intervals of perhaps five to 10 years, or after a severe flood that gives rise to revision of the flood study results. Such reviews need to address changes in:
- flood behaviour (perhaps a large flood has occurred since the plan was formulated or an upstream dam has been constructed);
 - roles and responsibilities of the various agencies concerned with floodplain management; and
 - aspirations of the community regarding future growth and development.
71. More detail about the floodplain management plan is contained in Annex D.

Figure 2:1—Recommended Floodplain Management Process

FLOOD EMERGENCY MANAGEMENT

72. The third of the principal systems that constitute the recommended floodplain management process is the flood emergency management system. This system is aimed at reducing the hazard during actual flood events. This is done by developing a local flood emergency plan.
73. If the existing, future and residual flood problems are to be effectively managed, close liaison and integration between the floodplain management planning process and the flood emergency planning process is essential (see Figure 3:1). To this end, it is essential that a local representative (and possibly a regional representative) of the flood response agency is a member of the floodplain management advisory committee.

Flood Hazard Analyses

74. The first step in flood emergency planning is to carry out a hazard and vulnerability analysis of floodplain areas under consideration.
75. This requires information concerning the extent, depth, velocity, duration and rate of rise of flood waters, as well as topographic information relating to loss of road access, the formation and/or submerging of 'islands', etc. The flood study generates all of this information. During the course of the flood study, it is important that there is close liaison between the engineers undertaking the investigation and emergency services personnel, who may have specific requests of the flood study, such as estimates of the time available before key roads become untrafficable.
76. Once the hazard analysis is complete, the more hazardous areas of the floodplain will have been defined as will the population at risk. Note that the degree of hazard and the extent of hazardous areas will generally change with flood severity. In most Australian States and Territories, emergency management agencies have recently adopted the PMF event as the basis for flood management planning.
77. More detail about the flood hazard is contained in Annex E.

Flood Warning Systems

78. Flood warning systems are increasingly being used when implementing floodplain management plans. Several points should be noted about such systems:
 - To be effective, warnings need to be timely, ie there needs to be sufficient time for emergency measures to be carried out, whether by individual landholders or by emergency agencies.
 - Forecasts of peak flood levels are predictions of future flood behaviour. Such forecasts are based on a knowledge of

progressive flood behaviour to date, either in terms of catchment rainfalls or upstream water levels. As such, forecast flood levels contain uncertainties, eg because additional rain falling in ungauged areas of the catchment is not 'seen' by the forecasting system. Thus, **forecast flood levels should be interpreted in terms of likely rather than absolute flood levels**. Undue reliance on the accuracy of forecast flood levels can exacerbate damage if actual levels are higher than predicted.

- Flood warning by itself does not alleviate hazard and flood damage. Accompanying flood defence and evacuation arrangements are required, ie a comprehensive flood emergency plan.

Flood Emergency Plan

79. After completing hazard analyses, emergency management agencies will prepare or amend the local flood emergency plan. This is a detailed document which will address, amongst other things, preparedness for, response to and initial recovery from flood emergencies.
80. The primary aim of a flood emergency plan is to reduce hazard during an actual flood event. To this end, essential issues addressed in the plan are flood forecasting, flood warning, evacuation and initial recovery.
81. The flood emergency plan complements the overall floodplain management plan. Again, close liaison is needed between emergency management personnel and other members of the floodplain management advisory committee during the floodplain management study to ensure proposed structural, land use planning and development and building control measures do not unduly increase hazards or put unreasonable claims on emergency management agencies during an actual flood event.
82. Local agencies generally have a significant role to play in flood emergency management with respect to flood warning, providing manpower and equipment and managing other flood-related tasks. All these issues need to be determined during development of a flood emergency plan.
83. Typically, a flood emergency plan has several 'trigger points' that result in the progressive activation and implementation of the plan as an actual flood event develops. Close liaison is required between the Commonwealth Bureau of Meteorology (generally the provider of flood forecasts), the emergency management agency and the local agency to ensure smooth and appropriate activation of flood emergency measures.
84. The flood emergency plan should also include responsibilities for protecting essential infrastructure (eg sewerage, water supply,

telephones, etc.).

Storm Surge Flooding

85. Whilst there are some similarities with mainstream flooding, the destructive forces accompanying a major storm surge event mean the attendant risk to life and limb and potential for structural damage can be expected to be substantially greater.
86. Uncertainties relating to storm surge are due to inability to confidently predict the route and speed of the accompanying cyclone. This means the surge height cannot be predicted with any certainty and areas likely to be affected cannot be clearly identified in advance.
87. As evacuation during a cyclone is almost impossible, areas that may be at risk need to be evacuated well in advance. This can lead to much larger areas being evacuated than will actually be affected and false alarms which can lead to a loss of public confidence in the warning process.
88. The unpredictability and increased risk level suggest that frequency for the defined storm surge event (for development control purposes) needs to be chosen carefully. Also, the planning and response phases of the emergency planning process need to be specifically tailored to address the higher risk and the uncertainties.

Further Information

89. More detailed best practice guidelines are available for Flood Warning (EMA 1999b) Flood Preparedness (EMA 1999a) and Flood Response (EMA 1999c).

Acceptance of Plan

90. After a flood emergency plan has been developed it needs to be formally accepted and approved by the State or Territory emergency management administration in accordance with the relevant legislation, regulation or order.

Implementation of Plan

91. Public awareness and public education are important elements of a flood emergency plan. It is important that the community understands the flood emergency plan and its provisions.
92. The local emergency management representative should liaise with the local agency to instigate appropriate awareness and education programs, which need to be seen as an on-going, long-term 'maintenance cost' of a flood emergency plan. Awareness and education must be fostered on a regular basis if the community element of flood emergency management is to be effective.

93. In addition, the local emergency management representative should ensure the local agency is aware of its role under the flood emergency plan and all necessary steps have been taken to ensure easy implementation when required.

Education, Training and Research

94. The floodplain management process described above represents a significant change from past practice. To foster the recommended process requires an on-going commitment to education and training of the nation's floodplain and flood managers by the three levels of government and by professional bodies, such as the Institution of Engineers, Australia.
95. Exchange of information, experiences, difficulties, problems and solutions between the States and Territories is essential to better floodplain management. This can be achieved by workshops and conferences, perhaps on a biannual basis. SCARM's Floodplain Management Working Group has a central role to play in fostering education, training and research.

CHAPTER 3

FLOOD EMERGENCY PLANNING

IN A NUTSHELL ...

Flood emergency management consists of Prevention, Preparedness, Response and Recovery (PPRR).

Floodplain management and flood emergency management must be coordinated.

OVERVIEW

1. Various aspects of flood emergency planning, namely flood preparedness, flood warning and flood response, are discussed in some detail in companion Guides (EMA 1999a, b and c). This section briefly describes the general approach to emergency management in Australia, as adopted by Emergency Management Australia and State and Territory flood emergency management agencies, so floodplain managers can better appreciate how they can contribute to the flood emergency planning process. In addition, this section identifies reciprocal opportunities for flood emergency managers to coordinate and liaise with the floodplain management planning process.

EMERGENCY MANAGEMENT IN AUSTRALIA

2. Through Emergency Management Australia, the community has adopted a national approach to emergency management that recognises four components to managing any emergency—they are:

- **prevention;**
- **preparedness;**
- **response; and**
- **recovery.**

Referred to as the 'PPRR' system of emergency management.

3. Table 3:1 shows the various activities embraced by each component, as they apply to managing flood emergencies. The following aspects of Table 3:1 should be noted:

- The four PPRR activities are 'components' rather than 'phases' of the flood emergency management process. **The four components are not sequential stages of an emergency operation.** For example, in managing flood emergencies, it is common for recovery operations to commence while flood response operations are still in train.

- Flood prevention (or mitigation) activities **can only be comprehensively, objectively and effectively defined** via the floodplain management planning process.
 - Flood prevention activities are aimed at reducing existing flood risk and controlling future flood risk.
 - Flood preparedness, response and recovery activities are aimed at managing existing, future and residual risk.
4. Thus, while the flood emergency planning system embraces the four PPRR components, 'prevention planning' can only be effectively undertaken through the floodplain management planning process, which SCARM describes in detail (SCARM 1998). The term 'flood emergency planning', as used in this manual, embraces flood preparedness, response and recovery activities.

ROLES AND RESPONSIBILITIES

5. From the nature of activities listed in Table 3:1, it is apparent that a variety of local, State and Territory and Commonwealth government agencies have roles to play in the four components of flood emergency management. Table 3:2 indicates the major areas of responsibility of various public agencies, the number of ticks indicating the relative significance of one agency's responsibilities compared to another's.
6. From Table 3:2 it is apparent that floodplain management planning is firmly centred on the prevention component with some overlap into the preparedness component (eg to foster community awareness and education in regard to flooding, develop a flood warning system).
7. It is also apparent that the flood emergency planning process encompasses preparedness, response and recovery activities.

Table 3:1—Details of the four components of Australia's flood emergency management system

Prevention activities	Preparedness activities	Response activities	Recovery activities
Legislation	Foster community awareness/ education	Issue warnings	Undertake cleanup operations
Structural mitigation measures	Develop disaster plans	Implement emergency legislation/ declaration	Restore essential services
Land use planning controls	Develop emergency communication systems	Implement evacuation plans	Provide counselling
Development and building controls	Develop flood warning system and sub-plan	Implement plans	Provide temporary accommodation
Relocation from unsafe areas	Undertake training exercises	Activate operations centres	Provide financial support/ assistance
Tax and insurance incentives/ disincentives	Mutual aid agreements with local, State and Commonwealth agencies	Mobilise resources	Provide health and safety information
Public information	Provide special resources	Notify public authorities	Provide long-term medical care
Community awareness/ education	Prepare resource inventories	Provide medical assistance	Restoration/ reconstruction of public assets and infrastructure
		Provide immediate relief	Assess economic impact
		Search and rescue	Review operation of flood emergency management system
		Evacuate people at risk	

Table 3:2—Broad areas of responsibility, major public agencies, flood emergency management

Agency		Flood Emergency Management Component			
Jurisdiction	Nature	Prevention	Preparedness	Response	Recovery
Local	Local agency	✓✓✓	✓✓	✓✓	✓✓
State and Territory	Emergency Services	✓	✓✓✓	✓✓✓	✓
	Recovery agency		✓	✓	✓✓
	Technical agencies	✓✓	✓	✓	
Commonwealth	Bureau of Meteorology		✓	✓✓	
	Emergency Management Australia	✓	✓✓	✓✓	✓
	Dept of Transport & Regional Services	✓			✓
	Dept of Finance				✓✓
	Telstra				✓

Key: The number of ticks denotes degree of involvement of the listed agency with the listed activity, therefore, ✓✓✓ denotes major involvement, ✓✓ moderate involvement, and ✓ some involvement.

Prevention Activities

8. Prevention activities are firmly centred on the floodplain management planning process. Consequently, the local agency plays the lead role in prevention activities, which are largely embodied in the floodplain management plan.
9. Of the State and Territory agencies, flood response and technical agencies also have roles to play in prevention activities. Therefore:
 - a number of technical agencies provide advice to the local agency during preparation of a floodplain management plan and, as such, play an active role in the prevention component, eg State water resource agencies ensure hydrologic and hydraulic studies undertaken to predict flood behaviour are of an appropriate technical standard and help interpret flooding behaviour; and

- State/Territory flood response agencies have an important role to play by ensuring emergency management considerations are addressed and integrated into the floodplain management plan.
10. Two Commonwealth agencies contribute to the prevention/mitigation component of flood emergency management. Emergency Management Australia provides community and school education material emphasising prevention/mitigation activities as well as funding and publishing best practice guidelines such as this publication. It also funds some State/Territory mitigation projects and is developing a national disaster mitigation framework for coordinated action. The Department of Transport and Regional Services is also involved by providing significant flood mitigation project funding for States and Territories.

Preparedness Activities

11. The preparedness component of flood emergency planning draws on the resources and experiences of agencies at all levels of government. Best practice principles dictate that a single agency be responsible for organising preparedness and response activities, ie a single 'flood combat agency'.
12. Of the State and Territory agencies, State/Territory Emergency Services are generally the lead agencies, or have a coordinating role with regard to flood preparedness activities.
13. In the course of preparing evacuation plans, the responsible agency will need information concerning flood behaviour. This information can be generated by the flood and floodplain management studies.
14. The State or Territory water resources agency has an important role to play in providing and interpreting information concerning flood behaviour.
15. Local agencies have an important, but subsidiary, role to play in flood preparedness activities. When a flood occurs, the local agency's human, equipment, infrastructure and economic resources will generally play a large role in flood response and recovery activities, eg distributing flood warnings, providing heavy equipment for evacuation purposes, etc. Local councils have an important role in helping the emergency agency foster community awareness and in making equipment, facilities and people available for training, response and recovery programs.
16. Two Commonwealth agencies have active roles to play in flood preparedness activities: the Bureau of Meteorology and Emergency Management Australia. The Bureau of Meteorology is Australia's lead agency with respect to flood forecasting. An appropriate flood warning system needs to be drawn up in consultation with of the State or Territory Flood Warning Consultative Committee. Emergency

Management Australia provides awareness and education material and campaigns and enhances State and Territory preparedness and response capabilities through funding and training programs.

17. Thus, the flood preparedness component of flood emergency planning is a complex process involving integration of the efforts of various local, State and Territory and Commonwealth agencies into a coordinated plan to be activated in a 'flood emergency'.
18. If this process is to be successful, it must be under the control and coordination of a single lead agency. Further, a number of flood preparedness procedures need to be practiced through training exercises. It is essential that local agencies and flood-prone communities realise that 'flood preparedness' is an on-going exercise and that the cost of training activities, together with 'flood awareness' programs, be appreciated as a 'maintenance cost' of responsible floodplain management.

Response Activities

19. When a flood emergency occurs, all agencies involved in flood emergency planning are called upon to undertake a number of response activities (see Table 3:2). The lead agency, with regard to flood response, is the State or Territory Emergency Service, which activates and coordinates all response activities (see Table 3:1).
20. Local agency personnel have a number of roles to play, such as:
 - disseminating flood warnings (in conjunction with the Bureau of Meteorology and the flood emergency management agency);
 - evacuating and sheltering people at risk (local equipment and buildings may also be needed); and
 - protecting council infrastructure (eg removing electric motors from sewerage pumping stations, etc).
21. Once flood response activities are initiated, the recovery agency will need to be notified to begin assessing the nature and dimension of recovery arrangements.
22. The State or Territory water resources agency can usually provide information on likely flood behaviour as the flood develops, especially if flood response involves releases from major storages.
23. The Bureau of Meteorology has the lead role in flood forecasting.
24. Emergency Management Australia has access to the full range of Commonwealth resources which can be used to facilitate defence and evacuation activities, if necessary. Under this arrangement, RAAF aircraft, for example, often provide food relief in the form of fodder drops to stranded livestock and re-supply of food to isolated

communities.

25. State and Territory welfare agencies are generally the lead agencies in recovery planning. As such, they need to liaise closely with State/Territory Emergency Services to ensure recovery plans are fully integrated with response plans.

Recovery Activities

26. A State or Territory welfare agency must play a major role in flood recovery activities. The welfare agency should coordinate provision of financial relief, along with temporary accommodation if required. In a major flood emergency this task may take several months.
27. Local agencies have key roles to play in clean-up operations and in reinstating local authority infrastructure, eg water supply and sewerage. They will be assisted in this work by a number of State and Commonwealth agencies, such as those responsible for public works (water supply, sewerage, repairs to public buildings) and main roads (repairs to public roads and bridges). Some State and Commonwealth agencies have explicit responsibility for repairing essential services, eg Telstra repairs the telephone network. Emergency Management Australia provides best practice disaster recovery manuals and training courses for States and Territories. It also plays an important role on the Commonwealth Counter Disaster Task Force (CCDTF) which is activated following major disasters involving a long recovery phase. The Commonwealth Department of Finance also has an important role in recovery as it administers and funds the National Disaster Relief Arrangements which involves substantial financial assistance to States and Territories following many significant natural disasters.
28. The State/Territory Emergency Service has a limited, but important role to play in recovery activities, namely to ensure initial recovery operations are adequately resourced. After this, on-going recovery operation and arrangements are left in the hands of the lead recovery agency.

NEED FOR A COORDINATED APPROACH

29. If management of existing, future and residual risk across our floodplains is to be effective, close integration of floodplain management planning and flood emergency planning processes and their associated activities is essential.
 - A floodplain management plan is the principal instrument for implementing the flood prevention component of flood emergency management. The lead agency in floodplain management planning is the appropriate 'local agency'.

- A flood emergency plan is the principal instrument for managing the flood preparedness, flood response and flood recovery components.

Planning Opportunities and Special Considerations

30. The floodplain management planning process provides a number of opportunities to prepare flood emergency plans to address rainfall and storm surge flooding. However, floodplain management plans do not generally address dambreak and tsunami flooding. If dambreak flooding is of concern, emergency service agencies will need to refer to a specific dambreak flood study (many such studies have been undertaken in Australia) to obtain specific information on the associated hazard. Even in these circumstances, a floodplain management study may provide useful information with respect to flood behaviour.
31. Thus, in preparing flood emergency plans, personnel from the flood emergency management agency and other agencies contributing to flood emergency planning need to be aware of the following opportunities presented by the floodplain management planning process:
 - The floodplain management advisory committee provides a venue for personnel from the flood emergency management agency and other agencies associated with flood emergency planning to contribute to the floodplain management planning process and to receive information from that process. It is therefore essential that key agencies involved in preparing the flood emergency plan be represented on the floodplain management advisory committee.
 - The flood study provides an opportunity for State/Territory Emergency Services personnel to have flood behaviour in particular flood prone areas of concern investigated via the hydrologic and hydraulic models developed for the flood study, eg to investigate the changing nature of hazard as flood severity increases or the time that a key evacuation route remains trafficable, etc.
 - An important outcome of the flood study is production of flood maps showing the extent of flooding for different flood events. By liaising with the floodplain management advisory committee, flood emergency management agencies can have customised flood maps produced to help them manage flood emergencies.
 - The floodplain management study provides a number of opportunities for the flood emergency management agency to integrate emergency planning considerations into the floodplain management plan. For example, it provides an opportunity to consider the emergency management consequences of proposed future land use, the adequacy of existing evacuation routes and the impact of additional pressure associated with future development on existing evacuation routes. In addition, it provides the flood

emergency management agency with the opportunity to comment on the emergency management consequences of proposed structural measures, such as the overtopping of levees and the relative expenditure between a flood warning system and structural controls. There is considerable merit in a joint study of flood hazard by the State/Territory Emergency Service and those preparing the floodplain management plan. This provides a consistency of approach to hazard assessment, to assessing the impact of land use on hazard and development of evacuation sub-plans.

REFERENCES

Commonwealth Bureau of Meteorology 1929, *Results of Rainfall Observations made in Western Australia*, Commonwealth of Australia.

Department of Primary Industries and Energy 1992, *Floodplain Management in Australia*, 2 volumes, Australian Water Resources Council, Water Management Series No. 21, Commonwealth of Australia.

Emergency Management Australia 1997, *Guidelines for Applying Risk Management to Emergency Management*, Commonwealth of Australia.

Emergency Management Australia 1999a, *Australian Emergency Manuals Series – Part III, Volume 3, Guide 4 - Flood Preparedness*, Commonwealth of Australia.

Emergency Management Australia 1999b, *Australian Emergency Manuals Series – Part III, Volume 3, Guide 5 - Flood Warning*, Commonwealth of Australia.

Emergency Management Australia 1999c, *Australian Emergency Manuals Series – Part III, Volume 3, Guide 6 - Flood Response*, Commonwealth of Australia.

Institution of Engineers, Australia 1987, *Australian Rainfall and Runoff. A Guide to Flood Estimation*.

Institution of Engineers, Australia undated a, 'Environmental Impacts of the Greenhouse Effect'.

Institution of Engineers, Australia undated b, 'Impact of Energy Use on the Greenhouse Effect'.

Institution of Engineers, Australia undated c, 'The Coastal Impacts of the Greenhouse Effect'.

Keller RJ and Mitsch B 1993, 'Safety Aspects of the Design of Roadways as Floodways', Research Report No. 69, Urban Water Research Association of Australia.

Standing Committee on Agriculture and Resource Management 1998, *Best Practice Principles, Floodplain Management in Australia*, SCARM.

Walsh M, Benning NJ and Bewsher D 1998, *Defining Flood Hazard in Urban Environments*, Proceedings of the 2nd SIA Regional Stormwater Conference.

THE FLOOD STUDY

INTRODUCTION

1. A flood study is a comprehensive technical investigation of flooding behaviour that defines the extent, depth and velocity of flood waters for floods of various magnitudes. This enables both the hydraulic category and hazard category of the defined flood area to be determined. A flood study is the principal technical foundation from which a floodplain management plan is formulated.
2. In addition, a flood study identifies aspects of flooding behaviour that require special consideration. For example, if the rate of rise of flood waters is especially rapid, the degree of hazard is increased because of shortened warning and evacuation times. Similarly, the degree of hazard is increased if rising flood waters create islands from which evacuation is difficult or impossible.
3. The two principal components to a flood study are:
 - hydrologic analysis or estimation of flood discharges for floods of various magnitudes; and
 - hydraulic analysis or determination of the extent, depths and velocities of flooding.

HYDROLOGIC ANALYSIS

4. The discharge of flood waters past a given point on a river system which is measured in terms of cubic metres per second (m^3/s) varies throughout the course of a flood event. Figure A:1 shows typical discharge hydrographs, or variations of discharge with time. The hydrographs are characterised by a relatively rapid rate of increase in discharge on the rising limb up to the peak discharge, followed by a slower decline in discharge on the falling limb. Blunder Creek at King Avenue, Brisbane, Queensland, has a catchment of 52 km^2 ; the Clarence River at Grafton, New South Wales, has a catchment of $19,900 \text{ km}^2$. Hence, the much higher peak discharge of the Clarence River and its slower rate of increase in discharge.
5. Before the depths and velocities of flood waters can be determined it is necessary to know the peak flood discharge and, in some situations, the entire discharge hydrograph. Two techniques are commonly used to estimate peak flood discharges and hydrographs: flood frequency studies and rainfall runoff models.

Figure A:1—Discharge Hydrograph

Flood Frequency Studies

6. A flood frequency study is a means of determining the relationship between peak flood discharge at a location of interest and the likelihood of occurrence of a flood event of that size.
7. Flood frequency studies are generally based on peak annual discharges determined at a stream gauging station close to the location of interest. In general, creek and river discharges are not measured directly. Rather, discharges are estimated from water levels, which can be measured relatively easily and inexpensively, eg automatic water level monitors are commonly used these days to record the change in water levels as a flood passes downstream. A rating curve is derived to relate measured water level to inferred discharge.
8. The rating curve is based on actual measurements of discharge (made with a current meter) and on hydraulic analyses.
9. Most discharge measurements made with a current meter are taken in the low discharge range, ie at discharges which may amount to only 10 per cent to 20 per cent of the 1 per cent AEP flood discharge. Further, whilst low flows are often 'well behaved', with the waters confined to

the main river channel, high discharge behaviour is often characterised by development of extensive areas of overbank flow and multiple major flow paths. Thus, whilst a rating curve may be reliable for low discharges, it becomes increasingly unreliable for higher discharges, especially for severe flood discharges. Hydraulic analyses are used to extend the rating curve into the range of water levels characteristic of larger floods. These analyses are approximate rather than exact for reasons outlined above. As a consequence, peak annual flood discharge estimates—as obtained from recorded water levels at a gauging station—are accurate to within about ± 20 per cent, even when made by an experienced hydraulic engineer.

10. Figure A:2 shows the rating curve for the stream gauging station at Walyunga (GS 616 011) on the Avon River, Western Australia. Gauged discharges are shown as solid circles. The curve indicates that for a gauge height of five metres, the discharge is some $350 \text{ m}^3/\text{s}$. The Avon River at Walyunga is actually a 'well gauged' river. The highest gauged discharge is $650 \text{ m}^3/\text{s}$, which is about 40 per cent of the 1 per cent AEP flood discharge of $1700 \text{ m}^3/\text{s}$.

Figure A:2—Rating Curve—Avon River at Walyunga

11. Once a rating curve has been defined, the peak annual flood levels recorded at a stream gauging station can be converted to peak annual

discharges and a frequency analysis of the discharges can be undertaken. Figure A:3 shows the frequency distribution of peak flood flows in the Avon River at Walyunga for the 13 largest floods over the period 1862–1985. Note that hydraulic models were used to estimate discharges at high flood levels.

12. According to this curve, the discharges of the 10 per cent AEP and 1 per cent AEP flood events are 650 m³/s and 1700 m³/s respectively.
13. Because of the generally short periods of recording at most gauging stations across the nation (20 to 50 years on average), there is always a degree of uncertainty in the estimates of peak discharges obtained from a flood frequency analysis. These uncertainties are of a statistical nature and are additional to inaccuracies arising from an unreliable rating curve.
14. These statistical uncertainties are illustrated in Figure A:3, which shows the 95 per cent and 5 per cent confidence limits for flood discharges in the Avon River at Walyunga. These confidence limits provide a measure of the statistical reliability of flood frequency discharge estimates and reflect the effects of a limited body of data (only 13 flood events) being used to estimate discharges. The 1 per cent AEP flood estimate for the Avon River at Walyunga is 1700 m³/s.

Figure A:3—Flood Frequency Curve for Avon River at Walyunga

The 5 per cent and 95 per cent confidence limits are 3000 m³/s and 1000 m³/s respectively, ie there is a 5 per cent chance that the 'true' 1 per cent AEP discharge is greater than 3000 m³/s and a 95 per cent

chance that it is greater than $1000 \text{ m}^3/\text{s}$. Needless to say, the 'best' estimate of the 1 per cent AEP discharge is $1700 \text{ m}^3/\text{s}$.

15. To summarise: flood frequency studies are a relatively rapid means of estimating the peak discharge of 'standard' flood events of interest. Additional studies enable the hydrographs associated with these peak discharges to be defined. Significant errors can arise through inaccuracies in rating curves and from using relatively short periods of recording to determine flood discharges.

Rainfall Runoff Models

16. A rainfall runoff model is a mathematical representation of the various catchment processes that transform rainfall into runoff. With these models, a nominated rainfall event is input to the model, which then simulates the associated discharge hydrograph at locations of interest in the catchment.
17. The two main catchment processes that affect the size and shape of discharge hydrographs are rainfall losses and storage routing effects as the runoff travels down the catchment. Rainfall runoff models can only approximate these processes—to obtain reliable estimates of discharge hydrographs it is necessary to calibrate the model to a flood event for which both rainfall and discharge data have been recorded.
18. The calibration process consists of adjusting rainfall loss rates and routing parameters to obtain agreement between the recorded and simulated hydrographs. The calibration process is often lengthy and difficult; calibration should also be verified against several other recorded flood events to ensure the model acceptably reproduces recorded results. Once calibrated, the rainfall runoff model can then be used with some confidence to predict discharge hydrographs associated with rainfall events of known severity.
19. Rainfall data throughout Australia are available in the form of intensity–duration–frequency data, from which it is possible to determine the intensity of rainfall (in millimetres per hour) for a given duration of storm (in hours) with a specified annual chance of occurrence for any given location (Institution of Engineers, Australia 1987).
20. In summary, rainfall runoff models are a useful tool for simulating discharge hydrographs and for estimating peak discharges. However, reliable results will only be obtained if the model is calibrated against a recorded flood (hopefully large) and verified against other floods. Rainfall runoff models provide a convenient way of estimating discharge hydrographs in catchments containing dams or reservoirs (the effects of these storages on discharge hydrographs can easily be incorporated in the model).

Comparison of Methods

21. Provided recorded flood data are available at a representative stream gauging station, and the period of record is adequate, a flood frequency study provides a rapid estimate of peak flood discharges. Actual flood hydrographs can be determined by investigating recorded hydrographs.
22. In general, rainfall records have been kept for longer and are more extensive than are streamflow records. Hence, rainfall data has a greater degree of statistical reliability than discharge data. Consequently, it is usual to use a rainfall runoff model to estimate peak discharges and hydrographs. Such a model can also simulate the effects of different land use developments on discharge hydrographs (eg urbanisation, dams, mitigation works etc.).

HYDRAULIC ANALYSIS

23. Having estimated the peak discharges (and the discharge hydrographs if necessary) of flood events of interest, water levels, velocities and the extent of flooding along the reach of the river under consideration can be determined. This requires an hydraulic model.
24. Hydraulic models are of two main types: numerical and physical. In numerical models, a computer is used to solve the equations representing the flow of water down a river system and so to predict water levels and velocities. A physical model is a 'scaled down' version of the actual river system being studied. Although useful in complex flooding situations, physical models are rarely used in flood studies these days. Before describing numerical models in some detail, the various factors that affect water levels and velocities are briefly discussed.

Water Levels and Velocities

25. The water level and velocity associated with a discharge of water past a given point on a river system depends principally on:
 - the available energy driving the flow;
 - the loss of energy associated with frictional effects as the flow moves over the bed and banks of the river channel and floodplains; and
 - the cross-sectional area of flow.
26. Water flows from one place to another because of a difference in energy levels. In broad terms, the available energy is defined by the slope of the river channel ('hydraulic gradient'). The greater the slope, the greater the gravitational energy available to cause water to flow from upstream to downstream locations and the faster the water flows. Flowing water uses energy to overcome frictional resistance as it

moves along the river channel and over the floodplains.

27. Rough surfaces, such as outcrops of rock, trees, tree roots, fallen logs and tangled and matted vegetation, produce much greater frictional resistance than smooth surfaces, such as grass, croplands and concrete-lined channels. Where the frictional resistance is low, water flows faster and shallower.
28. The area and depth of flow also affect water levels and velocities. The larger the area of flow, the smaller the velocity needed to pass a given discharge; shallower flows are 'slowed down' by friction to a greater extent than deeper flows.
29. It should be noted that in general the slope of the river channel will change along its length. In addition, the frictional resistance will generally vary across the width of a cross-section and along the reach of interest. Further, the width and shape of cross-section will also change along a river.
30. Because of these variations, the factors affecting water levels and velocities interact in a complicated way. This interaction is further complicated by the presence of raised road embankments or bridges across flood-labile lands, and the presence of any significant flow constrictions along the river system.

Development of Numerical Models

31. In a numerical model, the various equations which relate available energy to friction losses and the area and depth of flow are solved by the computer. This process provides estimates of water levels, velocities and the extent of flooding.
32. Numerical models require data concerning the bed slope, frictional resistance and topography of the river channel and floodplains. These data are obtained by:
 - closely studying the river reach of interest, both from topographic maps and from field inspection, to obtain a general understanding of likely flooding behaviour;
 - selecting and measuring a number of cross-sections which are representative of the topography and frictional resistance by field survey to enable channel slopes and the depth and areas of flow at these locations to be determined for any water level; and
 - estimating, by visual inspection of the area, the frictional resistance at the various cross-sections noting the type and nature of bed and bank materials, the presence of trees, scrub, rocks, logs, etc.
33. All this data is fed into the model, which is then ready for calibration. If the downstream end of the model is non-tidal, then a rating curve is used to determine the downstream water level. If the downstream end

of the model is a tidal river reach or the sea, it is necessary to incorporate the rise and fall of downstream water levels in the model.

Calibration of Numerical Models

34. The calibration process consists of adjusting various parameters in the model to obtain agreement between recorded and simulated water levels during a severe flood. First, a flood suitable for calibration is adopted. Next the peak discharge or discharge hydrograph of the flood is estimated and input to the model. Information on peak flood levels and flood behaviour is sought from old-time residents, newspapers, council records, etc. All of this information is used in the calibration process as a basis for adjusting frictional resistance parameters and modifying cross-sections to achieve agreement between recorded and simulated water levels.
35. There are a number of uncertainties in the calibration process: the most recent large flood suitable for calibration may have occurred some years ago and hydraulic conditions may have changed in the interim; and the passage of time will have reduced the number of old-time residents still living in the area and will have clouded their memories of the flood. Calibration of hydraulic models requires both detective work and judgement to uncover facts. Inconsistent 'facts' have to be identified and discarded; discrepancies have to be studied and explained.

BRIDGE AFFLUX

36. Constructing road embankments and bridges across floodplains impedes flood water flow. This results in the water level upstream of the bridge being higher than it would be in the absence of the bridge. This difference in water levels is referred to as 'afflux'.
37. The greater the constricting effects of embankments and bridges, the greater the afflux, and the greater the effect of bridges on upstream flood levels. The effect of bridges on flood behaviour is incorporated in hydraulic models through a set of relationships between the hydraulic characteristics of the waterway section of the bridge and upstream and downstream flood levels.

COASTAL EFFECTS

38. On inland streams and in the non-tidal areas of coastal rivers, the size and frequency of a flood at any point depends on the volume and timing of runoff from the catchment. However, in the lower tidal reaches of rivers, flooding is more complex as it depends not only on rainfall, but also on increased ocean levels arising from ocean tides and storm surge effects.
39. Elevated ocean levels increase flood levels in the lower reaches of a river by either impeding flood waters from discharging into the ocean or

by filling up low-lying land and estuarine areas before river flooding arrives.

40. Flooding around coastal lakes and lagoons can arise from a combination of elevated ocean levels (as discussed above), sediment constricting the lagoon entrance, river and stream flood waters discharging into the lake or lagoon and wind-generated waves in the lake itself.
41. All these influences need to be assessed and appropriately incorporated in the hydraulic models used to estimate flood levels.

THE GREENHOUSE EFFECT

42. A flood study should also address possible implications of the Greenhouse Effect on flooding behaviour.
43. The Greenhouse Effect refers to the inferred warming of the earth and its atmosphere due to accumulation of certain gases, such as carbon dioxide, nitrous oxide, methane and chlorofluorocarbons in the atmosphere. The Institution of Engineers, Australia has prepared several position papers on the Greenhouse Effect (Institution of Engineers, Australia a, b and c).
44. Because of the Greenhouse Effect, the temperature of the atmosphere may rise by 1.5°C to 4.5°C over the next 30 to 50 years. Greenhouse changes may have a number of possible adverse effects on flooding behaviour, such as:
 - rainfall patterns and intensities which are expected to change with more frequent floods and droughts, ie storms may intensify and so increase the severity of resulting floods;
 - tropical cyclones and sub-tropical low pressure systems which may increase their southern excursion by another 200–400 kilometres and increase in intensity; and
 - coastal sea levels which are expected to rise by 0.2 metre to 1.4 metres over the next 50 years and so exacerbate flooding problems in coastal areas, estuaries and along the tidal reaches of coastal draining rivers.
45. The consequences of increases in sea levels and more severe flood behaviour should be assessed as part of a flood study. The degree to which these changes are incorporated in flood level estimates should be decided after discussion with representatives from the various State water resources agencies.
46. In attempting to plan for the Greenhouse Effect, it is important that a floodplain management plan be 'robust', ie if in 30 years time the Greenhouse Effect is worse than currently anticipated, the adopted plan should not be unduly disrupted.

FLOODPLAIN MANAGEMENT MEASURES

1. This Annex provides general background information on the various categories of floodplain management measures and on individual measures themselves, including their advantages and potential disadvantages.
2. For convenience, the various measures have been described in isolation. But **a fundamental principle of good floodplain management is that management measures should not be considered in isolation.** Rather, they need to be considered collectively on a risk management basis from within the all-embracing framework of a floodplain management study that allows their interactions, their suitability and effectiveness, and their social, ecological and economic impacts to be assessed on a community-wide basis.

LAND USE CONTROLS

3. Land use controls, which include, inter alia, zoning controls and the voluntary purchase of properties located in unduly hazardous areas of the floodplain, are respectively aimed at shepherding inappropriate future development away from high risk areas of the floodplain and removing existing high hazard developments from the floodplain.
4. Appropriate land use controls are essential if the rate of growth of future flood damage is to be limited.
5. Planning measures will usually result in some community groups or areas of the floodplain being advantaged, whilst other groups or areas are disadvantaged. It is essential that planning measures be formulated and resolved within the context of an overall floodplain management plan so contentious issues can be addressed objectively and as equitably as possible.

Zoning

6. Division of flood-prone land into appropriate land use zones is an effective and sustainable means of limiting flood damage to future developments.
7. Local agencies should give due consideration to selecting appropriate zones and related development and building provisions when flood-prone land is being rezoned. As a matter of course, any flood-related zonings should be incorporated in town planning schemes (and other planning instruments) once the floodplain management plan has been finalised and adopted.
8. Zones over flood-liaible land should be based on an objective

assessment of social, economic and ecological issues, as well as flood risk. Issues to be considered would include:

- the objectives of the floodplain management plan;
- hazard rating;
- potential for future development to have an adverse impact on flood behaviour at existing developments, particularly the **cumulative effects** of on-going development;
- whether or not adequate evacuation routes are available during floods;
- whether certain activities should be excluded because of additional or special risk to users, eg accommodation for aged people, hospitals and the like; and
- existing planning controls.

Voluntary Purchase

9. In certain high-hazard areas of the floodplain it may be impractical or uneconomic to mitigate flood hazard to existing properties at risk.
10. In such circumstances it may be appropriate to cease occupation of such properties to free residents and potential rescuers from the hazard of future floods. This can be achieved by purchasing properties and removing or demolishing buildings as part of a floodplain management plan. In such circumstances, property should be purchased at an equitable price and only when voluntarily offered. Such areas should ultimately be rezoned to a flood-compatible use, such as recreation or parkland.

STRUCTURAL MEASURES

11. Common structural measures used to mitigate flooding include:
 - levees;
 - bypass floodways;
 - channel improvements;
 - dams; and
 - detention basins.

Levees

12. Levees are generally the most economically attractive measure to protect existing development in flood-labile areas. The height or crest level of a levee is determined by a variety of factors including the economics of the situation (including the nature of development

requiring protection), physical limitations of the site, and the height to which floods can rise relative to the ground levels in the area (important for safety considerations).

13. A levee may rarely be called upon to achieve its design requirements. If it fails at this time because of poor design, improper construction or lack of maintenance, the money spent on its construction has largely been wasted.
14. Even if design, construction and maintenance have been exemplary, **all levees will ultimately be overtopped** unless designed for the PMF event. Even if designed for PMF events, levees can still fail through lack of maintenance, inadequate construction or unforeseen circumstances. Thus, it is not a question of 'if' the overtopping of a levee will occur, but of 'when' and of the consequences. Hence, the importance of flood emergency plans that address the defence and evacuation of areas protected by levees.
15. In using levees for flood mitigation, some precautions need to be noted:
 - The likelihood of catastrophic damage and unacceptable hazard levels when the levee is overtopped. When in April, 1990, rising flood waters breached the emergency sandbag levees at Nyngan, NSW, hazardous conditions rapidly developed within the protected area, lives were at risk (although there were no fatalities) and the resulting damage and disruption cost over \$50 million.
 - Provision of spillways to enable the controlled overtopping of the levees to avoid uncontrolled high velocity overflows or even breaching when the levee is overtopped.
 - Proper maintenance of the levee crest level, grass cover and spillways, and avoiding damage by traffic or animals.
 - Flood emergency plans for levee overtopping and evacuation. The need for such plans is particularly important where escape routes can be severed (eg a ring levee) or where the protected area can fill rapidly once overtopping commences (eg Nyngan).
 - Analysis of flow conditions which may develop inside the protected area when overtopping occurs and the flood continues to rise. In some situations high-hazard conditions can develop within protected areas, particularly around breaches in the levee, the occurrence and location of which cannot be predicted.
 - On-going community education to ensure the population is aware of the risk of overtopping, is informed about flood emergency plans, and does not lapse into the common belief that levees 'provide total protection against all floods'.

- Levees have the potential to increase flood levels elsewhere on the floodplain. This aspect needs to be addressed when formulating any levee proposal.
 - Careful consideration needs to be given to draining local runoff water that collects within the protected area. It may be necessary to install pumps and sumps to remove this water during floods. If the pumps fail, 'internal' flooding may occur.
16. Some of these precautions do not all apply when the PMF is adopted as the defined event for levees. In such cases, important factors to consider include proper maintenance of the levee and provision of adequate 'freeboard' against wave action and subsidence.
 17. Despite their problems, levees are a common, important and effective management measure for existing flood problems. However, at best they are a partial solution and should be supplemented by comprehensive flood emergency measures.

Bypass Floodways

18. Bypass floodways redirect a portion of the flood waters away from areas at risk, and so reduce flood levels along the channel downstream of the bypass floodway offtake. Bypass floodways are commonly used in conjunction with levees.
19. Opportunities for constructing bypass floodways are limited by the topography of the area, ecological considerations and availability of land. Bypass floodways may exacerbate flood problems along the bypass channel itself and at locations downstream of the bypass channel through facilitating downstream transfer of flood waters. Despite these shortcomings, bypass floodways can provide a useful management option, especially in conjunction with levees.

Channel Improvements

20. The capacity of a river channel to discharge flood water can be increased by widening, deepening or re-aligning the channel, and by clearing the channel banks and bed of obstructions to flow.
21. Such improvements increase not only the velocity of flow and possibly the depth of flow, but also the hazard of the situation. It is essential (duty of care) that signage be erected to warn the public of any untoward hazard associated with 'channel improvements'.
22. In urban areas, particularly where drainage channels have degraded over time, channel improvements can provide the community with other positive benefits, such as enhanced visual aesthetics (by landscaping) and provision of recreation facilities, such as linear parks.
23. Channel improvements are likely to be most effective (including reducing the need for other structural works) along creeks and rivers

with low mainstream channel velocities caused by overgrown beds and banks. Channel improvements are unlikely to have a significant effect in flooding where there are extensive areas of overbank flooding or where flooding effects are dominated by increased tide levels.

24. As a mitigation measure, channel improvements have the potential disadvantages of:
- facilitating transfer of flood waters downstream and accentuating downstream flooding problems;
 - the cost of maintenance;
 - the destruction of riparian habitat; and
 - the visual impact of replacing naturally varying channel sections with a section of more uniform geometry.

Dams

25. Dams, even if full, can significantly reduce downstream flood discharges. As the flood wave passes through a dam, the dam is progressively filled to the point of overflow, and then provides temporary storage above the spillway crest level for flood waters subsequently passing through the dam. The ability of a dam to mitigate floods depends largely on the surface area of the dam at spillway level and its spillway capacity. The larger the surface area and the smaller the spillway capacity, the greater the reduction in downstream discharges. This effect is most beneficial immediately downstream of the dam and the benefits reduce as the flood wave travels downstream.
26. Most dams are 'multi-purpose', ie they provide water for irrigation and domestic use, as well as providing flood mitigation potential. Generally, constructing a dam purely for flood control cannot be justified economically. The mitigating effects of even large dams on severe floods is often surprisingly small because:
- the surface area of the dam at spillway level is relatively small and the spillway capacity is large;
 - the volume of water in a severe flood may be much greater than the storage capacity of even a large dam; and
 - floods may result from rainfall in parts of the catchment that are not commanded by dams. Consequently the benefits of flood mitigation dams are generally limited to mitigating the effects of a flood generated in only one portion of the catchment.

Detention Basins

27. A detention basin is a small dam that provides temporary storage for flood waters. It behaves in the same way as a large dam, but on a

much smaller scale. In urban areas, detention basins are most suitable for small streams which respond quickly to stormwater flooding.

28. Detention basins have a number of inherent disadvantages which should be carefully evaluated. They include:
 - a substantial area of land is required to achieve the necessary storage;
 - where used for multiple purposes, eg as playing fields as well as for flood mitigation purposes, public safety aspects during flooding need to be addressed;
 - long-duration or multi-peak storms (when the basin is partly or completely filled from a previous peak) can increase the risk of overtopping, breaching and resulting downstream hazard; and
 - depending on their size, detention basins may provide little attenuation of discharges when overtopping occurs.
29. Consequently, it is important that detention basins are properly designed, constructed and maintained and that their impact on the hazard of a range of flood events be investigated fully.
30. With appropriately designed outlet works, detention basins act as sediment traps thereby improving urban water quality by reducing the concentration of settleable solids. There may, however, be adverse downstream effects associated with this loss of sediment. Such issues also need to be assessed when considering the impacts of detention basins.

DEVELOPMENT AND BUILDING CONTROLS

31. Development and building controls refer to the conditions attached to developing defined flood areas and constructing buildings within these areas. Such controls are aimed at reducing the risk of a building being flooded above floor level and at reducing the resulting damage when above-floor flooding occurs. Typical development and building controls include floodproofing of buildings, minimum floor levels, house raising and freeboard. Careful and creative strategic site planning can reduce hazard and facilitate evacuation when required.

Strategic Site Planning

32. Developers and local agencies are urged to recognise the importance of strategic site planning. Developers are advised to liaise with local agencies and emergency management agencies to determine issues that need to be addressed as part of the strategic site planning process and the type of data and analysis required to satisfactorily address these issues.
33. Important factors that need to be taken into account at the strategic

site planning stage include:

- provision of suitable evacuation routes;
 - topography of the site; and
 - orientation and type of fences.
34. Providing evacuation routes appropriate to the proposed land use is fundamental to developing defined flood areas. If safe and effective evacuation routes cannot be provided, the proposed land use is inappropriate.
 35. Flood hazard may vary significantly across the site because of topography. For example, higher areas further away from the river will be flooded to shallower depths and may experience lesser velocities than lower areas closer to the river. By locating buildings in the higher, more benign areas of the site, their impact on flood behaviour will be reduced, potential flood damage will be lessened and evacuation can be facilitated.
 36. Fences are another site element that can significantly obstruct flood flows, increase flood levels and perhaps hamper evacuation. Solid or open mesh fences are the worst offenders, but may be appropriate if they are aligned in the direction of flow. During a flood, open mesh fences tend to clog up with debris and act as solid fences. Fences aligned transverse to the flow may require special treatment. Local agency planners need to address the issue of the type of fences appropriate for the site.

Floodproofing of Buildings

37. Floodproofing refers to the design and construction of buildings with appropriate water-resistant materials such that flood damage to the structure of the building itself (ie structural damage) is minimised when the building is flooded. At best, floodproofing is an adjunct to other management measures.
38. The decision to adopt floodproofing as a formal mitigation measure is best made from within the framework of a floodplain management plan. Whilst floodproofing can minimise structural damage to flood-affected buildings, the occupiers of flood-affected buildings still suffer the social disruption of flooding.
39. To prevent or minimise structural damage from flooding, buildings should be designed to withstand water immersion and debris and flotation forces. Particular methods of construction and certain types of materials are better able to withstand immersion than others. For example, plasterboard and chipboard, materials commonly used respectively for internal wall linings and built-in cupboard fittings, are generally irreparably damaged on immersion—even to a minimal depth—and have to be replaced. In contrast, double brick construction

can withstand immersion and may only need a 'hose and scrub down' when the flood subsides.

Minimum Floor Levels

40. The most effective floodproofing measure is to raise habitable floors to some 'defined floor level'. However, in commercial buildings the choice of floor level is also affected by economics and commercial risk-taking considerations. This can result in a commercial enterprise preferring to build the cost of flood losses into its operating costs in exchange for savings in capital costs associated with not having to raise floors to some higher level.
41. Local agencies have a duty of care in approving such 'non-conforming' developments and in deciding on appropriate conditions. They may require the proponent to submit detailed advice of measures proposed to avoid or cater for flood losses.
42. Irrespective of the proponent's desires, the overriding consideration should be that the proposed development will not adversely affect flood behaviour or increase the risk to life, limb or property, whether public or private. **The proper course is to determine levels of acceptable risk for specific areas of the floodplain and for specific land uses from within the overall framework of the floodplain management plan. Further, decisions for non-conforming developments must not be made on an ad hoc or isolated basis. Rather, such decisions must be taken on the basis of the cumulative development of the floodplain.**

House Raising

43. Home owners generally have very strong sentimental and emotional attachments to their dwellings, which generally represent a large capital investment. Avoiding flood damage by house raising, which in essence is another form of floodproofing, achieves the important objectives of:
 - reducing personal loss;
 - reducing risk to life and limb;
 - reducing costs of servicing isolated people who remain in their homes during floods to protect possessions; and
 - reducing stress and post-flood trauma.
44. In general, house raising is a suitable mitigation measure only for low hazard areas of the floodplain. In high hazard areas, structural means of protection are generally required, or voluntary purchase.
45. Not all houses are suitable for raising. Houses of single or double brick construction or slab-on-ground construction are generally either

impossible or too expensive to raise. Houses best suited to raising are timber framed and clad with non-masonry materials.

Freeboard

46. At times, there is confusion about the need for and amount of freeboard to be adopted in setting floor levels, etc. Freeboard incorporates such factors as:
- uncertainties in estimates of flood levels which can arise from a relatively short database of past floods, together with uncertainties and simplifications in the models used to predict flood discharges and flood levels;
 - differences in water levels across the floodplain because of 'local factors' not included in hydraulic models;
 - cumulative effect of subsequent infill development;
 - increases in water level as a result of wave action which can be of two types: wind-induced waves across fetches of open water and waves induced by powerboats and vehicles moving through flooded areas; and
 - increases in coastal water levels as a result of the Greenhouse Effect, eg increased storm rain will result in increased downstream flood levels in coastal rivers, with associated increases in storm surge.
47. In addition, freeboard also reduces the likelihood of sewer surcharges into buildings and provides an in-built factor of safety for floods slightly higher than the designated flood event.

FLOOD EMERGENCY MEASURES

48. Flood emergency measures include flood forecasting, flood warning, plans for defending and evacuating an area, for relieving evacuees and for recovering the area once the flood subsides. All these flood response measures are incorporated in the area's local flood plan, which is prepared by the lead Emergency Services agency in consultation with the floodplain management advisory committee. The flood emergency plan is complementary to the floodplain management plan.
49. The importance of flood emergency planning has become apparent in recent years, and was recently confirmed by experiences at Nyngan in New South Wales (1990) and Katherine in the Northern Territory (1998). Unless the PMF is adopted as the defined flood event, all structural and planning measures will ultimately be overwhelmed at some time by a larger flood. Developing and implementing effective flood emergency plans is the only means of reducing the damage and hazard associated with residual risk.

50. Preparedness measures, such as flood warning and evacuation, can be of substantial benefit in their own right. Flood warning and evacuation plans are an effective way to reduce the intangible as well as the tangible costs of flooding. Such plans may be the only economically justified management measure in situations where a relatively small number of people are subjected to an unacceptable degree of flood risk.

FLOOD AWARENESS

51. Not only do effective flood emergency plans need to be developed, but the affected community must be made aware—and remain aware—of their role in the overall floodplain management strategy for their area, including defending their town and evacuating themselves (and possibly personal possessions). Sustaining an appropriate level of flood awareness is not easy. It involves a continuous effort by local councils in conjunction with State and Territory Emergency Services. The cost of such efforts can be regarded as the maintenance cost of a flood emergency plan.
52. Irrespective of the available warning time, there is generally widespread variation in flood awareness from community to community and from household to household. This was demonstrated by surveys done of people's responses to the August 1986 floods of the Georges River, New South Wales:
- There was almost no effective warning time for these floods. Nevertheless, two person-hours of effort by a household with a high degree of flood awareness reduced damages by an amount that was some \$3,000–\$4,000 greater than that achieved by a household with a low degree of flood awareness.
 - Flood-affected residents in the New South Wales town of Forbes typically evacuate all their goods and possessions with little fuss or bother, even down to removing internal doors. These residents have ample warning time (two to three days) and are flooded regularly (three times in 1990). Hence, they are very flood aware.
53. The principal factor determining the degree of flood awareness in a community is usually the frequency of moderate to large floods in the recent history of the area. The more recent and frequent the flooding, the greater the awareness.
54. One difficulty with flood emergency planning is maintaining an adequate level of flood awareness during the extended periods when moderate to severe flooding does not occur, particularly in the face of population turnover. A continuing awareness program must be put in place to inform new residents, maintain the level of awareness of old residents and to cater to changing circumstances of flood behaviour,

new developments, etc. An effective awareness program requires an on-going commitment by the local agency.

FLOODPLAIN MANAGEMENT STUDY

1. A floodplain management study aims to identify all relevant issues, quantify them and weigh them appropriately into an overall plan by which the community as a whole is better off. Risk management planning plays a key role in this process. Like any social planning process, undertaking a floodplain management study and formulating an appropriate plan involves discussion and trade-off with various groups of stakeholders within the community.

PRIOR DECISIONS AND SUPPORTING STUDIES

2. By the time a floodplain management study commences, a number of important decisions and actions in the floodplain management process should already have been made:
 - appointment of a floodplain management advisory committee; and
 - commencement of a number of supporting studies, namely the flood study (described in Annex A), socio-economic studies, environmental studies and land use studies.
3. Socio-economic and environmental studies are important elements of a floodplain management study. These studies provide essential background information for assessing the impact and effectiveness of potential management measures.

Socio-Economic Studies

4. Floods and management measures to reduce flood risk can impose a variety of socio-economic costs on flood-affected communities. For example, the current flooding situation on any given populated floodplain has associated tangible, intangible and social costs. The cost of management measures needs to be weighed against the benefits of a reduction in flood risk and flood damage, it being noted that management measures may have quite high associated economic and social costs in themselves. To objectively compare issues and management measures, it is necessary to gather a variety of socio-economic data. Accordingly, flood damage assessment and social impact studies may be required.
5. The social impact of floods on the community, ie the community's vulnerability to flooding, needs to be assessed. For example, is flooding a regular occurrence and is the community flood aware?; or is a flood likely to have a highly disruptive effect on the community?
6. Floodplain management advisory committees should be aware of the need for socio-economic data and instigate appropriate studies as early as is practical.

Environmental Studies

7. Structural floodplain management measures, such as levees, detention basins and stream clearing, may have significant impacts on the floodplain environment. Environmental impact studies may be required.
8. Quite apart from potential adverse environmental impacts, under the provisions of various State and Territory environmental policies, local agencies and state agencies are required to consider enhancement of the river and floodplain environment. Thus, flora, fauna and habitat surveys may be required in their own right, together with studies that place the existing river and floodplain environment into the wider context of the 'total catchment' (in terms of relative importance, potential for enhancement, etc).
9. Again, floodplain management advisory committees should be aware of the need for the above types of environmental information and instigate appropriate studies as early as is practical.

Land Use Studies

10. In addition to socio-economic and environmental studies, a variety of land use studies also needs to be undertaken. These studies should encompass existing land use, likely future land use, location of existing urban infrastructure services, any excess capacity therein, etc. (Excess capacity in the water and sewer mains serving a flood-prone area may well justify the cost of additional management measures, this cost possibly being offset by savings in not having to provide additional infrastructure elsewhere.)
11. An important aspect of these studies is the desired or likely mix of future land use. It is only by effectively managing future land use that the rate of growth in flood damage can be reduced.
12. Land use studies must also address the community's aspirations for the use of flood-prone land. Local aspirations may be affected by State and regional land use policies, including integrated catchment management policies. It is important that floodplain management advisory committees are aware of and take into account broader land use policies. Again, any supporting local land use studies need to be commenced as early as practicable.

DEFINED FLOOD EVENTS

13. An important aspect of the floodplain management study is selection, by the floodplain management advisory committee, of defined flood events (DFEs) to be used for management purposes in the floodplain management plan. Before selecting DFEs, it is necessary to investigate the potential behaviour, hazard and damage of a range of flood events up to and including the PMF.

14. Selecting a DFE is not easy: selecting too mild a flood event will intensify the frequency and adverse consequences of larger flood events; selecting too severe an event will maximise the cost of management and mitigation measures.
15. A further complication is that, in general, different flood events will be appropriate to different management objectives, eg the DFE used for setting residential floor levels may not be appropriate for determining the location and floor levels of key infrastructure facilities, such as hospitals, telephone exchanges, police stations, etc.
16. It must be remembered that DFEs do not represent the maximum flood level or the maximum extent of flood-prone land. By definition, flood-prone land is all land flooded by the PMF event. DFEs generally define areas of land (defined flood areas) to which development and building controls and conditions apply.

RISK MANAGEMENT

17. Risk management provides an objective means of selecting DFEs. By considering the likelihood of occurrence of a range of flood events and their associated hazards, ie risks to life and limb and damage, together with the cost and benefits of various management options, it is possible to weigh the risks and costs of floods of various sizes against the benefits (ie reduction in risk) of various management measures. The risk management process is described in some detail in Annex E.

HYDRAULIC AND HAZARD CATEGORIES

18. An important aspect of the floodplain management study is identifying defined floodway and flood fringe areas of the floodplain and areas of low and high hazard. Identifying these areas is essential for responsible land use planning across the floodplain.
19. A flood study provides much of the information needed to define the hydraulic and hazard categories of flood-prone land, such as:
 - factors that influence the extent of the defined floodway and defined flood fringe areas (see Annex E); and
 - a variety of factors which affect flood hazard, eg depth, velocity and rate of rise of flood waters (see Annex E).
20. Future developments can influence hydraulic and hazard ratings and need to be appropriately considered on a cumulative impact basis when defining hydraulic and hazard categories.

FLOODPLAIN MANAGEMENT PLAN

21. Having assembled all the necessary information, it is then a matter of distilling a coherent and integrated floodplain management plan that provides equitable and efficient measures to effectively manage the

existing, future and residual flood risk and flood hazard problems.

22. This is not an easy process. Management measures have both advantages and disadvantages: whilst a proposed control, eg a levee, may alleviate flood damage, it may be detrimental to the environment in a general sense (eg loss of habitat, visual intrusion), and in a particular sense (eg it may adversely affect flood levels elsewhere). Annex D describes various elements of a floodplain management plan in some detail.
23. The floodplain management advisory committee oversees development and implementation of the floodplain management plan (see Annex D).

LOCAL FLOODPLAIN MANAGEMENT POLICY

24. Another key outcome from a floodplain management study is formulation, by the floodplain management advisory committee, of a local floodplain management policy. This policy should succinctly present the local agency's considered view on using and developing flood-prone land.

PUBLIC CONSULTATION

25. The public has an important role to play in better floodplain management, and especially in managing flood emergencies. To effectively meet their obligations, there is a real need for members of the public to be informed of flood risk, hazard and behaviour in their communities and of what actions they should take when a flood threat arises.
26. Public consultation during the course of a floodplain management study facilitates information flow to and from the floodplain management advisory committee concerning flooding matters of relevance to the community, and of the advantages and disadvantages of potential management measures. A series of public meetings over the course of the study allows the committee to inform the public of the progress of the study and to seek public opinion on specific issues.
27. Floodplain management advisory committees need to be aware of the importance of public consultation and facilitate this process during the course of the floodplain management study.

FLOODPLAIN MANAGEMENT PLAN

1. A floodplain management plan forms the heart of effective floodplain management. It is based on a comprehensive and detailed evaluation of all factors that affect and are affected by use of flood-prone land; it represents the considered opinion of the local community, the local agency and State agencies on how best to manage flood-prone land; and it provides a long-term path for future development of the community.
2. This Annex describes various elements of a floodplain management plan and describes a procedure to help weigh up options with conflicting consequences. It is not possible to provide specific guidelines for formulating a floodplain management plan because of the wide variety of issues to be canvassed and their changing significance from community to community. However, general elements of a plan can be identified and discussed.

DEFINITION OF ISSUES

3. It is imperative, at the outset, to identify and define the objectives and issues of a floodplain management plan. Failure to do so will lead to confusion and wasted effort. These issues can be of a social, economic, ecological and community nature, quite apart from flooding considerations.
4. The floodplain management advisory committee, in consultation with State agencies, expert advisers and the local community, is responsible for defining appropriate objectives and identifying significant issues associated with using flood-prone land.

POTENTIAL MANAGEMENT MEASURES

5. Floodplain management measures are detailed in Annex B. Key issues concerning various management measures are noted here.

Land Use Planning Controls

6. Land use controls, to ensure land use on flood-prone land is compatible with flood risk, are essential if the rate of growth in future flood damage is to be reduced.
7. Once flood-related planning measures have been finalised, it is important to formalise flood-related zonings and to incorporate the measures into statutory planning instruments.
8. It is also important to ensure zonings are defined so requirements based on the effects of cumulative impact can be adequately applied to individual proposals that may, in isolation, have minimal impact.

Structural Works

9. The feasibility, effectiveness and economics of various structural means of control need to be considered. Structural measures modify flood behaviour. Whilst they might reduce flood discharges and levels in the area of interest, such works may increase flood discharges and levels elsewhere. The hydrologic and hydraulic models developed in the flood study will need to be used to assess the impact of structural works on flood behaviour.
10. The various State water resources agencies can provide guidance and advice on technical aspects of structural works. Structural works have associated environmental, economic and social costs, which need to be evaluated. The floodplain management advisory committee may need to consider engaging specialist consultants to undertake these studies.
11. When contemplating and evaluating structural works, local agencies should be aware of the possible environmental benefits of such works, eg detention basins can also serve to improve water quality, river improvements can incorporate wetlands.

Development and Building Controls

12. Development and building controls are essential to limit resultant damage to flood-prone buildings.

Flood Emergency Planning

13. A flood emergency plan to address residual flood risk is essential. Such a plan is complementary to the broader floodplain management plan.
14. Local agencies have access to many of the resources needed for flood emergency planning and response (eg manpower, plant and machinery, buildings, etc.). It is essential to establish a cohesive working relationship between local agencies and emergency service agencies to fully utilise available resources.
15. Flood emergency plans are aimed at modifying the community's response to the onset and aftermath of a flood. No matter how accurate and timely a flood warning, and no matter how well thought out the emergency plan, **much effort will be wasted unless the community responds effectively**. Thus, there is a real need to make the community fully aware of its responsibilities in the onset and aftermath of a flood, and moreover, to maintain this awareness by a program of regular re-education of people living in flood-prone areas.

ASSESSMENT OF OPTIONS

16. Formulating a floodplain management plan involves considering

various options concerning land use and the mitigation of flooding, flood risk and flood hazard, together with an assessment of the social, economic and environmental consequences of proposed land uses and mitigation measures.

17. The risk management approach can help select defined flood events and measures to address existing, future and residual risks. However, these measures will generally have different economic, social and environmental impacts.
18. Formulation of a floodplain management plan is an exercise in decision-making aimed at achieving multiple and often conflicting objectives. The assessment process can be quite difficult because of the different nature of the underlying issues. For example, one development plan may be preferable from the community's point of view, but at an increased risk of flooding—an alternative plan may be environmentally preferable, have a lesser risk of flooding, but may be less desirable from the community viewpoint. How can these two plans be compared?
18. The easiest way is to use a matrix method of comparison. In this system, a matrix is prepared in which columns consist of various management options and rows consist of various floodplain management objectives and issues.

Matrix Method

20. It is necessary to assess how well the management options meet the objectives and issues and enter this information into the matrix. Where possible, the advantages and disadvantages of each option should be quantified. This can be done relatively easily in terms of the costs of flood mitigation measures and the associated reduction in flood damage. In other areas, such as the environment, community desires, etc., it is difficult to make a quantitative estimate. In these cases, a qualitative estimate of the advantages and disadvantages of the option needs to be made and entered into the matrix, eg ranking outcomes on an ordinal scale of (say) one (best) to five (worst).
21. Once the matrix has been prepared, it provides a framework for comparing the options on an issue-by-issue basis. The best option for each issue can then be determined; issues still in doubt can be identified and further investigated. This process facilitates comparison of options, both individually and collectively, leading to a balanced decision regarding the 'best' option(s).

ADOPTED PLANS

22. A floodplain management plan is never truly finished. Social and economic circumstances change; flooding behaviour may be

substantially altered by future developments or measures adopted in other areas of the catchment. A floodplain management plan represents the best appraisal of existing and likely future circumstances at the time the plan is adopted. For this reason, we do not speak of 'final' floodplain management plans, but of 'adopted' floodplain management plans, ie plans that have been adopted for the immediate future. Plans should be reviewed regularly (say every five to 10 years) to ensure their provisions remain current and appropriate.

SPECIFIC ISSUES OF CONCERN

23. Preparation of floodplain management plans in the States and Territories of Australia over the last five to 10 years has identified a number of specific issues of concern. **These issues are described below and should they arise in a particular flooding situation, need to be treated with diligence because of their potential significance.**

Future Planning Considerations

24. Preparing a floodplain management plan involves a realistic appraisal of desired and realisable future land uses. If future land use is not considered and appropriately incorporated in the plan, the benefits of measures implemented today may be overrun by the impacts of future development. To encompass the possibility of large-scale land use change and urban redevelopment, the planning horizon should be 20 to 30 years.
25. To this end, future land use planning provisions of a floodplain management plan need to be well researched, well publicised and based on community consultation.

Cumulative Impacts

26. A common problem on many floodplains across the nation is the cumulative impact of development. As developments are built, each may have an individually small effect on flood behaviour. However, the cumulative effect on flood behaviour of all these developments can be significant. Common examples of cumulative adverse effects are:
- progressive blocking of floodways and flow paths by individual developments;
 - filling of inappropriate floodplain areas on an ad hoc basis; and
 - increase, over time, in the at-risk population living and working in the more hazardous areas of the floodplain.
27. Whilst it is true that each development by itself may not lead to a significant increase in flood levels or flood hazard, the increase occasioned by the cumulative effect is often unacceptable.

28. This is one of the principal reasons this plan requires a ‘total catchment approach’—cumulative effects need to be evaluated before they occur. This involves:
- identifying the location and encroachment of ‘allowed’ development;
 - undertaking hydraulic and hazard studies to assess the impact of cumulative development in these areas; and
 - formulating planning, building and development controls to ensure future developments conform to the adopted plan.
29. ‘Conforming’ developments may proceed; ‘non-conforming’ developments should not be allowed unless compensating measures are fully investigated and implemented.

Infrastructure Protection

30. Careful consideration needs to be given to protecting essential infrastructure services, such as water supply, sewerage, telephone and electric power during the onset of a flood. The ready restoration of these services after the flood will facilitate clean-up and recovery, thereby minimising social disruption to the community.
31. Protection activities that could be considered include building temporary bunds around sewage treatment plants, water treatment plants and electricity sub-stations. Alternatively, design and fabrication to allow electric motors to be uncoupled and removed from pumps in flood-liaible sections of the sewerage and water supply systems will facilitate reactivation of these systems after the flood.
32. Needless to say, if new or upgraded infrastructure facilities are proposed, all endeavours should be made to locate them in flood-free areas, render them flood proof, or ensure services can be easily restored after a flood.

Larger Floods

33. It is essential that all floodplain management plans consider the implications of the full range of flood sizes—up to and including the PMF event—on flood risk and the management process in general. Management measures that may be appropriate for the defined flood event may be inadequate for larger floods.
34. The choice of DFEs is often a difficult compromise between increasing marginal costs of structural measures and decreasing marginal benefits. Whilst it is desirable to adopt the highest level of protection, this is not always economically possible.
35. Unthinking acceptance of the limited level of protection provided by structural measures, must give way to the need for flood emergency plans to mitigate the hazard associated with larger flood events.

36. The definition of the floodplain and flood-prone land should always be based on the PMF event and not on the more limited area inundated by defined flood events. In this way, the community will be aware of the possible extent of flooding and of their own need for appropriate action in the case of extreme events.

Levees

37. Levees are a tried and true flood protection measure—as long as they are not overtopped in an uncontrolled fashion and do not fail. It is essential to assess the consequences of levee overtopping in some detail, and to put appropriate emergency plans in place.

Islands

38. Formation of islands on the floodplain during a flood is always potentially hazardous and is generally **to be avoided**. People trapped on islands may be 'safe' during small floods, but at high risk in extreme floods. Development of land that becomes isolated prior to inundation increases the load on State/Territory Emergency Services during flood events. Furthermore, rescuing people from islands may place rescuers at undue risk.

Detention Basins

39. Detention basins are being increasingly used to control the peak discharge from newly-urbanised areas. Some basins are becoming quite large; in fact, they are more properly regarded as small dams and should be designed as such.
40. The potential hazard to downstream areas associated with overtopping and breaching of detention basin embankments ('dambreak') needs to be carefully addressed when designing these basins.
41. Special care needs to be taken when a system of basins is built on the tributaries of urban catchment. The likelihood and consequences of a 'cascade' failure of these basins needs to be assessed, ie the flood wave associated with the failure of an upper basin causing downstream basins to fail, so magnifying the resulting dambreak flood.

FLOOD HAZARD

1. Flood hazard, or threat to life and limb and damage caused by a flood, varies both in time and place across the floodplain. Flood waters flow swift and deep at some locations; in other places, they are shallow and slow-moving. The variation of hazard and flood behaviour across the floodplain need to be understood by flood-prone landholders, floodplain managers and flood emergency managers.
2. This Annex describes how the floodplain should be divided first, into 'defined floodway' and 'defined flood fringe' areas that reflect flooding behaviour, and the likely impact of future developments on this behaviour, and second, into areas reflecting the degree of hazard.

FACTORS AFFECTING FLOOD HAZARD

3. A variety of factors affect the hazard and disruption caused by a flood event. These factors can be grouped into the four broad categories of flood behaviour, topography, population at risk and emergency management.. Table E:1 identifies various factors in these categories.

Table E:1—Major factors affecting flood hazard

Flood Behaviour	Topography	Population at Risk	Emergency Management
Severity	Evacuation routes	Number of people	Flood forecasting
Depth	Islands	Number of developments	Flood warning
Velocity		Type of land use	Flood response plans
Rate of rise		Flood awareness	Evacuation plans
Duration			Recovery plans

Severity of Flood

4. The severity or size of a flood is generally the principal determinant of hazard. Not only does it affect aspects of flooding behaviour that individually influence hazard, eg depths, velocities, rates of rise, it also determines the number of people at risk. It is impossible to predict in advance when flooding will occur or the size of the flood. Further, there is no guarantee that, if a severe flood has occurred recently, another flood, perhaps larger, will not occur in the near future.

Depth and Velocity of Flood Waters

5. The threat to life and limb and gross structural damage (ie houses being washed away) caused by floods depend largely on the velocity of flow and depth of flood waters. These in turn are dependent on the size of the flood and the hydraulic characteristics of the river and its floodplain. Issues to consider include the following:
- Wading by able-bodied adults becomes difficult and dangerous when the depth of still water exceeds 1.2 metres, when the velocity of shallow water exceeds 0.8 metres per second, and for various combinations of depth and velocity between these limits.
 - In assessing the safety of wading, a number of factors other than depth and velocity need to be taken into account—is the ground surface even or are depressions, potholes, fences or major stormwater drains present, etc?
 - Small, light, low motor vehicles crossing rapidly-flowing causeways can become unstable when water depths exceed 0.3 metres. Evacuation by larger, higher sedans is generally only possible and safe when water depths are less than 0.4 metres.
 - As the depth of flood water increases, caravans and buildings of light construction will begin to float. In these circumstances the buildings can be severely damaged when they settle unevenly in receding flood waters. If the flood velocity is significant, buildings can be totally destroyed and cars and caravans can be swept away. In certain areas, the build up of debris and the impact of floating logs can cause significant structural damage to buildings and bridges.
 - At velocities in excess of two metres per second the stability of foundations and poles can be affected by scour. Grass and earth surfaces begin to erode, scour holes can develop.
 - At depths in excess of two metres, light-framed buildings can sustain damage from water pressure, flotation and debris impact, even at low velocities.
 - An important factor that tends to increase the depth of flooding, and hence the overall degree of flood damage, is the presence of obstructions to movement of flood waters. Such obstructions include buildings, embankments and bridges, areas built up by land-fill, and the blocking effect of trees, shrubs, fences and debris. The increase in flood levels depends on the velocity of the flood waters and the degree to which they are obstructed.

Rate of Rise of Flood Waters

6. The rate of rise of flood waters also affects the degree of hazard caused by a flood. Situations in which flood waters rise rapidly are

potentially far more dangerous than situations in which flood levels increase slowly. Typically, the rate of rise of flood waters is more rapid in small, steep catchments than in their larger, flatter counterparts.

7. Extremely high rates of rise of flood waters have been recorded in Australia, eg during the 1894 floods in the Kimberley District of Western Australia, the Lennard River rose at a rate of 0.9 metres per hour for 20 hours, the Fortescue River rose a reported 9 metres in 30 minutes and the Fitzroy River rose 18 metres in a 'few hours' (Commonwealth Bureau of Meteorology 1929).

Duration of Flooding

8. The duration of flooding or length of time a community, town or single dwelling (eg farm house) is cut off by flood waters can have a significant impact on the costs and disruption associated with flooding. Extended periods of isolation in stressful situations can exacerbate post-event anxiety and trauma-related disorders; shortages of water and food may occur thereby placing high demands on limited emergency services; medical emergencies may occur with treatment delayed or at worst prevented.
9. The duration of flooding generally correlates with the rate of rise of flood water, typically being longer for slow rates of rise (larger, flatter catchments) and shorter for rapid rates of rise (smaller, steeper catchments).

Evacuation Problems

10. The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation, may be difficult because of:
 - the number of people needing help;
 - the depth and velocity of flood waters;
 - wading problems (exacerbated by uneven ground, fences, debris, localised high velocities, etc);
 - the distance to flood-free ground;
 - the loss of trafficability on evacuation routes because of rising flood waters;
 - bottlenecks on evacuation routes, ie roads cannot cope with the increased volume of traffic, the large number of people and great volume of goods to be moved;
 - inability of those in need to contact emergency services; and
 - a shortage of resources (eg boats, heavy trucks, helicopters, etc).

Effective Flood Access

11. The availability of effective access routes from flood-prone areas and developments can directly influence the resulting hazard when a flood occurs.
12. 'Effective access' means a high-level exit route that remains trafficable for sufficient time to evacuate the population at risk, ie evacuation can be undertaken solely by motor vehicle.
13. In a number of urban development situations, access to flood-prone residents can be lost relatively early in the flood episode:
 - Where evacuation routes lead downhill onto and across the floodplain access to the evacuation route and trafficability can be lost because of rising flood waters.
 - Where cul de sac developments, built on rising land, have only downhill access vehicular access is likely to be lost early. It may be possible to evacuate residents by walking to high land behind the development, but motor vehicles and possessions which could have been transported by those vehicles will have to be abandoned.
 - It is becoming increasingly common to use roadways as overland flow paths to cater for severe stormwater flooding episodes. If these roadways also act as 'preferred' flow paths for mainstream flooding, their trafficability will be reduced early.
14. Thus, there is considerable benefit to be gained from taking possible evacuation needs into account in designing regional and local road networks for flood-prone areas.
15. Access is generally divided into two categories: pedestrian and vehicular. Providing road access that is trafficable in all weathers will obviously help reduce the flood hazard and enhance the effectiveness of emergency services, etc. Pedestrian access is far less effective due to problems with moving the aged, children and the disabled.
16. It is essential that the suitability of access routes be investigated for a range of flood events. Arrangements and evacuation routes which may be suitable for flood events up to the DFE may become unsafe or inoperable for more severe floods. In potentially hazardous situations, provision should at least be made for pedestrian access routes in extreme flood events. Without such access, the risk to life and limb of the entrapped and their rescuers may be unacceptable.
17. A potentially hazardous situation develops when rising flood waters isolate an area of land, leaving it as an island in a sea of flood water. The degree of hazard depends on the depth, velocity and rate of rise of flood waters between the island and possible places of refuge. Vehicle access may rapidly be cut. Rescue by boat, helicopter or large vehicle

may be necessary, so putting rescuer's lives at risk. Whilst such a situation may not develop for 'normal' floods, a check should be made to see whether or not rare flood events cause islands to develop, or even worse, to subsequently be submerged.

Population at Risk

18. The degree of hazard and social disruption obviously varies with the size of the population at risk. The larger the population at risk, the greater the flood damage and the greater the number of people who need to be evacuated.

Land Use

19. The type of land use also influences hazard. There are considerably greater difficulties in evacuating a hospital or an old people's home than an industrial area. Conversely, flooding in industrial areas may result in toxic industrial products escaping.

Flood Awareness

20. 'Flood awareness' refers to the ability of the population at risk to know what to do and how to do it effectively in the onset of a flood. A flood aware population is effective in evacuating itself and its possessions, thereby reducing hazard.
21. Flood awareness is largely related to past experience with flooding. Flood awareness greatly influences the time taken by flood-affected people to respond in an effective fashion to flood warnings.
22. In communities with a high degree of flood awareness, the response to flood warnings is prompt, efficient and effective. The community as a whole knows what to do on receipt of a flood warning; people as individuals know how to respond; residents and property owners have developed personal evacuation plans and can implement them effectively on receipt of a flood warning.
23. Promotion of flood awareness by public education campaigns is an essential component of flood emergency planning.

Warning Time

24. Flood hazard can be reduced by evacuation if adequate time is available. However, even if people and possessions are fully evacuated, a flood will still cause significant damage to buildings and infrastructure and still wreak substantial community disruption.
25. **Available warning time** is determined largely by catchment characteristics. The larger the catchment and the slower the rate of rise of flood waters, the longer the available warning time. In small steep catchments, there is often no available warning time, as the catchments respond too quickly.

26. In large catchments, flood warnings can be based on rates of rise and peak water levels at upstream gauges. In smaller, more responsive catchments, flood warnings need to be based on rainfall measurements. These days, automatic monitoring equipment is available to measure water levels and rainfalls.
27. In the smallest catchments, warnings need to be made on predictions of likely rainfall made before the rainfall occurs. Radar can detect the location and extent of heavy rainfall cells and provide the basis for short-term forecasts of rainfall in combination with meteorological forecasting models. Radar suitable for this task have been installed at various locations around Australia, although additional infrastructure including ground-based observations and processing systems are also needed.
28. **Effective warning time**, or actual time available for people to evacuate themselves and their possessions, is always less than the available warning time because of the time needed, firstly, to alert people to the imminence of flooding (by radio, loud-hailer, television, word of mouth), and secondly, to have them commence effective evacuation procedures.

DEGREE OF HAZARD

29. The degree of hazard varies across the floodplain in response to the above factors. As part of the floodplain management process, it is necessary to determine hazard. This is of considerable significance to the appropriateness or otherwise of various land uses.
30. This document recognises four degrees of hazard: low, medium, high and extreme.
 - **In low-hazard areas** of the floodplain, there are no significant evacuation problems. If necessary, children and elderly people could wade to safety with little difficulty; maximum flood depths and velocities along evacuation routes are low; and evacuation distances are short. Evacuation is possible by a sedan-type motor vehicle, even a small vehicle. There is ample time for flood forecasting, flood warning and evacuation; and evacuation routes remain trafficable for at least twice as long as the time needed for evacuation.
 - **In medium-hazard areas**, fit adults can wade to safety, but children and the elderly may have difficulty; evacuation routes are longer; and maximum flood depths and velocities are greater. Evacuation by sedan-type vehicles is possible in the early stages of flooding, after which 4WD vehicles or trucks are required. Evacuation routes remain trafficable for at least one and one-half times as long as the necessary evacuation time.

- **In high-hazard areas**, fit adults have difficulty wading to safety; wading evacuation routes are longer again; and maximum flood depths and velocities are greater (up to 1.0 metre and 1.5 metres per second respectively). Motor vehicle evacuation is possible only by 4WD vehicles or trucks and only in the early stages of flooding. Boats or helicopters may be required. Evacuation routes remain trafficable only up to the minimum evacuation time.
- **In extreme-hazard areas**, boats or helicopters are required for evacuation; wading is not an option because of the rate of rise and depth and velocity of flood waters. Maximum flood depths and velocities are over 1.0 metre and over 1.5 metres per second respectively.

ESTIMATION OF HAZARD

31. An appropriate flood hazard estimation procedure needs to involve assessment of all components of flood hazard shown in Figure E:1. Stability is a key component of this procedure.
32. The two principal factors that affect the stability of pedestrians wading through flood waters and motor vehicles traversing flooded roads are the depth and velocity of the flood waters. Pedestrians can be swept away by loss of friction (grip) between their shoes and the roadway (sliding), and being overtopped by flowing water (toppling).
33. Motor vehicles lose stability through loss of friction between their tyres and the roadway, leading to the vehicle being swept downstream.
34. There is a broad range of stability estimation procedures available. These are, however, inconsistent and inadequate in covering the depths and velocities likely to be encountered, and the data used may be significantly outdated (Walsh et al 1998). For this reason, no relationships between depth and velocity are recommended in this document. A comprehensive testing program of people, vehicles and structures is needed before definitive design guidelines can be presented.
35. It should be noted that any study on the impacts of flood hazard on people needs to consider not only the physical issues of flooding but also the psychological effects on people faced by floods.

Hazard Graphs

36. Emergency services agencies are responsible for undertaking hazard analyses as part of preparing a flood emergency plan. This can be a lengthy process as it requires detailed results from a flood study and an assessment of all factors affecting hazard, such as flood behaviour, flood awareness, possible evacuation problems.

Figure E:1—Estimation of Hazard along Evacuation Routes

HAZARD MAPS

37. Hazard maps of the floodplain are generally useful to local agencies and State/Territory Emergency Services. In preparing such maps, it is important to define hazard zones in 'broad brush' terms and to 'smooth out' any excessively detailed variation of hazard.

GLOSSARY

annual exceedance probability (AEP)

The likelihood of occurrence of a flood of a given size or larger in any one year; usually expressed as a percentage. For example, if a peak flood discharge of 500 m³/s has an AEP of 5 per cent, it means that there is a 5 per cent risk (ie a probability of 0.05 or a likelihood of one in 20) of a peak flood discharge of 500 m³/s or larger occurring in any one year (see also probability, likelihood of occurrence, average recurrence interval, flood risk).

annual flood risk (AFR)

Another way of specifying the likelihood of flooding, eg the 1 per cent AEP flood has a probability of 0.01 of occurring in any year; the risk of this flood occurring in any one year (annual flood risk) is 1 in 100 or 1/100.

average annual consequences

The average consequence associated with a series of annual events, each with its own probability of occurrence and consequence (see average annual damage).

average annual damage (AAD)

The average cost of flood damage per year to a nominated development situation caused by flooding over a long period of time. In many years there may be no damage, in some years there will be minor damage (caused by small, relatively frequent flood events) and in a few years there will be major damage (caused by large, rare flood events). If the damage associated with various annual events is plotted against their probability of occurrence, the average annual damage is equal to the area under the consequence/probability curve. Average annual damage provides a basis for comparing the economic effectiveness of different management measures, ie their ability to reduce the AAD (see average annual consequence).

average recurrence interval (ARI)

A statistical estimate of the average period in years between the occurrence of a flood of a given size or larger, eg floods with a discharge as big as or larger than the 100-year ARI flood event will occur on average once every 100 years. ARI is equal to the reciprocal of annual flood risk, eg an AFR of 1/100 has an ARI of 100 years. Note that the ARI of a flood event

gives no indication of when a flood of that size will next occur.

chance	The likelihood of something happening that will have beneficial consequences, eg the chance of a win in a lottery (see risk). Chance is often thought of as the 'upside of a gamble'.
consequence	The outcome of an event or situation, expressed qualitatively or quantitatively. Consequences can be adverse, eg death or injury to people, damage to property and disruption of the community, or beneficial.
dambreak flooding	Flooding caused by the breaching of a dam embankment. Note that dambreak flooding may inundate areas outside the floodplains defined in this manual.
defined flood area	That area of the floodplain covered by flood waters during the defined flood event.
defined flood events (DFEs)	Flood events selected for managing flood hazard, as determined in floodplain management studies and incorporated in floodplain management plans. Selection of DFEs should be based on an understanding of flood behaviour and the associated risk and consequences of flooding. It should also take into account the social, economic and environmental consequences associated with floods of different severities. Different DFEs may be appropriate for structural measures (eg levees), different categories of land use and for emergency services planning. The concept of a range of DFEs supersedes sole focus on the 100-year flood event (the 1/100 flood), as in earlier practice. DFEs do not define the extent of flood-prone land, which is defined by the Probable Maximum Flood (PMF).
defined flood fringe	The remaining area of land inundated by the defined flood event after defined floodway areas have been defined (see defined floodway).
defined flood level	The flood level associated with a defined flood event.
defined floodway	Those areas of the floodplain where significant discharge or storage of water occurs during a defined flood event. Floodways are areas which, if filled or even partially blocked, would cause a

significant redistribution of flood flow, or significant increase in flood levels. Floodways are often aligned with naturally defined channels and are often, but not necessarily, areas of deeper flow or areas where higher velocities occur, and also include areas where major storage of flood waters occurs. Each defined flood event has a 'defined floodway' and the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods (see defined flood fringe).

denial syndrome	The denial of flood risk, the belief that 'it can't happen to me'.
detention basin	A generally small self-draining storage constructed on a creek or drain that mitigates downstream flood discharges and flood levels by providing temporary storage to flood waters.
discharge	The rate of flow of water, as measured in terms of volume per unit time, eg cubic metres per second (m^3/s).
effective warning time	The time available for evacuating people and their possessions before the onset of flooding, ie the time available for people to evacuate themselves and their possessions or to take other flood counter-measures. The effective warning time available to a flood-prone community is equal to the time between the delivery of an official warning to prepare for imminent flooding and the loss of evacuation routes due to flooding. Improved flood forecasting systems and warning delivery systems increase the available warning time.
exceedance probability	A quantitative measure of the likelihood of occurrence of an event of a nominated or greater size, eg the exceedance probability of throwing a number equal to 4 or greater on the roll of a die is 3 in 6, or 0.5, or 50 per cent (see probability).
flash flooding	Sudden and unexpected flooding caused by local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within six hours of the rain which causes flooding.

flood	Relatively high water levels caused by excessive rainfall, storm surge, dambreak or a tsunami that overtop the natural or artificial banks of a stream, creek, river, estuary, lake or dam.
flood awareness	The ability of flood-affected landholders to defend themselves, their property and their community from flood threats and to effectively evacuate themselves and their possessions when necessary, ie an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures. In communities with a high degree of flood awareness, response to flood warnings is more likely to be prompt and effective. In communities with a low degree of flood awareness, flood warnings are liable to be ignored or misunderstood, and residents are often confused about what they should do, when to evacuate, what to take with them and where it should be taken.
flood awareness sub-plan	A component of a flood emergency plan. An agreed set of roles, responsibilities, functions and actions to develop and sustain flood awareness in flood-prone communities.
flood damage	The tangible and intangible costs of flooding. Tangible costs are quantified in monetary terms, eg damage to goods and possessions, loss of income or services in the flood aftermath, etc. Intangible damages are difficult to quantify in monetary terms and include increased levels of physical, emotional and psychological health problems suffered by flood-affected people and attributed to a flooding episode.
flood emergency	A condition or situation caused by flooding that requires urgent action or assistance.
flood emergency plan	An agreed set of roles, responsibilities, functions, actions and management arrangements to minimise hazard and protect property and infrastructure from flood events of all sizes. It involves arrangements to prepare for future floods and to respond to and recover from actual flood events. A local flood emergency plan forms an essential component of a floodplain management plan (see flood warning sub-plan, flood evacuation sub-plan and flood recovery sub-plan).

flood evacuation sub-plan	A component of a flood emergency plan. An agreed set of roles, responsibilities, functions, actions and management arrangements to facilitate safe and orderly evacuation of people and possessions during the onset of a flood.
flood fringe	See defined flood fringe.
flood hazard	Potential loss of life, injury and economic loss to property, possessions and infrastructure caused by future flood events. The degree of hazard varies with the severity of flooding.
floodplain	Area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by the probable maximum flood event, ie flood-prone land.
floodplain management advisory committee	A committee formed and chaired by local agency(s) or other appropriate body(s) to oversee development and implementation of a floodplain management plan. The committee should include representatives from all stakeholder groups and all agencies responsible for floodplain management or undertaking developments on the floodplain.
floodplain management measures	The full range of measures available to prevent or reduce flood hazard and disruption, as canvassed in a floodplain management study.
floodplain management options	Measures which might be feasible for managing a particular area of the floodplain. Preparing a floodplain management plan requires a detailed evaluation of management options.
floodplain management plan	The recommended means of assessing and managing the flood risk associated with using the floodplain for various purposes. Usually includes both written and diagrammatic information describing how flood-prone land is to be developed and managed to achieve defined objectives. A floodplain management plan should be developed in accordance with the principles and guidelines of this manual. Plans need to be reviewed at regular intervals to assess progress and to consider the consequences of any changed circumstances that have arisen since the last review.
Flood-prone land	Land subject to inundation by the probable maximum flood event. Floodplain management

plans should encompass all flood-prone land, rather than being restricted to land subject to defined flood events.

flood proofing	A combination of measures incorporated in the design, construction and alteration of individual flood-labile buildings or structures to reduce or eliminate flood damage.
flood recovery sub-plan	A component of a flood emergency plan. An agreed set of roles, responsibilities, functions, actions and management arrangements to facilitate clean-up, social and economic recovery and reinstatement of infrastructure of flood-affected communities.
flood risk	See annual flood risk.
flood severity	A qualitative indication of the 'size' of a flood and its hazard potential. Reference is often made to major, moderate and minor flooding.
flood storage areas	Those parts of the floodplain that are important for temporary storage of flood waters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity. Flood storage areas should be treated as part of the floodway (see floodway).
flood warning sub-plan	A component of a flood emergency plan. An agreed set of roles, responsibilities, functions, actions and management arrangements to produce and disseminate flood warnings to people at risk of imminent flooding.
floodway	See defined floodway.
freeboard	Height above a defined flood level (DFL), typically used to provide a factor of safety when setting floor levels, levee crest levels, etc. Freeboard compensates for effects such as wave action, localised hydraulic behaviour and settlement of levees, which increase flood levels or reduce the level of protection provided by levees. Freeboard also provides protection from floods that are marginally above the DFL. However, freeboard should not be relied on to provide protection for flood events larger than the DFE.
frequency	Measure of likelihood expressed as the number of occurrences of a specified event in a given time, eg the frequency of occurrence of a five-

year ARI flood event is once every five years on average (see likelihood and probability).

hazard	See flood hazard.																																				
high-hazard areas	Large trucks, boats or helicopters are required for evacuating people from high-hazard areas (see negligible, low and medium hazards).																																				
lead agency	The agency identified as being primarily responsible for a specific aspect of floodplain management, eg State and Territory emergency management agencies are the 'lead agencies' with respect to flood emergency management, State and Territory water resource agencies are the 'lead agencies' with respect to provision of technical advice on flooding matters.																																				
likelihood	A qualitative description of probability and frequency (see probability and frequency).																																				
likelihood of occurrence	<p>The likelihood that a specified event will occur. The likelihood of occurrence of flooding can be measured in terms of Annual Exceedance Probabilities (AEPs), Average Recurrence Intervals (ARIs) and Annual Flood Risk (AFR). For example, the 1 per cent AEP flood has an exceedance probability of 0.01, an ARI of 100 years and an AFR of 1/100. The following table presents equivalent measures of the likelihood of flooding.</p> <table> <thead> <tr> <th>AEP %</th> <th>Probability</th> <th>ARI (years)</th> <th>Annual Flood Risk</th> </tr> </thead> <tbody> <tr> <td>50</td> <td>0.50</td> <td>2</td> <td>1/2</td> </tr> <tr> <td>20</td> <td>0.20</td> <td>5</td> <td>1/5</td> </tr> <tr> <td>10</td> <td>0.10</td> <td>10</td> <td>1/10</td> </tr> <tr> <td>5</td> <td>0.050</td> <td>20</td> <td>1/20</td> </tr> <tr> <td>2</td> <td>0.020</td> <td>50</td> <td>1/50</td> </tr> <tr> <td>1</td> <td>0.010</td> <td>100</td> <td>1/100</td> </tr> <tr> <td>0.5</td> <td>0.0050</td> <td>200</td> <td>1/200</td> </tr> <tr> <td>0.01</td> <td>0.0010</td> <td>1,000</td> <td>1/1000</td> </tr> </tbody> </table>	AEP %	Probability	ARI (years)	Annual Flood Risk	50	0.50	2	1/2	20	0.20	5	1/5	10	0.10	10	1/10	5	0.050	20	1/20	2	0.020	50	1/50	1	0.010	100	1/100	0.5	0.0050	200	1/200	0.01	0.0010	1,000	1/1000
AEP %	Probability	ARI (years)	Annual Flood Risk																																		
50	0.50	2	1/2																																		
20	0.20	5	1/5																																		
10	0.10	10	1/10																																		
5	0.050	20	1/20																																		
2	0.020	50	1/50																																		
1	0.010	100	1/100																																		
0.5	0.0050	200	1/200																																		
0.01	0.0010	1,000	1/1000																																		
local agency	The agency or body responsible for preparing a floodplain management plan. Typically a local council in urban areas; may be a catchment management board or river trust in rural areas.																																				
low hazard areas	Fit adults can wade to safety from low hazard areas, but children and the elderly would have difficulties. Evacuation by sedan-type motor																																				

vehicles is possible in early stages of flooding, then 4WD vehicles or trucks are required (see negligible, medium and high hazards).

mainstream flooding

Inundation of normally dry land that occurs when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.

mathematical/computer models

The mathematical representation of the physical processes involved in runoff generation and stream flow. Due to the complex nature of these mathematical relationships, computers are often used to solve the underlying equations. In this manual, the models referred to are mainly involved with rainfall, runoff and stream flow.

medium hazard areas

Fit adults have difficulty in wading to safety from medium hazard areas. Motor vehicle evacuation possible only with 4WD vehicles and trucks. Boats or helicopters may be required (see negligible, low and high hazards).

minor, moderate and major flooding

The various State and Territory Emergency Services organisations and the Bureau of Meteorology use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood:

minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges.

moderate flooding: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered.

major flooding: extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas are flooded.

negligible hazard areas

There are no significant evacuation problems from negligible hazard areas. Elderly people and children would have no undue difficulty evacuating by walking. Evacuation by sedan-type motor vehicle is possible (see low, medium

and high hazard).

peak annual discharge	The highest discharge occurring in each water-year of record.
probability	The likelihood of a specific outcome, as measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between zero and unity, zero indicating an impossible outcome and unity indicating an outcome that is certain. Probabilities are commonly expressed in terms of percentage, eg the probability of 'throwing a six' on a single roll of a die is 1 in 6, or 0.167, or 16.7 per cent.
probable maximum flood (PMF)	The largest flood that could conceivably occur at a particular location. The PMF defines the extent of flood-labile land. Generally, it is not physically or financially possible to provide general protection against this event. It is difficult to define a meaningful annual exceedance probability for the PMF event. It is commonly assumed to be of the order of 10^{-4} to 10^{-7} , ie a flood risk of 1/10,000 to 1/10,000,000.
rainfall depth	The total amount of rain that falls over the duration of a storm.
rainfall flooding	Flooding caused by heavier than usual rainfalls.
rainfall intensity	The rate at which rain falls, typically measured in millimetres per hour. Rainfall intensity varies throughout a storm in accordance with the temporal pattern of the storm (see temporal pattern).
rainfall severity	A qualitative indication of the intensity of rainfall and its potential to cause flooding.
residual flood risk	The remaining level of flood risk that a community is exposed to after floodplain management measures to reduce risk have been implemented, ie 'untreated' flood risk. Residual risks vary with flood severity and may be substantial for flood events that are larger than the DFE adopted for planning purposes or for design of structural works.
risk	The likelihood of something happening that will have an adverse impact on objectives; a measure of potential loss. Risk is specified in

terms of both consequences and likelihood, eg if the 50-year ARI flood event causes \$20 million in flood damage, the risk of a flood causing \$20 million damage is 1 in 50 or 1/50 (see also chance). Risk is often thought of as the 'downside of a gamble'.

risk acceptance	An informed decision to accept the likelihood and consequences of a particular risk.
risk analysis	The systematic use of available information to determine how often specified flood events occur and the magnitude of their likely consequences. Flood risk analysis is normally undertaken as part of a floodplain management study and involves an assessment of flood levels and hazard associated with a range of flood events (see flood study).
risk management	The systematic application of management policies, procedures and practices to the tasks of identifying, analysing, assessing, treating and monitoring flood risk. Flood risk management is undertaken as part of a floodplain management study. The floodplain management plan reflects the adopted means of managing flood risk (see floodplain management study).
storm severity	A qualitative indication of the destructive potential of storms. Tropical cyclones have five categories of severity (see tropical cyclone warnings).
storm surge	The increase in coastal water levels caused by the inverted barometer effect and wind set-up. Some analyses of 'storm surge' also include wave set-up (see wave set-up).
storm tide flooding	Flooding along coastal areas and the tidal reaches of rivers caused by storm surge and wave set-up. Storm tide flooding may inundate areas outside floodplains defined in this manual.
storm tide water levels	Water levels experienced in tidal waters during storms, including the inverted barometer effect, wind set-up, wave set-up and tidal effects, together with any other factors that increase tidal water levels.
stormwater flooding	Inundation by local runoff: can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding

causing urban stormwater drainage system to overflow.

tropical cyclone warnings

The Australian Tropical Cyclone Scale recognises five categories or severities of cyclones, details of which are shown below (Bureau of Meteorology undated). The potential damage associated with cyclones relates more to wind damage than to storm surge damage.

Category	Max wind gust (kph)	Central pressure (hPa)	Potential damage
1	<125	>985	Minor
2	125–170	970–985	Moderate
3	170–225	945–970	Major
4	225–280	920–945	Devastating
5	>280	<920	Extreme

tsunami

Low-crested waves generated in the oceans by underwater volcanic or landslide activity or by underwater earthquakes. As tsunamis move into shallower coastal waters, their height can increase dramatically and extensive coastal areas may be subject to sudden inundation and hazard.

tsunami flooding

Flooding caused by a tsunami which may inundate areas outside the floodplains defined in this manual.

velocity of flood waters

The speed of flood waters, measured in metres per second.

vulnerability

The susceptibility and resilience of a community and the environment to flood hazards. Vulnerability is assessed in terms of the ability of the community and environment to anticipate, cope with and recover from flood events. Flood awareness is an important indicator of vulnerability.

water surface profile

A diagram showing the variation of surface water level along a watercourse.

www.ema.gov.au