Australian Disaster Resilience Handbook Collection

MANUAL 21

Flood Warning

Australian Institute for Disaster Resilience

AUSTRALIAN DISASTER RESILIENCE HANDBOOK COLLECTION

Flood Warning

Manual 21

Australian Government
Attorney-General's Department

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The Australian Institute for Disaster Resilience
370 Albert St
East Melbourne Vic 3002
Telephone +61 (0) 3 9419 2388
www.aidr.org.au

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History of the Australian National Disaster Resilience Handbook Collection

The first publications in the original Australian Emergency Manual Series were primarily skills reference manuals produced from 1989 onwards. In August 1996, on advice from the National Emergency Management Principles and Practice Advisory Group, the Series was expanded to include a more comprehensive range of emergency management principles and practice reference publications.

In 2011, Handbooks were introduced to better align the Series with the *National Strategy for Disaster Resilience*. Compiled by practitioners with management and service-delivery experience in a range of disaster events, the handbooks comprised principles, strategies and actions to help the management and delivery of support services in a disaster context.

In 2015, the Australian Institute for Disaster Resilience (AIDR) was appointed custodian of the handbooks and manuals in the series. Now known as the Australian Disaster Resilience Handbook Collection, AIDR continues to provide guidance on the national principles and practices in disaster resilience in Australia through management and publication of the Collection.

The Handbook Collection is developed and reviewed by national consultative committees representing a range of state and territory agencies, governments, organisations and individuals involved in disaster resilience. The Collection is sponsored by the Australian Government Attorney-General's Department.

Access to the Collection and further details are available at www.knowledge.aidr.org.au.

Australian National Disaster Resilience Handbook Collection (2011 –)

Handbook 1 Disaster health

Handbook 2 Community recovery

Handbook 3 Managing exercises

Handbook 4 Evacuation planning

Handbook 5 Communicating with people with a disability – National Guidelines for Emergency Managers

Handbook 6 National Strategy for Disaster Resilience – community engagement framework

Handbook 7 Managing the floodplain: a guide to best practice in flood risk management in Australia

- **Guideline 7-1** Guideline for using the national generic brief for flood investigations to develop project specific specifications
- **Guideline 7-2** Technical Flood Risk Management Guideline: flood emergency response classification of the floodplain
- **Guideline 7-3** Technical flood risk management guideline: flood hazard
- **Template 7-4** Technical project brief template
- **Guideline 7-5** Technical Flood Risk Management Guideline - flood information to support land-use planning
- **Guideline 7-6** Technical flood risk management guideline: assessing options and service levels for treating existing risk
- **Practice Note 7-7** Considering flooding in land-use planning activities

Handbook 8 Lessons management

Handbook 9 Australian Emergency Management Arrangements

Handbook 10 National Emergency Risk Assessment Guidelines *(plus supporting guideline)*

Guideline 10-1 National Emergency Risk Assessment Guidelines: practice guide

Handbook 11 *renamed Guideline 10-1 National Emergency Risk Assessment Guidelines: practice guide*

Handbook 12 *Spontaneous volunteer management*

Australian Emergency Management Manual Series

The most recent list of publications in the Manuals series includes 46 titles.

The manuals have not been reviewed since 2011 or earlier and the Manual Series is undergoing a review which will see relevant Manuals move into the Handbook Collection. Current and past editions of the Manuals will remain available on the AIDR Knowledge Hub at www.knowledge.aidr.org.au.

Manual Series Catalogue: 2004 - 2011

Manual 1 Emergency management concepts and principles (2004)

Manual 2 *Australian Emergency Management Arrangements (superseded by Handbook 9)*

Manual 3 Australian Emergency Management Glossary (1998)

Manual 4 Australian Emergency Management Terms Thesaurus (1998)

Manual 5 *Emergency risk management – applications guide (superseded by Handbook 10)*

Manual 6 *Implementing emergency risk management – a facilitator's guide to working with committees and communities (superseded by Handbook 10)*

Manual 7 Planning safer communities – land use planning for natural hazards (2002, currently under review)

Manual 8 *Emergency catering (2003, archived)*

Manual 12 Safe and healthy mass gatherings (1999)

Manual 13 Health aspects of chemical, biological and radiological hazards (2000)

Manual 14 Post disaster survey and assessment (2001)

Manual 15 Community emergency planning (1992)

Manual 16 Urban search and rescue – capability guidelines for structural collapse (2002)

Manual 17 Multi-agency incident management (replaced by AIIMS)

Manual 18 Community and personal support services (1998)

Manual 19 *Managing the floodplain (superseded by Handbook 7)*

Manual 20 Flood preparedness (2009)

Manual 21 Flood warning (2009)

Manual 22 Flood response (2009)

Manual 23 Emergency management planning for floods affected by dams (2009)

Manual 24 Reducing the community impact of landslides (2001)

Manual 25 Guidelines for psychological services: emergency managers guide (2003)

Manual 26 Guidelines for psychological services: mental health practitioners guide (2003)

Manual 27 Disaster loss assessment guidelines (2002)

Manual 28 Economic and financial aspects of disaster recovery (2002)

Manual 29 Community development in recovery from disaster (2003)

Manual 30 Storm and water damage operations (2007) (information may not be appropriate to all situations)

Manual 31 Operations centre management (2001)

Manual 32 Leadership (1997)

Manual 33 National Land search operations (2014) (refer to the Land Search Operations Manual website)

Manual 34 Road rescue (2009)

Manual 35 General and disaster rescue (2006)

Manual 36 Map reading and navigation (2001)

Manual 37 Four-wheel-drive vehicle operation (1997)

Manual 38 Communications (1998)

Manual 39 Flood rescue boat operation (2009)

Manual 40 Vertical Rescue (2001)

Manual 41 *Small group training management (1999, archived)*

Manual 42 *Managing Exercises (superseded by Handbook 3)*

Manual 43 Emergency planning (2004)

Manual 44 Guidelines for emergency management in culturally and linguistically diverse communities (2007)

Manual 45 Guidelines for the development of community education, awareness and education programs (2010)

Manual 46 Tsunami (2010)

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Foreword

This Guide is the result of a review of the second edition of the Australian Emergency Manual **Flood Warning**, which was produced in 1998-99 to extend and update the original manual on the topic (1995). The earlier editions were put together by teams of experienced flood response managers and flood warning specialists from around Australia. The review which produced the current edition was conducted by Allison Godber (Queensland Department of Community Safety) and Chas Keys (formerly of the New South Wales State Emergency Service), with input from Dale Russell (Queensland Department of Community Safety), Belinda Davies (New South Wales State Emergency Service), Andrew Gissing (Victoria State Emergency Service), Bob Stevenson (South Australia State Emergency Service), Andrew Lea (Tasmania State Emergency Service), Jim Elliott, Chris Wright, Linton Johnston, Peter Baddiley, Gordon McKay and Soori Sooriyakumaran (Australian Government Bureau of Meteorology), Lakshman Rajaratnam (Northern Territory Department of Natural Resources, Environment, the Arts and Sports), Mike Edwards (Victoria Department of Sustainability and Environment), Michael Cawood (Michael Cawood & Associates), John Handmer (RMIT University) and Michael Clarke (formerly of the New South Wales Department of Public Works). All these people have considerable experience and expertise in developing flood warning systems and/or delivering flood warning services.

The Guide is one of a series of documents on flood management whose review was instigated and managed by the National Flood Risk Advisory Group, a sub-group of the Australian Emergency Management Committee. The project was coordinated by Major General Hori Howard of the Australian Council of State Emergency Services and made possible by the financial contributions of the Commonwealth Attorney-General's Department and the Australasian Fire and Emergency Service Authorities Council.

The Guide is designed for use by all those who have roles to play in developing and operating flood warning systems and providing flood warning services. Among these people are flood forecasters, emergency management practitioners (including staff and volunteers in the State/Territory Emergency Service organisations which in most jurisdictions in Australia have a lead role in the management of floods), personnel employed by local councils and by various government departments, and members of flood-prone communities.

Like the other flood management documents in the series (**Managing the Floodplain, Flood Preparedness, Flood Response and Flood Emergency Planning for Dams Affected by Floods**), the Guide focuses on defining 'best practice' in flood warning as this is presently understood in Australia. In doing so it promotes a consultative, community-incorporating approach to the definition of flood warning issues, problems and solutions. The Guide does not seek to describe or define current flood warning practices, which may vary considerably between jurisdictions. Users will find it valuable to refer to the companion documents, especially **Flood Preparedness**, and to other documents in the Australian Emergency Manuals series.

Every attempt has been made to use neutral terminology. As a result the Guide does not use the specific terminology (for example in relation to officers, programs and management structures) or refer to the particular arrangements for flood management in the various states and territories.

Martin Studdert, AM
First Assistant Secretary
National Security Capability Development Division
Attorney-General's Department

CHAPTER 1

The Place and Purpose of Flood Warning

In a Nutshell...

The purpose of a flood warning is to provide advice on impending flooding so people can take action to minimise its negative impacts. This will involve some people taking action on their own behalf and others doing so as part of agency responsibilities.

Flood warnings can be said to be effective if they help agencies to carry out their roles during flood events and persuade community members to take actions which will lessen undesirable flood impacts.

This guide is designed to provide agencies responsible for developing and communicating flood warnings with a practical, step-by-step path through the development and operation of the total flood warning system. Thus it covers the prediction of flood levels and the likely impacts of a coming flood, the construction and dissemination of warning messages and means of reviewing the system's effectiveness following a flood event.

Introduction

Every year, despite the beneficial environmental impacts they create, floods impose substantial economic, social and environmental costs on Australian communities through:

- direct damage to residential, commercial, educational, recreational, cultural and industrial buildings,
- damage to infrastructure,
- damage to stock, equipment and facilities (for example farm animals, machinery, commercial stock and records and other contents of buildings),
- indirect losses due to disruption of economic activity, both in areas which are inundated and areas which are isolated,
- stress and anxiety in those affected by flooding,
- injury and death,
- polluted water supplies, and
- damage to wildlife habitats.

In terms of economic costs to the community, flooding is Australia's most damaging natural hazard. The Bureau of Transport Economics (2001, p35) estimated the costs of flooding in Australia between 1967 and 1999 at approximately $420 million per annum on average (in 2009 terms). Other sources put the average annual damage at rather higher levels when estimates are expressed in current dollar terms (see, for example, Standing Committee on Agriculture and Resource Management, 2000, p xi).

In most years, a small number of deaths occur as a consequence of flooding in Australia and there have been many cases of multiple deaths in a single flood episode. Between 1788 and 1996 at least 2213 people were killed by floods in Australia. Particularly lethal floods occurred in Gundagai (New South Wales) in 1852 (89 deaths), in the Claremont area in Queensland in 1916 (65 deaths) and in Brisbane and Ipswich in 1893 (47 deaths), but several other locations or regions have recorded more than 20 deaths in a single episode of flooding (Coates, 1996).

Large numbers of people in Australia live in flood-prone areas. Approximately 170,000 residential properties are susceptible to flooding in the 100-year (Average Recurrence Interval) flood (Leigh and Gissing, 2006). The number of commercial and industrial properties liable to flooding within the extent of the 100-year flood is not accurately known but would likely be measured in the tens of thousands, and the value of the agricultural, industrial, commercial, residential and public assets that are at risk is very large as is the cost of repairing or replacing infrastructure damaged or destroyed by flooding.

Of course, many more properties, sources of productive activity and critical items of infrastructure would be affected by floods bigger than the 100-year flood. It is likely that the total value of the assets at risk in Australia in Probable Maximum Flood (PMF) events – the biggest floods possible – considerably exceeds $100 billion.

The ‘Manageability’ of Flooding

Flooding is a highly manageable hazard where the flood risk can be defined and appropriate emergency preparedness and mitigation strategies developed. Floods happen often in Australia and, in some areas, according to a regular seasonal rhythm. Their location is predictable and there is usually some warning of their occurrence. Much can be known about flooding and its consequences in advance; thus it is possible to determine who will be affected and what problems they will face. Because of this, the opportunity exists to work out ahead of time (ie to plan) how a flood can best be managed in the interests of maximising public safety and minimising property and other damage. This allows the investment of money and effort in the management of flooding.

To reduce the negative impacts of flooding, many measures have been devised to help communities adjust to and live with the flood hazard. These measures have included:

- constructing levees, flood bypasses, channel improvements, detention basins and flood mitigation dams,
- instituting land use controls (such as zoning and the removal of existing buildings) and building restrictions (such as establishing minimum floor levels and raising buildings) in relation to development on flood-prone land,

- developing warning systems,
- developing response and recovery capabilities, and
- encouraging community understanding of both the flood threat and the means by which people can manage it.

While these measures rarely remove the flood risk entirely, they can modify the characteristics of flooding, alter communities in ways that reduce the impact of floodwaters and provide mechanisms that enable communities to cope better with flooding. For more detail on these measures, see Annex B of the Australian Emergency Manual **Managing the Floodplain**.

Flood warning systems and services are integral to the achievement of high-quality community flood response. The development of flood warning services requires information, knowledge sharing and effective communication. Well developed flood warning services that are understood and acted upon by the communities for which they are provided can contribute significantly to saving lives and protecting property. They should be regarded as central to the management of flooding.

The Value of Flood Warnings

Flood warnings are effective if they enable people to take action to lessen the negative impacts of a coming flood and help agencies carry out their essential tasks during flood events. The degree of effectiveness of warnings can be assessed by the extent to which the warnings reached the at-risk community, the level of recipient satisfaction with the information and advice contained in them, the degree to which appropriate behavioural adjustments are made and the amount of losses avoided by those who are advised.

Achieving effectiveness will depend on the cooperative involvement of stakeholders involved in warning system development. The stakeholders include the agencies which are responsible for the design and delivery of warning services, but they must also be seen as including the members of flood-prone communities.

In Australia, there have been many examples of communities being excluded from the planning of flood warning services and of flood warnings not reaching their potential. Often people have not understood the significance of the warnings they have received, have not known how to react or have simply not been given any clear indication of the severity of impending flooding: these things were noted more than 20 years ago (Handmer 1988) and still apply. There is considerable evidence that many people in flood-prone areas do not comprehend or trust the warning services that exist, and these things contribute to their lack of response to warning messages.

On the other hand, there is evidence that some elements of flood warning practice have improved over the past two decades or more. Current systems often provide more warning time than was formerly the case, and forecast accuracy has improved in relation to flood heights reached (see Figure 1). There is less evidence of improvement in the development and dissemination of flood warning messages over this period.

A critique of current flood warning practice in Australia is offered by Keys and Cawood (2009); often the warning task is poorly conceptualised, given a low priority and rendered poorly. This Guide describes ways in which the weaknesses can be overcome so the potential of flood warnings can be realised.

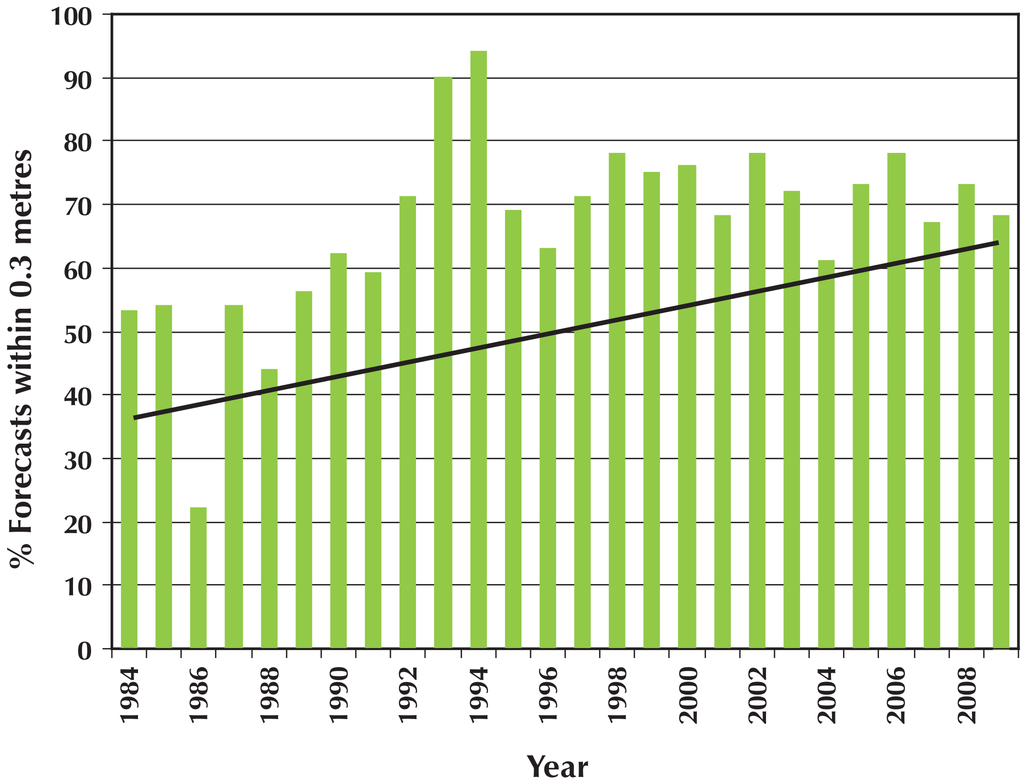

Figure 1: The Trend of Flood-Height Forecast Accuracy in New South Wales, 1984-2009 (Source: Australian Government Bureau of Meteorology)

CHAPTER 2

The Total Flood Warning System

In a Nutshell…

The goal of flood warning is to help flood management agencies and the members of flood-prone communities to understand the nature of developing floods so that they can take action to mitigate their effects. To achieve this goal, flood warning systems must be established and operated.

A flood warning system is made up of a number of components which must be integrated if the system is to operate effectively. The components of a 'total flood warning system' are:

- ***monitoring of rainfall and river flows that may lead to flooding,***
- ***prediction of flood severity and the time of onset of particular levels of flooding,***
- ***interpretation of the prediction to determine the likely flood impacts on the community,***
- ***construction of warning messages describing what is happening and will happen, the expected impact and what actions should be taken,***
- ***dissemination of warning messages,***
- ***response to the warnings by the agencies involved and community members, and***
- ***review of the warning system after flood events.***

The critical issues in developing and maintaining such a system are:

- ***it must recognise and satisfy the warning needs of the flood-liable community by ensuring the community is involved in system design and development,***
- ***it must incorporate all relevant organisations and be integrated with floodplain and emergency management arrangements,***
- ***it must be capable of operating for both 'routine' and severe flood events, and***
- ***each agency involved in the system must accept ownership of it and work cooperatively with other agencies to improve its operation.***

Introduction

In Australia, the concept of the 'total flood warning system' has been developed to describe the full range of elements that must be developed if flood warning services are to be provided effectively. This concept is illustrated in Figure 2. It recognises that flood warning systems are multi-faceted in nature and that their development and functioning involves input from a number of agencies with specialised roles to play. It is vital that the agencies involved in the establishment and operation of the various components accept that there must be close cooperation through all stages of developing and operating the system. It is also vital that in the design and planning of the system, and in the periodic reviews of system performance, there is community input.

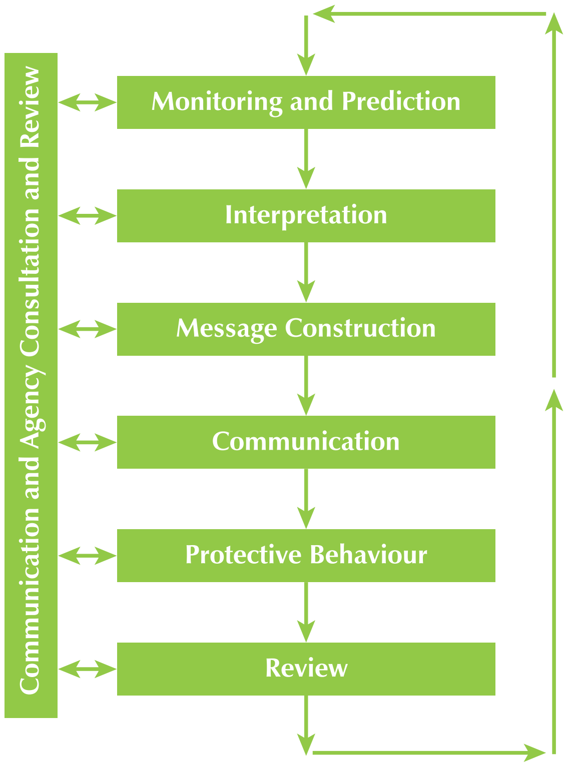

Figure 2: The Components of the Total Flood Warning System

The components of the total flood warning system are interdependent and linked. To be fully effective, all components must be present and operating appropriately. In addition, the system must include an inbuilt feedback loop that integrates the lessons learned from episodes of flooding back into the system. This will enable weaknesses to be identified and improvements made. Reviewing the performance of the system (including the responses by agencies and the community) is a vital component of the system.

System Components

At its simplest, an effective flood warning system can be defined as having six components:

- **Monitoring and prediction:** detecting environmental conditions that lead to flooding, and predicting river levels during the flood (see Chapter 3),
- **Interpretation:** identifying in advance the impacts of the predicted flood levels on communities at risk (see Chapter 4),

- **Message construction:** devising the content of the message which will warn people of impending flooding (see Chapter 5),
- **Communication:** disseminating warning information in a timely fashion to people and organisations likely to be affected by the flood (see Chapter 6),
- **Protective behaviour:** generating appropriate and timely actions and behaviours from the agencies involved and from the threatened community, and
- **Review:** examining the various aspects of the system with a view to improving its performance (see Chapter 7).

For a flood warning system to work effectively, **these components must all be present and they must be integrated rather than operating in isolation from each other**. The view that any one component of the system represents all of it, or is an end in itself, impairs the system's effectiveness. Currently in Australia, as is the case in most countries with serious flooding problems, the various components are developed to different degrees and one or more components may be virtually absent in some situations. As a general rule the components which are more easily definable and controlled (such as the prediction components) tend to be better developed than others (Handmer, 1997). Message construction and communication are usually less well developed.

The Flood Warning Consultative Committees in the various states (and their equivalent in the Northern Territory) have a vital role in overseeing the development of flood warning systems and services. Because they incorporate or can gain access to the agencies involved in the development of the various facets of the system in each jurisdiction, and because the various committees can communicate with each other through the Bureau of Meteorology, they are in a good position to ensure that system elements are well integrated and are operating to current notions of good practice.

System Design

In developing an effective flood warning system, the following points need to be addressed.

- The system must meet the needs of its clients in terms of identifying:
    - levels of flooding for which warnings are required (including the level at which flooding begins and critical levels such as levee heights),
    - what the impacts of flooding will be at different levels,
    - the warning time(s) the community requires and the amounts of time which can be provided,
    - appropriate subject matter content for warning messages,

- the ways in which warning messages are to be disseminated, and
- the frequency of warning updates.

- The system must be part of the emergency management arrangements established by the relevant State or Territory as defined in disaster or emergency management plans. Warning arrangements must be detailed in all plans relating specifically to flooding and should indicate the conditions under which warnings will be issued and the organisations or officers who will issue the warnings.
- The agencies concerned with prediction, interpretation, dissemination and response (including local government) must all be involved in system development and review, as must the community itself.
- The roles of the various agencies must be clearly identified for each element of the system.
- The flood warning system must be incorporated within the wider floodplain management perspective, with recognition that the inter-relationship between flood warning and other floodplain management measures needs to be planned for.
- The organisation, resourcing, public education, training and exercising necessary to ensure the system operates effectively must be carried out.

Critical Issues for Building Flood Warning Systems

Effective Consultation at the Design Stage

To ensure the **relevance** of flood warning systems and to encourage **local ownership** of them, community members should be involved in developing the warning systems which will generate the warnings. Agency personnel involved in system design must therefore listen to those at risk.

Flood warning systems and services are therefore best developed with the **input** of those who are affected by floods. Personnel in the agencies responsible for warning about flooding should meet with members of the community and establish their needs. These will relate to:

- the levels of flooding (usually at a specified gauge) for which warning will be needed,
- the consequences of flooding at different flood heights in areas around the gauge (ie in the gauge reference area),
- the amounts of warning time which will be required to take the required protective action, evacuation and other tasks which people may need to undertake for floods of specified severities,
- the ways in which warnings should be provided, and

- other matters related to the various components of the system.

Consultation should be with individuals or groups of people from flood-prone areas. Such people can be assembled, if necessary, by advertising in local newspapers but also by direct invitations to those known to have been affected by flooding in the past. Usually, council staff or SES members can identify such people. If flood warning services already exist, similar consultative mechanisms can be set up after a flood to check on the effectiveness of those services in the eyes of the people they are intended to help and to redesign them if necessary.

Ideally, the consultation should be locally driven. Where possible, a local 'champion' should convene meetings and be a point of contact for people to discuss flood warning issues. This person should have local flood experience and should be well regarded within the local community.

This approach will give the design of warning systems and procedures an appropriate focus and help ensure their relevance to the communities for which they are designed. The following steps are some practical guidelines.

- Identify potential clients of flood warning information at different levels of flooding, and their information needs. The clients may be farmers, caravan park proprietors, river-boat operators, gravel-extracting firms, mining companies, village, town or suburban residents, Aboriginal communities, operators of industrial or retail premises and many others. In some circumstances they may include people living below dams which have been classed as structurally deficient or as having inadequate spillway capacity to safely 'pass' big floods. Such dams are at some risk of failure.
- Determine what is known about the impact of flooding at different levels as measured at flood warning river height gauges (existing or proposed).
- Identify what responses will be required of people in the path of flooding.
- Determine the amount of time which will be needed to carry these responses out. Estimating time requirements is critical to ensuring warning services can be planned so necessary actions can be completed before onset of flooding renders the tasks impossible to complete.
- Develop appropriate means of disseminating warnings to different clients and at different flood levels.

Ongoing Planning and Maintenance

Several agencies need to be involved in planning, establishing and maintaining flood warning systems. These are time-consuming tasks, and they often require a greater and more continuous effort than do operational responses to floods. The establishment of a flood warning system requires both:

- the commitment of funds and resources to developing the various components of the system, and

- a willingness to maintain the investment in these components, even when flooding is not frequent or regular.

Fortunately, not every component is technically difficult and costly to devise. In fact several elements can be set up inexpensively because they involve defining arrangements and tasks rather than investment in hardware. Many of the problems associated with operating flood warning systems relate to the **lack** of such definition.

The agencies involved in flood warning activities (see Table 1 for a summary of agencies involved in the various states and territories and their responsibilities) must be made ready for the task. Agency personnel must be familiar with the impact of warning processes on carrying out their allotted tasks, and both intra-agency and inter-agency planning is essential.

Table 1: Summary of Current Organisational Responsibilities for Flood Warning in Australia

	Prediction	Interpretation	Dissemination	Response
Tas	BoM	LG/SES	BoM/SES	SES/LG/Police
SA	BoM	SES/Police	BoM/SES/Police	SES
WA	BoM	LG/FESA	BoM/Main Roads (road closures)	FESA/LG
NT	NRETAS/ BoM	NTES/Police	BoM/NTES/Police/DPI (road closures)	Police/NTES
NSW	BoM	SES	BoM/SES	SES
Qld	BoM	DCS/LG	BoM/DCS/LG	DCS/Police/LG
ACT	BoM	ACTES/Police	BoM/ACTES	ACTES/Police
Vic	BoM/MW	SES/LG/CMA	BoM/SES/LG MW	SES/LG/Police

Abbreviations:

BoM	Bureau of Meteorology
LG	Local Government
DCS	Department of Community Safety
S/TES	State/Territory Emergency Service
NRETAS	Northern Territory Department of Natural Resources, Environment, the Arts and Sports
CMA	Catchment Management Authority
MW	Melbourne Water
FESA	Fire and Emergency Services Authority

Flood Warning Consultative Committees should consider the **accountability** of the various agencies involved in flood warning system design, development and operation. Because there is no single lead agency, and because some organisations and individuals operate outside government while others function at different governmental levels, this will not be an easy matter to address. The Flood Warning Consultative Committees could, nevertheless, develop appropriate protocols (perhaps through memoranda of understanding) to encourage agency participation in and commitment to system development and operation. Responsibilities could be defined in writing and performance indicators designed to help assess the degree to which agencies meet those responsibilities. In doing this, it may be necessary to recognise that not all agencies in all locations will have the resource capabilities needed to fulfill their responsibilities, and this may need to be addressed at the state/territory or national level.

While planning for warning activities cannot address unpredictable circumstances, plans must be sufficiently flexible to allow for rapid adjustment to new situations. They must be regularly 'exercised' on a multi-agency basis in ways which will provide opportunities for examining the implications of different levels of flooding. Such exercises provide practice in receiving predictions, interpreting them and generating appropriate reactions. They also allow for periodic reassessment of the amount of time needed after a warning is received to carry out specified tasks. This reassessment can be used in renegotiating warning lead times.

Continued Community Engagement

The members of flood-prone communities must be **made ready for flood warnings** as well as for floods themselves. Periodic interaction with the community is also needed to ensure that people recognise, and continue to recognise, the purpose and meaning of flood warnings and understand how to react to them. In other words, a conscious effort must be made to educate people about flood warning services and how to 'utilise' warning messages. Community flood education programs to date have often failed to address the question of educating people about warnings.

There are numerous means by which communities can be educated about these matters. One method, in areas which are frequently affected by flooding, is to provide flood information (cards, brochures, booklets and DVDs) by periodic doorknocking campaigns conducted out of flood time. Such campaigns might include, in places such as caravan parks, persuading park owners and managers to display relevant safety information, to develop response plans which will help residents and visitors save belongings and, if necessary, to evacuate safely. In some states, evacuation plans and displays of safety information are conditions of license for caravan parks. Visits by response agency personnel to shop and factory owners in flood-liable areas can act as reminders of the existence of flood problems or as prompts to effective reactions once warnings are received.

Once some community members are involved, system credibility will rise as information about the system flows through informal communication networks to the remainder of the flood-liable community. This will also help ensure the system can be kept 'alive' in people's minds during the periods between floods. Continuing education will still be needed however, so that high levels of community readiness can be maintained.

It is important that a mix of strategies be employed. Additional means of raising community understanding of flood threats and the availability and value of flood warnings might include the following.

- Flood markers (as stand-alone structures or on telephone poles, buildings or bridges adjacent to key gauges) to indicate the levels reached by historic floods. The markings should incorporate a range of actual floods of different severities that have been experienced at that location: these will help people visualise the spread of floodwaters in events forecast to reach specified heights at gauges.
- Articles in local newspapers, highlighting such things as the gauge levels at which flood warning services are activated and the sorts of impacts which occur at specified flood levels at the gauges,
- Interviews of response agency personnel on radio (including talkback shows),
- Use of council rates notices to carry reminder messages about flood impacts, flood warnings and safety information,
- 'Advertisements' on radio to promote understanding of the existence of a combat or lead agency for flooding and to publicise the actions which people should take before and after floods and for different predicted heights during floods,
- Provision of flood action guides, brochures, booklets and flood plans to schools and libraries and to individual members of the flood-liable community. These should be customised for defined areas, containing locally-specific information about the entry level for warning services and the expected consequences of flooding to different gauge heights,
- Meetings with people living or working in flood-liable areas, to explain or negotiate elements of the flood warning system,
- Static displays in public buildings about flooding and its impacts (including maps showing the extent of flooding in events of different severity), and
- Periodic public tests of the flood warning system.

Further information on community engagement in flood management can be found in Chapter 6 of the Australian Emergency Manual **Flood Preparedness**.

Handling Extreme Events

An important element of planning the development of flood warning systems is to ensure they are sufficiently robust to cope with the range of events which can occur. Flooding is a phenomenon which is subject to wide natural variability in scale and severity. Events of magnitudes well outside the range of historical experience can and do occur, and it is important that systems are able to cope with floods approaching extreme proportions.

Flood warning systems must, therefore, be designed to predict and cater for rare, severe events as well as less serious and more common ones. However, inherent uncertainties in prediction are likely to be magnified during extreme events and warning systems must recognise such limitations of science and technology. Communities at risk and agencies involved in flood response activities must recognise the potential for flooding which is worse than they have experienced in the past. Such flooding will obviously do much more damage and is also more likely to result in deaths.

It should be noted that rainfall intensity and flood height records are frequently broken in Australia. For example in 2007, a year of drought across much of the country, record rainfalls and/or flood heights were set in the first nine months of the year in separate locations in every state and territory except Western Australia and the Northern Territory (Molino, 2007). Sometimes, when flood records are broken, the new records are **much** higher than the previous ones. This was the case at:

- Launceston (in the Tamar Valley, Tasmania) in 1929,
- Port Fairy (on the Moyne River, south-west Victoria) in 1946,
- Singleton and Maitland (in the Hunter Valley, New South Wales) in 1955,
- Nyngan (on the Bogan River, New South Wales) in 1990,
- Charleville (on the Warrego River, Queensland) in 1990, and
- Katherine (on the Katherine River, Northern Territory) in 1998.

Moreover there is increasing evidence in the paleo (pre-historic) record of very big floods, in some cases much larger than have been recorded since the beginning of European settlement in Australia (Isdale et al, 1998, Snowball et al, 2006). Occasional very big floods, larger than have been seen in recent times, should be expected in all flood-liable areas.

CHAPTER 3

Flood Prediction

In a Nutshell…

Flood predictions are estimations of the height of water in a river or other flooded area at a specific place at some future specified time. They may be expressed for a location (usually a gauge) as:

- ***a precise value (eg 12.3 metres),***
- ***a range (eg between 12.0 and 12.5 metres),***
- ***being above a particular critical value (eg greater than 12.0 metres),***
- ***being 'near' (approaching) a specified value, or***
- ***a class of flooding (minor, moderate or major).***

These predictions can be seen as having relevance for a 'reference area' around the relevant gauge.

Predictions are made by monitoring weather, rainfall, river and catchment conditions that can lead to flooding, by measuring rainfall within the catchment and river levels at important locations, and by using appropriate mathematical techniques to predict future river levels. The critical issues are to:

- ***understand where predictions are needed and why,***
- ***ensure the predictions address the requirements of those at risk,***
- ***appreciate that it is not usually possible to be certain about a prediction,***
- ***maintain good communication between prediction agency, lead response agency and community about prediction accuracy and flood impacts,***
- ***have clear protocols relating to issuing, receipt and use of predictions,***
- ***reduce the likelihood that particular groups within the community will compete with the official prediction agency, and***
- ***take special care in describing predictions of extreme events.***

Introduction

Flood prediction is an essential component of effective flood warning. At the initial stages of a flood event, as part of routine monitoring, it involves predicting expected river levels to assess the **likelihood** of flooding. If flooding is expected, predictions provide information on **expected river behaviour** during the flood – that is, the height which will be reached at specified gauge stations at particular times. The predictions themselves provide the basis for understanding the severity of an oncoming flood. From this, the actions necessary to mitigate the effects of the flood can be initiated.

The various products which the Bureau of Meteorology issues in relation to flood prediction (flood watches, flood warnings, severe weather warnings and severe thunderstorm warnings) are outlined in Chapter 3 of the Australian Emergency Manual **Flood Response**.

Catchment Monitoring

Routine catchment monitoring is carried out to maintain a continual awareness of the rainfall amounts needed to produce flood runoff. Data from networks of rainfall and river-level stations are used to monitor catchment wetness (ie soil moisture) and river conditions, normally on a daily basis. This is done in close liaison with the 24-hour meteorological monitoring and detection role of routine weather forecasting, which includes future rainfall forecasts by global and regional Numerical Weather Prediction models together with specialist local interpretation. The combination of current catchment state and future rainfall allows an early assessment to be made of the possibility of future flooding and the river levels likely to be reached.

Effective routine monitoring of the potential for flooding requires:

- sufficient rainfall and river flow data to provide a representative picture of what is happening over the river basin,
- close liaison between meteorological and hydrological forecasting groups, and
- a hydrological prediction capability to assess the impact of changes (predicted or detected) in meteorological conditions.

Early Prediction and the Question of Accuracy

People threatened by a flood need to know as accurately as possible how high the flood will be, and with enough time to protect themselves and their belongings. But the time available for warning depends on the rate at which streams respond to rainfall. A small urban creek may respond within minutes, producing flash flooding, while floods on the Darling and Murray rivers may take months to reach some downstream communities.

Usually a flood can be predicted with high accuracy only in the later stages of its development when more information such as observed rainfall becomes available. Therefore, in order for sufficient warning time to be provided it is often necessary to accept a less accurate prediction. Thus there is a trade-off between prediction accuracy and warning time. A particular problem exists in relation to flash floods, for which warning time is unavoidably short.

The diagram below (Figure 3) illustrates an example of the trade-off between the warning time which can be provided and the level of accuracy which can be achieved for the case of flash flood warning.

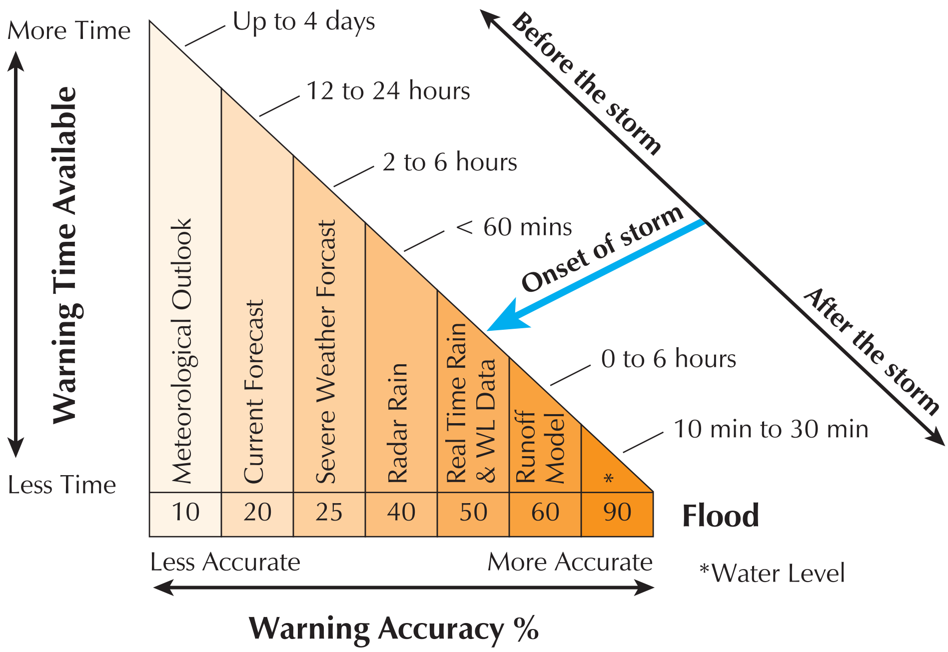

Figure 3: The Trade-off Between Warning Time and Flood Forecast Accuracy for Flash Flood Situations (Wright, 2001)

Early in a flood event, predictions often have to be made using **forecast rainfalls** rather than falls which have actually occurred or stream heights which have already been recorded at gauges. Because of the inherent uncertainty in using forecast rather than recorded rainfall, such predictions will generally not be very precise. To reflect this uncertainty it is common to use a **range** of possible forecast rainfalls in making this initial assessment. The more modern numerical weather modelling systems are able to attach specific probabilities (ie percent chance) to such rainfall amounts and it is possible to get some estimates of the uncertainty involved.

These early flood predictions can be used as the basis for warning products such as a Flood Watch, which is issued by the Bureau of Meteorology as a 'heads up' for emergency management agencies and the public to the possibility of flooding in the near future (usually over the next few days). With these products, it is important that the inherent uncertainty is known and understood through appropriate public education and in the design of the product. While such products provide more time to prepare for the flood, this benefit has to be traded off against the possibility that the flood conditions will not develop as anticipated. Furthermore such predictions are normally made for larger areas covering several river basins, again to cater for the inherent uncertainty in the movement of rainfall-bearing weather systems.

In the case of the medium to large river basins, with floodwaters taking longer times to travel, more accurate predictions are normally possible later in the event but still prior to the flood fully developing. In the case of flash flooding, however, these early and less certain predictions may be all that is possible in the time available.

The trade-off between accuracy and uncertainty can be summarised as follows in relation to the basis on which predictions can be made:

- Predictions based on forecast (pre-storm) rainfall can only be very approximate.
- Predictions based on amounts of recorded rainfall are likely to be more accurate, but they need to take account of rainfall losses due to evaporation, seepage and water that has flowed into and been impounded by dams. Given the complexity of the processes involved in transforming rainfall amounts into subsequent river flow, inaccuracies in predictions are likely.
- Predictions based on measured stream heights upstream of a specified gauge are generally the most accurate, especially in streams with little additional inflow between the two gauges.

The Elements of Flood Prediction

Flood Height and Time

During a flood event, the normal requirement is prediction of expected stream levels at specific times at key locations on a river. Predictions can be of:

- flood stages (the levels reached at specified times as the flood rises towards the peak),
- the peak flood level, and
- particular significant levels (eg the lowest point on the crest of a levee) that will be reached or exceeded as the river rises.

River level predictions as the river recedes are also useful to guide post-flood recovery activities.

A prediction is normally made for a particular location and time and ideally is expressed as a specific river level at a nominated gauge. This requires confidence that available data and prediction techniques allow the hydrologic behaviour of the catchment and the hydraulic behaviour of the river to be reliably modelled. Where this is not possible, a prediction may be given as a range, which is an indication of the **class** of flooding (minor, moderate or major) to be expected. Each class corresponds to a range of river levels and a prediction of a class of flooding means that the river is expected to reach a level somewhere within the relevant range.

Associated with the growing ability to express rainfall forecasts in probabilistic terms is the capability to attach specific probabilities to river level predictions. These types of forecasts result from a more complete processing of the various sources of uncertainty in the hydrological forecasting process and can provide a more objective measure of the real uncertainty of the prediction process. Response agencies will need to develop a capability to make best use of this improved information.

A prediction of the expected stream level at a single location is **by itself** of limited use for response. As discussed in a later chapter, what the particular predicted level **means** for areas at risk in the floodplain surrounding that location (that is, the likely impacts on the community) needs to be established. This interpretation task has not usually been the responsibility of the agency responsible for flood prediction (normally, the Bureau of Meteorology). However, with the improved hydraulic modelling capability now available it has become more feasible for prediction agencies to produce predictions as **flood extents** as well as heights at key locations. This would greatly facilitate better interpretation of impacts (for example in the form of areas and depths of inundation, water velocities in the floodplain and impacts on structures such as levees). As is the case for river level predictions, these types of predictions are associated with some uncertainty.

Warning Lead Time

Warning lead time is the time between the issuing of a message containing a prediction and the time when the predicted height is reached (or when the stream peaks below that height). In general, the longer the lead time, the better. The value of flood prediction is determined by both the accuracy of the prediction itself (where optimal performance represents the predicted level actually being reached at the expected time) and the amount of warning lead time provided.

The potential warning lead time is a function of the hydrology of the catchment draining to the forecast location and the technical components of the flood prediction system. Where a location can be flooded by runoff from small catchments which respond very quickly to rainfall (flash flooding) the potential lead time is very small (from less than an hour up to several hours). In these situations the use of forecast rainfall is needed to increase the available lead time, but this can be at the expense of forecast accuracy. As catchment size increases, the 'natural' delay between rainfall and flood runoff increases, creating the opportunity to use a combination of observations of rainfall and river level with rainfall-runoff modelling to capture this natural delay as the warning lead time. Such modelling approaches are also subject to forecast uncertainty but this is normally less than with those methods which rely mainly on forecast rainfall.

Locations flooded by large, slow-moving, low-gradient rivers can have potential warning lead times of the order of many days up to weeks in some cases in inland Australia. In these cases predictions are based on observations of upstream river levels and are normally very accurate. Recognition of this inter-relationship between accuracy and lead time should be built into the development of response strategies.

It should be clearly understood by response agencies that flood predictions take time to prepare. Time is required for:

- collection and management of data from the network of gauges in a catchment area,
- meteorological forecasting,
- running the flood prediction models (hydrologic and hydraulic), and
- preparing the message containing the prediction.

If there are important actions that need to be taken before particular and critical stream levels are reached (eg the evacuation of an area behind a levee which would be overtopped at a known gauge height), these levels should be identified by the key response agency. They can then be built into the objectives of the prediction system.

Prediction Frequency

The optimal frequency of predictions varies from area to area and reflects the speed of rise and fall of floods. In flatter valleys and long rivers on which floods may travel long distances, predictions need to be revised less often and less quickly than is the case where gradients are steep and travel distances short. In flash flood catchments especially, predictions usually need to be updated quite rapidly. Messages containing flood predictions should indicate the period over which the prediction applies and should nominate the time at which the next prediction will be issued.

User Requirements

The requirements for flood predictions should be determined from an understanding of flood effects at different river levels and the types of protective behaviour most appropriate to each situation. There is a need to determine:

- the locations on the river system at which predictions are needed,
- the level(s) within the reference areas of specified gauges at which flooding requiring community warning can be said to begin (these levels will create 'entry levels', usually defined as 'minor flood' heights, for the prediction agency),
- what river levels are critical (for example, the gauge levels at which farmland is inundated, roads cut, houses flooded or evacuation routes closed or other specified impacts are felt),
- the time needed to undertake the necessary protective responses (for example to relocate irrigation pumps or livestock, evacuate a certain number of houses or sandbag gaps in levees), and
- the desired frequency with which predictions will be made.

In the early stages of an event, the prediction may be that a particular level will be reached or exceeded, with the expectation that the river will later peak at a higher level. It is important for response agencies to be aware that not all predictions are of peak levels.

It is important that the expected **trend** of the river (rising, steady or falling) is indicated in messages containing flood predictions. As a flood is developing, many users also seek information on the rate of rise in the period immediately preceding the issuing of the prediction.

Key Agency Responsibilities and Requirements

The key agency responsible for **flood response** or the development of **flood emergency plans** (ideally this would be the same agency for both functions) should be primarily responsible for:

- establishing user requirements for flood predictions in close consultation with other agencies and the community (for example, in small-group meetings with flood-affected people and held periodically, including soon after floods when memories are fresh), and
- communicating these requirements clearly to the prediction agency.

It may not be possible to establish user requirements precisely, particularly as flood impacts are not always known or may change with time. Change may occur as a result of change in community features (for example the development of irrigation farming or new levees) and/or elements of infrastructure (for example the building of a new bridge at a higher level than the one it replaces, altering the flood height at which communities are cut by flooding). Nevertheless, it should always be an objective to work toward determining and refining these requirements as fully as possible consistent with the significance of the flood problem. Periodic consultation with members of the flood-prone community will be necessary to ensure the requirements fit the needs of the community in general as well as those of participating agencies. Each community is likely to have its own unique set of requirements.

There will always be limits on the accuracy of flood predictions. Response agency personnel and (as far as possible) community members should have a clear awareness of the accuracy limitations associated with the flood prediction process. A response agency can use information on prediction accuracy to examine the sensitivity of its response actions within the prediction limits. This allows the agency either to be better prepared, should a 'worst-case' situation eventuate, or to be more confident that the actions planned are the most appropriate.

An exact prediction is not always needed, and in any case it must be appreciated that flood impacts will not be identical in the reference area of a gauge even for two floods which peak at the same height there. Often a range within fairly tight bounds (say 0.3 metres) is sufficient for people to do what is necessary in their responses. There are other situations, however, where a high degree of accuracy is more important although this usually applies only at particular levels (for example, at the height equivalent to that of a levee protecting part of a town).

Coordination and Communication

Operational coordination and communication are essential between the prediction agency and the lead response agency involved in the reception and interpretation of predictions. On-site reports provide valuable feedback to the prediction agency on the impacts of flooding and on the accuracy of the predictions. Information on forecast accuracy can be used to adjust hydrological prediction models so future forecasts can be made more accurate.

When there is local doubt or confusion about the validity of the prediction within local groups, the reason for this doubt should be discussed with the prediction agency. The reason for concern, together with any supporting data (including locally-operated data networks that may not be available to the prediction agency) is best shared in a co-operative environment to ensure only a single prediction is made. This reduces the potential for confusion among the recipients of the warnings.

In some circumstances the communication occurs directly between the prediction agency and the community at risk, the prediction agency taking responsibility for disseminating most of the information. This can occur either where there is no lead response agency available or capable of undertaking this role, or in situations of urban flash flooding where there is insufficient time available to undertake separate prediction and interpretation activities. In the latter case it is important that the prediction agency and the lead response agency agree formally ahead of time on the principles which will underlie the dissemination of predictions, warning information and advice. This issue is discussed further in Chapter 5.

The Role of Technology

The technical quality of flood prediction (accuracy, timeliness and reliability) can vary considerably depending on the type of technology used. The measurement of the basic data inputs to a prediction system (rainfall and river level and flow) can be achieved using simple manual observation techniques, but the use of automatic and semi-automatic devices can lead to substantial improvements in prediction quality and to considerable savings of time in the prediction process. Devices can include float-well or pressure sensing equipment for river level measurement, and tipping-bucket gauges for rainfall coupled with telemetry devices to communicate the information to the prediction centre with speed. Ultrasonic techniques for streamflow measurement and radar-based systems for rainfall measurement are becoming increasingly common.

A wide range of technologies is available. The design of the prediction system should match the prediction requirements and consider the cost-benefit relationships with respect to the likely effectiveness of flood warning as a mitigation strategy.

Data Communication

Data can be communicated to the prediction centre using a range of telemetry systems. Radio, telephone, mobile phone and satellite systems are the most common. Increasingly, internet-based technologies are coming into use. System reliability can be improved by investing in more robust options such as dedicated landline or microwave links, the provision of redundancy by duplicating systems or creating alternate communication paths, or simply by increasing the number of stations in the network.

Where gauges have been telemetered, a ‘manual’ gauge reading capability for key sites should be maintained to provide a measure of insurance against technical failure and the destruction of automatic gauges by floodwaters.

Model-Based Prediction

Flood models are used to convert rainfall and streamflow data and catchment information into a prediction of the height that will be reached at a downstream gauge at a specified time.

Hydrologic and hydraulic modelling techniques vary widely. Although relatively simple procedures can predict river behaviour with reasonable levels of accuracy, investment to increase the density of real-time rainfall and river level measurement, along with more data on physiographic characteristics of the river and its catchment, provides scope for applying increasingly sophisticated modelling tools. These tools can improve the accuracy of prediction for the more common flood events, and can also provide a greater confidence in predictions for the more severe events not yet experienced. Again, the choice of technique should be based on a consideration of prediction needs and the value returned from investment in improved procedures.

Flood Information

In recent years, the rapid development of the internet has made it possible to provide a wide range of flood information products. For example, the Bureau of Meteorology web site (www.bom.gov.au) provides for all of Australia:

- weather forecasts (both general and for specific locations),
- current warnings for flood and severe weather (including flash flooding),
- radar rainfall images (updated every 10 minutes or so and in animated displays) including quantitative amounts, with forecasts also being planned,

- observed rainfall for periods from the past hour out to several days in both map and bulletin form (this information is available for point rainfall, colour-coded in amounts and in tables listed by river basin), and
- observed river levels in map and bulletin form as well as time series plots.

For response agencies, the Bureau of Meteorology may be able to supply information from flood forecast models as graphs showing anticipated stream levels at each gauging station. These predicted flood hydrographs will allow agencies to determine when critical flood levels may be reached and the expected rates of rise and fall of a flood.

Such information has value in assisting users to build a wider picture of flooding as it develops to provide a context for better understanding the more specific prediction information that is contained in individual messages. There is an increasing trend towards community demand for more information.

Computer Systems

Modern computer, communications and database technology provide the basic infrastructure to support a fully integrated 'on-line' system that integrates all components of flood prediction operations. Such technology also allows these systems to be combined with meteorological forecasting systems and product dissemination through modern technologies, in particular the internet, to provide a fully streamlined operation.

In addition to supporting these 'core' prediction activities, technologies such as 'web-cam' are being used. Thus images from a video camera sited at a key flood warning gauge can be transmitted over the internet. This allows actual floods to be filmed and gauges to be photographed to check on their operation (eg to determine whether they have been vandalised or fouled by debris).

The choice of technology should always be driven by client needs. Technological alternatives should be assessed as a balance between the potential reduction in flood damage from an improved quality of prediction and the cost of the technology needed to gain that improvement. This approach can often be difficult to implement in practice as there are many other considerations that dictate the eventual prediction system used. Nevertheless, as a principle, the need to achieve this balance should guide decisions on the choice of technology as far as is practicable.

Automated Systems

Technology provides many opportunities to automate the detection, prediction and warning dissemination processes for flood warning. This is of particular advantage for local and broader scale flash flooding across urban and other heavily populated areas. One example here is the application of ALERT (Automated Local Evaluation in Real Time) and similar systems implemented in many small catchments throughout Australia, especially in circumstances where warning time is short.

These systems automate the detection of predefined threshold conditions for flooding and can telemeter messages to response agency personnel by mobile devices when designated rainfall intensities are recorded or critical stream levels are reached. They also make a wide range of flood data readily available to response agencies for subsequent extension into a wide range of warning products suited to broadcasting via the internet, SMS and mobile phone.

The increasing availability of high-quality weather radar has seen the growth in systems for generating a range of new graphical products that are aimed at improving the quality of flash flood warning. The improved rainfall measurement and forecasting capability provided by this radar, coupled with increasingly sophisticated Digital Elevation Model (DEM)-based hydrological analysis and prediction tools, is leading to the production of systems for the rapid identification and forecasting of potential flash flood risk zones. This information can be produced automatically and speedily transmitted to response agencies and the public, again through media such as the internet and mobile devices.

It is important to recognise, however, that automated systems will of themselves have little if any effect if they are not supported by appropriate warning dissemination methods and associated public education to ensure the warnings are understood and acted upon. Equally the automated systems must be maintained by an agency with the appropriate technical skill and commitment.

'Informal' Prediction Systems

It is important to recognise that an informal prediction system may exist in addition to the official one. This informal system is usually made up of local residents who will have their own impressions of how serious an impending flood will be, often based on their own records from past floods. Seeking the advice of these people is important, and they should be identified and encouraged to share their information which can then be incorporated into the prediction process. Council staff and local response agency members can usually identify such people.

Although it might be done on a case-by-case basis, it is useful to explore ways to incorporate this capacity to feed into the prediction process. One possibility is to employ such people as gauge readers, though this can create its own problems when readers are busy protecting their own property or are otherwise not contactable. Another approach is to encourage them to contact the prediction agency if they have information which suggests flood forecasts are in error. The outcome may be a revised official forecast. It is important to ensure that there is a **single** acceptable forecast rather than competing ones from different sources. Competing predictions create the potential for confusion in the community.

The strategy of acceptance and incorporation helps integrate the informal system with the official one and minimise the undesirable effects of competing predictions arising during flood periods. Liaison here should work both ways and include making local groups and agencies aware of the essential details of the flood prediction process. It is very important to stop unauthorised independent predictions reaching local media outlets. Incorporating local people and local agencies within the formal prediction system also gives them part ownership of it and increases their confidence in its operation. In other words, local informal prediction systems need to be managed as part of the overall arrangements for flood warning.

A risk that has to be carefully managed here is that of the loss of local 'experts' when they move away from the area. With the relative infrequency of flooding in many parts of Australia and the high level of residential mobility within the population, there is a real likelihood that key individuals may not be available for the next flood. Furthermore, as mentioned above, local people may also be involved in their own personal flood management activities and so can not always be relied on to provide their particular input to the prediction system.

It is equally important that those agencies whose personnel receive products from the formal prediction system treat them with respect and care. Agencies using Bureau of Meteorology predictions, for example, should not modify them in ways that allow the modifications of the predictions to be published in the community, for example by advising local radio stations of the changes. To do this also causes confusion by creating conflicting forecasts. It is, of course, quite appropriate for local agencies to **plan** for flooding worse than that which has been forecast, but discipline needs to be exercised to ensure this can be done without causing confusion among community members.

Setting up Informal Systems

There are cases where it is necessary to establish a kind of informal prediction system deliberately. For many creeks and rivers there are no formal, scientifically-based warning systems but there is a case for developing an alternative system if people and property are affected by flooding and if a local demand for warning information exists. This can often be done by gaining access to informal local community system networks which, in some areas, have been passing flood information from upstream to downstream locations, often from farmer to farmer, for decades.

Where this is the case it is usually a simple matter for a local response agency to gain access to the network, formalise it to an appropriate degree and use it to develop assessments and spread information more broadly. In many situations, local agencies already tap into such sources to fine-tune predictions.

A particular case here is for small creeks where the establishment of locally-based monitoring and prediction systems can be effective. One approach is for a local response agency to set up an information-gathering system whereby individuals along a stream can be contacted for details of current flood situations. Assessments can then be made, by the response agency, by comparing an existing flood with past ones in terms of apparent severity, developing response actions accordingly and providing warning information to the wider community as necessary. These local systems are best established in coordination with agencies such as the Bureau of Meteorology and the response agencies which can advise on available technologies and other aspects of system design and operation.

Existing Local Informal Systems in New South Wales

Informal prediction systems have been set up in numerous locations in Australia including along Mirrool Creek (in the Riverina area) and Thalaba and Moomin creeks in the north-west of New South Wales between Moree and Walgett. These creeks flow only intermittently and there are few stream gauges, but occasional flooding can cause damage to farm installations and in villages. Local State Emergency Service units have set up networks of 'creek readers' who make telephone contact downstream and with their local SES Controller when flooding begins. The creek readers also act as wardens, alerting members of their own communities to approaching flooding. The system is intended to ensure the provision of basic flood information to response agencies and to the community via the media and other means.

Many such systems have been established in Australia, some pre-dating the era of formal flood warning services. They are, however, prone to become ineffective if not consciously kept 'alive'. Where such networks are established, attention needs to be given to maintaining them during the often long periods which can elapse between episodes of flooding. It is also wise to examine the technical basis (if any) of these systems to ensure they have some scientific basis. Reminding the participants of their roles, and devising simple exercises to practice them, will help keep the systems 'fit for purpose'. Reminders should be given on at least an annual basis.

CHAPTER 4

Interpreting Flood Predictions

In a Nutshell…

- ***Predictions of flood heights are most useful when they are accompanied by appreciations of the spread of the water in areas around the relevant gauge. This requires knowledge about what will be affected at the forecast heights.***
- ***Predictions are best interpreted by a response agency at the local level. This is the level at which the likely impacts of flooding at different heights can most easily be understood.***
- ***Information needs to be collected on the effects of flooding at different heights so that the levels at which water encroaches on particular areas (for example, farmlands, residential properties and business premises) can be identified.***
- ***A comprehensive understanding of the likely impacts at predicted flood heights is vital to formulating effective warning messages targeted at the flood-prone community.***

Introduction

Predictions of likely flood heights at a gauge are of little use by themselves. To unlock their **meaning** to response agencies and the community in the reference area around the gauge, the effects of flooding at the predicted heights must be able to be estimated: in other words, value has to be added to the predictions. This requires flood risk information to be compiled, either from historical records or from flood modelling.

The availability of flood risk information which describes the impacts and potential effects of flooding is highly variable across the country. This variability influences the ability of response agencies to understand the potential risk and to communicate the likely impacts to the community.

In some parts of Australia which are frequently affected by flooding, an impressive array of data has been collected to describe what has happened during past events. In addition, flood studies have often developed estimates of impacts at various flood heights. As a result, the floor levels of buildings relative to gauge heights are known and the inundation sequence during typical events is well understood in the response agencies and to some extent in the community. Many people in such areas know the meaning of particular gauge heights and will be able to respond appropriately to an imminent flood.

In many other areas, including some potentially high risk urban centres, flood events have been infrequent and data collection poor. As a result, response agency members and the public have limited direct experience or knowledge of flooding in their own areas. In many cases, it has not been possible to establish an accurate picture of the likely impacts of flooding and while models can generate estimations, these may have little meaning to potential clients and their usefulness can be restricted outside technical agencies. It follows that where flood information or intelligence is lacking or of poor quality, warning services and response strategies are likely to be impaired.

Response agencies have a duty to ensure that predictions and other information released to the community can be readily understood so that people can comprehend what the impacts of a coming flood will be and how they should react. Research has shown that most members of the general community cannot easily interpret gauge or flood heights, particularly if they lack direct experience with flooding in their local area. When a flood prediction is received, information from past floods or technical results from models need to be used to identify likely consequences within the local area. To do this, flood intelligence systems are required to add local context and meaning to flood predictions. Where quantitative predictions are provided, this means linking impacts to the numbers.

Resources must be allocated to developing these systems. Data should be gathered from local government bodies, water management agencies and other agencies and from formal flood studies which have been undertaken. Additional data should be collected during times of flooding. All this data can be used to interpret and add meaning to flood predictions.

Information Needs for Warning

Flood intelligence records provide key resources that aid in the interpretation of flood predictions and provide content for warning messages. The Flood Preparedness manual provides detail on how to compile and use the flood intelligence records, which should be developed for the **reference area** around a stream gauge, both upstream and downstream (see Figure 4). This is the area for which gauge heights have meaning in terms of riverine flooding, independent of local flooding or flooding from tributary creeks. The entries themselves should consist of the known or estimated heights at which the following occur:

- floodwaters encroach on specified farmlands, caravan parks, residential and business properties, rural and isolated properties, community facilities (including potential evacuation centre locations), institutions (eg nursing homes and schools) and utilities (eg sewerage and water supply systems and electrical substations). Impacts at different locations can be indicated by map grid references,
- buildings are flooded over their floorboards,
- roads are cut, causing individual houses, communities or parts of communities to become isolated and traffic movements to be disrupted,
- railway lines are cut,
- airfields begin to be or are inundated,
- other significant effects (including the overtopping of levees) occur or can be expected. Where

studies have been carried out on the integrity of levees and 'imminent failure heights' have been identified below design levels, these heights should also be recorded. Note that levee crest heights usually include an allowance for freeboard, but both operational experience and the findings of law courts indicate that this should not be relied upon,

- record and historic flood peaks in recent memory (or particular design floods such as the 1 per cent AEP event or PMF peak).

Figure 4: Stream Gauges and Reference Areas, Clarence River, New South Wales

It will also be useful to record the depth and velocity of floodwaters at specified locations when particular heights are reached.

In compiling these records, care should be taken to:

- ensure that effects are **correctly ascertained in a causative sense** relative to gauge heights. It is important not to include effects which did not relate directly to specified heights being reached during a particular event (eg effects on a tributary which occurred at the time a height was reached at a gauge on the main stem of the river but were not the result of that height being reached),
- note any **interdependencies**, such as where an impact at a particular height at a gauge will occur only if some other effect, unrelated to that gauge, also occurs. An example would be a road being cut at a certain height, necessitating a longer journey on an alternative route between two places but with the possibility of all access being lost when this route closes as a consequence of flooding on another stream,
- ensure that effects are noted in terms of **types of impacts**, eg roads closed to different classes of vehicles, or properties affected in different ways (such as by **inconvenience**; if additional distance is added to journeys; or by complete **isolation** which may necessitate resupply; or by **inundation**),
- keep detailed **lists of affected properties**, by type (residential, farm, retail, industrial, caravan park, etc).

It should be noted that virtually all flood intelligence records are **approximations**. Further, no two floods in an area, even if they peak at the same height at the reference gauge, will have identical impacts throughout. This may be because their gradients differ, because they rise or fall at different rates, or because they are at or near their peaks for different lengths of time. In addition the channel and floodplain environments in which they occur are unlikely to be the same.

The fact that height/consequence links are approximations, with some cases being estimates of likely rather than certain occurrences, should not be of concern. **On no account should lack of complete accuracy be allowed to discourage efforts to develop flood intelligence records**. Indeed the fact of approximation should be regarded as a positive because the information disseminated in warning messages usually needs to be generalised. In any case it needs to be only 'sufficiently accurate' to lead people to appropriate responses: it does not need to be precise in all respects. The alternative to inexact information, often, would be to have no useful information on which to base operational decisions and construct warning messages. Where substantial known variability exists in the heights at which particular effects can occur, this can be noted by listing a range of heights.

Apart from recording height/effect relationships, the records may indicate specific actions which may need to be:

- undertaken before specific heights are reached (eg barricading a road which will be dangerous to travel on, or closing drainage valves to prevent backwater flooding), and/or
- completed in advance of floodwaters reaching particular levels (eg moving farm animals before paddocks are inundated, evacuating people to safety before escape routes are cut, or removing electric motors from sewerage pumping stations before they are submerged).

In such circumstances, indications of the **amount of time required** to carry out the required actions are particularly useful.

The flood intelligence record should identify flood levels that produce significant impacts for the various sectors of a community (eg urban, rural, residential and business) and for different locations within the reference area of the gauge. In doing so the record will link the physical and social information gathered through analyses of the hazard and the community and will provide a framework for managing problems which will occur at heights which can be known, at least approximately, in advance. This means that barricades to close roads can be assembled and school bus companies advised, allowing decisions on alternative routes to be taken, and pre-event identification and prioritisation of evacuation requirements can be made for houses, schools, hospitals and business premises. Equally, data can be assembled on which premises will need to be warned about the likelihood that inundation will occur.

Most importantly, recording heights against consequences and actions helps develop a modus operandi for flood managers which involves routinely looking ahead to ensure responses occur at appropriate times. In turn, this will mean that actions which need to be undertaken are carried out when they can most effectively be done rather than when they are most needed to be done – which is often later than is preferable. Estimating the amounts of time needed to carry out these tasks will facilitate their successful completion.

Examples of intelligence record statements for particular gauge heights might include those listed in Table 2.

Gathering, Updating and Displaying the Data

For particular areas some of this information may already exist in local government engineering records or from studies of past floods. It is important that, where possible, any gaps be filled and the records updated by the systematic gathering of data **during** and **immediately after** flood events. This information can be fed to a response agency operations centre for assessment and immediate use. It should then be held for the after-event updating of records and debrief meetings.

Table 2: Examples of Entries in Flood Intelligence Records

- Water begins to enter __________ Caravan Park. Relocation of up to (number) vans to high ground at (location) must be completed before this height is reached. Disconnecting vans from sewerage, pumping up tyres and carrying out the relocation takes ______ hours.
- River breaks banks at (location); farmers in vicinity (define) need to be advised in case of need to move livestock and equipment. Warning time required: ______ hours.
- ____________ area cut off from ____________ at (location), (number) houses isolated for (approximate period of time, expressed as a range of hours or days). Resupply necessary; can be conducted by high-clearance vehicle until gauge height (metres) is reached after which resupply must be by boat or air. Note that some dwellings may be inundated over floorboards at _____ metres. See annex for details of houses affected.
- Shops in ________ Street begin to take in water. Need sandbagging which takes (time required). Note that access to these shops is lost at _____ metres.
- Approach to ___________ Bridge cut 8–10 hours after this height is recorded; access to (town) available only via (alternate route) which may be closed at (location) by flooding on ungauged (name) creek. School bus drivers need to be advised.
- Overfloor inundation of houses in ______________ Street begins. Note that evacuation route (describe) may be cut at (location) at gauge height lower than this level (define). Time needed to raise furniture and effect evacuation is (hours required). See annex for address list.

What this means is that response agencies at the local level need to develop **expertise** about the characteristics of flooding in their own areas. It does not mean response personnel must become specialist hydrologists or duplicate the work done by prediction agencies. They should, however, develop an understanding of local flood characteristics and the ability to record information to help further that understanding and to ensure the usefulness of flood predictions can be fully realised. This is vital to effective decision making and to provision of high-quality warnings to the community.

While most of the information collected will be related to the specific effects of flooding at particular heights, it is also useful to note any special characteristics of the flood itself to better relate the effects to the gauge heights. Data on the features and behaviours of individual flood events could be recorded including, as appropriate, information on:

- relative contributions of individual streams/creeks/sub-catchments to the flood,
- some indications of flood volumes and their correlations with gauge heights,

- tidal states, and
- any additional observations not normally captured by automated data collection systems.

Geographic Information Systems

It is worthwhile investing in **Geographic Information Systems** (GIS) so that the data are collated into a single repository. A GIS will also help to interpret height predictions operationally. With current software it is possible to build maps on a computer to show the locations of creeks, streets, utilities, property boundaries, contours and flood lines and to overlay census information, cadastral data sets that illustrate property type and land use, utility and lifeline networks and critical components (such as power and water substations).

GIS can be used in various components of the total flood warning system, providing real benefits to agencies and subsequently to at-risk communities. Considerable developmental work is needed, however, to build the data sets and information displays required during a flood management operation. This work includes geocoding elements at risk, digitising operational management features such as evacuation routes and management sectors and building a library of flood surfaces. These are typically outputs of the planning process and must be prepared in non-operational periods.

Ideally, a GIS should be integrated with an agency's operations management system(s) through being connected to property databases, telemetered rainfall and river-height data, hydrologic model results and other decision support tools. However, less sophisticated set-ups, such as single installations, can also be of value.

The most common application of GIS in flood management lies in the interpretation of flood predictions. The practice of drawing a likely flood extent on a paper map is an old one which is made very simple when data is available in a GIS format. More advanced approaches of intersecting digital terrain models, and height-attributed property and/or road data with flood surfaces, are emerging. Typically, elements at risk of flooding identified through the review of flood intelligence records would be geocoded and attributed with height information (both gauge height and relative to a standard datum such as mAHD).

Figure 5 shows such an example of a flood map displayed using a GIS. This shows inundation of Euroa, in the north of the Victoria, from a series of eleven inundation maps covering events ranging from nuisance floods to the assessed 1 per cent AEP flood. All are referenced to the key gauge in the town. Such maps may indicate the depth of floodwater in different locations on the floodplain, the velocity and direction of flood flows, and the properties which are likely to experience overfloor and/or overground inundation at particular flood heights on the gauge. Ideally, this mapping should go beyond the 1 per cent AEP event. It could extend to cover the PMF or, where appropriate, dam-failure floods.

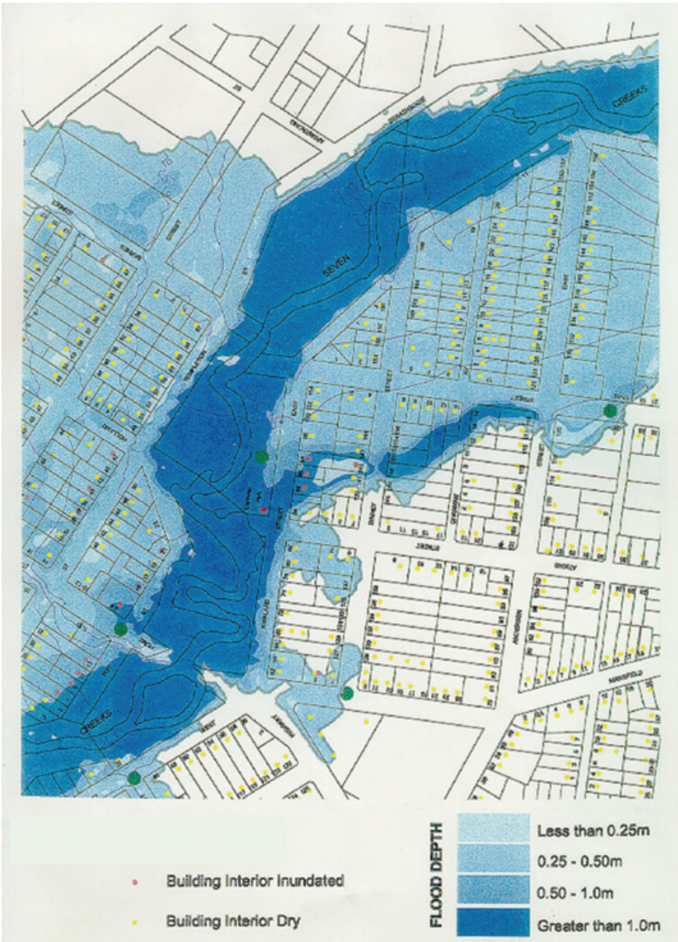

Figure 5: Inundation at Euroa in a Flood Reaching 6.1 metres (the 1% AEP flood)

Because of their visual power, aerial and ground photographs showing the physical extent of flooding in events of differing severity are also vital tools for aiding the understanding of flood behaviour and communicating potential impacts. They are useful complements to GIS map products and flood information tables.

Further detail on the use of GIS for flood management planning and response is available in Chapter 2 of the Australian Emergency Manual **Flood Preparedness** and Chapter 3 of the Australian Emergency Manual **Flood Response**.

Flood Classifications

In Australia there are standard flood classifications that describe the severity of flooding at stream gauges linked to the potential effects in the reference areas of the gauges (Figure 6). The classifications of minor, moderate and major flooding can be used as a general guide for response agencies and provide examples of how to translate numerical results into impacts on the ground that can be graphically or verbally communicated to the public.

Major Flooding: This causes inundation of large areas, isolating towns and cities. Major disruptions occur to road and rail links. Evacuation of many houses and business premises may be required. In rural areas widespread flooding of farmland is likely.

Moderate Flooding: This causes the inundation of low lying areas requiring the removal of stock and/or the evacuation of some houses. Main traffic bridges may be closed by floodwaters.

Minor Flooding: This causes inconvenience such as closing of minor roads and the submergence of low level bridges and makes the removal of pumps located adjacent to the river necessary.

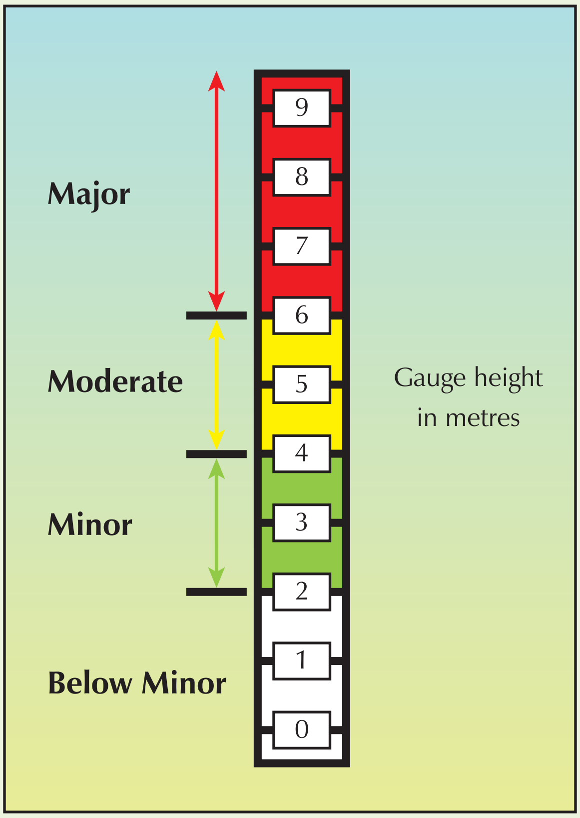

Figure 6: Minor, Moderate and Major Flooding

Recording Information for a Gauge Reference Area

A Victorian example of flood information relating to a particular gauge (Tallandoon, on the Mitta Mitta River) is shown in Table 3. This figure illustrates an effective structure for recording height-impact and action data, though a much greater volume of useful information could be envisaged. Note that actions are recorded against the heights at which particular effects are **expected** rather than at some unrelated lower height as often happens. This logic is intentional and designed to discourage actions being initiated on the basis of those arbitrary lower heights being reached. Rather, actions should be defined in terms of the time required to carry them out well before floodwaters reach the expected height and render the actions difficult or impossible to complete.

Linking the Numbers to Potential Impacts

A flood prediction normally provides an estimation of flood height for a nominated future time at a specified location. For such a prediction to be useful to a response agency, tools must be available by which the consequences at the predicted height can be understood before it is reached and the timing and sequencing of inundation can be known. If these tools are available, decisions can be taken about appropriate actions. It is critical that height predictions not be allowed to stand by themselves. Their utility must be enhanced by a deliberate process of adding value.

When a flood prediction is received, a primary task of the response agency (usually the local council, local SES or catchment management authority) should be to **link the predicted conditions to potential impacts within the local area**. This will then determine and direct response and recovery operations and the messages communicated to the community. As flood effects ultimately impact on the community itself, it is worthwhile for response agencies to develop knowledge of the local conditions and potential reactions, both within the physical and social environments.

The goal should be to ensure that agency responders and members of the public have as clear an idea as possible about the impending flood event and what it means to them in their current location. This includes making predictions as **comprehensible as possible**, without compromising the quality of the content, in terms of the **areas likely to be flooded**, **the properties likely to be affected** (whether by isolation or inundation) and **roads likely to be obstructed**. The potential impacts from an event can be communicated to the public in a variety of ways that translate the numerical predictions into tangible experiences eg flood markers throughout a town, pictures of previous events and written descriptions of the potential extent of inundation.

Table 3: Flood Intelligence Record for Tallandoon

Gauge Name: Tallandoon			River: Mitta Mitta		
Key Heights (metres)		1. Minor: 4.2	2. Moderate: 4.9	3. Major: 5.6	
Height (m)	Flow (ML/day) Date	Effect	Location	Action	
5.97	93,000 Aug 1955				

Gauge Name: Tallandoon			River: Mitta Mitta	
Key Heights (metres)		1. Minor: 4.2	2. Moderate: 4.9	3. Major: 5.6
Height (m)	**Flow (ML/day) Date**	**Effect**	**Location**	**Action**
5.66	62,500 Jul 1974	Bridge on Omeo Hwy inundated. Some rural houses isolated and some flooded above floor level.	Two kilometres down-stream of the junction of Lockharts Gap Road and Omeo Hwy.	Rural evacuations required downstream of this location.
5.6	60,000	Major Flood Level.		
5.55	52,400 Nov 1974	Omeo Hwy inundated for 8 km.	From Tallandoon downstream	Liaise with VicRoads re road closure. Evacuation only possible upstream via Omeo.
5.48	47,300 Sep 1975			
5.37	39,700 Nov 1996	Omeo Hwy cut at 40,000 ML/day.	Upstream and down-stream of Tallandoon.	Lockharts Gap Road not accessible.
		Water over road at Tallandoon. (Highest flood since Dartmouth Dam construction.)		Liaise with VicRoads re notification of road closure. Limited vehicle access; 4WD only.
4.9	25,700 Dec 1992 Second Event	Moderate Flood Level. Widespread inundation of farmland.	Below Tallandoon.	Further stock movement to higher ground required. Consider future closure of Omeo Hwy at 40,000 ML/day and impacts on evacuation routes. Consider property evacuations.
4.3	17,800 Nov 1992			

Gauge Name: Tallandoon			River: Mitta Mitta	
Key Heights (metres)	1. Minor: 4.2		2. Moderate: 4.9	3. Major: 5.6
Height (m)	**Flow (ML/day) Date**	**Effect**	**Location**	**Action**
4.2	16,500 Dec 1992 First event	Minor Flood Level. Pigs Point camping area inundated.		Consider stock movement. Campers evacuated.
3.7	12,655 Sep 1983	Inconvenience to landholders. Low-lying grazing land inundated.		Possible stock movement required in the lower reaches of the river. Additional information required to know what/ where inconvenience occurs.
3.4	10,000	Irrigation pumps affected Tallandoon (bank full).	Downstream of Tallandoon.	Community/farmers to monitor flows for impact on pumps. Landholders to contact Dartmouth Dam telephone flow advice.

From a community standpoint, the principal purpose of achieving high-quality flood interpretation is so meaningful information can be provided about the coming flood and advice given about what people can do to manage its impacts. Effective interpretation will help develop the content of the warning messages which will be disseminated to communities in the path of a flood.

In some locations, flood markers have been placed on bridges and in other prominent locations to provide residents with a visible point of reference for flood events. Markers such as these have the potential to be linked to the flood warning system, effectively 'personalising' the warning system when local flood effects are mentioned in warning messages broadcast during floods. They help make it possible for residents to assess the likely impacts in **their** local area, enabling them to make effective decisions about protecting property and if and when to evacuate. Using such markers does, however, require an education campaign to ensure that community members understand what they represent and are able to interpret them correctly when a prediction of a particular height is promulgated in a warning message.

CHAPTER 5

Designing Warning Messages

In a Nutshell…

A flood warning message provides information on what a flood prediction will mean to the target audience and what the audience should do.

Warning messages are the critical link in communicating information on expected flooding. They provide the signal for those at risk to take action before the flood arrives or reaches particular levels.

Message construction should be based on the needs of those at risk and should be in language familiar to those expected to take action. The critical issues are:

- ***ensuring messages are forward-looking and provide helpful information and advice,***
- ***persuading those at risk they should respond and within an appropriate time frame, and***
- ***ensuring messages include the predicted severity (height) of the flood, describe its likely consequences and indicate the actions people should take.***

Introduction

The warning message is the critical link between flood prediction and interpretation on the one hand, and the taking of protective action on the other. It must be 'user friendly', it should explain what is happening and what will happen, where, how the flood will affect the recipient of the message and what he or she can do about it. The message must come from a credible source (such as the Bureau of Meteorology or a State or Territory Emergency Service), be informative and persuasive and be clearly understood by those receiving it. The message may be either in written form or communicated verbally.

Understanding the Flood Problem

A precondition for effective flood warning message design is a detailed knowledge of the flood problem. This includes knowledge of the physical dimensions of flooding and of the communities at risk as well as an understanding of how those communities are affected by flooding. The characteristics of the flooding, the nature of the community and the interaction between flood and community should influence how warning messages are constructed and disseminated.

The Floodwater

The particular physical characteristics of flooding relevant to providing flood warnings include:

- when the floodwaters will arrive or reach certain heights,
- when the flood will occur (eg during the day or late at night),

- how long the flood will last,
- where the water will go (ie in terms of areas which may be inundated),
- the depth and velocity of the expected floodwaters, and
- other factors which may affect safety.

Some of this information, specifically that on which areas will be inundated at the forecast height, should be contained in flood intelligence records along with information on the locations at which roads will be cut. It also needs to be incorporated in any GIS being developed or in use to help manage floods within the area.

The Community

The 'public' is not a uniform group of people who think and act in the same way, with the same values, perceptions and expectations. Agencies responsible for disseminating warnings require a thorough understanding of the needs and characteristics of the various 'publics' or groups in their areas of responsibility. These needs and characteristics should influence the design of warning messages. For example:

- People have a variety of flood experience, exposure to flooding of different severities and financial or emotional 'stake' in the flood-prone area, and they differ in a host of social factors (including age, household structure and level of familiarity with English).
- Some people have dwellings on the floodplain, others have business interests, and others again have responsibility for institutions (eg schools) or items of infrastructure.
- Some people may not have ready means to carry out protective actions eg to evacuate to safety.

It follows that different people are likely to have different information requirements and that some may face particular difficulties in either understanding and/or translating the message into appropriate action, ie in finding the intended meaning and its implications and acting upon it.

Those at risk need to know about:

- their risk,
- how they can expect to be warned,
- what sorts of responses are appropriate for them to make, and
- what to do if they need help.

It is necessary to communicate with the people at risk on these issues to ensure community requirements are fully understood and so well-informed planning can be done to meet the requirements of community members.

Special attention should be paid to identifying high-risk groups. These may be defined by physical factors related to flooding (eg dwelling location relative to areas of high-velocity flow) or by social characteristics (eg elderly people or families without cars).

Message Construction and Content

Using Specialist Assistance

Construction of flood warning messages requires specific communication skills which may not be readily available within the emergency management agencies usually responsible for warning of impending flooding. These organisations should not hesitate to call on outside help for such specialist assistance.

The media can be particularly helpful in improving message quality. Agencies responsible for providing flood warnings will frequently be dependent on the media to relay the warning to the community. Media cooperation and support in message formulation and transmission are essential to ensure effective communication. They will help ensure that:

- messages are kept **brief** (In general, those broadcast over radio should take no longer than 60 seconds to read, additional material being covered in later messages. It is better to have several short messages, perhaps for different areas or 'groups', than a single long one. This requirement may be relaxed in very severe events requiring large-scale evacuation, when the news value of the flooding will encourage the media to focus upon it and allow more information to be carried),
- content is **ordered** (with an early description of the likely severity of the flood to seize people's attention), and
- the language used is **clear** and avoids jargon.

Persuasiveness

Messages which are intended to **persuade** people to act need to present information or data, but they also need to arouse some emotion or feeling. Reactions generated by flood warnings can include disbelief, boredom, anxiety, fear or even excitement. Many warnings, though, fail to generate any feelings or interest at all; indeed they are often ignored completely (Pfister, 2002). This suggests that they have failed to 'break through' to people's consciousness: indeed some do not realise that a warning message they have heard was in fact such a message.

Receiving a warning and facing imminent flooding, some people also report a sense of powerlessness associated with an inability to decide what to do (Maitland, 2008). Flood warning messages have a role in overcoming the indecisiveness they feel in relation to taking action.

To overcome these problems, flood warning messages should be delivered in ways which are purposefully designed to **motivate** or arouse. This can be done by the use of 'arresting' language, or by having messages accompanied by a siren or alarm sound (the use of the Standard Emergency Warning Signal, SEWS, is appropriate in this context, at least when severe flooding necessitating evacuation is developing).

While those designing messages are sometimes concerned about causing inappropriate concern or 'panic', this is rarely a problem. The bigger problem is almost always one of overcoming 'torpor' on behalf of those at risk and persuading them to take appropriate action and in an appropriate time frame. Flood warnings must grab people's attention as a prerequisite to convincing them of a need to act.

Comprehension

Messages must be able to be **comprehended** by the target audience. Those at risk cannot be expected to respond appropriately if they do not understand the terms used in the message. Research shows that even apparently straightforward terms like 'flash flooding' can convey a wide variety of meanings. Some terms are simply not understood by lay people and are frequently used under a wide range of meanings even by specialists. Using simple, non-technical, user-friendly language helps avoid these problems.

Experience shows that people often fail to realise that a warning message applies to **them** personally. The liberal use in messages of the names of places or localities to which a warning applies (and in which a coming flood will have consequences) is effective in helping people to recognise the relevance of a message to their own circumstances. One way of achieving this is to refer to flooding on a river reach from the upstream edge of the relevant gauge reference area (using the relevant locality name) to the downstream edge (also named).

Tone

The **tone** of messages is important. As far as possible, messages should:

- be **positive** rather than negative, saying what to do rather than what not to do (eg, '*Stay at home*' rather than '*Don't leave your home*'),
- suggest **action** rather than inaction: '*Raise your belongings*', encourages definite action,
- invite **sociability** rather than isolation. Social interaction is part of the process of message confirmation, and messages like '*Advise your neighbours*' or '*Check to see whether your neighbours need help*' encourage sociability and help ensure people are assisted where necessary and also in touch with others,

- be **vivid**. The message should arouse emotional interest and be easy for those at risk to relate to their own situations, eg *'Avoid walking or driving into the floodwaters because these are the main causes of death during floods'* will help attract attention by noting a possible cost. If evacuation is sought, it is legitimate to describe the possible negative consequences of over-floor inundation thus: *'To stay in your house is likely to become difficult, uncomfortable and dangerous because the telephone, power and water supply could fail and snakes, spiders and insects may gain entry'*.
- **connect flood consequences with suggested actions** eg *'Farmland near the river will be inundated and farmers should consider relocating pumps, other equipment and livestock'.*

Avoiding Confusion

Much flood warning is done using broadcast radio, and experience has shown that people easily confuse the various numbers they hear in a warning message. Thus current gauge heights may be confused with predicted heights, and the heights provided for different gauges may become mixed up in people's minds. It is nevertheless desirable that both current and predicted heights are broadcast so that people can gain an idea of the difference between present and expected future river levels.

The solution to the problem of number confusion is to restrict the use of numbers **in individual messages** to a minimum, for example by restricting the content of individual warning messages to the reference area for a single gauge. This may mean that there will need to be several messages to cover a number of predictions on a river, but it will help maintain simplicity and help avoid confusion.

It will also keep the messages short. Long messages which make many points are not likely to be well absorbed by listeners. Therefore, many short messages containing manageable amounts of information are preferable to a smaller number of long messages containing so much information that people 'lose' large amounts of it. Short messages are also more likely to be broadcast in full and repeatedly by radio stations: they are more 'station-friendly'.

Discussions with floodplain residents also show that they can be confused and frustrated by the use of terms such as minor, moderate and major flooding. **By themselves**, these terms and their formal definitions (see Figure 6) are not well understood in the community, and they are often thought to be vague, unhelpful and even annoying. They therefore are not persuasive on their own as descriptors of flood severity.

It should be noted here that these terms were introduced during the 1970s as 'shorthand' terms to describe the likely severity of a developing flood. In this context a legitimate goal of flood warning practice might be, as flood intelligence records become sufficiently well developed, to use the intelligence to replace or at least qualify the terms in warning messages. In many areas in Australia the flood intelligence is well up to the standard at which this is possible.

Using flood intelligence to define the likely consequences and referring to them explicitly (even in a general sense by referring to 'low-lying farmland' and 'local roads' in nominated localities) will help message-writers to give context to the use of the terms 'minor flooding', 'moderate flooding' and 'major flooding'. Where impacts can be noted specifically (eg the expected closure of an individual road or the inundation of a particular part of a town), every effort should be made to do so. In short the words 'minor', 'moderate' and major' should not be used without additional information to describe, at least in broad terms (and more specifically if possible), the actual flood effects (eg road closure, farmland inundation, levee overtopping) which are anticipated.

Designing Messages Outside Flood Time

In most flood situations, the time available for constructing warning messages is short and it is difficult to ensure quality of communication. This means that warning messages constructed as a flood is developing tend to lack specificity of information, do not achieve the appropriate tone and cause confusion. One means of overcoming this problem is for those responsible for devising messages to produce 'template' messages **out of flood time**, using flood intelligence to indicate likely impacts for floods of different severities and seeking to communicate with different subsets of the community. This allows consideration of style issues, content, tone, terminology and completeness and provides models from which real messages can be constructed by editing the template messages during flood operations.

Such messages have been developed in New South Wales for the reference areas of many gauges for which flood predictions are issued. For each reference area, several messages have been prepared covering a range of flood levels in 'height bands' from nuisance flooding to events which will exceed the greatest heights recorded in the past. There are up to six messages per gauge reference area. In general, more information needs to be included in messages when very big floods are predicted, especially because of the need to advise people about how to evacuate (ie what to do before and on leaving, what to take, where the evacuation centres are located and what routes to take, what to do with pets, etc).

Once flooding is actually predicted there is scope to incorporate information specific to the time of release (such as information on what has already happened) and to fine-tune messages to fit the precise height of the prediction. Operations staff must edit the template drafts quickly and efficiently: on no account should a template be sent without being checked for relevance to the current and prospective situation.

Developing these template messages has helped operations staff to comprehend the flood problems of their areas and to deal more quickly and efficiently with the warning task once a coming flood has been detected. They have helped to save time in issuing warning messages to radio stations, and the quality of the real-time communication has improved. Some examples are provided in Tables 4 and 5 for the Macksville area, on the Nambucca River on the north coast of New South Wales.

Table 4: Example Warning Message for Minor Flooding in the Macksville Area

Warning of Minor Flooding at Macksville and in Nearby Areas

The Bureau of Meteorology has predicted that flooding will reach/exceed **[delete one]** [1.7-2.0] metres **[insert predicted height]** at the Princess St gauge, Macksville, at **[time, day].** This will cause minor flooding along the Nambucca River. At this height, low-lying areas near the river will be inundated from about Wirrimbi and Congarinni to Nambucca Heads and along Warrell Creek. The consequences are likely to be as follows:

- Farmland near the river will be inundated. Farmers should take the necessary action to protect pumps and other equipment and move livestock.
- Road surfaces may be damaged, and people should avoid driving through floodwaters. Entering floodwaters is the most common cause of death during floods.
- Water may flood yards and under-floor areas in Kings Point and North Macksville. Residents should secure items in garages and outdoors to prevent them from floating away.

[Note for Operations centre staff: a short section here on known current effects, including road closures, would be appropriate. Care should be taken not to predict effects which have already occurred]

Messages for Flash Flood Situations

The practice of setting up messages **before** flooding occurs is especially valuable when warnings of flash flooding are being considered. In flash flooding environments it is probable that **any** warning messages will need to be constructed beforehand because there will be insufficient time to design them once the rain event has begun. Such messages will have a largely generic content, with reference being made to:

- the rain that has already fallen,
- the potential for further rain, as indicated in weather forecasts,
- the areas of greatest risk (low-lying areas especially if near creeks or drains), and
- what people should do to protect their property (by raising it in situ onto tables, beds and benches) and preserve their safety (either by staying or leaving, as appropriate to the local environment, but recognising the dangers of evacuating through fast-flowing or deep water). Where such conditions exist or are imminent it is usually wise to recommend that people stay rather than leave.

Table 5: Example Warning Message for Major Flooding in the Macksville Area

Warning of Major Flooding at Macksville and in Nearby Areas

The Bureau of Meteorology has predicted that flooding will reach/exceed **[delete one] [2.6-3.0]** metres **[insert predicted height]** at the Princess St gauge, Macksville, at **[time, day]**. This will cause major flooding.

At the forecast height, large areas of the Nambucca River valley will be inundated from upstream of Macksville to Nambucca Heads. Many roads will be closed, large areas of farmland will be inundated, and low-lying areas of Macksville will be flooded as water enters North Macksville, Kings Point, East Macksville and Nambucca Heads.

This is likely to be the most serious flood experienced in the Macksville area since May 1977, when a peak of 2.65 metres occurred/ March 1974, when the peak was 2.95 metres **[delete one]**.

It is critical to understand the potential danger which this flood poses. Houses and roads in low-lying parts of the main business area **[over-floor inundation begins at 2.3 metres]**, Kings Point **[over-floor inundation begins at 2.5 metres]** and North and East Macksville **[over-floor inundation begins at 2.8 metres] [delete cases above the predicted level]** will be flooded, water entering houses and shops.

People in Kings Point, the Macksville Central Business District and North and East Macksville **[delete as appropriate]** are urged to prepare as quickly as possible to evacuate. They should:

- raise as many household and business items as possible onto beds, benches and tables, putting electrical items on top,
- gather together valuables and personal items such as family memorabilia, photograph albums, heirlooms and important papers. These should be taken in your car along with spare clothes and essential medicines, or packed in a suitcase if you need transport.

Advice on evacuation will follow in the next bulletin within 15 minutes.

Using pre-designed messages in flash flooding environments can be triggered by:

- decision rules determined beforehand (eg threshold rainfalls exceeded, with further heavy rain forecast), the messages going automatically to radio stations when the appropriate conditions are fulfilled, or

- a person determining the environment is ripe for flash flooding and providing a message to the radio stations: this requires the responsible person (who could be a member of a prediction agency or a response agency) being prepared to take a risk in a situation where the possibility of error is high.

It should be recognised that such messages will increase the likelihood that useful information will reach the community in these environments in time for actions to be undertaken. Even very small quantities of warning time, amounting to only several minutes, can be valuable in areas in which flash flooding occurs.

Word Pictures

The message should say **what is expected to happen** and **when it will occur**; and indicate **how people should act**. It is also useful, subject to space constraints, to describe the flood and indicate what is happening currently.

In its description, the message needs to go beyond merely specifying predicted gauge heights and using the terms 'minor', 'moderate' and 'major' to identify the flood's likely severity. It needs to create a 'word picture' that attracts the listener's attention by describing what is likely to happen.

Instead of simply saying, '*A major flood of N metres on the town gauge is expected to arrive at time Y*', a word picture would describe what the flood will look like, with an emphasis on the likely impact as it relates to people. For example: '*Serious flooding, reaching N metres on the town gauge at P [location] is expected by midday on Thursday. Houses in A and B streets could be inundated over their floors, river flats between X and Y will be flooded and the Z bridge across the river will be closed*'.

This approach is particularly useful with floods predicted to reach extreme levels significantly above the threshold of major flooding, or where the effects are likely to be very serious (eg where there will be fast-flowing water across roads). A message might say something like: '*This flood has the potential to wash cars off roads and kill people*'.

Such messages must include an **action statement** – in this case not to attempt to drive through the floodwaters. In other messages, the action statement may relate to the need to use particular routes to avoid travelling through floodwaters, to lift or relocate belongings in advance of floodwaters arriving, to stock up on food and other essentials before isolation occurs, or to evacuate by a certain route by a specified time.

It is important to note that the examples given above are forward-looking, that is, they seek to **predict** the effects of the flood (just as prediction agencies forecast its height) and derive action statements from an understanding of the prediction. Flood warning messages or bulletins may also carry information on what has already happened, eg: '*The road from X to Y is closed at Z bridge*'.

Thus actual, current impacts should be included as well as likely or certain future ones provided that care is taken to ensure that what has happened and what is likely to happen can be differentiated. Effective flood intelligence records (and effective relaying of data from the field to the operations centre during a flood) will help here. As far as future flood effects are concerned, all listed effects up to the flood height predicted can be expected to occur, broadly speaking, in the sequence indicated on the flood intelligence record, and the message can be written from the information contained therein.

It is sometimes necessary to forestall inappropriate responses by indicating what the flood will **not** do. A message might note, for example: *'At the predicted height, the flood will not enter the town of X'*.

Almost always, it is appropriate to issue more than a single message at a particular time during a flood. Standardised message formats offer some advantages, particularly in terms of generalised messages intended for whole communities. However, such messages are unlikely to be appropriate to the requirements of all community members. A workable approach would be to prepare a number of messages with the needs of particular subsets of the community in mind (eg farmers, operators of Central Business District premises, people who will need to evacuate) as well as general ones for mass communication purposes. This will increase the relevance of the communication, from the standpoint of the recipients of warning messages, and help increase persuasiveness.

Using Benchmarks

The comprehension and persuasiveness of a warning message can be enhanced by referring to recent and/or extreme events and comparing the impending flood with specified floods of the past. Statements like, *'This flood will be similar to the flood of 1989'*, or, *'This flood is expected to be significantly more severe than (or half a metre higher than) the flood of 1989'*, help tap into the 'community memory' of flooding. In doing so, they help people to assess the severity of the coming flood, or to ask questions of those who witnessed the event referred to.

If minor floods are to be used as benchmarks, it is important that they be **recent** ones. Otherwise they will not be remembered. Severe events from longer ago will be recalled by some, however.

Record floods which occurred in the very distant past can also be used even though they will not be remembered in the literal sense by present community members. In some areas such floods are understood to have been important in history and some people are likely to have heard of them and have some understanding of what a repeat will mean. If a coming flood is comparable with (or likely to be worse than) the worst ever known at a location, the comparison will help reinforce the seriousness with which it should be taken.

Dealing with Uncertainty

Inevitably, predictions of flood heights and flood consequences involve an element of uncertainty. This is likely to be particularly true of predictions which are issued early in a flood event when the likely eventual severity is difficult to ascertain (perhaps because the rain event is not yet over). The existence of such uncertainty should influence message design.

Words like '*may*', 'probably' and '*likely*' can be used to describe potential impacts. **It is preferable to use words such as these rather than remaining silent about possible consequences merely because those who formulate the warning message are not completely certain about what will happen.**

Despite the existence of uncertainty, a warning should contain a message about what people should be prepared to do. This is preferable to providing advice only in a later warning when the uncertainty has disappeared. **To wait before providing any advice is likely to encourage responses which are too late to be effective.**

One consequence of the uncertainty which attends the need to look forward is that messages will, in some instances, be shown to have been inaccurate in the information provided and the actions recommended. Warnings may be given of floods which do not eventuate or which do not reach the gauge heights expected. While this can create some problems, agencies should not exaggerate the consequences of 'false alarms' or 'over-warning'. Rather, it should be recognised that the costs incurred by such warnings are usually limited, and that these costs will be strongly outweighed by the benefits which will accrue when flooding does occur or matches the severity predicted.

In any case, the so-called 'cry wolf' problem can be used to raise flood awareness and to create opportunities to check that operational procedures and links to radio stations are working effectively. Over-warning should never be practised deliberately, but when it does occur the situation should be explained as quickly as possible to the community through the media, in specially-called public meetings or in discussions with particular groups. An explanation given as soon as possible will help ensure system credibility is retained and will maximise the opportunity to turn a negative into a positive.

CHAPTER 6

Communicating Flood Warnings

In a Nutshell…

Those at risk from flooding will be unable to take appropriate protective action unless they are advised about coming floods and the impacts that are likely to affect them, and are encouraged to take actions in response and in appropriate time frames.

Message dissemination involves transferring warning information to those at risk in ways that are likely to elicit appropriate responses.

Warning messages should be communicated by:

- ***a wide variety of modes, ranging from radio announcements to doorknocking and from newspapers to personal telephone calls and emails, with more modes being utilised in severe floods than in lesser ones,***
- ***selecting modes which are appropriate to the nature of the flood problem and the community at risk, and***
- ***adopting and changing delivery modes as technology develops.***

The critical issues are:

- ***identifying the appropriate communication dissemination modes for different target audiences,***
- ***ensuring the consistency of the message is maintained when different dissemination modes are used to create redundancy, and***
- ***ensuring those at risk receive and can confirm the warning.***

Introduction

The best predictions, the best interpretive material and the best warning messages are of little value if they have no impact on damages or safety. Failure is guaranteed if warning messages based on flood predictions and interpretations of them are not conveyed effectively to those expected to respond. In essence, a warning which is not communicated effectively is no warning at all: if it is not heard or understood, it cannot be heeded.

Warning communication occurs between:

- key stakeholder agencies. These communications, conducted during floods, form the main conduits for information needed for operational decision making.

- between emergency service organisations with flood warning responsibilities and the people whose interests are threatened by flooding. The communication must occur in a manner which is designed to obtain appropriate responses from those who are at risk and which does so in a timely fashion. In different flood circumstances, and when there are different target audiences, different dissemination methods will be necessary.

Rapid advances in electronic communications and their adoption by the general public have broadened the options available to warn members of the public. Technological advances now enable many of those at risk to receive a standard message and/or a personalised telephone call, and/or to gain access to information through the internet. In using these new methods, agencies charged with disseminating flood warnings may need to obtain specialist advice, for example in relation to the transmission of information by graphical means or to ensure that the language used attracts the attention of recipients (see Chapter 5 on **Persuasiveness**, **Comprehension** and **Tone** in relation to messages).

General and Specific Warnings

Warning messages provide to community members can be classified as 'general' or 'specific'. The distinction relates to the target audience.

- **General** warnings are disseminated ('broadcast') to whole communities or regions.
- **Specific** warnings are intended for individuals or parts of communities, and reflect the need for 'narrowcasting' to specific audiences who may have specific characteristics or be at different kinds of risk.

Types and Modes of Dissemination

Dissemination channels or modes also fall loosely into two categories, which align with the different categories of warning message noted above.

- General modes are mainly represented by the mass (broadcast) media, and increasingly the internet, and seek to communicate with whole populations.
- Specific modes provide warnings to particular householders, businesses, primary producers or other clearly identifiable individuals, groups or organisations.

In general in Australian flood management, a strong reliance is placed on general warnings and on the use of broadcast modes. There remains considerable scope for expansion in the use of specific warnings targeted to subsets of communities.

The two categories should be seen as complementary. Specific warnings serve to reinforce and confirm the general warnings typically available early in a developing flood, or to provide particular information of relevance to only some members of a flood-liable community.

In most floods, both types of mode should be used, partly because doing so will increase the likelihood of the message getting through. Even in minor floods, which often only affect farmers, it is legitimate to convey warnings by the broadcast media and also by telephone to individuals who will then alert neighbours. As a rule, however, use of specific modes is likely to be greater for the more severe events, additional 'layers' of warning methods being used in the bigger floods.

There is now a wide range of dissemination modes available. Figure 7 gives a number of the major modes available, listing them in terms of their suitability in circumstances involving different amounts of warning time. An extended list of modes is provided in Table 6 at the end of this chapter along with a brief indication of the advantages and disadvantages of each mode.

The Media

The broadcast media offer significant benefits for disseminating general messages. The media offer an essentially free channel and, in many cases, provide the only way to achieve rapid message dissemination to large and diverse audiences.

Both the electronic broadcast and print media offer avenues, as floods are developing, for raising the awareness of those at risk and advising them about appropriate actions to take to protect their interests. If time is available newspapers can publish the actual gauge heights at which areas, sites or installations would be inundated along with flood action guides to help generate appropriate responses. To do this requires high-quality flood intelligence, including spot heights. Printing excerpts of the flood intelligence record for a town will indicate the areas expected to be inundated at particular heights on the local gauge, enabling people to assess their own risks and to determine appropriate personal action strategies. Newspapers have been used to carry such information on the western plains of New South Wales where several days' warning is possible.

Newspaper and radio dissemination, in situations where both are appropriate, may have complementary strengths. If a message read over radio is misheard or misunderstood, it is lost. In contrast, newspaper reports can be read and re-read in an individual's own time. There is no need to wait for a message to be broadcast at an uncertain and possibly inconvenient time in the future. Further, much more detail can be included in a newspaper article than in most radio announcements. Newspapers lack the immediacy and speed of transmission which radio offers, but these features may not be important when warning times are long.

Frequently Used Warning Modes	
General	
More quickly disseminated	
↓	**Radio** message (including local community radio): break-in community announcements or interviews with flood forecasting or emergency service staff.
	Television: 'crawlers' (messages drawn across the screen) or announcements during news or ad breaks.
	Scheduled **news** bulletin: may take longer to go to air.
	The **internet** (web sites).
	Notice boards: community or tourist information boards in town centres.
	Newspapers: local or regional.
More slowly disseminated	
Specific	
More quickly disseminated	
↓	**Telephone** (including phone trees or cascades where each person contacted calls others), voice mail and automated mass dialling with taped or digitally-recorded messages intended to be heard by numerous households simultaneously.
	Facsimile: especially for businesses (including farms) and institutions.
	Computer links, including internet (email).
	Two-way radio: CB (Citizens' Band) or 'packet' radio.
	Loud hailers, public address systems or sirens: either mobile (on police or fire vehicles) or fixed in one place.
	Doorknocking
More slowly disseminated	

Figure 7: Available General and Specific Warning Modes

The most commonly-used mass dissemination mode is still broadcast radio. It is critical that agencies responsible for the dissemination of flood warnings develop professional relationships with radio stations and plan with them the delivery of warning messages. Negotiations need to be undertaken in relation to the:

- desired frequency of message dissemination,
- need to broadcast messages in full, without truncation or editorialising,

- need for regular, pre-announced broadcasts of warnings, as far as possible at specified standard times which listeners will get accustomed to (eg immediately after the top-of-the-hour news broadcast) and for the repetition of a message while it is current,
- circumstances in which it will be appropriate for networked programs to be interrupted and for broadcasts to emanate from a local studio and to focus principally on the flood issue. This is likely during major flood operations, for example those involving large-scale evacuations,
- need to ensure that on-air announcers are aware of the flood problem and its management. This will include educating station personnel about the nature of flood mitigation systems and the importance of careful descriptions of what is happening during a flood. It is critical that the meanings of terms like 'levee' and 'spillway' are clearly understood so that information is correctly imparted. Cases have been known of announcers speaking of levees being 'breached' when in fact spillways were operating as intended. Mistakes of this kind can produce unnecessary alarm in the community and also lead to a loss of confidence in the quality of the warning and other information being broadcast, and
- sharing of information by media organisations with emergency services. Much information now comes to media organisations by email or SMS. Thus the media is an increasingly important source of information which can be used by emergency services to update flood situations, construct warning messages or stimulate response actions.

When using the media to disseminate information, care must be taken in relation to confidentiality considerations. Some flood information which is known to flood managers and recorded in flood intelligence records should not be publicly disclosed in warning messages. Privacy laws may apply, and information which could jeopardise individual or commercial interests should not be incorporated in such warning messages.

An example relates to caravan parks, whose operators will regard the broadcasting of information about the parks' potential inundation as hostile to their interests. In such cases, warning information should be provide to caravan parks by personal communication eg by telephone and email.

Telephones

Modern telephone technology allows automated dialing of large numbers of telephones at the same time and the capacity to warn by voice mail. This technology is particularly useful if the number of households and/or premises to be contacted is large relative to the time available or sparsely situated across a large area, rendering doorknocking difficult to complete.

An increasing number of flood warning systems (eg those operating in Euroa, Benalla and Maribyrnong in Victoria) now incorporate this technology. When a flood is expected to reach a specified level (such as the height at which over-floor flooding of dwellings will occur), the relevant local council calls the nominated telephone service provider, enters an identification number and records a message to alert receivers to the situation and advise them to listen to the local community FM radio station for additional information as the flood develops.

Recipients can be grouped by street blocks or zones of addresses or by floor height relative to the key river height warning gauge so the information is targeted to those likely to experience inundation. This needs to be established during periods without flood activity. Addressees can then be grouped together, up to the capacity of the telephone exchange. The system identifies and reports on those telephones which did not answer or were engaged at the time the call was made. Those premises can then be targeted by doorknockers.

A similar system has been established for Pacific Haven (Howard) in the Hervey Bay City Council area in Queensland, where flash flooding from a billabong located off the Burrum River is a serious problem. There, alerts are set off automatically when local rain and river gauges reach nominated levels and messages are provided simultaneously by telephone to all households which could experience flooding.

Automated dialing systems have wide applicability and can be used in many types of flood environment. They are particularly suited to alerting people in situations in which there is little time available (eg flash flood environments). They are also suitable to potential cases of dam failure, in which floods will rise very quickly and to levels potentially well above human experience (and where people are not normally considered flood-liable and would not be likely to believe they would be at risk). Such technologies will help fill the awareness gap during the real time of a potential dam-failure event, although continuous education campaigns would still be needed.

The availability of technically sophisticated systems of the type described does not imply that warning information and advice cannot usefully be disseminated by more traditional uses of telephone (and facsimile) technology. At Inverell, in northern New South Wales, local negotiation has resulted in telephone calls being made, as floods rise, to the numerous business houses of the Central Business District. These are organised in bands identified by level relative to the local gauge, the lower-placed locations being called first. In numerous areas in Australia, flood bulletins produced by response agencies are sent by faxstream to flood-prone residents, especially farmers.

In many areas, organised telephone' trees' or 'cascades' are used to spread warning information about floods. In areas likely to be flooded or isolated by floodwaters, information provided by response agencies via telephone calls to selected individuals can be relayed to other individuals in the area at risk. An example is the passage of information on likely or prospective road closures to school principals, who then pass it on to staff members or the drivers of school buses.

Computer-Based Warning

Warnings and other flood information are now routinely disseminated through the internet. Web pages can be set up to provide detailed, up-to-date information in text and graphical form, incorporating historical material, details on the current threat and warnings and advice. Once such sites become established and known, media, individuals, government and commerce are able to check them on demand for warning messages and advice. To date, however, such sites have tended to be used more to advise of the activities of response agencies than to provide warnings to people at risk of flooding.

Nevertheless there is a strong trend in emergency management generally towards web-based warning and information provision. Moreover the information provided is becoming more detailed and increasingly, where relevant and possible, property-specific.

Simultaneous access via the internet by response personnel in the field (such as State Emergency Service volunteers), those living in the area at risk, those providing traffic advice or information through the media and those in response agency operations centres is possible – no matter how far apart these various interested parties might be.

Doorknocking and Contact People

Doorknocking should be carried out if radical action, including evacuation, is expected to be necessary, provided time permits and it is safe for doorknockers to operate. Doorknockers should, ideally, deliver printed material giving advice on how to prepare for and respond to the coming flood. The oral and printed messages should include information on:

- evacuation routes and evacuation centres,
- what people should do before leaving home, and
- what they should take with them.

If the number of people to be contacted is small and the doorknocking can be planned before flooding begins, local contact people ('wardens') can be used. Such people will need to have been recruited by a response agency for the task, and should be known to the residents. Normally, they will belong to the flood-prone community itself and may have previously been used as community representatives for the negotiation of flood warning services and/or circulation of educational material about flooding and flood warning services.

Specialist cases of such contact people may include Chamber of Commerce officials or managers of industrial estates who may be used to pass warnings by doorknock or telephone 'cascade' to shopkeepers and owners of industrial premises in flood-prone areas. In areas with substantial Aboriginal populations, contact with community leaders in housing cooperatives or development organisations may fulfill similar purposes. In the Kimberley region of Western Australia, the State Emergency Service operates through Community Liaison Officers to negotiate matters relating to flood warning including organising evacuations when floods are approaching.

Where the number of people to be doorknocked is large, as occurs when substantial built-up areas are facing inundation, emergency service personnel are likely to be required to carry out the task. In these instances the number of doorknockers needed may be substantial and considerable planning may be necessary if the job is to be done effectively, especially when time constraints are severe.

To be effective, doorknocking as a means of delivering flood warnings in such situations requires detailed planning. The planning needs to take into consideration:

- the areas which will need to be doorknocked,
- the circumstances under which a doorknocking operation will be necessary,
- the number of buildings which will need to be attended to,
- how long it will take to assemble and brief the doorknockers,
- how long it will take to doorknock each building,
- how long each doorknocker or doorknocking team can work, and
- the materials the doorknockers will need to carry, usually including maps of the area they are dealing with and written copies of warning messages to hand out.

Detail on the organisation of doorknocking operations can be found in Chapter 6 of the Australian Emergency Manual **Flood Response**.

Choosing Appropriate Modes

Utilising multiple modes of dissemination increases the chance that a warning message will be both heard and believed, increasing the reliability of the warning process. It also helps to ensure that people who are unlikely to be reached by some modes will still receive the warning, and by virtue of the different communication methods employed it creates redundancy and repetition which add to message credibility.

Redundancy also provides 'insurance' against the failure of individual dissemination modes for technical or other reasons. The deficiencies and potential reasons for failure of warning methods are outlined in Table 6 at the end of this chapter.

Some of the more 'general' delivery modes, often favoured because of their simplicity where warning times are very short, have been shown to be relatively ineffective **by themselves.** This includes sirens and alarms which are not accompanied by clear voice instructions. Unless the people at risk are fully aware of what the alarm means and what they are expected to do, normal reactions are to ignore the signal or to seek additional information. Another limitation of sirens is that they will not be heard by many households, especially when their occupants are asleep. In contrast, most people hear their telephone ringing, day or night.

Not all modes are equally useful or appropriate in all circumstances, eg:

- Newspapers cannot be used to warn of rapidly-rising, short-duration floods, but they may be valuable in warning of floods approaching slowly from considerable distances.
- Doorknocking is generally inappropriate for events with little impact and, in any case, the benefits of using it in such circumstances would be outweighed by the costs it imposes in terms of resources. On the other hand, doorknocking should be used, time permitting, if evacuation is sought.
- One unfortunate characteristic of the broadcast media is that many people will not receive the warning message for some time. This is especially the case in the metropolitan areas where many broadcast channels exist. Some radio stations (those using news-talk or talkback formats, for example) will generally put any warnings to air promptly, but others may wait until a scheduled news broadcast which may cause significant delays. Television can be particularly slow and is unlikely to carry warnings except for severe events unless agreements can be reached about the use of 'crawler messages' ('pull-throughs') for particular areas of transmission. Warning messages crawled across television screens must be kept very brief.
- Different modes are more effective at different times of the day. For households, radio is best during breakfast and the morning rush hour, but its usefulness tapers off during the afternoon. Television is the more effective medium from mid-afternoon and throughout the evening. At some workplaces there may be no media coverage available.

Even when the warning is broadcast by the electronic media, there is no way of knowing who has heard the message, much less understood and believed it. It is not uncommon for people to hear only **part** of a message, not realising its relevance to them until the reading of it is nearly completed. In such cases much of the message is lost to the recipient. As noted in Chapter 5, it is important to mention place names in messages to create a sense of the locations to which a warning applies.

Specific warnings offer distinct performance advantages. They are usually more persuasive than those disseminated through the mass media. There are a number of reasons for this. People are much more likely to hear, understand and believe a message which is delivered to them **personally** (for example, by telephone or doorknock). They need to be able to relate the message to their own situation, and to be able to question and assess the credibility of the message deliverer.

The final choice of modes in particular circumstances will depend on what has to be achieved in a given time. In turn this depends on:

- warning requirements in terms of critical heights and update frequency,
- flood severity,
- available warning time,
- target audience,
- what resources are available,
- the time of day and the day of the week, and
- the required reaction.

A general principle is that in the more severe floods it is wise to use more communication channels, and to emphasise those that are specific in their targeting. The key to effective dissemination is to use, in combination, those delivery modes which most help people understand what the coming flood will mean to them. Improved understanding will provide a platform for appropriate self-protecting and damage-reducing actions to be undertaken.

Communicating with Individuals on Their Specific Flood Risk

It is increasingly possible to advise people outside of flood time about their individual flood risk, and where this is done the warnings disseminated as floods are approaching will generally be better understood. In many circumstances, people can be provided with the **actual gauge height** at which their properties will experience over-ground or over-floor inundation or at which their evacuation route will be cut. Such information can be issued as part of household-based educational initiatives, and reminders of the critical numbers can be provided when floods are rising – whether by doorknock, by telephone or by other means. This is already done in some parts of the world, customised reports being provided to individual residential and commercial properties and indicating:

- the gauge height at which water first enters the building,
- the depth of water inside the building, outside it and at low points on evacuation routes relative to a range of gauge heights,
- suggested actions for people to take before the next flood, and
- suggested actions for different forecast flood levels as a flood is rising.

In Brisbane, Queensland, a GIS-based appreciation of the severity of an oncoming flood on the Brisbane River allows emergency managers to identify, in advance, the approximate depth of water at specific property locations. Estimates of these depths can be passed direct to the occupants of these properties as a flood is rising, as follows:

- an occupant phones a council-established 24-hour call centre and provides his/her property details, and
- information on the high and low points of the property is displayed on a computer screen and current and predicted river heights are assessed against them.

An elaboration could include the addition of floor heights so the possibility of water entering buildings can be assessed more accurately.

The Importance of Confirmation

Those initiating and delivering a warning should seek to confirm that the message has been appropriately disseminated to and received by the target audiences. This can be achieved though liaison with the media and with response agencies.

Whatever the mode(s) utilised, recipients must be able to confirm the validity of the message. This is something people will frequently seek to do. Confirmation should be facilitated, as people may delay appropriate response until they have satisfied themselves the message is real and applies to them.

The need for confirmation may be satisfied by additional warnings, especially if these are from separate sources or disseminated by different modes. But total reliance on this approach is not advised.

Establishing a **Flood Information Centre** for the duration of a flood can provide a useful focus for those seeking warning confirmation or clarification and other flood-related information. Doorknockers can fulfill a similar function.

Another approach is the use of dedicated telephone numbers that provide callers with up-to-date flood information and response advice. If this number is advertised over the media, people will be encouraged to call in search of additional information or to confirm what they have heard over the radio or from other sources. Note that some numbers are free to the caller, whereas others are charged to the caller on a time basis.

The telephone confirmation service should not be provided directly through an operations centre whose personnel will need to focus on other matters.

Providing a confirmation service reduces the chance of rumours taking hold and conveys greater credibility because a particular accessible source of further information can be specified in broadcast warning messages. Such a service also helps minimise the number of telephone calls made by members of the public to response agencies.

The 'Informal' System

People's behaviour will often be influenced by other factors than 'official' flood warnings, and specifically by hearing 'informal' or 'unofficial' warnings. Typically they will assess the weather conditions for themselves: heavy, continuous rain is more likely to suggest flooding than is drizzle. Anxious friends or relatives may telephone urging them to evacuate. Alternatively, they may observe that their neighbours seem unconcerned by the warnings. All of these things may influence decisions to act or not to act.

Whatever the official channels, unofficial flood information will usually be disseminated in parallel through informal, word-of-mouth networks. Often, these will be much more extensive than the official system. A major challenge is to recognise that informal networks will persist, and to find ways of using them constructively while still maintaining a single credible source of official information. This is as important in the context of warning dissemination as it is in the context of flood prediction (see Chapter 3).

In particular, the informal system can help serve the need for confirmation. It is important to avoid a situation where the official and unofficial systems are seen to be competing with each other. Clearly recognising interactions between the official and informal systems will help avoid this problem by giving people who are not part of the official system a stake in it.

Table 6: Warning Communications Methods

Method	Description	Advantages	Disadvantages
Doorknocking	Doorknocking involves using emergency service personnel to go door to door or to groups of people to deliver a personal message	Allows for direct communication with population at risk. Allows for questions to be asked and further information to be provided Doorknockers can collect information whilst warning the community	Slow and resource intensive
Sirens/alarms	Sirens use a distinctive noise to alert affected communities. At best they have traditionally told people to seek further information unless an intensive program of public education is used to instruct people what to do when the signal sounds	Fast speed Able to reach outdoor populations	May be misunderstood, if not associated with education program regarding use Difficult to propagate sound inside buildings
Modulating electrical voltage	Modulating electrical voltage can be used to communicate through a fluctuating signal or to trigger pre-installed devices in peoples homes which would emit a warning tone or flashing light	Fast speed Potential to reach large areas	Fails if electricity fails May be misunderstood, if not associated with education program regarding use
Modulating electrical frequency	When the electrical frequency is altered warning devices can be activated, delivering a warning tone or flashing light	Fast speed Potential to reach large areas 24hr availability	Fails if electricity fails

Method	Description	Advantages	Disadvantages
Fixed and mobile public address systems	Systems either fixed or mobile which allow the communication of the amplification of a voice	Fast speed Allows for a voice message to be communicated	Difficult for people to hear a warning broadcast from a moving vehicle Announcements maybe rendered incomprehensible by distance, sound reflections or simultaneous transmission from several loud speakers at different distances Difficult for people to confirm the warning Difficult to propagate sound inside buildings
Tone Alert Radios	Tone alert radios are a device that can be remotely activated. They provide a warning signal and some types can subsequently broadcast a verbal warning message. The radio operates in a standby condition. Upon the receipt of a code the radio emits a tone and broadcasts a pre-recorded or read message. The code and message are broadcast from a radio transmitter. The radio receivers operate on normal electrical power and some have battery back-ups	Fast speed Ability to combine alerting signal with specialised messages 24hr availability Can be heard indoors	Maintenance problems Availability during power failures Limited broadcast range Difficulty using outdoors
Dial out systems	System works by having a computer database of pre-selected telephone numbers for the areas in which the warning has to be disseminated. When the system is activated the computer dials each number on the database delivering a warning message	Fast Speed: dial out occurs simultaneously to large numbers of subscribers Ability to pass voice message	People who are not near a phone will not hear the message Phones that rely on power will not work if power is disrupted Capacity of telephone system maybe inadequate to cope with the volume of calls Dependent on the phone network operating

Method	Description	Advantages	Disadvantages
SMS	SMS is sent to mobile phones to warn of emergency.	Fast Speed	People who are not near a phone will not hear the message Mobile phone needs to be switched on. Short message length Dependent on the phone network operating Database of numbers must be constantly updated
Variable message signs	Electronic programmable signs are generally used as a traffic management tool. These signs can be programmed with warning messages and simple instructions and communicated in the event of a flood	Can use solar power if mains power unavailable Effective at reaching motorists, and can focus on safety messages specific to motorists such don't drive through floodwaters	Short message length Need to be aware of the message to receive its contents
Radio	Broadcast radio provides information to the community including emergency warnings. It is one of the most regularly used methods of warning in Australia.	Fast speed Ability to communicate detailed information to large audience Capable of being battery operated	Radio must be switched on Radio broadcast often reaches areas not at risk All information must conveyed verbally Problems can arise with priorities of station management Not available if radio not battery powered during power interruptions
Television	Warnings can be broadcast over commercial television. This can be done by interrupting normal programming with a bulletin, or displaying scrolled text on the bottom of the screen. Television is particularly good at warning for slow developing events.	Ability to communicate detailed information to large audience Ability to use graphics and images Can use scrolled text in addition	Television must be turned on Broadcasts at the discretion of station Not available when power disrupted

Method	Description	Advantages	Disadvantages
Internet	Internet technology is a means of rapidly and widely disseminating warning messages. To date, warning has been via so called 'pull processes, whereby information is placed on websites, but in order to access the warnings, people must be logged in to the internet and actively browse pages.	Wide coverage Widely available	People must be logged on to the internet and actively seek warnings May be disrupted by power outages or network failures
SMS Cell Broadcasting	Cell broadcasting is an emerging technology in natural hazards warning. Cell broadcasting is an existing function of most modern digital mobile phone systems. The difference between it and SMS is that SMS can only distribute messages one-at-a-time, whereas Cell Broadcasting allows simultaneous transmission of messages.	Claimed that networking overloading avoided Very fast speed to reach large audience Can be used in a geo-specific manner by selecting which cells receive the broadcast	People who are not near a phone will not hear the message Short message length Dependent on the phone network operating Database of numbers must be constantly updated Existing mobile phone users might have to have this feature switched on for their handset Privacy issues relating to mass spamming of phones
Email	Email is a widely used communications medium	Fast distribution to wide audience Widely available	People must be logged on to the internet and actively seek warnings May be disrupted by power outages or network failures Requires the maintenance of a list of email addresses Users change email addresses relatively frequently

Method	Description	Advantages	Disadvantages
Newspapers	Newspapers can communicate warnings textually and graphically to audiences	Widely available Wide audience coverage Available on the internet Can use graphics and text Can present large amounts of information	Printed newspaper are slow to reach their audience
Community Wardens and Telephone Systems	Members of the community can be appointed as flood wardens to warn their local communities	They involve local people Recipients are more likely to believe a warning issued by a local warden whom they know Local wardens can take over the maintenance of contact details Wardens can supply information to emergency services	Reliance on community members to warn the public can sometimes be prone to failure – it is important to ensure the system is robust and has backups Warning schemes need maintaining In low risk areas it is often difficult to get volunteers and maintain commitment In some areas community spirit is lower and people don't want to get involved

Source: Molino et al (2002).

CHAPTER 7

System Review and Improvement

In a Nutshell…

System review involves critical examination of some or all aspects of the flood warning system with the aim of improving performance.

System review is needed to:

- ***maintain warning system performance and reliability,***
- ***ensure the lessons from operational experience are not lost, and***
- ***ensure account is taken of changing conditions in the catchment and the river, in the communication and other technologies available and in the communities at risk.***

Reviews range from informal exchanges through to formal public meetings. The people at risk are important stakeholders in the warning system who should be encouraged to meet and discuss system performance and ways of improving it.

The critical issues are to ensure:

- ***reviews move beyond ritualistic 'back-patting' or blame-shifting exercises,***
- ***organisations involved in the flood warning system are able to discuss criticisms and problems in a constructive and comprehensive manner,***
- ***recommendations are acted on, and***
- ***reviews contribute to the improvement of the system.***

Introduction

Flood warning systems need regular attention to ensure they will function as intended and to continue to improve their performance. System review should occur at different levels and, where possible, performance indicators should be devised so system effectiveness can be assessed objectively.

There are two levels at which review should be undertaken. These are:

- the strategic level, where the relevant Flood Warning Consultative Committee or its equivalent should be involved, along with local government; and
- the operational level, at which individual agencies examine the performance of their own functions (including performance in terms of the reactions of community members to warning messages) and their interaction with other stakeholder agencies.

A key point about the review process is that all relevant agencies should be involved to ensure organisational changes can be implemented. Similarly, the process must be open to input from the flood-affected community, members of which are likely to have ideas about how warning systems and services can be more effectively implemented. The views of community members are essential to improving warning systems, and people should be actively encouraged to put forward their opinions on system performance and ways to improve it.

Considerations for Review Processes

Reviews of flood warning systems may fall short of their ideal objective for a range of reasons. Often:

- they are ritualistic, being carried out because they are a requirement rather than because improvements are recognised as being possible and necessary,
- participants have not thought constructively about why they are having a review,
- the main aim of the participants is to shift blame for operational shortcomings to another agency,
- participants make no attempt to get beyond organisational 'position' statements, or
- the review is a mutual 'back-patting' or public relations exercise.

Reviews should be held as soon as possible after a flood, in which the warning system will have been tested operationally. The review process provides an opportunity to examine critically whether the system is meeting its aims, and how each part it is functioning.

Reviews should not be limited to identifying successes or failures. They should also pinpoint weaknesses in performance and prediction or reliability that could lead to failure, or areas where performance can be improved.

Reviews should cover both the technical and non-technical elements of the flood warning system. The performance of the **prediction system** should be examined, for two reasons:

- to help improve and possibly re-calibrate flood prediction models based on the lessons of the flood, and
- to ensure any problems which might have been experienced in communicating and interpreting predictions are identified and rectified.

Post-flood reviews of the system's performance should also be aimed at finding out whether aspects such as **data collection** and **communication networks** could be improved. **Flood intelligence systems** should also be examined, with a view to updating and modifying the data records, adding new information and ensuring changes in the characteristics of flooding are appropriately incorporated. In doing this, specialist interpretation may be needed to explain differences in flood behaviour in different events. The effectiveness of the data collection and collation procedures which 'feed' flood intelligence systems should also be checked and steps taken to rectify any deficiencies.

Where flood studies have been undertaken, the review process should compare their assumptions and the results of their modelling components with actual flood data to refine the accuracy of forecasting models.

Where they are used, the levels which are taken to denote 'minor flooding', 'moderate flooding' and 'major flooding' should be reviewed periodically to ensure that the defined gauge heights adequately note the nature of the flooding described by the terms (for definitions of minor, moderate and major flooding, see Chapter 4). Periodically there will be a need to alter the levels, some of which have not been reviewed since the 1970s.

What Can Go Wrong if Reviews are not Held: an Example

A case at Narromine, in New South Wales, indicates why reviews are necessary. The original 'minor flood' level was set during the 1970s as the height on the local gauge at which a low-level bridge connecting two parts of the community would close. Later, the bridge was replaced by a higher-level structure, but the 'minor flood' level was not reviewed until after 2000. The result was that the prediction agency continued to issue flood predictions, but these were no longer appropriate. The community received unnecessary warnings of very small river rises, contributing to some loss of confidence locally in the warning service provided since warnings were being received of events of little consequence.

Given that such environmental change is common, reviews of flood classification levels should be undertaken periodically. Yet many flood classification levels around Australia appear not to have been queried for years for their continuing meaning and relevance.

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Reviews should include investigation of the **content** and **delivery** of the flood warning messages, posing the following questions (eg at public meetings):

- Did the target audience receive the warnings in time?
- Did they understand the warning messages?
- Were their responses appropriate? If not, why not?
- What evidence is there for the answers to these questions?

Reviews should also be held when **technological**, **environmental** or **organisational changes** occur. Typically, technological change in relation to the prediction function affects rain and stream monitoring and hydrological prediction methods, and ideally the adoption of improved technologies should lead to greater system reliability and better predictions. But the promise of such improvements may not be fulfilled if the rest of the system is not ready for them or is unable to incorporate them effectively.

Environmental change generally refers to changes in catchment or stream channel conditions which may alter runoff and streamflow characteristics. These changes may be largely natural in origin, occurring as a result of landslides, bushfires, and major stream channel alterations. Some, however, may be the direct result of human activity, including land use changes, the clearing of natural vegetation, construction of new bridges or raising of causeways. All of these can alter the behaviour and impact of floodwaters. The assessment of the likely impacts of such changes should be carried out by agencies with the requisite skills and entries to flood intelligence records altered accordingly.

Organisational change is also important. Staff turnover, alterations to telephone numbers and changes to procedures and priorities within organisations will occur, and the impacts of these things on the operation of warning systems need to be assessed. The potential costs of not taking note of such changes can be illustrated by an actual case in which a local radio station experienced a change of ownership and orientation and had its studios relocated. When a severe flood occurred soon afterwards, the station was not ready to play the crucial role expected of it in the warning process. This example shows the importance of regular liaison between radio stations and key flood response agencies.

Even if the system has not been activated and there have been no significant changes to the context in which it functions, reviews should be held **regularly**. This is to remind the stakeholders of their roles and to ensure changes do not take warning system participants by surprise. Test exercising of the warning system can be useful here.

It is not possible to be prescriptive about how often reviews should be held. This is partly because most reviews will test **parts** of the warning system rather than the whole. Reviews of some sort should always be going on, however, with major system-wide reviews involving several agencies being undertaken at least occasionally.

Developing Performance Indicators

One way of formalising the review process and overcoming the problems noted above is to develop indicators of system performance. This is best done by breaking the system down into functions and components and rating performance in each element. Audits should be done regularly and on a range of areal scales, eg for specific locations such as towns, for whole river reaches (the reference areas of particular gauges), and for whole catchments.

Key performance indicators may include such things as prediction accuracy and timeliness, the percentage of those who were intended to evacuate who actually did so, and evidence of community acceptance and comprehension of the warnings that were disseminated (on this measure, information could be obtained from community meetings held soon after a flood). As in all reviews of the performance of management systems, the goal of continuous improvement should be the driving force.

A useful framework for reviewing the performance of flood warning systems and the services they provide may be found in Parker and Neil (1990). Table 7 provides a checklist based on the elements of the total warning system as set out in this Guide. Agencies responsible for the various components of flood warning systems should develop appropriate Key Performance Indicators (KPIs) relevant to the components for which they are responsible.

Table 7: A Framework for Monitoring Total Flood Warning System Performance

Component	Factors affecting performance during floods	Activities to improve performance between floods	KPI
Prediction	Clear understanding of prediction needs.	Improve hydrological prediction models.	
	Early advice of potential flood producing rainfall.	Maintain and improve data collection system.	
	Adequate network density.	Increase network density.	
	Data collection technology robust, reliable, timely, etc.	Improve routine catchment monitoring capability.	
	On-line data management system streamlined.	Improve meteorological forecasting input to system.	
	Accuracy and timeliness of river predictions.	Refine prediction requirements.	
	Good communication between prediction agency and recipients.		
	Good cooperation between official and other prediction agencies and groups.		
	Good communication of uncertainty.		

Component	Factors affecting performance during floods	Activities to improve performance between floods	KPI
Interpretation	Quality and detail of available flood intelligence. Collection of flood intelligence. State of preparedness of agency receiving prediction.	Work with the community to determine data required. Undertake detailed flood studies to improve understanding of flood impacts. Develop floodplain mapping. Prepare flood intelligence storage system. Prepare system for collecting data for next flood. Collect flood damage information.	
Message construction	Knowledge of the physical characteristics of the flood problem. Knowledge of the characteristics of the at-risk population. Extent to which messages met criteria in checklist.	Improve understanding of the flood characteristics of the area. Improve understanding of population characteristics. Work with community to improve message targeting and design.	
Communication	Use of appropriate dissemination mode(s) Ability of those at risk to confirm warning. Appropriate mix of general and specific warnings.	Establish flood information centres. Provide facilities to allow confirmation of message. Work with community to improve communication.	
Response	Appropriateness of actions taken by response agencies and individuals. Extent to which response plan was followed. Feedback within system.	Prepare/improve flood response plan. Rehearse response plan. Improve inter-agency liaison.	
Review		Undertake review at both policy-making and operational levels, establishing review panels and guidelines. Review all elements of the total system after an event. Ensure recommendations from review feed back into agency plans.	

CHAPTER 8

Conclusion

This manual has described a set of 'best practices' to aid flood warning endeavours in Australia. In essence, the flood warning task can be boiled down to five questions, each of which has been examined in detail in the preceding chapters. These questions are as follows:

- How high will the flood reach, and when? (Chapter 3).
- Where will the water go at the predicted height, and who and what will be affected? (Chapter 4).
- What information and advice do the people affected by the flooding need to respond effectively? (Chapter 5).
- How can the people affected by the flooding best be given the appropriate information? (Chapter 6).

If flood managers ask and respond to these questions in 'quiet time', and again in the lead-up to a flood, **and** they have developed and implemented appropriate client-focused warning systems beforehand (Chapter 2), high-quality warnings can be provided to communities at risk. Rigorous post-flood reviews of warning systems and their operation, together with continuing public consultation (Chapter 7), will maintain and improve warning quality.

A concerted effort at carrying out all of these activities will maximise the opportunities to manage the impacts of floods in terms of the safety of individuals and their ability to protect their lives and property.

Acronyms and Glossary

AEP: Annual Exceedence Probability
The chance, expressed as a percentage, of a flood equalling or exceeding a given size (usually measured as the peak height recorded at a gauge) each year. A 1% AEP flood has that chance of occurring or being exceeded at a given location in any year.

AHD: Australian Height Datum
A base level for measurement, set at mean sea level. Elevations, including flood heights at gauges, are often measured in metres AHD (mAHD). Note that not all gauges to which flood warnings apply are set to this datum.

ALERT: Automated Local Evaluation in Real Time
A system of real time reporting from rainfall and stream gauges to a central location for analysis and further dissemination.

ARI: Average Recurrence Interval
The long-term average length of time between floods of a specified size at a given location, expressed in years.

CSA: Community Service Announcement
An announcement made over the electronic media, often about emergency matters and intended to be of community benefit.

DCF: Dam Crest Flood
A flood which reaches the crest of a dam wall.

DEM: Digital Elevation Model
A gridded representation of the earth's surface showing the elevation of points relative to a datum.

Extreme Flood
A rare and usually very severe flood, greater in magnitude than the 1% AEP event and possibly approaching the magnitude of the PMF.

Floodplain
The land which may be covered by water when a river overflows its banks during a flood. The extent of a floodplain will normally be greater than the area covered in the 1% AEP flood, its ultimate extent being defined by the PMF.

GIS: Geographic Information System
A computerised database for the capture, storage, analysis and display of locationally defined information. Commonly, a GIS portrays a portion of the earth's surface in the form of a map on which information is overlaid.

GPS: Global Positioning System

A satellite-based navigational system used for determining location.

Hydraulics
The study of water flow in a river and across a floodplain and evaluation of flow characteristics such as height and velocity. This may include assessment of the effects of obstructions such as bridges and buildings on water flow and changes in the slope of the water surface during a flood.

Hydrograph
A graph depicting the change in river level or discharge over time at a particular point on a stream.

Hydrology
The study of the rainfall-runoff process as it relates to the development of flooding and the derivation of hydrographs at given locations on a river system for given floods.

IFF: Imminent Failure Flood (for a dam)
A flood which, if exceeded, will cause a dam to fail.

Prediction Agency
The agency responsible for predicting floods and flood severity.

PMF: Probable Maximum Flood
An estimation of the largest flood that could occur at a particular location. Such a flood would result from the most severe combination of meteorological and hydrological conditions as these are currently understood.

PMP: Probable Maximum Precipitation
The greatest amount of rainfall that is physically possible at a given location, according to current knowledge.

Response Agency (or Combat or Lead Agency)
The agency charged with leading community reactions to flooding. Such an agency may also have responsibility for community preparedness for flooding.

SEWS: Standard Emergency Warning Signal
A siren sound, designed for playing over the electronic media, to alert people to an emergency announcement that is about to be made.

SMS: Short Message Service
A service which allows the keying in the text of a message on a mobile phone and sent to another mobile phone.

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Manual 19 **Managing the Floodplain**

Manual 20 **Flood Preparedness**

Manual 22 **Flood Response**

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